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Salinity/Alkalinity in the Uralla-Walcha district on the Northern Tablelands of New South Wales

Technical Booklet

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Salt Action

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NATIONAL LANDCARE PROGRAM

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1. Summary of the Research Project

Research into salinity/alkalinity was initiated by the Harnham and BOZO landcare groups in response to concerns expressed by landholders about the apparent increase in saline/alkaline scalds in the early 1990s. The aim of this project was to investigate the extent and severity of saline/alkaline scalds with a view to testing different methods of making them productive again.The project was initiated in 1992 and funded under the National Landcare Program (NLP) program, formerly the National Soil Conservation Program (NSCP). The project concentrated on the districts of Uralla, Wollun and Walcha, an area of approximately 30000 hectares.

Two surveys (landholder and field surveys) were carried out initially to gauge the extent of the problem within the study area. A total of 82 saline/alkaline sites were located from the landholder survey, and more detailed information collected from 50 of these in field surveys. The surveys indicated a wide variety of characteristics among the scalds and the general pattern appeared different from the pattern of salinity described for other parts of Australia. Twenty experimental sites were then chosen based on similar site characteristics such as position in the landscape, slope, site characteristics and vegetation. Five replications of a control and 4 treatments consisting of ponding, reverse interception drains and the application of gypsum and epsomite were set up. The gypsum and epsomite were applied inside steel rings at the same sites.

A total of 46 piezometer tubes were installed across the two landcare groups at a depth of 4 metres, to tap shallow groundwater. The electrical conductivity (EC) and pH of water from the piezometer tubes were highly variable across all the scalds sampled in the two landcare groups.

The average EC to different depths can be estimated using electromagnetic induction surveys. Two instruments (EM31 and EM38), each with slightly different characteristics, were used for a broadscale survey of several sites and more detailed surveys of the 20 experimental sites. These surveys again emphasised the variability among the different scalds and indicated that the highest levels of salinity did not necessarily occur beneath the bare areas. Soil cores and piezometer tubes located in the centres of scalds need not necessarily provide information which is representative of each scald. Electromagnetic surveys of individual scalds would be beneficial if they were carried out prior to either the installation of piezometers or further studies of scald characteristics.

The treatments all proved successful in modifying specific aspects of the scalds. The ponding treatment lowered soluble salt concentrations in the soil by dispersing salts as the water was pumped to areas away from sites of concentration. The reverse interception drains alleviated waterlogged sites and re-directed both surface and lateral flow of water from the scalds. The gypsum and epsomite at 5 tonnes per hectare proved successful in changing the chemical status within the soil profile to a depth of at least 400 mm by replacing sodium ions with the divalent cations calcium and magnesium. Calcium was provided by the gypsum and the epsomite provided magnesium. The surface infiltration rates were improved at the scalds with reverse interception drains as well as the gypsum and epsomite treatments but did not change over time for the ponding and the control treatments.

The scalds with a reverse interception drain were colonised by *Cynodon dactylon* (couch), *Hordeum marinum* (sea barley grass) and *Pennisetum alopecuroides* (swamp foxtail grass) while the chemical applications were associated with the introduction of other grasses 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). Little change occurred in the vegetation at the control scalds or those with ponds.

This study provides some basic information to assist landholders in choosing the best treatments for saline/alkaline scalds. Each scald requires its own evaluation of the problems at that site and the treatment used should be based on the characteristics of individual scalds. Chemical ameliorants can be used on flat land, while ponds are suitable for slopes of 1-2% and reverse interception drains for situations above 2%.

Apart from the implementation of treatments, landholders can also assist future research by monitoring individual saline/alkaline scalds. This can be accomplished by pegging the margins of scalds and periodically mapping and photographing them to gauge their expansion or contraction. It is only through such consistent data that the actual patterns of change of saline/alkaline scalds can be understood.

2. Land Use and Salinity/Alkalinity in the Uralla-Walcha District

Salinisation and alkalinization problems have only become an issue among landholders on the Northern Tablelands of New South Wales in recent years, although saline/alkaline scalds were known to the early settlers. It is unclear just how these saline/alkaline scalds have been affected by land use and grazing practices.

European settlement commenced in the region as early as 1840, predominantly with grazing enterprises involving cattle, sheep and fat lambs and small amounts of cropping on individual farms (Walker 1963). Recent observations suggest that stock tend to congregate on scalds where they contribute to soil compaction by grazing and trampling and create erosion problems by licking the soil, often at the top of the B horizon. Soil structure is broken down and the infiltration rate is reduced by these activities. One of the major problems associated with scalds is that improved pasture species usually will not grow on them because of poor soil structure and high pH levels which may be over 10.

Whether saline/alkaline scalds are likely to spread is of major concern to landholders, yet the processes involved in their formation are not clearly understood. Whether these scalds will eventually expand under present grazing practices is unknown at this stage.

3. Salinity/Alkalinity in the Uralla-Walcha District

Scalds are widespread throughout the Uralla-Walcha district and are generally characterised either by patches of bare ground or a sparse cover of *Cynodon dactylon* (couch grass) and/or *Hordeum marinum* (sea barley grass) (Kreeb *et al.* 1995). The soluble salts are predominantly carbonates and/or bicarbonates instead of chlorides and can occur in a range of positions in the landscape (Kreeb *et al.* 1995; Murray 1997). Saline/alkaline scalds vary in size, shape and degree of severity, although the electrical conductivity of the surface can be quite low. Information on how long these scalds have existed is highly subjective and based on landholder information. Discussions with James Street and Andrew Burgess suggest that they are not a new phenomenon. According to these and other landholders, some scalds have undergone natural rehabilitation and no longer appear to be a threat, others have remained the same, whilst still others have deteriorated and increased in size.

In Australia saline and alkaline soils occur in arid, semi-arid and higher rainfall areas. Soil profiles in all but the wettest parts of the continent hold vast amounts of salt, derived from the ocean and deposited on land by rain for many thousands of years. Cyclic salt has become concentrated in the subsoil but left to its own devices the salt store is quite harmless because it remains below the root zone of grasses and shrubs and the ecosystem which has developed around such areas operates effectively. Problems arise when the salt store in the soil profile is disturbed. The problems which emerge when the salt store is disturbed will vary according to site specific characteristics such as rainfall patterns, soil type, geology and hydrogeomorpholgy. Therefore salinity problems experienced in arid areas such as central Australia will be different to the salinity problems in the wheat belt of Western Australia and Victoria. The salinity problems in Western Australia result from the removal of vegetation while those in Victoria are due to an increase in the water table in combination with capillary rise of groundwaters containing soluble salts (Hookey 1987). The time lapse in the wheat belt of Western Australia between clearing and the appearance of saline seeps is of about 15 to 20 years. In south Western Australia a dual aquifer system is the norm. Near the surface, in the porous, coarse textured soil, an unconfined aquifer usually exists that is dependent upon the abundance of recent rainfall. This shallow 'perched' aquifer, up to about 3 m thick, sits above a finer-textured clay-like layer in which we usually find a perennial and more saline groundwater system. With the clearing of forests for crops and pastures the summer evapotranspiration was reduced and the regular winter rainfall contributed to the already high water table. This carries salt up towards the soil surface causing saline seeps (Teakle and Burvill 1938; Cope 1958; Bettenay *et al.* 1964; Rowan 1971 and Hookey 1987).

In the southern Tablelands of New South Wales Van Dijk (1969) observed saline seep development on dense subsoils of low permeability which may include more permeable layers. Valley and hillside seeps are common in this region with hillside seeps occurring in shallow (0.3 m) stoney loams overlying an irregular thickness of dense clay and partly decomposed rock. The seeps occur in areas where the clay layer is very thin or non-existent. Valley seeps tend to be found in strongly differentiated silty-loam surface soil overlying dense clay subsoils.

Kreeb *et al.* (1995) described scalds near Uralla as occurring more or less parallel with the contours on the lower part of a slope and postulated the existence of several closely associated but distinct aquifers each with different potentiometric head and water chemistry. Piezometer tube data revealed a rapid response of these aquifers to rainfall sequences and that these different aquifers were separated by impermeable layers of rock within the profile. The rapid response to rainfall sequences indicated local intake for the aquifers and the discharge was very localised indicating that the groundwater was probably moving through cracks and fissures in the underlying metamorphosed sedimentary rocks.

The Northern Tableland's salinity problems differ from Western Australia and Victoria as they do not occur as a result of vegetation clearing. Scalds on the Northern Tablelands can be found in areas which have not been cleared. The soluble salts in Western Australia and Victoria predominantly consist of sodium chloride while those occurring in scalds on the Northern Tablelands consist of sodium carbonates/bicarbonates. Scalds on the Southern Tablelands of New South Wales differ from those on the Northern Tablelands due to different summer and winter rainfall seasonal patterns. The Southern Tablelands of New South Wales possessing a Mediterranean climate with wet winters while the Northern Tablelands receives its highest rainfall in the summer.

On the Northern Tablelands of New South Wales salinity problems occur under diverse conditions and the individual characteristics of particular scalds are intimately related to rock structure, lithology and landform as well as exhibiting superimposed effects of present and past climate and varied land use.

Reclamation of scalds is important to prevent such sites deteriorating in the future because once it is bare of vegetation, a scald is essentially unproductive and useless to landholders. The present research project has focused on ameliorative strategies which could provide solutions for landholders, and involve minor engineering works such as the construction of drainage and ponding systems and the application of ameliorants to rectify soil structural and soil infiltration problems.

4. Geology Underlying Saline/Alkaline Scalds

Palaeozoic metamorphic sediments, generally of marine origin and 230-670 million years old dominate the Uralla and Walcha region. Granites of various types are found intruded into these metamorphic sediments. The granites were covered with tertiary basalts some 65-10 million years ago, but only a few caps remain. The landscape is gently undulating with broad, shallow valleys.

The highly folded and deformed sedimentary beds consist of a number of permeable and impermeable layers containing cracks and fissures which allow the passage of groundwater in irregular patterns. Generally these rocks are higher in sodium and potassium than calcium and magnesium. The potassium generally becomes immobilised in clays, while the sodium tends to remain quite mobile and possibly occurs in the form of silicates. Carbon dioxide charged water percolating through these sediments will result in the formation of sodium carbonates/bicarbonates (Janitzky and Whittig 1964). These soluble salts will be deposited if the water reaches the soil surface and evaporates. Geomorphological features such as folds in permeable and impermeable layers and cracks and fissures within them, play a critical role in determining the occurrence of saline/alkaline scalds and their position in the landscape.

5. Types of Soils Prone to Salinity/Alkalinity

A great diversity of soils are found on the Northern Tablelands (Jessup 1965) and yellow podzolics and solodics predominate in the Uralla-Walcha region. The main characteristic displayed by these duplex soils is the abrupt change between the A and B horizons. The A horizon varies from a loamy sand to a silt loam or clay loam while the B horizon has a much higher clay content becoming firm when moist and plastic and sticky when wet. The B horizon of the solodics is blocky, prismatic and often dispersed with very poor permeability and exhibits a rise in pH with depth. These solodics tend to develop saline /alkaline scalds.

6. What Do Saline/Alkaline Scalds Look Like?

A number of attributes are generally associated with possible saline/alkaline scalds and include the following:

- grasses dying and bare patches of soil appearing; surface of the bare soil is "puffy" to walk over;
- stock congregating on and licking the surface of the soil
- soil becoming sticky when waterlogged;
- salt encrustations appearing on the soil surface and at the interface of the A and B horizons;
- trees dying for no apparent reason (near the vicinity of a scald);
- excess quantities of run-off flowing from the area;
- pH at the soil surface 9 and above and increasing down the soil profile;
- if grass species present, dominated by couch and sea barley grass with swamp foxtail grass on the perimeter of the scald.

Table 1 Percentages of the 82 saline/alkaline scalds in the Harnham and BOZO landcare groups having the different attributes investigated in the field survey.

Key recognition feature	Percentage of the 82 scalds surveyed having the relevant attribute
stock congregating on and licking the surface	100%
grasses dying and bare patches of soil appearing	96%
surface of the bare soil is "puffy" to walk over	96%
soil becoming wet or waterlogged	87%
salt encrustations appearing on the soil surface	86%
trees dying for no apparent reason (near vicinity of scald)	84%
excess quantities of run-off flowing from area	65%

Saline/alkaline scalds can be classified into the following groups:

a) Scalded spring - these springs do not possess vegetation and consist of a waterlogged bare area sometimes with water flowing from the ground. Salt encrustations are common on the surface of the waterlogged soils.

b) Green local - these areas are not consistently waterlogged, but during periods of high rainfall they tend to become boggy and sticky with low water infiltration capacity. Vegetation is present on these sites all year round and generally consists of *Cynodon dactylon* (couch), *Hordeum marinum* (sea barley grass) and *Pennisetum alopecuroides* (swamp foxtail).

c) Scalded local - these areas are saline/alkaline scalds which are bare of vegetation all year round, but become sticky and boggy after rain and crusty and puffy during dry periods.

Green springs are also common on the Northern Tablelands and the water has a low salt content and green vegetation is present all year round. The water in these springs probably flows through rocks with a low soluble salt content into a confined aquifer or fault which results in hydraulic pressure forcing water to the surface.

Scalds often have smaller surface water catchment areas than adjacent sites without scald development. The implication is that water and chemicals are not travelling long distances to the scalds and that vertical water movement is also important. Mesalike hummocks occur at some scalds with their tops apparently the un-eroded natural soil surface. These flat tops are usually vegetated with *Cynodon dactylon* (couch) and *Hordeum marinum* (sea barley grass). It is not known whether the mesas have been preserved because of the presence of the grass before erosion commenced, or whether the erosion has produced the soil moisture and chemistry conditions which favour these grasses.

The field survey of 50 of the 82 scalds located in the Walcha-Uralla district revealed the following general characteristics of saline/alkaline scalds (Table 2).

Vegetation - Sharp vegetation boundaries occurred between scalds and unaffected pasture. Vegetation immediately surrounding scalds consisted of two dominant grass species: *Cynodon dactylon* (couch) which occurred at 96% of scalds and *Hordeum marinum* (sea barley grass), 92% of scalds. Sixty eight percent of sites also had *Pennisteum alopecuroides* (swamp foxtail grass) usually at the perimeter of the couch and sea barley grass. A serious problem encountered during the winter was a lack of vegetative cover beside the scalds as *Cynodon dactylon* (couch) dies off leaving the soil bare and prone to erosion. The scalds become extremely boggy when wet and puffy when dry. These conditions also result in little or no vegetation cover.

Size of Scalds - The majority of scalds (70%) were relatively small, covering an area of between 5-50 m^2. Only 22% of the scalds had areas greater than 50 m̄ and a small percentage (8%) ranged from 1-4 m^2 (Table 2). It is unknown if these scalds have increased in area as no long term monitoring has ever been implemented for individual scalds and available information is anecdotal.

Surface pH - Differences of up to four pH units were observed over small distances (15-50 cm) at the edges of scalds. Kreeb *et al.* (1995) reported similar sharp pH gradients at "Miramoona". Vegetation patterns were also correlated with pH levels with the dominant grass species in high pH areas being *Cynodon dactylon* and *Hordeum marinum* grading to *Vulpia bromoides, Bromus brevis and Eleusine tristachya* as the pH decreased (Kreeb *et al.* 1995). Fifty eight percent of scalds in the study region possessed pH levels of 8.0 and above, while 28% had pH levels of between 7.0 and 8.0 and only 14 % of scalds were not considered alkaline at the soil surface with pH levels less than 6.0.

Carbonates/Bicarbonates - Carbonates/bicarbonates were present at 86% of all scalds investigated in the survey and usually occurred at the top of the B horizon. Work by Kreeb *et al.* (1995) showed that alkalinity also resulted from the presence of carbonates and/or bicarbonates of sodium at "Miramoona".

Table 2 Percentage of the 50 scalds or springs surveyed having the attributes

Attribute		Percentage of the 50 scalds surveyed having the attribute
Position on landscape	valley floor	0%
	lower to mid slope	98 %
	upper slope	2 %
Slope	<2%	4%
	2-3%	96%
	>3%	0%
Site Characteristics	green spring	4%
	scalded spring	2%
	green local	6%
	scalded local	88%
Vegetation	*Cynodon dactylon*	96%
	Hordeum marinum	92%
	Pennisetum alopecuroides	68%
Scald area	1-4 m^2	8%
	5-50 m^2	70%
	>50 m^2	22%
Surface pH	6.0 -7.0	14%
	7.0-8.0	28%
	8.0-9.0	26%
	>9.0	32%
Carbonates/bicarbonates	present	86%

7. Where Does Salinity/Alkalinity Occur in the Landscape?

In general, scalds are found in mid to lower slope positions in the landscape with only a small minority on the upper slopes (Table 2). Most of the scalds occur on the side of a valley which has the lower relief. Most of the literature dealing with salinity in other parts of Australia states that salinity is found in depressions or at the base of a slope but this is not the case in the Uralla-Walcha district.

The majority of scalds (96%) occurred on slopes of 2-3%, with 4% of scalds occurring on slopes less than 2% (Table 2). No scalds occurred on slopes greater than 3%.

8. What Causes Salinity/Alkalinity?

Most literature describing the causes of salinisation/alkalinization in Western Australia, South Australia and Victoria has focused on the removal of native woody vegetation from the landscape as the main cause of salinity problems, resulting in additional groundwater, rising water tables and salt seeps.

Conacher and Murray (1975) stated that tree removal results in excess water percolating into the soil profile ultimately reaching groundwater systems, where stored salts are mobilised and re-distributed to other parts of the landscape via lateral movement of water as throughflow and capillary rise. Lateral movement of water results in waterlogging of low lying areas or outcropping of the water table in positions in the landscape where there is a change of slope particularly where groundwater slope and land surfaces intersect. This scenario is particularly evident in winter rainfall environments where the soil profile is saturated most winters and tree removal means that little water is removed by evapotranspiration during the summer when the soil surface is dry. The soluble salt is usually sodium chloride (Conacher and Murray 1975).

Comprehensive research on the development of scalds on the Southern Tablelands by Wagner (1987) indicated that different rainfall patterns from year to year could affect scald expansion and contraction. Through discussion with landholders in combination with aerial photography, Wagner postulated the following three scenarios in relation to the development of salt scalds.

1. Many salinised areas became evident in the 1950s, as a result of a period of well above average rainfall followed by dry years.

2. Two or three years of well above average rainfall, followed by a return to 'normal' (or drier) years, appear to exacerbate the surface expression of the problem, whereas a more prolonged period of moderately wet years (e.g. 1978 to 1983) appeared to alleviate it.

3. Annual average rainfalls outside the range 400-800 mm were not conducive to this type of salinity

development, maximum rates of occurrence appear in the range of 600-700 mm.

Fogarty (1991) stated that the removal of native woody vegetation on the Northern Tablelands may have contributed to the salinity/alkalinity experienced, by changing the hydrological balance from pre-European settlement conditions. The problem with Fogarty's analysis is that there is no regular winter saturation of the soil profile on the Northern Tablelands because season to season and year to year patterns of rainfall are so variable. Forgarty's (1991) assumptions do not appear consistent with either Wagner's (1987) conclusions or the latest detailed studies completed by Kreeb *et al.* in 1995.

Kreeb *et al.* (1995) described three distinct rows of scalds more or less parallel with the contours on the lower part of a slope and postulated the existence of several closely associated but distinct aquifers each with different potentiometric heads and water chemistries. Piezometer tube data revealed a rapid response of these aquifers to rainfall sequences and that these different aquifers were separated by impermeable layers of rock within the profile. The rapid response to rainfall sequences indicated local intake for the aquifers and the discharge was very localised indicating that the groundwater was probably moving through cracks and fissures in the underlying metamorphosed sedimentary rocks. The scalds were about 20 m below and 1 km from the top of the watershed. The soluble salts on these scalds (usually carbonates and bicarbonates of sodium) were mostly concentrated at the surface. The data were collected in late 1991 following two years (1989 and 1990) when the winter rainfall was very high. The winter of 1991 was dry and the water levels in the piezometer tubes fell dramatically. It is postulated that similar rainfall sequences can lead to expansion and contraction of the saline/alkaline scalds as described by Wagner (1987) for the Southern Tablelands.

Periods of high rainfall, particularly in the winter when evapotranspiration is low, lead to the saturation of the soil profile whatever the vegetation and recharge of the confined aquifer. The water then moves down slope carrying varying amounts and kinds of dissolved solids, depending on the chemistry of the particular rock strata through which the water passes. The dissolved solids will accumulate at the soil surface where the aquifers discharge and may lead to the development of saline/alkaline scalds if the salt concentration and pH are sufficiently high to cause plant death. The development of these scalds is exacerbated by dry weather following heavy rain but subsequent periods of moderate rainfall will leach the soluble salts from the scald surface leading to colonisation by salt/alkaline tolerant plant species such as *Cynodon dactylon* (couch) and *Hordeum marinum* (sea barley grass).

The scalds therefore expand and contract in response to high, low and moderate rainfall sequences perhaps in response to El Nino and La Nina events.

Gardner (1854) described extensive swamps along the drainage lines at the time of European settlement of the Northern Tablelands. If the aquifers reached the surface within the confines of a swamp, then dispersal of the dissolved solids would occur. If the swamp dried up in a drought then surface salts would accumulate but would be dispersed as soon as sufficient rain fell to re-fill the swamp. These swamps were drained by the early settlers allowing accumulation of soluble salts where the aquifers discharged and, in some cases, the development of saline/alkaline scalds (Gardner 1854).

Kreeb *et al.* (1995) argued that the primary cause of this scald development is the irregular occurrence of wet and dry periods in combination with the chemistry and structure of the underlying lithology and swamp drainage and that tree clearing in the past will have had little impact on the extent of scald development in the Uralla-Walcha district. They also describe the occurrence of salt effloresences in road cuttings to the east of Walcha where the mean annual rainfall is of the order of 1000 mm pa and the landscape has been little modified for agriculture. It would seem, therefore, that there is not a close association between land clearing and saline/alkaline scald formation apart from swamp drainage towards the end of last century.

An effective strategy for the amelioration of saline/alkaline scalds in the Uralla/Walcha district would be to prevent the localised accumulation of soluble salts at the point of discharge of the localised aquifers. This prevention of soluble salt accumulation could possibly be achieved by re-creating the earlier swamps or by the installation of reverse interception drains to spread the groundwater discharge. Alternative treatments which might be effective would be the use of soil ameliorants such as gypsum (calcium sulphate) or epsomite (magnesium sulphate) to replace the sodium and improve infiltration rates and so hasten leaching. It is unlikely that even extensive tree planting on the nearby intake beds for the aquifers would have any significant impact on the scalds, certainly not in the short term.

9. Where Do Soluble Salts Concentrate at Saline/Alkaline Sites?

A saline/alkaline scald on the property "Adgin Green", Uralla was sampled in detail as little information was available concerning the below ground distribution of salts of saline/alkaline scalds in the Uralla-Walcha district. An area of 20 metres by 24 metres was pegged out in a 4 by 5 m grid and at each grid intersection a soil core was removed intact at 0-100 mm, 100-200 mm, 200-300 mm and 300-400 mm depths using an hydraulic soil corer which was mounted on a 4WD supplied by Lanfax laboratories. A surface map was generated of the scald areas by sketching the location of bare patches within the grid (Fig. 1). Laboratory analyses of the soil samples were carried out by Lanfax Laboratories, Armidale for electrical conductivity, chlorides and carbonates. Total soluble salts (cations + anions) were calculated for each layer of the whole area (Table 3).

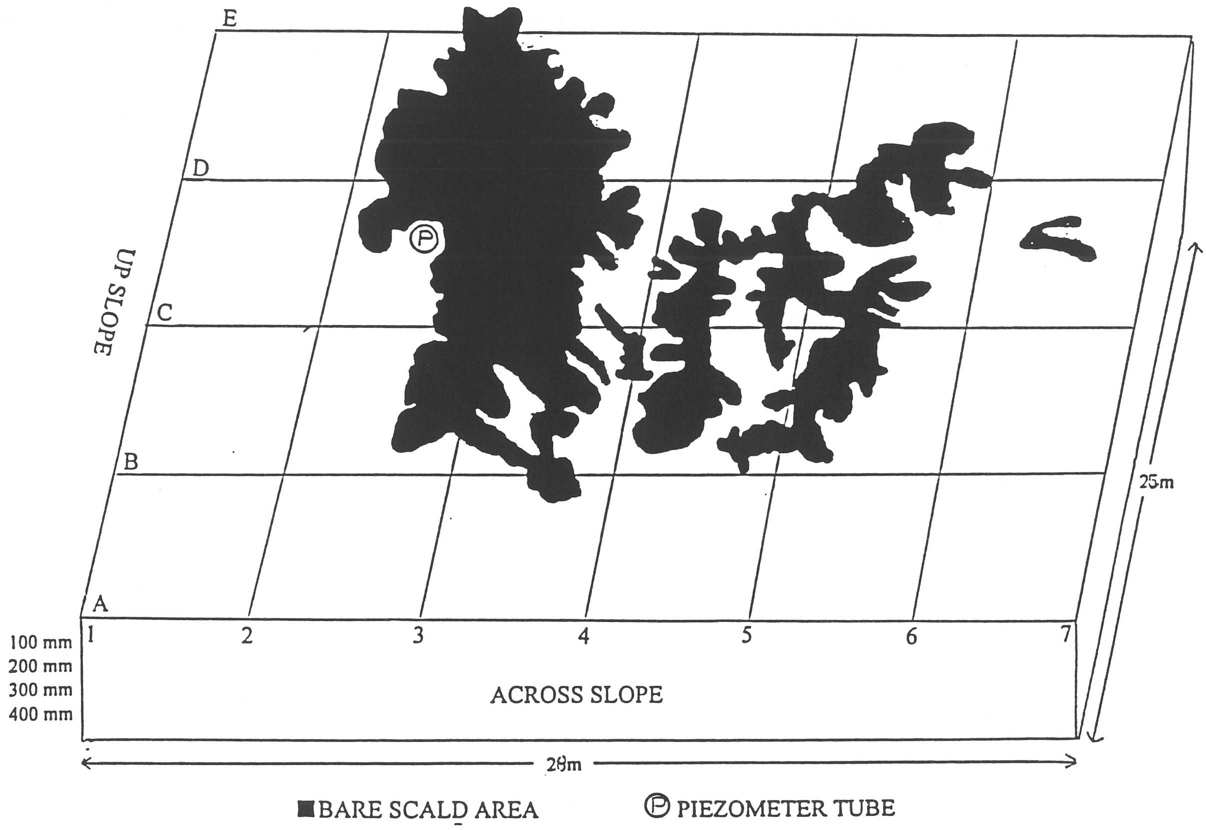

Figure 1 Diagrammatic representation of the grid system on a scald at "Adgin Green", Uralla.
P refers to the location of a piezometer tube.

The soluble salt load over the whole area increased down the soil profile (Table 3). Higher conductivity were found in the region where the bare scalds occur (Figs. 1 and 2), e.g. in the regions 3E, 3D, 3C, 4D, 4C, 4B, 5D, 5C, 5B, 6D and 6C. However, high figures are also found at 6A, 6B, 7B, 7C and 7A which were heavily vegetated. This would indicate that high salt loads are not necessarily directly related to bare scalds but may extend underground to areas not having a visible problem, or the high salt load values in vegetated areas may indicate a future expansion of a scald.

Table 3 Salt loads of a scald at "Adgin Green", Uralla for areas measuring 25 m x 28 m at depths of 100 mm increments down the soil profile.

Soil Profile Depth	Salt Load (kg) 700 m^2
0-100 mm	507.42
100-200 mm	648.78
200-300 mm	859.55
300-400 mm	905.15
Total (0-400 mm)	2920.9

The carbonate levels were much higher than the chlorides (Figs. 3 and 4 - note the differences in scale) and surface levels were closely associated with the scald. On the other hand, high carbonate levels were found at 6A, 6B, 6C, 7A, 7B and 7C which were heavily vegetated. The high carbonate levels beneath the vegetated areas generally did not extend to the soil surface.

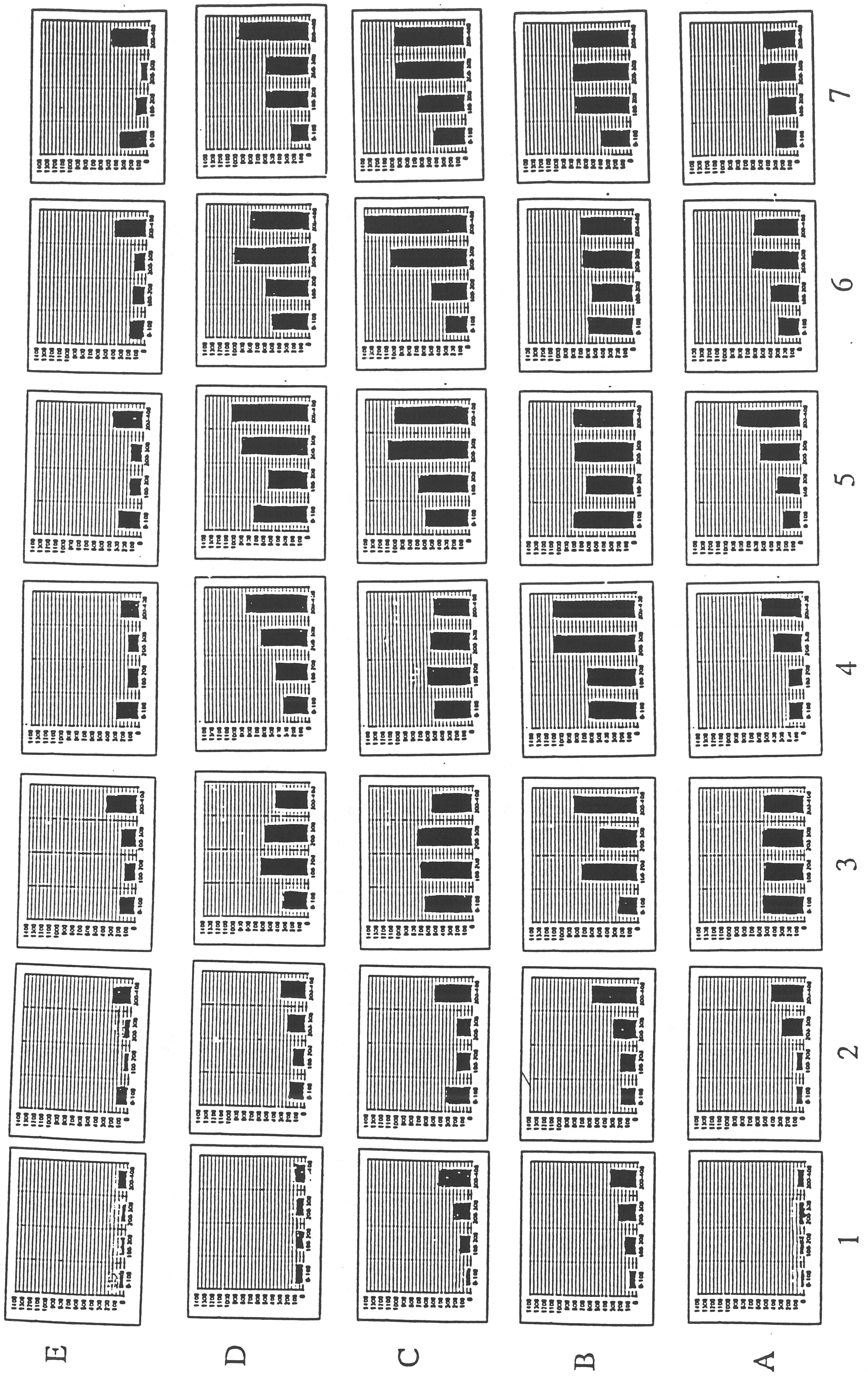

Figure 2 Electrical conductivity measurements (microsiemens/cm) of individual soil cores of the grid system on a scald at "Adgin Green", Uralla.

Figure 3 Chlorides measurements (mg/100g soil) of individual soil cores of the grid system on a scald at "Adgin Green", Uralla.

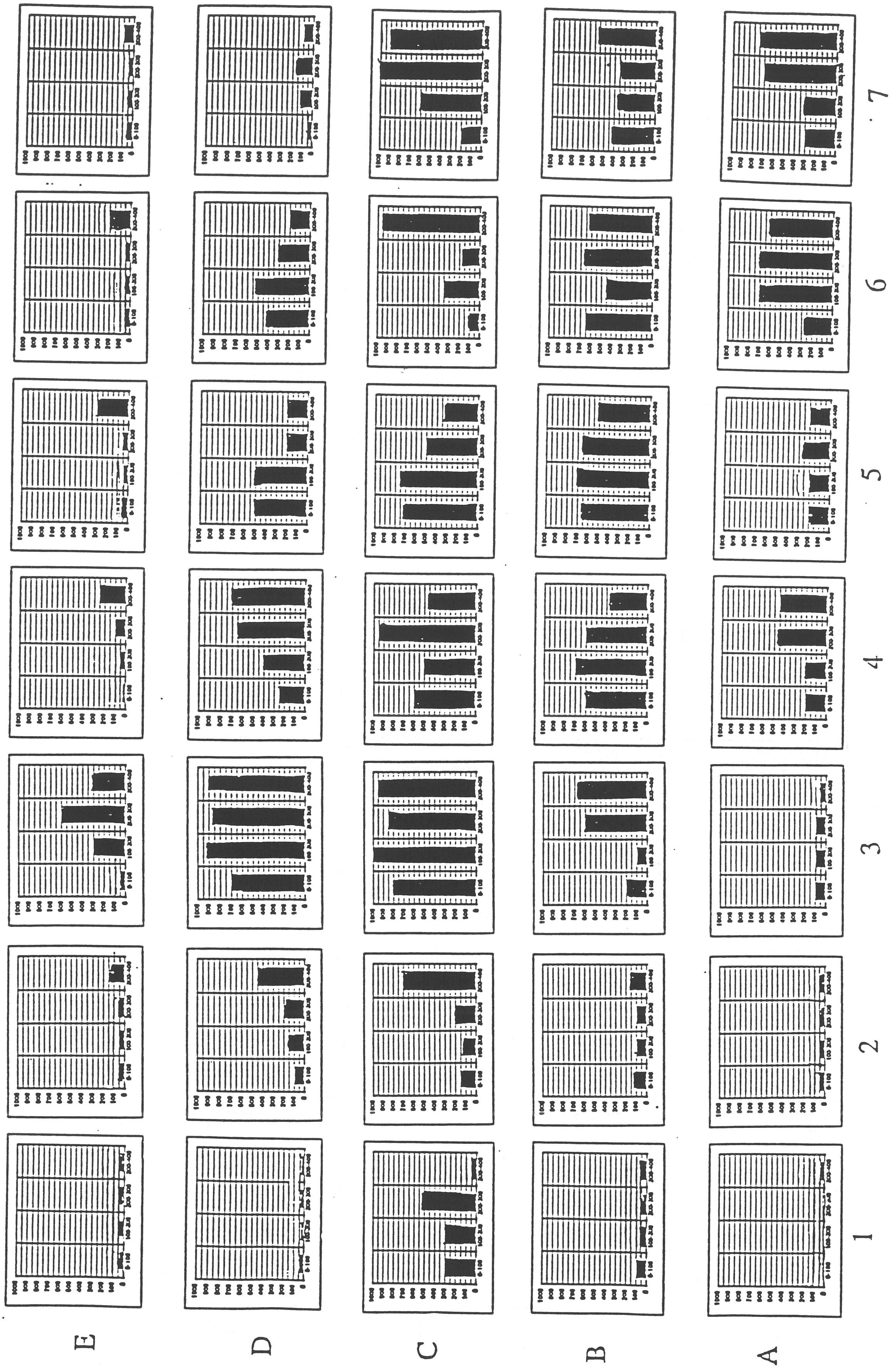

Figure 4 Carbonates measurements (mg/100g soil) of individual soil cores of the grid system on a scald at “Adgin Green”, Uralla.

Two EM units were also used for detailed and broadscale electromagnetic mapping of the experimental scald sites, the EM38 and the EM31. The EM38 operates at a frequency of 14.6 kHz. The EM31 operates at a frequency of 9.8 kHz. The EM31 was also mounted on a four-wheeled motorbike allowing large areas of land to be surveyed relatively quickly to a depth of 5 m. A soil core was also taken at each of the 20 experimental sites where the EM31 and EM38 electromagnetic surveys were carried out, to make comparisons between soil core results and corresponding EM data. A hand auger was used to extract soil samples to a depth of 0.75 m and the samples mixed and a subsample taken to represent 0-0.75 m depth. The soil cores and the EM surveys were carried out on the same day to ensure uniformity of data collection to enable groundtruthing of the EM38 EC values by comparison with the EC of the soil (Table 4) (Fig 5).

The EM38 and EM31 units average the EC value from the soil surface to the specified depths of 0.75 and 1.5 m for the EM38 and 3.0 and 6.0 m for the EM31. Therefore interpretation of the computer generated maps can be misleading. In addition, the readings produced by the electromagnetic survey units are affected by factors other than salt. Soil EC readings may increase with increasing soil water content, clay content and temperature but decrease with increasing bulk density (Slavich 1990).

Table 4 Comparison between EM38 survey and soil cores extracted at the 20 experimental sites.

Property	Treatments	EC (dS/m) for EM38 to 0.75 m depth	EC (dS/m) for soil sample to 0.75 m depth
Maryland	control	3.21	2.3
Glendella	control	0.98	1.42
50 Wilgar	control	2.64	2.43
The Glen	control	1.98	1.65
Ingleholme	control	1.56	1.24
Adgin Green	ponding	7.2	5.89
Blaxland (r)	ponding	4.5	2.87
Blaxland (c)	ponding	2.15	1.56
Wollun Station	ponding	5.62	2.56
Wilgar	ponding	2.20	1.24
Lakeview	drains	2.78	2.98
Maryland	drains	2.12	2.56
Glendella	drains	1.11	0.98
Acton	drains	1.64	1.54
Bergen Op Zoom	drains	3.50	3.10
Church Gully	chemicals	5.20	4.89
Maryland	chemicals	5.87	4.21
Wollun Station	chemicals	6.89	5.95
Buri West	chemicals	4.69	4.22
Wilgar	chemicals	3.45	2.56

The soil core EC results were similar to the EM38 data for the twenty scald sites but some discrepancies occurred. The maximum EM38 and soil samples EC readings were 7.2 dS/m and 5.89 dS/m respectively, while the minimum reading for both was 0.98 dS/m.

In general the data showed that scalds were not always positioned directly above the places with the highest EC values. The detailed soil core data collected at "Adgin Green" also indicated that patches of high soil salinity were not necessarily directly below scalds. One soil core located in the middle of a scald may give a misleading impression of the distribution of soluble salts underground.

Electromagnetic surveys can be a useful tool and should be carried out prior to any future studies on saline/alkaline scalds to give a better understanding of the characteristics of individual scalds. However limitations do exist in the interpretation of the EM surveys because the data represent an integration of the EC values from the soil surface to the depth specified.

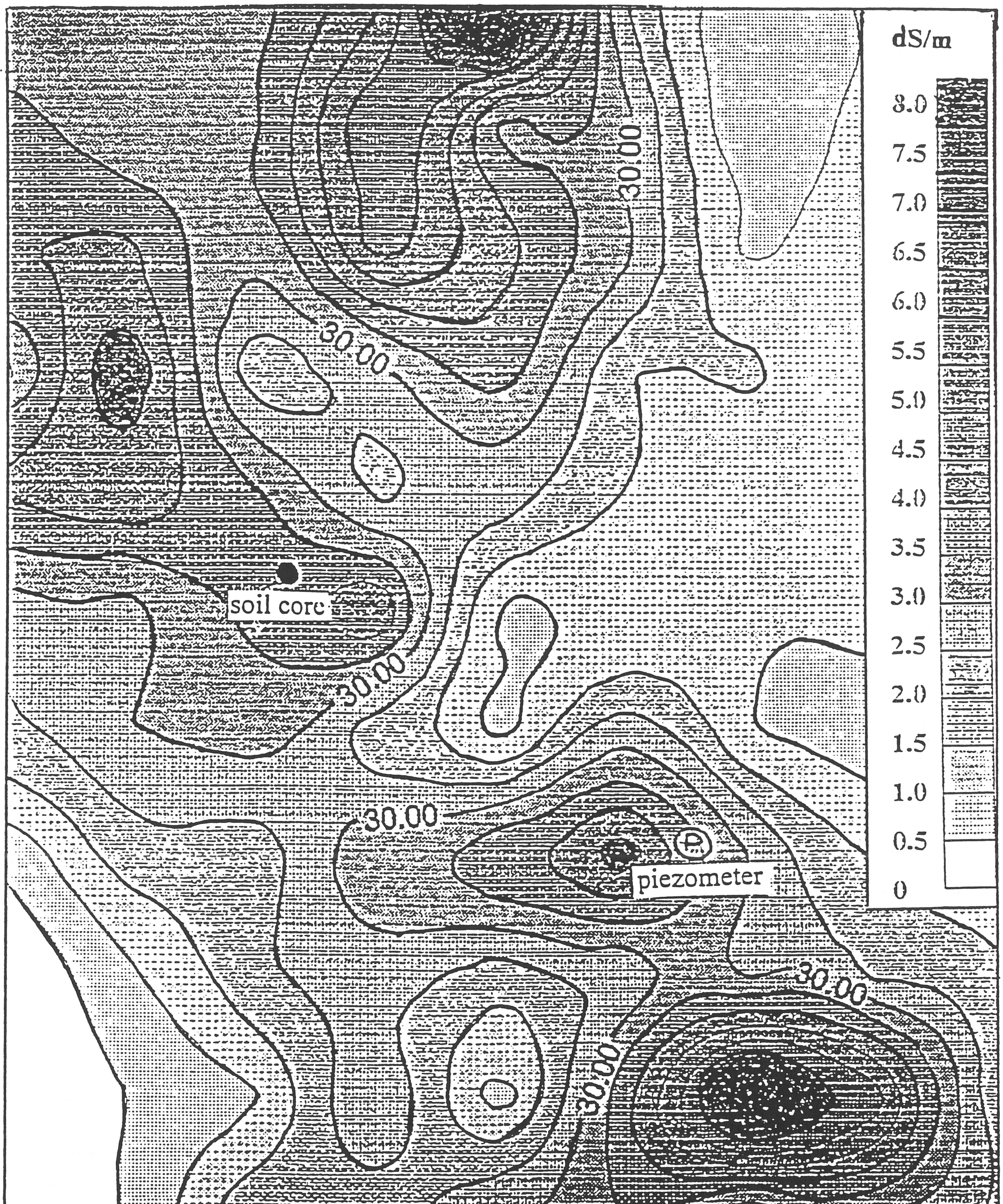

Figure 5 Electromagnetic computer generated survey of 0-0.75 m depth at "Bergen Op Zoom", Walcha. An ● indicates where the soil core was extracted and P indicates the position of the piezometer.

10. Reclamation of Saline/Alkaline Scalds in the Uralla-Walcha district

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 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.

Quicker results are anticipated from activities designed to disperse soluble salts which are already concentrated in saline/alkaline scalds and are directed at the scalds themselves. Such treatments include:

1. a form of ponding designed to re-create swamps similar to those originally occurring in the region to disperse the soluble salts by draining the water from the ponds,

2. reverse interception drains as used in Western Australia and

3. the application of two chemical ameliorants namely gypsum (calcium sulphate) and epsomite (magnesium sulphate).

10.1 Ponding Technique

Ponding involves flooding an affected region, so that the soluble salts in the topsoil dissolve in the ponded water and can be dispersed through a drainage system (Fig 6). Leaching works in a similar way except that the soluble salts are dissolved and leached through the profile and removed via a subsoil drainage system. It is important that the drainage from the ponds results in the dispersal of the soluble salts and not their concentration in another location. Figures 7 and 8 show total dissolved salts (kg) and sodium (kg) removed per pumping from each individual dam for the five experimental ponding sites from 25/11/93 to 25/02/96.

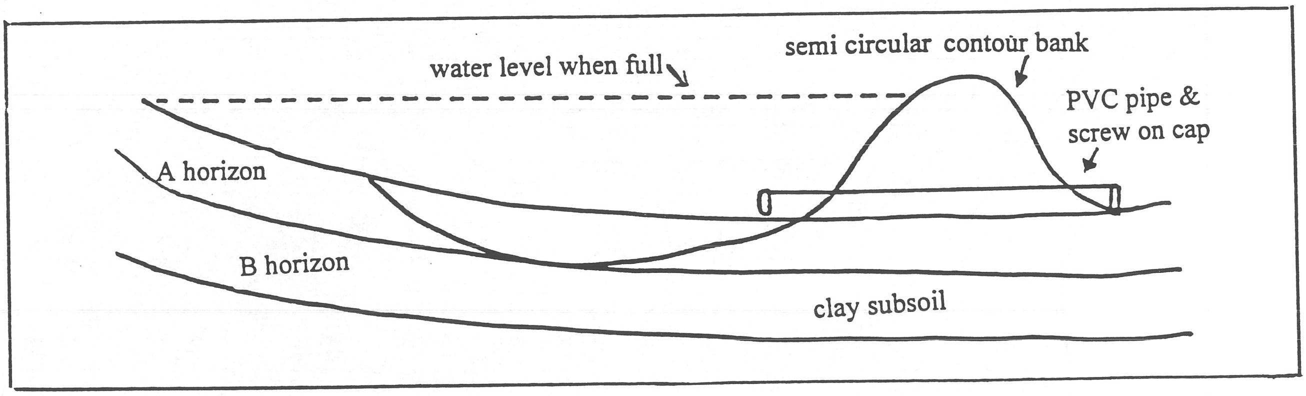

Figure 6 Diagrammatic representation of a ponding system to dissolve and disperse soluble salts.

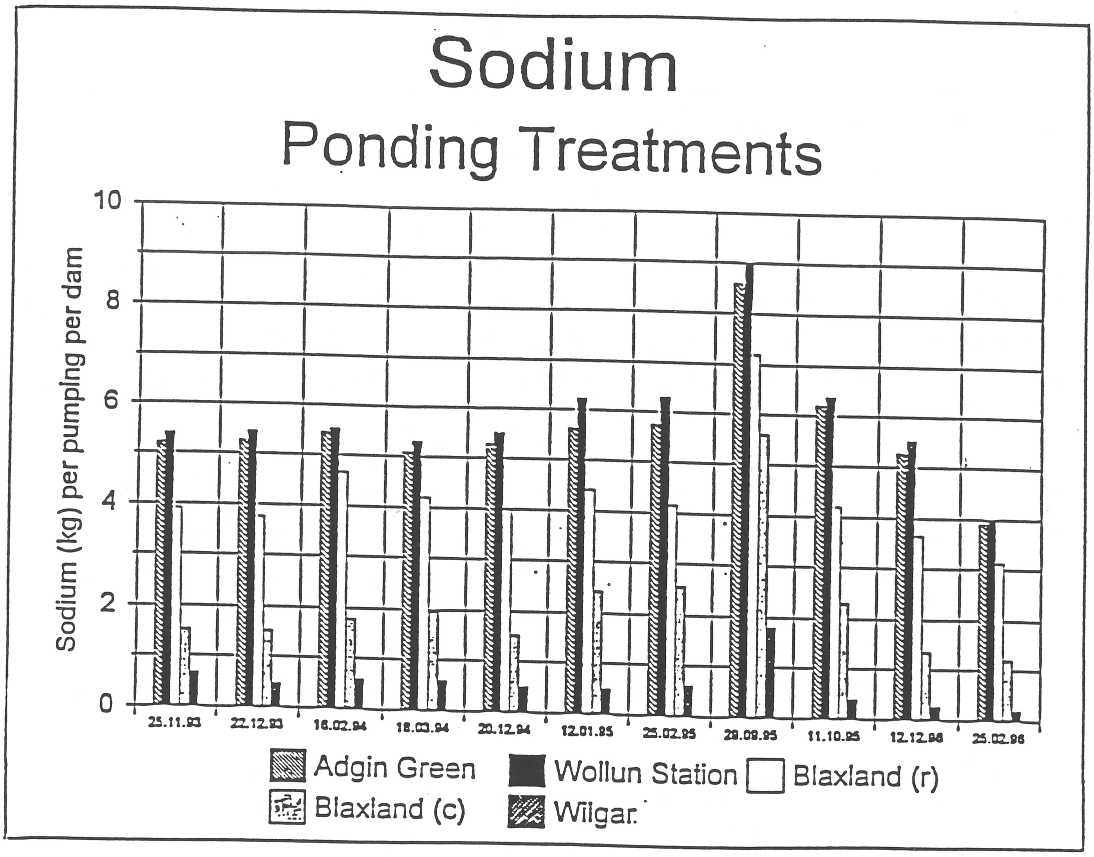

Figure 8 Sodium (kg) per pumping per dam for the five experimental ponding treatments from 25/11/93 to 25/02/96.

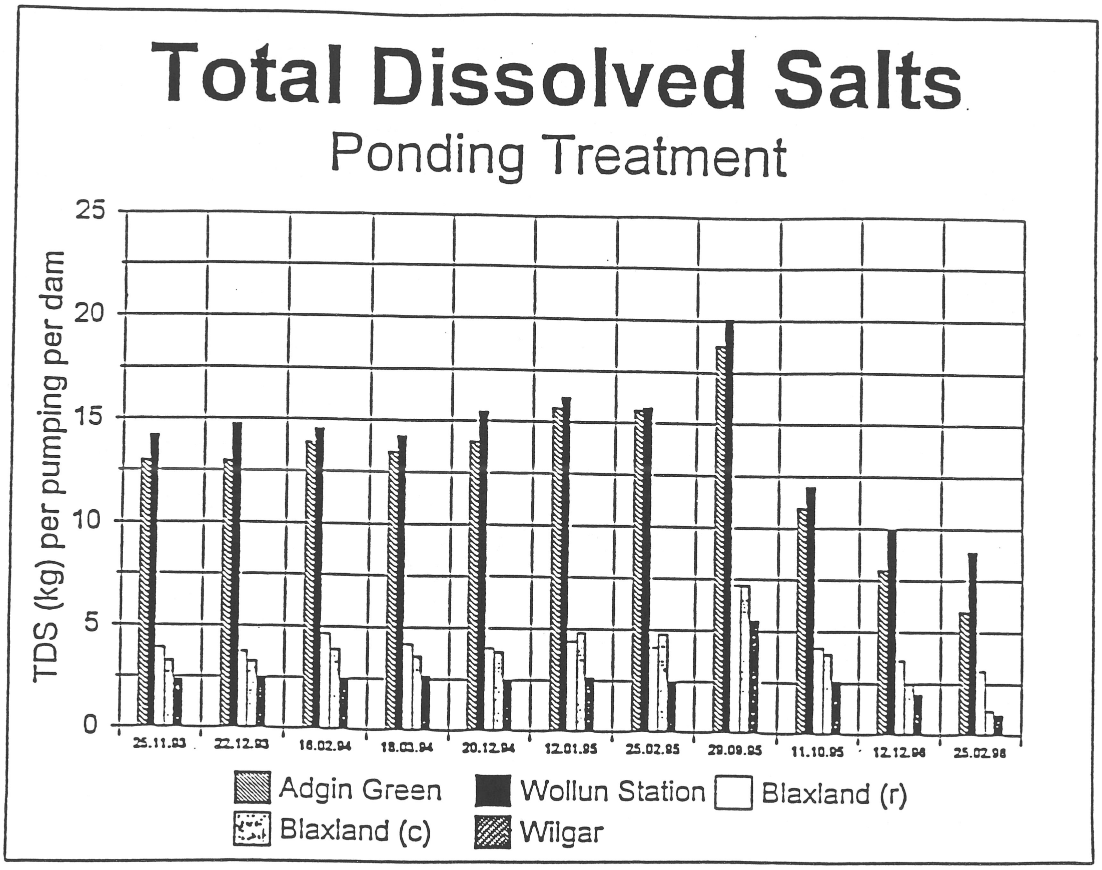

Figure 7 Total dissolved salts (kg) per pumping per dam for the five experimental ponding treatments from 25/11/93 to 25/02/96.

10.2 Reverse Interception Drains

Interception drains are those which intercept both surface and sub-surface water moving down hillsides and prevent if from reaching the areas to be protected. Research conducted by Cox and Negus (1985) showed that interception drains were effective in reducing waterlogging down slope. The use of open surface drains has the benefit of removing large quantities of water quickly and efficiently. Where duplex soils occur and the surface is free draining, open surface drains can assist in lowering the watertable (Cole and Middlemas 1985).

The advantage of interception drains lies in their ability to cut off and divert underground water from seepages on sloping areas if the seepage is caused by impermeable rock or clay at shallow depth. The amount of flow intercepted is dependent upon its depth relative to the thickness of the water bearing layer (George 1978). Surface drainage is useful when:

1. the topography is up to 3° slope and the soils are relatively impermeable,
2. there are depressions that hold water,
3. large amounts of runoff from surrounding land accumulate,
4. overflow from streams or rivers is likely,
5. the natural drainage lines are ill-defined or discontinuous.

(George 1978)

In 'conventional' interception drains, overland flow and interflow are removed in the same channel but the up slope batter often erodes resulting in silting of the channel. Therefore reverse interception drains were developed. Reverse bank interceptors have the spoil from the channel placed on the up slope side which prevents storm water flows from entering and scouring the drain channel, whereas conventional interception drains have the spoil on the down slope (see Fig. 9). Plates 1 and 2 show a scalded surface at a reverse interception drain site at "Maryland" prior to (Plate 1) and after drain establishment (Plate 2) showing almost complete revegetation of the previously bare surface.

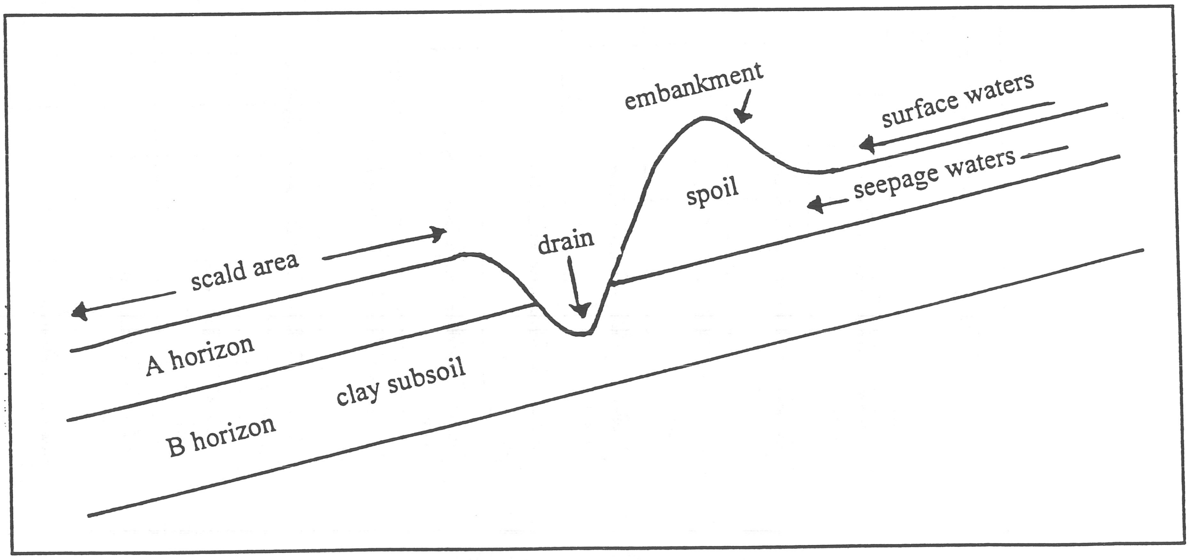

Figure 9 Diagrammatic representation of a reverse interception drain.

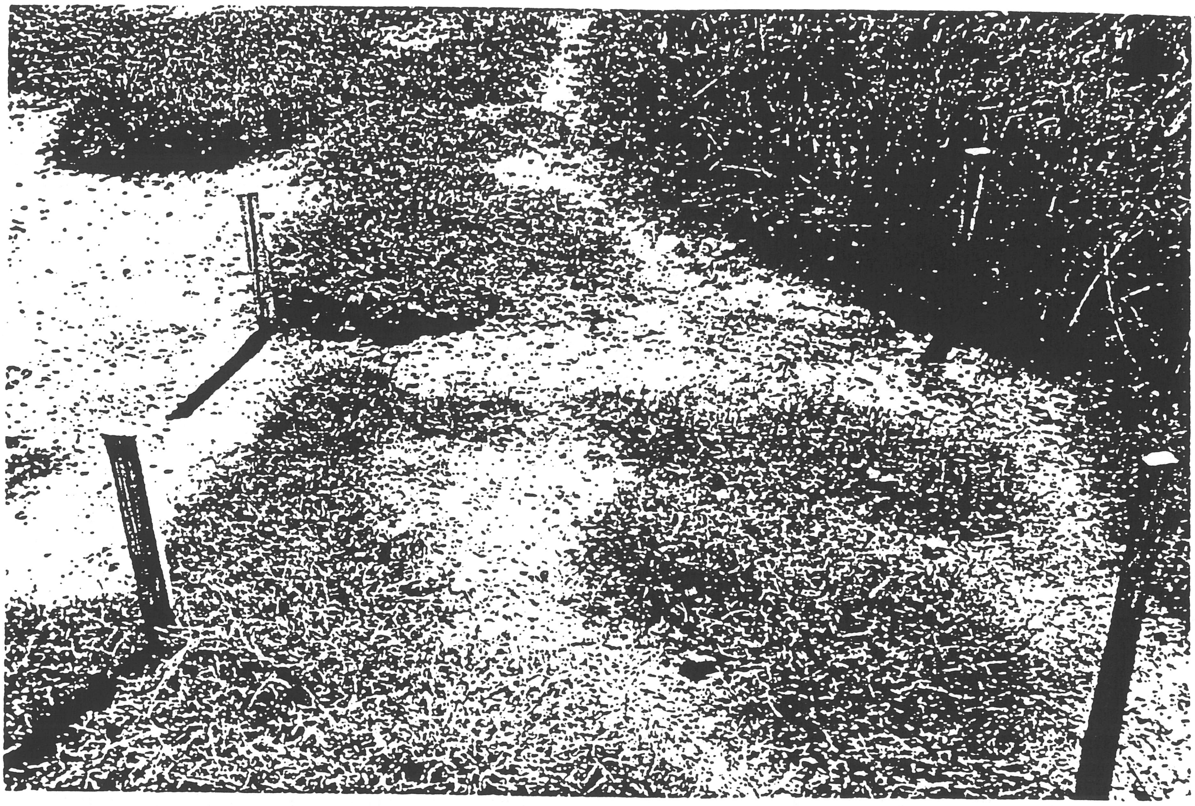

Plate 1 Scalded surface at the reverse interception drain site at "Maryland" prior to drain establishment (14/04/93.

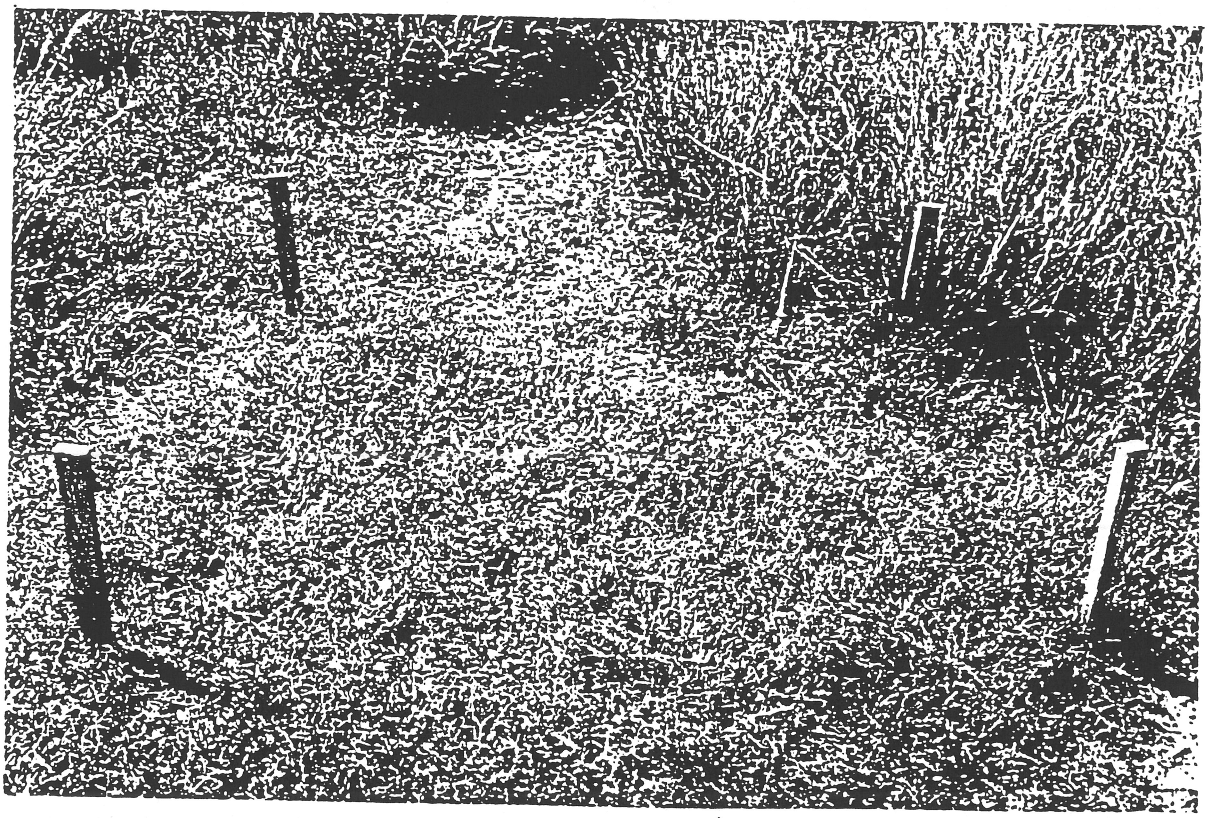

Plate 2 Reverse interception drain site at "Maryland" after the drain establishment showing almost complete revegetation of the previously bare surface (24/04/96).

10.3 Chemical Ameliorants: Gypsum (*calcium sulphate*) and Epsomite (*magnesium sulphate*)

Gypsum is widely used as a calcium source and epsomite as a magnesium source for different crops and as soil conditioners for sodic soils because of the low cost, availability and ease of handling of these chemicals. An application rate of 5 tonnes per hectare can be used to replace the sodium ions with calcium and magnesium (Tables 5 and 6). Both the gypsum and epsomite have proved to be successful in increasing infiltration of water into the soil and in improving soil structure (Figure 10).

Table 5 Exchangeable sodium, calcium, magnesium and potassium (mg/kg^{-1}), pH, ESP and SAR of initial and final soil cores for the five experimental treatments of gypsum (calcium sulphate) for the following depths: 0-100 mm, 100-200 mm, 200-300 mm and 300-400 mm.
An * represents those results which had significant differences between initial and final soil cores using Scheffe's test (P<0.05)).

Gypsum	0-100mm	0-100mm	100-200mm	100-200mm	200-300mm	200-300mm	300-400mm	300-400mm
	initial	final	initial	final	initial	final	initial	final
sodium	2453	*710	2693	*515	2773	*937	2807	*1107
calcium	1401	*2140	1165	*2985	1136	*2596	1205	*1891
magnesium	389	391	370	432	512	595	729	761
potassium	213	126	161	116	117	94	148	129
pH	8.3	8.1	8.8	8.2	8.9	8.7	8.9	8.6
ESP %	47.0	*15.9	52.6	*16.1	54.6	*17.7	48.8	*21.7
SAR	14.7	*3.0	16.3	*4.0	17.0	*4.3	16.0	*5.7

Table 6 Exchangeable sodium, calcium, magnesium and potassium (mg/kg^{-1}), pH, ESP and SAR of initial and final soil cores for the five experimental treatments of epsomite (magnesium sulphate) for the following depths: 0-100 mm, 100-200 mm, 200-300 mm and 300-400 mm.
An * represents those results which had significant differences between initial and final soil cores using Scheffe's test (P<0.05)).

Epsomite	0-100mm	0-100mm	100-200mm	100-200mm	200-300mm	200-300mm	300-400mm	300-400mm
	initial	final	initial	final	initial	final	initial	final
sodium	2453	*653	2693	*510	2773	*786	2807	*1207
calcium	1401	1092	1165	993	1136	1223	1205	1192
magnesium	389	*931	370	*934	512	1502	729	*1116
potassium	213	155	161	173	117	105	148	118
pH	8.3	8.2	8.8	8.4	8.9	8.8	8.9	8.7
ESP %	47.0	*14.9	52.6	*14.9	54.6	*16.1	48.8	*23.6
SAR	14.7	*3.6	16.3	*4.9	17.0	*5.2	16.0	*6.2

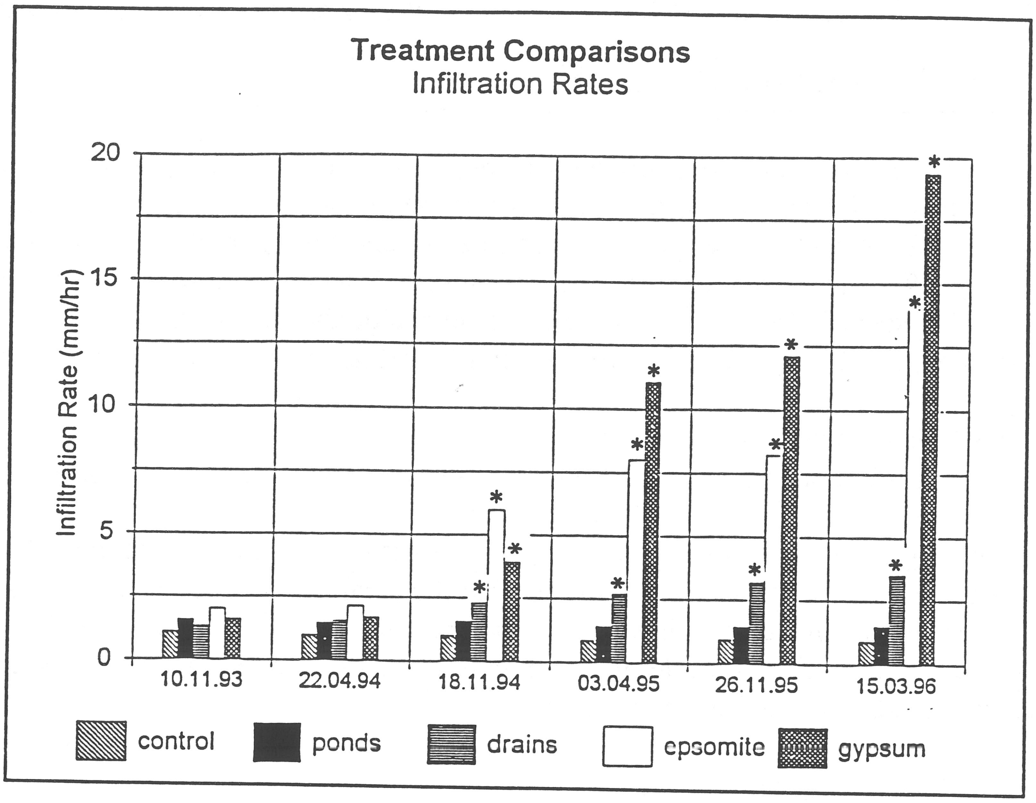

Figure 10 Infiltration (mm/hr) for the five treatments of control, ponding, reverse interception drains and the application of gypsum and epsomite from 10/11/93 to 15/03/96. (An * represents those means which were significant (P<0.05) different from the control values at the same time).

11. General Guidelines on Which Reclamation Technique to Use

The first step for landholders is to determine whether a particular scald is or is not saline/alkaline. Surface soil pH of saline/alkaline scalds can be determined in the field by the use of a field test kit and 2M hydrochloric acid can be used to test for the presence of free carbonates/bicarbonates. If the pH is above 7.5 and carbonate/bicarbonate is present then one or more of the treatments 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 on which treatment to apply.

a) Flat land (not waterlogged)
- apply chemical ameliorants, either gypsum or epsomite (or a mixture) at 5 tonnes per hectare.

The addition of gypsum or epsomite would only be effective on scalds on flat or almost flat land because the movement of surface water will wash the chemicals away. The epsomite produces more rapid cracking of the soil surface than gypsum whereas the gypsum may well produce a greater change in the water infiltration rate after a couple of years. It may be that a mixture of both chemicals will be the most effective treatment.

b) Flat land (waterlogged)
- construct reverse interception drains.

c) Medium slopes, 1 to 2 % slope (not waterlogged)
- construct reverse interception drains if water is on top of the B horizon, otherwise use ponding.

Ponds will only be effective on slopes between 1 and 2% because on greater slopes, the wall must be too high and the amount of soil necessary to build it is excessive. 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
Saline/alkaline scalds are rarely found on slopes in excess of 3°. If they do occur, then reverse interception drains are the most likely structures to be effective.

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 a water course because the solute laden water moving down slope can be easily directed into the drainage line. Reverse interception drains on nearly flat land can possibly be combined with chemical ameliorants.

(e) Other sites
Sites not covered above may require unusual treatments which take account of the local landscape and the position and characteristics of the saline/alkaline scald.

The effect of fencing alone (to exclude stock) does not appear to be an effective treatment in reclaiming saline/alkaline scalds in the Uralla-Walcha district.

Tree planting is recommended on ridges and hill tops but not on the actual saline/alkaline scalds. Tree planting is a long term approach and needs to be done in combination with one or more of the above treatments according to site conditions.

N.B.

Whilst every care has been taken to ensure accuracy and reliability of the foregoing information no responsibility for the consequences which may arise from acceptance of recommendations or suggestions made can be accepted, as many other external factors may affect the processes and outcomes.

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