1-1-1989

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ISSN 0729-3135
May 1989

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Resource Management Technical Report No.86

Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Table of Contents

1. Summary

This catchment study in a low rainfall farming area identifies some of the problems involved in developing a total catchment approach to management of secondary soil salinity. Absorption banks, designed to store surface runoff were assessed. Information on crop water use, particularly on acid sandy soils, was obtained in order to devise cropping strategies to reduce groundwater recharge. Representative transpiration and soil moisture measurements were carried out.

The absorption bank system was effective in reducing surface runoff and thus reducing flooding and waterlogging of low lying land. However additional deep drainage below bank channels occurred in the coarser textured soils. Prevention of this problem will require controlled release of water from the banks.

Although much of the overland flow had been stemmed with the absorption bank system, a 1.2 m depth main drain was required to drain low-lying areas which tend to become waterlogged in wet periods.

Triticale and lupins were found to be the most effective water using crops on the acid sandplain soils. Continuous cropping of recharge areas with high water-using crops, combined with selective revegetation of unproductive areas with perennial shrubs and trees will help to maximize water use on potential recharge areas.

2. Introduction

The widespread salinization of agricultural land in the south-west of Western Australia has resulted from changes to the landscape water balance due to the replacement of native plants with annual crops and pastures.

Effective catchment management aims for the most efficient use of rain falling on the catchment. Nulsen and Baxter (1982), hypothesized that salt encroachment can be reduced, halted or prevented by re-establishing a hydrologic regime similar to that which occurs in the uncleared state. This requires that plant water use be maximized to minimize recharge in each landscape unit.

It was shown by Nulsen and Baxter (1982) that there are sufficient differences in water use between various crop species such that strategic cropping rotations could achieve a reduction in recharge to groundwater. Additionally, localized major recharge areas (if definable) could be revegetated with deep rooted, fast growing perennial species.

The East Perenjori catchment (Fig. 1) is located on the north-eastern fringe of the agriculture area in Western Australia. It experiences a dry, warm Mediterranean climate with a mean annual rainfall of 310 mm, 66 per cent of which falls during the growing season from May to September.

The catchment has a total area of 139 km^2 of which 65 per cent was cleared of native vegetation in the period 1962-1967, and a further 12 per cent was cleared in the following decade. The remainder is uncleared in a pastoral lease. Wheat cropping is the main agricultural activity, although there has been a recent trend toward increased cropping of lupins and triticale and increased sheep grazing on annual pastures. Under this agricultural system soil salinity was developing rapidly and in 1986 affected 2.4 per cent of the area of the catchment.

Landholders in the catchment were concerned about water management and the development of soil salinity. Rapid overland flow, generated by high intensity summer and autumn storms commonly results in the erosion of hillslopes and the flooding and waterlogging of low-lying land.

A catchment study to help understand the processes involved in salinity development was carried out from 1983 until 1986. The results of this study are documented in DRM Technical Report No. 85 and this includes a description of the five land units in this catchment.

During this period, contour earthworks were carried out in the catchment and a number of agronomic trials were set up to address the issue of increasing the water use in recharge areas. This report is an assessment of some management strategies for reducing land degradation problems in the East Perenjori catchment.

3. Management Strategies.

3.1 Surface Water Control

The catchment soil conservation group of land users assigned a high priority to the control of surface runoff. True contour absorption banks were recommended because of the lack of sites for grassed waterways which are required for traditional grade banking terraces. The land users also wished to hold runoff on the slopes because of their concern about losing water generally. An awareness that contour working of the catchment would promote even absorption of rainfall, together with structures to temporarily store runoff from higher intensity storms.

A system of bulldozer-built absorption banks which store runoff on catchment slopes were designed and surveyed. The banks were built to at least 1.2 m height above the natural surface and were designed to store approximately 18 mm of surface runoff before overflow around their ends. Approximately 50 per cent of the cleared section of the catchment was treated by June 1983 and a further 7 per cent in 1985.

3.2 Reducing Recharge

Information on crop water use was required so that appropriate cropping strategies could be devised to maximize water use. Cereal test plots with four replications of each treatment, were sown in 1984 and 1985 (Table 1).

Table 1. Cereal test plot treatments

Plot	**Treatments**	
	1984	**1985**
1	Wheat (cv. Gutha)	Wheat (cv. Gutha)
2	Lupins (cv. Yandee)	Wheat (cv. Gutha)
3	Barley (cv. Stirling)	Cereal Rye (cv. SA Commercial)
4	Triticale (cv. Coorong)	Bare fallow

The test plot site had been cleared of native vegetation (Acacia resinomarginea, A. neurophylla, Allocasuarina spp., Grevillea spp. and Hakea spp.) in 1979 and was cropped twice since then. The soil was a Gnl.21 in land unit 2, occurring in a mid-slope position with a northerly aspect. The soil profile was described as a yellowish brown loamy sand over sandy loam at 20 to 50 cm and sandy clay loam at 100 to 125 cm. The soil pH (1:5 H_2O) was 5.0 at the surface decreasing to 4.3 at 100 cm.

The experimental block comprised of 16 plots 40 x 4.6 m. Wheat (Triticum aestivum cv. Gutha) and barley (Hordeum vulgare cv. Stirling) were sown at a rate of 50 kg ha^{1}, triticale at 70 kg ha^{-1} and lupins (Lupinus angustifolius cv. Yandee) at 100 kg ha-1. Fertilizers were applied according to district recommendations.

Rainfall was measured on-site. Soil moisture measurements using a neutron moisture meter (Campbell Pacific Nuclear Corp., model 501) were carried out on eight plots with two access tubes per plot. Access tube holes were either augered by hand or drilled with a power rotary auger to an average depth of 3.4 m. Upon insertion of a 50 mm diameter aluminium tube, the remaining annular space was backfilled with dry sand.

Measurements commenced in May 1984 and continued at fortnightly intervals throughout the growing season. A further six tubes were installed within undisturbed native vegetation and measurements commenced in 1985 and continued at monthly intervals. Readings were taken at depth intervals of 25 cm. Details of installation and calibration are described in DRM Technical Report No. 85. Details of watertable monitoring can be found in the same report. An infra.-red thermometer was used to assess transpiration on one day per fortnight. The method used is outlined by Nulsen and Baxter (1986).

3.3 Production from Saline Areas

A test plot (0.5 ha) of halophytes was established in July 1984 on a Db2.43 soil in land unit 5 which had become salinized to the extent that barley (Hordewn spp.) production was no longer economic. Species included bluebush (Maireana brevifolia), quail brush (Atriplex lentiforrnis) and wavy leaf saltbush (A. undulata). They were planted with the Mallen Niche Seeder (Malcolm and Allen, 1981), which uses an elevated niche to avoid waterlogging and to help leach salt from the seed bed.

4. Evaluation of Surface Water Control Measures.

Storage characteristics were measured on a sample of 25 absorption banks. With land slopes of less than 3.5 per cent, the storage in bank channels was generally small relative to above-ground storages. The banks had their ends turned up by 0.5 m. Average bank length was 1344 m, ranging from 205 m to 2125 m in the sample measured. Average spacing was 381 m, with a range of 20 m to 720 m. Average interbank areas are approximately 50 ha, for convenient cropping with large machinery.

The banks were subjected to a number of relatively large rainfall events. In 1984, March to May rainfall totalled 300 mm, which is close to the annual average for the catchment. One storm event of 70 mm in 24 h (May, 1984) resulted in some 10 per cent of the catchment becoming untrafficable to farm machinery for a period of at least 3 weeks. Although this was largely due to insitu waterlogging, banks were seen by landholders to have a beneficial effect in reducing flooding. However, erosion and waterlogging still occurred in some interbank areas. Both saturation excess and infiltration excess mechanisms of surface runoff generation were thought to occur in the catchment.

Seventy-three absorption banks totalling 107 km in length received runoff from 37 km^2 during the May 1984 event. The total storage was estimated at 0.57 x 106 m^3 with an average storage (in a sample of 15 banks) of 20.5 mm per bank prior to overflow.

By mid 1985, runoff from 61 km^2 was being stored in absorption banks. Average storage was 18 mm prior to overflow and the total capacity behind the banks was then estimated at more than 1.1 x 106 m^3.

4.1 Hydrograph Estimation

To determine the effect of absorption banks on the volume of surface runoff, pre-bank and post-bank hydrographs were generated using a computer model. The following method was used:

(i) The duration of the design storm (in hours) was taken as tc, where tc is the time of concentration of the catchment.

$$tc = 0.76\ A^{\circ 38}$$

where A is catchment area in km^2

For A = 106 km^2, t_c = 5 hours (approximately).

Due to the elongate shape of the catchment, t~ has been assumed to be 6 hours.

(ii) The 1 in 10 year return period event has been used for the design storm.

(iii) The 1 in 10 year, 6 hours rainfall intensity for the area is estimated to be 8.32 mm h^{-1} (McFarlane, 1986).

(iv) For the temporal pattern of rainfall bursts, the graphs provided in “Australian Rainfall and Runoff”, have been used (Institution of Engineers, 1977).

(v) The pre-bank Initial-Loss (IL) was calculated using the equation of Flavell (1986):

$IL = 460\ P^{-0.41}\ L^{-0.08}$

where L = mainstream length (km) and P = mean annual rainfall (mm). Substituting values of P. = 310 mm and L = 19 km, the initial loss was calculated to be IL = 34.5 mm (for pre-bank condition).

(vi) The Continuing Loss (CL) was assumed at 3 mm ha^{-1} (Flavell, 1986).

(vii) For calculation of the peak flood values, from rainfall data, RORB-version 3 Runoff Routing Program, was used, (Laurenson and Mein, 1985).

The total rainfall for the design storm is 50 mm.

Results showed that under pre-bank conditions, only 5 mm out of the 50 mm design storm would contribute to surface runoff. Outflow from the catchment would occur 4 hours after commencement of the storm and the peak flow would be 24 $m^3\ s^{-1}$. The total volume of the flood would be 0.53 x 10° m^3.

Under post-bank conditions, the 50 mm design storm would not generate runoff at the catchment outlet. The existing absorption banks have the capacity to accommodate the 5 mm of surface runoff as well as having a capacity to store runoff generated from a storm greater than 1 in 10 year probability. However, storms of less than 1 in 10 year frequency can still result in waterlogging of the valley floor.

Runoff generated from the 39 km^2 uncontoured area of the catchment was calculated for the 1 in 10 year and the 1 in 50 year storms. Although no runoff would be generated at the catchment outlet in the former case, a flood with a peak flow of 32 m^3 s~ would be generated in ‘the latter case.

4.2 Watertable Responses beneath Absorption Banks

Absorption banks were surveyed across the landscape without regard for changes in soil type. The risk of ponding water in the deep sandplain soils of land unit 2 was apparent and measurements were carried out during three storm events in 1986 to gauge the recharge potential of these structures.

Two highly localized storm events occurred in the summer/autumn period of 1986. Falls of up to 29 mm occurred in durations of approximately 15 minutes. Because raingauges were sparsely located and storms were highly localised, rainfalls could have been co~isiderably higher where the banks filled with runoff. A general rain in May 1986, produced a total fall of 38 mm including up to 32 mm in 4 hours and 20 mm ina.3 hours. Each of these storms resulted in some absorption banks to be filled completely with water.

Major source areas for surface runoff were roadways as well as rock outcrops and breakaways on the pediment slopes (land unit 3). Water flowing into absorption banks was channelized laterally from the finer textured pediment slope soils (land unit 3) to the coarse textured soils of the sandplain slopes (land unit 2). Water remained ponded for many weeks in bank channels on the pediment slopes, flooding cropland for some tens of metres upslope of the banks until the water infiltrated, causing waterlogging in places by lateral seepage downslope of the banks.

Perched watertables beneath sandplain slopes (land unit 2) were monitored following a storm on January 8, 1986. The data in Table 2 shows that although perched watertables dropped where there had been no surface ponding, there were rises of up to 0.5 m in areas where ponding of water occurred.

Table 2. Responses of the perched watertable to a localized storm on January 8, 1986

Site[A]	Land unit	Depth of ponded water (m)	Change watertable in (m)[B]
PN1A	2	0	-0.55
l9.1A	2	0	-0.05
l8A	4	0	-0.04
l9A	2	0	-0.03
14A	4	0.05	+0.03
6A	2	0.20	+0.27
13A	2	0.30	+0.37
BA	4	0.70	+0.49

[A] Refer to Fig 4, DRM Technical Report No. 85 for site locations.
[B] Observation period Dec. 11, 1985, to Jan. 15, 1986.
\- = fall in perched watertable level.
\+ = rise in perched watertable level.

Water levels in absorption banks constructed in the coarser textured soils dropped at a mean rate of 0.13 m day~, indicating the potential for rapid recharge to perched watertables beneath bank channels. Responses of perched watertables to a storm on March 4, 1986 are shown in Fig. 2. This event again showed that where water had ponded in absorption banks, there was significant recharge to the perched watertable.

5. Implementation of a Drainage Scheme

Although much of the overland flow had been stemmed with the absorption bank system, the next step was to remove excess surface water accumulations (and groundwater where practicable) below areas affected by the banks. Hence, integration of a drainage system with the absorption banks was required to allow complete water management of the catchment.

A 1.2 m deep, 15 km length open main drain was constructed in September/October 1987, with the outlet at Monger's Lake. The purpose of this drain was to remove surface ponded waters, reduce the occurrence of waterlogging in the valley floor land unit and to provide a discharge outlet for tributary drains. The construction of tributary drains was to be the responsibility of individual landholders as need and/or economics dictated.

The longitudinal slope of the main drain changed from 0.001 m m^{-1} at the downstream end to 0.002 m at the upstream end. Manning's equation was used to calculate the velocity and depth of water in the drain. A value of 0.035 was chosen for Manning's roughness coefficient. A relatively high value was used to compensate for minor irregularities in construction work and for weed growth in the drain.

The drain, which was constructed with an excavator was designed to have a trapezoidal shape with a side-slope ratio of 1:1. This particular drain cross-section was selected because of the low maintenance requirement, maximum velocity for lower discharges and ability to carry the maximum discharge without erosion of the batters. The drain with maximum depth of 1.2 m was adequate to drain low-lying areas, which tend to become waterlogged in wet periods.

The drain spoil was placed continuously as a levee bank on both sides of the drain and at 1 to 2 m distance from the edge of the drain. This was to reduce batter erosion and sedimentation in the drain by excluding surface water, except at entry points at approximately 100 m intervals along the drain.

6. Evaluation of Methods for Reducing Recharge

Crops in the cereal test plots began transpiring water 20 days after seeding (May 20) and stopped transpiring at 170 days post seeding (October 17) (R.A. Nulsen, pers. commun., 1984). Triticale transpired the greatest amount of water, followed by wheat, lupins and barley (Table 3). Although barley was initially transpiring at a higher rate than both wheat and lupins until 60 days after seeding, transpiration rates then dropped rapidly relative to the other crops as the barley roots encountered the acid subsoil of the Gnl.21 soil.

Table 3. Results of 1984 cereal trials

Treatment	Grain yield (kg ha-^{1})	Transpiration (mm)	Change in soil water storage (mm)
Triticale	1600	157	-43
Wheat	1250	127	-30
Lupins	400	102	-46
Barley	660	73	-15
Measurement period:		May 20-Oct. 17	June 21 - Oct. 23

Rainfall, May 1 - October 23 : 276 mm.

The highest grain yields (Tables 3 and 4) were obtained from triticale and cereal rye on the acid soils. Poor lupin performance was attributed to weed competition and disease.

Lupins and triticale were the most effective crops in reducing stored moisture in the top 150 cm of the soil profile during the 1984 season. In comparison with wheat, lupins reduced stored soil moisture levels by an additional 13 mm and triticale by an additional 6 mm (Fig. 3). In the 1985 season, cereal rye used more soil water than wheat, and there was an overall increase in stored soil water under bare fallow (Table 4).

Table 4. Results of 1985 cereal trials

Treatment	Grain yield (kg ha^{1})	Change in soil water storage (mm)
Cereal rye	580	-24
Wheat	496	-8
Bare fallow	-	+4
Measurement period:	July 3 - Sept. 18	

Rainfall, May 1 - September 18 : 132 mm.

Nulsen and Baxter (1982) have shown the importance of high water use cropping rotations relative to annual pastures for helping to reduce the rate of recharge. Estimates of evapotranspiration indicate that lupins are a particularly efficient water user. Provided that fertilizer levels and agronomic factors are adequate, there is evidence that both grain yields and water use can be maintained at acceptable levels in a lupin-wheat or lupin-triticale rotation on most recharge areas (R.A. Nulsen, pers. commun., 1986). However, exceptions such as acid sandplain and deep white sands will occur.

The importance of agronomic manipulation is that the soil water reservior in the root zone is sufficiently depleted to be able to store the following seasons rainfall. As an approximate estimate (based on rainfall probability), the root zone should be able to store 100 mm of water early in the growing season. If less storage is available, water will be lost to deep percolation. To reduce the probability of water being lost to deep percolation, consideration should be given to revegetating particular areas of the landscape (e.g. deep acid sands) with deep rooted perennial vegetation.

Figure 4 compares soil water content profiles, under annual crop and native vegetation for the 1986 growing season. At site N9 a crop of triticale was grown, while at site Ni the triticale crop was stunted due to excessively high soil acidity. Site 2.2 was located in the intergrove of a mallee and acacia tree shelterbelt, while site N3 was located within 3 m of the base of a clump of mallee trees (Eucalyptus leptopoda). The soil type at each site was a sandy earth (Gnl.21).

Profile 1 (May 13, 1986) shows soil water contents in the late autumn, following a virtually rainless period of 70 days. Profile 2 (June 11, 1986) shows soil water contents after 62 mm of rain had fallen on the catchment. Profiles in the top 1.0 m wetted up by 20 mm in the cropland and by 30 mm within the trees. Profile 3 (July 1, 1986) shows soil water contents following 63 mm of rainfall. Profiles in the top 1.0 m wetted up by a further 10 mm, except at site N13 where the gain in soil water was 30 mm. The base of mallee trees appeared to concentrate water within the sand and debris which deposit about the stems. Similar effects were noted by Nulsen ~ ~. (1986). However in the 1 to 3 m depth range, soil water storages decreased by 4 mm under cropland and by 10 mm beneath the trees. At site N9 the perched watertable reached its lowest level below the ground surface (4.15 m) on this date.

Profile 4 (August 28, 1986) shows soil water contents following another 64 mm of rainfall and crop height was now at 0.4 m. Soil water storages in the top 1.0 in of soil were reduced by 24 mm at site Hg, by 14 mm at site Ni, by 28 mm at site 2.2 and by 39 mm at site N13. In the 1 to 3 m depth range there was negligible change in storage under cropland, but at site 2.2 storage decreased by 43 mm and at site Nl3 by 16 mm. Similar decreases occurred in the 3 to 6 m depth range. During the redistribution phase, drainage to groundwater was occurring beneath cropland, and at site N9, the perched watertable rose by 0.-35 m, reaching its highest level of 3.77 m below the ground surface on September 18. Profile 5 shows soil water contents on October 27, following 30 mm of rain. Soil water storages continued to be reduced by 10 mm at all sites in the top 1.0 in, and there were negligible changes from 1 to 3 m depth.

7. Discussion

Surface runoff has been reduced in the catchment and landholders report benefits of improved crop yields due to contour working and improved holding of moisture on the slopes. Flooding and waterlogging have been greatly reduced in low-lying areas and in the valley floor. However, rapid recharge of perched watertables was occurring from ponding of water in deep coarse-textured soils indicating a trade-off situation exists in catchment water management.

Barrett-Lennard (1986) has shown a positive interaction between waterlogging and salinity at relatively low levels of soil salinity. Hence by controlling one of the components of this interaction, i.e. waterlogging, the impact of salinity can be reduced. This is particularly so in this landscape as the presence of the red brown hardpan may act as a choke for upward capillary movement of salt and water from the shallow saline regional watertable.

It is rapidly becoming uneconomic for farmers to crop the acid sandplain soils or to apply fertilizer onto these soils for pasture production. Hence it has been suggested (Halse, 1985) that in the next 20 years, low rainfall areas in Western Australia will be cropped much less intensively and that cropping will be confined to the better soils to optimize returns. Cropping land in the lower parts of the catchment will therefore be further threatened by salinity because of decreased water use by pastures in the upsiope recharge areas.

It is essential that water use be increased on the lateritic uplands (land unit 1) and the sandplain slopes (land unit 2) where recharge to groundwater is continuing to occur (see DRM Technical Report No. 85). A combination of high water using acid tolerant crops and the revegetation of selected areas with deep rooted perennials are appropriate.

Revegetation with trees and shrubs is relatively unresearched in low rainfall areas. Pests such as birds and rabbits which have devastated young trees planted in these environments would need to be controlled. Perennial species should be selected as a fodder source and for other economic uses such as essential oils. In the East Perenjori catchment species trials have commenced as a first step.

Greenwood ~ ~j., (1985) showed that in a 680 mm rainfall zone annual evaporation ranged from 400 mm in pastures to 2000 nun from trees. They concluded that planting discrete areas with trees had the evaporative potential to assist in the reclamation of salinized land. At East Perenjori the most significant recharge areas are the highly acidic deep yellow sands on the sandplain slopes where crop and pasture growth are severely limited. It is recommended that these areas be fenced and sown to appropriate high water use perennials.

8. Future Recommendations for Catchment Management.

Both agronomic and engineering solutions are proposed in a land management package. The following management options are recommended for each of the five land units as described in DRM Technical Report No. 85. Some of these solutions have already been implemented and others are currently being experimented with.

Land unit 1

This land unit has a moderate to high groundwater recharge potential. High water using pasture-crop rotations which are relatively acid tolerant are recommended. Rotations could include the use of wheat, triticale and lupins. Tillage practices which maximise crop water use and minimise runoff should be used.

Land unit 2

The deep pockets of yellow sand which occupy 50 per cent of this land unit have a high groundwater recharge potential. It is recommended that these deep sands be culled from cropping programmes and either be left to regenerated naturally or else be revegetated with perennial species. Revegetation trials commenced in 1987, in association with the Department of Conservation and Land Management, to compare the growth and survival of a range of fodder trees and oil producing eucalypts.

Ponding of water is to be avoided in this land unit as this increases recharge to the local perched groundwater system and eventually to the deep groundwater system. The construction of absorption banks is not recommended and alternative methods for surface water control should be considered. In the case of existing banks, modification of bank structures to prevent future ponding of water is necessary.

Land unit 3

This land unit has a low to moderate recharge potential and hence traditional crop-pasture rotations (which includes wheat and peas) are suitable. Absorption banks in this land unit were extremely beneficial in reducing the effects of soil erosion plus flooding and waterlogging of low lying areas and valleys.

Land unit 4

It is recommended that the sandy upslope areas of this land unit be revegetated with deep rooted perennials. R.J. George (pers. commun.) planted Eucalyptus spp. in contour strips upsiope of sandplain seeps in the Merredin area. The trees have performed extremely well in the first 12 months due to the roots having access to a shallow and relatively fresh watertable. It was anticipated that in time these trees will dewater the perched groundwater system and reclaim the seep.

Sandplain seeps are also reclaimable with deep drainage. R.J. George (pers. commun.) has demonstrated a significant reduction in the area of sandplain seeps using deep drains to intercept the flow of water to the seep. The drainage effluent has also been fresh enough to be suitable as a stock water supply. Preliminary work at East Perenjori suggests that buried tube drainage is preferable to open ditches due to slumping of the sandy batters.

Land unit 5

Rotations in land unit 5 could include wheat or barley with the introduction of a legume such as serena medic. Attempts should be made to improve soil structure using such techniques as minimum tillage and/or gypsum application. Severely salinized areas should be fenced and revegetated with halophytes. The productivity of saline discharge areas can be increased by the establishment of halophytes as these shrubs provide a useful drought fodder reserve. For successful establishment, the revegetated areas would require fencing.

It was recommended that a buffer zone extending 10 m either side of the main drain be fenced and revegetated with perennial shrubs and grasses.

Tributary drains would be required to collect water from surrounding areas of the main drain where ponding problems are being observed. There are at least three source areas which require dewatering. Firstly, shallow spur drains should be used to connect up low spots, depressions and clay pans in the valley floor which become waterlogged in winter, and this water should be led into the main drain.

Secondly, water ponding in some absorption banks could be released from storage using control pipes and discharged into the main drain. This additional volume of water would assist in the flushing of accumulated salt in the main drain out of the catchment. Depending on storm yields it may take a few days for water to be fully drained from bank channels. The high cost of drainage pipe precludes draining absorption banks higher up in the catchment. The problem of water in absorption banks crossing land unit boundaries and entering recharge areas should be prevented by the installation of channel stops.

Thirdly, it may be practical to dewater some of the sandplain seeps occurring in land unit 4 where perched aquifers have a saturated hydraulic conductivity of about 0.5 in day^{1}. It is recommended that perforated tube drains (in preference to open ditch drains) be installed on a herringbone layout for dewatering sandplain seeps. The effluent from these subsurface drains could either be discharged into the main drain, or else used as a stock water supply if the water is of sufficient quality (R.J. George, pers. commun., 1987).

9. Acknowledgements

The research work was funded by the Wheat Industry Research Committee of Western Australia. Field and laboratory work was carried out by JA. Bessell-Browne, K.R. Southon and A.T. Ryder.

10. References

Barrett-Lennard, E.G., 1986. Effects of waterlogging on the growth and NaCl uptake by vascular plants under saline conditions. Reclam. Reveg. Res. 5: 245-261.

Flavell, D.J., 1986. Losses for design flood estimation in Western Australia. Hydrology and Water Resources Symposium. Inst. of Eng. Aust.

Greenwood, E.A.N., Klein, L., Beresford, J.D. and Watson, G.D., 1985. Differences in annual evaporation between grazed pasture and eucalyptus species in plantations on a saline farm catchment. J. Hydrol. 78: 261-278.

Halse, N.J., 1985. Director looks at farming's future. The Countryman, Centenary Issue, December 12, 1985.

Institution of Engineers, Australia, 1977. Australian Rainfall and Runoff Flood Analysis and Design. 159 pp.

Laurenson, E.M. and Mein, R.G., 1985. RORB Version 3 Runoff Routing Programme User Manual. Monash Univ. Dept of Civil Eng.

Malcolm, C.V. and Allen, R.J., 1981. The Mallen Niche Seeder for plant establishment on difficult sites. Aust. Ranael. J. 3(1): 106-109.

McFarlane, D.J., 1986. Rainfall. In "Soil Conservation Earthworks Design Manual". West. Aust. Dept. Agric.

Nulsen, R.A. and Baxter, I.N., 1982. The potential of agronomic manipulation for controlling salinity in Western Australia. J. Aust. Inst. Agric. ~.ç.j. 48: 222-226.

Nulsen, R.A. and Baxter, I.N., 1986. Water use by some crops and pastures in the southern agricultural areas of Western Australia. Div. of Resourc. Manage. Tech. Rept. No. 32. W. Aust. Dept. Agric.

Nulsen, R.A., Bligh, K.J., Baxter, I.N., Solin, E.J. and Imrie, D.H., 1986. The fate of rainfall in a mal].ee and heath vegetated catchment in southern Western Australia. Mist. J. of Ecology 11: 361-371.

11. Appendicies

Figure 1. Location map, East Perenjori catchment.

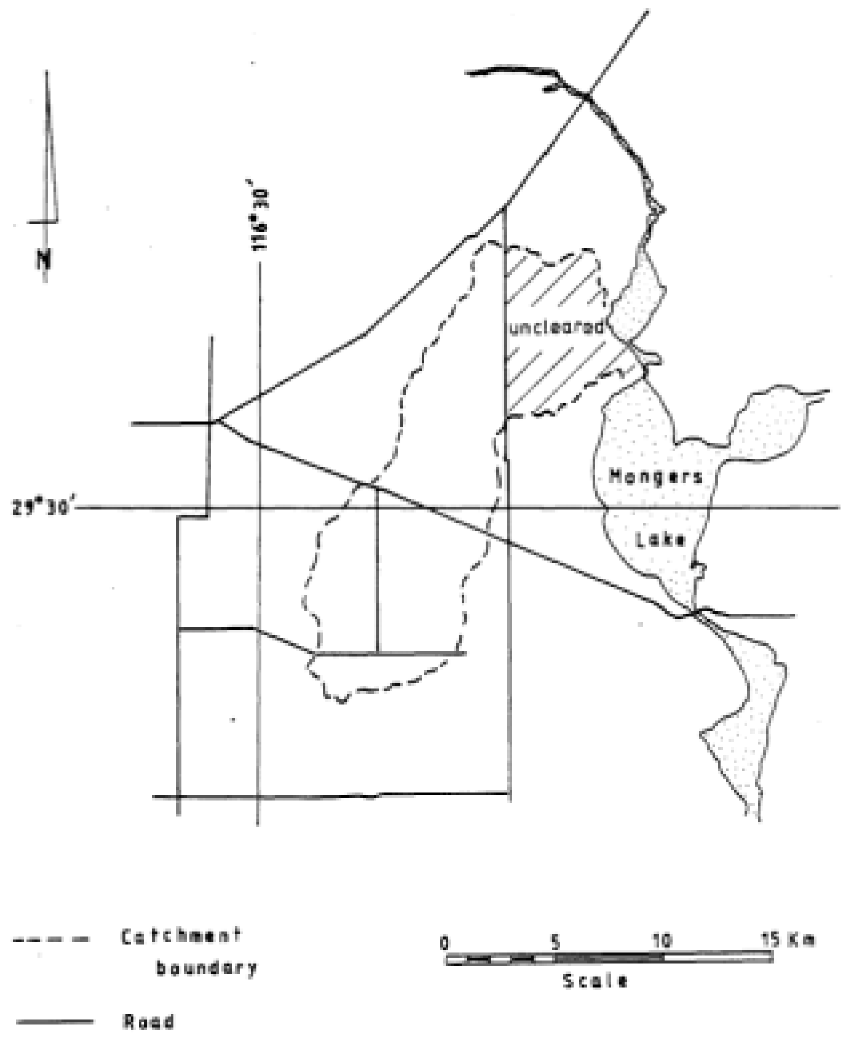

Fig. 1 Location map, East Perenjori catchment

Figure 2. Perched Watertable responses to a sorm event on March 4, 1986

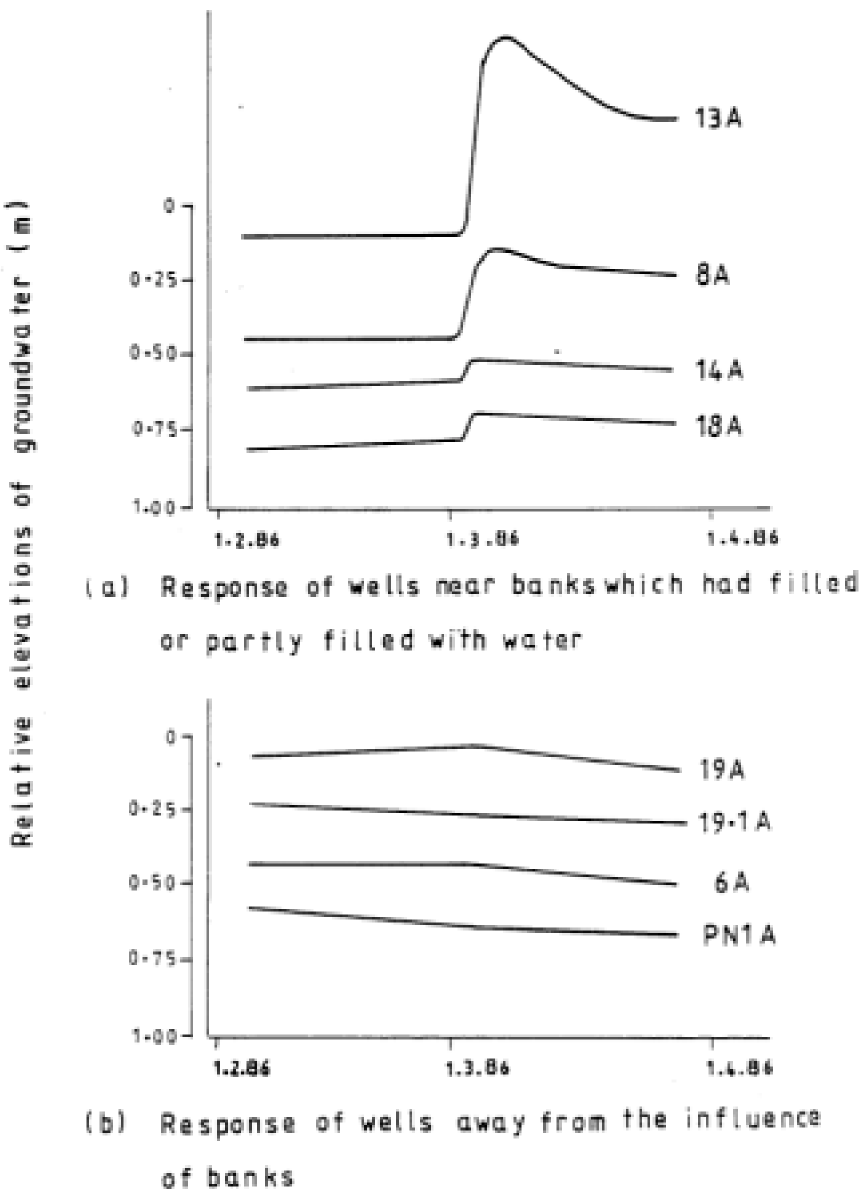

Fig. 2 Perched watertable responses to a storm event on March 4, 1986.

Figure 3. Soil Water content profiles under treatments of lupins, triticales, wheat and barley.

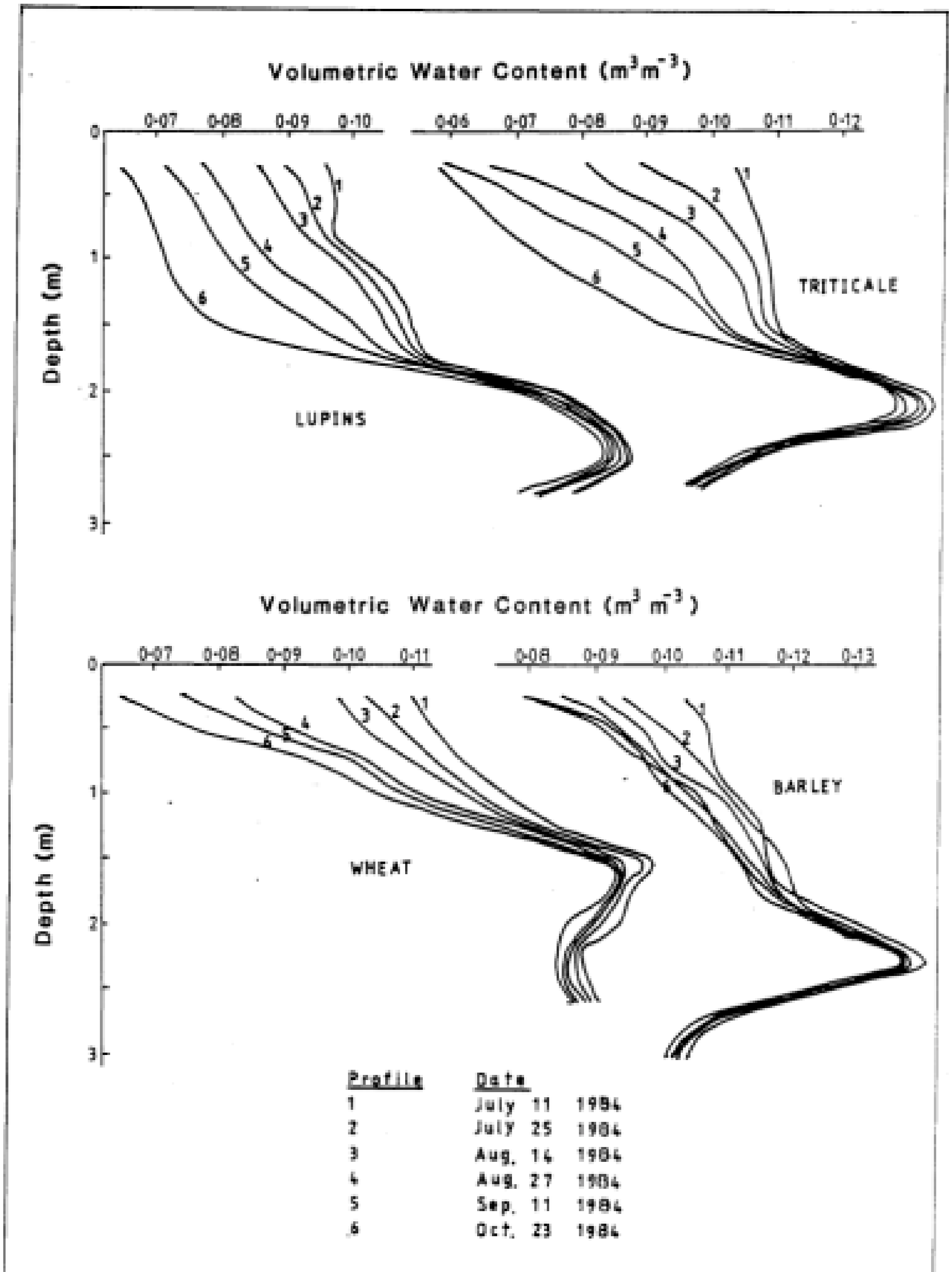

Fig. 3 Soil water content profiles under treatments of lupins, triticale, wheat and barley.

Figure 4. Soil Water content profiles, 8(z), under annual crop and native vegetation.

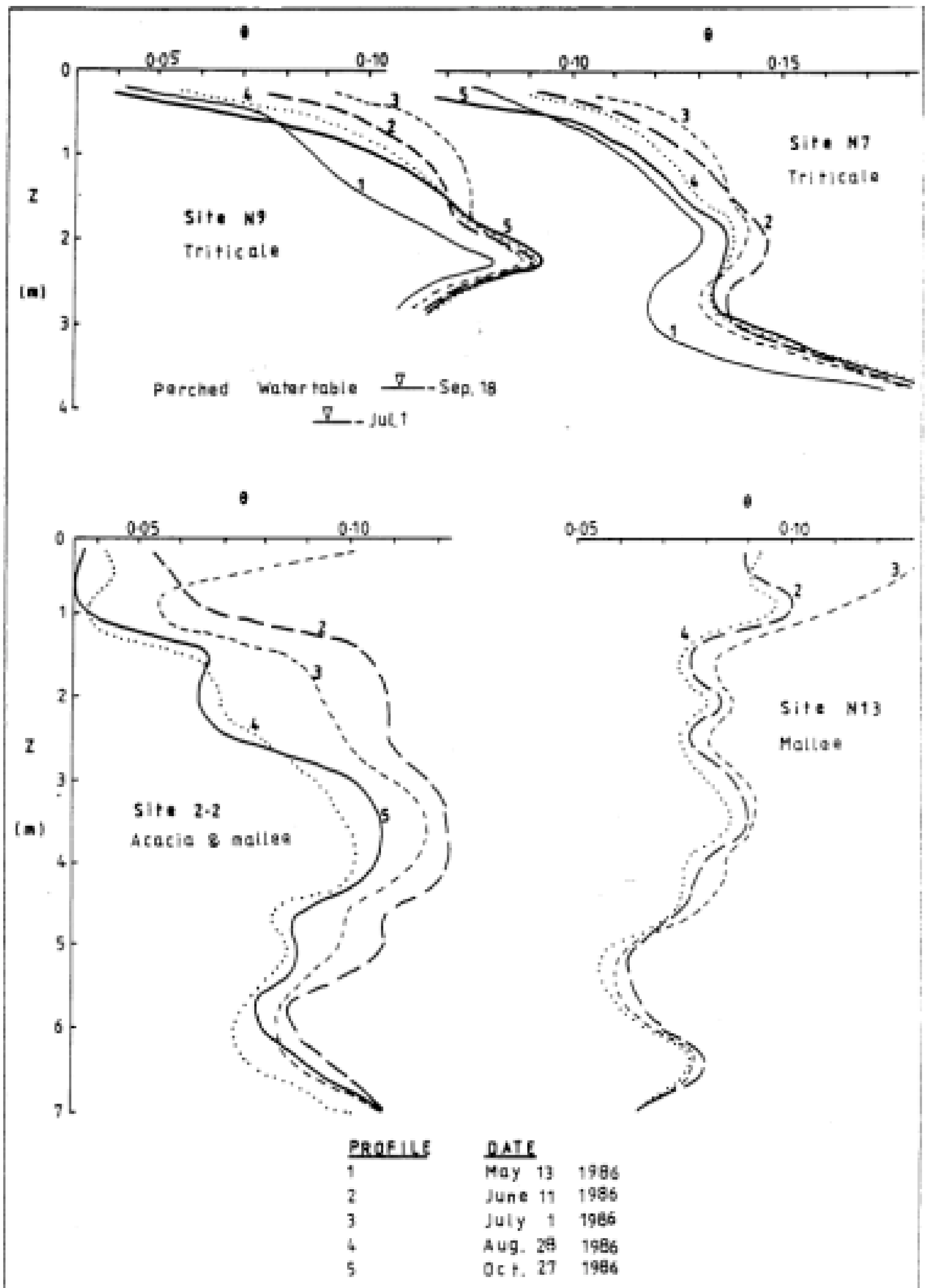

Fig. 4 Soil water content profiles, θ(Z), under annual crop and native vegetation.