Groundwater Level and Salinity Response under Agroforestry at Flynn's Farm in the Darling Range of Western Australia

by M. A. Bari, N. J. Schofield, and D. W. Boyd

Report No. WS 72

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Telephone (09) 420 2420

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SUMMARY

Stream and groundwater salinities have increased in the south-west of Western Australia due to the replacement of deep-rooted, native, perennial vegetation with shallow-rooted annual agricultural crops and pastures. The clearing of native vegetation has resulted in a decrease in evapotranspiration and an increase in groundwater levels. The rising groundwater levels mobilises salt previously 'stored' in the unsaturated zone and discharges it to the land surface and streams. Research into reclamation by partial reforestation of the cleared land began in the 1970s.

One important partial reforestation strategy involves planting trees in wide-spaced rows or grids allowing agriculture to continue between the trees. This option, known as agroforestry, has been hydrologically studied at three sites in Western Australia. This report describes the groundwater level and salinity response to an agroforestry plantation established in 1978 at Flynn's Farm (700 mm yr^{-1} rainfall) in the Darling Range of Western Australia. Groundwater level and salinity data have been analysed for the period 1979 to 1989.

Over this period groundwater levels at the agroforestry site declined by 1.0 m relative to groundwater levels beneath pasture at a nearby control site. Most of the decline took place in the fourth year (1982) and since then no significant lowering has taken place. The plantation was progressively thinned and pruned between 1982 and 1988, which probably explains the 'levelling off' of the groundwater table decline.

The yearly changes in minimum groundwater level were compared with the annual rainfall from each preceding year. The results indicated if annual rainfall was less than 670 mm over the pasture site the groundwater level could be expected to decrease in the following year. Similarly, a decrease in water level could be expected at the agroforestry site if the preceding year's rainfall was less than 700 mm.

The results also indicated water level would have risen under both pasture and agroforestry if long term average rainfall conditions had occurred.

The average salinity of groundwater under both the agroforestry and pasture sites decreased during the study period. However, the percentage change in salinity in the observation bores was not consistent, especially at the agroforestry site. It appears salinity conditions are localised.

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1. INTRODUCTION

Stream salinisation is a major and increasing problem in southern Western Australia (Schofield et al., 1988; Schofield and Ruprecht, 1989). One of the most promising options to control and reverse salinisation is partial reforestation (Schofield et al., 1989). Various reforestation strategies embracing different combinations of trees and agriculture have been tested in Western Australia (W.A.). One such strategy is agroforestry which involves planting trees in widely spaced rows or grids over a high proportion of the agricultural land.

Agroforestry has been researched for some 12 years in W.A. It has been demonstrated that agroforestry can increase total land productivity above that of agriculture or forestry alone (Malajczuk et al., 1984; Anderson and Moore, 1987; Anderson et al., 1988). There are also potential environmental benefits from the use of widely spaced plantings, including shelter for animals, erosion control and salinity control (Batini et al., 1983).

An agroforestry research site was established at Flynn's Farm in Mundaring Weir catchment in 1978. The site consists of one hectare blocks which have various planting combinations of mainly Pinus Radiata. The principal objective of the study was to determine the extent to which the plantations could lower the groundwater table, which in turn should reduce groundwater solute discharge to streams. This report represents the most in depth and up-to-date analysis of data from this site and is an important contribution to the assessment of agroforestry as a salinity control strategy. Less detailed hydrological analyses of data from this site were carried out by Anderson et al. in 1982, Edgeloe et al. in 1984, Bell et al. in 1988 and Schofield et al. in 1989.

2. SITE DESCRIPTION

2.1 Location

The experimental site is located in the Darling Range, approximately 60 km east of Perth (Fig. 1). It lies within the predominantly forested Mundaring Weir catchment.

2.2 Site History and Layout

The experimental site consists of two parts : the agroforestry catchment and control catchment (Fig. 1). Both catchments include farmland (pasture), native forest and reforestation. The site was partially cleared of native forest and sown to pasture in 1958. In 1960 the land was purchased by the State Government as part of a reforestation programme to control the inflow salinity to Mundaring Reservoir.

At the time of purchase about 50% of the agroforestry site had been cleared (Fig. 2). Native vegetation was left on the upper slopes of the catchment (40% of site) and on a strip adjacent to Warlin Brook (10% of site). In 1978 the agroforestry plantation was established on about 60% of the cleared land. Details of the plantation treatment are given in Table 1.

The control site is 3 km south of the agroforestry site and is adjacent to an unnamed tributary of the Helena River (Fig. 1). About 98% of this catchment area was cleared. Native forest was left adjacent to the stream. In 1977, trees were established in small plots on the lower slopes (Fig. 1), covering about 8% of the catchment area. In 1983, more trees were planted on the catchment ridge but establishment was only partially successful (Fig. 1).

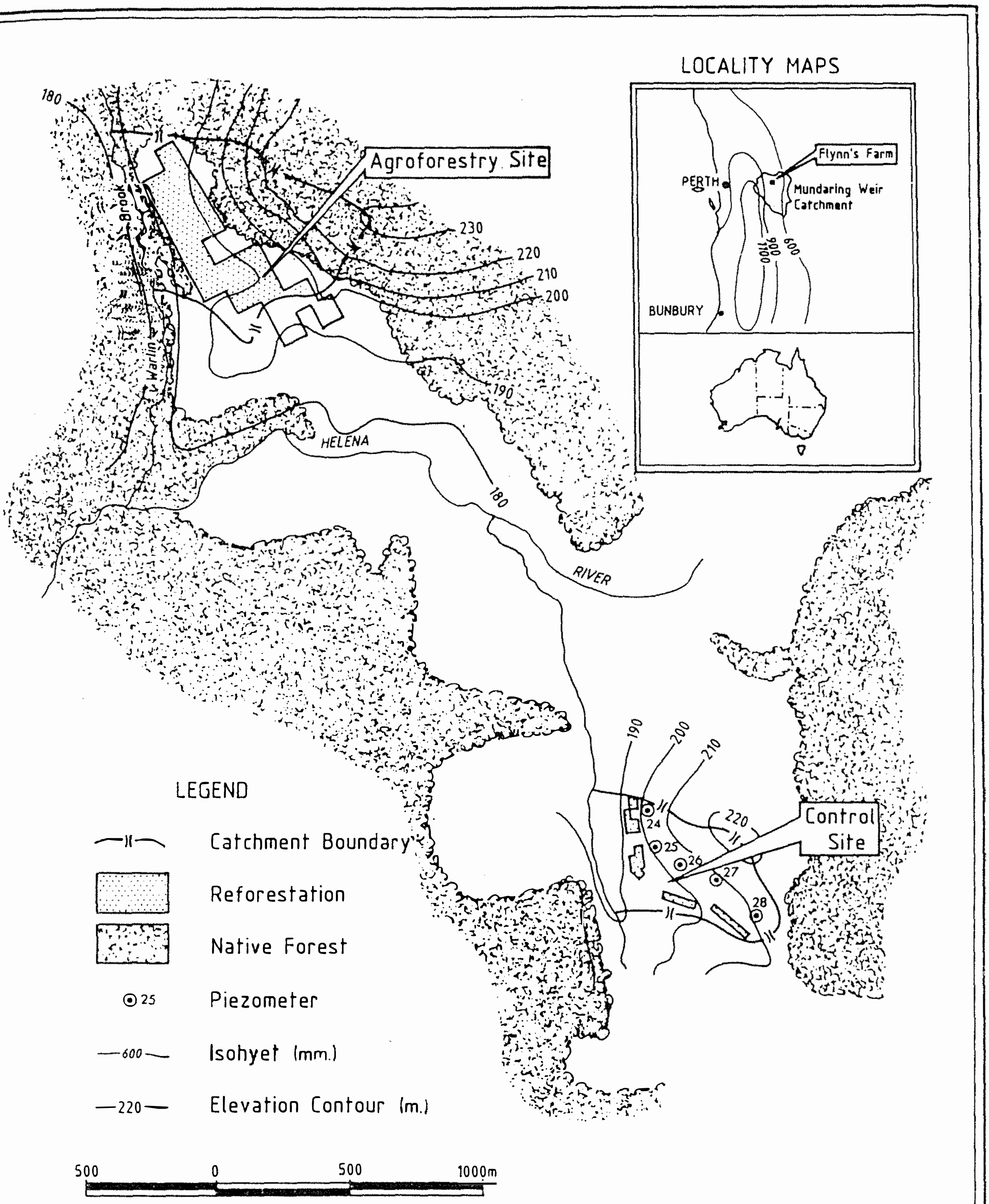


Figure 1 :Location of the study area

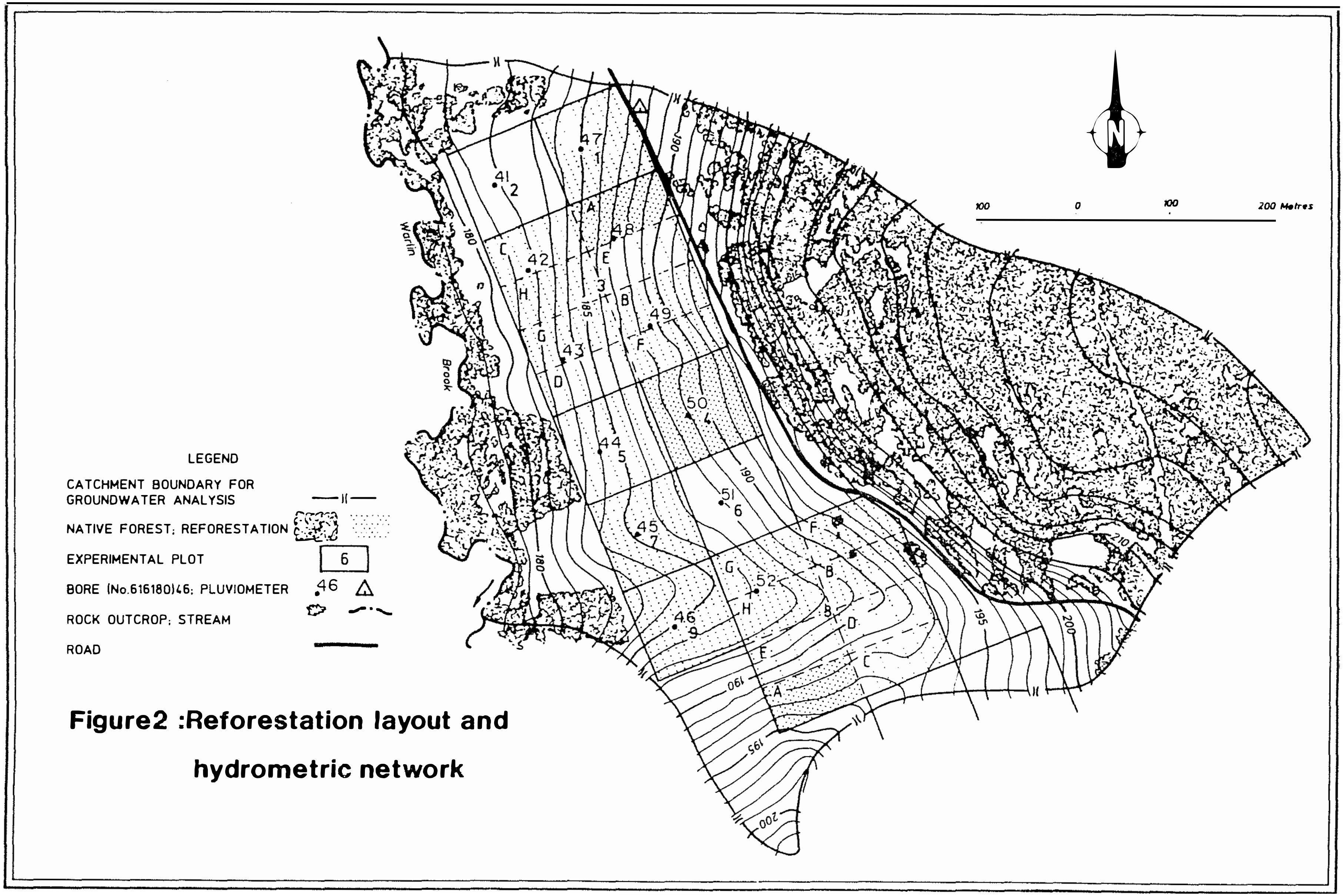


Figure2 :Reforestation layout and hydrometric network

Table 1 Experimental site - hydrogeological and plantation details

Plot No.	Area (Ha)	SWRIS Bore No.	Hydrogeological: Depth of Heath-ering (m)	Initial Depth to water table (m)	Initial Salinity (Mg L^{-1}) TSS	Reforestation: Species Planted	Stem density (Stems/Ha) 1978	1982	1983	1985	Thinning period 1982	1983	1985	Pruning Detail FIRST	LAST	Present Density (Stem Ha^{-1})	Crown Cover (%)
1	1	61618047	6.1	5.74	1224	P. Pinaster	380	250	100	75	March	April	May	3/82	4/88	75	-
2	1	61618041	3.0	2.22	249	Pasture	-	-	-	-	-	-	-	-	-	-	-
3	4	61618042	5.5	1.80	7244	P. Radiata	760	500	200	150	March	April	May	10/81	4/88	142	15
		61618043	5.8	3.66	305												15
		61618048	12.5	6.80	134												9
		61618049	10.7	8.06	473												25
4	1	61618050	13.1	7.58	7880	P. Radiata	1140	750	300	225	March	April	May	3/82	4/88	218	23
5	1	61618044	6.1	3.31	2842	P. Radiata	380	250	100	75	March	April	May	3/82	4/88	75	15
6	1	61618031	11.6	6.76	131	Pasture	-	-	-	-	-	-	-	-	-	-	-
7	1	61618045	13.1	4.66	2264	E. Camaldulensis	380	250	100	75	March	April	May	3/82	4/88	75	10
8	4	61618052	5.9	2.30	268	P. Radiata	760	500	200	150	March	April	May	3/82	4/88	144	11
9	1	61618046	6.0	1.28	198	P. Radiata	760	500	200	150	March	April	May	3/82	4/88	150	4

2.3 Climate

The Mundaring catchment area has a Mediterranean climate with cool, humid, wet winters and hot, dry summers. About 80% of the total annual rainfall occurs in winter. The long term average rainfall (1926 to 1988) of the experimental site is estimated to be 717 mm yr^{-1}. The annual average pan evaporation is 1800 mm (Luke et al., 1988). Generally, temperature ranges from a minimum of 4°C to a maximum of 38 °C.

2.4 Topography

The elevation of the agroforestry site varies from 178 m AHD (Australian Height Datum) to 231 m AHD (Fig. 2). The mean slope of the site is about 6%. The upslope forested portion of the catchment is steeper (6.3%) than the reforested zone (5.0%).

The elevation of the control site varies from 188 m AHD to 215 m AHD. The mean slope of the site is 6.8%, which is comparable to the agroforestry site. The slope is more or less uniform over the site.

2.5 Soil and Geology

Soil profiles of both sites are lateritic and of granitic origin. The profile mainly consists of shallow sandy gravels of variable thickness overlying a mottled clay subsoil. The surface soils have high infiltration capacities which are rarely exceeded by rainfall intensity. The mottled clay subsoils are of lower permeability. The depth of weathering varies from 3 m to 13 m at the agroforestry site (Fig. 3a). The depth of weathering of the control site varies from 0 m to 20 m. In the central area of the site, where the control bores are located, the depth to bedrock varies from 9 m to 15 m.

The depth to bedrock at both sites is less variable than the weathering profiles. Also the bedrock slopes are more subdued than the natural surface slopes.

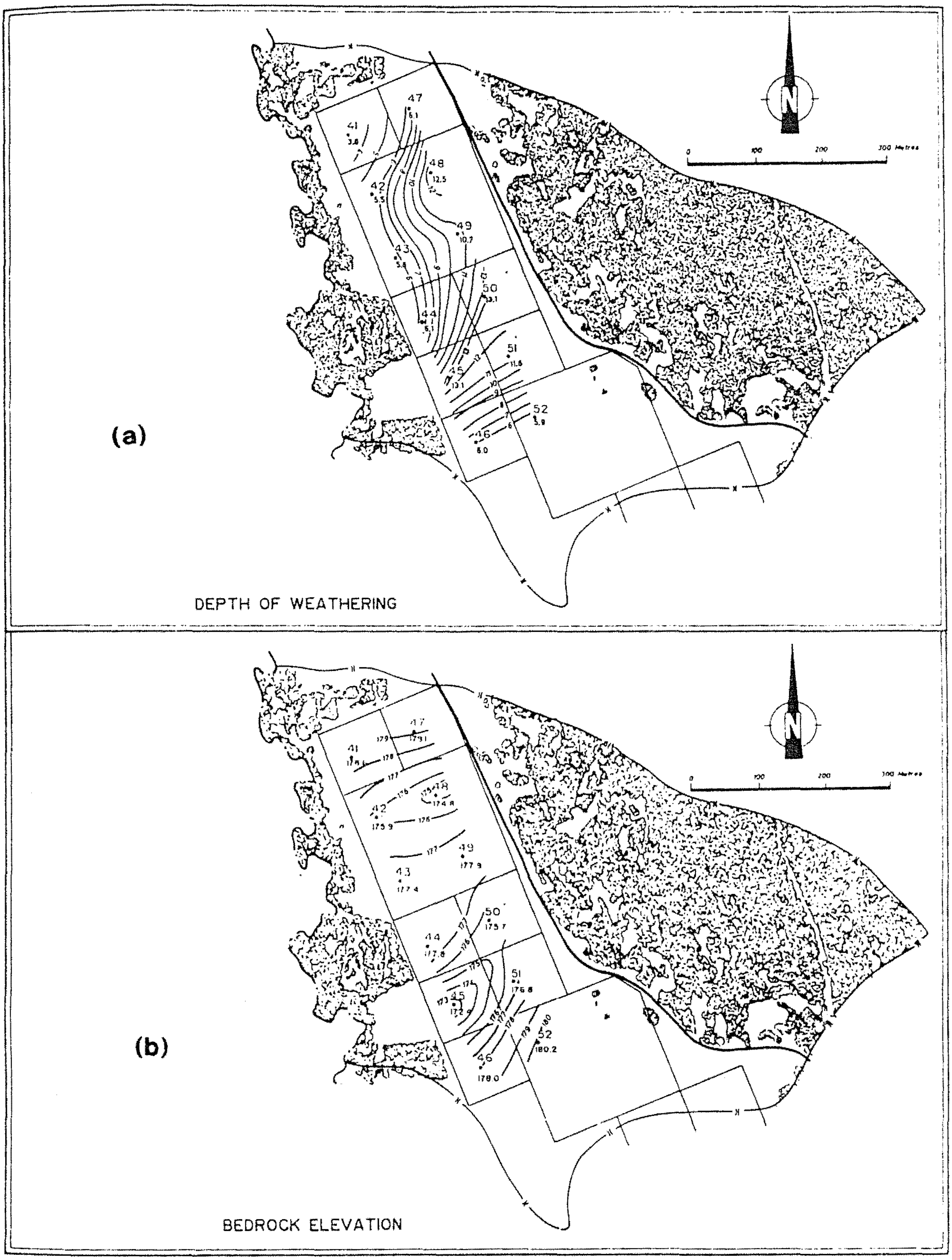


Figure3 :Depth of weathering and bedrock topography ---

agroforestry site

2.6 Vegetation

The cleared area of the agroforestry site had been under clover-based pasture for about 20 years prior to reforestation (Anderson *et al.,* 1988). Two species of *Pinus* and one species of *Eucalyptus* were planted in 1978. Details of the agroforestry plantations are given in Section 4. The upslope native vegetation is dominated by jarrah (*E. marginata*) with the principal sub-dominant being marri (*E. calophylla*). The valley floor overstorey is dominated by *E. wandoo.*

The control site is predominantly covered by annual grasses and various subterranean clover.

3. EXPERIMENTAL OBJECTIVES

The study has both production and salinity control objectives. The production objective was the assessment of pine growth for high quality sawlogs and of sheep carrying capacity on the pasture. Results from this work have been reported by Anderson and Moore (1987) and Anderson et al. (1988) and are not described further here.

The salinity control objective was to determine the effectiveness of agroforestry in lowering groundwater levels. The specific sub-objectives were to:

(i) describe the initial groundwater conditions prior to agroforestry treatment;

(ii) determine groundwater table seasonal variations and longer term trends beneath pasture;

(iii) determine the effect of agroforestry on groundwater level;

(iv) identify the groundwater flow direction and any change brought about by the agroforestry treatment; and

(v) determine the temporal variation in groundwater salinity under pasture and agroforestry.

4. PLANTATION ESTABLISHMENT, MANAGEMENT AND GROWTH PERFORMANCE

4.1 Plantation Establishment and Layout

The agroforestry trial comprises 32 one hectare blocks of which four blocks were retained under pasture. Of these blocks, 13 plantation and 2 pasture blocks are within the Water Authority's experimental study area (Fig. 2). The details of the plantings in terms of species, initial and final stem densities, thinning times and pruning periods are given in Table 1, while the layout is shown in Fig. 2. *P. radiata* was planted on 11 ha, while only one hectare each of *P. pinaster* and *E. camaldulensis* were planted. Layouts varied from initial stem densities of 380 stems per hectare (sph) to 1120 sph and from grid spacing to double and triple tree rows.

4.2 Plantation Management

The thinning and pruning history of the agroforestry trial is given in Table 1. Thinning of the plantation was carried out in 1982, 1983 and 1985, leaving final stem densities ranging from 75-225 sph. Trees were pruned annually, commencing in 1982. The last pruning during the study period was carried out in 1988 when trees were prunned to a height of 8-10 m.

4.3 Plantation Growth Performance

The diameter at the breast height over bark (DBHOB) and the tree height are the main indications of the growth performance of the plantation. For this particular trial, thinning and pruning resulted in well-formed trees with small defect cores. At the age of 6 years, there was no effect of tree density on height or DBHOB (Anderson *et al.,* 1987). Measurements of basal area were made periodically. The total basal areas are given in Table 2. The temporal variation in basal area is shown in Fig. 4. A near uniform average basal area growth rate of 0.91 m^2 ha^{-1} yr^{-1} is apparent over the period 1983-89.

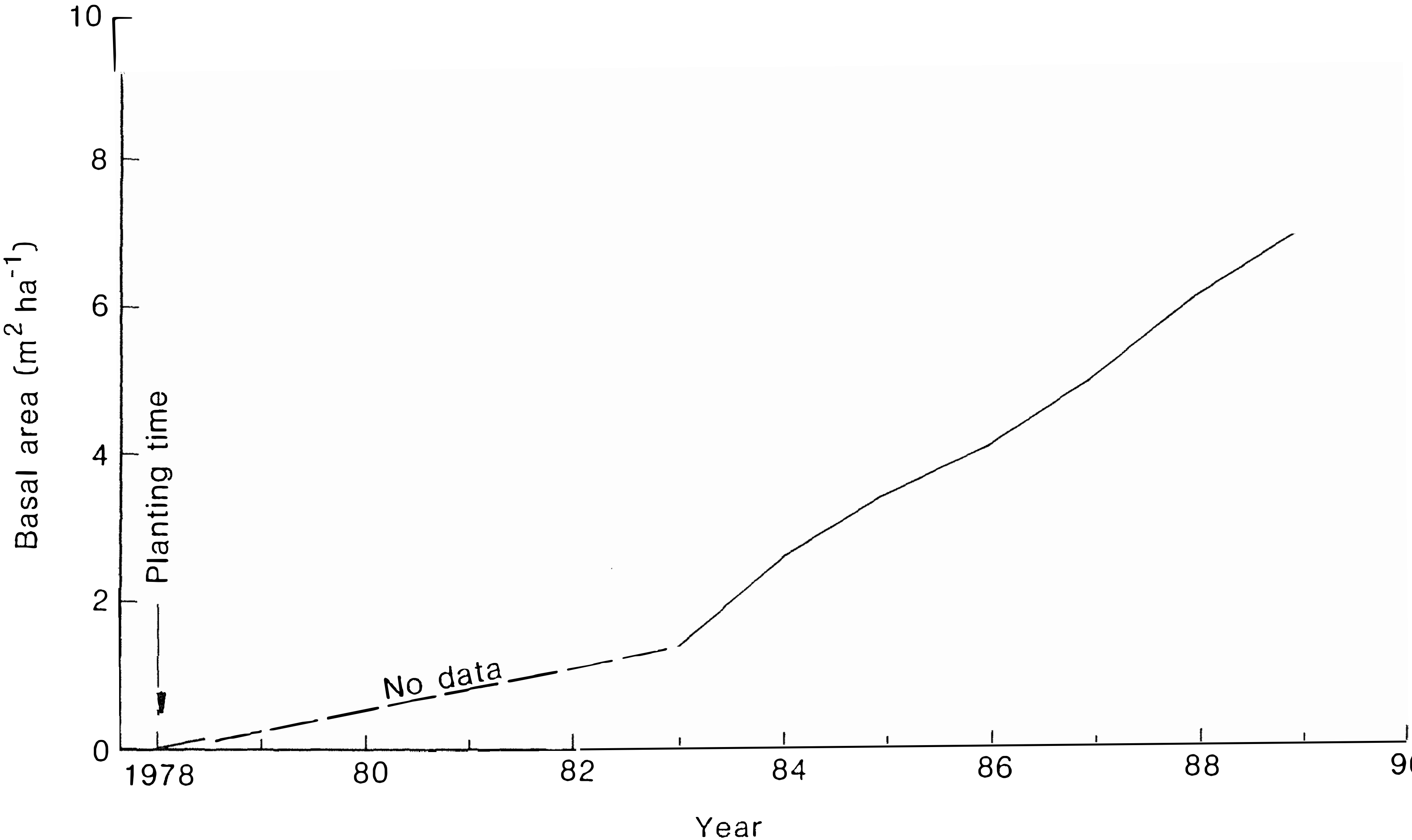


Figure4 :Temporal variation of basal area

Table 2 : Agroforestry basal areas (m^2 Ha^{-1})

Block No.	Species Planted	Treatment	5/83	5/84		4/85		4/86		4/87	5/88	5/89
				B/T(*)	A/T(**)	B/T	A/T	B/T	A/T			
1	P. Pinaster	760 sph x 6 m	0.47	1.51	0.61	1.35		2.30	1.12	1.51	2.04	2.64
3A	P. Radiata	760 sph x 3 m	2.72	4.63		6.09	4.21	5.60		6.68	8.04	9.59
3C		760 sph x 9 m	0.62	1.55		2.69	2.01	3.09		3.93	5.00	6.02
3D		3 Row Strip x 17 m	1.34	2.49		3.65	3.01	4.18		5.31	6.53	7.68
3E		3 Row Strip x 24 m	1.074	2.08		3.91	2.76	3.96		4.76	5.78	6.92
3G		760 sph x 6 m	0.71	1.42		2.16		3.01		3.71	4.65	5.26
4	P. Radiata	1140 sph x 6 m	2.26	4.43	3.48	4.61		6.06		7.78	9.44	11.22
5	P. Radiata	380 sph x 6 m	1.07	1.51	1.21	1.79		2.33		3.02	3.81	4.22
7	E. Camaldulensis	760 sph x 6 m	1.55	2.46	0.91	1.26		1.77		2.24	2.71	3.23
8A	P. Radiata	760 sph x 3 m	2.02	3.59		4.95	3.71	5.22		6.22	7.37	8.46
8C		760 sph x 9 m	1.95	3.65		5.17	3.92	5.37		6.73	8.21	9.57
8D		3 Row Strip x 17 m	1.04	2.17		3.31	2.87	4.22		5.28	6.53	7.58
8E		3 Row Strip x 24 m	1.53	2.73		3.76	3.39	4.65		5.61	6.68	7.49
8G		760 sph x 6 m	1.56	2.77		3.83	5.22	5.22		6.28	7.46	8.50
9	Radiata	760 sph	1.06	2.08	1.81	2.79		4.00		5.25	1.47	7.56
AVERAGE			1.395	2.605		3.421		4.065		4.954	6.048	6.887

(*) B/T => Before thinning

(**) A/T => After thinning

4.4 Crown Cover

Crown cover is defined as the percentage of the ground area covered by the vertical projection of the vegetation canopy on the ground surface. One measurement of crown cover at the agroforesty site was made in December, 1987 using a crownometer similar to the one described by Montana and Ezcurra (1980). Crown cover of each block is shown in Table 1. The range of cover was 4% to 25%, and the plantation average was 14%.

4.5 Pasture Performance

The pastures were sown in 1958 and left ungrazed for 14 years. They were neither managed nor used until 1982 when sheep started grazing. Fertilisers were used to overcome superphosphate deficiency. Once grazing commenced, there was a general improvement in pasture production.

5. HYDROLOGICAL DATA COLLECTION

5.1 Rainfall

Rainfall was continuously recorded at pluviometer M510008 located approximately 50 m from block no. 2 (Fig. 2). For periods of missing rainfall, data from the nearest pluviometer (M510017) were transposed using the correlation equation derived in Fig. 5. The close correlation of monthly rainfall between these pluviometers (Fig. 5) suggests that this would introduce very little error. Record was missing from M510008 for only 6.5% of the time during the study period (1979-1989). Annual rainfall was measured over the hydrological water year (1st April to 31st March). Rainfall record for M510008 is available from 1970 onwards. The long term average rainfall (1926-86) for this study site was estimated at 720 mm yr^{-1} (Hayes and Garnaut, 1981; Bell et al., 1990). It was extended to 1988 rainfall year (31st March 1989) by incorporating the pluviometer data to give a long term average of 717 mm yr^{-1}.

5.2 Groundwater Monitoring

The groundwater bore network for the control site is shown in Fig. 1 and for the agroforestry site in Fig. 2. Bore details are given in Table 3. Twelve bores were installed to bedrock at the agroforestry site. Each bore was screened at the base. Screen length varied from 1.5 m to 4 m. Five bores were installed to bedrock on the middle slope of the control site (Fig. 1). Each bore had a slotted screen of 3 m length.

All bores were monitored for water level and salinity once a month during the study period (1979-1989). Salinity was determined from samples collected within the screen area of the bores. Pumped samples were taken from all bores towards the end of the study. The electrical conductivity (EC mSm^{-1}) of samples was measured in the laboratory and converted to TSS (mg L^{-1}) based on the following relationship:

Table 3a Details of the Observation Bores - Control Site

S.W.R.I.S. Bore Number	Drillers Bore Number	Commencement of Operation	Bore Classif-ication	Top of Inner Tube (AHD)	Natural Surface Level (AHD)	Bottom of Tube (AHD)	Length of Slotting (m)	Length of Inner Tube (m)	Height of T.O.I.T. Above N.S.L.(m)	Depth of B.O.T. Below N.S.L. (m)
61618024	24	04/07/1977	Pasture	203.520	203.400	193.480	3.00	10.040	0.120	9.920
61618025	25	04/07/1977	Pasture	201.800	201.630	187.070	3.00	14.730	0.170	14.560
61618026	26	04/07/1977	Pasture	205.040	20.4850	195.570	3.00	9.470	0.190	9.280
61618027	27	04/07/1977	Pasture	210.410	210.270	195.270	3.00	14.670	0.140	14.530
61618028	28	04/07/1977	Pasture	212.760	212.580	202.460	3.00	10.300	0.180	10.120

Table 3b : Details of the Observation Bores - Agroforestry Site

S.W.R.I.S. Bore Number	Drillers Bore Number	Commencement of Operation	Bore Classif-ication	Top of Inner Tube (AHD)	Natural Surface Level (AHD)	Bottom of Tube (AHD)	Length of Slotting (m)	Length of Inner Tube (m)	Height of T.O.I.T. Above N.S.L.(m)	Depth of B.O.T. Below N.S.L. (m)
61618041	41	18/05/1978	Pasture	181.798	181.547	178.568	1.50	3.230	0.251	2.979
61618042	42	18/05/1978	Reforest	181.691	181.440	175.911	2.00	5.780	0.251	5.529
61618043	43	18/05/1978	Reforest	183.269	183.176	177.369	2.00	5.900	0.093	5.807
61618044	44	18/05/1978	Reforest	184.114	183.903	177.814	2.00	6.300	0.211	6.089
61618045	45	18/05/1978	Reforest	185.722	185.509	172.392	2.00	13.330	0.213	13.117
61618046	46	18/05/1978	Reforest	184.135	183.936	177.945	4.00	6.190	0.199	5.991
61618047	47	18/05/1978	Reforest	185.346	185.138	179.046	2.00	6.300	0.208	6.092
61618048	48	18/05/1978	Reforest	187.425	187.311	174.805	2.00	12.620	0.114	12.506
61618049	49	18/05/1978	Reforest	188.711	188.576	177.891	2.00	10.820	0.135	10.685
61618050	50	18/05/1978	Reforest	189.057	188.750	175.657	2.00	13.400	0.307	13.093
61618051	51	18/05/1978	Pasture	188.648	188.439	176.818	2.00	11.830	0.209	11.621
61618052	51	18/05/1978	Reforest	186.198	186.044	180.178	2.00	6.020	0.154	5.866

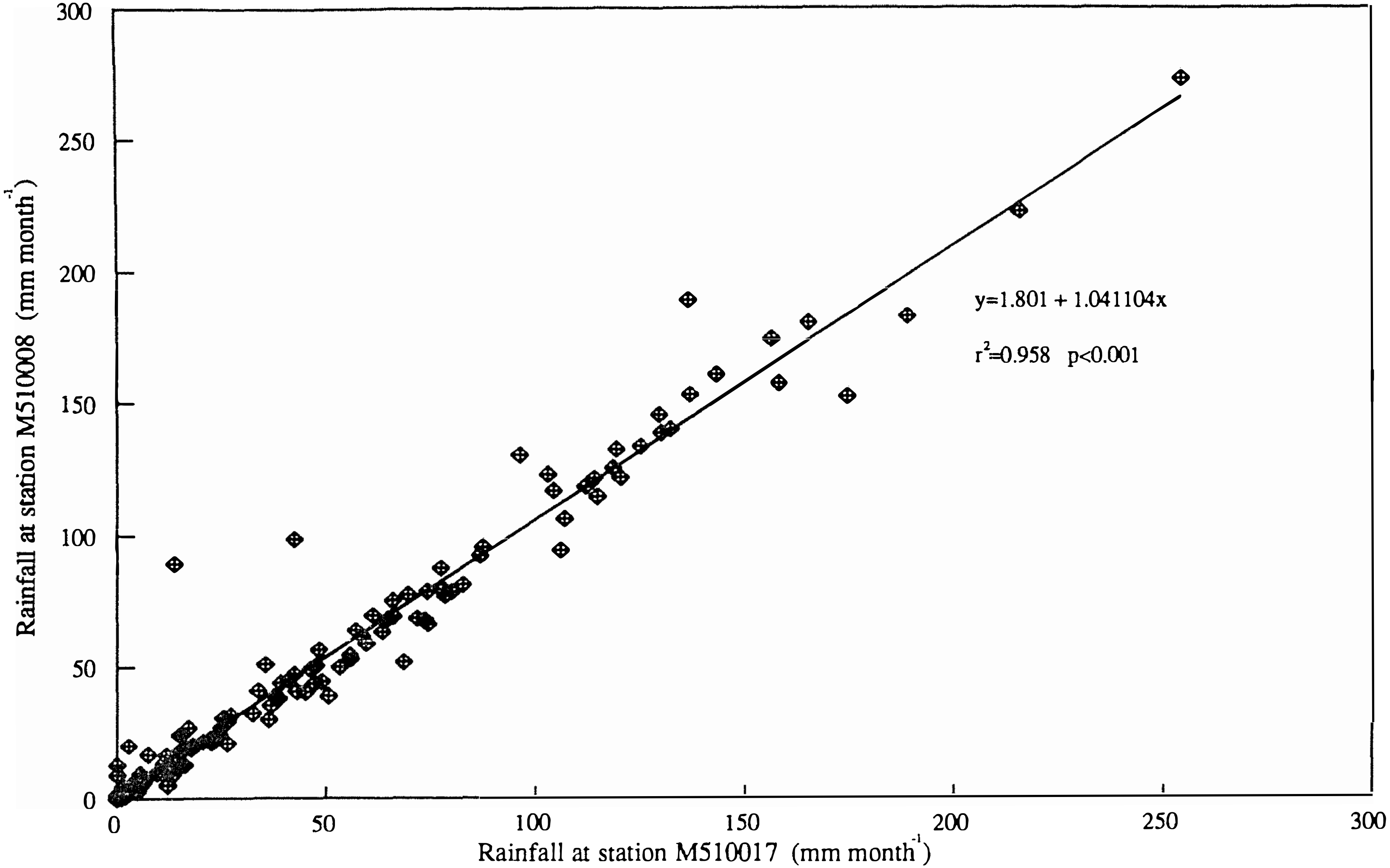


Figure 5Relationship between two rainfall stations

$$TSS = 55.96 + 5.62\ EC \tag{1}$$
$$(r^2 = 0.998,\ p < 0.001)$$

Equation 1 was determined from chemical analysis for major ions of one sample per bore per year over the period 1986-88 (Fig. 6).

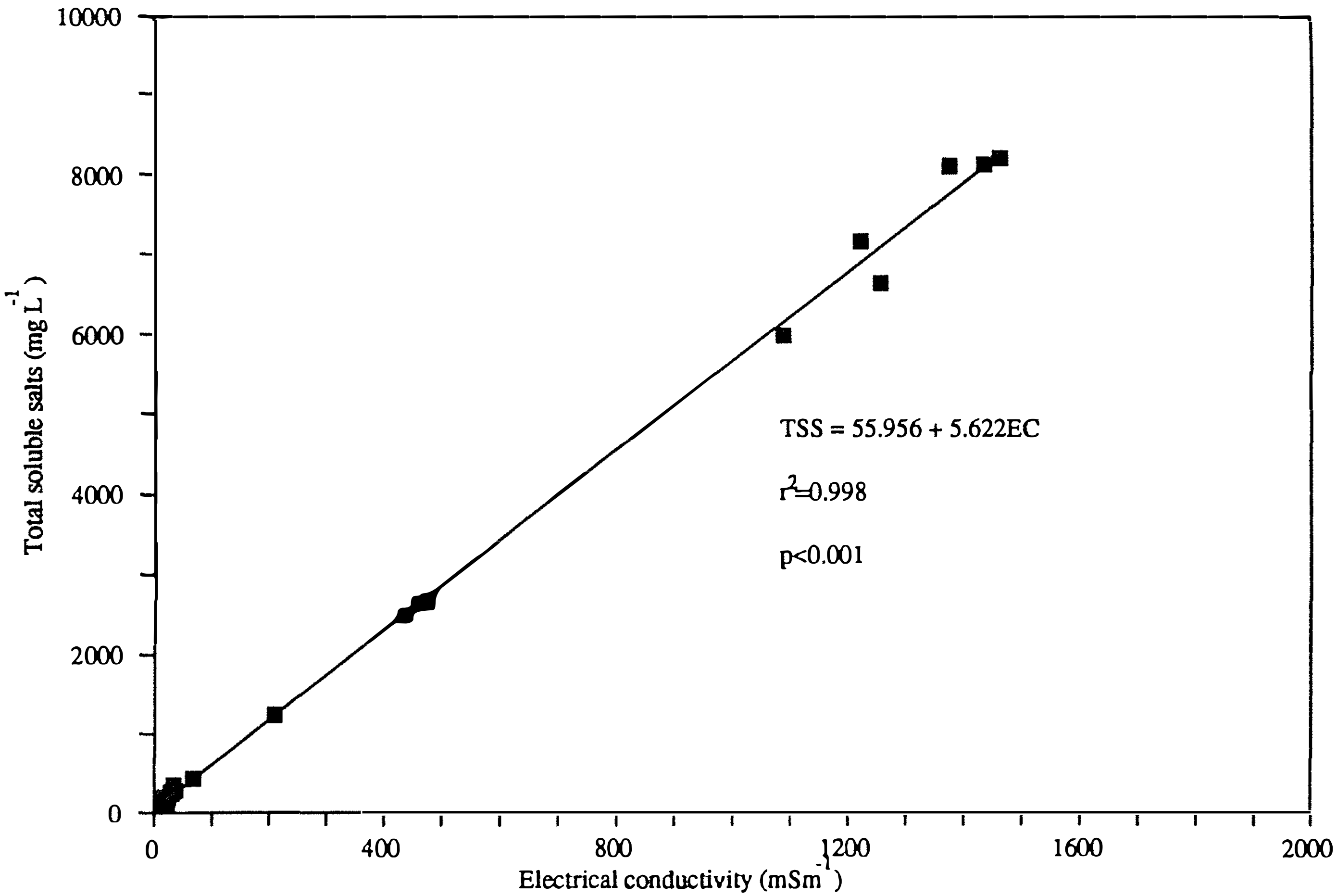


Figure6: Relationship between electrical conductivity and total soluble salts

6. DATA ANALYSES AND INTERPRETATION OF RESULTS

6.1 Rainfall

Rainfall varied from 473 mm yr^{-1} to 973 mm yr^{-1} during the period 1979 to 1988 (Fig. 7). The average for the period, 654 mm yr^{-1}, was 9% below the long term (1926-88) average of 717 mm yr^{-1}. Three years (1981, 1983 and 1988) had rainfall higher than the long term average. Most of the rain (>80%) fell in winter (May to October).

6.2 Groundwater Levels Beneath Pasture

Hydrographs for the bores drilled at the control site are shown in Appendix A. The hydrographs of all five bores have also been plotted together on the one graph (Fig. 8) to show the similarity in trends.

The annual minimum groundwater levels for all pasture bores are given in Table 4a. The variation in yearly minimum groundwater level relative to 1979, averaged for the five bores, is shown in Fig. 7. In two years (1982 and 1984) the groundwater levels increased due to significantly above average rainfall in the preceding year. Over the whole period there was a nett decline in groundwater level of 0.6 m.

The annual maximum groundwater levels for all pasture bores are given in Table 4b. The variation in the yearly maximum groundwater level relative to 1979, averaged for the five bores is shown in Fig. 9. The fluctuation in groundwater levels was directly related to variation in annual rainfall. The overall nett decline was 0.34 m.

Linear regressions were developed to predict the change in groundwater level under long term average rainfall conditions.

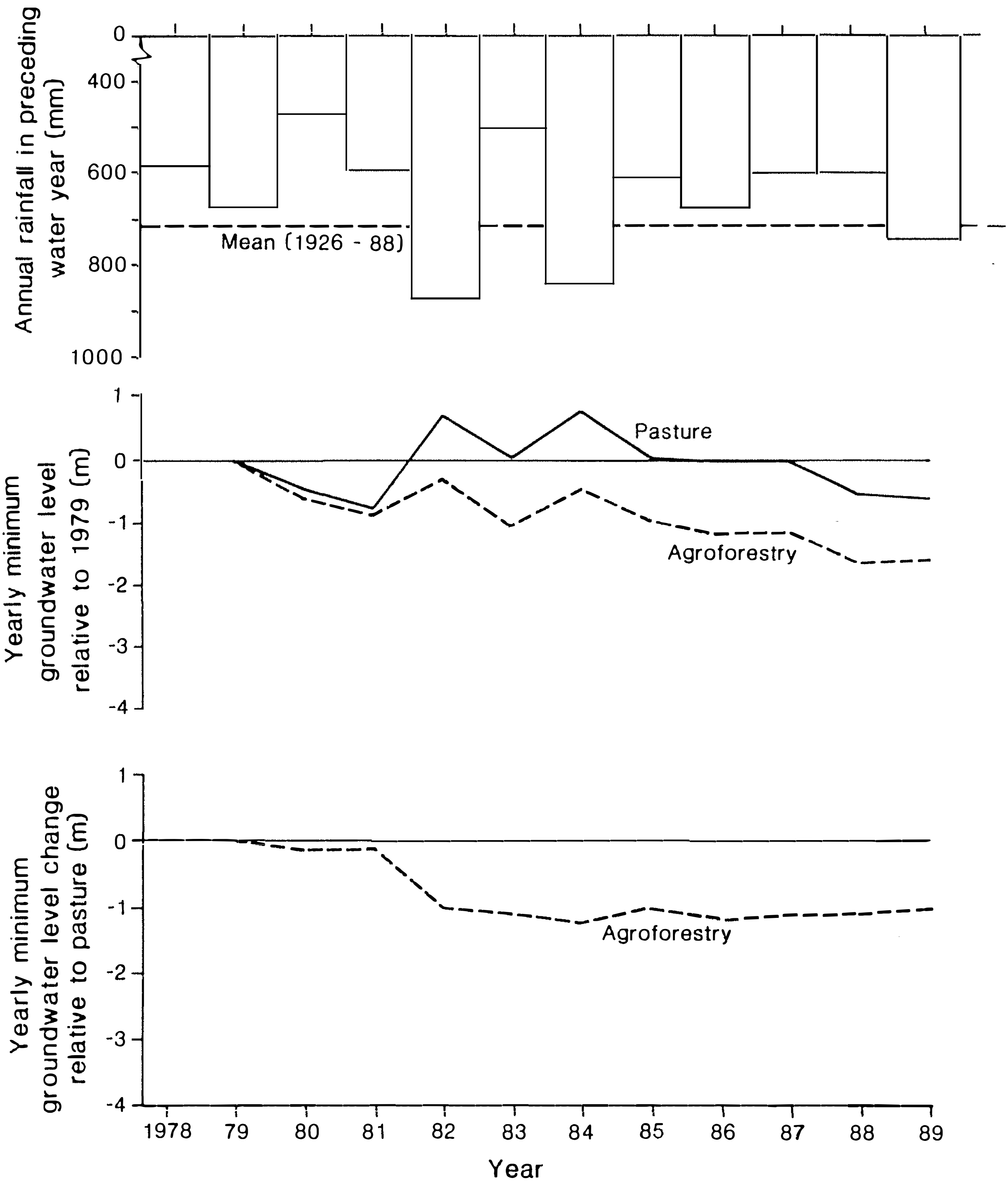


Figure7 :Annual rainfall and minimum groundwater level at the agroforestry site

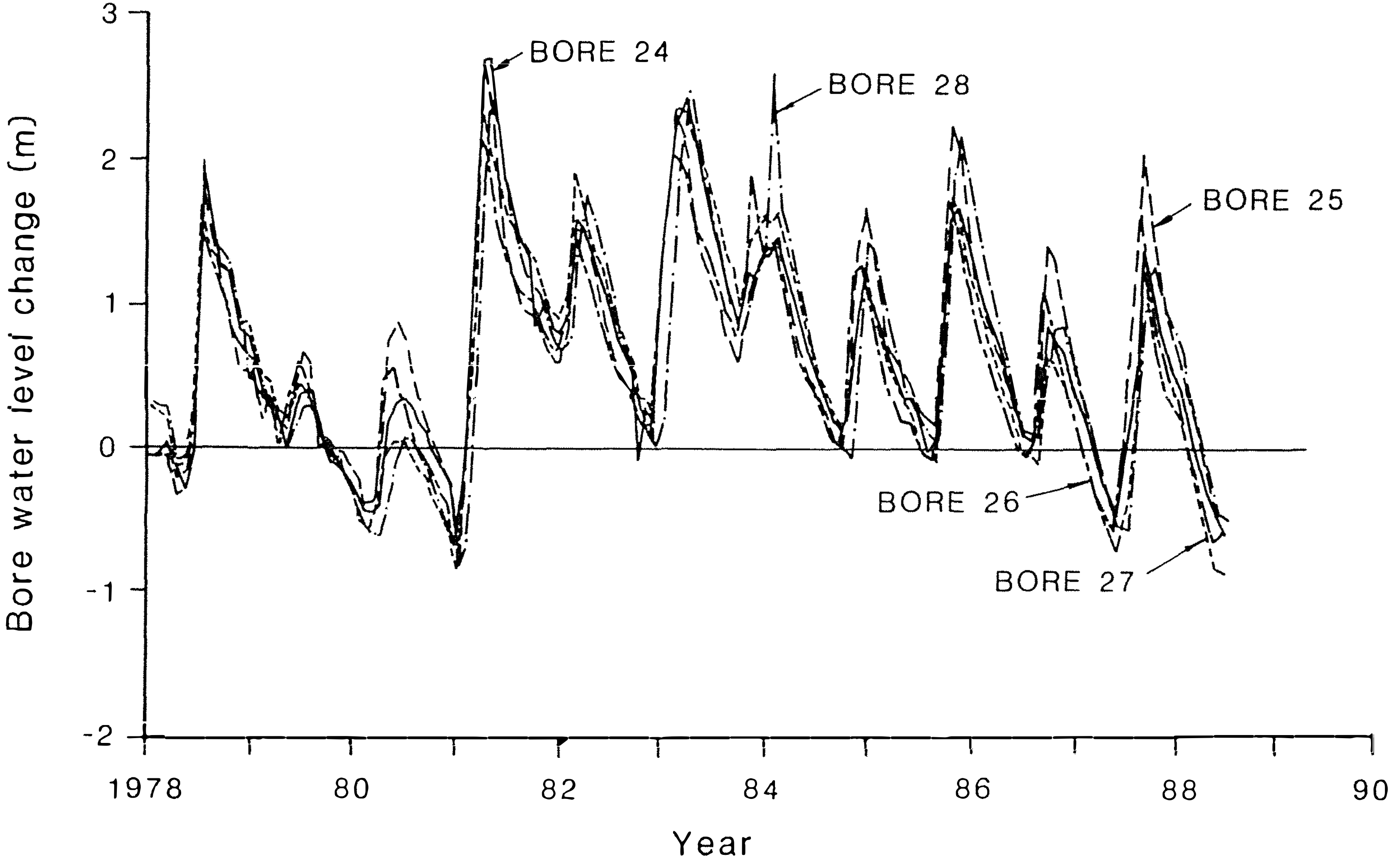


Figure 8:Groundwater levels at pasture control site relative to 1979 minimum level

Table 4a: Yearly minimum groundwater level (m AHD) of all pasture bores

Bore No.	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
G61618024	197.950	197.513	197.381	198.740	197.870	198.810	198.060	197.920	198.030	197.500	197.360
G61618025	196.420	196.050	195.565	197.020	196.470	197.030	196.420	196.570	196.480	195.960	195.960
G61618026	199.970	199.596	199.291	200.630	200.030	200.730	199.990	199.890	199.910	199.390	199.340
G61618027	204.040	203.496	203.193	204.935	204.260	205.030	204.180	203.940	203.920	203.340	203.190
G61618028	205.520	204.909	204.651	206.190	205.540	206.290	205.470	205.550	205.480	204.970	205.030

Table 4b: Yearly maximum groundwater level (m AHD) of all pasture bores

Bore No.	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
G61618024	198.770	198.285	200.640	199.485	200.390	199.410	199.130	199.640	198.810	199.320	198.380
G61618025	197.100	197.320	199.140	198.025	198.750	197.910	198.130	198.650	197.840	198.470	197.050
G61618026	200.690	200.545	202.130	201.520	202.010	201.857	201.260	201.702	201.070	201.620	200.320
G61618027	204.932	204.100	206.500	205.940	206.400	205.680	205.300	205.790	204.680	205.270	204.210
G61618028	206.410	205.600	207.930	207.270	208.040	208.117	206.960	207.680	206.380	206.800	206.200

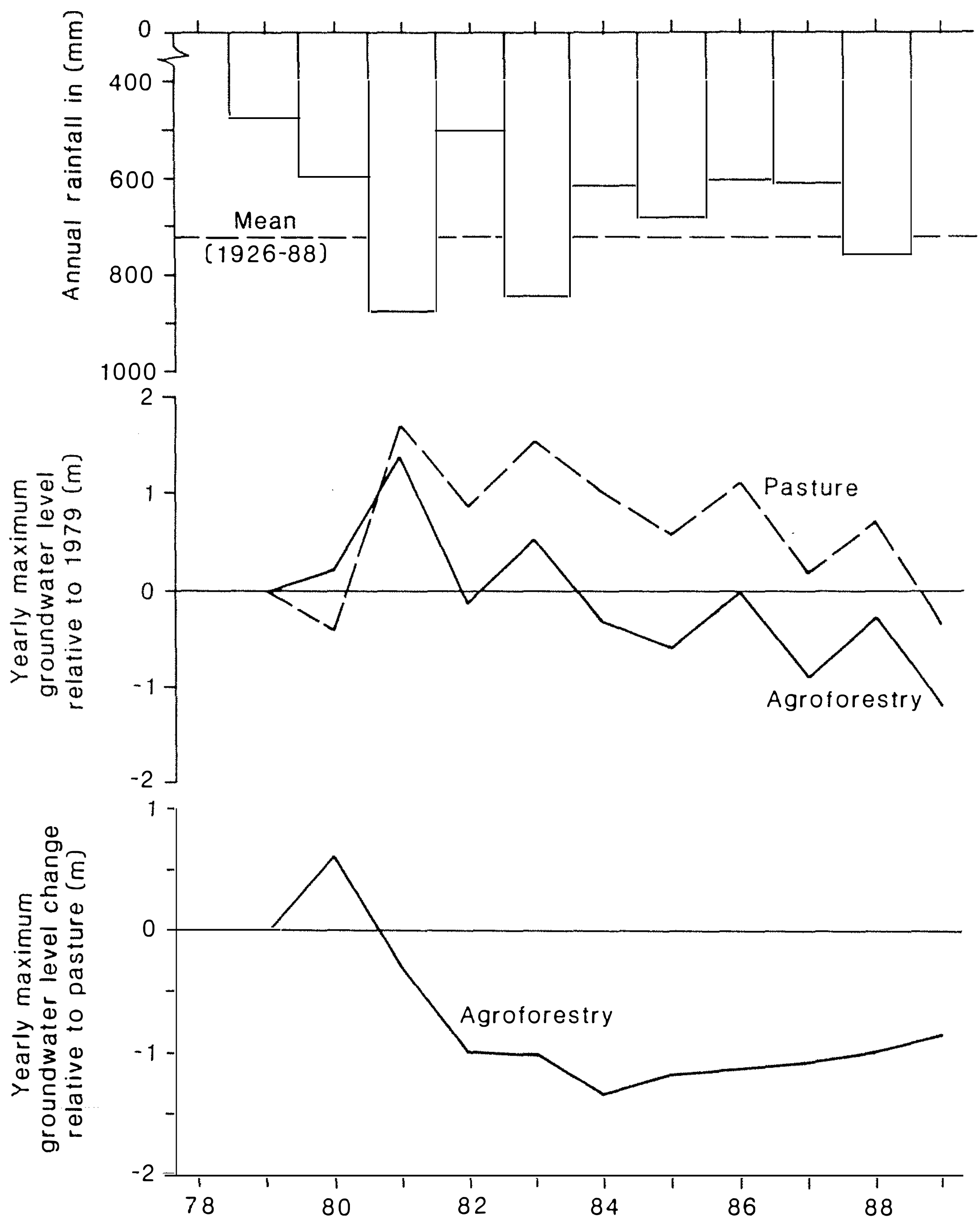


Figure9 :Annual rainfall and maximum groundwater level at the agroforestry site

The minimum groundwater level occurs in autumn. This level is strongly influenced by the rainfall during the previous winter. Therefore, annual change in minimum groundwater level (y) was plotted against the rainfall for the preceding year (x).

The regression based on minimum groundwater levels is:

$$y = -3000 + 4.5\ x \quad \text{(mm)} \tag{2}$$

Equation 2 predicts a rise in the average minimum groundwater level of 230 mm yr^{-1} for the long term average rainfall (717 mm yr^{-1}). For the minimum groundwater level to decrease the annual rainfall in the preceding year would need to be less than 670 mm (Fig. 10a).

As maximum groundwater level occurs soon after the winter rains (in the same year), the annual change in average maximum groundwater level (y) was plotted against the rainfall which had occurred in the same year (x).

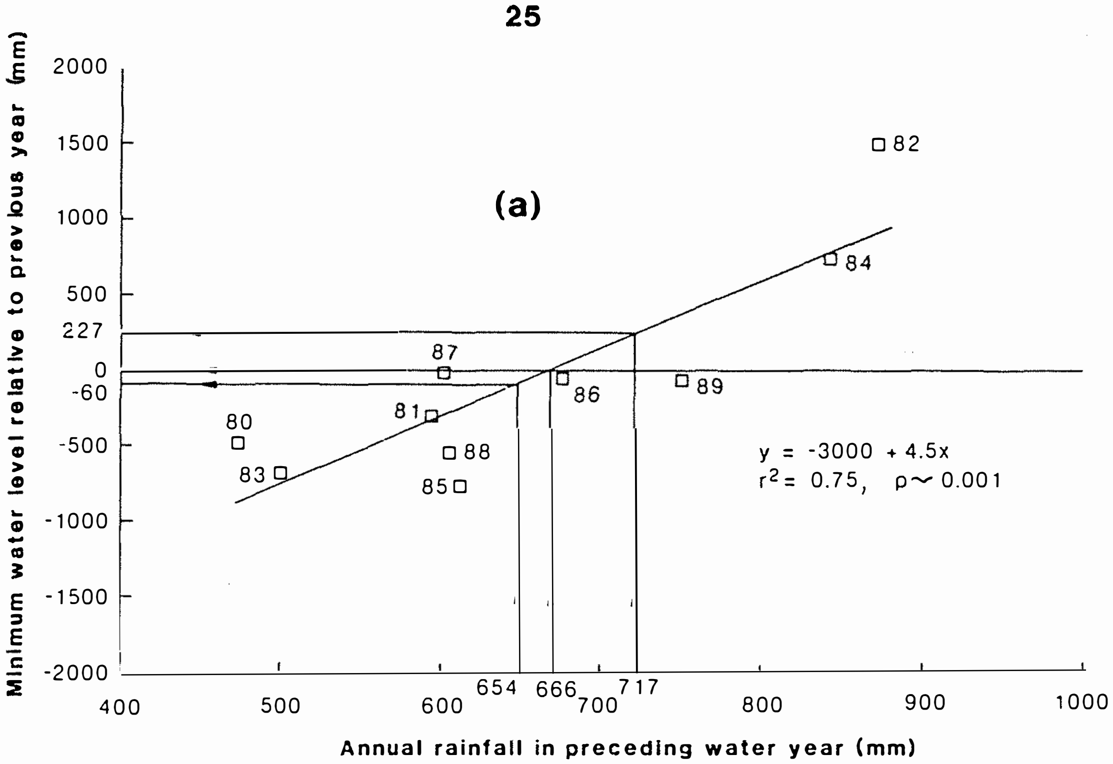
The regression based on maximum groundwater levels is:

$$y = -4050 + 6.2\ x \quad \text{(mm)} \tag{3}$$

From equation 3 the rise in average maximum groundwater level would be 400 mm yr^{-1} in an average rainfall year. For the maximum groundwater level to decrease, the rainfall would need to be less than 650 mm that year (Fig. 10b).

6.3 Groundwater Levels Beneath Agroforestry

Trees planted on agricultural pastures have the potential to decrease the vertical recharge to the aquifer system by increasing transpiration and interception loss (Eastham et al., 1988; Schofield, 1990). The effect of reforestation on groundwater table is shown in Fig. 11.



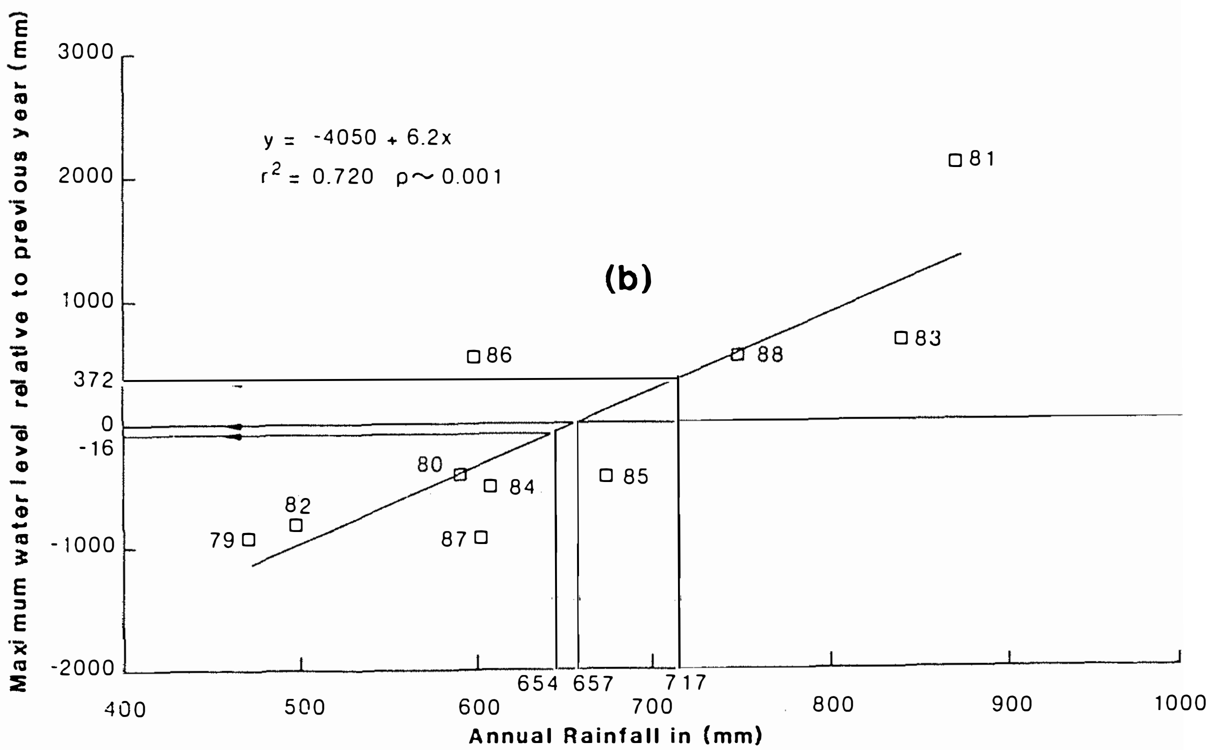


Figure 10 :Relationship between groundwater level and annual rainfall --- pasture bores (a) minimum, (b) maximum

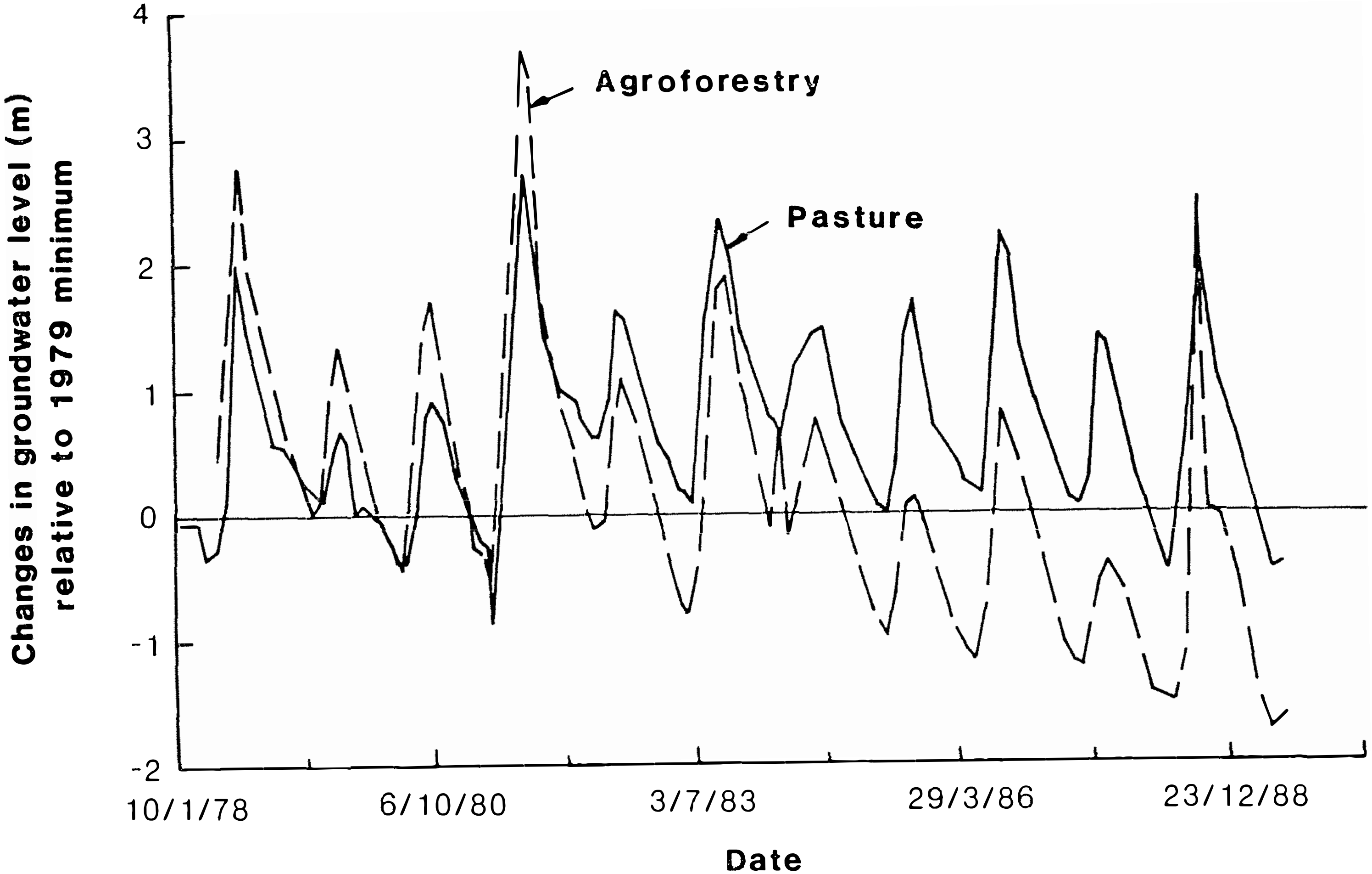


Figure11 :Typical groundwater level response at agroforestry and pasture sites relative to 1979 minimum level

The minimum and maximum groundwater level changes relative to 1979, averaged for all agroforestry bores, are shown both in absolute terms and relative to the control in Figs. 7 and 9.

6.3.1 Minimum Groundwater Level

The annual minimum groundwater level of all agroforestry bores are shown in Table 5a.

Changes in minimum groundwater level at the agroforestry and control sites were similar during the first three years of the agroforestry plantation. In 1980, the average minimum groundwater level under agroforestry had declined by 0.88 m compared with a fall of 0.76 m under pasture. At both sites, annual variations in groundwater level were strongly influenced by rainfall in the preceding years (Fig. 7).

In 1981, following a year of well above average rainfall, the groundwater level at the agroforestry site dropped 1.0 m relative to the control site. Between 1982 and 1985 declines in levels under agroforestry relative to pasture were only small. Since 1986 groundwater level under agroforestry has risen gradually relative to the control. This reversal in trend may be the result of thinning and pruning the agroforestry site over the period 1981-1988. At the end of the study period (1989) the absolute reduction in the average minimum groundwater level under agroforestry was 1.6 m. The reduction relative to the pasture control was 1.0 m.

6.3.2 Maximum Groundwater Level

The annual maximum groundwater level of all agroforestry bores are shown in Table 5b.

The match between yearly maximum groundwater levels at the agroforestry and control sites in the first three years was not particularly good, but for the rest of the study period the trends were similar to those observed for minimum groundwater

Table 5a : Yearly Minimum Groundwater Levels (m AHD) of all Agroforestry Bores

Bore No.	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
G61618042	178.971	178.522	178.431	178.786	178.221	178.551	178.191	178.001	177.961	177.561	177.361
G61618043	178.959	178.479	178.291	178.709	178.119	178.469	178.159	178.039	177.989	177.509	177.459
G61618044	180.259	179.518	179.274	179.799	179074	179.634	179.354	179.234	179.214	178.634	178.674
G61618045	180.242	179.593	179.120	179.667	178.942	179.622	179.442	179.412	179.282	178.592	178.802
G61618046	181.440	180.461	179.945	180.770	179.715	180.635	179.995	180.195	180.025	179.315	179.535
G61618048	179.865	179.406	179.210	179.770	179.085	179.525	178.955	177.745	178.565	178.165	178.365
G61618049	180.121	179.695	179.511	180.011	179.311	179.931	179.141	178.941	178.881	178.611	178.391
G61618050	180.952	180.362	180.125	180.832	180.017	180.637	179.987	179.837	179.827	179.407	179.437
G61618052	182.908	182.141	181.894	182.673	181.798	182.658	181.888	181.658	181.688	181.168	181.288

Table 5b : Yearly maximum groundwater level (m AHD) of all reforested bores

Bore No.	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	
G61618042	180.351	180.536	181.396	180.141	180.571	179.951	179.531	179.951	179.001	179.381	178.761
G61618043	180.779	180.534	181.409	180.099	180.529	179.929	179.639	180.059	179.129	179.509	178.709
G61618044	181.384	181.694	182.929	181.324	182.004	181.364	180.934	181.454	180.414	180.694	180.184
G61618045	182.202	182.152	183.152	181.522	182.272	181.702	181.432	181.992	180.792	181.382	180.442
G61618046	183.585	183.835	183.935	183.785	183.905	183.715	183.635	183.835	183.525	183.885	182.405
G61618048	181.195	181.545	183.740	180.980	182.905	180.615	180.565	182.265	181.125	181.045	181.095
G61618049	181.461	181.846	183.821	181.211	182.031	180.881	180.261	180.921	179.771	182.621	181.451
G61618050	181.957	182.097	184.017	182.017	182.837	181.877	181.217	181.697	180.767	181.187	182.107
G61618052	185.143	185.749	185.998	185.815	185.978	185.108	185.508	185.818	185.488	185.978	182.918

levels (Fig. 9). At the end of 1979 the average maximum groundwater level under agroforestry had risen by 0.41 m, compared with a fall of 0.22 m under pasture. The rise in water levels under agroforestry may be attributable to the immaturity of the plantings. By the end of following year levels had risen under both sites, with the rise being greater under pasture. This resulted in a nett reduction in water levels under agroforestry relative to pasture. In the ensuing period, the vartiations of the maximum groundwater levels were generally similar to the minimum groundwater levels, especially the relative changes. At the end of the study period (1989) the average maximum groundwater level under agroforestry had reduced by 1.11 m in absolute terms. The reduction relative to the control was 0.77 m.

6.3.3 Comparison of Minimum and Maximum Groundwater Level Reduction

The reduction of yearly minimum and maximum groundwater levels relative to the pasture control were fairly closely matched (Fig. 12) except in 1980, when the maximum groundwater level rose but the minimum declined.

6.3.4 Linear Regression Analysis

Linear regressions were developed to predict the change in groundwater level at the agroforestry site under long term average rainfall conditions.

For minimum groundwater levels, the annual change in groundwater (y) was plotted against the rainfall for the preceding year (x). The regression derived was:

$$y = -2300 + 3.3\,x \quad (\text{mm}) \qquad (4)$$

This regression predicts the average minimum groundwater level would rise 70 mm yr^{-1} under long term average rainfall conditions. For the minimum groundwater level to decrease, the annual rainfall in the preceding year would need to be less than 700 mm (Fig. 13a).

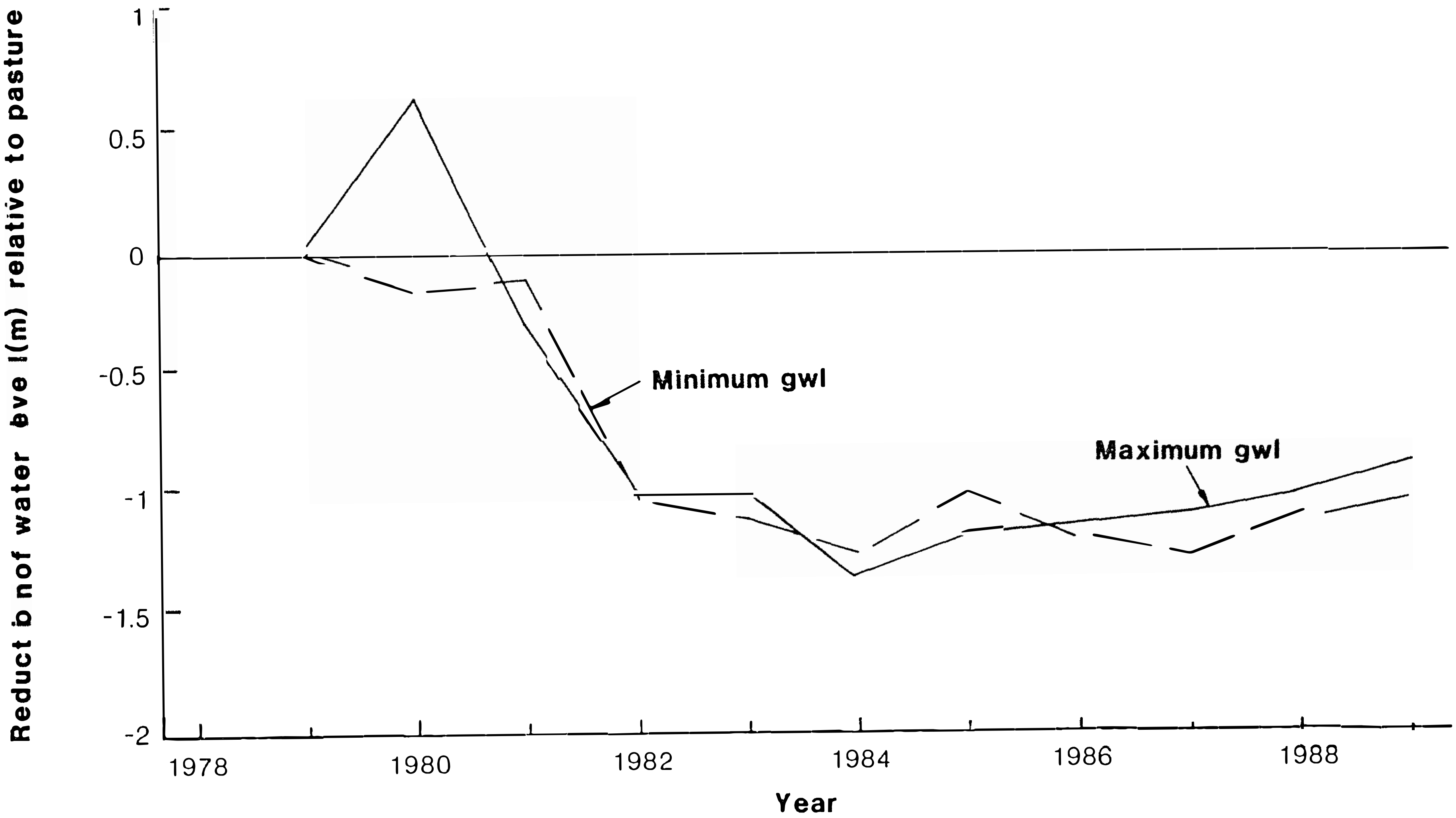


Figure 12 :Comparison of the reduction of minimum and maximum groundwater levels relative to pasture

The annual change in average maximum groundwater level (y) was plotted against the rainfall which had occurred in the same year (x). Although correlation was not high (r^2 = 0.65) the line of best fit was:

$$y = -3600 + 5.3 x \quad \text{(mm)} \qquad (5)$$

Thus the average maximum groundwater level is predicted to rise 200 mm yr^{-1} under long term average rainfall conditions. For the maximum groundwater level to decrease, the rainfall would need to be less than 680 mm that year (Fig. 13b).

6.4 Groundwater Flow

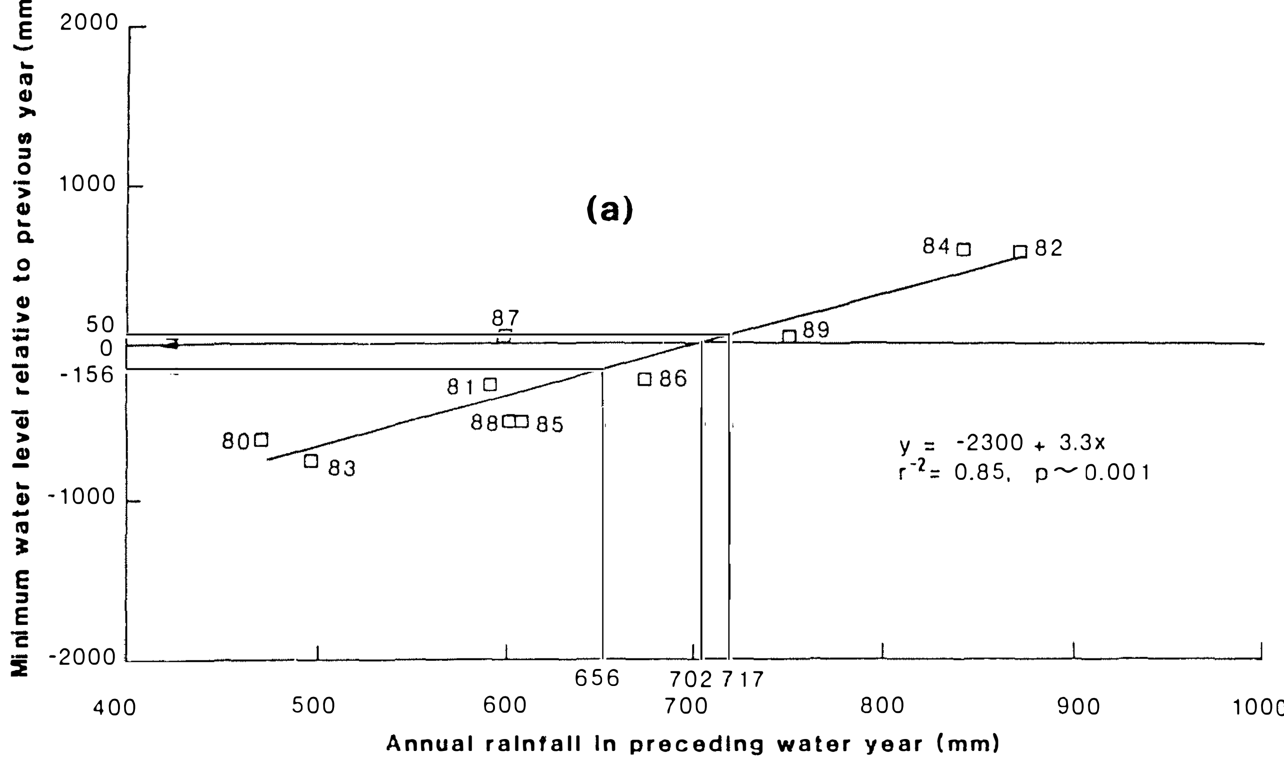
Minimum and maximum groundwater potentiometric contours for each year have been analysed. The flow direction for both minimum and maximum levels under agroforestry was similar ie, towards the stream. Because the flow direction was consistent year to year, only plots of contours at the beginning and the end of the study period are shown in Fig. 14. Although reforestation reduced groundwater levels over the study period it did not alter the direction of the flow.

6.5 Groundwater Salinity Trends Under Pasture

Salinity information from the five control bores were analysed in five categories:

(1) All bores
(2) Fresh bores
(3) Saline bores
(4) Bores screened at the water table
(5) Bores screened below the water table

Plots of the average annual salinities of each of these groups (Fig. 15) show similar downward trends in groundwater salinity over time. The average annual salinity of the pasture control is



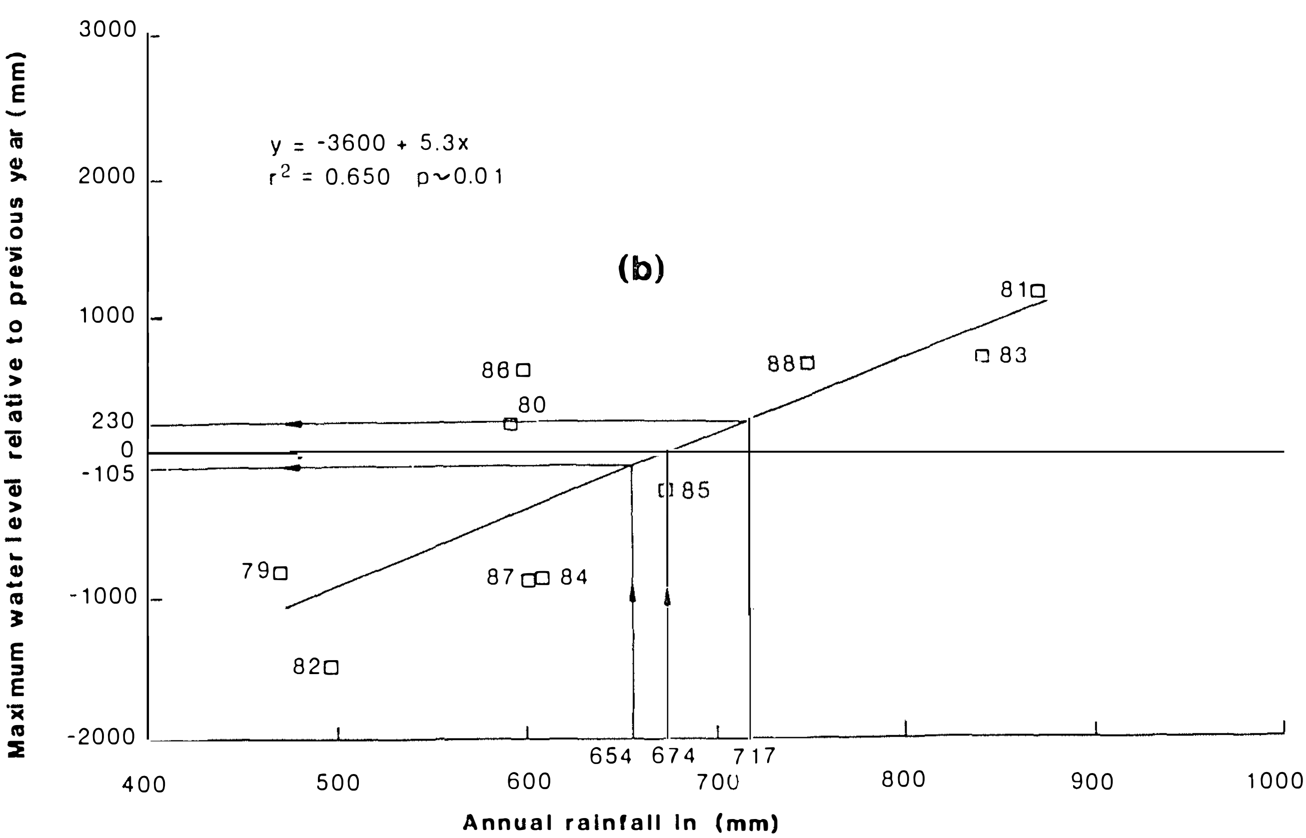


Figure 13 :Relationship between groundwater level and annual rainfall --- agroforestry site (a) minimum, (b)maximum

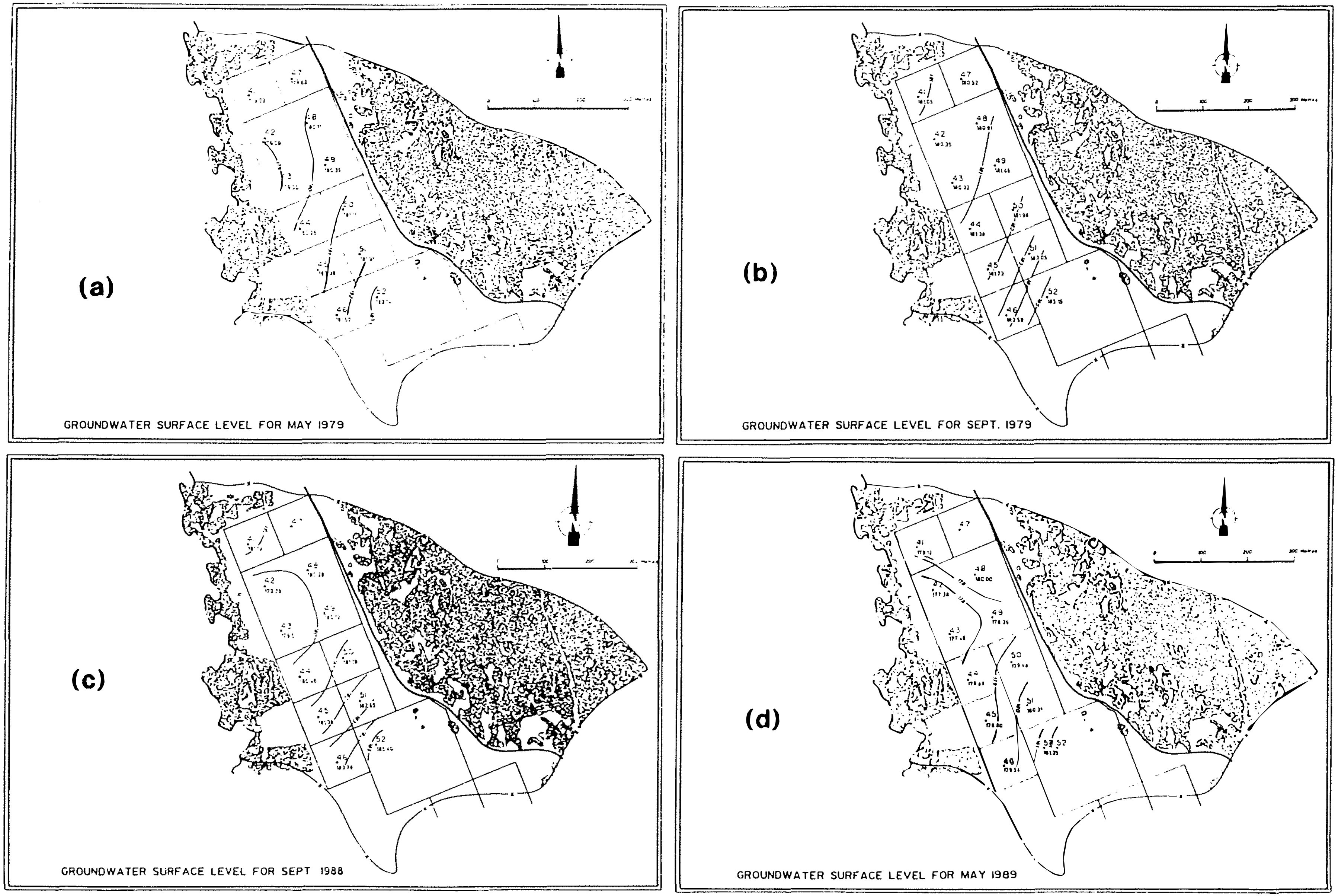


Figure14 :Regional groundwater surface levels and flow directions

highly variable (Table 6). In 1979 bore salinities varied from 560 mg L-1 TSS (bore 61618028) to 10271 mg L-1 (bore 61618026) TSS. Over the study period, salinity decreased in all bores, ranging from 22% (bore 61618026) to 77% (bore 61618024). The arithmetic average of all bores shows a groundwater salinity decrease of 31% over the 1979-88 period. Salinity data of 1989 was not considered because processing of the collected data was incomplete. In 1988, bore salinities varied from 405 mg L-1 TSS (bore 61618028) to 8015 mg L-1 TSS (bore 61618026).

In order to test the validity of the salinity sampling procedure and salinity trends, all bores were pumped in May 1989 and their salinities compared to results obtained in May 1979 (Table 7). This analysis shows an average reduction in groundwater salinity of all bores of 33%, closely comparable to the annual data.

6.6 Groundwater Salinity Trends Under Agroforestry

A similar analysis, using the same five categories was carried out on salinity results from bores at the agroforestry site.

The average annual groundwater salinity of five bore groups (Fig. 16) show that, in this case, only marginal changes in groundwater salinity have taken place. Table 8 shows high spatial variability in salinity under agroforestry. In 1979, groundwater salinity varied from 198 mg L-1 TSS (bore 61618046) to 7880 mg L-1 TSS (bore 61618050). During 1979-88, three of the eight bores (61618044, 61618045 and 61618050) had increase in salinity and others declined. Bore salinities varied from 179 mg L-1 TSS (bore 61618096) to 7901 mg L-1 TSS (bore 61618050) in 1988. The average of all bores salinities showed a nett decline by 3% in 1988 compared to 1979. Analysis of groundwater salinity changes following pumping of the bores in 1989, indicated a slightly higher decrease of 9% for all bores (Table 9). Two bores (61618043 and 61618044) had 18% and 6% increase in salinity; while others had declined, ranging from 0.5% to 56%. Although this reduction is less than under pasture, the significant aspect of the results is salinity did not increase as a result of reforestation.

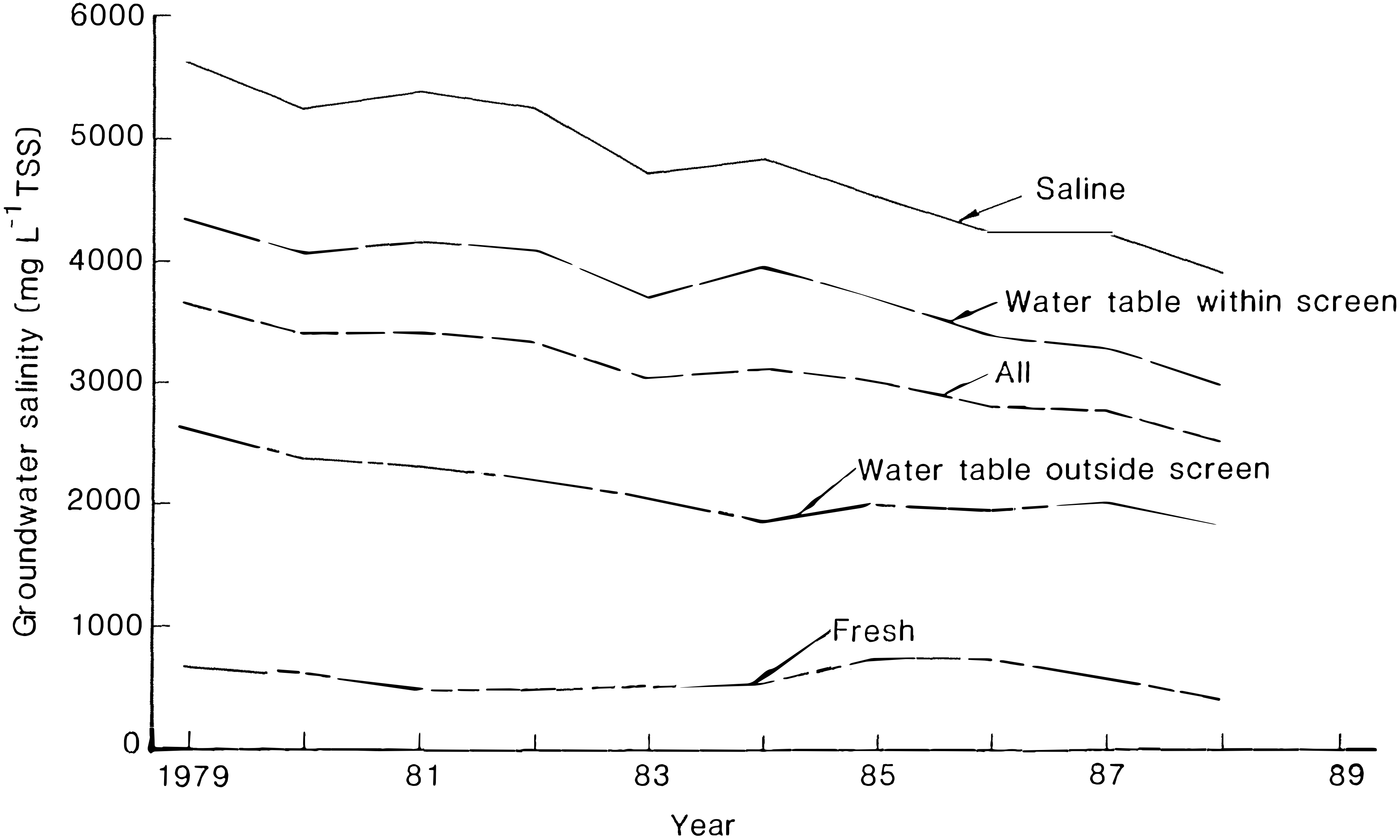


Figure 15 :Annual average salinity trends --- pasture bores

Table 6 : Annual salinity (mg L^{-1}) of all pasture bores

Bore No.	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	% change	Remarks
G61618024	2210.8	1886.1	1815.8	1329.0	1052.0	828.8	674.1	650.2	573.2	513.1	-76.8	Saline, slotting at watertable
G61618025	4400.1	4143.9	4199.4	3908.2	3505.3	3076.2	2960.8	3023.2	3294.8	3253.4	-26.1	Saline, slotting not at watertable
G61618026	10271.4	9741.8	10205.1	10566.8	9634.6	10678.3	9998.8	9098.7	8893.3	8014.6	-22.0	Saline, slotting at watertable
G61618027	841.6	620.5	438.8	520.1	611.3	644.7	1057.3	871.5	746.3	411.6	-51.1	Fresh, slotting not at watertable
G61618028	559.8	646.2	533.4	451.3	446.0	430.0	455.3	429.3	426.7	405.4	-27.6	Fresh, slotting at watertable

Table 7 : Comparison of May '79 Salinity of All Pasture Bores with that of May '89

Bore Set		Salinity ($mg\ L^{-1}$) on 01/05/79		Salinity ($mg\ L^{-1}$) 25/05/89		% Change in Salinity	
Classification	Bore No.		Average		Average		Average
All	61618024	2080.0		494.0		-76.25	
	61618026	10457.0		7955.0		-23.93	
	61618028	537.0	3692.60	395.0	2481.60	-26.44	-32.80
	61618025	4559.0		3131.0		-31.32	
	61618027	830.0		433.0		-47.83	
Fresh	61618026	537.0	683.5	395.0	414.0	-26.44	-39.43
	61618027	830.0		433.0		-47.83	
Saline	61618024	2080.0		494.0		-76.25	
	61618026	10457.0	5698.7	7955.0	3860	-23.93	-32.26
	61618025	4559.0		3131.0		-31.32	
Slotting	61618024	2080.0		494.0		-76.25	
at Water	61618026	10457.0	4358.0	7955.0	2948.0	-23.98	-32.35
table	61618028	537.0		395.0		-26.44	
Slotting	61618025	4559.0	2694.5	3131.0	1782.0	-31.32	-33.87
Not at	61618027	830.0		433.0		-47.83	
Watertable							

Table 8 : Annual salinity (mg L^{-1}) of all reforested bores

Bore No.	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	% change	Remarks
G61618042	7243.9	6537.8	6701.5	6728.3	6514.0	5959.1	5756.9	5767.7	5818.6	6131.6	-15.4	Saline, slotting at watertable
G61618043	304.9	299.7	333.7	322.8	320.6	289.9	297.1	294.7	319.5	264.1	-13.4	Fresh, slotting at watertable
G61618044	2841.8	2780.8	3326.3	3423.5	3744.1	2807.4	2991.4	3142.4	2932.7	3304.0	16.3	Saline, slotting at watertable
G61618045	2264.3	2110.8	2219.8	2373.3	2590.2	2694.0	2726.4	2696.8	2666.4	2506.8	10.7	Saline, slotting not at watertable
G61618046	198.3	194.1	182.3	164.2	176.7	176.8	173.4	175.1	197.8	179.0	-9.7	Fresh, slotting at watertable
G61618049	472.7	574.8	638.4	773.3	573.4	604.5	477.0	386.4	419.8	362.1	-23.4	Fresh, slotting at watertable
G61618050	7879.5	7889.8	7769.9	7558.1	7527.6	7597.8	7843.3	7967.1	8073.8	7901.3	0.3	Saline, slotting not at watertable
G61618052	268.2	212.0	278.2	271.2	223.8	182.4	185.3	179.4	180.5	183.1	-31.7	Fresh, slotting at watertable

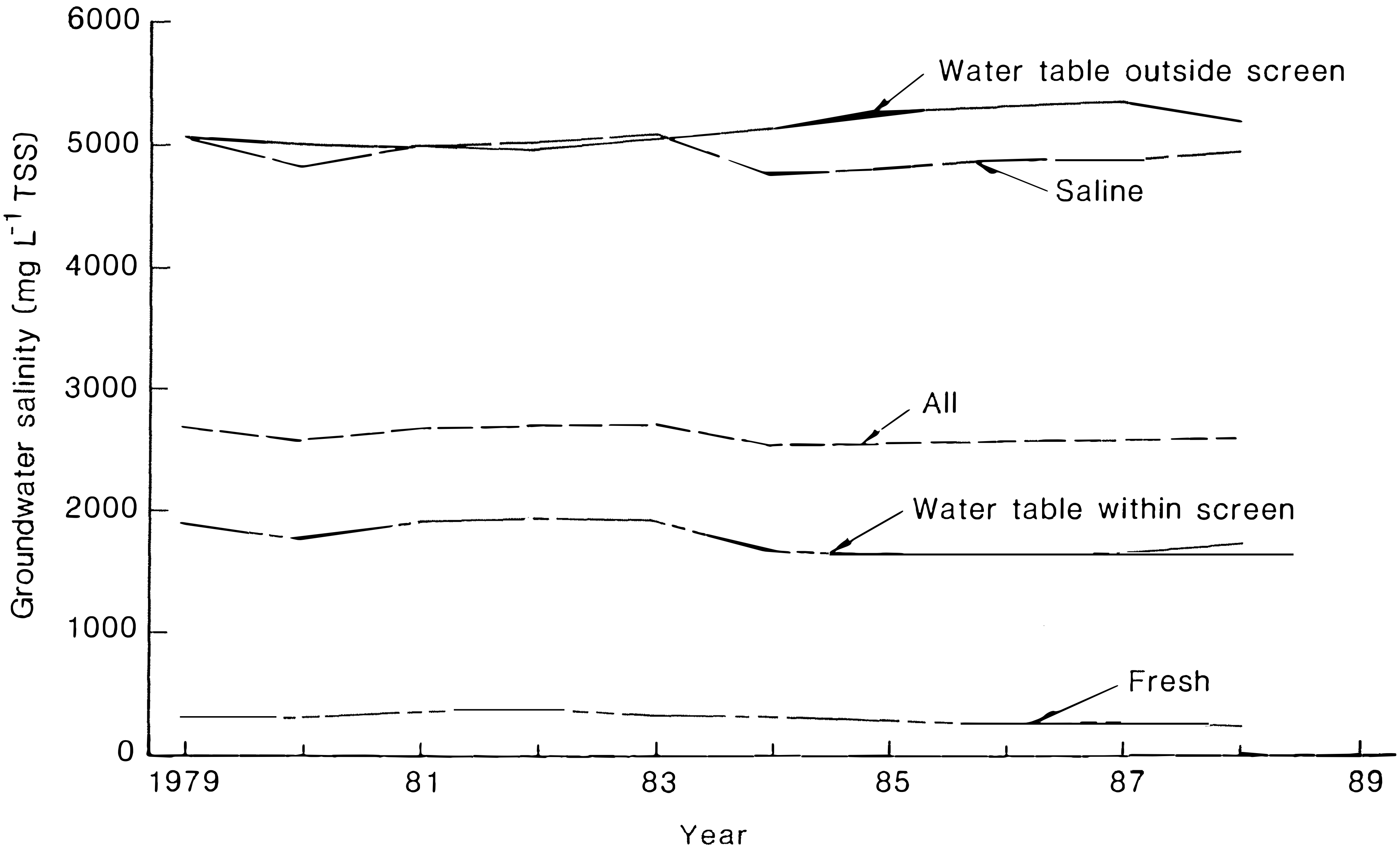


Figure16 :Annual average salinity trends --- agroforestry site

Table 9 : Comparison of May '79 Salinity (mg L^{-1}) of all Reforested Bores with that of May '89

Bore Set		Salinity (mg L^{-1}) on 01/05/79		Salinity (mg L^{-1}) 25/05/89		% Change in Salinity	
Classification	Bore No.	Individual	Average	Individual	Average	Individual	Average
All	61618043	401.0		471.0		17.46	
	61618046	194.0		188.0		-8.09	
	61618049	732.0	2810.8	322.0	2510.5	-56.01	-8.90
	61618052	438.0		198.0		-547.79	
	61618042	6999.0		5588.0		-20.16	
	61618044	3384.0		3570.0		5.50	
	61618045	2400.0		2389.0		-0.46	
	61618050	7938.0		7758.0		-2.27	
Fresh	61618043	401.0		471.0		17.46	
	61618046	194.0	441.3	188.0	294.8	-3.09	-33.20
	61618049	732.0		322.0		-56.01	
	61618052	438.0		198.0		-54.79	
Saline	61618042	6999.0		5588.0		-20.16	
	61618044	3384.0	5180.3	3570.0	4826.3	5.50	-6.83
	61618045	2400.0		2389.0		-0.46	
	61618050	7938.0		7758.0		-2.27	

7. DISCUSSION

7.1 The Effect of Rainfall on Groundwater Levels

The average annual rainfall during the study period was 9% lower than the long term average (1926-88). Groundwater levels at the agroforestry and control (pasture) sites decreased during this period. If long term average rainfall conditions had prevailed, regression analysis indicated groundwater levels would have risen at both sites. The rise would have been less under agroforestry than pasture. Thus rainfall has a significant effect on changes to groundwater levels.

It is predicted groundwater levels will continue to decline at both sites if the current drier conditions prevail. The decline should be greater under agroforestry.

7.2 The Impact of Plantation Management on Groundwater Levels

Changes in groundwater levels beneath agroforestry, relative to levels beneath the pasture control were negligible during the first three years after planting (1979-81). This has been attributed to the immaturity of the plantings. In the fourth year (1982), groundwater levels beneath agroforestry decreased markedly relative to the control. This possibly resulted from a significant increase in crown cover probably brought about by rapid growth stimulated by high rainfall in 1981, combined with the high stem density. Thinning and pruning did not commence until March 1982.

There have been no further significant changes in groundwater levels beneath agroforestry, relative to the control. This is thought to be attributable to the plantation management activities of thinning and pruning which took place between 1981 and 1988. Once final pruning has been completed it is possible groundwater levels under agroforestry will decline relative to the control in response to continuing growth of the plantation.

7.3 Groundwater Salinity

The average groundwater salinities at the control site, which was 90% under pasture, declined significantly during the study period from 3657 mg L^{-1} TSS to 2520 mg L^{-1} TSS. Reduction was fairly uniform over the study period. If this rate of decline continued then salinities would decrease to below 1000 mg L^{-1} TSS in a relatively short time. However, most analyses of solute leaching from a soil indicate an exponential decay of salt with time (e.g. Mulqueen and Kirkham, 1972), in which case the rate of decline would reduce over time. One exception is work carried out by Peck (1973) in which he observed a near-linear decay in solute concentration in experiments on the displacement of a saline groundwater with increased but uniformly distributed recharge in an inclined soil slab. It may be that further analysis of the rate of solute export and groundwater and stream salinity decline in agricultural systems which are approaching a recharge - discharge equilibrium needs to be undertaken to resolve this matter.

At the agroforestry site average groundwater salinities decreased only slightly. However, the main significance of this result is that salinities have not increased as a result of evaporative concentration as a number of authors (e.g. Conacher, 1982; Morris and Thomson, 1983; Williamson, 1986) thought might occur under agroforestry. The slight decrease in groundwater salinity may indicate solute leaching from the aquifer beneath the reforestation stand is occurring at a slightly faster rate than increasing concentration due to transpiration. In the situation of a declining groundwater table other processes may also affect groundwater salinity, such as solution-dissolution rates and solute deposition in the unsaturated zone.

7.4 The Effect of Species Type and Layout on Groundwater

Plant water use is regarded as one of the most important criteria in reforestation design (Morris, 1979), but its evaluation has been limited by the difficulty of measurement and other complications. A recent review by Schofield *et al*. (1989) shows that some plant species can transpire significantly more water than others. Two Pinus species and one Eucalyptus species were planted in the agroforestry site. Species type and layout had no observable influence on groundwater behaviour. Changes in groundwater level and salinity were seen to be more on a regional scale. The area supporting different types of plantings (one hectare blocks) was too small to cause localised effects.

8. CONCLUSIONS

Based on the analyses and interpretation of data, the following conclusions can be drawn:

8.1 Groundwater Level

(i) Agroforestry covering 58% of farmland (final stem densities of 75-225 sph) has lowered the groundwater level by an average of 1.0 m relative to groundwater level beneath a pasture control site.

(ii) The main decline in the water table took place in the fourth year of the plantation, just prior to the first thinning and pruning operations. Since then there has been little nett change.

(iii) There was no significant difference between the reduction in minimum and maximum groundwater levels beneath agroforestry relative to the pasture control.

(iv) Rainfall was 9% below the long term average during the study period. Had long term rainfall conditions prevailed, groundwater levels under both agroforestry and pasture would have risen. However, if the current drier climatic conditions continue groundwater levels could be expected to decline further. The decline should be greater under agroforestry.

8.2 Groundwater Flow

(i) Groundwater flow was towards the stream.

(ii) Although reforestation reduced groundwater levels it did not alter the direction of the flow.

8.3 Groundwater Salinity

(i) The spatial variation of groundwater salinity at both the agroforestry and control sites was high, ranging from fresh to highly saline.

(ii) The decrease in groundwater salinity under agroforestry during the study period was in the order of 10%. This decrease was contrary to some early expectations of a number of authors who thought there may have been a concentration of salts as a result of increased evapotranspiration.

(iii) Groundwater salinity beneath pasture decreased by about 30% over the study period. The rate of decrease was fairly uniform. This result merits further investigation of solute leaching under agriculture in moderate to high rainfall zones.

(iv) The effectiveness of this agroforestry site in salinity control has been limited but further monitoring is required to determine longer term effects after thinning and pruning has ceased.

9. RECOMMENDATIONS

- To identify the effects of further crown and tree growth, bore monitoring should be continued so yearly minimum and maximum groundwater levels can be obtained.

- Bore salinity sampling should be continued so groundwater salinity trends under both pasture and agroforestry can be assessed further. The groundwater monitoring programme is detailed in the Research Operation and Data Review for Perth South Region.

- To support interpretation of the groundwater data, tree basal area measurements should be continued annually and tree cover less frequently (5 yearly).

10. ACKNOWLEDGEMENTS

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REFERENCES

Anderson, M., Loh, I.C. and Stone, K. (1982). Groundwater monitoring of reforestation, Strip Plantings Site, Bingham River Valley. Public Works Dept. Rep. No. WRB 20, 59 pp.

Anderson, G.W. and Moore, R.M. (1987). Productivity in the first seven years of a Pinus radiata - annual pasture agroforest in Western Australia. Aust. J. Exp. Agric. 27, 231-238.

Anderson, G.W., Moore, R.M. and Jenkins, P.J. (1988). The integration of pasture, livestock and widely-spaced pine in south west Western Australia. Agroforestry Systems 6, 195-211.

Batini, F.E., Anderson, G.W. and Moore, R.M. (1983). The Practices of Agroforestry in Australia. In : 'Foothills for Food and Forest' : Ed. D.B. Hannaway pp 233-249, Symposium Series No. 2. Oregon State University, College of Agricultural Science, Oregon, USA.

Bell, R.W., Anson, B. and Loh, I.C. (1988). Groundwater response to reforestation in the Darling Range of Western Australia. Water Authority of W. Australia, Surface Water Branch, Rep. No. WS 24, 89 pp.

Bell, R.W., Schofield, N.J., Loh, I.C. and Bari, M.A. (1990). Groundwater response to reforestation in the Darling Range of Western Australia. J. Hydrol. 119, 179-200.

Conacher, A. (1982). Dryland agriculture and secondary salinity. In : W. Hanby and M. Cooper (Editors), Man and the Australian Environment. McGraw-Hill, Sydney, 113-125.

Eastham, J., Rose, C.W., Cameron, D.M., Rance, S.J. and Talsma, T. (1988). The effect of tree spacing on evaporation from an agroforestry experiment. J. Agricul. and Forest Mat. 42, 355-368.

Edgeloe, R.W. and Loh, I.C. (1984). Groundwater monitoring of reforestation, Valley Planting Site, Bingham River Valley. PWD (unpublished).

Hayes, R.J. and Garnaut, G. (1981). Annual rainfall characteristics of the Darling Plateau and the Swan Coastal Plain. Public Works Dept. of W. Australia, Water Resources Branch, Rep. No. WRB 3, 28 pp.

Luke, G.J., Burke, K.L. and O'Brien, T.M. (1988). Evaporation data for Western Australia. W. Australian Dept. Agric. Div. Resour. Manag., Tech. Rep. No. 65, 29 pp.

Malajczuk, G., Morrison, D., Havel, J., Anderson, G. and Moore, R. (1984). An economic study of agroforestry in the Manjimup Region, Western Australia. Tech. paper no. 10, Forests Dept. of W.A.

Montana, C. and Ezcurra, E. (1980). A simple instrument for quick measurement of crown projections. J. Fores. 78, 699.

Morris, J. (1979). Reforestation as a control measure for dryland salinity in Victoria. Forests Commission of Victoria.

Morris, J.D. and Thomson, L.A.J. (1983). The role of trees in dryland salinity control. Proc. R. Soc. Vic. 95(3), 123-131.

Mulqueen, J. and Kirkham, D. (1972). Leaching of a surface layer of sodium chloride into the drains in a sand tank model. Soil Sci. Soc. Amer. Proc. 36, 3-9.

Peck, A.J. (1973). Analysis of multi-dimensional leaching. Soil Sci. Soc. Amer. Proc. 37, p 320.

Schofield, N.J. (1990). Determining reforestation area and distribution for salinity control. J. Hydrol. Sci. 35, 1-19.

Schofield, N.J., Loh, I.C., Scott, P.R., Bartle, J.R., Ritson, P., Bell, R.W., Borg, H., Anson, B. and Moore, R. (1989). Vegetation strategies to reduce stream salinities of water resource catchments in south-west Western Australia. Water Authority of W.A., Surface Water Branch, Rep. No. WS 33, 98 pp.

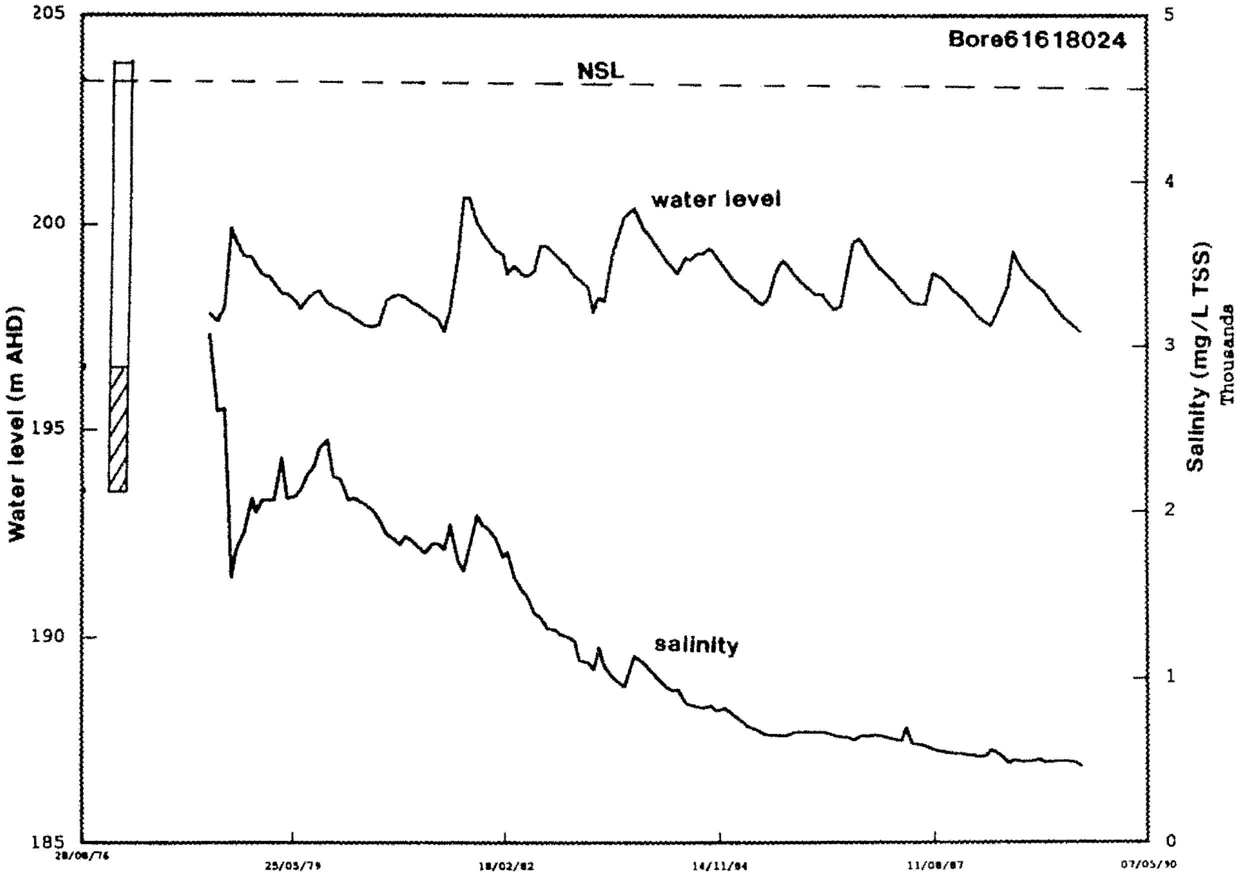
Schofield, N.J. and Ruprecht, J.K. (1989). Regional analysis of stream salinisation in south west Western Australia. J. Hydrol. 112 : 18-38.

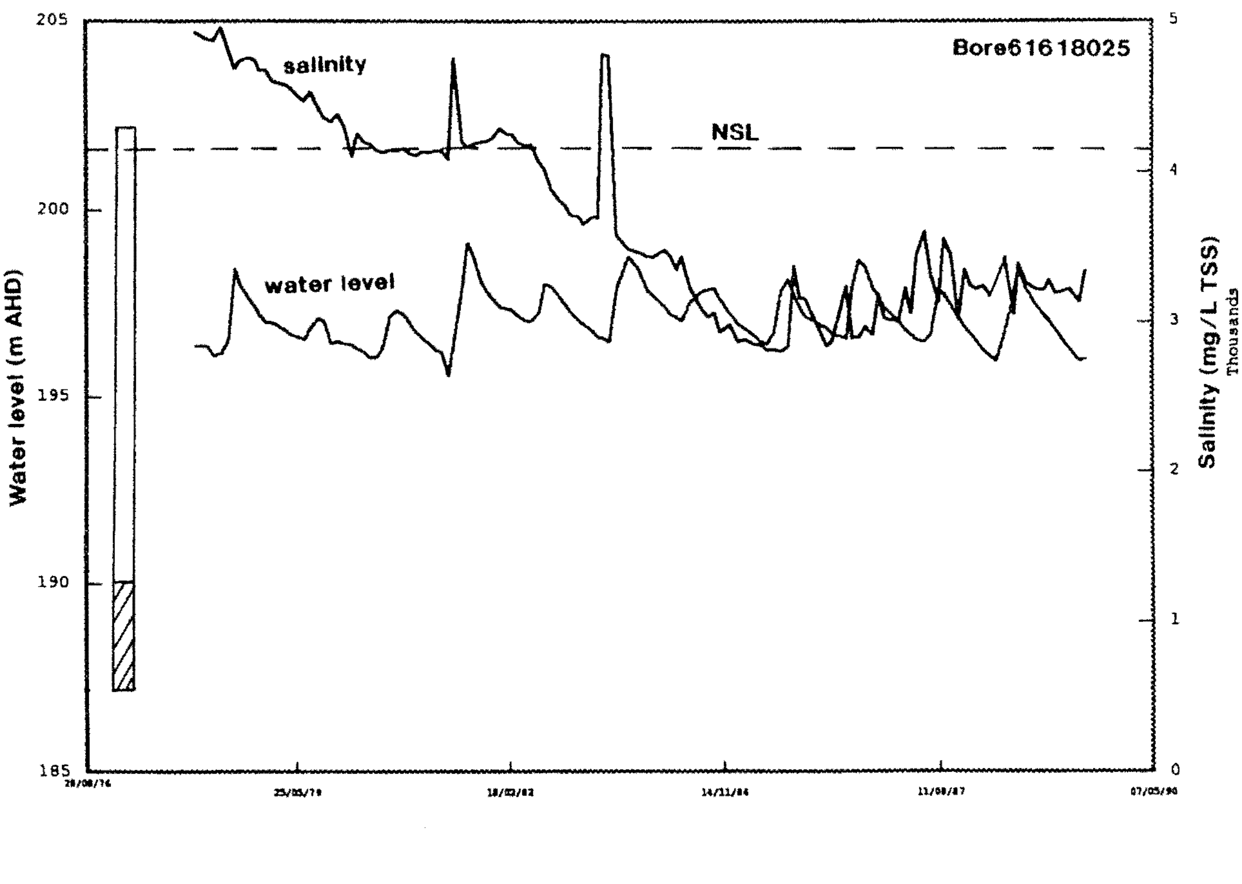
Schofield, N.J., Ruprecht, J.K. and Loh, I.C. (1988). The impact of agricultural development on the salinity of surface water resources of south-west Western Australia, Water Authority of Western Australia, Surface Water Branch, Rep. No. WS 27, 69 pp.

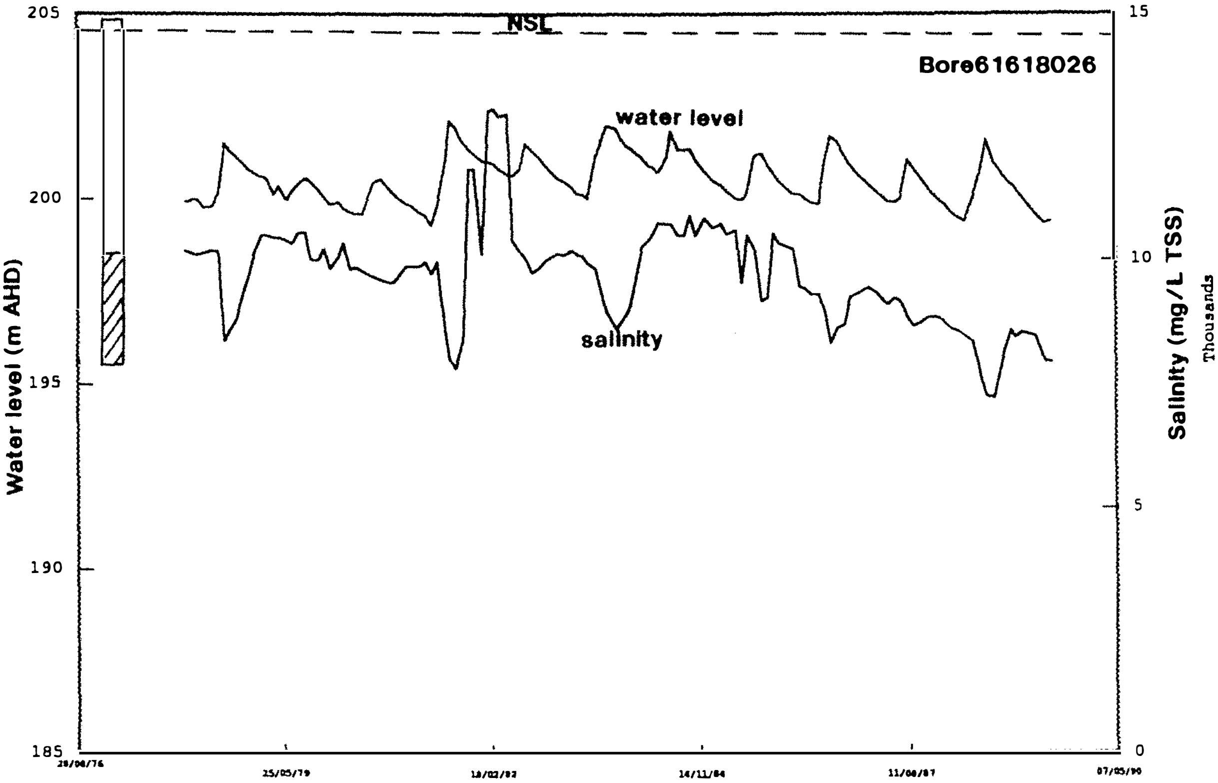
Williamson, D.R. (1986). The Hydrology of salt affected soils in Australia. Reclam. Reveg. Res. 5, 181-196.

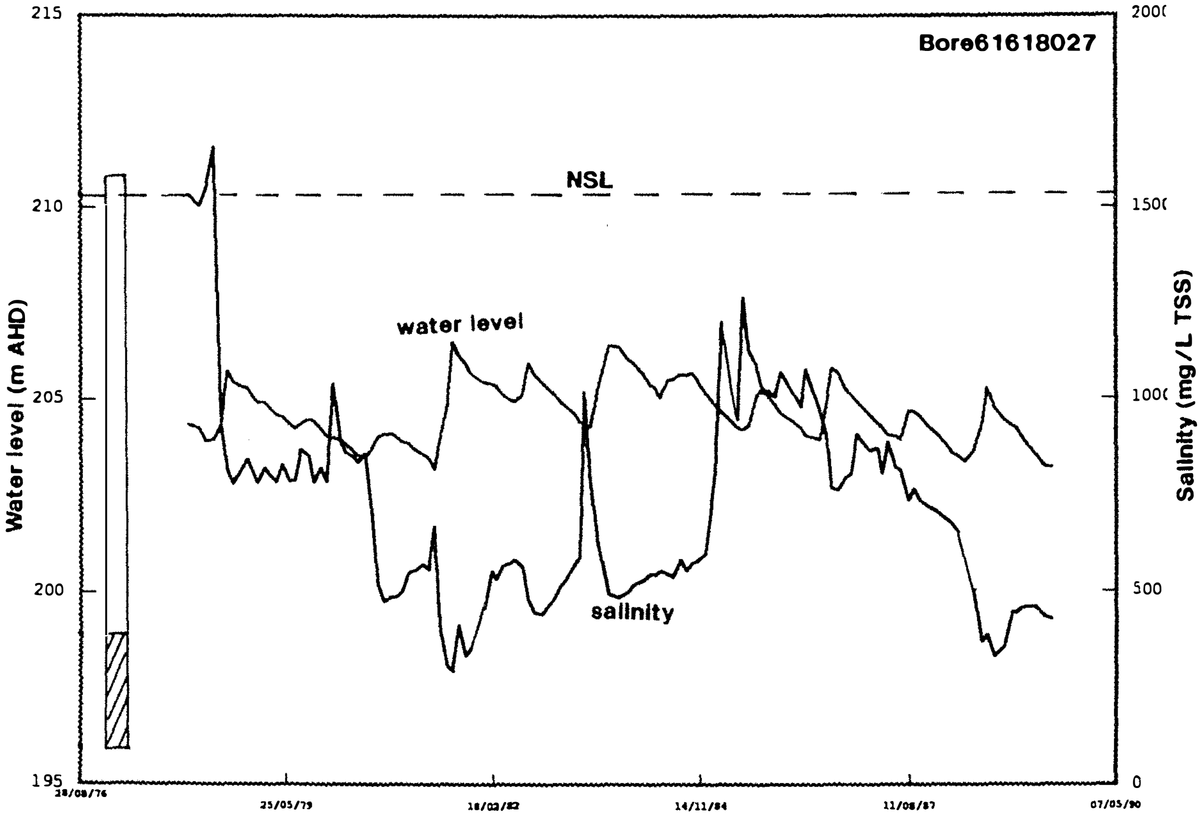
APPENDIX A

Groundwater Level and Salinity
Time Series for each Agroforestry
and control bore


Bore61618024
NSL
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
Thousands
205
200
195
190
185
5
4
3
2
1
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90


Bore61618025
NSL
salinity
water level
Water level (m AHD)
Salinity (mg/L TSS)
Thousands
205
200
195
190
185
5
4
3
2
1
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90


NSL
Bore61618026
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
Thousands
205
200
195
190
185
15
10
5
0
25/05/79
14/11/84
11/08/87
07/05/90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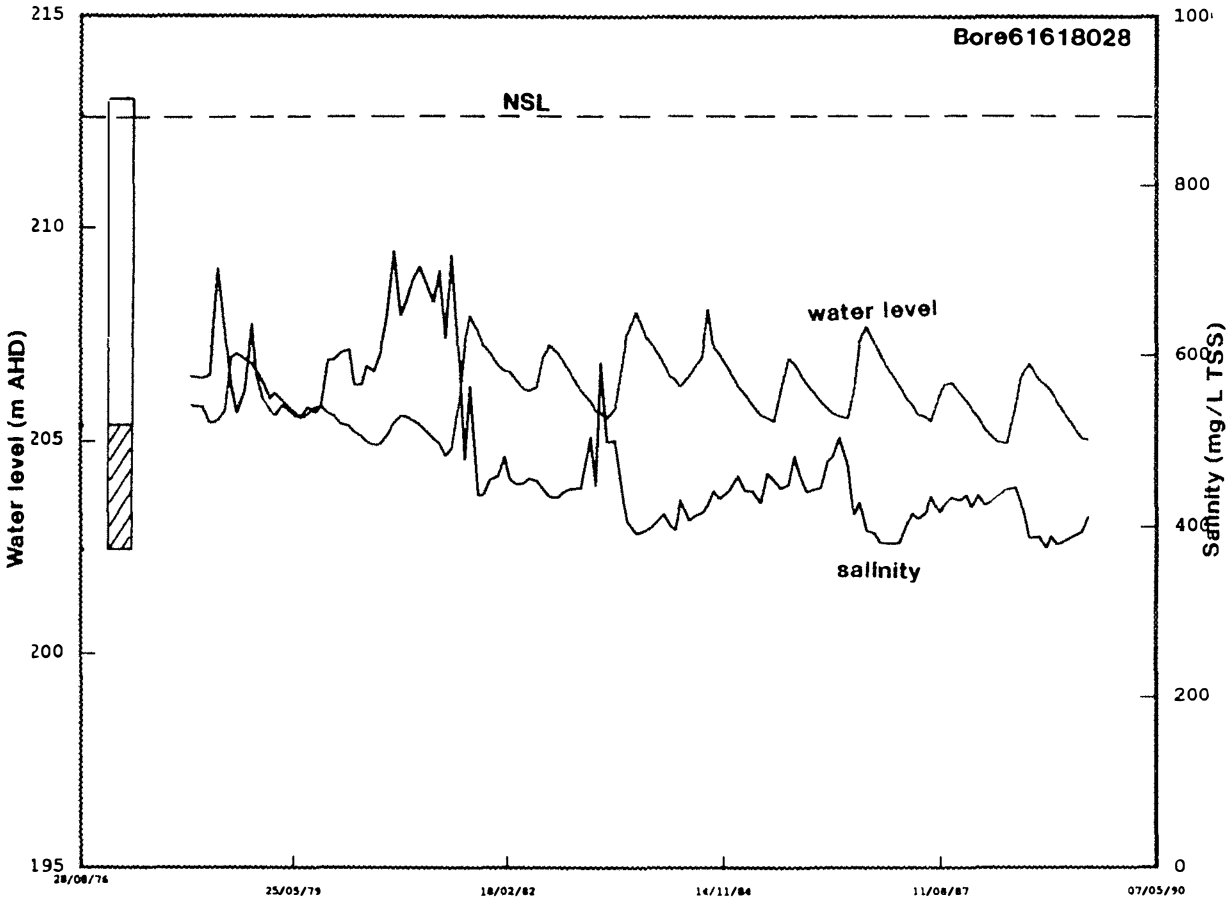
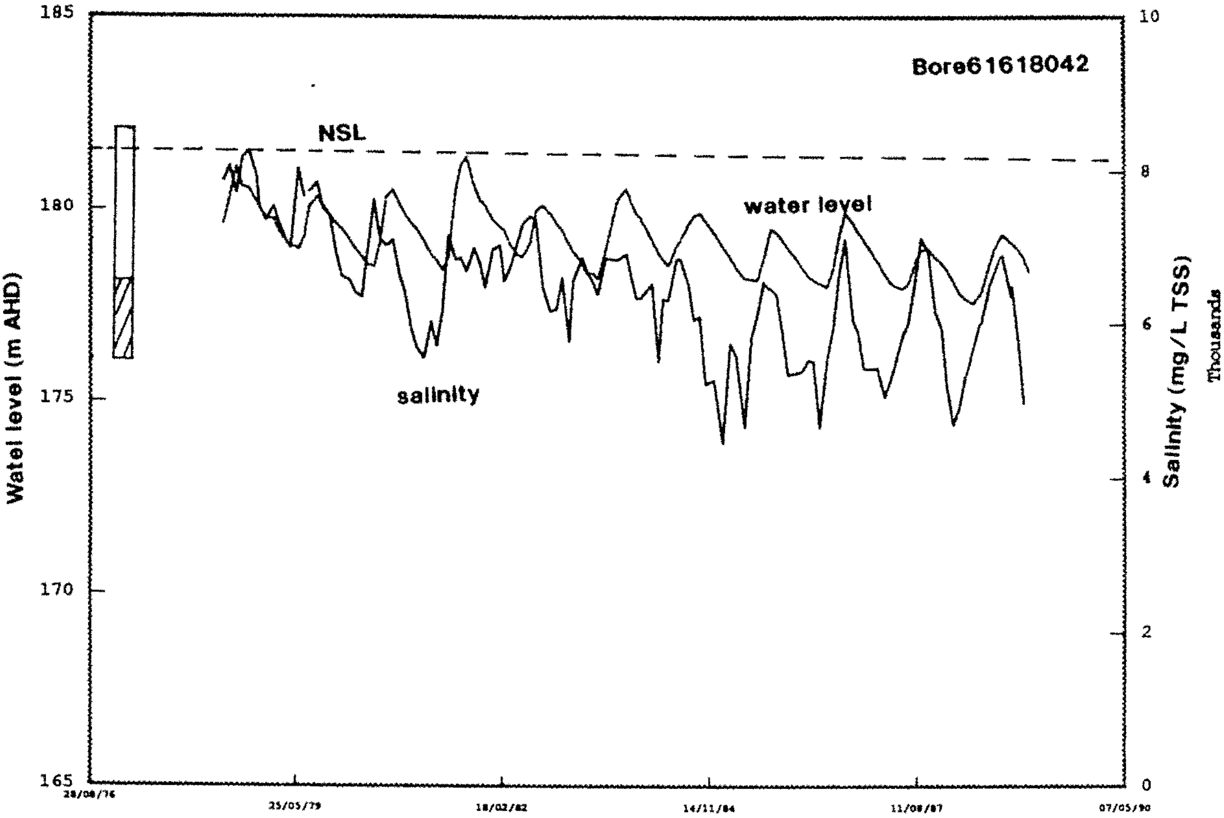
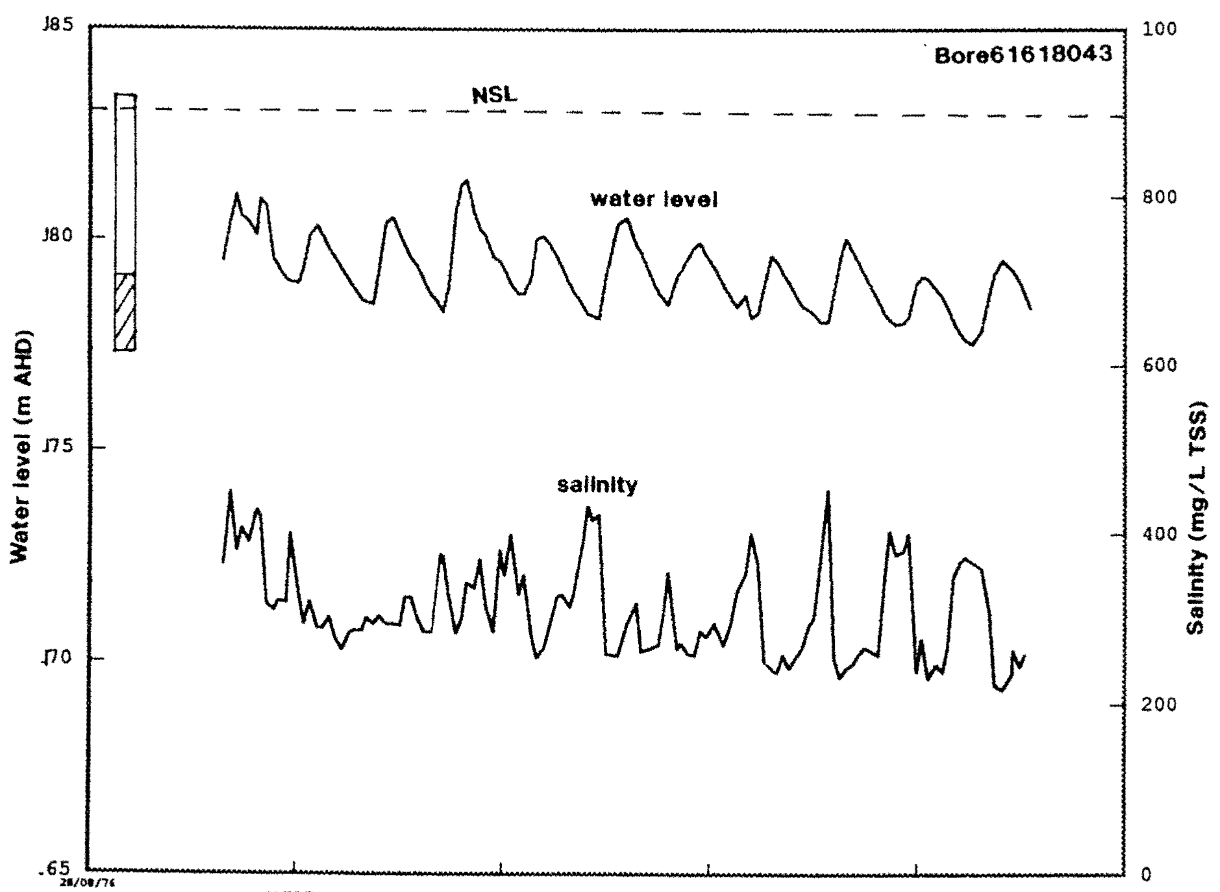
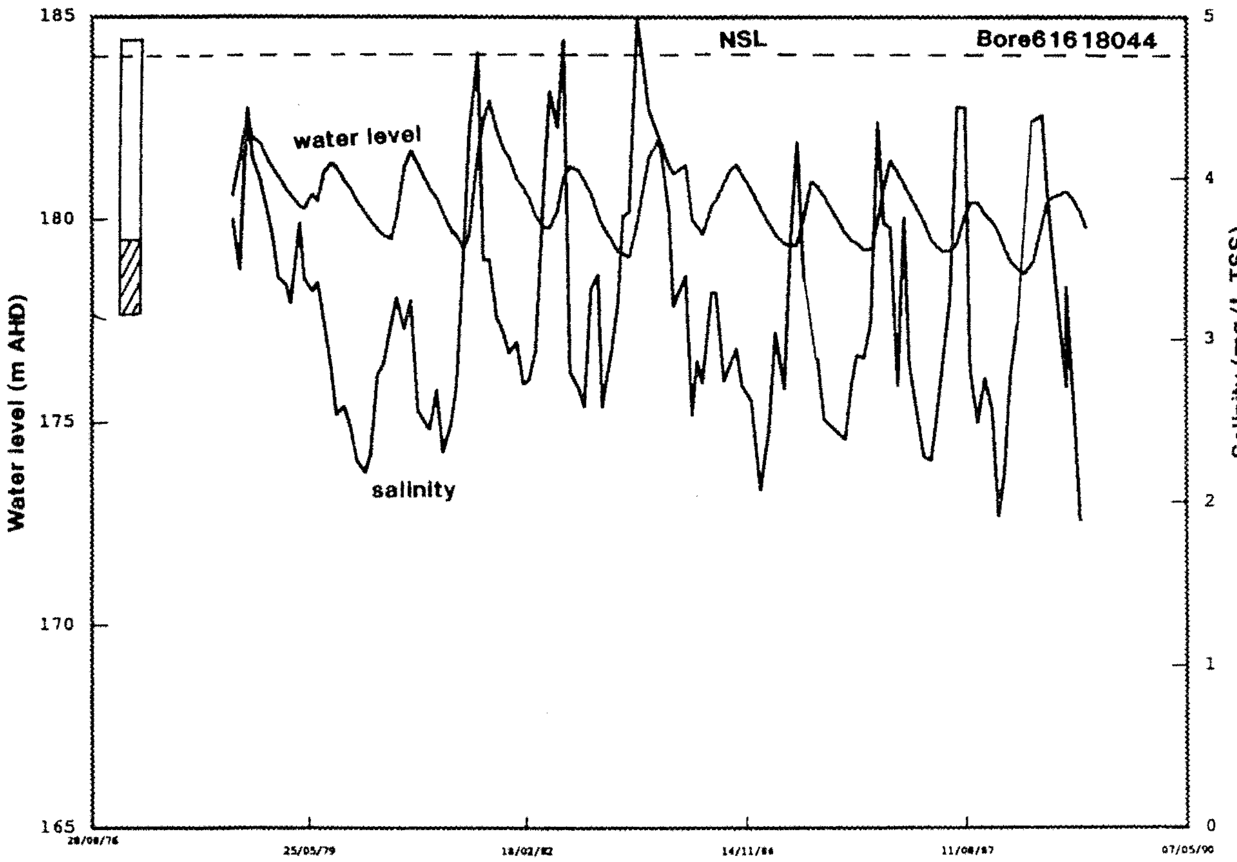
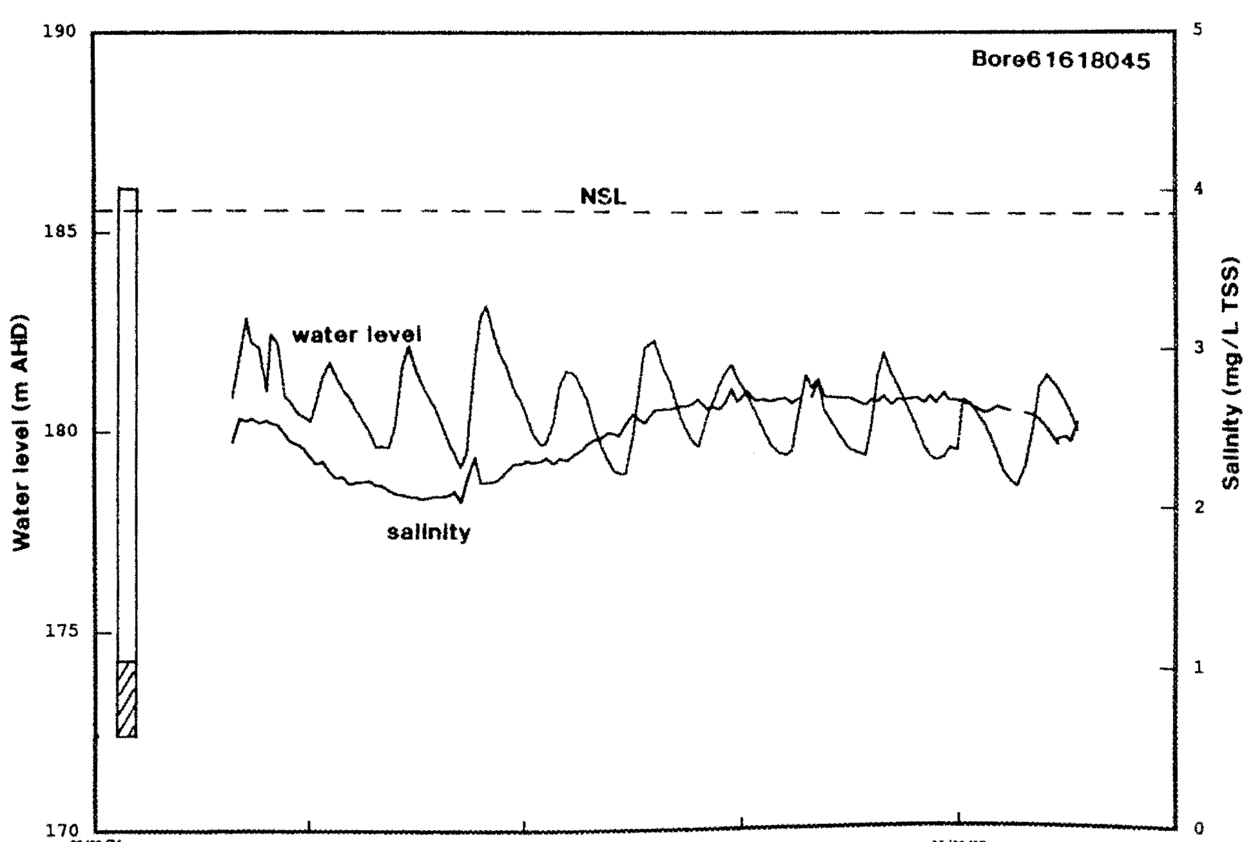
NSL
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
215
210
205
200
195
500
0
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90

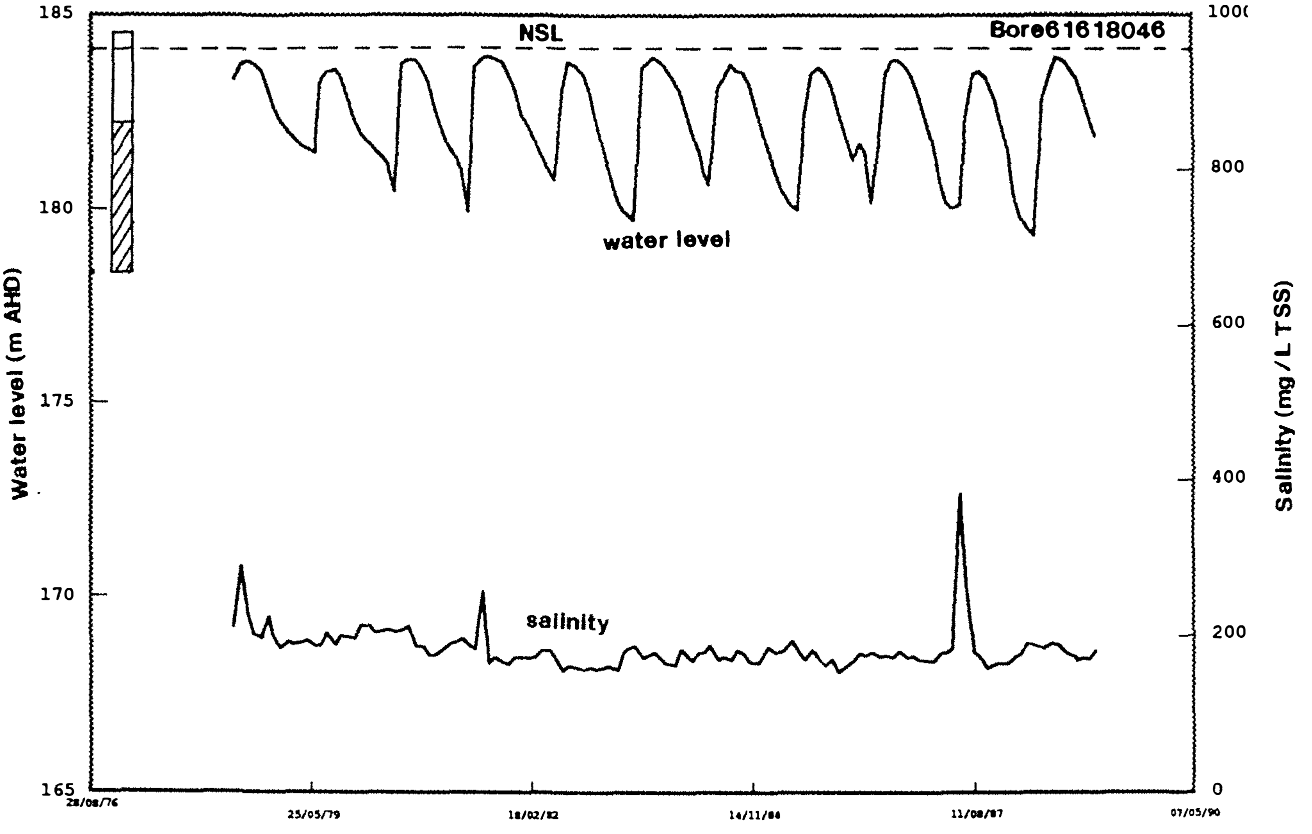

Bore61618028
NSL
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
215
210
205
200
195
800
600
400
200
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90


Bore61618042
NSL
water level
salinity
Watel level (m AHD)
Salinity (mg/L TSS)
Thousands
185
180
175
170
165
10
8
6
4
2
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90

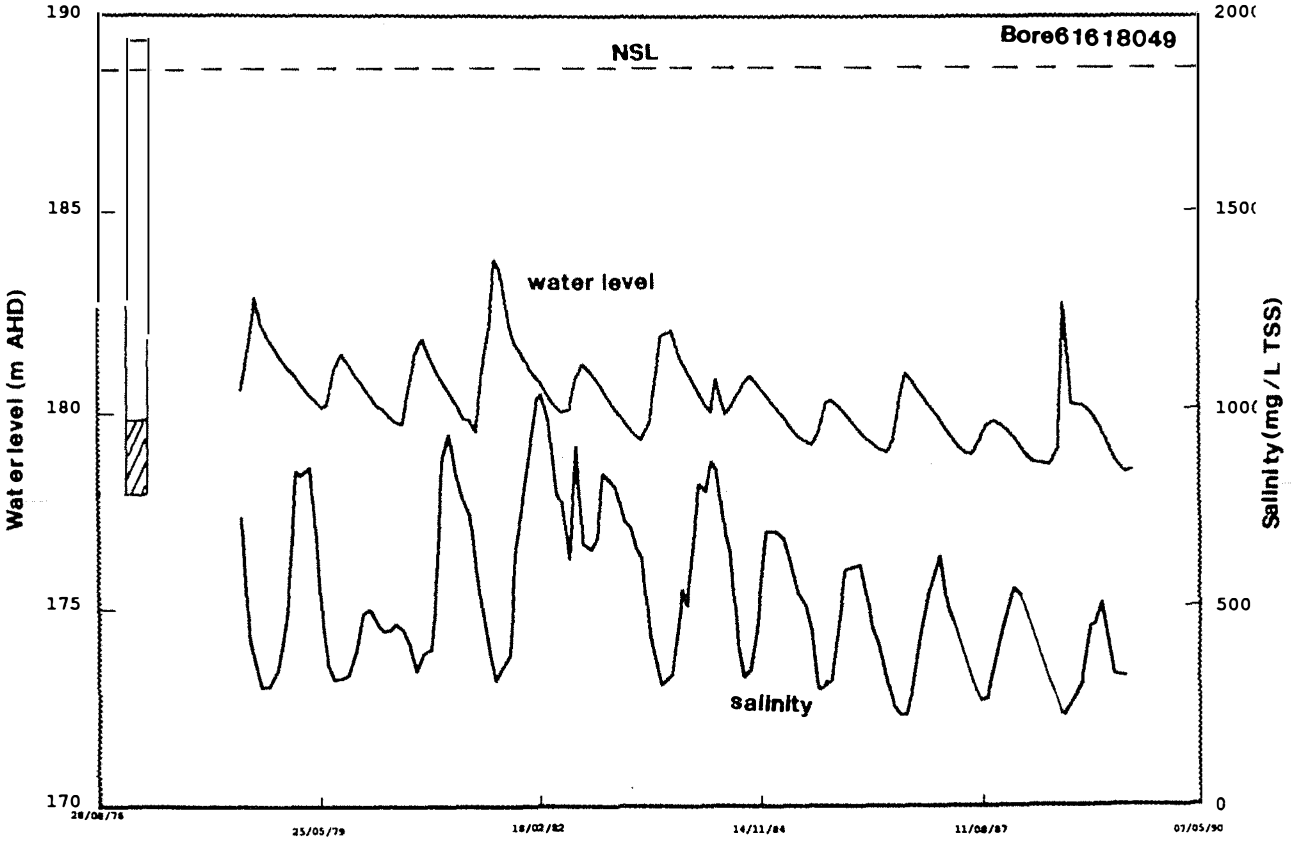

Bore61618043
NSL
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
185
180
175
170
165
100
800
600
400
200
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90


Bore61618044
NSL
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
Thousands
185
180
175
170
165
5
4
3
2
1
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90

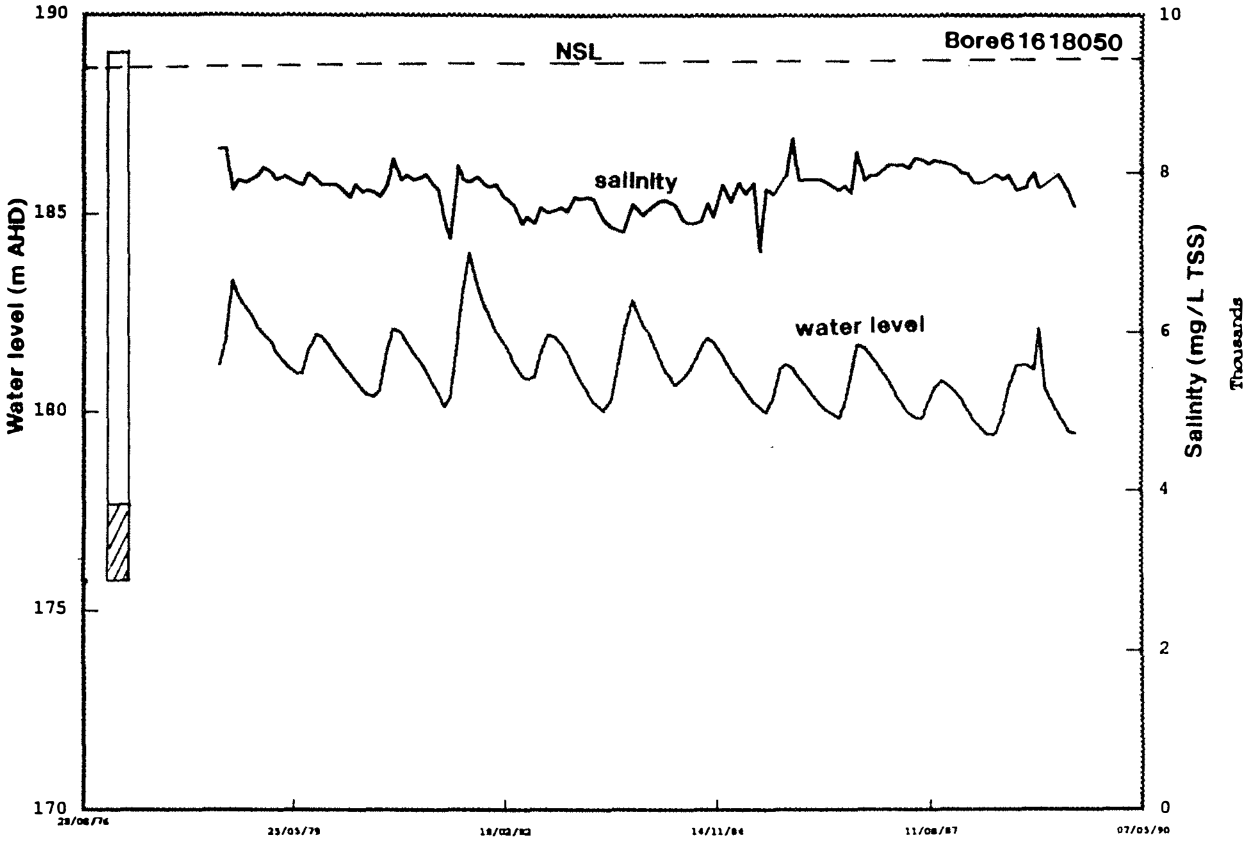

Bore61618045
NSL
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
Thousands
190
185
180
175
170
5
4
3
2
1
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90

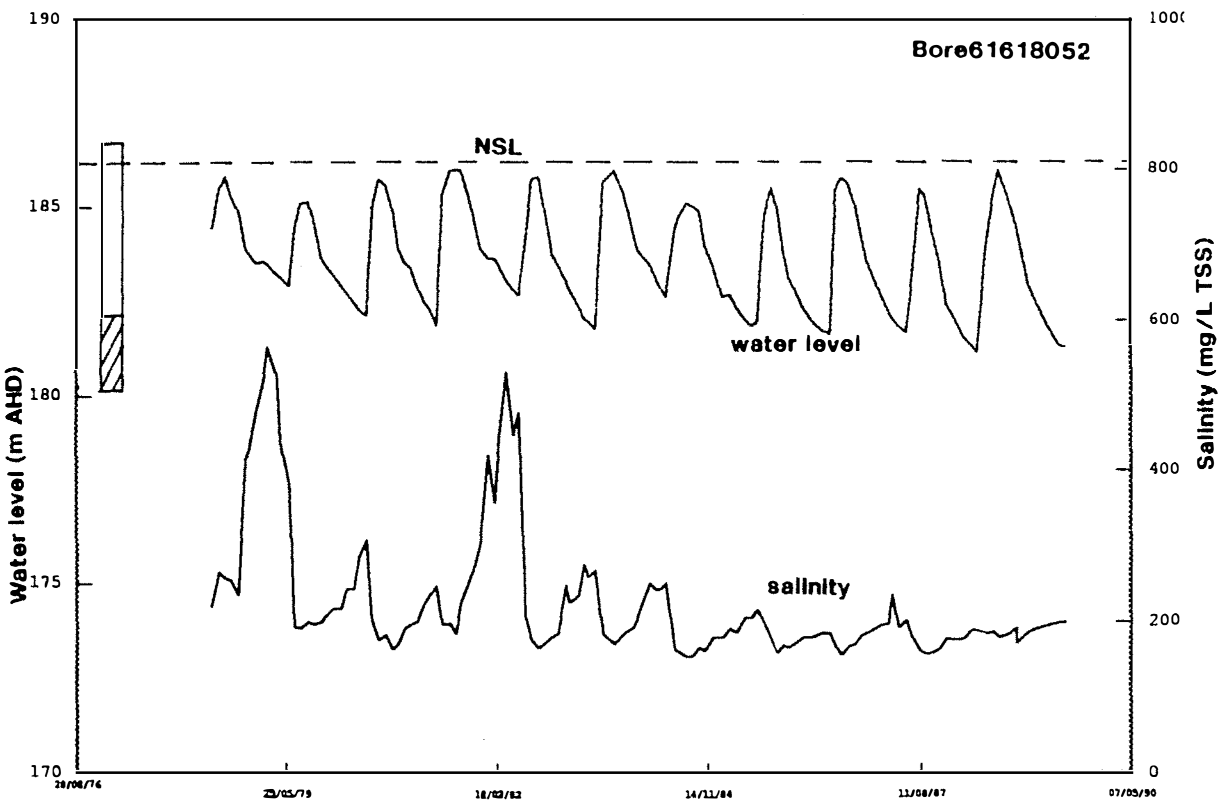


NSL
Bore61618046
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
185
180
175
170
165
1000
800
600
400
200
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90



NSL
Bore61618049
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
190
185
180
175
170
2000
1500
1000
500
0
28/08/76
25/05/79
18/02/82
14/11/84
11/08/87
07/05/90


Bore61618050
NSL
salinity
water level
Water level (m AHD)
Salinity (mg/L TSS)
Thousands
190
185
180
175
170
10
8
6
4
2
0
23/05/79
18/02/82
14/11/84
11/08/87
07/05/90


Bore61618052
NSL
water level
salinity
Water level (m AHD)
Salinity (mg/L TSS)
190
185
180
175
170
800
600
400
200
0
23/05/79
18/02/82
14/11/84
11/08/87
07/05/90