7. INFILTRATION AND WATER MOVEMENT IN RIVERINE PLAIN SOILS USED FOR RICE GROWING

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ABSTRACT: *Infiltration and water movement during prolonged ponding were studied on four soil groups used for rice growi Three of the groups had texture-differentiated soils. The fourth group comprised mainly uniform, swelling, clay soils. Cumulative infiltration from 1-16 weeks after ponding differe significantly among the groups; it was highest in the lighte textured prior stream soils and lowest in the transitional re brown earth group. The saturated hydraulic conductivity of t B-horizon of the latter group was of the order of 0.1 mm day and this severely restricted infiltration. In the texturall uniform, self-mulching clay soils, flow restriction occurred much greater depth, where the hydraulic conductivity at saturation was around 1 mm day^{-1}. Deep seepage in such soils was not negligible. These results confirm previous data obtained on isolated sites.*

INTRODUCTION: The practice of rice growing under ponded conditions is considered to be a major factor in raising wate tables in the southern New South Wales irrigation areas and districts. In the Murrumbidgee and Coleambally Irrigation Areas (MIA and CIA), rice currently occupies between 20-25 pe cent of the land surface and its water use represents some 60 80 per cent of the total diversion of water for irrigation. Water tables and potentiometric levels in deeper (> 20 m) aquifers of these areas rise between 0.3-1.5 metres each year where water tables are not already high.

Routinely recorded water consumption by rice indicates that deep seepage varies with soil type and stratigraphic conditions. In particular, studies on evaporation from rice (Talsma and van der Lelij 1976a), and on water movement throu swelling soil (Talsma and van der Lelij 1976b), showed that seepage varied between 2-20 per cent of consumptive use from one field to another.

An investigation of this variation is the subject of thi paper. The results of studies on infiltration and on some aspects of water movement during ponding into broad soil grou that have been used for rice growing are reported.

OIL DESCRIPTION AND SITE SELECTION: The MIA and CIA (Figure .1) lie on the north-eastern part of the Riverine Plain. The lain here slopes to the west with an average gradient of 40 cm m^{-1} and has been largely formed by fluviatile deposition from rior streams [see, e.g. Butler (1950); Stannard (1968)]. oils formed on these deposits are of considerable age and most ave mature, texture-differentiated profiles. Most prior treams are still present as relic features, but they may be iscontinuous at the land surface as a result of subsequent eolian and fluviatile deposition (Butler 1958).

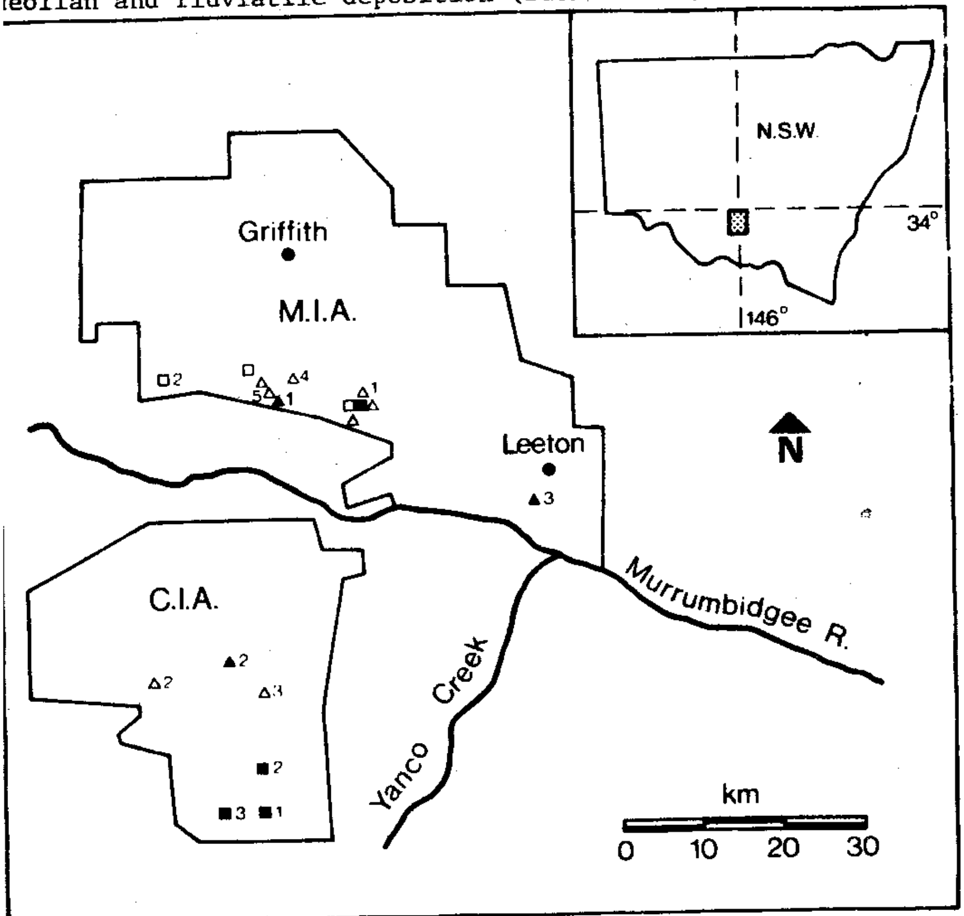

FIGURE 7.1 Location of experimental sites.
□ on soil group Ia; ■ Ib;
ΔII; ▲ III. (W.R.C. N.S.W.)

The distribution of soil types is often of considerable complexity and detailed mapping has been carried out for a small proportion of the Irrigation Areas only. Correlation of infiltration behaviour with soil properties has therefore been attempted only on a broad soil-group level. For this purpose the soil mapping units of Stannard (1968) have been adopted and have provided some basis for broad-scale land use planning for irrigation. The units used are - I: prior stream formations, II: plains of transitional red-brown earths, and III: plains of self-mulching clays.

Unit I has been further subdivided on the basis of soil texture. Group Ia comprises lighter-textured soil profiles, and group Ib the finer-textured soils. Groups Ia, Ib and II contain texture-differentiated surface soils, while the majority of soils in group III have a uniform clay texture and exhibit shrinkage cracks when dry.

The extent of these groups on the plain, mean clay percentages of subsoils (B-horizons), and named soil types within these groups (van Dijk 1961; van Dijk and Talsma 1964) are given in Table 7.1.

TABLE 7.1 Details of selected soil groups

Group	n*	Extent on plain + (%)	Mean clay content at 20 - 30 cm ($\% < 2\mu m$)	Soil types
Ia	7	5	43	Cobram and Thulabin sandy loams
Ib	14	15	56	Cobram, Thulabin and Birganbigil loams
II	23	55	69	Willbriggie and Mundiwa clay loams
III	16	20	63	Yooroobla, Wunnamurra and Gogeldrie clays. Tuppal and Morago clay loams

* n = number of infiltrometers

\+ Balance of 5% is made up of other soils not used for rice

Potentiometric levels in aquifers underlying the sites were relatively deep and did not affect the percolation through the surface horizons. The effect of deeper stratigraphy on infiltration rates has not been taken into account.

PROCEDURE

Infiltration - Infiltration rates during ponding were measured at several sites (Figure 7.1) using large, buffered, ring infiltrometers. The technique is fully described by Talsma and van der Lelij (1976a). Replication varied from 2-10 infiltrometers for each field. Sites III-1, II-1 and II-2 correspond to fields 1-3 of Talsma and van der Lelij (1976a); the results of site III-2 were reported in detail by Talsma and van der Lelij (1976b).

In order to have a valid basis for comparison between all sites (representing data collected over several years), measurements were restricted to infiltration between 1-16 weeks after ponding. Infiltration during preponding irrigations and the first ponding day could often not be measured accurately.

Data collected during the first week of ponding varied considerably from year to year and from field to field, depending especially on the topsoil moisture content just before ponding. Preliminary analysis indicated that approximately steady rates were achieved during the second ponding week. Although some fields were ponded for longer periods, records for all were complete only to 16 weeks (112 days of ponding).

Water movement - Piezometers and/or tensiometers were placed adjacent to the ring infiltrometers at several sites. Piezometers consisted of 2.4 cm I.D. steel pipe and had small, unlined cavities below the pipe. Most tensiometers were fitted with mercury manometers and had 1 bar ceramic tips, 42 mm long and 18 mm diameter. Piezometers and tensiometers were installed at regular (c. 30 or c. 50 cm) depth intervals to obtain potential gradients. Hydraulic conductivity could then be calculated from infiltration rates and gradients, where both were steady with time. Values so obtained were compared with hydraulic conductivities measured on undisturbed core samples (30 cm diam., 10 cm deep) at sites II-3 and III-2.

RESULTS AND DISCUSSION

Infiltration - The distribution of infiltration totals within each group showed positive skewness (e.g. group II Figure 7.2). This is commonly found for hydraulic conductivity as well as infiltration [e.g. Dmitriyev and Manucharov (1968); Nielsen et. al. (1973); Talsma and van der Lelij (1976b)]. Skewness was confirmed at the 1% level for groups Ib-III, but was not calculated for group Ia because of insufficient data. Conversion to a log basis removed the skewness almost completely. Using small sample techniques ($n < 30$, see Table 7.1) on the transformed data showed that all group means differed significantly from each other.

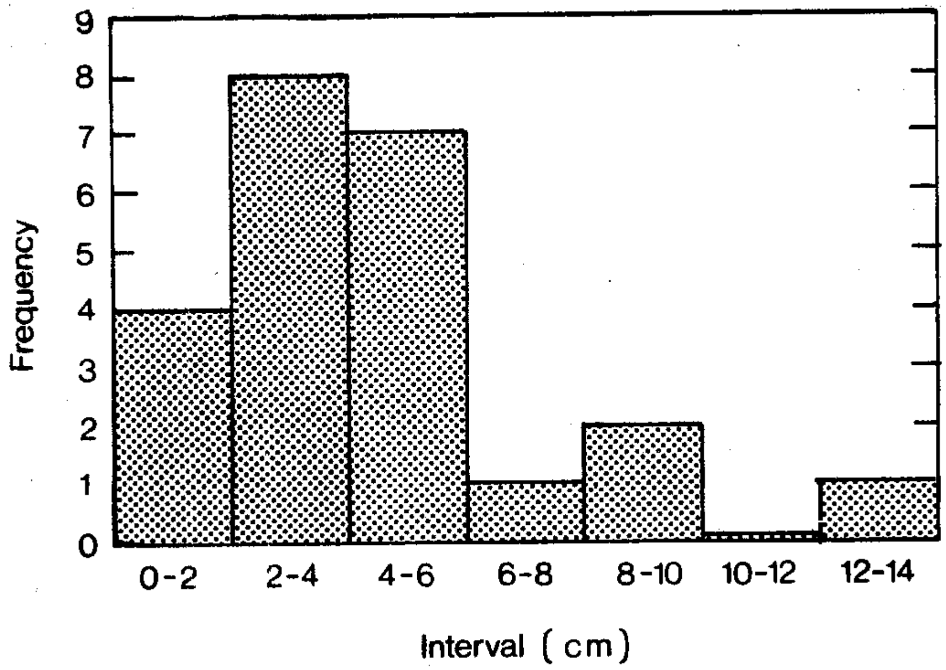

FIGURE 7.2 Frequency distribution of infiltration totals (weeks 2-16 from permanent ponding) for group II soils (W.R.C. N.S.W.).

TABLE 7.2 Comparison of transformed data, log i at week 16. Probability levels of significant difference

Means	Group	Ia	Ib	II	III
2.549	Ia	-	0.01	0.01	0.01
1.788	Ib	-	-	0.05	0.01
1.570	II	-	-	-	0.01
2.177	III	-	-	-	-

Mean cumulative infiltration curves are shown in Figure 7.3 using geometric mean values, since these estimate whole field performance rather closely (Talsma 1965; Talsma and van der Lelij 1976b). The curves for groups Ia, Ib, and III are slightly S-shaped, which indicates that infiltration rates were somewhat lower during the mid-ponding season. The detailed study of Talsma and van der Lelij (1976b) indicates that this is due to a temporary decrease of hydraulic conductivity at the soil surface. Mean infiltration rates near the end of ponding, derived from Figure 7.3 were 2.9, 0.43, 0.25 and 1.4 mm day^{-1} for groups Ia to III respectively.

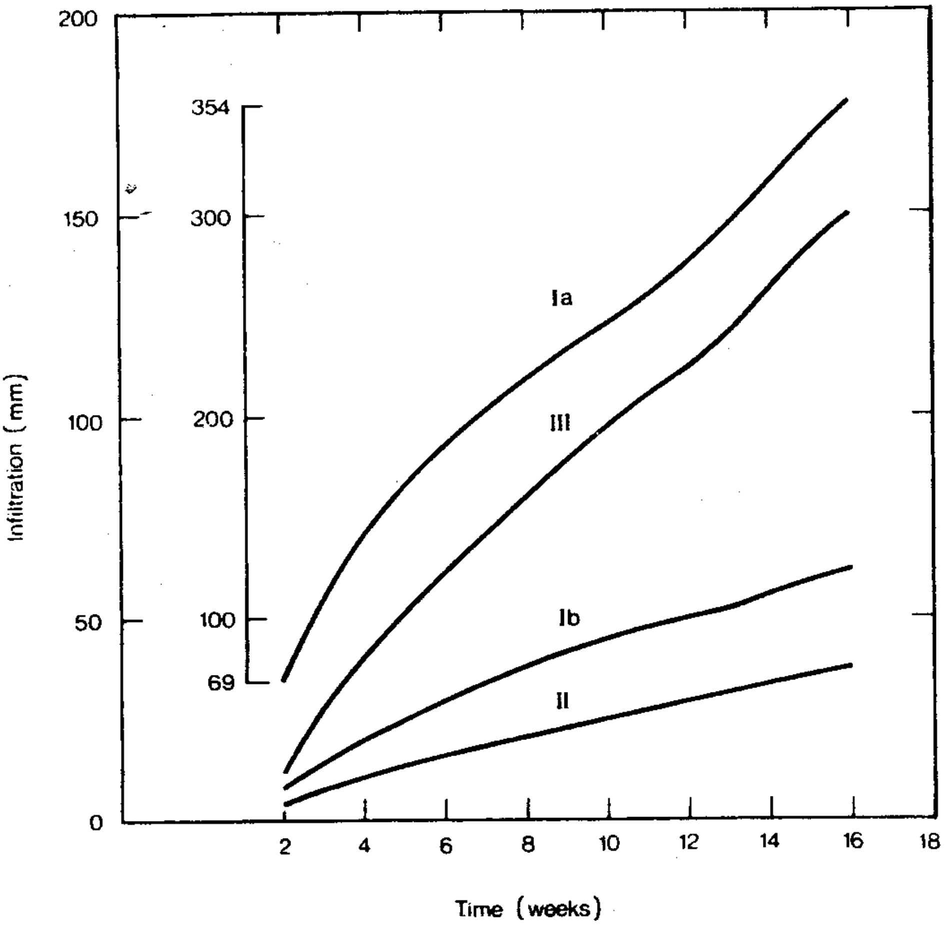

FIGURE 7.3 Mean cumulative infiltration curves for all soil groups. Inset scale is for group la only (W.R.C. N.S.W.)

These results indicate that seepage losses to deeper layers during ponding may be quite high where rice fields are located on group Ia soils, but are quite small on group Ib and II soils. Losses on group III soils are intermediate. The different infiltration behaviour of group III versus group Ib and II soils is also apparent from routinely measured water consumption data for rice (including pre-ponding irrigation). For example, in the northern part of the CIA (Figure 7.1), where group III soils dominate, the average water consumption of 156 fields during 1974-5 was 1.79 metres, while in the southern CIA, which has mostly group Ib and II soils, 153 fields used an average of 1.65 metres water. The standard deviation of both means was around 2.3 cm.

Water movement - Average manometric potentials, before and during ponding, are shown in Figure 7.4 for sites Ia-2, Ib-1, II-3 and III-2. These were recorded by tensiometers placed immediately below the fine-textured B-horizons of groups Ia to II, and at a similar depth in the texturally-uniform group III soil. All potentials were negative before ponding, and, for the texture-differentiated soils, remained so during the whole ponding period. In contrast, the average potential in the group III soil became positive (i.e. a transient water table developed) soon after ponding.

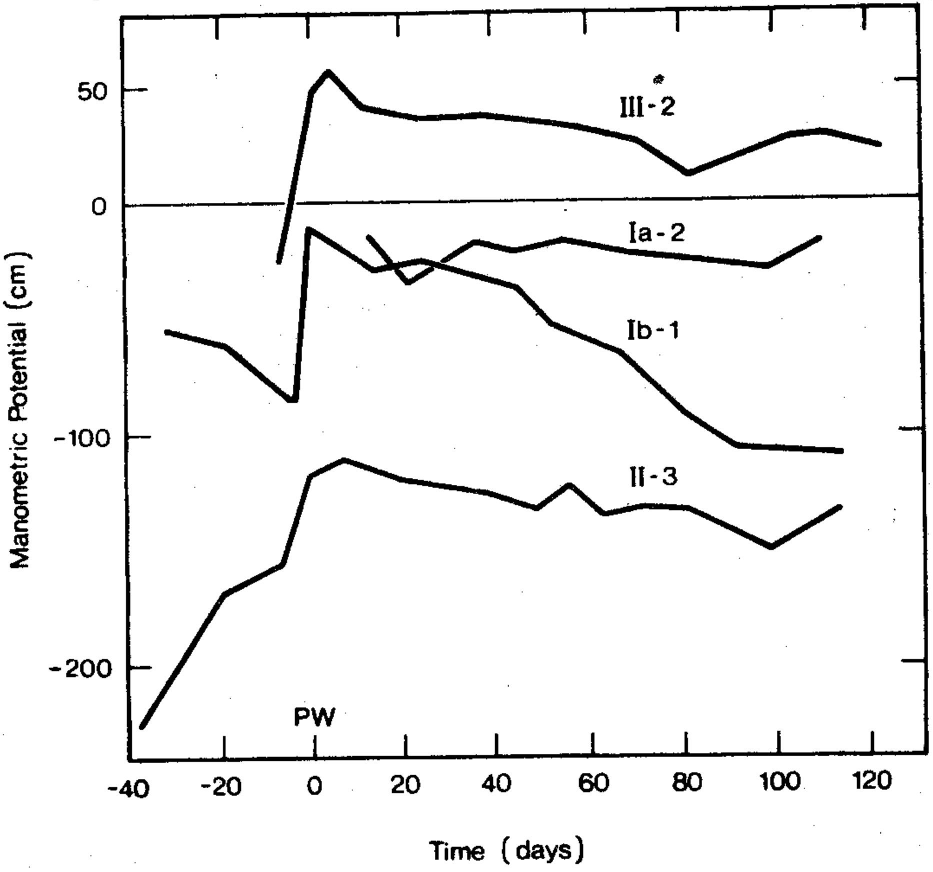

FIGURE 7.4 Manometric potentials in shallow sub-soil at various sites. Site III-2 at 45 cm; lA-2 at 50 cm; lb-1 at 47 cm; 11-3 at 60 cm depth (W.R.C. N.S.W.)

Since during ponding the manometric potential at the soil surface was positive (about + 15 cm, the average ponding depth) it follows that in groups Ia to II flow of water was restricted by the finer-textured B-horizons. This throttle was most pronounced in the very-fine-textured B-horizon of group II soils (Table 7.1), where the average potential remained at about -125 cm of water at both the 30 and 60 cm depths (Figure 7.4) during ponding. Much the same result was obtained by McIntyre *et. al.* (1976) in a study on similar soil in the western part of the MIA (Figure 7.1). At site Ib-1, where rice was grown for the first time, the manometric potential decreased steadily during ponding. We attribute this to gradual swelling of, and consequent closure of fissures in, the initially dry B-horizon.

Selected potential gradients (grad ϕ), calculated for periods when both the infiltration rate, v and mean potential at various depths were reasonably steady, are shown in Table 7.3 at two depth intervals. Also listed are values of hydraulic conductivity, K, calculated from fluxes and gradients, and, for comparison, mean K-values obtained on large undistrubed core samples at sites II-3 and III-2. The two sets of hydraulic conductivity values agree satisfactorily, values calculated from fluxes and gradients being slightly higher. This is reasonable since they represent conductivities integrated from the more permeable soil surface to the indicated tensiometer depths. Subsoil hydraulic conductivities at sites Ia-2, Ib-1, Ib-2 and II-3 represent values obtained on unsaturated soil, while others were at or close to saturation. Subsoil conductivities obtained at sites II-4 and II-5 at near zero potential were 2.6 and 6.8 mm day^{-1} respectively.

In contrast to the texture-differentiated soils, the hydraulic conductivity of the uniformly-textured soil at site III-2 (Talsma and van der Lelij 1976b) decreased, and consequently the gradients increased with depth. This is more clearly shown in Table 7.4, which lists data with piezometers at site III-3 (Kelly, priv. com.). Here two metres of uniform swelling clay overlies a slightly more porous material. Such behaviour is in agreement with that predicted for uniform, swelling soils (Philip, 1968).

CONCLUSIONS: The results of this study show that infiltration differed significantly amongst the soil groups used for rice growing in south-eastern Australia. Where possible, light-textured levee soils (group Ia) have been excluded in irrigation designs for rice. Infiltration rates were low in the remainder of the texture-differentiated soils that have well defined swelling clay B-horizons (groups Ib and II). These soils cover some 70 per cent of the irrigated land (Table 7.1). Seepage to aquifers or a deep water table during ponding on such soils should therefore not contribute greatly to problems created by rising water tables. Infiltration into uniform fine-textured soils was about three times higher than in group Ib and II soils, and some of the infiltrated water undoubtedly reaches underlying aquifers or water tables. Moisture sampling before and after start of irrigation on

TABLE 7.3 Potential gradients (Ø) and hydraulic conductivities (K).

Soil group and site	Period	Topsoil					Subsoil			
		v	Depth interval	grad Φ	K calc.	K cores*	Depth interval	grad Φ	K calc.	Potential+
-	(days)	(mm day^{-1})	(cm)	-	(mm day^{-1})	(mm day^{-1})	(cm)	-	(mm day^{-1})	(cm H_2O)
Ia-2	10-110	13.3	0-50	1.3	10.2	-	50-70	1.0	13.3	-25
Ib-2	at 100	1.10	0-45	2.4	0.46	-	60-206	1.2	0.89	-65
Ib-1	at 100	0.40	0-47	3.5	0.11	-	47-235	0.9	0.43	-108
II-3	10-100	0.14	0-30	5.9	0.023	0.018	30-120	0.7	0.21	-136
III-2	10-100	2.0	0-45	0.73	2.7	2.3	120-150	1.8	1.11	+

* At 20-30 cm depth interval

\+ Below or in B-horizon

TABLE 7.4 Gradients and conductivities at site III-3. Infiltration rate v = 1.25 mm day^{-1} at 100 days after ponding (Kelly, priv. com.)

Depth Interval (cm)	grad ϕ	K (mm day^{-1})
0-50	0.06	20.8
50-100	0.16	7.8
100-150	0.94	1.3
150-200	1.76	0.7
200-305	0.86	1.5

sites II-3, III-1 and III-2 (Water Resources Commission unpublished data; Talsma and van der Lelij 1976b), indicated that from 1-20 cm of water passed beyond the sampled profiles (3-4.5 m).

Infiltration rates in the texture-differentiated soils (groups Ia-II) were controlled by the restricting properties of their B-horizons. The hydraulic conductivity of these layers varied from 0.02-0.5 mm day^{-1}, the lowest value corresponding to the highest clay percentage (group II soils). In texturally-uniform, swelling clay soil (group III), however, flow restriction occurred at much greater depth, where the hydraulic conductivity was still around 1 mm day $^{-1}$. Apparently, in such soils, the closing of previous shrinkage cracks, which may penetrate to 3 m depth (Talsma and van der Lelij 1976b), is never fully effective preventing downward seepage. In this regard it is of interest to note that site III-3 has been under irrigation for some 50 years, during which many crops of rice have been grown.

Deeper stratigraphy has little effect on infiltration and water movement in group Ib and II soils, where the restriction occurs in the B-horizon. This contrasts with soils of groups Ia and III where restrictions at greater depth would be relevant. This latter aspect is beyond the scope of this paper.

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