Water Authority
of Western Australia

WATER RESOURCES DIRECTORATE

Wellington Dam Catchment Regeneration

Report No. WS 16

March 1988

Wellington Dam Catchment Regeneration

by I. Loh and B. Anson

First published in "Itinerary and Notes for the AGM and Study Tour 1987" of the Australian National Committee on Irrigation and Drainage, October 1987

Report No. WS 16
March 1988

WELLINGTON RESERVOIR CATCHMENT REGENERATION

by I.C. Loh and B. Anson

1. INTRODUCTION

Wellington Reservoir has the largest water yield of any individual reservoir in the south-west of the state (approximately 100 x $10^6 m^3$). As such it is a major water resource in the region and the continued deterioration of its inflow salinity has necessitated an active programme of catchment management and rehabilitation. The catchment spans a rainfall range from over 1200 mm per annum in the west to 600 mm per annum in the east of the catchment. Clearing of the original Jarrah and Wandoo Forest in the 600 to 900 mm rainfall zone for agricultural development has resulted in major increases in stream salinity. This paper briefly summarises the history of stream salinity increases, and the catchment management measures introduced to minimise these increases.

2. EARLY CLEARING HISTORY AND SUBSEQUENT STREAM SALINITY INCREASES

Prior to agricultural development the salinity of the Collie River at Wellington Dam has been estimated to be between 200 and 250 mg/L. Agricultural development commenced at the turn of the century and expanded slowly over the following 30 years. No salinity problem was evident when the small irrigation dam was constructed in 1933. Growth in agricultural development virtually ceased through the depression years and it was not until the 1950's that agricultural development again expanded. To service increased demand for both irrigation on the coastal plain, and water supply in the wheatbelt towns of the Great Southern District, Wellington Dam was raised to its current height during the late 1950's.

The potential conflict between continued agricultural development and deterioration of salinity was appreciated as early as 1952.

Concern developed through the 1950's and was sufficient to convince the government not to release further land for agricultural development in 1961. However there was insufficient data to convince members of an interdepartmental community (Purity of Water Committee) that the more difficult step of controlling clearing on land privately owned was necessary.

Figures 1 and 2 show the yearly variations in salinity and inflow volume and the trend in the salinity of a median inflow year over the last 40 years.

In the early 1960's the stream salinity had only just begun to increase significantly. In 1962/63 the estimated average inflow salinity was about 360 mg/L. Yearly fluctuations of stream salinity were much higher than the then small annual increase in salinity of about 15 mg/L per year. The following two wet years (1963 and 1964) reduced reservoir salinities to the lowest level for over 15 years. No means of accounting for wet and dry years or for predicting the effect of further clearing on stream salinity was available at the time.

With the introduction of bulldozers in the late 1950's and 1960's land clearing accelerated and extended upslope from the valleys where most of the early clearing had occurred. The salinity deterioration consequently accelerated through the late 1960's and early 1970's. By 1972/73 average inflow salinity was about 540 mg/L and was increasing at 22 mg/L per year. In the dry year of 1972/73 the inflow salinity was 685 mg/L.

3. CLEARING CONTROLS AND THE EFFECT OF PAST CLEARING

By the mid 1970's the deterioration had become much more apparent. Sufficient data had now been collected to clearly link agricultural development to increased stream salinity. More particularly, means of predicting the effects of further clearing had developed.

Realising the seriousness of the then current salinity levels and recognising that the full effect of past clearing was not yet reflected in the inflow salinity at that time, the State Government introduced legislation to control further agricultural development in November, 1976. The Country Areas Water Supply Act was amended to prohibit unlicenced clearing on the catchment. While small scale essential clearing is licenced, large scale agricultural development is not permitted. Farmers affected can claim compensation for their inability to further develop their farm enterprise.

Application of the legislation has effectively held the level of clearing to 64 000 ha or 23% of the total catchment and has avoided the expansion of agriculture to a possible 100 000 ha or 35% of the total catchment.

Prediction at the time indicated that if the level of clearing was maintained at the 1976 level the salinity of inflow in a median year would ultimately reach about 1100 mg/L TSS. Subsequent detailed groundwater simulation studies have been carried out on subcatchments in the extreme eastern portion of the catchment which suggest that the original estimates are of the correct order. If the catchment as a whole is similar to the areas studied in detail, then salinities observed to date reflect about two-thirds of the full effect of past clearing. The ultimate salinity of a median inflow year could range from 1050 to 1250 mg/L but the best estimate is considered to be approximately 1150 mg/L TSS. The groundwater simulations indicate the salinity of inflow discharge will approach 1100 mg/L in about the year 2010 when 95% of the full effect of previous clearing should have developed. Ultimate equilibrium is approached slowly and should be achieved about 2040.

The estimated future inflow salinities resulting from past clearing are shown in Figure 3 for years of median inflow.

Most importantly, however, are the likely salinity levels in dry years. While dry year estimates are subject to considerable uncertainty, it has been estimated that for an annual inflow volume likely to be exceeded in 90% of years the inflow salinity in 2010 would be approximately 1800 mg/L, approaching 1880 mg/L TSS by 2040.

Figure 3 also shows the trend in salinities of median inflow years if the clearing control legislation had not been imposed and clearing had continued to its potential of 100 000 ha by 1990. Ultimate salinity in a year of median flow would have reached 1700 mg/L TSS, while in a dry year (90% probability of exceedance) salinity would have approached 3000 mg/L TSS.

4. REFORESTATION

4.1 Progress of the Programme

While the clearing control legislation has had a major effect in minimising further deterioration in reservoir salinity levels, estimates of the full effect of clearing current at the time of the legislation indicated the quality of both town water and irrigation supplies would eventually become unacceptable, particularly in dry years. In addition the deterioration would limit the future utility of the presently uncommitted yield from Wellington Reservoir. Consequently reforestation of cleared farmland in the drier, high salt-yielding parts of the catchment was commended in 1979/80.

The reforestation programme was initially proposed to run for six to ten years with an annual replanting target of 2000 ha. The actual planting rate achieved has varied between 700 and 800 ha per year, with a total of 5087ha having now been reforested (1987 inclusive). The areas planted have been concentrated in the eastern and south eastern portion of the catchment where the annual rainfall is usually less than 750 mm per annum. The reforestation strategy involved planting along the valley bottoms and lower side-slopes, the remaining mid- and upper slopes providing viable strips of cleared farmland which could then be exchanged for lower slope areas on adjacent farmland to further extend the area of reforestation.

By September 1984 sufficient land had been purchased to enable approximately 8000 ha to be planted. This programme is expected to exert control of salt discharges from 18500 hectares of the 51000 ha of cleared farmland in the highly salt susceptible zones of the catchment. At the current rate of 700 to 800 hectares per year the programme is expected to continue into the early 1990's.

4.2 Research Results

As large scale reforestation had not been carried out for salinity control purposes before, a significant monitoring and research programme was commenced in parallel with the planting programme. Both groundwater and surface water hydrologic responses to reforestation have been monitored. Specific research on tree species water use has been carried out and research on ways of improving the establishment of trees in saline seasonally waterlogged sites has commenced.

4.2.1 Groundwater Responses

Table 1 summarises the details of the sites at which groundwater responses beneath reforestation have been monitored. Differences at the sites include the portion of the landscape planted, the tree species used, the initial and current stem density, the local hydrogeological conditions and the original portion of the landscape cleared. Conditions range from fresh to highly saline sites and include a range of sites where between 6% and 90% of the upslope cleared land has been reforested.

The results have been prepared for two locations in Figures 4 and 5. Figure 4 shows the results from Flynn's farm, a farm in the Mundaring Weir Catchment but with similar rainfall and hydrogeological conditions to the Wellington Reservoir Catchment area where the reforestation is taking place. Figure 2 shows that water levels have reduced by about 2 metres since 1978 at a site (called the Hillslope site) where some 80% of the upslope landscape was planted at a high density of 1200 stems/ha. At the nearby agroforestry site where densities have been thinned to between 75 and 225 stems/hectare, but where the area replanted was about 90% of the upslope cleared land, similar reductions of about 1.8 metre have been observed. In contrast, at the landscape plantings where only 6% to 20% of the upslope cleared land was planted reductions of only about 0.4 metres were recorded.

Figure 5 shows the responses of three sites at Stenes Farm in the Wellington Reservoir Catchment. The largest reductions have again occurred at the site where the largest area planting has taken place (Arboretum site). This site was chosen to test the suitability of a wide variety of Eucalypts for planting in the Wellington Reservoir Catchment. Of the 70 species planted, most successfully established although some repeatedly failed. Overall about 80% of the area has been successfully planted. Average reductions of about 3 metres have been recorded. Significant reductions of about 1 metre have been recorded at the valley planting site where about 31% of the upslope area has been planted. The agroforestry site where current tree densities range between 150 and 900 stems/hectare and cover between 40% and 60% of the upslope cleared land, reductions of about 0.6 metre since 1981 have been recorded. Significant increases in the groundwater level beneath the adjacent pasture is also evident at the Stenes Farm locality.

Figures 6 and 7 show typical cross-sections at the valley plantings and arboretum sites. Figure 8 shows the overall relationship between percentage replanted and reduction in water table level.

The obvious implication is that the larger the area planted the larger the reduction in groundwater level. More importantly, however, is the observation that valley plantings (at about 30% of the landscape) can lower water table significantly near drainage lines when levels beneath the adjacent upslope pasture continue to rise (see Figure 6).

4.2.2 Tree Water Usage Research

In an effort to more directly compare the water use characteristics of specific species, detailed studies of leaf conductance were undertaken at the Stenes Arboretum site. This involved the measurement of the transpiration rate of individual leaves throughout the canopies of some 20 species. The study enabled the selection of species with the ability to continue to transpire into the late summer-autumn period when shallow soils are dry and the trees can only extract water in the deeper groundwater system. E. microcarpa, E. woollsiana (Grey Box), E. sideroxylon (Red Ironbark), and E. botryoides (Southern Mahogany) have been found to possess this ability. Variations in local site conditions are also important in affecting both growth performance and water use characteristics.

Nevertheless, those four eucalypt species performed better than some of the conventionally selected salt tolerant species such as E. camaldulensis (Red River Gum) at mild to moderately salt affected sites.

The better transpiring species are being progressively introduced into the operational planting programme and can be expected to improve its effectiveness over the next few years.

4.2.3 Tree Establishment Research

While there is now strong evidence to suggest that we can reduce groundwater tables adjacent to saline discharge areas and where groundwaters are not yet actively discharging at the soil surface, problems of controlling groundwater discharge over broad saline flats where strong vertical groundwater gradients exist is still to be resolved.

In these areas groundwater flow theory would indicate that active lowering of the watertable across the saline flat is required. This necessitates the successful establishment of high transpiring, highly salt tolerant species on extremely harsh sites.

Research into tree establishment techniques commenced recently. One study is to improve the design of ridge mounds which have been formed in the soil to reduce waterlogging in the seedling root zone. Initial indications are that increasing mound height increases tree establishment and that a double ridge mound with the seedlings planted in the depression between the ridges is better than the traditional single ridge mound. It appears that single ridge mounds tend to shed water so that salts accumulate in the seedling root zone over summer as soil water evaporates. In contrast the double ridge design facilitates rainfall percolation, and therefore salt leaching, from the soil in the seedling root zone. Other studies are to evaluate the use of drainage, mulching and various seedling containers and to find the best fertilizer regime, planting time and species to plant.

4.3 Current Knowledge and Uncertainties

We now have sound evidence that trees can lower highly saline water tables. To obtain significant reductions in level, however, about 30% or more of the landscape should be planted. The higher the proportion planted the larger the reduction in groundwater.

Tree water usage studies have identified species with better transpiration characteristics than those originally planted and those conventionally considered as suitable species for planting along saline water courses. Improved reductions in groundwater levels can therefore be expected as these species are incorporated in the operational plantings.

Initial work on improving the establishment of seedlings on harsh sites is encouraging but work is at a very early stage. Many more years of observation and measurement will be required. It is too early to expect evidence of changes in stream salinity as a result of reforestation as these responses are highly variable and strongly dependent on the distribution of rainfall each winter.

The major uncertainties still relate to controlling groundwater discharge from broad saline flats with strong vertical gradients of groundwater.

5. EXPECTED SALINITY IMPROVEMENTS

With the current planting rate and present knowledge of groundwater responses to reforestation, inflow salinities to Wellington Reservoir are not expected to reduce until the mid to late 1990's. Figure 7 shows the estimated effect of the current reforestation programme on inflow salinities in a year of median inflow. A range of levels in controlling saline discharge have been assumed to reflect or current uncertainty about the long term effectiveness of reforestation. If the programme is moderately effective (reducing groundwater discharge by 70%) then average inflow salinities are likely to peak in the early to mid 1990's and return to figures of about 950 mg/L by the year 2010. This would represent a deterioration of a further 50 to 60 mg/L over the current estimated average inflow salinity (1987). Much higher salinities will occur in drought years.

FUTURE DIRECTIONS FOR CATCHMENT MANAGEMENT

Efforts to date in reforestation research and management have concentrated on controlling the saline discharge zone. While this is considered highly necessary and was the appropriate initial priority, there is a need to evaluate means of reducing upslope recharge in a cost effective manner. As the cost of acquiring further upslope land is expensive, strategies which are both cost effective to the individual landowner and will minimise recharge must be developed. Only if they are financially attractive will they be likely to be implemented by the landowner, and only then can the secondary salinity benefit be obtained.

Results from the agroforestry pine planting sites suggest that reduction in groundwater levels are possible with only moderate densities (100 to 200 stems/ha). The concept of fast growing Eucalypt plantations of short rotation (10 years or less) to produce woodchips also appears attractive and is likely to have value in minimising recharge.

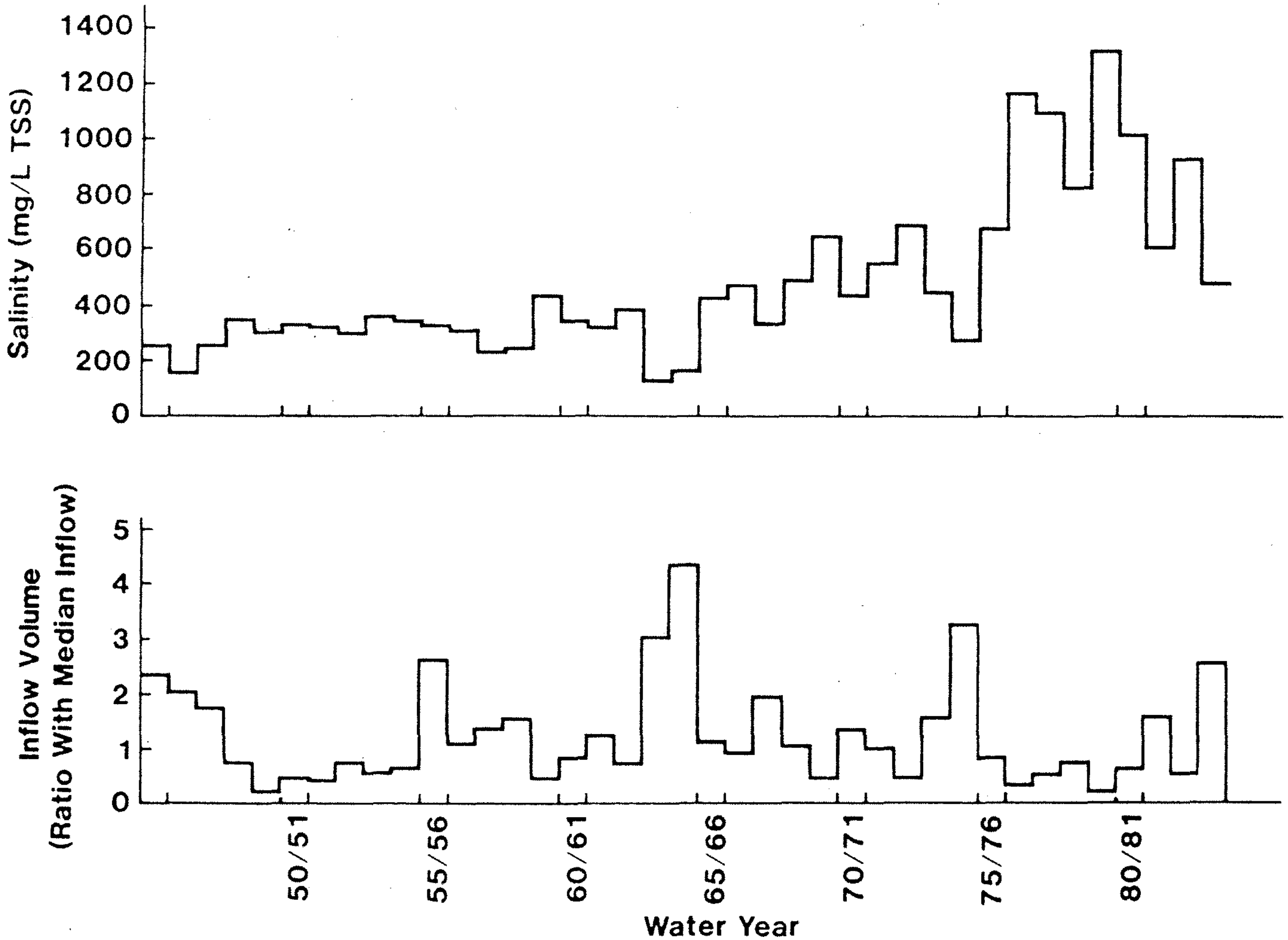
Improved agronomic techniques for consuming more water and increasing the agricultural production is also a means of minimising groundwater.

Active research on the water use of all three approaches is required.

1021W

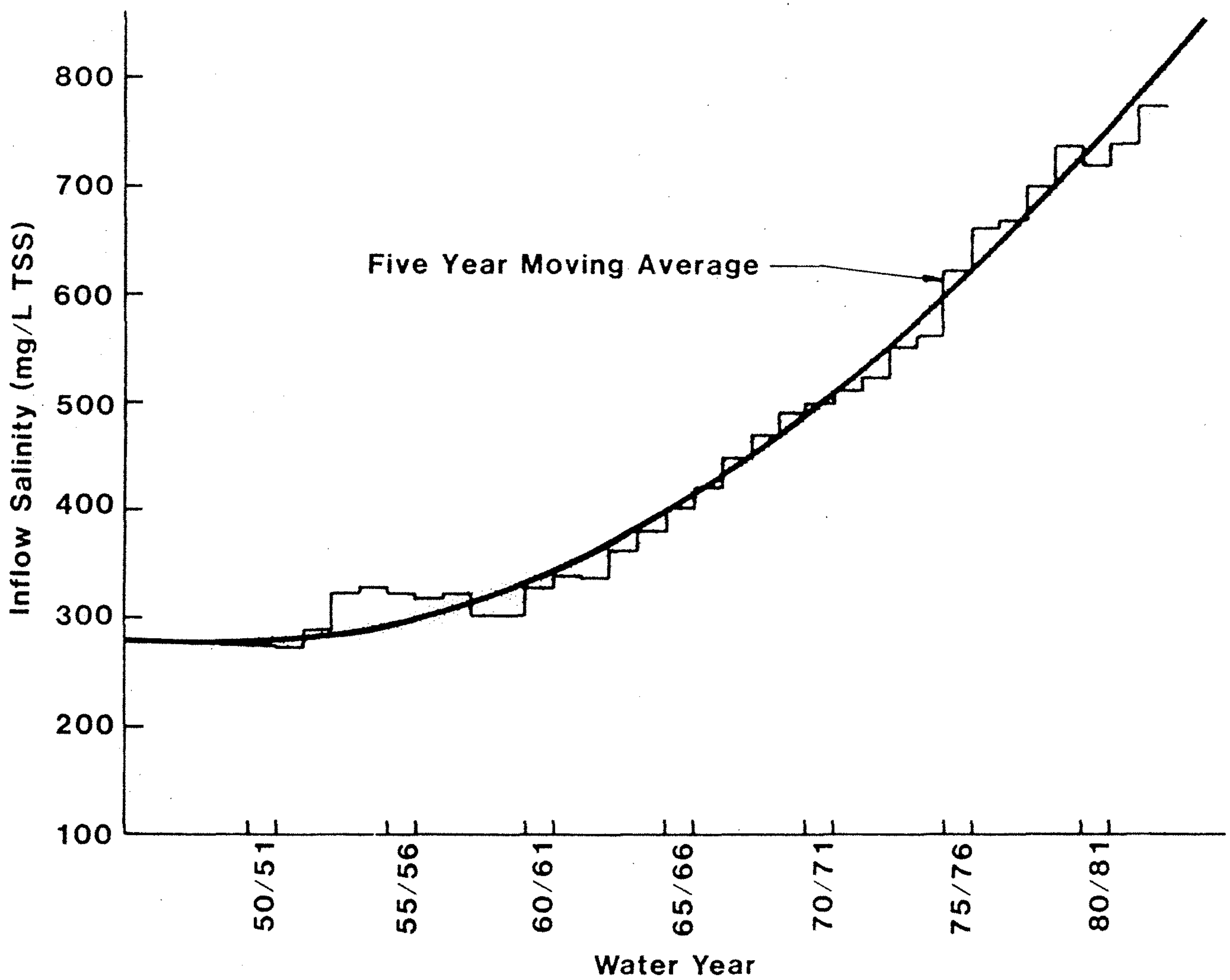
TABLE 1 - SUMMARY OF STUDY SITES

LOCATION	PLANTING YEAR	PORTION PLANTED	ANNUAL RAINFALL	PLANTING DENSITY (stems/ha)		MAIN SPECIES	PORTION OF HILLSLOPE CLEARED	SALINE GROUNDWATER DISCHARGE	WEATHERING DEPTH	NO. OF GROUNDWATER MONITORING BORES BENEATH		
			mm	Initial Planting	As at 1986		Prior to Reforestation			Reforestation	Pasture	Adjacent Forest
<u>Flynns Farm</u>												
Hillslope Plantings	1978	80%	700	1200	1000	E camaldulensis E wandoo	100%	Yes	5 to 20 metres	8	5	0
Landscape Plantings	1978	6% to 20%	700	667	600	E wandoo E camaldulensis P Pinaster P radiata	80%	Yes	2 to 20 metres	14	5	0
Agroforestry Plantings	1975	~90%	700	380-1140	75-225	P radiata E camaldulensis	~30%	No	3 to 13 metres	10	2	0
<u>Stenes Farm</u>												
Valley Plantings	1979	31%	750	625	600	E Wandoo E rudis	~30%	No	20 metres plus	7	2	5
Arboretum	1979	80%	750	833	Variable	70 species	~30%	Yes	20 metres plus	23	0	5
Agroforestry Site	1978	40% - 60%	750	900	150-900	E wandoo E camaldulensis	~30%	Yes	20 metres plus	8	0	0
<u>Maringee Farms</u>												
Experimental Catchment	1981/ 1982	18% - 34%	650	925	~200	E wandoo E camaldulensis	100%	Yes	20 metres plus	16	4	0
<u>Balingup</u>												
Experimental Catchment	1977/ 1980	80%	900	1100-1330	500-700	P radiata E globulus	88%	Yes	unknown			



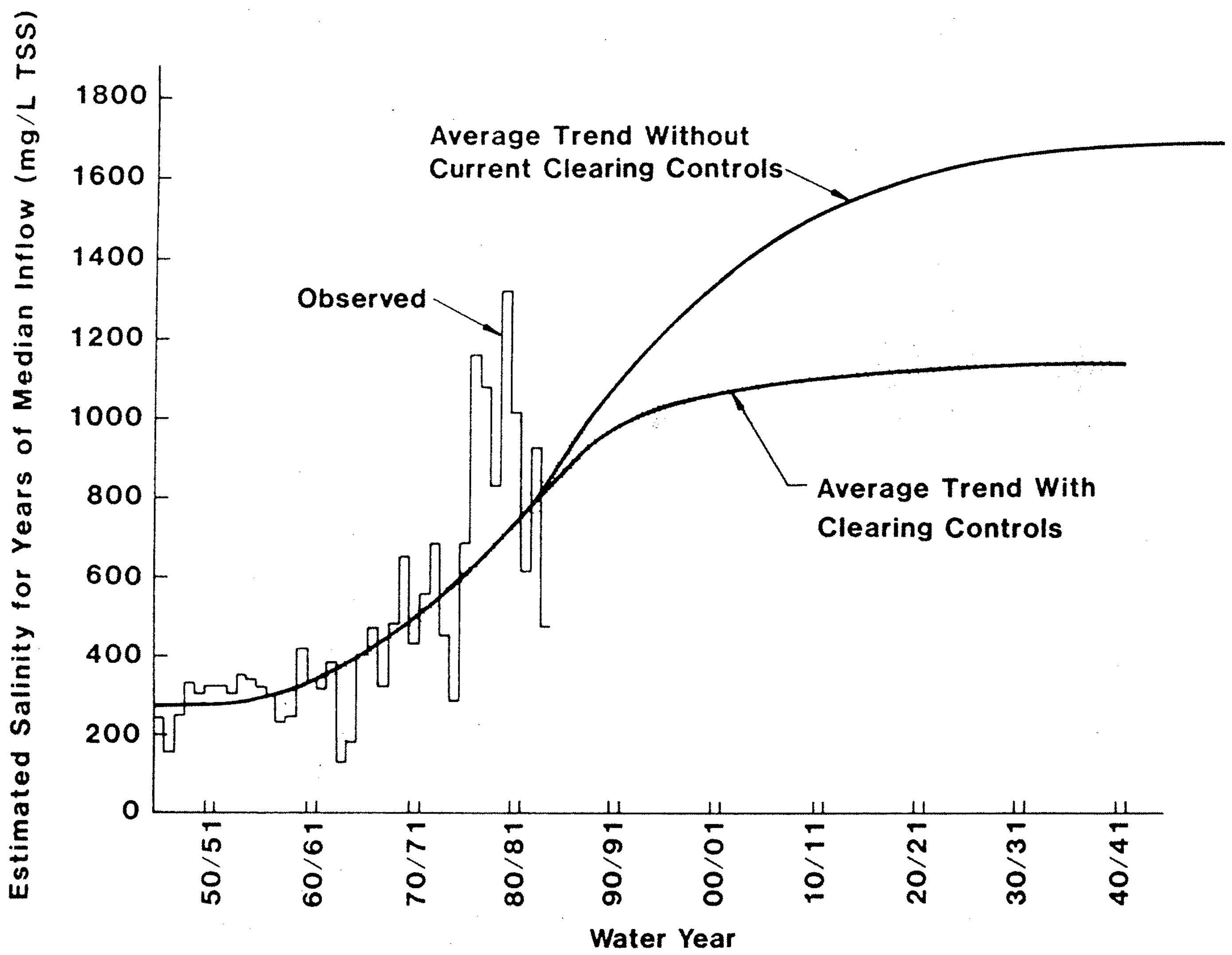
Inflow Salinities And Flow Volumes To Wellington Reservoir

Figure 1



Average Inflow Salinity To Wellington Reservoir

Figure 2



Observed And Projected Inflow Salinities To Wellington Reservoir

Figure 3

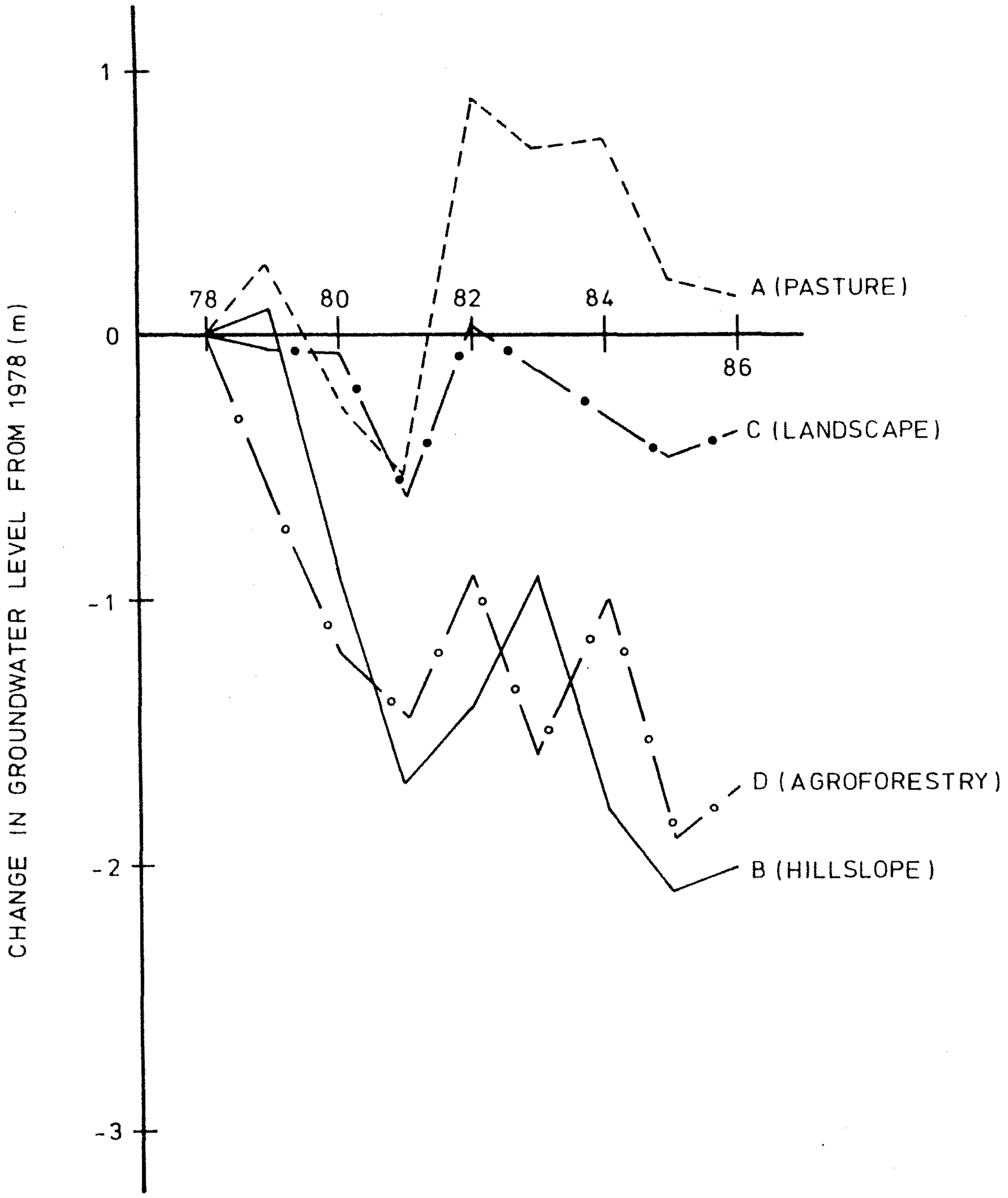


FIG. 4 GENERAL TREND IN WATER LEVEL CHANGE (FLYNN'S FARM)

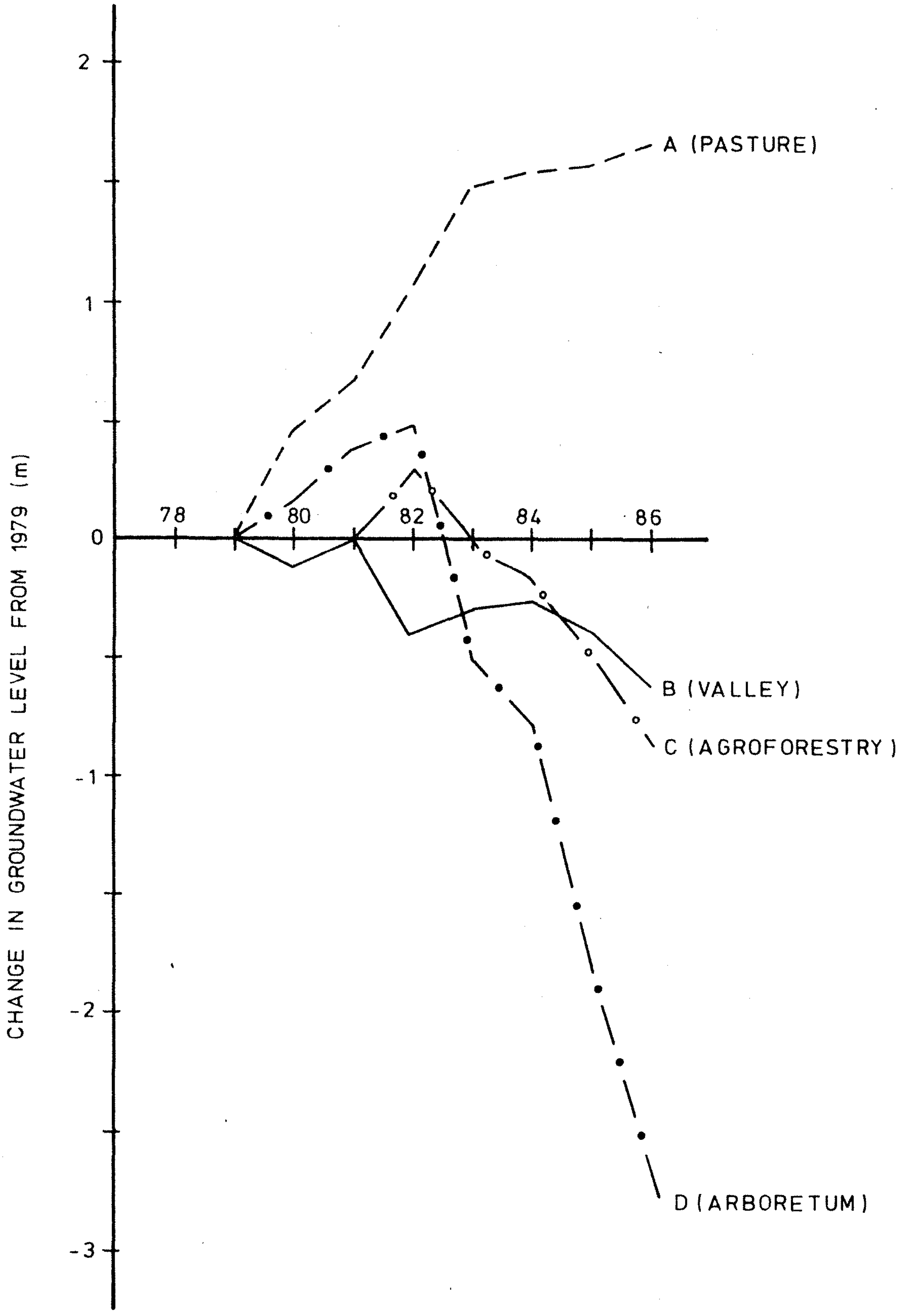


FIG. 5 GENERAL TREND IN WATER LEVEL CHANGE (STENES)

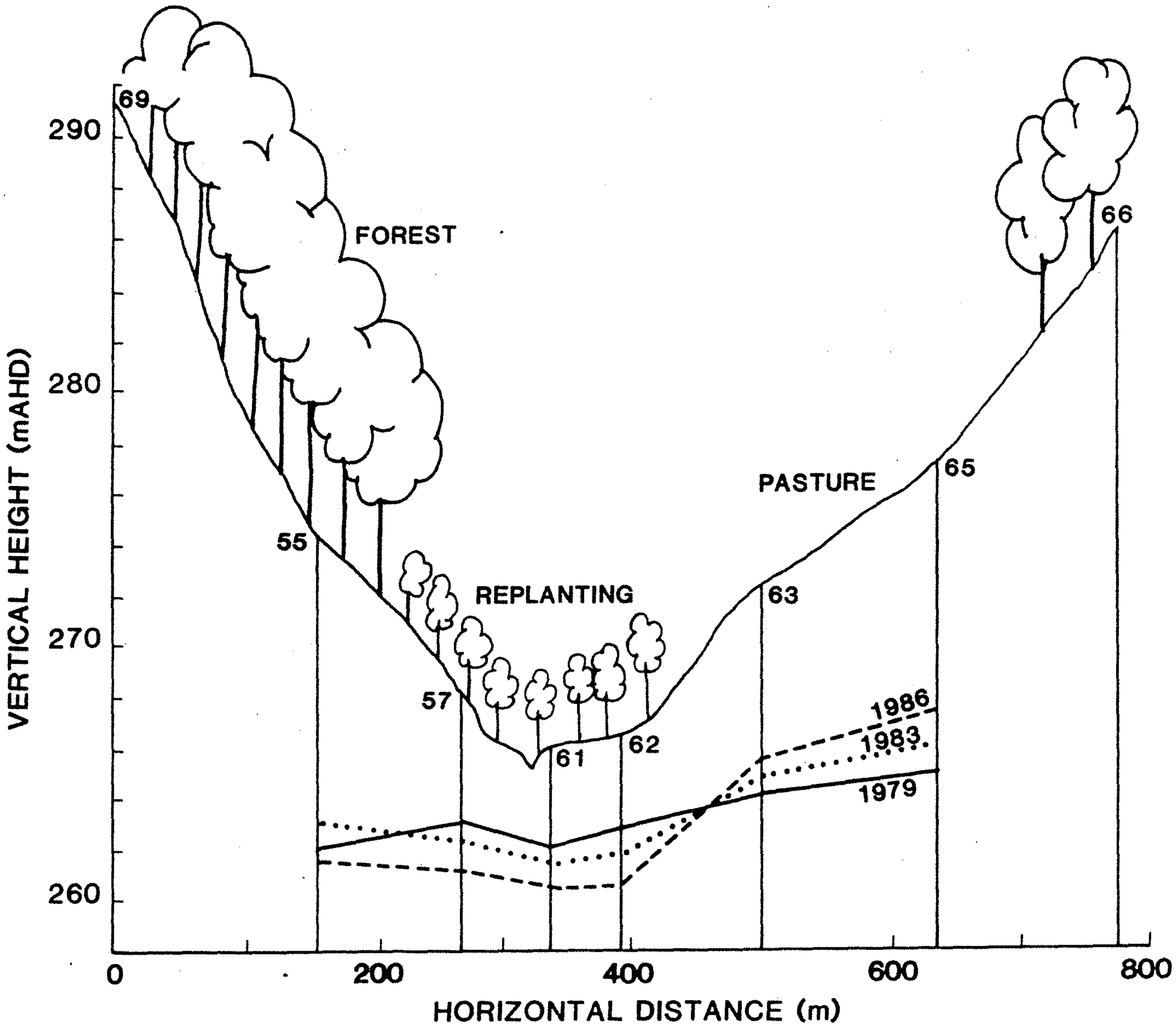


Fig 6 GROUNDWATER PROFILE,STENE'S VALLEY PLANTING

FIG. 6

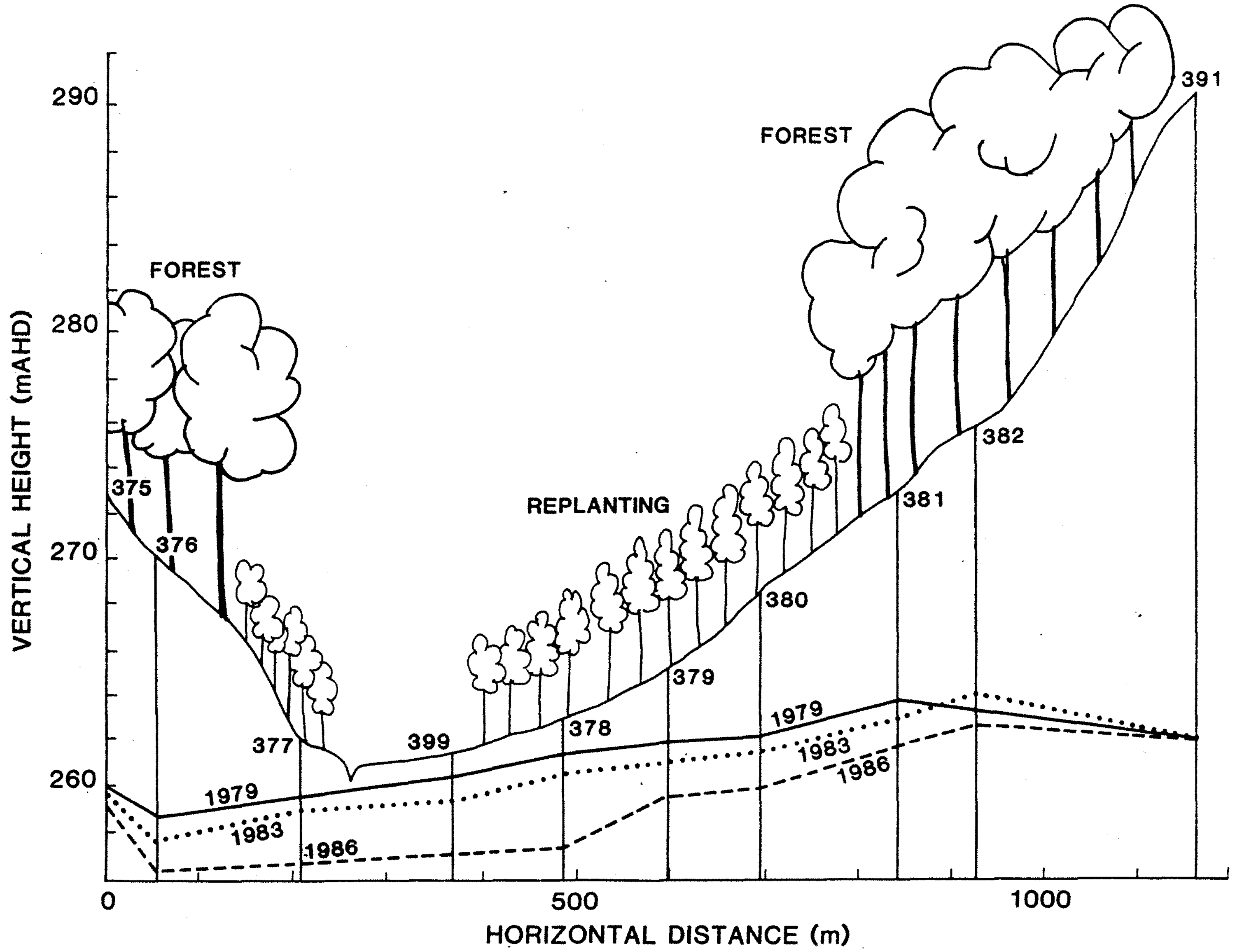


Fig 7 GROUNDWATER PROFILE,STENE'S ARBORETUM

FIG. 7

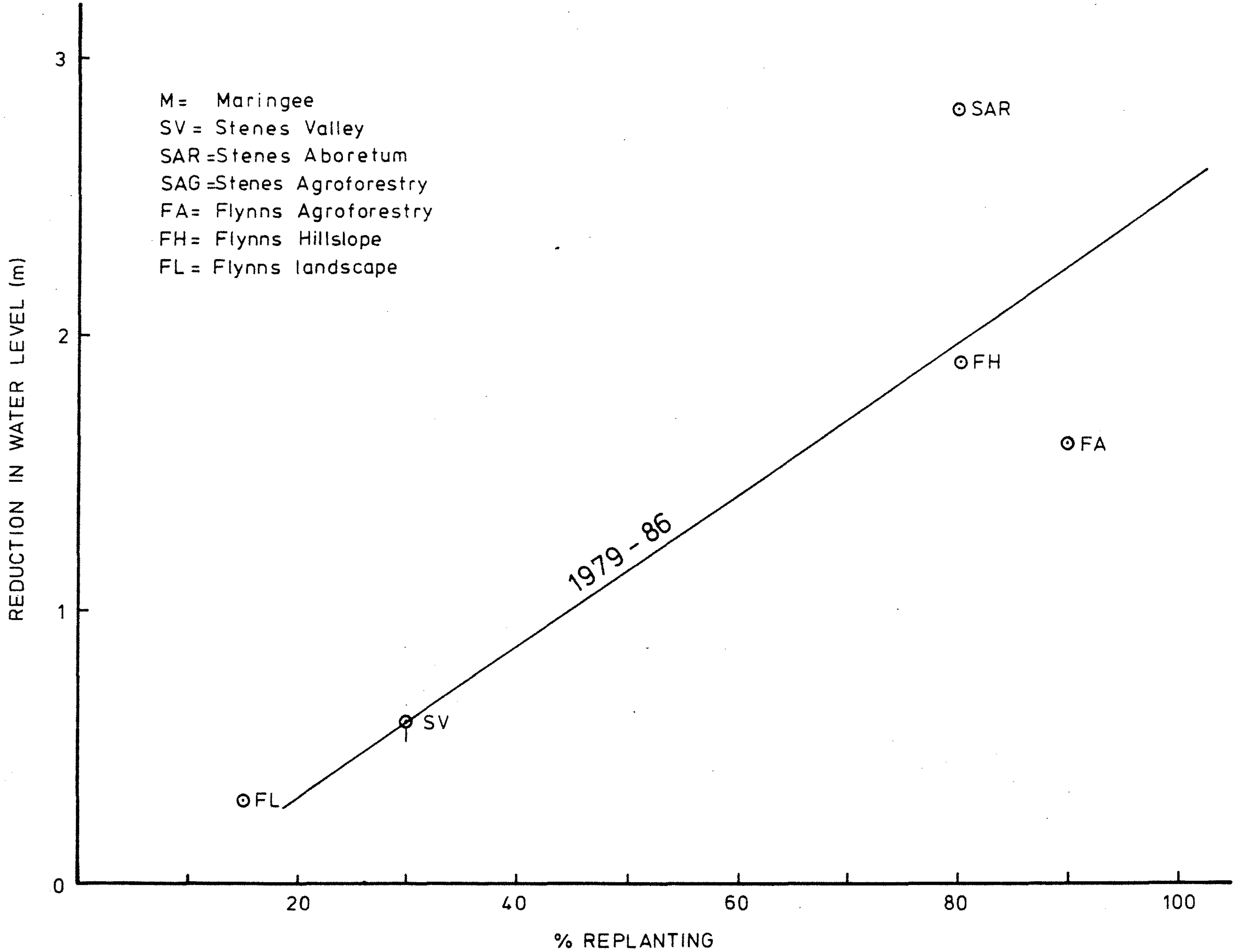
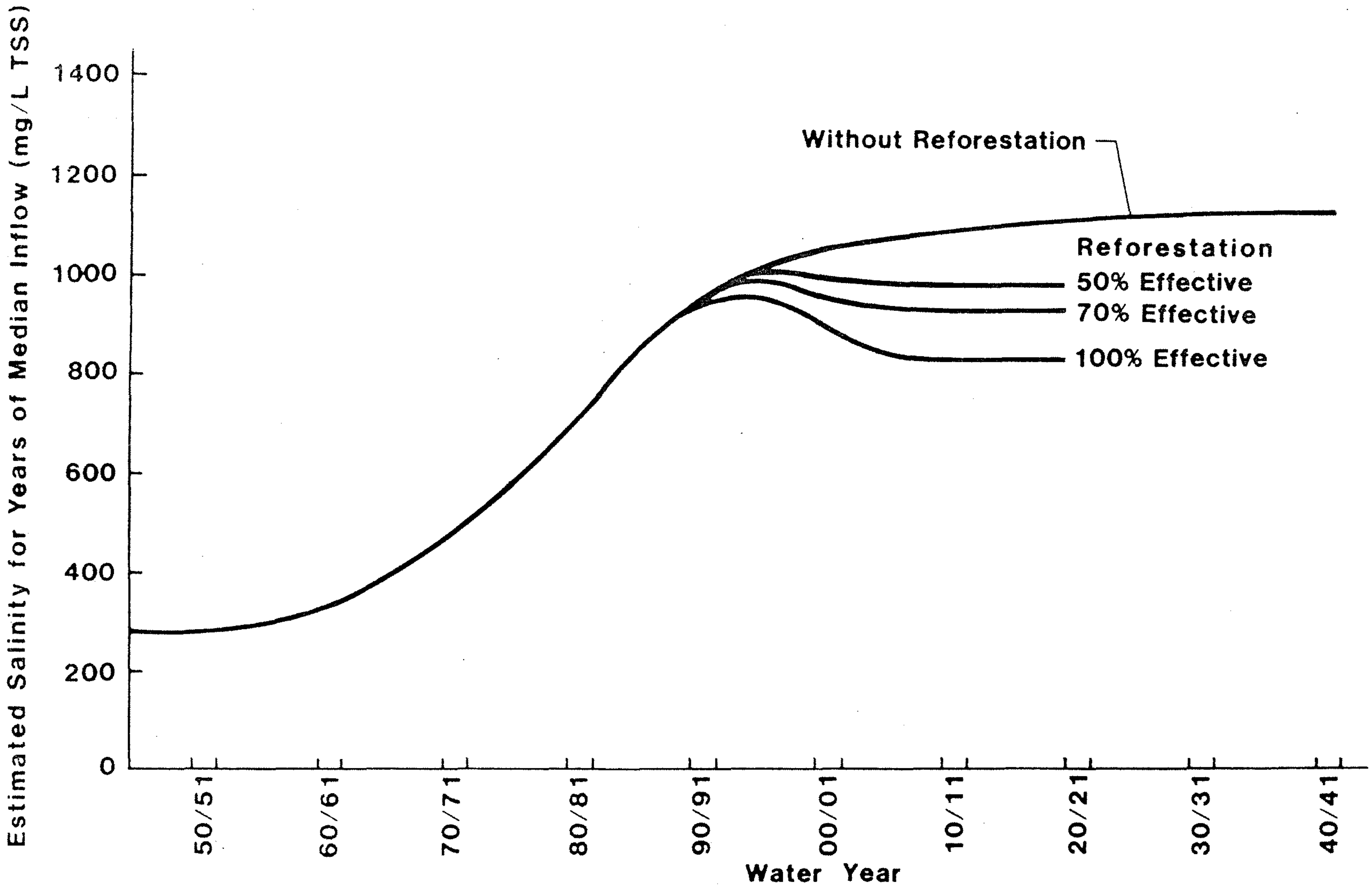


FIG. 8 EFFECT OF REPLANTING AREA ON WATER LEVEL

FIG. 8



Effect Of Current Reforestation Programme On Average Inflow Salinities

Figure 9