Water Authority
of Western Australia

WATER RESOURCES DIRECTORATE

SURFACE WATER BRANCH

GROUNDWATER RESPONSE TO REFORESTATION IN THE DARLING RANGE OF WESTERN AUSTRALIA

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SUMMARY

Increased stream salinities in the south-west of Western Australia following agricultural development are due to the replacement of deep-rooted native forest with annual agricultural crops and pastures. This change in vegetation results in reduced evapotranspiration rates and therefore increased groundwater recharge rates. Consequently, groundwater tables rise and gradually transport soluble salts, previously stored in the soil profile, to the surface stream system. An active programme of research and investigation of reforestation as a measure to reverse this trend commenced in the mid to late 1970s. The objective of the reforestation is to reduce groundwater levels and hence ultimately control salt discharge to streams.

This report reviews the groundwater response, during the period 1978-86, to reforestation at eight experimental sites located in the 600 to 900 mm annual rainfall zone of the Darling Range. In this region groundwater discharge and consequent high stream salinity has had the greatest impact on water resources. The majority of the reforestation took place at the sites between 1976 and 1982, and ranged in area from about 13% to 85% of the locally cleared land. The density of planting ranged from that characteristic of a wide-spaced agroforestry to a commercial plantation (crown covers in December 1987 of 14-25% and 29-47% respectively). The location of the reforestation in the landscape for all sites was close to saline seeps and streams, and extended upslope to varying degrees.

Although rainfall was less than average during the study period, groundwater levels under pasture are still rising at most sites as a result of previous clearing. In areas under the influence of reforestation, the average changes in the minimum water table ranged from a slight increase to reductions of 2.5 metres over the period 1979-1986. The greatly varying

responses of the experimental sites can be largely explained by the extent of their reforestation. In fact a close correlation was found between the change in groundwater level and site crown cover (defined as the product of the reforestation crown cover and the proportion of the cleared land that was reforested). Based on this regression it was found that planting less than 15% of the cleared land, at any density, did not significantly reduce groundwater levels, while planting 40% at a high density (tree crown cover of about 40% after 8 years) would produce a reduction in groundwater level of over one metre in a seven year period. Within the range of forest densities observed in this study, a further increase in site crown cover would produce a proportionately larger reduction in groundwater level.

The correlation between change in groundwater level and site crown cover implies that both the stem density of the trees at planting (and subsequent crown cover) and the percentage of the cleared landscape that is reforested are important in contributing to lowering the water table. Therefore, for a given area of reforestation, high density plantations are more effective than wide-spaced agroforestry plantations at lowering groundwaters. However, this does not necessarily imply that agroforestry strategies should not be actively considered for large scale catchment rehabilitation. Significant reductions in groundwater levels beneath agroforestry stands have been recorded. The economic attractiveness and the possible higher acceptance by the farming community of agroforestry practice, in comparison with high density plantations, make this an important option for stream salinity reclamation.

It should be noted that due to insufficient data, the influence of the species planted on lowering the water table has not been evaluated in this report. It is highly probable that some tree types have a greater effect on lowering the water table than others and thus species selection of trees, at both the species and provinance levels, is also important.

There is a trend for the groundwater salinities, corresponding to the minimum groundwater levels, to decrease in the later years of this study. This has been most noticeable at the sites where the greatest water table reductions have occurred. The most liklely explanation for this is that the general lowering of the water table at these sites has enabled fresh rainwater to recharge the groundwater system and thus is reflected in the water samples that have been taken.

The most effective location for reforestation in the landscape for controlling saline groundwater discharge within the first 10 years of planting is substantial valley and lower slope reforestation. Based on the results of this study, planting 40% of the cleared landscape with suitable eucalypts at a high stem density should lower the water table in the vicinity of the stream or seep so that groundwaters do not discharge to the stream. This strategy leaves a large proportion of the landscape available for agricultural use.

There is concern that the reforestation strategy of planting in the valley areas, where upslope recharge is continuing, will lead to a mass transport of salts from the recharging upslope areas to the valley floors. This may result in an accumulation of salt in the root zone of the valley reforestation and subsequently threaten its long-term survival. This can be best avoided in two ways. Firstly by selecting appropriate species with the ability to continue to transpire water in such harsh saline conditions. Secondly by economically minimising groundwater recharge in upslope areas by either commercial tree plantations, agroforestry or modified agricultural practice. Upslope recharge control limits the quantity of salt that may be transported to the valley and aids in stabilising the water table in the valley at a depth lower than would occur without upslope recharge control.

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1. INTRODUCTION

The impact of land clearing for agriculture on the surface water resources of the south-west of Western Australia has been dramatic. Prior to agricultural development, virtually all the divertible surface water resources were believed to be fresh (Loh, 1985). Recent updating of the water resource inventory (Western Australian Water Resources Council, 1986) indicates that only 48% remain fresh (less than 500 mg/L TSS) and 36% have become so saline that they are no longer potable (greater than 1,000 mg/L TSS). The remaining 16% are of marginal quality and require active catchment management to protect their quality from further deterioration in the long term.

Legislation was introduced in 1976 to control further large-scale agricultural development on the Collie River catchment. This legislation was extended in 1978 to apply to four other highly valued marginal water resource catchments (Denmark, Kent, Mundaring and Warren). It was recognised at the time, however, that strategies to actively rehabilitate catchments may also be necessary to maintain these catchments as potable water supplies in the future.

It is generally accepted that the deterioration of water quality in terms of increasing stream salinity is due to the removal of native forest and woodland vegetation for planting annual agricultural crops and pastures. The removal of deep-rooted vegetation causes a reduction in evaporation rates and therefore an increase in groundwater recharge rates. Consequently, groundwater tables rise and transport soluble salts, previously stored in the soil profile, to the surface stream system. Active rehabilitation of salt-affected catchments thus mainly involves strategic planting of deep-rooted trees to control and, in time, reverse the current trend of rising groundwater level.

To this end, a number of experimental sites were established from 1976 onwards to study the response of local groundwater systems under different tree planting strategies. While the individual sites were established with slightly different objectives, taken as a group they represent areas of reforestation that range from about 13% to 85% of the locally cleared land. The intention generally was to reduce groundwater levels in the vicinity of streamlines and thereby reduce the contribution of salt to the surface stream system. Consequently all sites had plantings close to the streamlines, or saline seeps, and also extended upslope to varying degrees.

A wide range of forest densities have resulted. This generally is a consequence of initial planting densities, early survival and subsequent growth. In some other cases plantations were thinned to the low densities of wide-spaced agroforestry stands.

This report reviews the results of tree planting at the main study sites on Mundaring and Collie catchments. The main emphasis is on the response of the groundwater system under different planting strategies. Various types of information have been used in the analysis, including bore water level, crown cover and groundwater salinity data. Since this report is one of the periodic reviews of the reforestation studies (Anderson et al., 1982; Edgeloe and Loh, 1984), updated information on the monitoring bore network, processed data of crown cover, minimum ground water level and corresponding groundwater salinity is also included in the Appendices for future reference.

2. DESCRIPTION OF THE EXPERIMENTAL SITES

The region where control of groundwater discharge is most important to the Water Authority of Western Australia is in the 600 to 900 mm annual rainfall zone of the Darling Range. Typical areas of clearing for agricultural purposes in this zone in the eastern portion of Wellington and Mundaring Reservoir catchments were selected for the initial studies of catchment rehabilitation by reforestation (Figure 1). The studies were developed as joint projects between the then Forests Department (now the Department of Conservation and Land Management - CALM), CSIRO - Division of Land Resources Management (now CSIRO - Division of Water Resources) and the then Public Works Department (now Water Authority of Western Australia). Other similar sites have also been established by CSIRO and the Department of Agriculture, but are not reported here.

Table 1 summarises the planting details and hydrogeological conditions at the reforestation sites.

2.1 Flynn's Farm

Flynn's farm was an old established farm on Mundaring catchment and has a long term average annual rainfall of 725 mm. It was repurchased by the Government in 1960. The farm had a long history of clearing and pasture development, mainly of the lower and middle slopes. In 1976 a wide range of planting strategies were proposed with the aims of simultaneously assessing tree, pasture and livestock performance, and measuring groundwater responses and salinity changes. In 1977 and 1978 three experimental sites were established. Figure 2 shows the relative locations of the three major planting strategies at the farm.

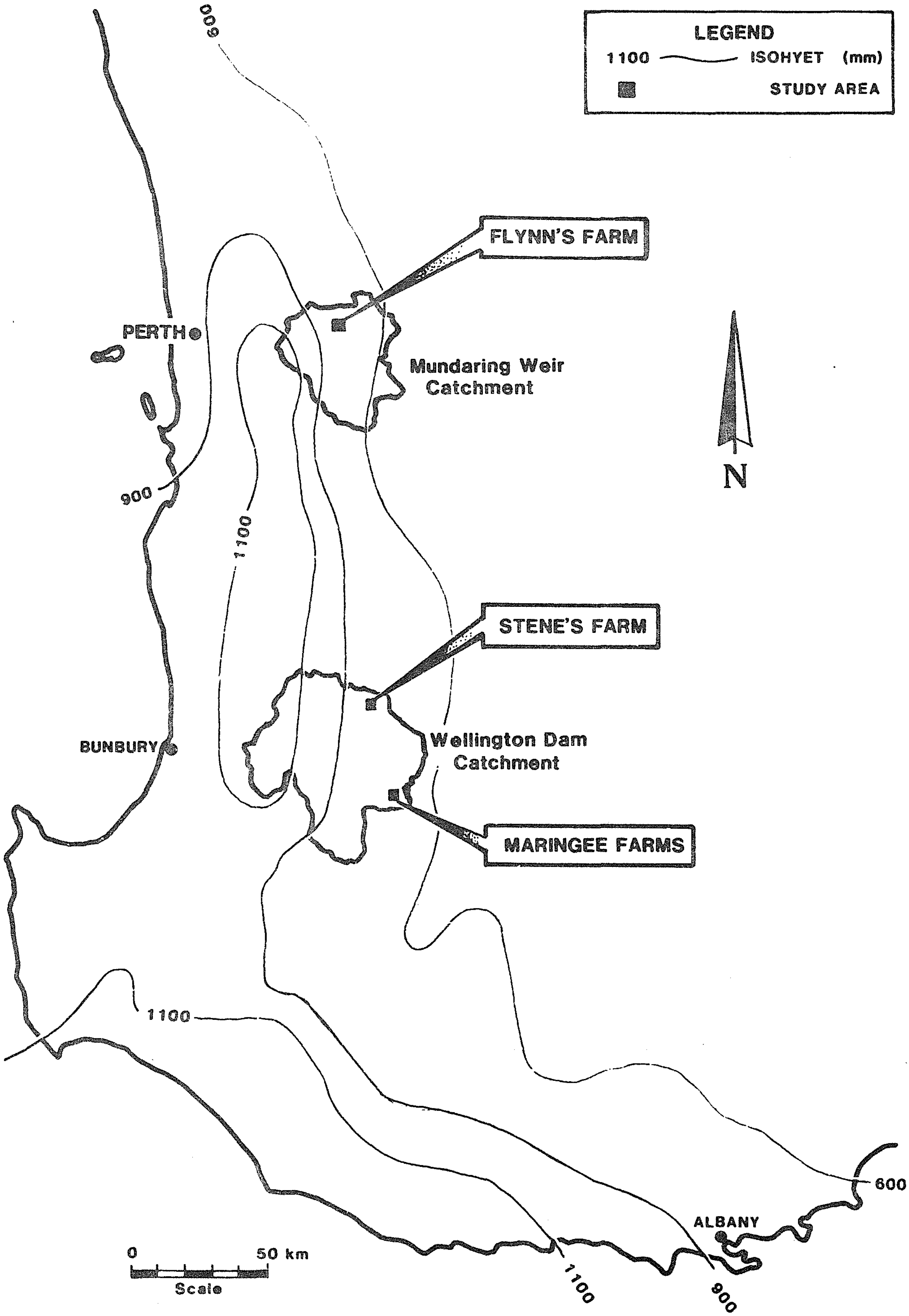

Figure 1. Location of the Study Areas

Table 1 - Summary of Study Sites

LOCATION	PLANTING YEAR	PORTION PLANTED (1)	AVERAGE ANNUAL RAINFALL mm	STEM DENSITY (stems/ha) Initial Planting	STEM DENSITY (stems/ha) As at 1986	MAIN SPECIES	PORTION OF HILLSLOPE CLEARED (2)	GROUNDWATER DISCHARGE (3)	WEATHERING DEPTH	NO. OF GROUNDWATER MONITORING BORES BENEATH Reforestation	Pasture	Adjacent Forest
<u>Flynns Farm</u>												
Hillslope	1978	70%	725	1200	1000	E. camaldulensis E. wandoo	100%	Yes	5 to 20 metres	8	0	0
Landscape	1977	13%	725	667	600	E. wandoo E. camaldulensis P. pinaster P. radiata	100%	Yes	2 to 20 metres	20	6	0
Agroforestry	1978	85%	725	380-1140	75-225	P. radiata E. camaldulensis	30%	No	3 to 13 metres	10	2	0
<u>Stenes Farm</u>												
Strip Plantings	1976/ 1978	13%	725	1250	850	P. radiata P. pinaster E. globulus E. camaldulensis + others	30%	Yes	20 metres plus	27	12	10
Valley Plantings	1979	30%	725	625	600	E. wandoo E. rudis	30%	No	20 metres plus	8	3	9
Agroforestry	1978	50%	725	900	150-900	E. wandoo E. camaldulensis	30%	Yes	20 metres plus	16	0	0
Arboretum	1979	70%	725	833	Variable	70 species	30%	Yes	20 metres plus	23	0	8
<u>Maringee Farms</u>												
Experimental Catchment	1981/ 1982	28%	650	925	200	E. wandoo E. camaldulensis	100%	Yes	20 metres plus	74	15	0

Notes : (1) Proportion planted of the cleared landscape

(2) Prior to reforestation

(3) Groundwater discharge was present at the time of planting and in all cases was brackish or saline

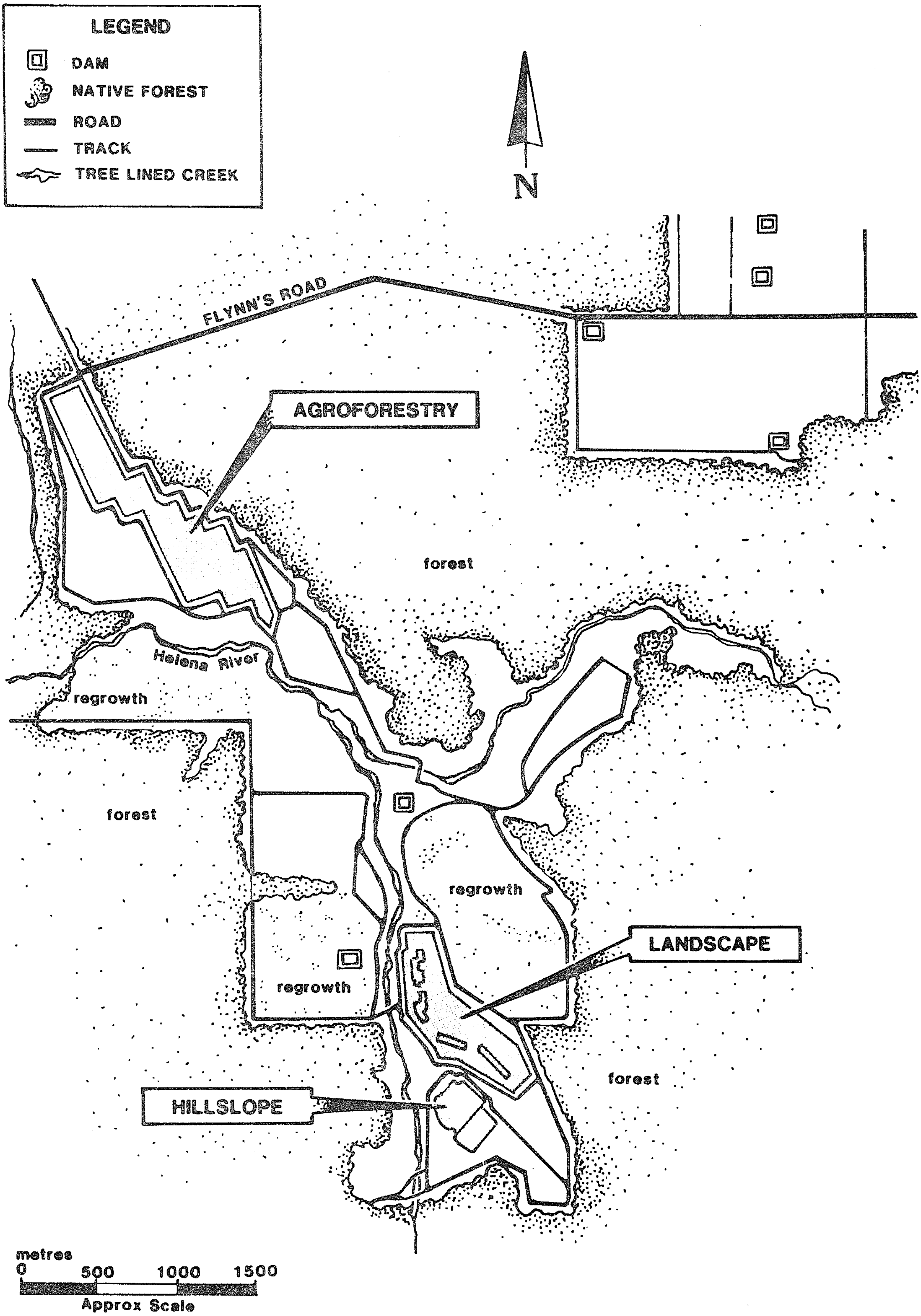

Figure 2. Flynn's Farm Study Area

Hillslope Planting

The hillslope planting was established to represent an extensive and dense planting (Figure 3). Approximately 70% of the hillside was planted in 1978 to E. camaldulensis and E. wandoo at 4 metre by 2 metre spacing (1250 stems/ha). The site had a pronounced saline seep at the base of the hillslope which was not reforested. The hydrogeology of the site was typical of the Darling Range. In situ weathering has produced a variable bedrock topography overlain by an extensive pallid clay zone with high salt storage.

Landscape Planting

In an adjacent area, plots of 50 or 100 metres wide were established in 1977 in the lower sections of the landscape (Figure 3). The planting area covered a small portion (13%) of the upslope cleared land with a density of 667 stems/ha. The depth of weathering in this site is highly variable. Rock outcrops occur through the landscape, but weathering depths of 20 metres plus also occur. Depths to the saline groundwater at the base of most plots were less than 2 metres. The range of species planted are summarised in Table 1.

In 1983 additional upslope plantings took place on this site, but their hydrologic impact is considered to be negligible over the period of groundwater analysis (1978-1986).

Agroforestry

The agroforestry site at Flynn's farm covers an area of approximately 35 hectares and is located some 3 kilometres from the landscape and hillside plantings (Figure 2). The site was divided into 32 one-hectare plots in which wide-spaced plantings have been maintained (Figure 4).

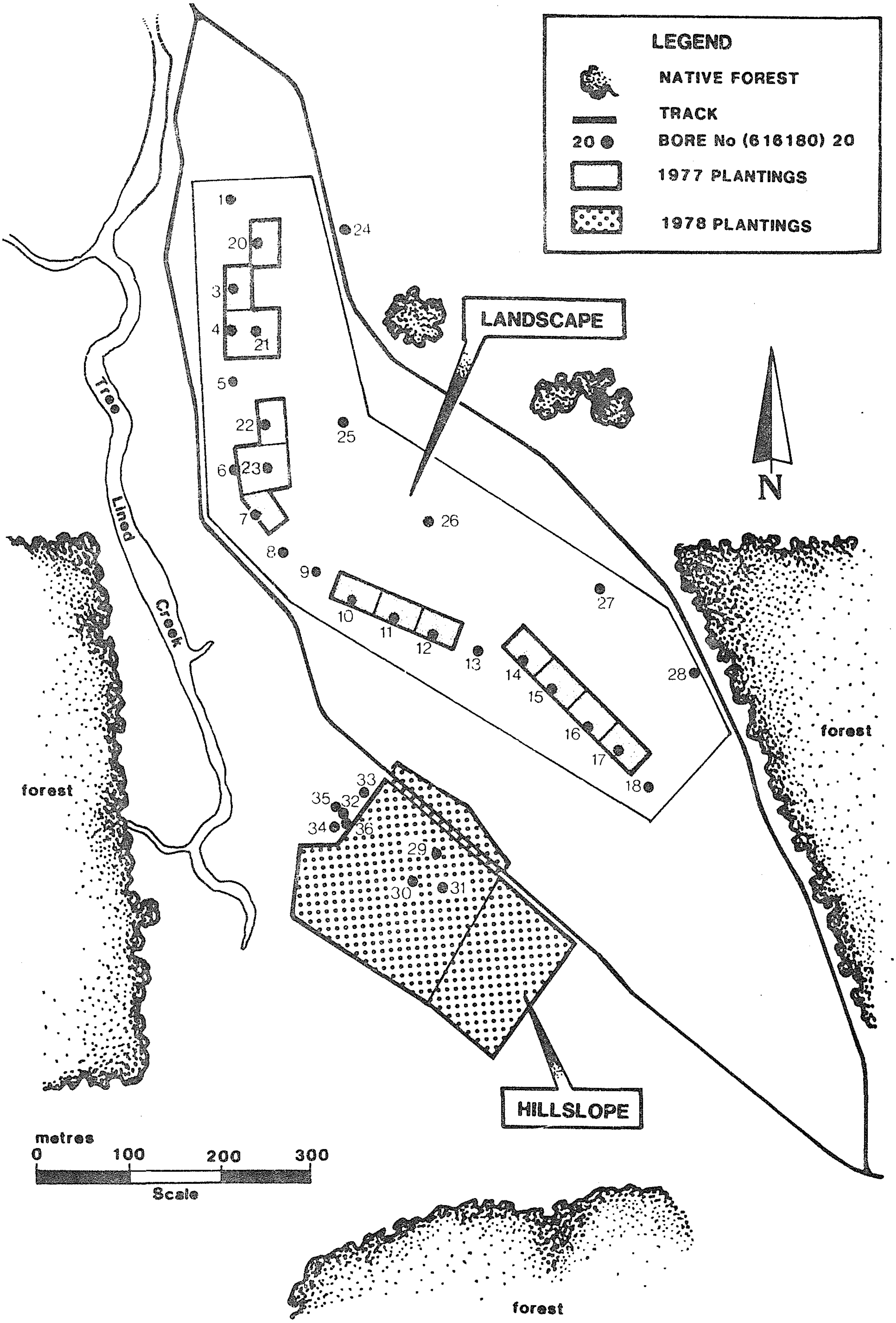

Figure 3. Flynn's Farm: Hillslope and Landscape Planting Sites

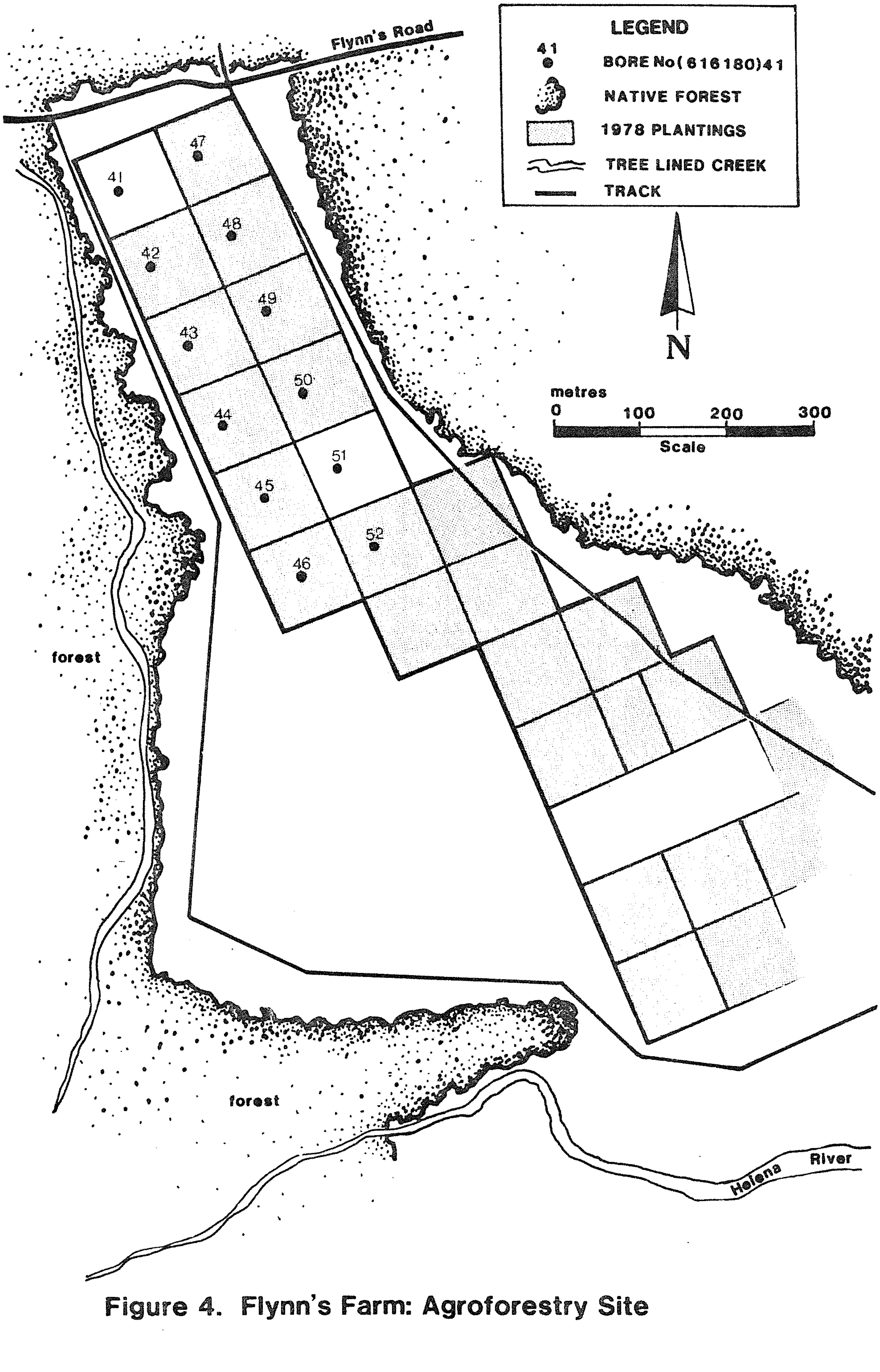

Figure 4. Flynn's Farm: Agroforestry Site

The stem densities presently range from 75 stems/ha to 225 stems/ha. Four control plots with no trees were left under pasture. The site covered most of the cleared land in a relatively narrow band of 200 to 400 metres between a forested wandoo creek-line and a mid to upslope jarrah-marri forest. With the exception of the control plots, virtually all of the remaining pastured areas were replanted. No obvious saline groundwater discharge was apparent and it is unlikely that any groundwater was contributed to the site from the upslope forest area. The weathering depth ranged between 3 and 13 metres and was less variable than the hillslope and landscape sites.

2.2 Stene's Farm

The Stene's farm site is located in a 725 mm annual rainfall area of the north-eastern portion of the Wellington Reservoir catchment. Clearing of the farm began in the 1950s and was mostly limited to the valley areas. The property was purchased in 1976 to avoid the possible large-scale clearing of the remaining forest on the property, just prior to the introduction of clearing controls.

Four separate sites (Figure 5) were established on this property as experimental plantings between 1976 and 1979 and are discussed below.

Strip Plantings

The experimental site covers an area of about 140 ha (Figure 6). The area was characterised by valley clearing between 1964 and 1970 along an 800 metre section of the main valley of Bingham River and clearing up a small side tributary for approximately 1 200 m. Two salt scalds have developed along the river flat in recent years and appear to be extending. The reforestation work was carried out in the area north of Collie-Williams Road in the 1976-1978 period.

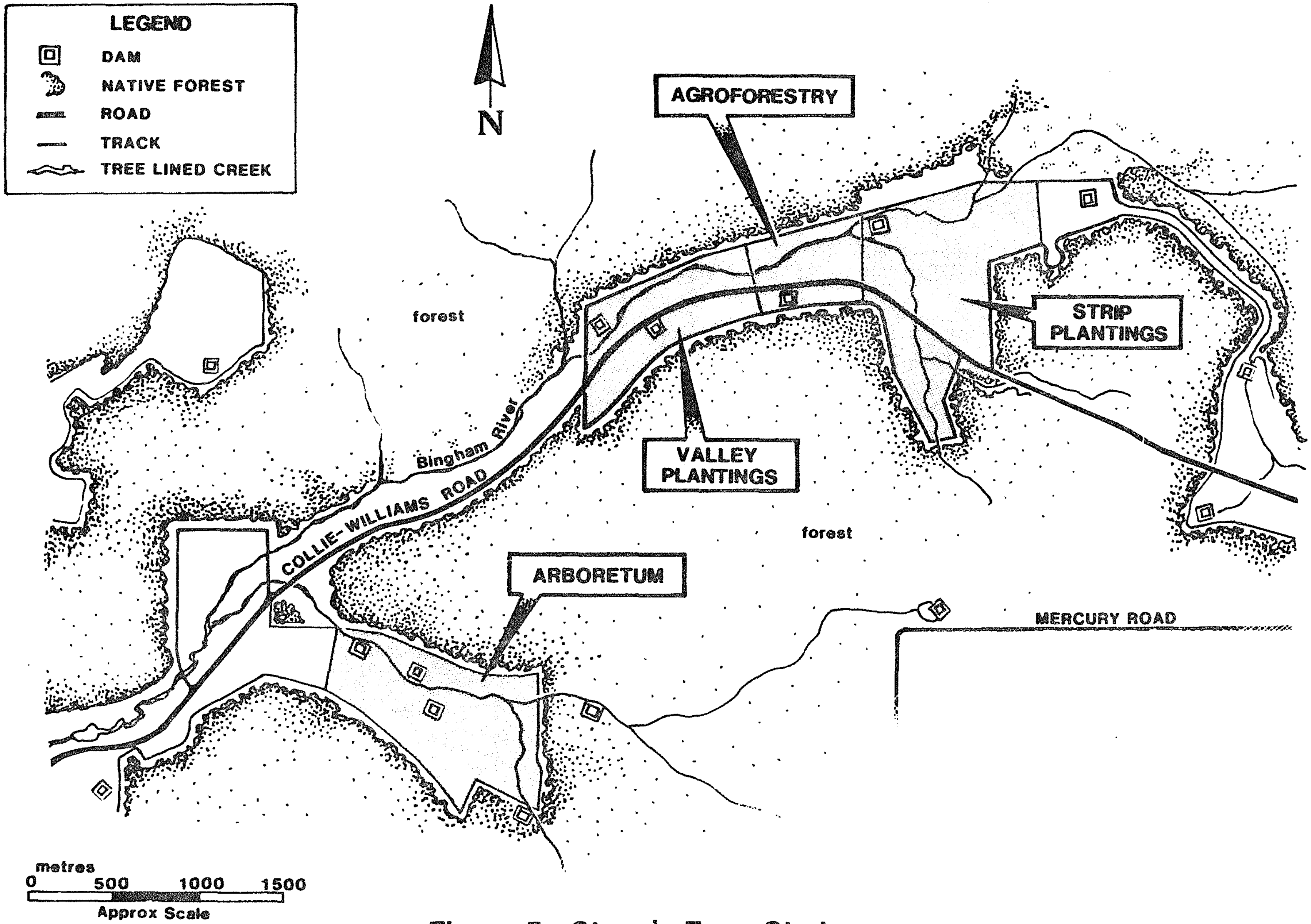

Figure 5. Stene's Farm Study area

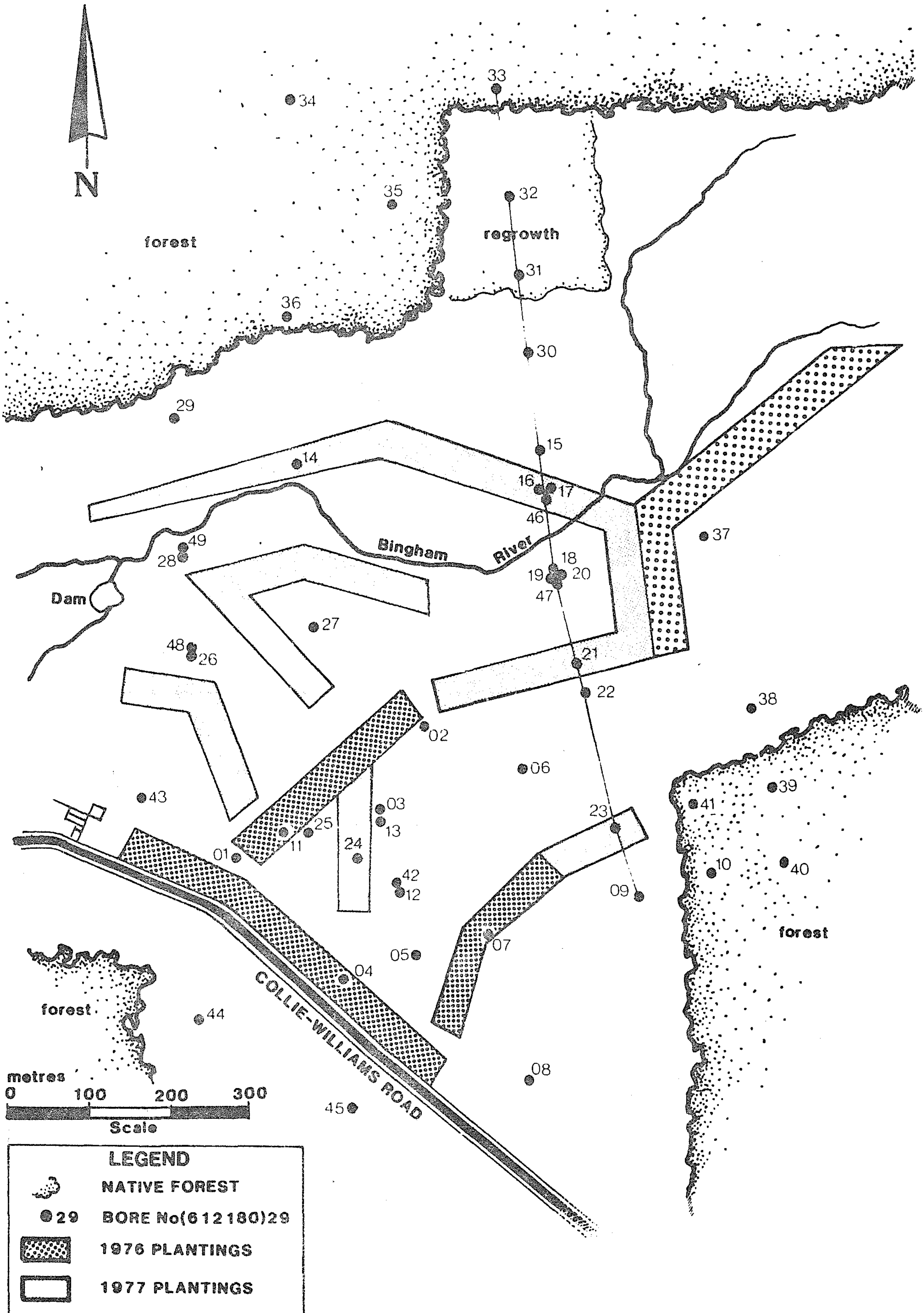

Figure 6. Stene's Farm : Strip Plantings Site

The planting strategy was based on a number of considerations. Firstly, a 40 m strip of trees was placed parallel to the road to minimise the effect of any groundwater contribution from the large cleared areas south of the road. Secondly, strips were placed to ring the salt scalded areas in an attempt to draw water tables down locally and thereby minimise saline groundwater discharge. Thirdly, strips of trees were placed upslope to ensure that there were only small areas where the gap in tree cover was greater than 200 metres. The assumption here was that 30 metre strips placed two hundred metres apart would act as groundwater pumps and cause local groundwater drawdown in a similar fashion to agricultural drains. This design was based on the models of Peck (1976).

Valley Plantings

Agricultural development at the valley plantings site took place in the 1950s at the lower slopes along the streamline and the upper southern portion of the farm (Figure 5). In 1979 a 200 metre wide strip of trees was established across the valley section and a further 400 metres of upslope pastured area was left under the existing sheep grazing land use (Figure 7). From the centre line of this creek, the reforested area represented approximately 30% of the upslope cleared land. The depth of weathering was over 20 metres in the valley.

A number of observation bores were established at this site to monitor the response of the groundwater system to the tree planting. Most of these bores were drilled along a transect across the valley and extended to the native forest upslope (Figure 7). While visual evidence of saline discharge existed in the upper reaches of the valley planting site (aerial photography 16/11/1976), the groundwater level at the bore hole locations were below the stream invert when planting took place.

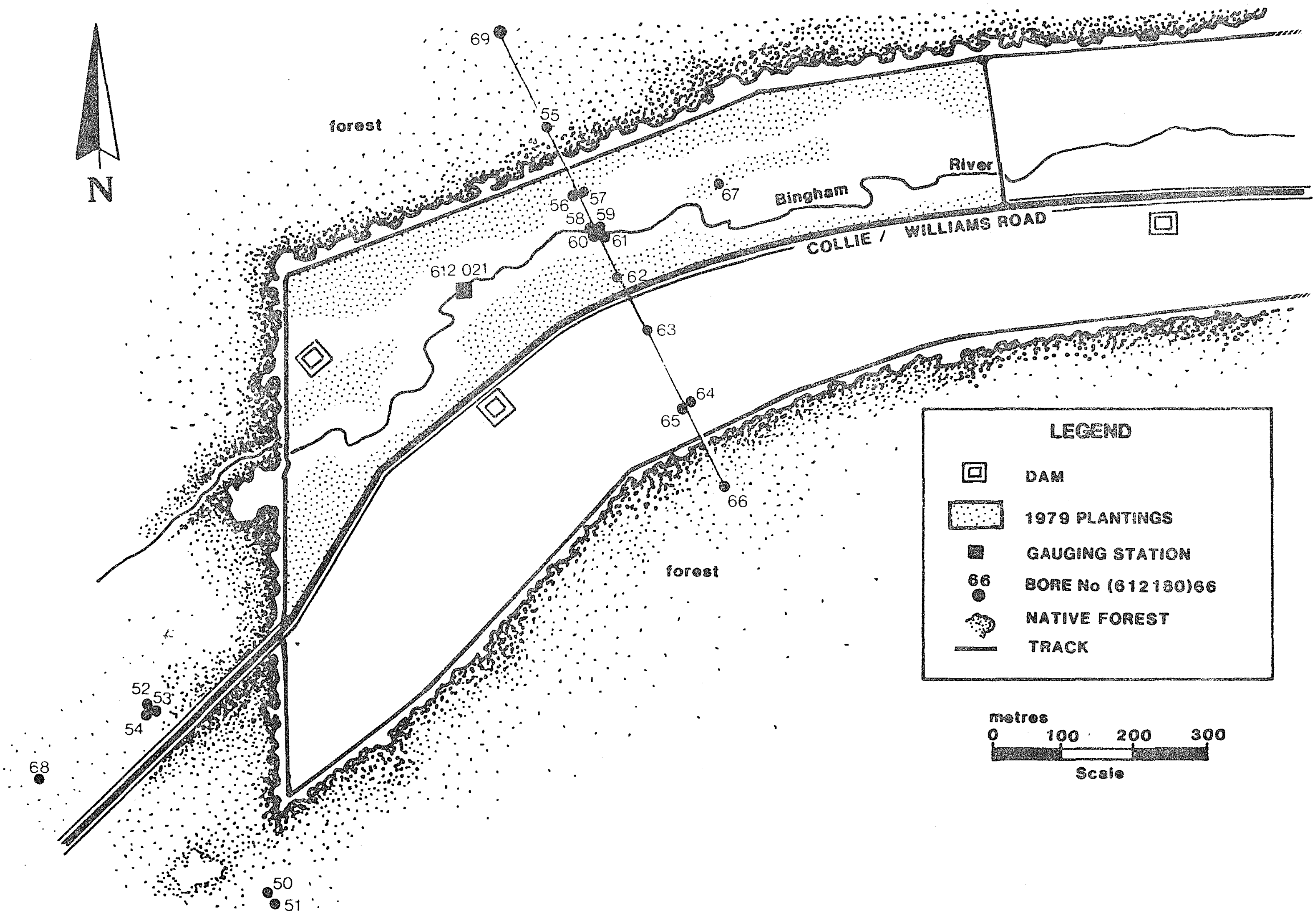

Figure 7. Stene's Farm: Valley Plantings Site

Further down the same valley where the original wandoo and swamp vegetation along the creek-line had not been cleared, the depth to groundwater was over 10 metres. No groundwaters contributed from the upslope forested area on the south side of the transect. However, groundwater was present beneath the forest on the north side of the transect. Local topography indicated that it was unlikely to extend upslope very far. Consequently as the majority of the upslope landscape remained under forest, the valley groundwater systems were not fed by extensive groundwater systems originating from high elevations beneath the ridge lines of the landscape.

Agroforestry

Approximately one kilometre upstream from the valley plantings site a wide-spaced agroforestry experiment was established in 1981 (Figure 5). The valley area was planted in 1978 and thinned in 1981 to achieve a range of stem densities to evaluate their varying effects on pasture production and on local groundwater levels. Four plots were established with densities ranging from 150 stems/ha to 900 stems/ha and covered 50% of the previously cleared land (Figure 8). Local groundwater conditions were similar to those at the valley plantings site except that saline seeps were evident along the stream line.

Arboretum

In 1979 a large arboretum (Figure 9), located on another tributary of the Bingham River (Figure 5), was established to evaluate the performance of 70 eucalypt and pine species judged likely to be suitable for reforestation in the Wellington Reservoir catchment. Species plots were made as large as practical (0.5 ha) to provide an inner core reasonably representative of a whole forest in which growth and transpiration characteristics could be studied.

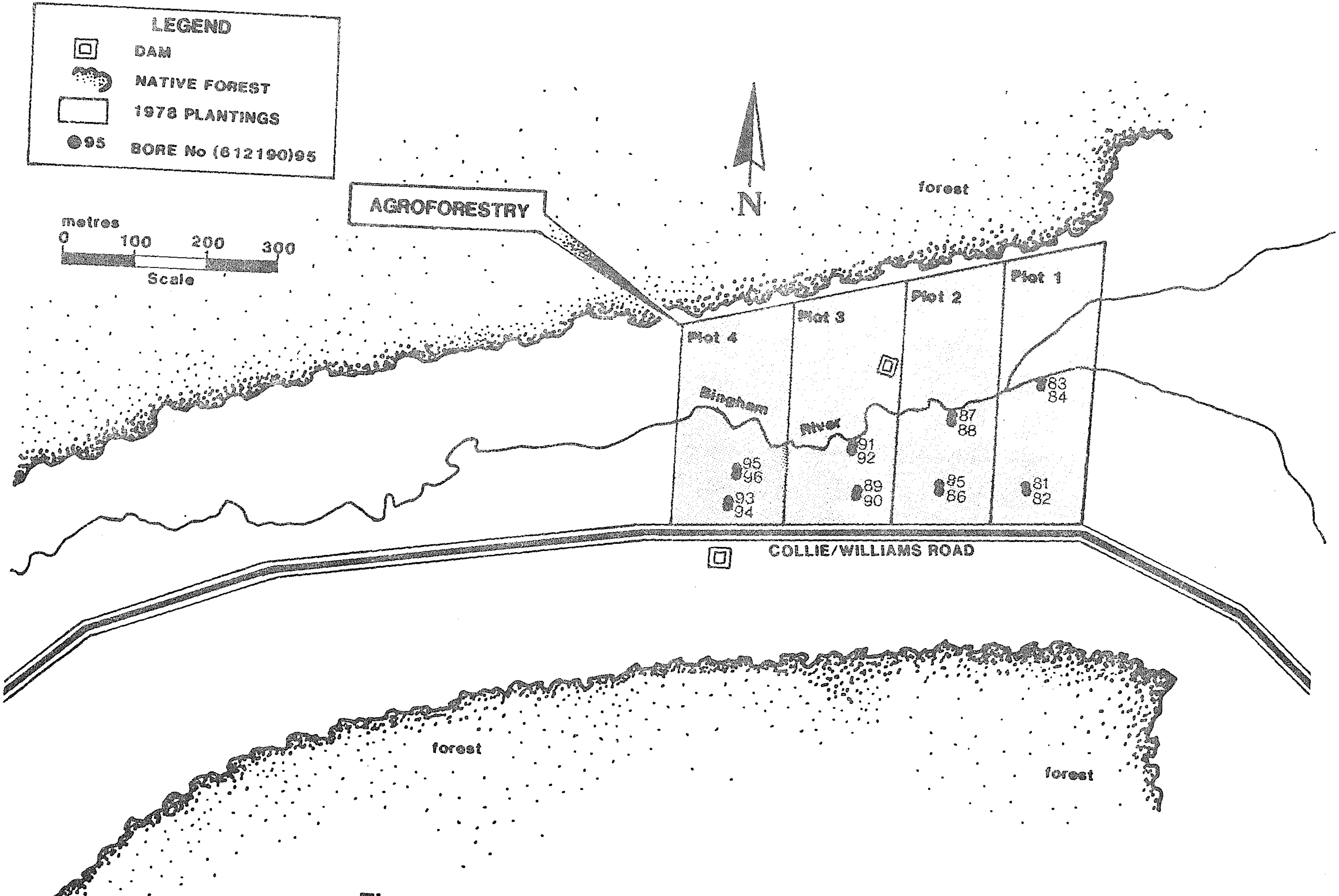

Figure 8. Stene's Farm: Agroforestry Site

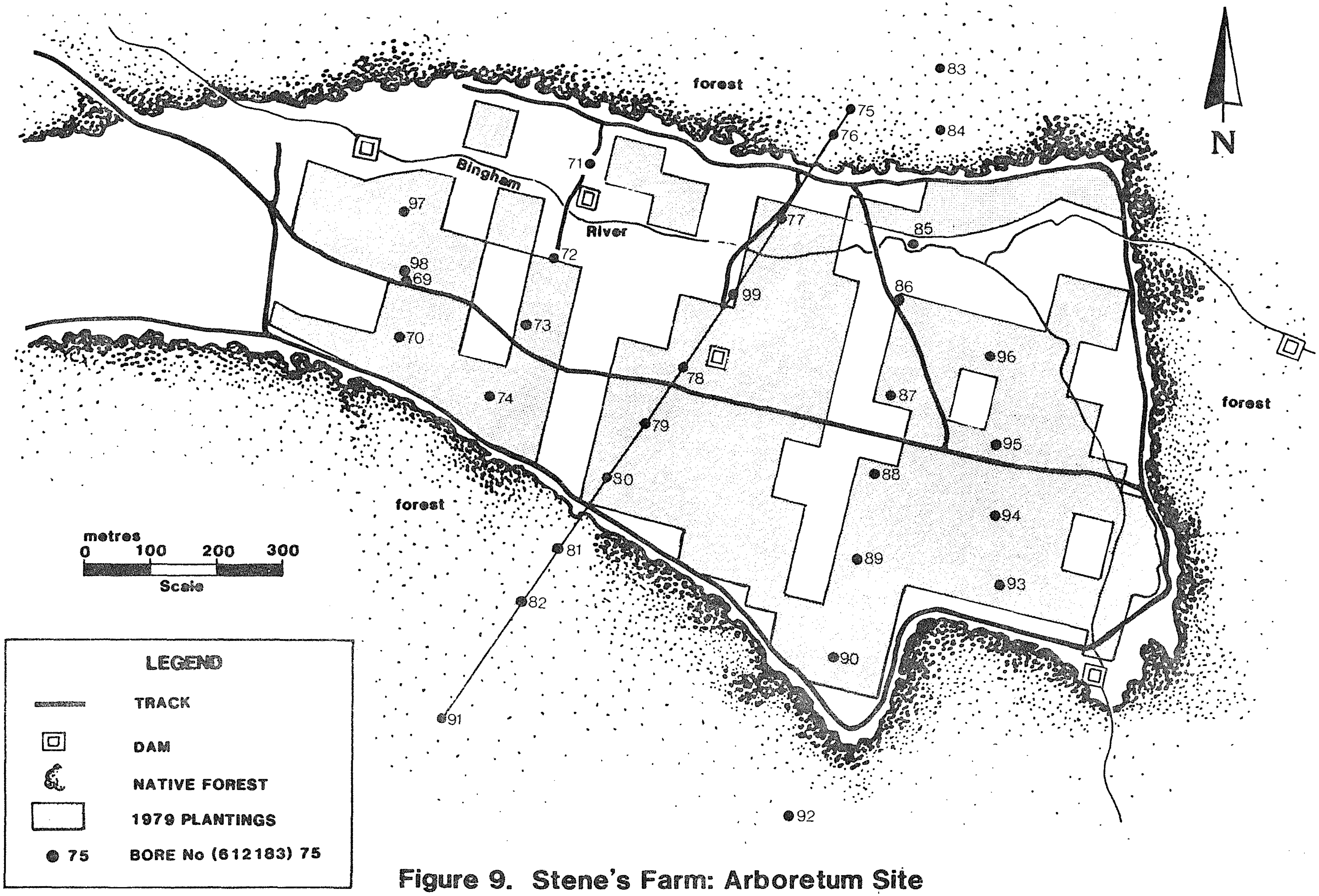

Figure 9. Stene's Farm: Arboretum Site

Similar to the other Stene's sites, clearing had been restricted to the lower valley slopes. Saline discharge along the main valley was apparent at the time of planting in 1979. Drilling revealed a deeply weathered profile, generally extending from 15 to 30 metres below the natural surface. Groundwater existed in some locations in the adjacent forest but did not extend far upslope. Strong vertical gradients of groundwater discharge were not apparent in the discharge zone.

2.3 Maringee Farms

In 1980 a partial reforestation programme on a large operational scale commenced on the Wellington Reservoir catchment. One of the early areas to be planted under this programme was a portion of Maringee Farms in the south-eastern part of the catchment (Figure 1). This site has the lowest average annual rainfall (650 mm) considered in this study. The area of planting represents approximately 25% of the upslope cleared land (Figure 10). Extensive surface and groundwater monitoring was established at this experimental site. Details of the hydrogeology and initial groundwater flow patterns are given by Martin (1984). The catchment had been mostly cleared to the ridge-line and extensive saline seeps now exist along the watercourse. Transects of bores across the lower section of the valleys reveal a deeply weathered profile (in excess of 20 metres) and a strong upward vertical gradient of groundwater in the valley discharge zones. The uniform clearing on both sides of the streamline and the fact that clearing has extended to the ridge-line presumably contributes significantly to these vertical gradients of groundwater and to the harshness of the site for reforestation.

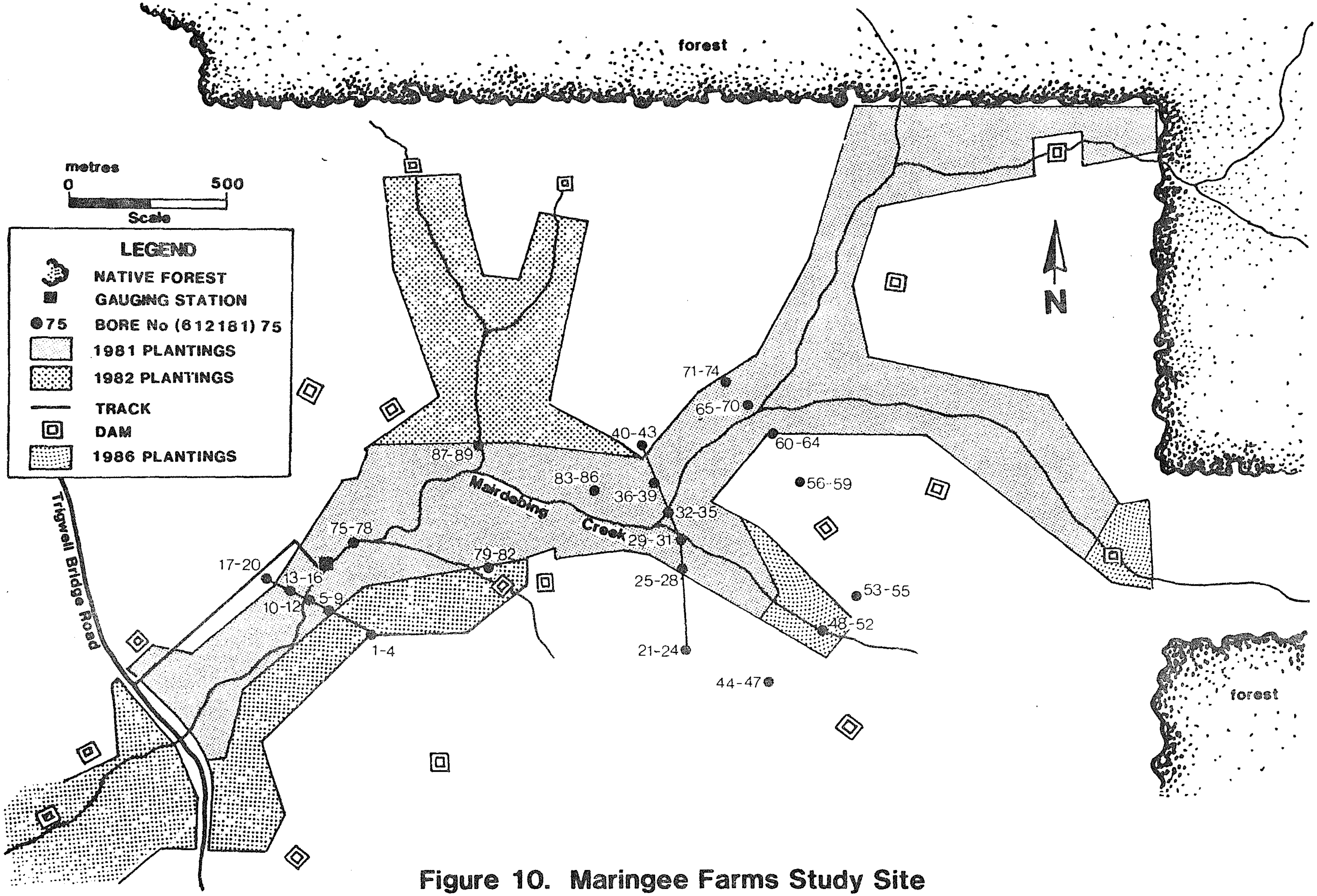

Figure 10. Maringee Farms Study Site

3. DATA COLLECTION

3.1 Groundwater Investigation

The bores established at the experimental sites are of standard monitoring type which has been described by Borg et al. (1987) and schematically illustrated in Figure 11. They are constructed by auger drilling 127 mm diameter holes to a given depth. A 38 mm diameter PVC tube, fitted to reach from the bottom of the hole to approximately 50 cm above the soil surface, is inserted into each hole and packed into place with graded sand. The tube is slotted from a given depth to the bottom of the hole and its bottom end is sealed with a plug. For protection, an 89 mm diameter steel or asbestos cement pipe is placed over the PVC pipe and is cemented in at the soil surface. A removable cap is placed on top of the external pipe to prevent rain and debris from entering the bore.

Figures 3, 4 and 6 to 10 present the locations of the 251 groundwater observation bores documented in this report for the 8 experimental sites examined. The bores are positioned to monitor groundwater under the valley, midslope and upslope areas of different land use (pasture, forest and reforestation). In some cases the bores located in pasture just downslope of reforested plots are assumed to reflect the effect of the reforestation, rather than the pasture, since the recharge upslope is considered to control groundwater levels locally.

Some bores of differing depths are located within a few metres of each other to form a 'bore nest'. These nests are used to monitor the vertical pressure gradients of the groundwater system and changes in salinity at different depths.

All bore details are included in Appendix A. Details such as the State Water Resources Information System (S.W.R.I.S.) bore number, driller's bore number, date of commencement of

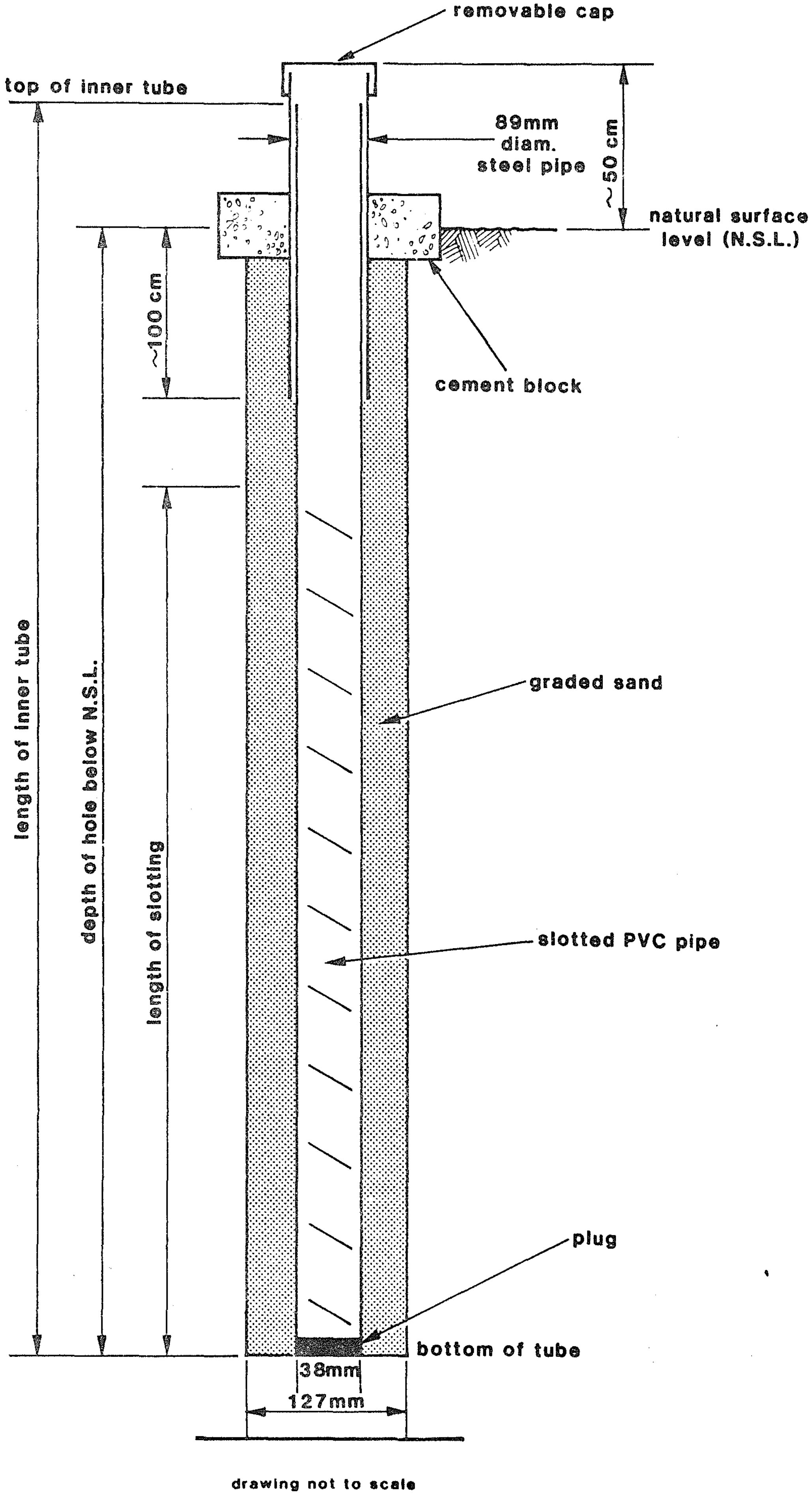

Figure 11. Schematic of an Observation Bore

operation, bore classification (reforested, pasture, etc), the Australian Height Datum (AHD) of the top of the inner casing, natural surface level, bottom of hole and the difference in depth between these levels together with length of slotting are listed. In general, the time of construction and commencement of monitoring of the bores corresponds to the time of reforestation. Stene's agroforestry is an exception since it was planted in 1978 and bores were estalished in 1981. The overall depths of the bores below the ground ranged from 1.2m to 34.2m with slotting lengths of 1.0m to 28.24m. Thus, the shallow and deeper groundwaters are well represented in this study.

Initial monitoring for all bores in this study was monthly. This involved measuring the water level in the bore and taking a water sample from the bottom of the bore. The Total Soluble Salts (TSS) of this water sample was subsequently estimated from electrical conductivity measurements determined at the Water Authority laboratories. This will be referred to in this report as groundwater salinity.

Monitoring of the 89 bores at Maringee Farms was rationalised at the end of 1983. Monitoring ceased at 44 bores and the remainder are visited in April, May, June and September, October, November to identify yearly minimum and maximum groundwater levels. At Stene's farm monitoring frequency was also reduced in 1984 to a level where only the maximum and minimum water levels were obtained. Not all visits involved taking water samples. The arboretum resumed the more intense monthly sampling in 1985 as part of a leaf conductance study at this site (Hookey et al., 1987). All Flynn's farm bores were sampled monthly throughout the period of this study.

The groundwater monitoring programme for all of the experimental sites in this study has been designed to:

(a) identify the general water table levels,

(b) provide detail on the groundwater levels along the transects across the valley areas,

(c) identify the vertical pressure gradients using bore nests,

(d) determine the effect of reforestation on the groundwater table,

(e) identify the differences in recharge beneath pasture and reforestation, and

(f) identify the areas of high and low groundwater salinity and determine the consequent effect of reforestation.

Due to the large number of bores involved in this study (251), it has not been possible to individually scrutinise the quality of record for every bore. This should be kept in mind when viewing the results.

3.2 Crown Cover Sampling

An objective of this report is to relate the changes in groundwater level at the experimental sites to a suitable measure of transpirative capacity of reforestation. A simple measure of this capacity is crown cover. In this report crown cover refers to the percentage of the ground area covered by a vertical projection of the vegetation canopy onto the ground surface. It was assessed with a crownometer similar to the one described by Montana and Ezcurra (1980). This instrument gives a vertical line of sight. If the line of sight intercepts vegetation, a 'hit' is recorded. When a number of readings have been taken, crown cover is calculated as the number of hits divided by the total number of observations.

For an unlogged native forest, the sampling strategy is simply walking in a line sampling at a predetermined interval. In the case of sampling reforested sites and relating this to bore groundwater levels, more involved sampling strategies are required. Because of the varying nature of the experimental sites examined in this study, two sampling strategies were used:

(i) Sampling biased to the location of the bores.

This technique involved finding the location of a particular reforestation bore and using a compass to determine the directions of North, South, East and West. Twelve readings were taken in all four of these directions at an interval of four paces to give a representation of the crown cover surrounding the bore. When this strategy for a given bearing took the observer outside of the reforestation boundary, the interval of sampling for that direction was reduced to two paces. If this still took the observer outside the boundary, no further samples would be taken on that bearing.

This strategy was used at Stene's arboretum and the valley plantings site.

(ii) Sampling at 45^{o} to the Tree Planting Lines

Generally, 50 to 100 observations were taken for each reforestation plot using this technique. It involved starting at the corner of the plot and taking a bearing at 45^{o} to the line of tree planting. The interval between observations ranged from two to five paces, so that the desired number of samples could be taken, and generally two diagonal bearings would be run.

The need for this alternative approach arose for two reasons. Firstly, some bores classified as reforested are actually located in the pasture. The groundwater response of these bores are reflected by the crown of the reforested plot immediately upslope of it. Secondly, at the agroforesty sites the lack of competition between crowns in adjacent tree lines is such that the compass bearing approach could have run a sampling direction between these two crowns and recorded no hits. This would cause large inaccuracies in crown cover estimates.

All experimental sites at Flynn's farm and the strip plantings and agroforestry at Stene's farm used this sampling approach.

Crown cover sampling was attempted at Maringee Farms but was abandoned because many of the bores are located in the broad open flats of the valley areas. These bores are obviously influenced by the reforestation in the upslope areas, but it is not possible to identify the corresponding crown(s). Also, the crown cover at this harsh site is low, which thus requires a larger number of readings for each bore than at other sites. This was not possible within the time limit for this study.

All crown cover measurements were taken between the 4th and 10th of December 1987. Even though the time of measurement does not correspond to the period in which groundwater reductions have been considered (up to 1986), the comparison of 1987 crown covers is indicative of the groundwater response of the preceding years. Note that extensive thinning of the E. camaldulensis took place in 1986 at the Flynn's hillslope site. An estimate of the 1987 unthinned crown cover at this site was made by considering the same species of a similar age (about 9 years) at the Stene's valley plantings site.

The number of hits, total observations and the resulting percentage of crown cover is listed in Appendix B for all of the bores that have been classified as "reforested" in this study. Thus, the mean of the crown covers at each site (given at the bottom of the crown cover column in Appendix B) is a value which is comparable with the minimum groundwater response to be presented in the following chapter.

4. GROUNDWATER RESPONSE

4.1 Variations in Minimum Groundwater Levels with Time

To evaluate changes in annual groundwater levels, a standard measure is required. Annual maximum and minimum groundwater levels were considered by Anderson et al. (1982) and Edgeloe and Loh (1984) on the Stene's strip and valley plantings sites respectively. The analyses performed in this study are limited to only evaluating minimum levels which are recorded between March and June each year. The reasons for excluding maximum values, which occur in September to November, are:

(i) the measurement of minimum groundwater levels are generally more accurate because in autumn changes of the water table are slow and hence the day of recording is not critical,

(ii) maximum levels are substantially more sensitive to seasonal variations than minimum values, and

(iii) draining perched water tables following the winter rains can bias maximum groundwater levels measured in spring.

4.1.1 Mean site response

Figures 12, 13 and 14 present the mean responses for the reforestation experimental sites at the three locations: Flynn's farm, Stene's farm and Maringee Farms. For each site, the mean change in minimum groundwater level since the first year of record was calculated for the group of bores representative of the water table influenced by reforestation. The mean change in minimum groundwater level was also considered for the 'pastured' bores at each farm location. This acts as a control for the 'reforested' bores because it reflects the response of the site had no reforestation taken place.

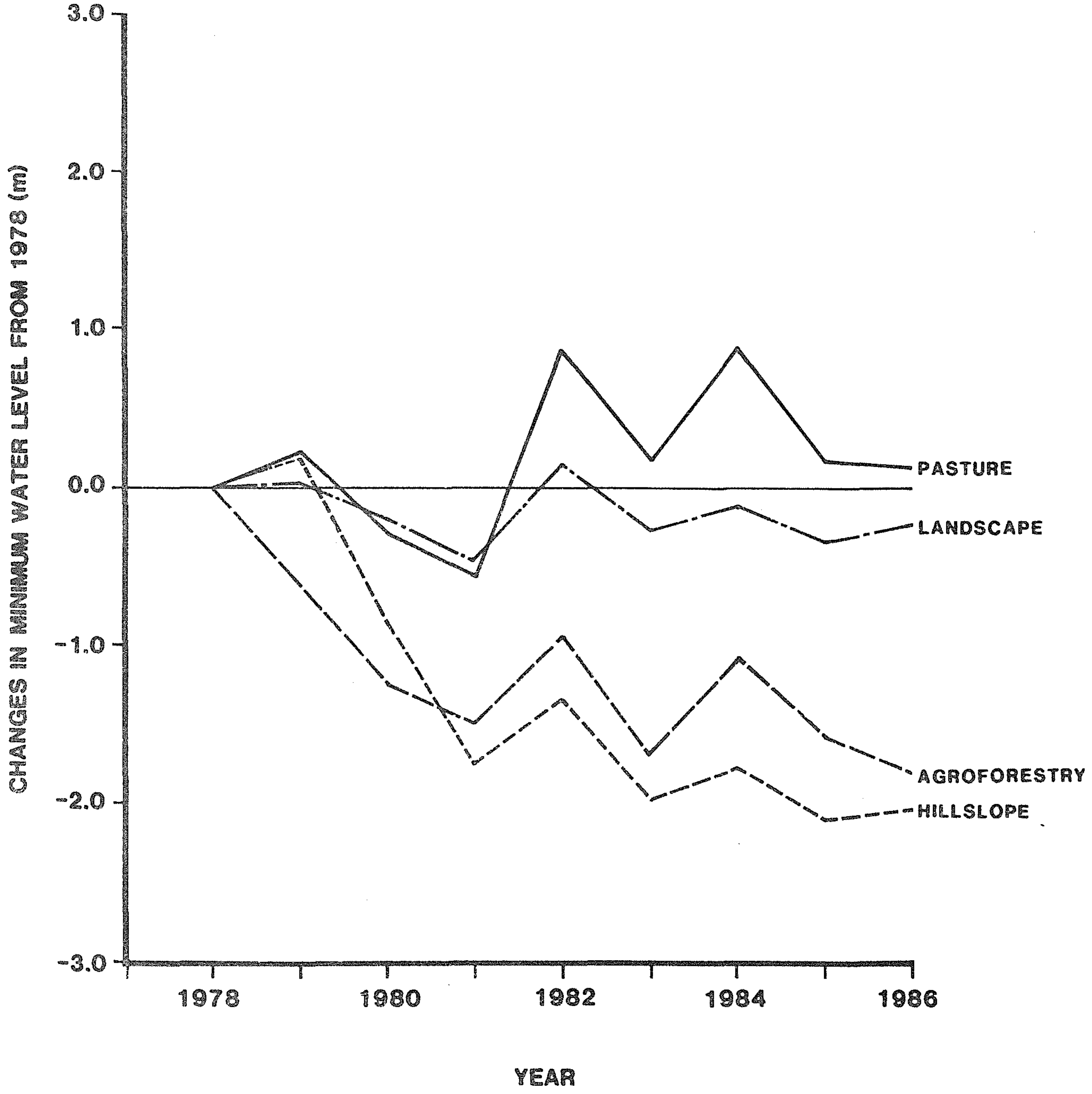

Figure 12. Flynn's Farm: Mean Site Groundwater Level Response

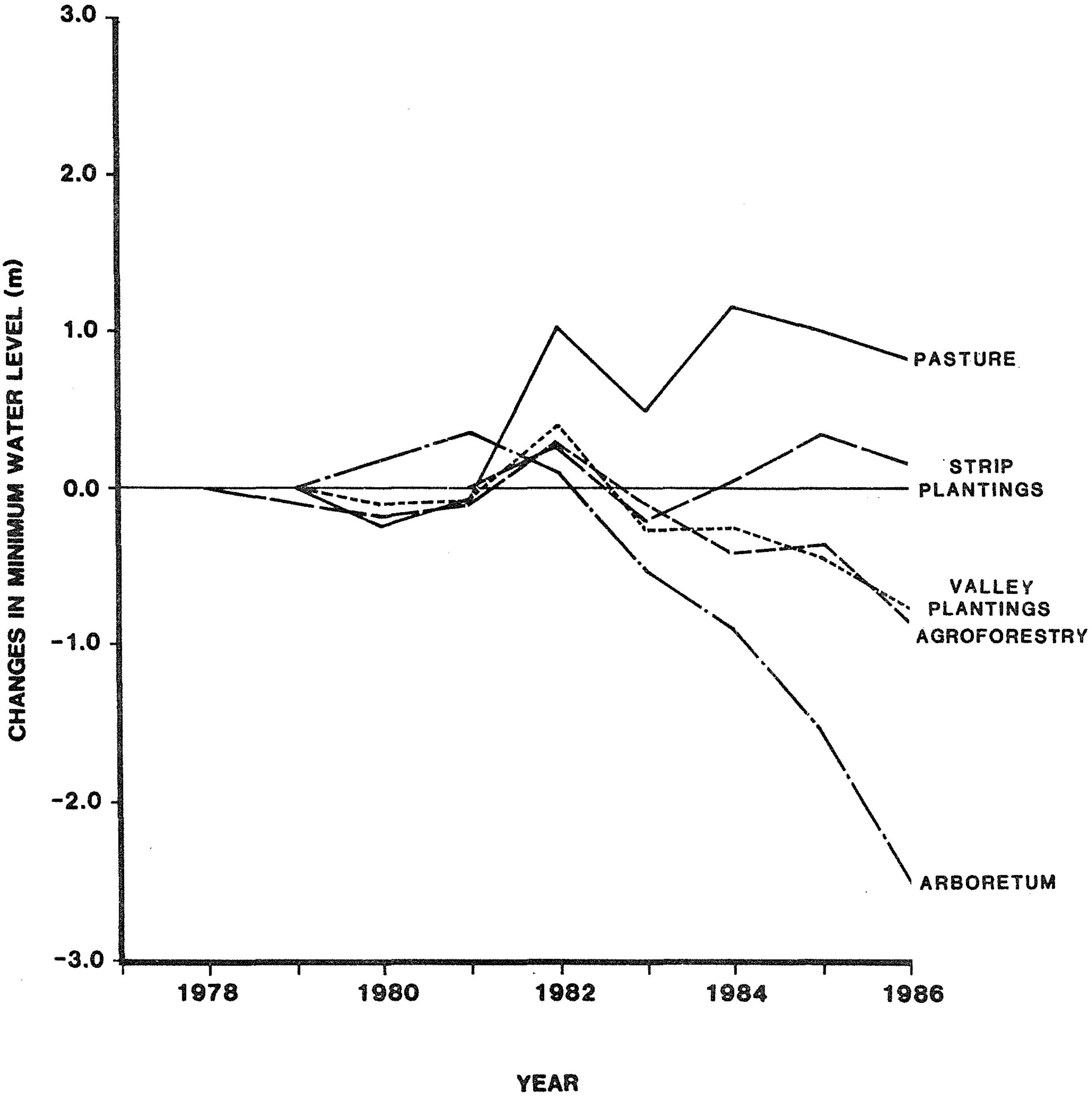

Figure 13. Stene's Farm : Mean Site Groundwater Level Response

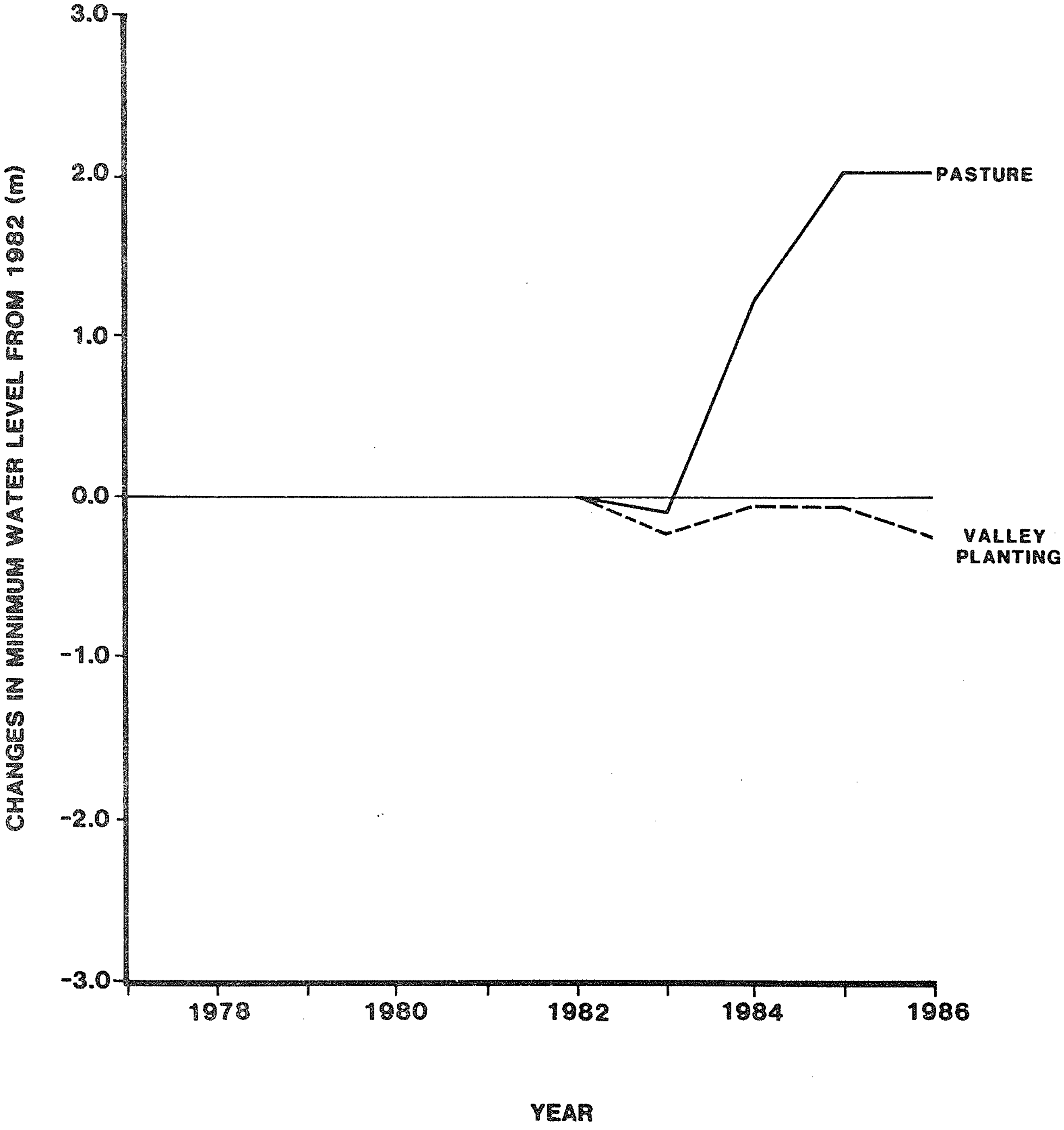

Figure 14. Maringee Farms: Mean Site Groundwater Level Response

The selection of bores to represent the groundwaters under reforestation or pasture was based on bore location and the possible influence of the trees on nearby bores. Appendix C lists these bores together with their minimum water level (AHD) for each year of record. Any bores which went dry during the period under investigation (1978-1986) were not included in the analysis.

In the selection of 'reforested' bores, the bores located in pasture just downslope of reforestation (say within 50m) are assumed to reflect the effect of reforestation on local groundwater levels and therefore have been included in this group. In the case of bore nests, only the shallowest bore which had not gone dry was included in the analysis. To gain a good spatial distribution of reforested bores, the deep observation bores (length of casing greater than 20m) not belonging to any nests were included even though it is recognised that the deeper groundwaters do not necessarily reflect the response of the water table.

Figure 12 presents the groundwater responses at Flynn's farm. The pasture response is calculated from the 6 bores located upslope of the landscape plantings. Between 1978 and 1982, groundwaters in this area rose by 1.0m. However, following the general low rainfall in the years after 1983, the pastured groundwaters have fallen to about the same level as they were in 1978.

Water levels at the landscape planting site have shown a decrease of only 0.2m. This is not significantly less than observed for the pasture bores upslope. The agroforestry and hillslope sites have shown by 1986 much greater reductions, 1.8 and 2.0m respectively.

The pastured response at Stene's farm (Figure 13) is determined from 2 bores at the valley plantings and 7 at the strip plantings. The 1986 pasture groundwater levels have increased by 0.8m from those recorded in 1979. The strip plantings have on average not lowered the water table (0.2m increase). It must be noted that the water levels are still 0.6m lower than what they would have been had no reforestation taken place. The valley planting and agroforestry sites have shown very similar groundwater responses with reductions of 0.8m between 1979 and 1986, and 1981 and 1986 respectively. The greatest reduction in groundwater level at any reforestation site was at Stene's arboretum. Groundwater levels dropped on average by 2.5m between 1979 and 1986.

For the sites at Stene's farm that have shown the most substantial reductions in groundwater level (valley plantings, agroforestry and arboretum), the rates of groundwater reduction in both absolute terms and relative to pasture, have been most dramatic in the last three years (Figure 13). In particular, Stene's arboretum has shown the most significant reduction over this period with an average rate of 660 mm per year. Flynn's farm (Figure 12) tends to display an opposite trend to this. The best performed sites, Flynn's agroforestry and hillslope, show the greatest reductions in groundwater level in the initial three years and tend to be levelling off in the later years. The differing responses through time between the experimental sites at Flynn's and Stene's farms at present cannot be explained and requires further investigation.

Figure 14 shows the response of groundwaters under the pastured and reforested areas at the Maringee Farms experimental site. Between 1982 and 1986, the groundwaters in the upslope pasture bores rose by about 2.0 m. The valley reforestation managed a 0.25 m reduction in groundwaters. Using the pasture response as a control, the reforestation response has been promising, especially when it is noted that the upslope heads driving to the valley have risen.

The greatly differing groundwater response to reforestation at the eight experimental sites can be explained by the proportion of the cleared land that is reforested (proportion planted), the stem density at planting and the subsequent crown cover achieved as the trees mature. The development of a correlation between groundwater reductions and site crown cover (a product of the tree crown cover and the portion of the landscape planted) is discussed in section 4.3.

4.1.2 Water table response

The changes in minimum groundwaters beneath individual plots of reforestation can be best investigated by considering the valley cross-section water table response. This is examined by considering lines of bores (transects) through the valleys. This also assists in defining the direction of groundwater flow and locations of groundwater discharge to the ground surface and stream invert.

At Flynn's farm there were no lines of bores crossing the valley to allow valley cross-section water table responses to be examined. Furthermore, the spatial distribution of the bores was not adequate to draw contours of the water table responses.

The potentiometric surfaces (Australian Height Datum, AHD) of the bore transect 61218033-61218009 (Figure 6) through the main valley of the Stene's strip plantings for three separate years (1978, 1982 and 1986) are presented in Figure 15. The general trend is for groundwaters to flow north from bore 61218009 towards the valley floor. The build up of head on the south side is due to increased recharge resulting from clearing of deep rooted vegetation. On the north side of the valley there is no groundwater gradient towards the stream. The forest and regrowth in this area has lowered groundwaters by 0.5 m.

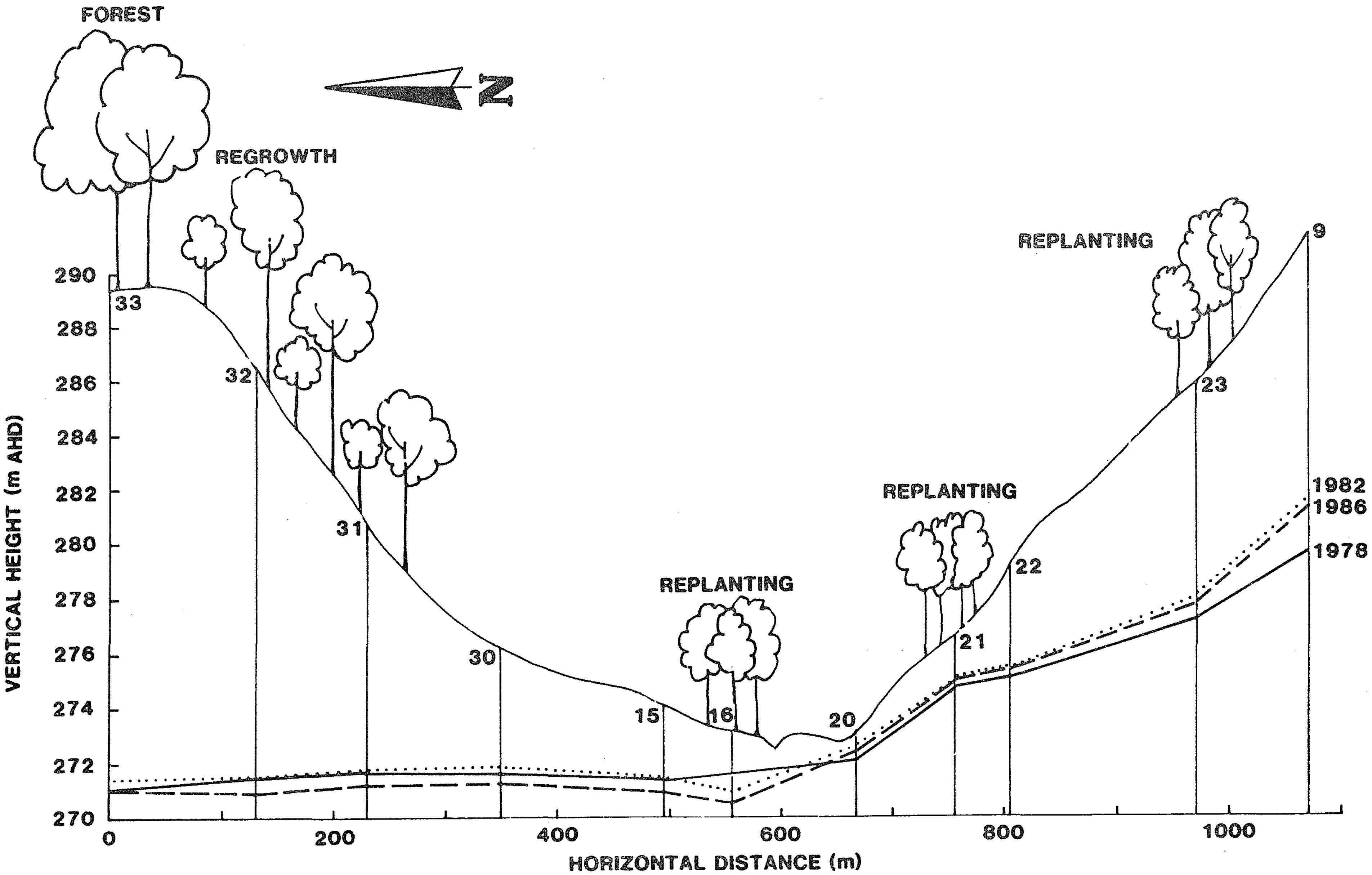

Figure 15. Stene's Strip Plantings: Variation in Minimum Water Table Through Bore Transect 61218033-61218009

The potentiometric surfaces (Figure 16) along the bore transect 61218066 - 61218069 (Figure 7) across the valley at Stene's valley plantings show a steady increase of water level under the pasture. Comparatively, the groundwater level under the valley reforestation has been decreasing despite the increase in groundwater gradient. The response of this site clearly demonstrates the difference in water use, and thus recharge, between the deep rooted trees and the pasture.

Figure 17 presents the potentiometric surfaces across the valley (transect 61218375 - 61218391, Figure 9) at Stene's arboretum. In 1979 at the time of reforestation, a lateral groundwater gradient caused flow from the south to discharge into the valley. This also shows, as was observed for mean site response presented in sub-section 4.1.1, groundwater levels have reduced substantially. Contours of the reductions in groundwater level between 1979 and 1986 are presented in Figure 18. Reductions of over 4.0m were observed midslope while the valley areas had reductions of about 2.0m. Even though minimum water levels are being considered here, it can be concluded that the reduction in groundwater level in the valley is sufficient to stop saline groundwater discharge into the stream throughout the whole year. The maximum amplitude of seasonal fluctuations in groundwater level in this rainfall zone of the Darling Range is 2.0 m. This is demonstrated in section 4.3 (Figures 20-25) where the hydrographs of the water levels in bore nests are presented.

At Maringee Farms, the potentiometric surfaces (Figure 19) of the bore transect 61218121-61218142 (Figure 10) show the general response of the groundwaters to valley reforestation. Under the pasture on the southern side of the valley (bore 61218121) the groundwaters have risen substantially. The valley bore 61218131, located in reforestation, shows groundwater discharge into a nearby stream. Fifteen percent of the landscape from the valley to the ridge-line is reforested. A larger proportion of planting would be necessary to reduce

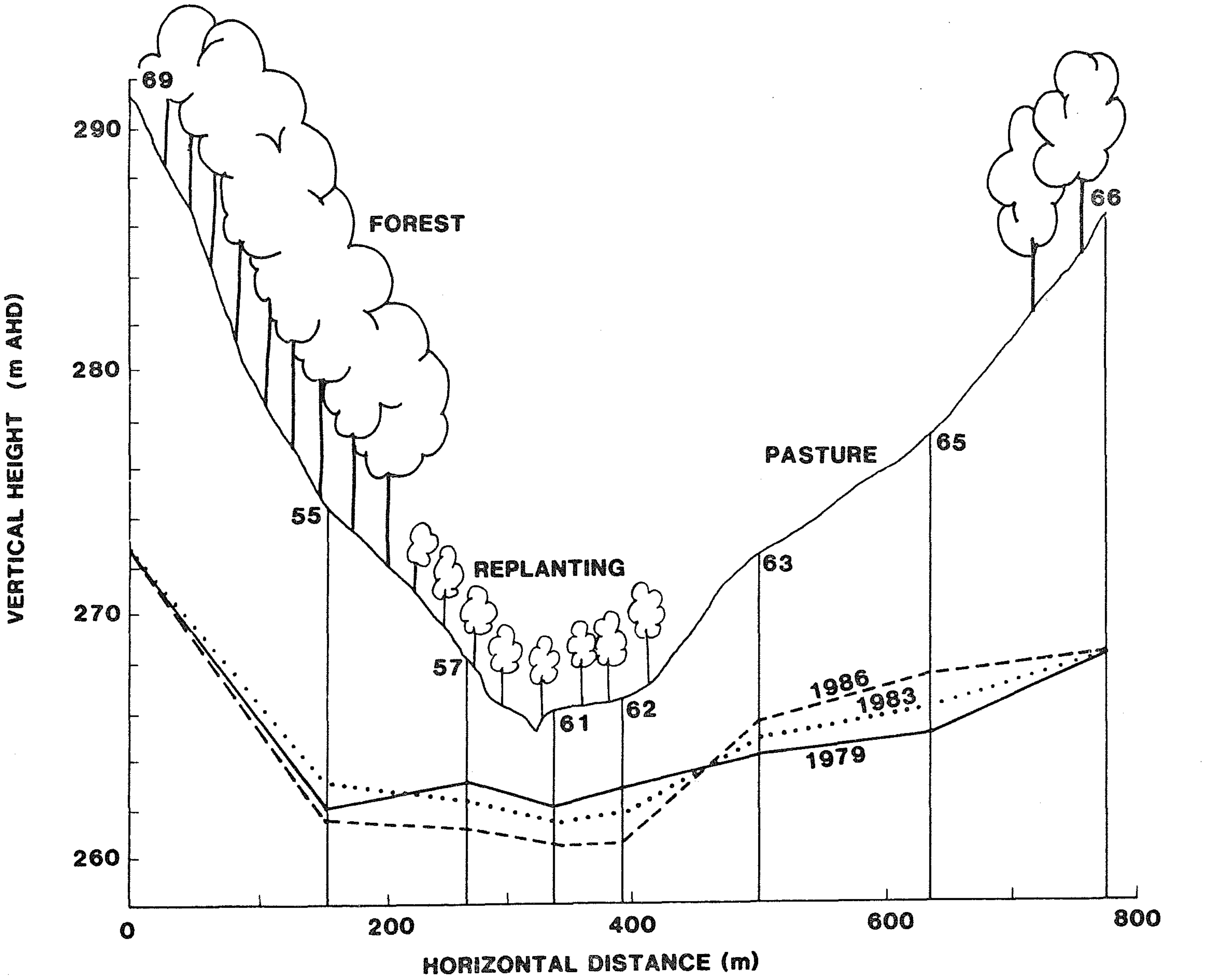

Figure 16. Stene's Valley Plantings: Variation in Minimum Water Table Through Bore Transect 61218069-61218066

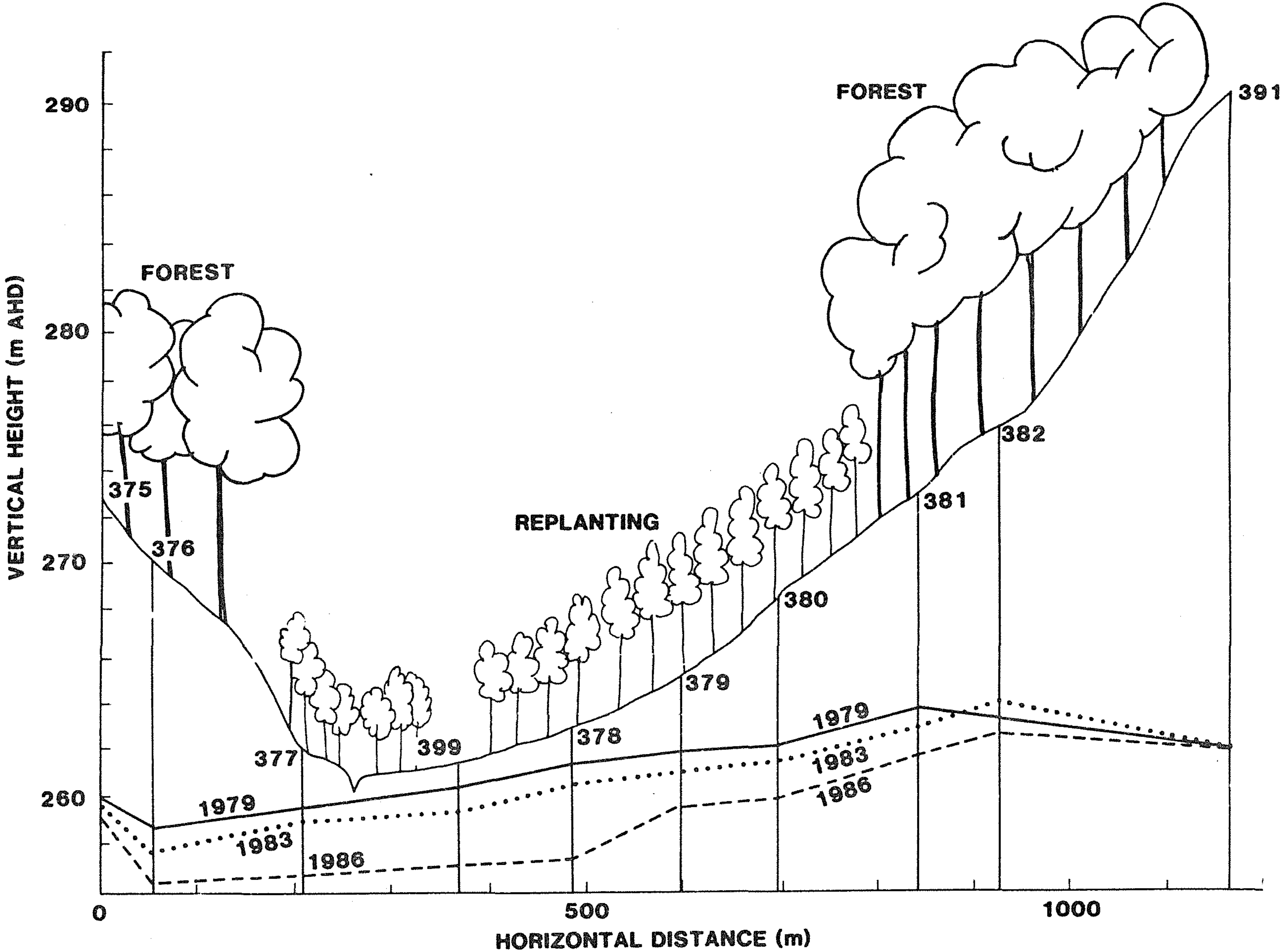

Figure 17. Stene's Aboretum: Variation in Minimum Water Table Through Bore Transect 61218375-61218391

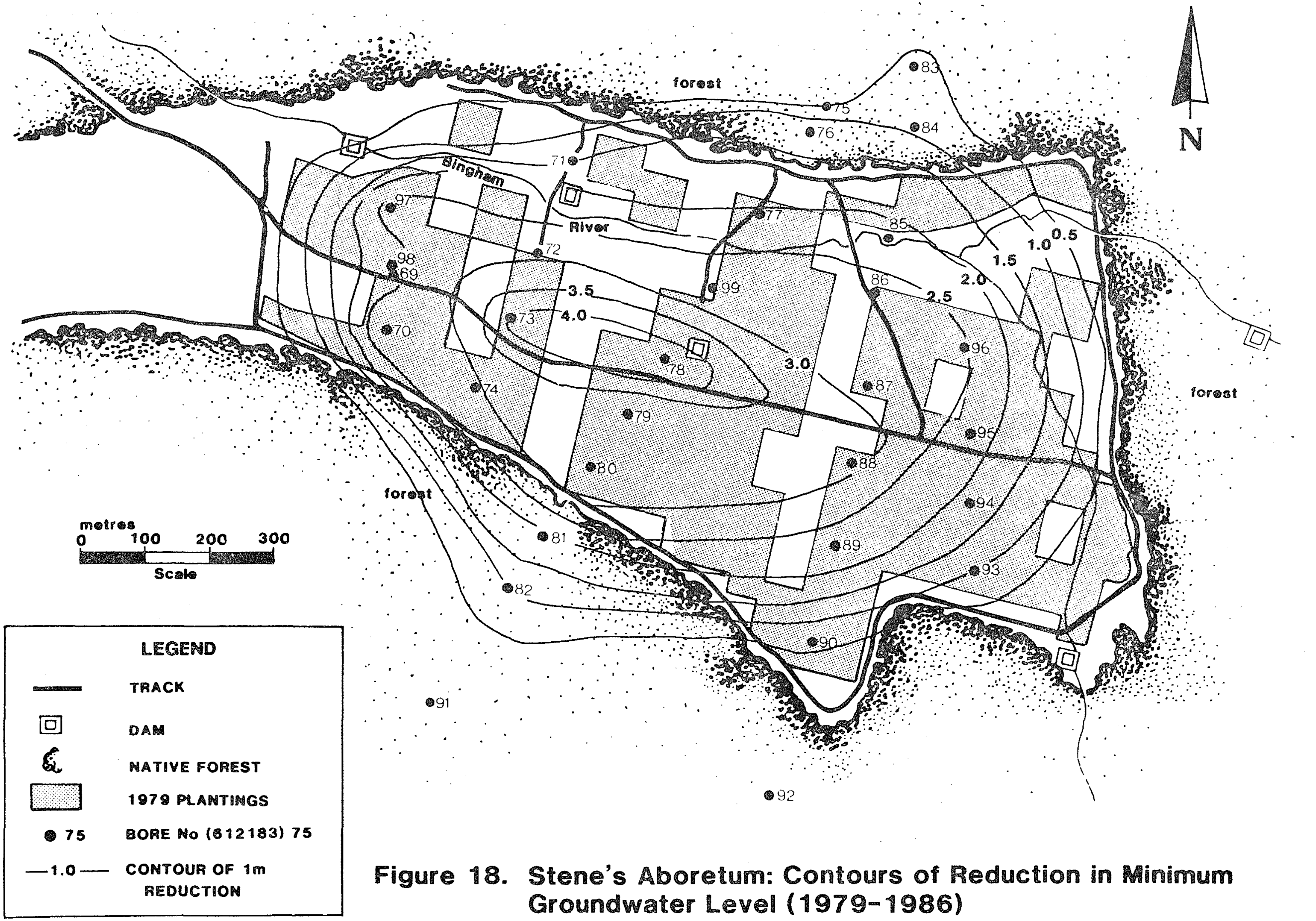

Figure 18. Stene's Aboretum: Contours of Reduction in Minimum Groundwater Level (1979–1986)

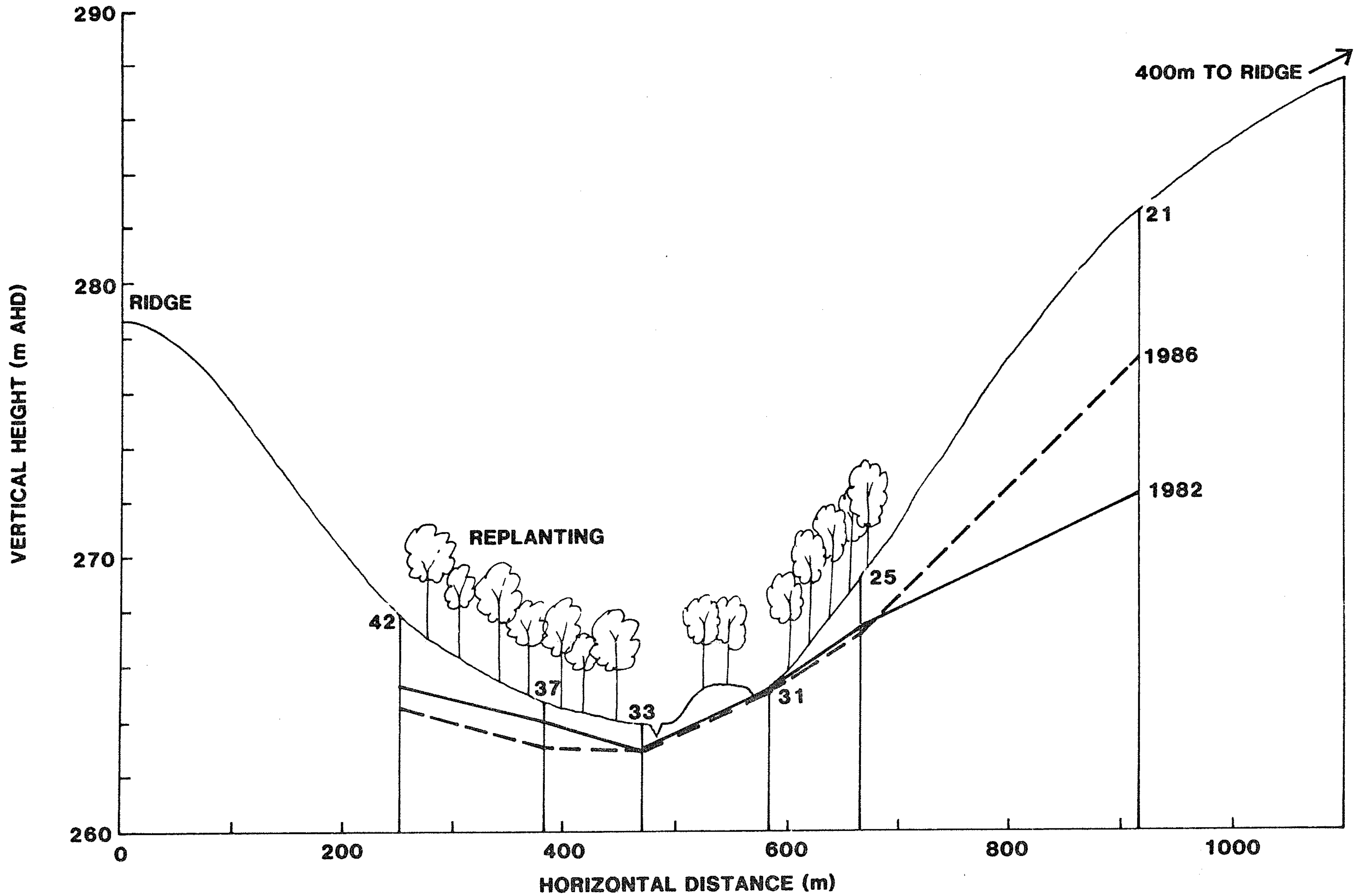

Figure 19 Maringee Farm: Variation in Minimum Water Table Through Bore Transect 61218142-61218121

valley groundwater levels and at the same time reduce the rate of increase of the head under the pasture upslope. On the northern side of the valley, water levels under reforestation have reduced by 0.5m. The slope at this side is less steep than the southern side and a greater proportion (40%) of the landscape is reforested.

4.2 Vertical Pressure Gradients

Figure 20 presents the water levels of the bore nest 61618032, 36 located just downslope of the Flynn's farm hillslope site (Figure 3). Bores 61618034,35 also form part of this nest but have not been included since they do not give any additional information. At the time of replanting in 1978, there was a strong upward vertical gradient in the groundwater. This is a result of saturation of the valley areas following agricultural development and the consequent saline seep that had formed just downslope of the nest.

Since 1982 and associated with the general decline in groundwater heads, a slight downward vertical gradient has formed through the winter and spring months. As pressure heads at depth (bore 61618032) have reduced, presumably through reduction in the upslope groundwater levels, the saline seep has receded (pasture observations by G Anderson, CSIRO) and local recharge of fresh winter rains has been possible.

At the Stene's strip plantings site there are two nests that are of interest located in the valley floor near the stream. As shown in Figure 6, bore nest 61218016,46 is located in a reforested plot just upslope from the stream while nest 61218018,19,47 is positioned in pasture in the centre of the main stream. The reforested nest (Figure 21) showed in the first four years of monitoring small downward vertical gradients following winter recharge. No saline groundwater discharge was observed. However, since 1982 a strong upward gradient has developed at the time of year when groundwater

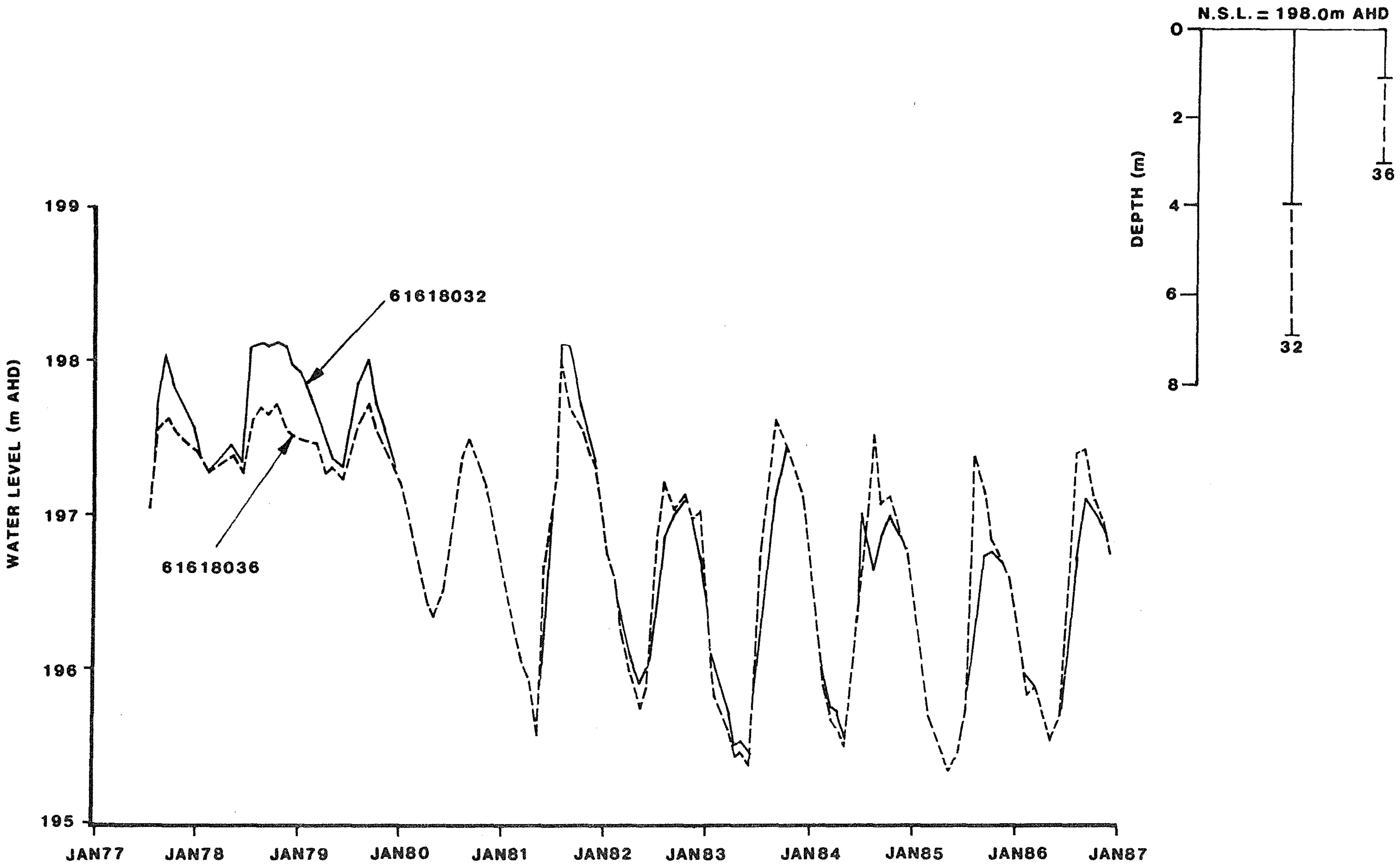

Figure 20. Flynn's Hillslope: Hydrograph of Bore Nest 61618032,36

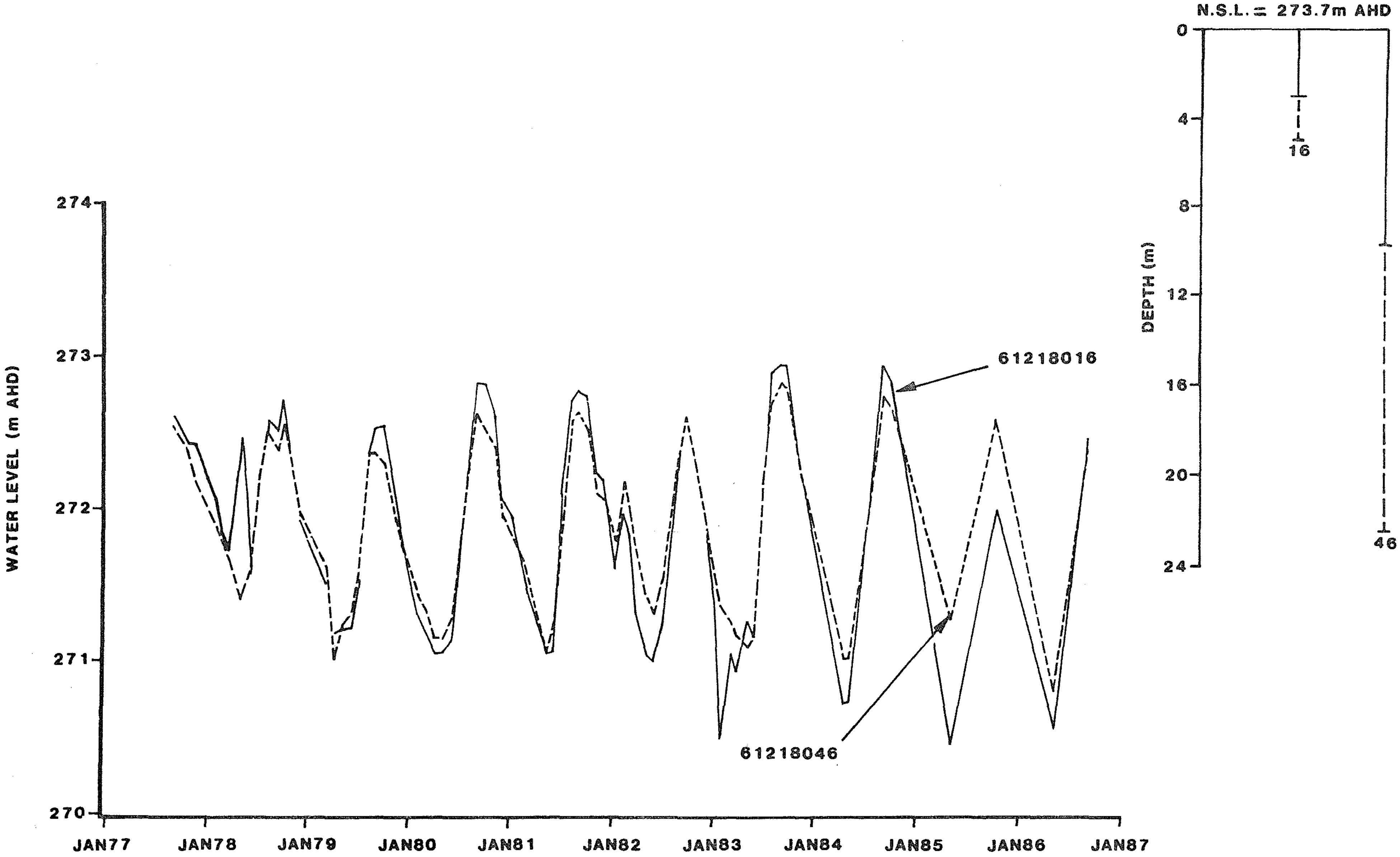

Figure 21. Stene's Strip Plantings: Hydrograph of Bore Nest 61218016,46

levels are at minimum (autumn). This is considered to be a consequence of the trees tapping and lowering the water table at a depth of 4 metres (bore 61218016) while having no influence on the groundwater system at a depth greater than 10 metres (bore 61218046).

The nest located in pasture in the centre of the main valley (61218018,19,47) shows a strong upward vertical gradient which exists throughout the year (Figure 22). This is the typical saline seep situation where saline groundwaters contribute salt to the soil surface. The salt is transported into the stream during winter and produces high stream salinities. Upslope plantings appear to be insufficient to have affected the saline discharge in this area.

The water levels for bore nest 61218060,61, located in reforestation near the stream at the valley plantings is presented in Figure 23. Bores 61218058,59 are part of this nest but are not included because they do not give any further information. In the initial years following planting (1979), a downward vertical gradient was present. As the groundwater level reduced, an upward gradient developed in the latter years. A similar response was observed for the nest 61218056,57 (Figure 24) positioned just 80m upslope of the previous nest. This showed initially no vertical gradients, but in later years a substantial upward gradient was induced with the drop in groundwater levels. The development of an upward vertical gradient after the trees were of age 3 to 4 years is similar to that observed under the reforestation at the strip plantings site (Figure 21). It appears that the trees at this age had sufficient root development to tap the shallow groundwaters, lower the water table and induce an upward groundwater pressure gradient.

The final bore nest to be examined is 61218105,07 (Figure 25) located in the valley reforestation of Maringee Farms, 70m from the stream invert. A strong upward gradient has been present

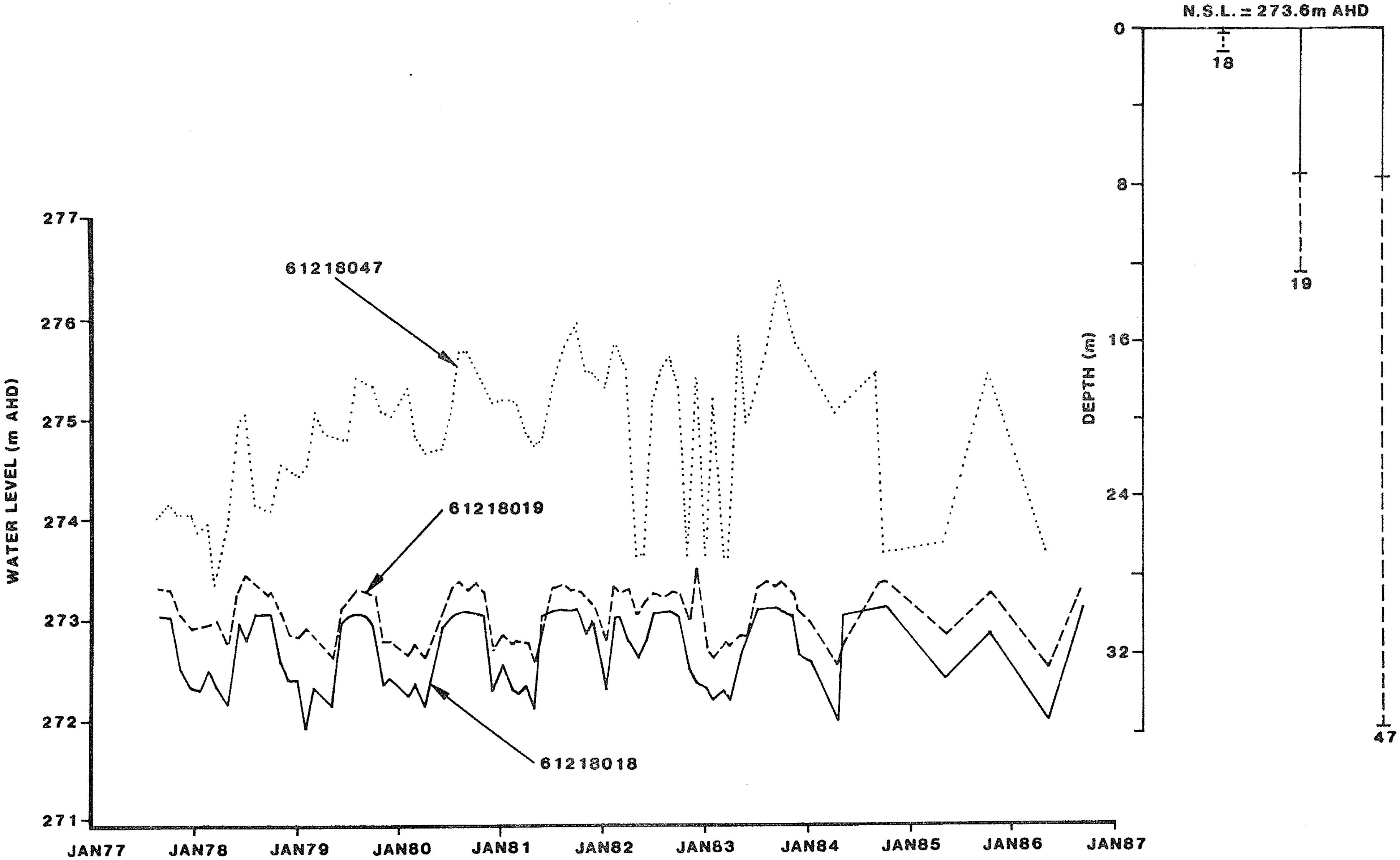

Figure 22. Stene's Strip Plantings: Hydroqraph of Bore Nest 61218018,19,47

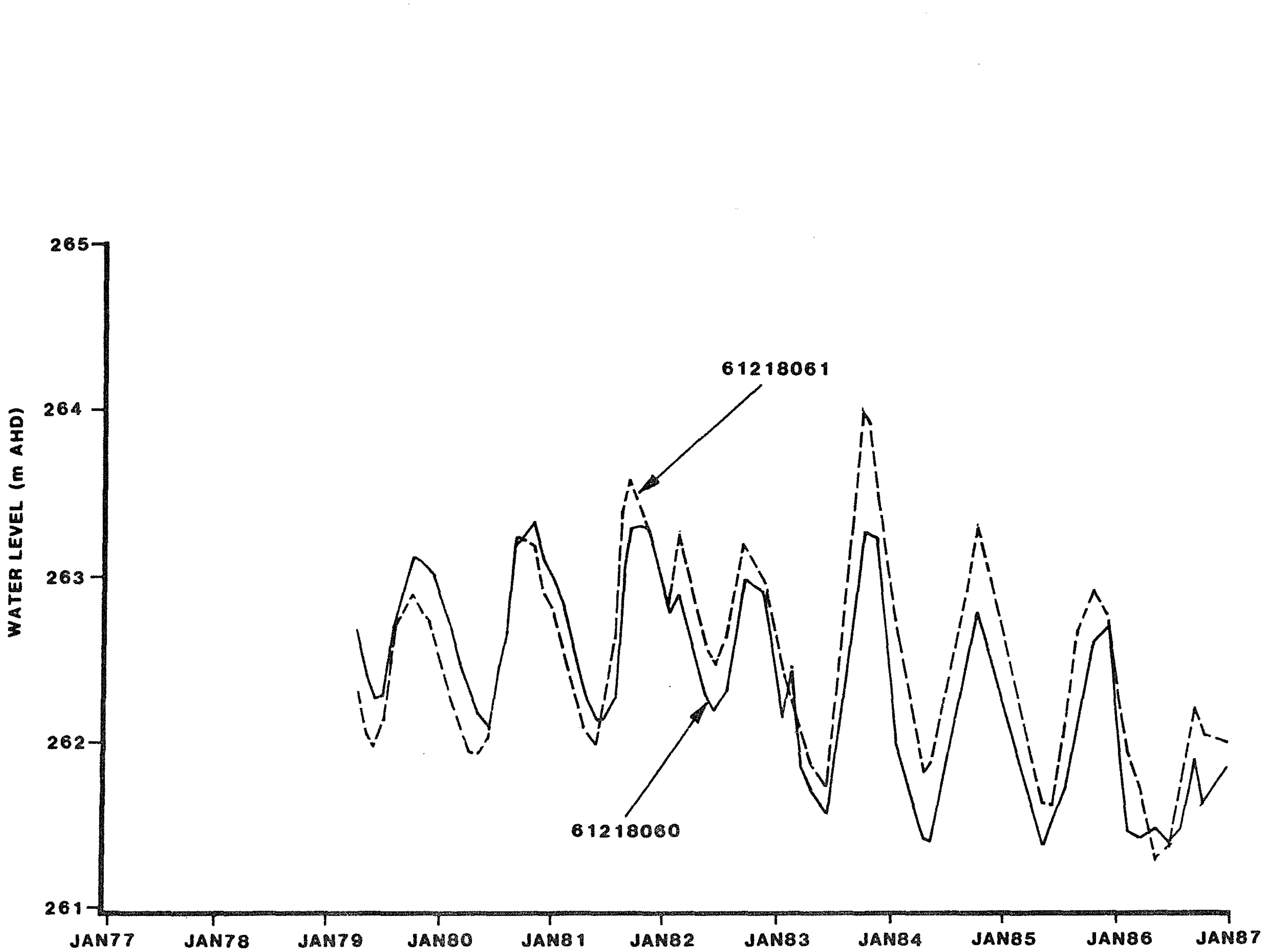

Figure 23. Stene's Valley Plantings: Hydrograph of Bore Nest 61218060,61

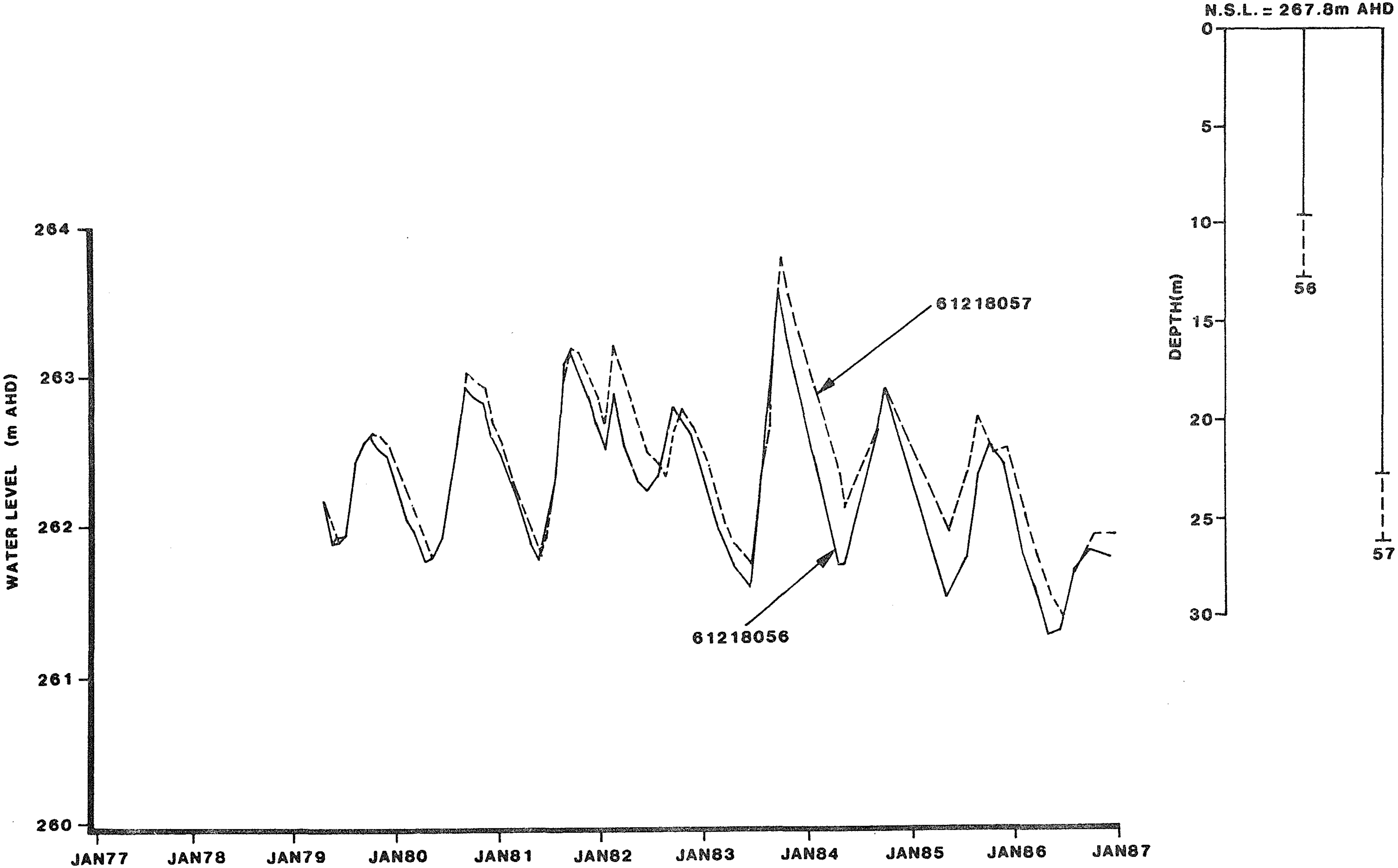

Figure 24. Stene's Valley Plantings: Hydrograph of Bore Nest 61218056,57

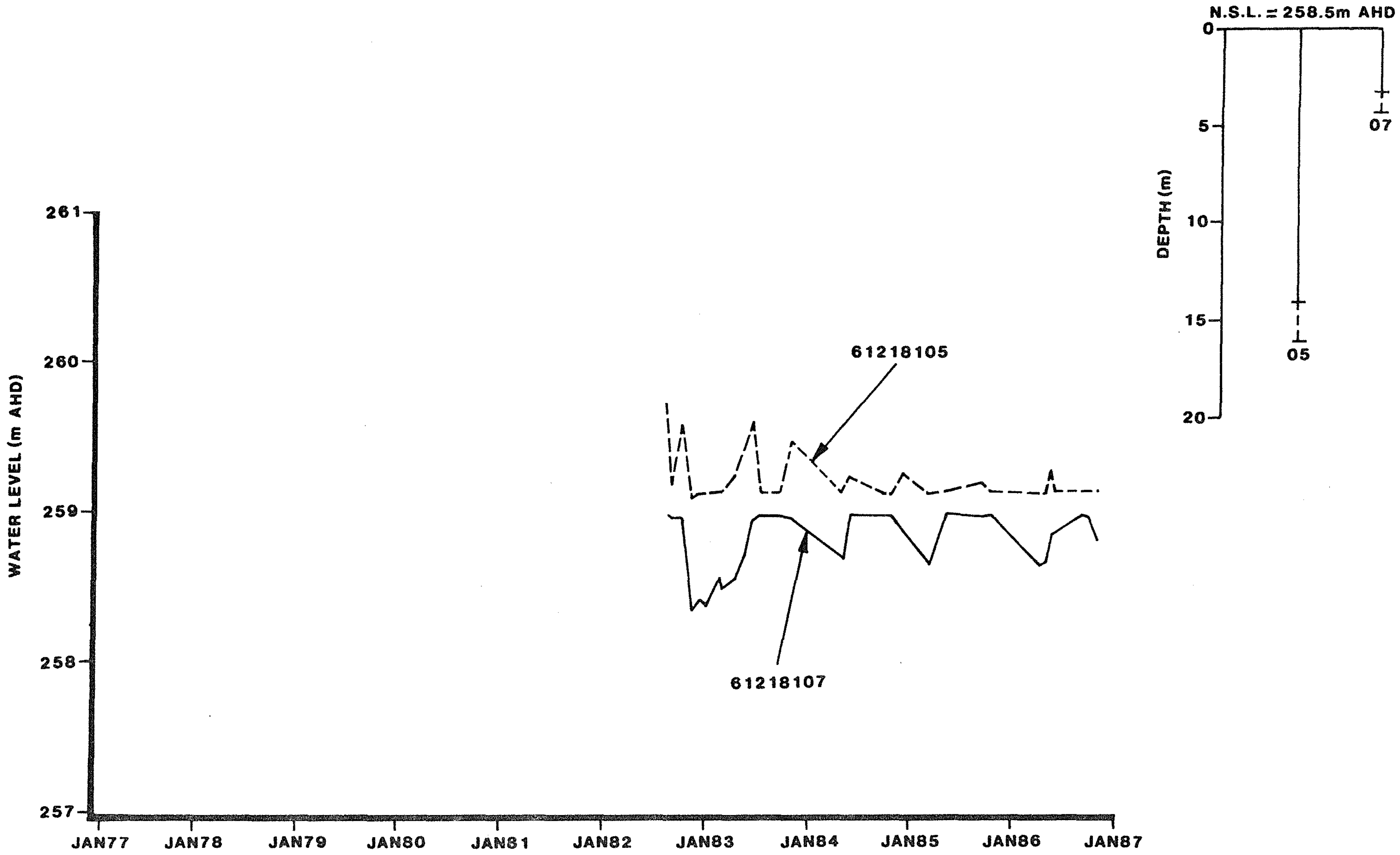

Figure 25. Maringee Farms : Hydrograph of Bore Nest 61218105,07

at this discharge site since monitoring began. A hydrogeological survey (Martin, 1984) at this site showed that upward gradients were noticeable up to 150 m from the stream. This site is regarded as a typical broad flat saline valley characteristic of many of the harshest rehabilitation sites in the eastern areas of the Wellington Reservoir catchment.

4.3 Correlation with Site Crown Cover

Table 2 lists all site averaged data used in correlating changes in groundwater level with the degree and density of reforestation. Maringee Farms data are not included for reasons given in section 3.2. The table includes the mean crown covers as measured in December 1987 (data are listed in Appendix B together with the mean for each site). The next column gives the proportion of the originally cleared land that is reforested (proportion planted). The 'site crown cover' (third column) is defined in this study as the product of the mean crown cover (%) and the proportion planted. This parameter is a simple index of the transpirative capacity of the reforestation from the time of planting to December 1987.

Table 2 also lists the mean changes in groundwater level between 1979 and 1986 at 6 of the 7 experimental sites. Both the absolute change in groundwater level beneath the reforestation and the change relative to the groundwater levels under the pasture (control) are considered. Stene's agroforestry is not included since monitoring of the groundwaters at this site did not begin until 1981. Note that reforestation and monitoring began at Flynn's farm and Stene's strip plantings prior to 1979. It was decided, in the case of this analysis, to ignore the differing ages of the sites. Consistency between years of measurement is more important due to the large variation in annual rainfall.

The linear regression of minimum groundwater level change (1979-1986) on site crown cover is shown in Figure 26 for the

Table 2 : Data Used in Forming a Correlation Between Mean Changes in Groundwater Level and Site Crown Cover.

EXPERIMENTAL SITE	MEAN CROWN COVER(%) (1)	PROPORTION PLANTED(%) (2)	SITE CROWN COVER(%) (3)	MEAN CHANGES IN MINIMUM GROUNDWATER LEVEL BETWEEN 1979 & 1986(4) ABSOLUTE (m)	RELATIVE TO PASTURE (m)
			X	Y1	Y2
FLYNN'S FARM					
Hillslope	29	70	20.3	-2.21	-2.12
Landscape	43	13	5.6	-0.27	-0.17
Agroforestry	14	85	11.9	-1.19	-1.09
STENE'S FARM					
Strip Plantings	47	13	6.1	0.26	-0.58
Valley Plantings	41	30	12.3	-0.76	-1.59
Agroforestry	25	50	12.5	(5)	(5)
Arboretum	39	70	27.3	-2.51	-3.34

Notes : (1) The collection of crown cover data and calculation of mean values are discussed in section 3.2. The data are listed in Appendix B together with the mean for each site.

(2) The percentage of the cleared land that was successfully planted with trees (reforested).

(3) Site crown cover (%) is a product of mean reforestation crown cover (%) and proportion planted (fraction)

(4) Negative values correspond to reductions in groundwater level.

(5) Groundwater monitoring at Stene's agroforestry did not commence until 1981.

(6) Linear regressions:
Absolute : $Y1 = 0.60 - 0.12 * X$; $r^2 = 0.92$
Relative to Pasture :
$$Y2 = 0.37 - 0.13 * X; \; r^2 = 0.97$$

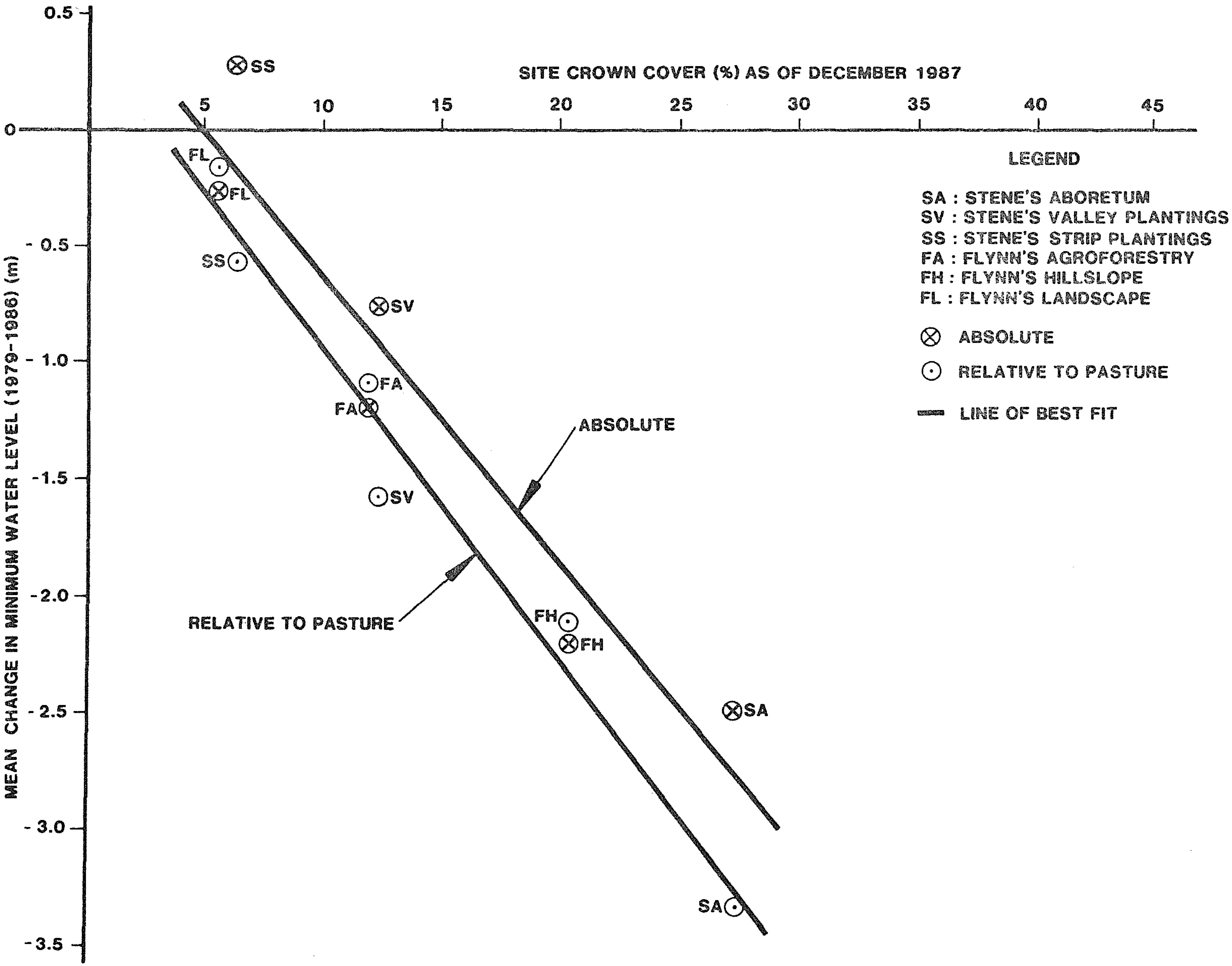

Figure 26. Effect of Site Crown Cover on Mean Changes in Minimum Water Level (1979-1986)

experimental sites previously discussed. Regressions were calculated for both absolute groundwater level changes and groundwater level changes relative to pasture. The calculated regression equations and corresponding correlation coefficients are listed in the notes of Table 2. The regressions clearly indicate that the magnitude of groundwater level change is strongly dependent on site crown cover. The fact that the regression intercepts are close to the origin shows that the net change in groundwater level over seven years is almost directly proportional to the site crown cover, i.e. a doubling in groundwater level reduction would require a doubling in site crown cover. The regression can also be used to determine the level of site crown cover necessary to achieve a required groundwater level reduction. The site crown cover may then be achieved by a range of combinations of plantations crown cover and proportion planted, whose product is equal to the given site crown cover. This approach should be reasonable within the range of data in Table 2.

5. GROUNDWATER SALINITY

5.1 Site Response

The water quality samples taken from bores are dependent on the slotted length of the bore. Long slotted lengths may intersect more than one soil stratum while short slotted lengths are more characteristic of the adjacent soil stratum. Consequently the salinity of the water within a bore can vary quite significantly over the depth range of the groundwater (Anderson et al., 1982).

The water quality of groundwaters also varies greatly with location, that is, from bore to bore within a field. This is because the distribution of salt storage, both over area and within the soil profile, is highly variable (Schofield and Ruprecht, 1988). Subsoil clays generally have the highest concentrations of salt, but can also be very variable. Figure 27 presents the isohalines at the Stene's arboretum site in 1979. These isohalines were derived from salinities corresponding to the minimum bore water levels. In most of the valley areas, groundwater salinities were found to be of the order 2000 mg/L TSS while the south eastern portion of the site had much higher salinities of up to 12,000 mg/L TSS.

No attempt was made in this report to analyse the salinity characteristics of all of the bores at the 8 experimental sites. The general site water quality was considered more appropriate due to the large variability of groundwater salinity within a site, as discussed above. Table 3 presents the mean annual groundwater salinities for the 8 experimental sites. The means are calculated from the salinity values corresponding to the minimum groundwater level in every bore at each site. Appendix D lists additional to the means, the number of observations, standard deviation and maximum and minimum salinities. Some important observations can be made from this analysis:

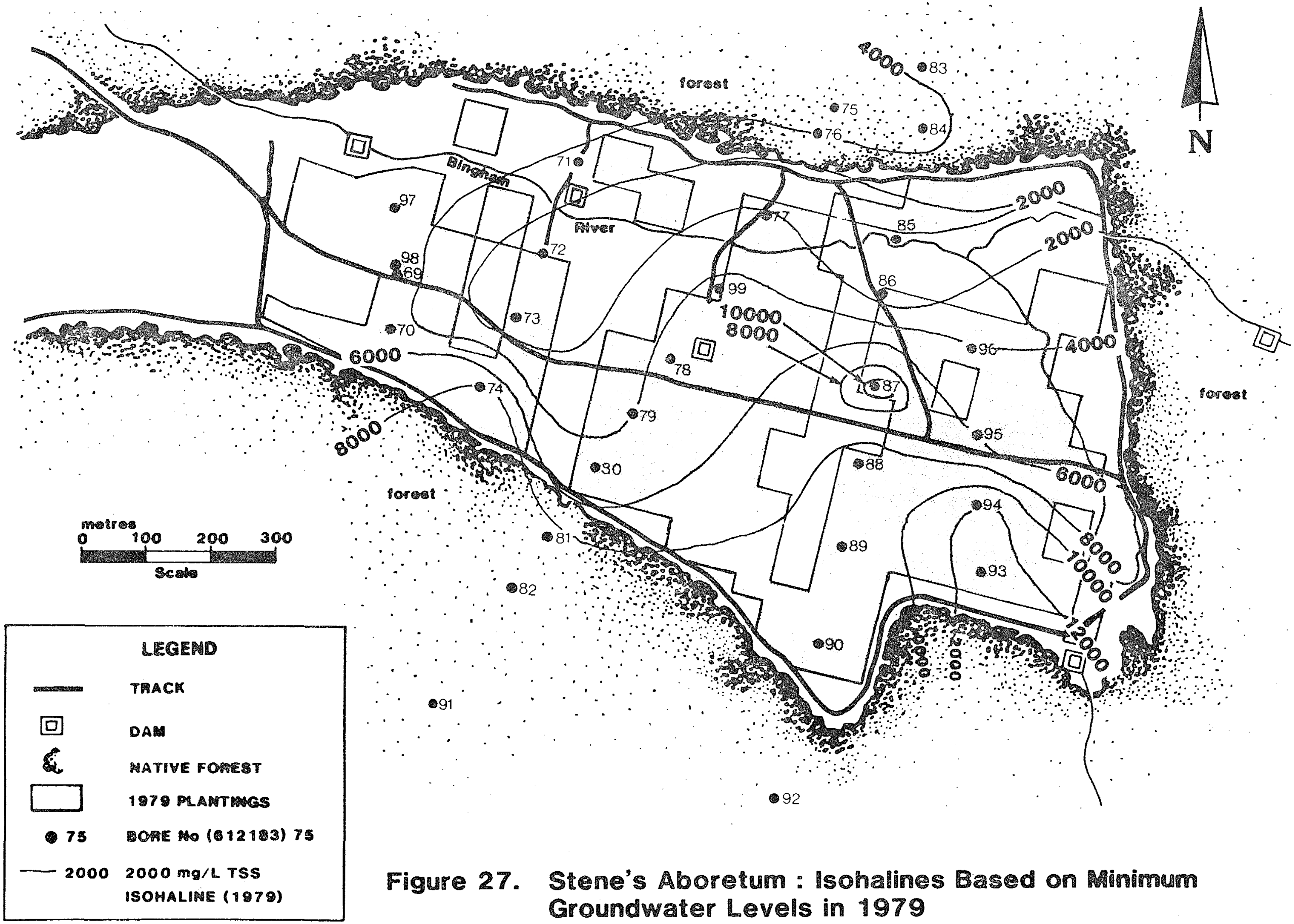

Figure 27. Stene's Aboretum : Isohalines Based on Minimum Groundwater Levels in 1979

Table 3: Mean Annual Groundwater Salinities

MEAN GROUNDWATER SALINITY (mg/L TSS) (1)

YEAR	FLYNN'S FARM			STENE'S FARM				MARINGEE
	Hillslope	Landscape	Agroforestry	Strip	Valley	Agroforestry	Arboretum	FARMS
1978	7364	4792	2375	7538				
1979	6605	4260	2402	7549	5494		5548	
1980	6761	4362	2198	6893	4968		5859	
1981	6009	3867	2039	6646	5130	6626	5366	
1982	6396	4296	2134	7234	3677	6482	2775	15797
1983	5869	5106	2149	7494	4774	6003	5144	15520
1984	6058	4843	2062	6839	4563	4555	4075	14981
1985	4908	5628	2133	6743	3556	5283	3091	13332
1986	5519	4040	1829	6662	4624	4781	4103	15222

Note: (1) The means are calculated from the salinity values corresponding to the minimum groundwater level in each bore.

(2) Appendix D also lists the number of observations, standard deviation and maximum and minimum salinities.

(i) The most favourable site, in terms of water quality, is Flynn's agroforestry. It had groundwater salinities of just over 2,000 mg/L TSS. The harshest site was Maringee Farms with salinities of 15,000 mg/L TSS.

(ii) The site standard deviations of bore salinities (Appendix D) are of the same magnitude as the yearly means. This demonstrates that the groundwater salinities within a site and over the depth range of the groundwater, are highly variable. The minima reflect the perched fresh groundwaters sampled in the shallow bores. The maxima correspond to the deeper saline groundwaters.

(iii) There is a trend for the quality of the water in the bores to improve, that is, salinities have been seen to reduce in the later years of this study. This has been most noticeable at the sites where the greatest water table reductions have occurred (Flynn's hillslope and agroforestry and Stene's valley plantings, agroforestry and arboretum). The most likely explanation of these results is that the general lowering of the water table at these sites has enabled fresh rainwater to recharge the groundwater system and this is thus reflected in the water samples that have been taken.

5.2 Bore Nest Response

A more detailed investigation of water quality response was performed for the two nests: 61618032,34-36 (Flynn's hillslope, Figure 3) and 61218058-61 (Stene's valley plantings, Figure 7). As discussed in section 4.2, the Flynn's hillslope nest is located between an extensive saline seep in the valley and a hillslope planting. In the initial years of reforestation a strong upward vertical gradient was observed from the nest. This changed to a downward gradient in the winter months of the latter years. The water level and salinity responses of each bore in this nest are presented in Figure 28 together with a

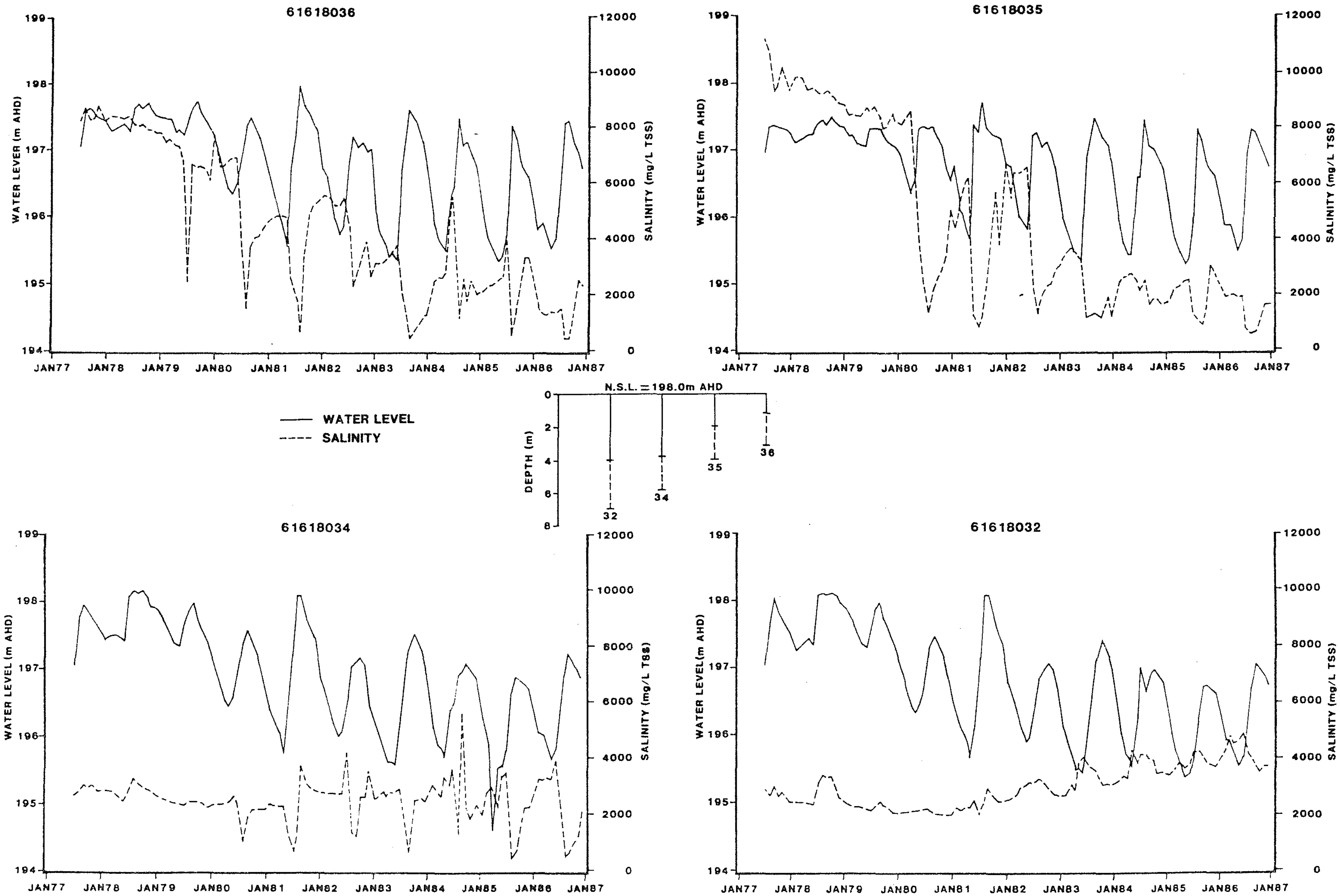

Figure 28. Flynn's Hillslope: Groundwater and Salinity Levels in Bore Nest 61618032,34-36

schematic showing the depth of the bores below the natural surface level (N.S.L.) and their length of slotting. The two shallow bores, 61618035 and 61618036, have shown reductions in

salinity from 10,000 mg/L TSS to 1,000 mg/L TSS. The deeper bores, 61618032 in particular, have shown increases in groundwater salinity. This response is a consequence of the reforestation which dewatered the area surrounding the nest sufficiently to allow winter rains to infiltrate to the water table. Lower salinities at the water table would tend to result from this fresh recharge. This was observed in the shallow bores that sample these waters. Increases in groundwater salinity at a depth of approximately 3 to 4 metres below the water table may be due to the addition of salt leached from vertically above.

The Stene's valley plantings bore nest (61218058-61) is located near the stream in the valley reforestation. Its water quality response is presented in Figure 29. Bore 61218060 is slotted at about the level the water table was in the later years of reforestation (5m below the surface). An increase of groundwater salinity from 4 000 to 9 000 mg/L TSS was observed. This increase occurred over a period of one year. The deeper bores, 61218059 and 61218061, slotted at depths greater than 2.5m below the water table have shown slight decreases in salinity.

Three possible explanations for the increase in salinity at the water table can be provided. Firstly it could be a consequence of an increased extraction of soil water by the replanted trees at and near the water table causing an increase in the concentration of salt. Secondly it could be caused by an accumulation of salts at the water table as a result of upward groundwater flow (Figure 22). Thirdly, because the time scales involved with the above processes are expected to be much longer than the one year observed, it may not be a real increase at all, but rather an inconsistency in the data caused

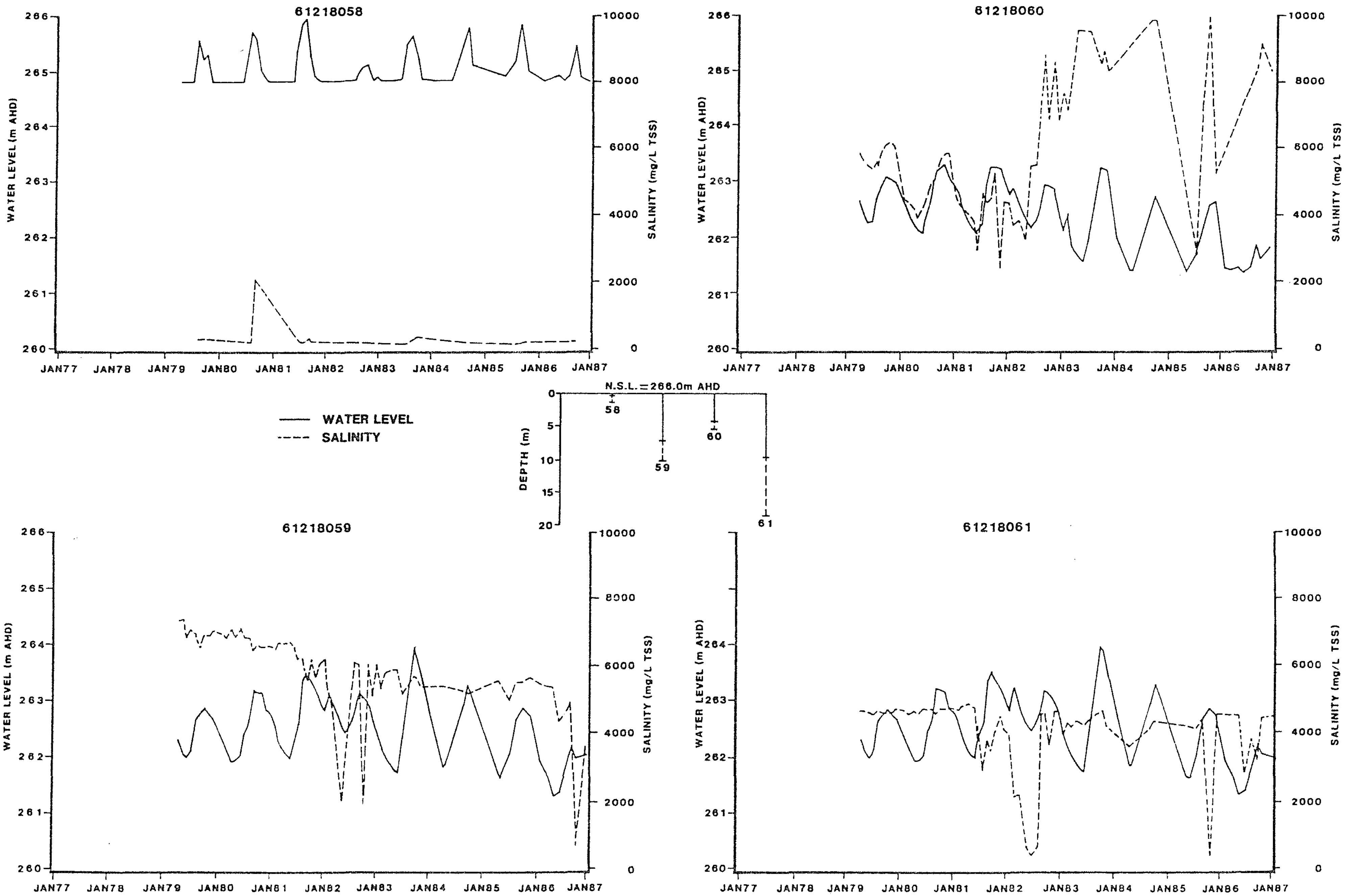

Figure 29. Stene's Valley Plantings: Groundwater and Salinity Levels in Bore Nest 61218058-61

by deterioration in bore condition and sampling difficulties over the period of record. At present, it is not possible to determine the relative contributions of these three factors.

6. CONCLUDING DISCUSSION

During the study period (1978 to 1986) the annual rainfall in the research areas were generally below average (Sadler et al., 1987). In spite of this, groundwater levels under pasture at most sites are still rising as a result of previous clearing. However, in areas under the influence of reforestation, reductions in the water table have generally been observed. Reductions in minimum groundwater level of greater than 4 metres occurred at the midslope of the extensive Stene's arboretum reforestation site. A lowering of 2 metres was observed downslope of a hillslope planting located above an extensive saline seep (Flynn's hillslope). The groundwaters under valley reforestation at some sites showed reductions of 1 to 2 metres depending on the extent of replanting upslope. At some other sites no absolute lowering of the water table was observed. However, relative to the pasture response, it can be concluded that tree planting has had a positive effect in lowering groundwater levels.

The response of the groundwater system to reforestation is likely to depend on a number of factors including depth to groundwater, harshness of the site (groundwater salinity), species planted, planting strategy (location of the reforestation in the landscape), rainfall, soil properties such as saturated hydraulic conductivities, proportion of the cleared land that was reforested (proportion planted), and the stem density at planting and the subsequent crown cover achieved as the trees mature. Figure 26 (section 4.3) shows for the range of data collected to date, a linear relationship between the mean change in reforested minimum groundwater levels between 1979 and 1986 (absolute and relative to pasture groundwater levels) and the product of the mean crown cover of the reforestation and the proportion of the landscape that was reforested (site crown cover). This strong correlation implies that:

(i) Irrespective of species planted, planting strategy, etc, higher stem densities of tree planting, and subsequent crown covers, and larger proportions of the cleared landscape that is reforested, result in greater rates of reduction in groundwater level.

(ii) High density plantations are more effective in lowering groundwaters than agroforestry strategies for a given area of reforestation.

(iii) The poor performance of the Flynn's landscape and Stene's strip plantings sites is a result of an insufficient proportion of the landscape being reforested (13%). The better performing sites such as Flynn's agroforestry and hillslope and Stene's valley plantings, agroforestry and arboretum have either large percentage reforestation (up to 85%) and/or high tree crown covers (up to 47%).

It must be noted that the correlation between site crown cover and groundwater level reduction does not include the influence that species type has on the water table. In general a large range of species were planted at each of the experimental sites (Table 1) and therefore an averaged response has been examined in this study. It has not been possible to isolate the separate effects of different species on water table responses. It is highly probable that some species have a greater effect on lowering the water table than others (Hookey et al., 1987). Therefore, the issue of species selection in catchment rehabilitation should not be ignored.

The establishment of the experimental sites examined in this study aimed at deriving suitable reforestation strategies for controlling saline groundwater discharge into the valley areas and thus improving stream salinity. The reforestation strategies for the eight experimental sites can be categorised into four groups.

Flynn's landscape and Stene's strip plantings sites represent a high density low percentage (less than 15%) planting placed strategically in the landscape near streamlines and seeps where groundwater discharge occurs. Because the trees are placed low in the landscape, groundwater level reductions under this strategy are most likely to occur from extraction of water from the water table. At present, this approach has not been seen to have a significant impact on the local groundwater systems and therefore this strategy alone is considered insufficient to reverse stream salinities.

The second group are sites where the valley areas from the streamline have been planted at a high density and account for 20% to 40% of the landscape. Reductions in groundwater levels predominantly occur through extraction of water by the trees from the water table. This strategy is termed valley reforestation. Stene's valley plantings and Maringee Farms sites are based on this approach. The former had 30% of the cleared landscape reforested and has shown a lowering of the water table in the valley of about one metre. Maringee Farms, planted in 1981 and 1982, is a younger and harsher site (poor survival of plantings) and therefore has not produced a substantial change in the valley water table levels. Even though, where adequate plantings did exist (30-40% of the landscape), a promising depression of the water table was observed.

The third group involves sites where the lower slopes are reforested and extraction of water from the water table occurs, but upslope 'recharge control' plantings is the major contributing factor to the downslope groundwater response. A large percentage of reforestation is involved (>50%). Flynn's hillslope and Stene's arboretum sites are based on this strategy. Due to the extensiveness of their treatments (70% reforestation at a high stem density), these two sites have shown the greatest reductions of the water table. In particular at Stene's arboretum where the plantings encompass the area immediately surrounding the stream (Figure 9), a lowering of the water table in this area of two metres was observed.

The final reforestation category examined in this study is represented by Flynn's and Stene's agroforestry sites. These experimental sites are characterised by their wide-spaced (low density) plantings with mean site crown covers of 14% and 25% respectively. Both sites have a high percentage of reforestation. Extraction of water from the water table and recharge control are both considered to have an important influence on the groundwater system response. Reductions in groundwater level of about one metre were observed below each site.

Even though it is recognised that higher stem densities at planting and consequent crown covers lead to greater groundwater level reductions, the observed reductions at the agroforestry sites are significant and should not be discounted. As agroforestry strategies are designed to improve the economic returns from the land (through combined agriculture and forestry production), they have the potential to be taken up by individual private land owners and extended over a high percentage of the landscape. The hydrologic benefits through reduced groundwater recharge from mid and upslope areas, would be substantial.

The above discussion does not clearly highlight a preferred reforestation strategy. Many factors will affect the final choice of a particular strategy in a particular case. However a number of general points can be made. The strategy of low percentage plantings (less than 20% of the upslope cleared land), placed strategically in the landscape near streamlines and seeps is considered insufficient to reverse stream salinities, certainly within the first 10 years of planting. Not surprisingly, the larger the area planted and the denser the plantation, the larger and quicker is the reduction in groundwater. Nevertheless, agroforestry density plantings over high proportions of the landscape and on favourable sites have shown significant reductions. In terms of location of the plantings in the landscape, valley reforestation is the most suitable strategy for controlling saline groundwater discharge since lowering the groundwaters in this area will have the most immediate response on groundwater salt contributions to streamflow.

This study has suggested that planting 40% of the cleared landscape in the valley areas to suitable eucalypts at a high stem density within seven years will result in reductions in minimum groundwater level of greater than one metre (assuming a crown cover of approximately 40% has been attained in this time). It would appear that given enough time the water table would lower further to a level where its influence on streamflow generation would be negligible and stream salinities would consequently improve. Higher proportions of planting would provide more rapid reductions in water table levels and improvements in salinity, however, such strategies would imply a much greater reduction in land available for agricultural use.

However, in the longer term there is some concern with the reforestation strategy of solely planting in the valley areas. The long-term survival of these trees may be endangered by salt accumulation in the root zone and/or increased salinity of groundwater used by the trees (Williamson, 1986; Morris and Thomson, 1983). This would primarily be caused by convection of salts from the cleared recharging upslope areas to the forested valley floors.

In this study at a valley planting site where only 30% of the landscape has been planted and where upslope recharge is continuing (Stene's valley plantings), groundwater salinity has increased as the water table declined (Figure 29). This observation could be construed as the initial evidence that valley reforestation will lead to a major redistribution of salts from the upslope to the valley areas and cause consequent problems of survival of its vegetation. However as discussed in Chapter 5, this is not the case since the actual cause(s) of the increase in salinity at the water table over the period recorded is most likely due to local effects. The time scale for the redistribution of salts from upslope recharge areas to valley areas is considered to be long term (30 plus years).

Nevertheless, the observation of an increase in groundwater salinity at the water table emphasises the concern to select appropriate species with an ability to continue to transpire water in such harsh saline conditions and to minimise groundwater recharge in upslope areas. The latter has a two-fold effect. Firstly it limits the quantity of salt that would be transported to the valley. Secondly it aids in stabilising the water table in the valley sufficiently below the root zone so that it will be no longer necessary for the trees to draw on this supply of water (Morris and Thomson, 1983). Means of achieving recharge minimisation economically, either by commercial tree plantations, agroforestry or modified agricultural practice, should be actively pursued.

Evidence of reductions of salinity in the lowering shallow groundwater above a saline seep were observed at a site where a high proportion of the hillslope upslope of the seep had been planted (Flynn's hillslope, Figure 28). Noting the observations that the seep has been receeding, this represents a general desalinisation of the shallow soils and provides an opportunity to plant these previously saline areas and further reduce salt discharge. This high percent replanting strategy provides the most secure approach for generating a stable state of salt storage within the soil profile similar to the one it had prior to agricultural development taking place. Its impact on agricultural production is, however, substantial.

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APPENDIX A

GROUNDWATER OBSERVATION BORE DETAILS

(Abbreviations used :

S.W.R.I.S. : State Water Resources Information System
T.O.I.T. : Top of inner tube
N.S.L. : Natural Surface Level
B.O.T. : Bottom of tube)

Flynn's Farm - Hillslope & Landscape

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)
61618001	1	04/07/1977	REFOREST	192.540	192.150	187.810	3.00	4.730	0.390	4.340
61618003	3	04/07/1977	REFOREST	195.060	193.010	172.160	3.00	22.900	2.050	20.850
61618004	4	01/08/1979	REFOREST							
61618005	5	04/07/1977	REFOREST	192.570	192.410	179.020	3.00	13.550	0.160	13.390
61618006	6	01/08/1979	REFOREST							
61618007	7	04/07/1977	REFOREST	192.760	192.480	184.490	3.00	8.270	0.280	7.990
61618008	8	04/07/1977	REFOREST				1.00	2.720		
61618009	9	04/07/1977	REFOREST	196.150	195.720	190.470		5.680	0.430	5.250
61618010	10	04/07/1977	REFOREST	197.420	196.990	187.280	3.00	10.140	0.430	9.710
61618011	11	04/07/1977	REFOREST	198.220	197.890	189.730	3.00	8.490	0.330	8.160
61618012	12	04/07/1977	REFOREST	199.450	199.200	189.620	3.00	9.830	0.250	9.580
61618013	13	04/07/1977	REFOREST	201.050	200.630	196.990	3.00	4.060	0.420	3.640
61618014	14	04/07/1977	REFOREST	203.080	202.670	198.020	1.00	5.060	0.410	4.650
61618015	15	04/07/1977	REFOREST	203.650	203.280	201.370	1.00	2.280	0.370	1.910
61618016	16	04/07/1977	REFOREST	205.000	204.660	202.090	1.00	2.910	0.340	2.570
61618017	17	04/07/1977	REFOREST	207.020	206.580	198.270	3.00	8.750	0.440	8.310
61618018	18	04/07/1977	PASTURE	208.660	208.270	205.770		2.890	0.390	2.500
61618020	20	04/07/1977	REFOREST	195.620	195.320	189.930	3.00	5.690	0.300	5.390
61618021	21	04/07/1977	REFOREST	195.670	195.360	185.880		9.790	0.310	9.480
61618022	22	04/07/1977	REFOREST	194.650	194.170	184.570	3.00	10.080	0.480	9.600
61618023	23	04/07/1977	REFOREST	193.910	193.580	183.750	3.00	10.160	0.330	9.830
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	204.850	195.570	3.00	9.470	0.190	9.280
61618027	27	04/07/1977	PASTURE	210.410	210.270	195.740	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
61618029	29	04/07/1977	REFOREST	205.020	204.870	185.720	3.00	19.300	0.150	19.150
61618030	30	04/07/1977	REFOREST	204.980	204.900	191.650	3.00	13.330	0.080	13.250
61618031	31	04/07/1977	REFOREST	207.090	206.930	192.260	3.00	14.830	0.160	14.670
61618032	32	04/07/1977	REFOREST	198.080	197.980	191.080	3.00	7.000	0.100	6.900
61618033	33	04/07/1977	REFOREST	198.500	198.350	188.240	3.00	10.260	0.150	10.110
61618034	34	04/07/1977	REFOREST	198.070	197.920	192.170	2.00	5.900	0.150	5.750
61618035	35	04/07/1977	REFOREST	198.010	197.850	193.930	2.00	4.080	0.160	3.920
61618036	36	04/07/1977	REFOREST	198.290	198.190	195.080	2.00	3.210	0.100	3.110

Flynn's Agroforestry

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	52	18/05/1978	REFOREST	186.198	186.044	180.178	2.00	6.020	0.154	5.866

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)
61218001	1-76	01/06/1976	REFOREST	278.562	277.900	265.432	6.00	13.13	0.662	12.468
61218002	2-76	01/06/1976	REFOREST	278.616	277.960	269.616	7.00	9.00	0.656	8.344
61218003	3-76	01/06/1976	REFOREST	279.172	278.490	268.862	7.00	10.31	0.682	9.628
61218004	4-76	01/06/1976	REFOREST	281.253	280.620	272.363	7.50	8.89	0.633	8.257
61218005	5-76	01/06/1976	REFOREST	285.732	285.060	273.232	9.00	12.50	0.672	11.828
61218006	6-76	01/06/1976	PASTURE	282.359	281.700	271.849	8.00	10.51	0.659	9.851
61218007	7-76	01/06/1976	REFOREST	290.118	289.500	273.588	13.00	16.53	0.618	15.912
61218008	8-76	01/06/1976	PASTURE	295.767	295.090	274.677	18.00	21.09	0.677	20.413
61218009	9-76	01/06/1976	PASTURE	291.092	290.400	274.432	14.00	16.66	0.692	15.968
61218010	10-76	01/06/1976	FOREST	293.985	293.370	263.635	18.00	30.35	0.615	29.735
61218011	11-76	01/06/1976	REFOREST	275.085	274.490	266.735	8.00	8.35	0.595	7.755
61218012	12-76	01/06/1976	REFOREST	282.888	282.200	279.388	2.00	3.50	0.688	2.812
61218013	13-76	01/06/1976	REFOREST	279.173	278.550	275.673	2.00	3.50	0.623	2.877
61218014	1-77	30/07/1977	REFOREST	273.511	272.850	251.511	18.27	22.00	0.661	21.339
61218015	2-77	30/07/1977	REFOREST	275.056	274.540	257.056	5.00	18.00	0.516	17.484
61218016	3A-77	30/07/1977	REFOREST	273.733	273.180	268.153	2.00	5.58	0.553	5.027
61218017	3C-77	30/07/1977	REFOREST	273.731	273.200	271.961	1.00	1.77	0.531	1.239
61218018	4A-77	30/07/1977	PASTURE	273.587	273.060	271.787	1.00	1.80	0.527	1.273
61218019	4B-77	30/07/1977	PASTURE	273.540	273.060	260.510	5.00	13.03	0.480	12.550
61218020	4C-77	30/07/1977	PASTURE	273.603	273.060	267.103	2.00	6.50	0.543	5.957
61218021	5-77	30/07/1977	REFOREST	277.257	276.700	262.107	8.60	15.15	0.557	14.593
61218022	6-77	30/07/1977	REFOREST	279.352	278.790	269.212	5.00	10.14	0.562	9.578
61218023	7-77	30/07/1977	REFOREST	285.845	285.300	257.085	11.00	28.76	0.545	28.215
61218024	8-77	30/07/1977	REFOREST	278.025	277.400	268.355	6.48	9.67	0.625	9.045
61218025	9-77	30/07/1977	REFOREST	276.348	275.890	263.428	8.92	12.92	0.458	12.462
61218026	10-77	30/07/1977	REFOREST	272.549	272.030	254.549	5.00	18.00	0.519	17.481
61218027	11-77	30/07/1977	REFOREST	273.208	272.710	239.768	23.00	33.44	0.498	32.942
61218028	12-77	30/07/1977	REFOREST	271.602	271.060	255.762	6.00	15.84	0.542	15.298
61218029	13-77	30/07/1977	PASTURE	276.153	275.460	261.093	6.00	15.06	0.693	14.367
61218030	14-77	30/07/1977	PASTURE	277.019	276.420	265.199	5.00	11.82	0.599	11.221
61218031	15-77	30/07/1977	FOREST*	281.548	280.980	264.798	6.00	16.75	0.568	16.182
61218032	16-77	30/07/1977	FOREST*	286.888	286.280	262.388	12.00	24.50	0.608	23.892
61218033	17-77	30/07/1977	FOREST	290.012	289.420	266.252	6.00	23.76	0.592	23.168
61218034	18-77	30/07/1977	FOREST	306.491	305.840	277.351	6.00	29.14	0.651	28.489
61218035	19-77	30/07/1977	FOREST	290.274	289.690	261.574	14.00	28.70	0.584	28.116
61218036	20-77	30/07/1977	FOREST	285.239	284.720		5.00		0.519	
61218037	21-77	30/07/1977	REFOREST	277.568	276.940		6.00		0.628	
61218038	22-77	30/07/1977	PASTURE	284.607	284.020		6.00		0.587	
61218039	23-77	30/07/1977	FOREST	290.181	289.640				0.541	
61218040	24-77	30/07/1977	FOREST	297.284	296.710				0.574	
61218041	25-77	30/07/1977	FOREST	287.274	286.670		12.00		0.604	
61218042	26-77	30/07/1977	REFOREST	282.927	282.400	269.387	7.88	13.54	0.527	13.013
61218043	28-77	30/07/1977	REFOREST	276.632	275.980				0.652	
61218044	29-77	30/07/1977	PASTURE	287.460	286.860				0.600	
61218045	30-77	30/07/1977	PASTURE	285.512	284.880				0.632	
61218046	3-77	30/07/1977	REFOREST	273.736	273.170	250.466	13.00	23.27	0.566	22.704
61218047	4-77	30/07/1977	PASTURE	273.558	273.060	237.318	28.24	36.24	0.498	35.742
61218048	10A-77	30/07/1977	REFOREST	272.547	272.000	259.547	8.50	13.00	0.547	12.453
61218049	12A-77	30/07/1977	REFOREST	271.643	271.120	265.053	3.00	6.59	0.523	6.067

* Located in an area of natural regeneration

Stene's Valley Plantings

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)
61218050	1A-78	10/05/1978	FOREST	278.775	278.275	277.075	1.00	1.700	0.500	1.200
61218051	1C-78	10/05/1978	FOREST	278.759	278.260	247.589	2.30	31.170	0.499	30.671
61218052	2A-78	10/05/1978	FOREST	264.095	263.600	262.400	1.00	1.695	0.495	1.200
61218053	2B-78	10/05/1978	FOREST	264.104	263.600	258.604	1.00	5.500	0.504	4.996
61218054	2C-78	10/05/1978	FOREST	264.095	263.600	247.595	5.00	16.500	0.495	16.005
61218055	C-79	19/03/1979	FOREST	274.725	274.240	254.885	3.00	19.840	0.485	19.355
61218056	11-79	19/03/1979	REFOREST	268.306	267.770	255.166	3.00	13.140	0.536	12.604
61218057	C-79	19/03/1979	REFOREST	268.347	267.760	241.797	3.00	26.550	0.587	25.963
61218058	1-79	19/03/1979	REFOREST	266.688	265.920	264.708	1.00	1.980	0.768	1.212
61218059	3-79	19/03/1979	REFOREST	266.514	266.010	255.814	3.00	10.700	0.504	10.196
61218060	2-79	19/03/1979	REFOREST	266.521	266.050	260.701	1.00	5.820	0.471	5.349
61218061	c-79	19/03/1979	REFOREST	266.513	266.030	247.093	9.00	19.420	0.483	18.937
61218062	6-79	20/03/1979	REFOREST	267.508	266.970	256.898	3.00	10.610	0.538	10.072
61218063	7-79	20/03/1979	PASTURE	272.639	272.120	259.369	3.00	13.270	0.519	12.751
61218064	10-79	20/03/1979	PASTURE	277.931	277.430	262.691	3.00	15.240	0.501	14.739
61218065	C-79	20/03/1979	PASTURE	277.981	277.430	243.231	6.20	34.750	0.551	34.199
61218066	C-79	20/03/1979	FOREST	286.866		267.976	3.00	18.890		
61218067	4-79	20/03/1979	REFOREST	267.278	266.800	256.968	3.00	10.310	0.478	9.832
61218068	5-79	20/03/1979	FOREST	262.615	262.090	248.905	3.00	13.710	0.525	13.185
61218069	SITE10	07/08/1979	FOREST	292.220	291.540	272.520	3.00	19.700	0.680	19.020

Stene's Agroforestry

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)
61219081	A1/81S	13/03/1981	REFOREST	276.600	275.800	274.600	1.00	2.000	0.800	1.200
61219082	A1/81D	13/03/1981	REFOREST	276.300	275.800	265.450	1.00	10.850	0.500	10.350
61219083	A2/81S	12/03/1981	REFOREST	270.010	269.210	268.010	1.00	2.000	0.800	1.200
61219084	A2/81D	12/03/1981	REFOREST	269.690	269.210	265.510	1.00	4.180	0.480	3.700
61219085	B1/81S	13/03/1981	REFOREST	272.920	272.120	270.920	1.00	2.000	0.800	1.200
61219086	B1/81D	13/03/1981	REFOREST	272.620	272.120	264.920	1.00	7.700	0.500	7.200
61219087	B2/81S	12/03/1981	REFOREST	269.790	269.020	267.740	1.00	2.050	0.770	1.280
61219088	B2/81D	12/03/1981	REFOREST	269.520	269.020	264.820	1.00	4.700	0.500	4.200
61219089	C1/81S	13/03/1981	REFOREST	271.210	270.450	269.170	1.00	2.040	0.760	1.280
61219090	C1/81D	13/03/1981	REFOREST	270.950	270.450	264.100	1.00	6.850	0.500	6.350
61219091	C2/81S	14/03/1981	REFOREST	269.150	268.350	267.120	1.00	2.030	0.800	1.230
61219092	C2/81D	14/03/1981	REFOREST	268.960	268.350	262.840	1.00	6.120	0.610	5.510
61219093	D1/82S	16/03/1981	REFOREST	270.220	269.420	268.220	1.00	2.000	0.800	1.200
61219094	D1/81D	16/03/1981	REFOREST	269.920	269.420	263.800	1.00	6.120	0.500	5.620
61219095	D2/81S	16/03/1981	REFOREST	269.040	268.240	267.040	1.00	2.000	0.800	1.200
61219096	D2/81D	16/03/1981	REFOREST	268.740	268.240	264.040	1.00	4.700	0.500	4.200

Stene's Arboretum

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)
61218369	1.2/79A	09/05/1979	REFOREST	266.740	266.260	236.300	3.00	30.440	0.480	29.960
61218370	1.3/79	09/05/1979	REFOREST	271.032	270.550	246.092	3.00	24.940	0.482	24.458
61218371	2.1/79	09/05/1979	REFOREST	261.723	261.240	245.893	3.00	15.830	0.483	15.347
61218372	2.2/79	09/05/1979	REFOREST	262.069	261.500	249.849	3.00	12.220	0.569	11.651
61218373	2.3/79	09/05/1979	REFOREST	267.098	266.600	253.608	3.00	13.490	0.498	12.992
61218374	2.4/79	09/05/1979	REFOREST	271.810	271.320	253.770	3.00	18.040	0.490	17.550
61218375	3.1/79	09/05/1979	FOREST	273.639	273.130	260.039	3.00	13.600	0.509	13.091
61218376	3.2/79	09/05/1979	FOREST	271.067	270.580	254.557	3.00	16.510	0.487	16.023
61218377	3.3/79	09/05/1979	REFOREST	262.636	262.120	242.406	4.00	20.230	0.516	19.714
61218378	3.5/79	09/05/1979	REFOREST	263.650	263.190	247.420	3.00	16.230	0.460	15.770
61218379	3.6/79	09/05/1979	REFOREST	265.806	265.290	253.536	3.00	12.270	0.516	11.754
61218380	3.7/79	09/05/1979	REFOREST	269.031	268.500	234.401	3.00	34.630	0.531	34.099
61218381	3.8/79	09/05/1979	FOREST	273.610	273.080	257.350	3.00	16.260	0.530	15.730
61218382	3.9/79	09/05/1979	FOREST	276.414	275.900	257.274	3.00	19.140	0.514	18.626
61218383	4.1/79	09/05/1979	FOREST	272.319	271.850	254.759	3.00	17.560	0.469	17.091
61218384	4.2/79	09/05/1979	FOREST	270.901	270.410	254.181	3.00	16.720	0.491	16.229
61218385	4.3/79	09/05/1979	REFOREST	263.429	262.900	251.469	3.00	11.960	0.529	11.431
61218386	4.4/79	09/05/1979	REFOREST	263.021	262.250	252.381	3.00	10.640	0.771	9.869
61218387	4.5/79	09/05/1979	REFOREST	270.056	269.540	256.416	3.00	13.640	0.516	13.124
61218388	4.6/79	09/05/1979	REFOREST	275.084	274.550	256.864	3.00	18.220	0.534	17.686
61218389	4.7/79	09/05/1979	REFOREST	281.649	281.180	260.489	3.00	21.160	0.469	20.691
61218390	4.8/79	09/05/1979	REFOREST	288.063	287.530	267.873	3.00	20.190	0.533	19.657
61218391	3.10/79	09/05/1979	FOREST	290.849	290.330	262.099	3.00	28.750	0.519	28.231
61218392	4.10/79	09/05/1979	FOREST	305.055	304.530	285.155	3.00	19.900	0.525	19.375
61218393	5.4/79	09/05/1979	REFOREST	275.908	275.370	259.068	3.00	16.840	0.538	16.302
61218394	5.3/79	09/05/1979	REFOREST	274.007	273.470	257.307	3.00	16.700	0.537	16.163
61218395	5.2/79	09/05/1979	REFOREST	271.165	270.680	254.705	3.00	16.460	0.485	15.975
61218396	5.1/79	09/05/1979	REFOREST	267.104	266.580	252.104	3.00	15.000	0.524	14.476
61218397	1.1/79	09/05/1979	REFOREST	261.619	261.080	249.459	3.00	12.160	0.539	11.621
61218398	1.2/79B	17/05/1979	REFOREST	266.779	266.270	252.169	3.00	14.610	0.509	14.101
61218399	3.4/79	17/05/1979	REFOREST	262.207	261.680	253.207	3.00	9.000	0.527	8.473

Maringee Farms

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)
61218101	MA1	26/07/1982	REFOREST	268.051	267.500	239.081	2.00	28.970	0.551	28.419
61218102	MA1A	26/07/1982	REFOREST	268.112	267.530	266.412	1.00	1.700	0.582	1.118
61218103	MA1B	26/07/1982	REFOREST	268.059	267.560	261.109	1.00	6.950	0.499	6.451
61218104	MA1C	26/07/1982	REFOREST	268.115	267.600	255.615	1.00	12.500	0.515	11.985
61218105	MA2	26/07/1982	REFOREST	259.083	258.450	242.283	2.00	16.800	0.633	16.167
61218106	MA2A	26/07/1982	REFOREST	258.956	258.480	257.256	1.00	1.700	0.476	1.224
61218107	MA2B	26/07/1982	REFOREST	258.959	258.480	254.209	1.00	4.750	0.479	4.271
61218108	MA2C	26/07/1982	REFOREST	259.065	258.470	252.295	1.00	6.770	0.595	6.175
61218109	MA2D	26/07/1982	REFOREST	259.001	258.450	247.471	1.00	11.530	0.551	10.979
61218110	MA3	26/07/1982	REFOREST	258.236	257.757	250.636	2.00	7.600	0.479	7.121
61218111	MA3A	26/07/1982	REFOREST	258.312	257.787	256.312	1.00	2.000	0.525	1.475
61218112	MA3B	26/07/1982	REFOREST	258.197	257.747	253.697	1.00	4.500	0.450	4.050
61218113	MA4	26/07/1982	REFOREST	258.706	258.147	242.106	2.00	16.600	0.559	16.041
61218114	MA4A	26/07/1982	REFOREST	258.668	258.147	256.968	1.00	1.700	0.521	1.179
61218115	MA4B	26/07/1982	REFOREST	258.618	258.147	252.118	1.00	6.500	0.471	6.029
61218116	MA4C	26/07/1982	REFOREST	258.552	258.147	248.122	1.00	10.430	0.405	10.025
61218117	MA5	26/07/1982	REFOREST	261.524	261.183	249.904	2.00	11.620	0.341	11.279
61218118	MA5A	26/07/1982	REFOREST	261.567	261.053	259.567	1.00	2.000	0.514	1.486
61218119	MA5B	26/07/1982	REFOREST	261.503	261.003	257.303	1.00	4.200	0.500	3.700
61218120	MA5C	26/07/1982	REFOREST	261.628	261.103	253.628	1.00	8.000	0.525	7.475
61218121	MB1	26/07/1982	PASTURE	283.161	282.561	258.011	2.00	25.150	0.600	24.550
61218122	MB1A	26/07/1982	PASTURE	283.098	282.598	272.098	1.00	11.000	0.500	10.500
61218123	MB1B	26/07/1982	PASTURE	283.157	282.627	268.657	1.00	14.500	0.530	13.970
61218124	MB1C	26/07/1982	PASTURE	283.023	282.543	265.523	1.00	17.500	0.480	17.020
61218125	MB2	26/07/1982	REFOREST	269.744	269.204	256.644	2.00	13.100	0.540	12.560
61218126	MB2A	26/07/1982	REFOREST	269.741	269.251	268.041	1.00	1.700	0.490	1.210
61218127	MB2B	26/07/1982	REFOREST	269.646	269.206	262.646	1.00	7.000	0.440	6.560
61218128	MB2C	26/07/1982	REFOREST	269.576	269.136	259.476	1.00	10.100	0.440	9.660
61218129	MB3	26/07/1982	REFOREST	265.466	264.956	253.166	2.00	12.300	0.510	11.790
61218130	MB3A	26/07/1982	REFOREST	265.450	264.870	262.450	1.00	3.000	0.580	2.420
61218131	MB3B	26/07/1982	REFOREST	265.499	265.059	257.449	1.00	8.050	0.440	7.610
61218132	MB4	26/07/1982	REFOREST	264.131	263.621	251.581	2.00	12.550	0.510	12.040
61218133	MB4A	26/07/1982	REFOREST	264.139	263.689	261.139	1.00	3.000	0.450	2.550
61218134	MB4B	26/07/1982	REFOREST	264.138	263.638	257.118	1.00	7.020	0.500	6.520
61218135	MB4C	26/07/1982	REFOREST	264.209	263.759	255.629	1.00	8.580	0.450	8.130
61218136	MB5	26/07/1982	REFOREST	265.240	264.790	250.840	2.00	14.400	0.450	13.950
61218137	MB5A	26/07/1982	REFOREST	265.389	264.789	261.889	1.00	3.500	0.600	2.900
61218138	MB5B	26/07/1982	REFOREST	265.408	264.808	258.908	1.00	6.500	0.600	5.900
61218139	MB5C	26/07/1982	REFOREST	265.207	264.807	254.277	1.00	10.930	0.400	10.530
61218140	MB6	26/07/1982	REFOREST	268.195	267.695	248.995	2.00	19.200	0.500	18.700
61218141	MB6A	26/07/1982	REFOREST	268.257	267.787	266.557	1.00	1.700	0.470	1.230
61218142	MB6B	26/07/1982	REFOREST	268.191	267.751	263.241	1.00	4.950	0.440	4.510
61218143	MB6C	26/07/1982	REFOREST	268.176	267.756	255.676	1.00	12.500	0.420	12.080
61218144	MC1	26/07/1982	PASTURE	284.995	284.385	266.545	2.00	18.450	0.610	17.840
61218145	MC1A	26/07/1982	PASTURE	285.021	284.471	278.521	1.00	6.500	0.550	5.950
61218146	MC1B	26/07/1982	PASTURE	284.856	284.426	274.856	1.00	10.000	0.430	9.570

Maringee Farms

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)
61218147	MC1C	26/07/1982	PASTURE	284.824	284.334	271.324	1.00	13.500	0.490	13.010
61218148	MC2	26/07/1982	REFOREST*	274.271	273.721	260.651	2.00	13.620	0.550	13.070
61218149	MC2A	26/07/1982	REFOREST*	274.028	273.518	272.528	1.00	1.500	0.510	0.990
61218150	MC2B	26/07/1982	REFOREST*	273.944	273.494	270.944	1.00	3.000	0.450	2.550
61218151	MC2C	26/07/1982	REFOREST*	274.253	273.733	269.223	1.00	5.030	0.520	4.510
61218152	MC2D	26/07/1982	REFOREST*	274.390	273.690	265.190	1.00	9.200	0.700	8.500
61218153	MC3	26/07/1982	PASTURE	280.009	279.369	269.209	2.00	10.800	0.640	10.160
61218154	MC3A	26/07/1982	PASTURE	279.983	279.543	276.003	1.00	3.980	0.440	3.540
61218155	MC3B	26/07/1982	PASTURE	279.821	279.381	273.321	1.00	6.500	0.440	6.060
61218156	MD1	26/07/1982	PASTURE	279.614	279.114	257.214	2.00	22.400	0.500	21.900
61218157	MD1A	26/07/1982	PASTURE	279.574	279.074	268.574	1.00	11.000	0.500	10.500
61218158	MD1B	26/07/1982	PASTURE	279.609	279.109	264.089	1.00	15.520	0.500	15.020
61218159	MD1C	26/07/1982	PASTURE	279.608	279.108	259.608	1.00	20.000	0.500	19.500
61218160	MD2	26/07/1982	REFOREST	269.300	268.800	249.100	2.00	20.200	0.500	19.700
61218161	MD2A	26/07/1982	REFOREST	269.337	268.837	266.837	1.00	2.500	0.500	2.000
61218162	MD2B	26/07/1982	REFOREST	269.315	268.845	262.845	1.00	6.470	0.470	6.000
61218163	MD2C	26/07/1982	REFOREST	269.462	268.822	256.462	1.00	13.000	0.640	12.360
61218164	MD2D	26/07/1982	REFOREST	269.197	268.737	253.727	1.00	15.470	0.460	15.010
61218165	MD3	26/07/1982	REFOREST	266.509	265.909	239.989	2.00	26.520	0.600	25.920
61218166	MD3A	26/07/1982	REFOREST	266.744	266.244	265.004	1.00	1.740	0.500	1.240
61218167	MD3B	26/07/1982	REFOREST	266.588	266.138	262.548	1.00	4.040	0.450	3.590
61218168	MD3C	26/07/1982	REFOREST	266.555	266.115	259.555	1.00	7.000	0.440	6.560
61218169	MD3D	26/07/1982	REFOREST	266.571	266.021	255.051	1.00	11.520	0.550	10.970
61218170	MD3E	26/07/1982	REFOREST	266.487	265.987	247.987	1.00	18.500	0.500	18.000
61218171	MD4	26/07/1982	REFOREST	271.448	270.948	259.118	2.00	12.330	0.500	11.830
61218172	MD4A	26/07/1982	REFOREST	271.333	270.783	269.333	1.00	2.000	0.550	1.450
61218173	MD4B	26/07/1982	REFOREST	271.324	270.784	266.324	1.00	5.000	0.540	4.460
61218174	MD4C	26/07/1982	REFOREST	271.316	270.806	263.316	1.00	8.000	0.510	7.490
61218175	MF1	26/07/1982	REFOREST	259.026	258.528	245.676	2.00	13.350	0.498	12.852
61218176	MF1A	26/07/1982	REFOREST	258.932	258.518	257.382	1.00	1.550	0.414	1.136
61218177	MF1B	26/07/1982	REFOREST	259.073	258.528	251.073	1.00	8.000	0.545	7.455
61218178	MF1C	26/07/1982	REFOREST	259.009	258.558	248.558	1.00	10.451	0.451	10.000
61218179	MF2	26/07/1982	REFOREST	263.985	263.514	241.683	2.00	22.302	0.471	21.831
61218180	MF2A	26/07/1982	REFOREST	264.084	263.624	261.584	1.00	2.500	0.460	2.040
61218181	MF2B	26/07/1982	REFOREST	264.046	263.554	257.546	1.00	6.500	0.492	6.008
61218182	MF2C	26/07/1982	REFOREST	263.939	263.554	249.489	1.00	14.450	0.385	14.065
61218183	MF3	26/07/1982	REFOREST	264.405	263.765	240.655	2.00	23.750	0.640	23.110
61218184	MF3A	26/07/1982	REFOREST	264.362	263.862	261.862	1.00	2.500	0.500	2.000
61218185	MF3B	26/07/1982	REFOREST	264.370	263.870	258.870	1.00	5.500	0.500	5.000
61218186	MF3C	26/07/1982	REFOREST	264.399	263.899	252.899	1.00	11.500	0.500	11.000
61218187	MF4	26/07/1982	REFOREST	262.031	261.446	250.681	2.00	11.350	0.585	10.765
61218188	MF4A	26/07/1982	REFOREST	262.059	261.566	260.309	1.00	1.750	0.493	1.257
61218189	MF4B	26/07/1982	REFOREST	262.002	261.514	256.002	1.00	6.000	0.488	5.512

* Planted in 1986

APPENDIX B

CROWN COVER DATA OF THE REFORESTED SITES AS OF DECEMBER 1987

(Crown cover is calculated as the number of hits divided by the total number of observations. All crown cover measurements were taken between the 4th and 10th of December 1987)

Flynn's Hillslope

REFOREST. BORE NO.	NO. OF HITS	TOTAL OBSERVATIONS	CROWN COVER(%)
61618029	33	121	27
61618030			30*
61618031			30*
61618033			30*
61618036			30*
MEAN			29

* Trees were thinned in 1986. Value estimated from similar trees at the Stene's Valley Plantings site.

Flynn's Landscape

REFOREST. BORE NO.	NO. OF HITS	TOTAL OBSERVATIONS	CROWN COVER(%)
61618001	40	89	45
61618003	13	26	50
61618005	33	91	36
61618007	9	24	38
61618008	75	156	48
61618009	75	156	48
61618010	19	55	35
61618011	26	50	52
61618012	30	51	59
61618013	95	225	42
61618014	17	55	31
61618015	23	59	39
61618016	33	57	58
61618017	22	54	41
61618020	17	30	57
61618021	10	33	30
61618022	12	30	40
61618023	12	37	32
MEAN			43

Flynn's Agroforestry

REFOREST. BORE NO.	NO. OF HITS	TOTAL OBSERVATIONS	CROWN COVER(%)
61618042	15	100	15
61618043	16	107	15
61618044	18	118	15
61618045	10	98	10
61618046	4	113	4
61618048	10	107	9
61618049	23	92	25
61618050	22	96	23
61618052	12	107	11
MEAN			14

Stene's Strip Plantings

REFOREST. BORE NO.	NO. OF HITS	TOTAL OBSERVATIONS	CROWN COVER(%)
61218001	39	54	72
61218004	25	54	46
61218007	30	53	57
61218012	48	101	48
61218013	18	48	38
61218014	39	51	76
61218015	18	50	36
61218016	18	50	36
61218021	17	48	35
61218022	17	48	35
61218023	44	54	81
61218024	18	48	38
61218025	18	48	38
61218027	14	50	28
61218037	*	*	
61218043	39	54	72
61218048	12	43	28
61218049	14	50	28
MEAN			47

* No value recorded.

Stene's Valley Plantings

REFOREST. BORE NO.	NO. OF HITS	TOTAL OBSERVATIONS	CROWN COVER(%)
61218056	21	49	43
61218059	16	49	33
61218062	21	45	47
61218067	20	49	41
61218013	18	48	38
61218014	39	51	41
61218015	18	50	36
61218016	18	50	36
61218021	17	48	35
61218022	17	48	35
61218023	44	54	81
61218024	18	48	38
61218025	18	48	38
61218027	14	50	28
61218037	*	*	
61218043	39	54	72
61218048	12	43	28
61218049	14	50	28
MEAN			47

* No value recorded.

Stene's Agroforestry

REFOREST. BORE NO.	NO. OF HITS	TOTAL OBSERVATIONS	CROWN COVER(%)
61219082	34	109	31
61219084	34	109	31
61219086	25	116	22
61219088	25	116	22
61219090	26	93	28
61219092	26	93	28
61219094	24	119	20
61219096	24	119	20
MEAN			25

Stene's Arboretum

REFOREST. BORE NO.	NO. OF HITS	TOTAL OBSERVATIONS	CROWN COVER(%)
61218369	23	49	47
61218370	11	49	22
61218371	*	*	
61218372	13	37	35
61218373	31	47	66
61218374	14	49	29
61218377	24	49	49
61218378	13	37	35
61218379	17	49	35
61218380	22	49	45
61218385	17	49	35
61218386	19	49	39
61218387	7	49	14
61218388	14	43	33
61218389	23	49	47
61218390	21	47	45
61218393	18	49	37
61218394	23	49	47
61218395	17	49	35
61218396	18	49	37
61218397	15	49	31
61218398	23	49	47
61218399	19	49	39
MEAN			39

* No value recorded

APPENDIX C

MINIMUM GROUNDWATER LEVELS (AHD) OF THE 'REFORESTED' AND 'PASTURED' BORES

(The selection of bores to represent the groundwaters under reforestation or pasture was based on bore location and the possible influence of the trees on nearby bores. Any bores which went dry during the period under investigation (1978-1986) have not been included)

Flynn's Hillslope

MINIMUM GROUNDWATER LEVEL (AHD)

BORE NO	1978	1979	1980	1981	1982	1983	1984	1985	1986
61618029	200.670	200.900	199.812	198.866	199.390	198.610	198.790	198.430	198.470
61618030	200.090	200.610	199.201	198.177	198.640	197.930	198.180	197.840	197.870
61618031	201.170	201.760	200.645	199.597	200.250	199.310	199.580	199.030	198.980
61618033	197.430	197.100	196.450	195.700	196.020	195.600	195.720	195.540	195.680
61618036	197.270	197.230	196.334	195.553	195.740	195.360	195.500	195.330	195.510

Flynn's Landscape

MINIMUM GROUNDWATER LEVEL (AHD)

BORE NO	1978	1979	1980	1981	1982	1983	1984	1985	1986
61618001	190.680	190.495	190.510	190.176	190.925	190.600	190.790	190.510	190.640
61618003	189.586	190.261	189.884	189.774	190.446	189.916	190.146	189.836	190.056
61618005	189.980	190.000	189.692	189.507	190.230	189.780	189.190	189.700	189.940
61618007	190.210	190.135	189.966	189.726	190.390	189.970	190.150	189.870	190.030
61618008	191.836	192.006	192.036	191.889	192.126	191.986	191.956	191.896	192.366
61618009	195.200	195.430	195.305	194.904	195.390	195.110	195.220	195.110	195.280
61618010	196.520	196.820	196.554	196.040	196.700	196.320	196.480	196.240	196.380
61618011	197.185	197.015	196.837	196.465	197.030	196.630	196.800	196.540	196.660
61618012	197.730	197.940	197.642	197.284	198.070	197.530	197.830	197.450	197.550
61618013	199.460	199.450	199.278	198.670	199.410	198.950	199.330	199.030	199.150
61618014	200.870	200.580	200.196	200.048	200.470	199.870	199.910	199.750	198.980
61618015	201.110	201.075	201.059	201.076	201.090	201.080	201.100	201.080	201.100
61618016	201.690	201.800	201.810	201.827	201.840	201.840	202.113	201.840	201.890
61618017	204.850	204.470	203.892	203.448	204.170	203.430	203.570	203.270	203.350
61618020	191.640	191.585	191.220	191.184	191.820	191.180	191.480	191.180	191.280
61618021	191.705	191.850	191.418	191.152	192.140	191.510	191.880	191.400	191.480
61618022	191.010	191.070	190.822	190.548	191.365	190.910	191.150	190.830	190.940
61618023	190.660	190.570	190.524	190.255	191.070	190.600	190.710	190.530	190.660

Flynn's Agroforestry

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1978	1979	1980	1981	1982	1983	1984	1985	1986
61618042	179.641	178.971	178.522	178.431	178.786	178.221	178.551	178.191	178.001
61618043	179.514	178.959	178.479	178.291	178.709	178.119	178.469	178.159	178.039
61618044	180.594	180.259	179.518	179.274	179.799	179.074	179.634	179.354	179.234
61618045	180.852	180.242	179.593	179.120	179.667	178.942	179.622	179.442	179.412
61618046	182.635	181.440	180.461	179.945	180.770	179.715	180.635	179.995	180.195
61618048	180.515	179.865	179.406	179.210	179.770	179.085	179.525	178.955	177.745
61618049	180.571	180.121	179.695	179.511	180.011	179.311	179.931	179.141	178.941
61618050	181.167	180.952	180.362	180.125	180.832	180.017	180.637	179.987	179.837
61618052	183.748	182.908	182.141	181.894	182.673	181.798	182.658	181.888	181.658

Flynn's Pasture

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1978	1979	1980	1981	1982	1983	1984	1985	1986
61618018	206.225	206.510	205.926	205.591	206.795	205.970	206.560	205.970	205.970
61618024	197.645	197.950	197.513	197.381	198.740	197.870	198.810	198.060	197.920
61618025	196.090	196.420	196.050	195.565	197.020	196.470	197.030	196.420	196.570
61618026	199.760	199.970	199.596	199.291	200.630	200.030	200.730	199.990	199.890
61618027	203.910	204.040	203.496	203.193	204.935	204.260	205.030	204.180	203.940
61618028	205.410	205.520	204.909	204.651	206.190	205.540	206.290	205.470	205.550

Stene's Strip Plantings

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1978	1979	1980	1981	1982	1983	1984	1985	1986
61218001	276.962	277.072	276.882	277.072	277.762	277.272	277.742	277.752	277.132
61218004	278.083	278.253	277.993	278.143	279.173	278.693	279.213	279.503	280.353
61218007	279.618	279.288	279.128	279.588	280.608	279.908	280.708	280.538	280.288
61218012	279.343	279.368	279.438	279.458	279.468	279.388	279.468	279.728	279.428
61218013	276.673	276.763	276.593	276.773	277.293	276.823	276.953	277.503	277.353
61218014	270.631	270.541	270.411	270.391	271.041	270.511	270.471	270.711	270.221
61218015	271.416	271.316	271.136	271.136	271.546	271.166	271.196	271.556	270.956
61218016	271.563	271.183	271.043	271.043	270.983	270.493	270.723	271.233	270.553
61218021	274.747	274.717	274.607	274.697	275.117	274.857	274.827	275.257	275.047
61218022	275.082	275.092	274.982	275.062	275.492	275.202	275.282	275.652	275.452
61218023	277.135	277.065	276.825	277.205	277.995	277.415	278.005	277.945	277.755
61218024	277.115	277.125	276.895	277.005	277.675	277.195	277.605	277.925	278.525
61218025	276.568	275.838	276.528	276.628	276.348	276.348	274.848	276.348	277.138
61218027	270.778	270.688	270.588	270.528	270.868	270.458	270.468	270.578	270.238
61218037	274.458	274.218	273.808	274.088	274.298	274.038	274.198	274.268	273.788
61218043	274.392	274.442	274.432	274.482	274.522	274.442	274.632	274.852	274.532
61218048	269.367	269.297	269.237	269.007	269.287	267.697	268.767	268.907	268.497
61218049	269.933	269.903	269.813	269.783	270.143	268.113	269.693	269.783	269.513

Stene's Valley Plantings

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1979	1980	1981	1982	1983	1984	1985	1986
61218056	262.296	262.146	262.176	262.706	261.926	262.086	261.826	261.516
61218059	262.001	261.921	261.971	262.451	261.711	261.821	261.611	261.301
61218062	261.958	261.858	261.938	262.448	261.818	261.798	261.618	261.298
61218067	264.928	264.848	264.838	265.198	264.628	264.438	264.368	264.048

Stene's Agroforestry

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1981	1982	1983	1984	1985	1986
61219082	271.020	271.590	270.770	270.240	269.850	269.150
61219084	266.760	267.010	266.660	266.360	266.490	266.020
61219086	267.010	268.045	267.170	268.690	265.520	265.000
61219088	266.680	267.040	266.710	266.440	266.620	266.130
61219090	268.890	269.260	268.520	268.240	268.300	268.120
61219092	266.490	266.700	266.220	265.950	266.110	265.730
61219094	266.660	266.720	266.300	266.200	266.220	265.990
61219096	267.770	267.860	268.350	267.930	268.160	267.510

Stene's Arboretum

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1979	1980	1981	1982	1983	1984	1985	1986
61218369	58.520	258.670	258.680	259.510	258.090	258.030	257.140	256.240
61218370	258.932	259.362	259.412	260.172	258.592	258.372	257.282	256.222
61218371	257.953	257.853	258.323	258.573	258.063	258.213	257.953	257.373
61218372	259.349	259.549	259.469	259.729	258.519	257.999	257.509	256.409
61218373	260.308	260.628	260.388	260.718	258.898	258.228	257.498	256.278
61218374	260.190	260.830	261.360	261.750	260.000	259.460	258.590	257.430
61218377	259.116	259.236	259.206	259.326	258.666	258.316	257.736	257.116
61218378	261.290	261.530	261.370	261.390	260.340	259.660	259.100	256.910
61218379	261.736	262.166	262.036	262.116	260.846	260.136	259.456	258.436
61218380	262.101	262.351	262.261	262.391	261.131	260.531	259.761	258.861
61218385	259.099	259.309	259.259	259.339	258.559	258.019	257.699	256.919
61218386	259.391	260.061	259.531	259.461	258.561	257.871	257.711	256.831
61218387	261.966	262.466	262.336	262.316	261.346	261.076	260.076	259.076
61218388	263.684	264.094	264.354	264.274	263.244	263.144	261.884	260.584
61218389	266.129	266.249	266.739	266.759	266.039	265.899	264.879	263.649
61218390	268.133	268.033	268.673	268.573	267.973	267.993	267.923	267.893
61218393	264.178	264.808	265.058	264.808	264.728	264.718	264.108	263.308
61218394	265.057	265.487	265.607	265.247	264.447	264.307	263.267	262.257
61218395	262.985	263.565	263.515	263.315	262.175	261.845	261.195	260.865
61218396	259.894	260.334	260.164	260.154	259.284	258.634	258.154	257.374
61218397	257.839	254.989	257.979	258.539	257.289	256.889	256.569	255.329
61218398	258.519	258.729	258.749	259.569	258.109	258.019	257.039	256.199
61218399	260.467	260.657	260.517	251.247	259.657	259.097	258.517	257.527

Stene's Pasture

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1979	1980	1981	1982	1983	1984	1985	1986
61218008	281.717	281.167	281.767	283.157	282.677	283.767	283.587	283.387
61218009	279.702	279.522	279.852	281.172	280.522	281.462	281.272	281.302
61218029	269.853	269.683	269.723	270.303	269.803	269.853	269.803	269.553
61218030	271.549	271.229	270.299	271.879	271.369	271.559	271.499	271.299
61218038	275.267	275.527	275.757	276.297	276.097	276.297	276.367	275.907
61218044	277.740	277.510	277.690	278.820	278.160	278.980	278.880	278.940
61218045	279.752	279.482	279.752	280.942	280.452	281.362	281.162	281.342
61218063	264.039	263.689	264.169	265.199	264.319	264.969	264.739	264.429
61218064	64.171	263.701	264.171	265.391	264.781	265.881	265.511	265.121

Maringee Farms - Reforestation

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1982	1983	1984	1985	1986
61218103	262.939	262.609	262.699	262.889	262.459
61218107	258.304	258.359	258.659	258.619	258.609
61218112	257.457	256.957	257.647	257.467	257.447
61218115	257.455	257.418	257.248	257.248	257.168
61218119	259.123	258.523	258.903	259.063	258.903
61218125	267.484	267.174	267.224	267.614	267.294
61218131	265.484	265.399	265.484	265.479	265.449
61218133	263.019	263.119	263.069	262.849	262.939
61218137	263.969	263.489	263.339	263.484	263.089
61218142	265.261	264.931	264.891	264.841	264.491
61218161	266.907	266.837	267.537	267.557	267.037
61218167	265.448	265.388	265.568	265.308	265.338
61218173	270.074	269.764	270.074	270.114	269.724
61218176	257.672	257.582	257.942	257.822	257.832
61218181	263.701	263.421	263.556	263.556	263.196
61218185	263.480	263.190	263.180	263.160	262.870
61218188	260.659	260.359	260.359	260.429	260.359

Maringee Farms - Pasture

MINIMUIM GROUNDWATER LEVEL (AHD)

BORE NO	1982	1983	1984	1985	1986
61218121	272.221	272.601	274.401	275.681	276.261
61218144	275.675	275.985	277.895	279.075	279.645
61218153	277.769	277.449	278.189	278.619	278.159
61218156	271.014	270.264	271.064	271.394	270.764

APPENDIX D

ANNUAL SITE STATISTICS OF GROUNDWATER SALINITIES

(The statistics are calculated from the salinity values corresponding to the minimum groundwater level in each bore)

Flynn's Hillslope

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS) MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1978	8	7364	3720	2389	12062
1979	8	6605	3249	2141	10615
1980	8	6761	3482	2081	11623
1981	8	6009	3348	2216	11035
1982	8	6396	3391	2718	11921
1983	8	5869	3428	2771	11382
1984	8	6058	3962	2742	12218
1985	7	4908	3397	2429	11358
1986	8	5519	3785	1393	11225

Flynn's Landscape

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS) MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1978	19	4792	3954	331	16557
1979	23	4260	4235	396	18161
1980	23	4362	4078	355	17306
1981	22	3867	3112	324	11436
1982	23	4296	4732	347	21993
1983	21	5106	4544	330	19022
1984	22	4843	4758	350	19022
1985	22	5628	5888	314	22462
1986	20	4040	2886	366	10928

Flynn's Agroforestry

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS) MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1978	12	2375	2971	134	8442
1979	11	2402	3009	74	8159
1980	10	2198	3103	90	7875
1981	10	2039	2772	102	7501
1982	11	2134	2960	90	7565
1983	10	2149	2828	83	7518
1984	10	2062	2816	85	7714
1985	10	2133	2880	86	7924
1986	11	1829	2660	74	7900

Stene's Strip Plantings

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS) MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1978	46	7538	5685	150	24586
1979	25	7549	5905	215	25397
1980	26	6893	6132	149	25022
1981	39	6646	5496	121	25043
1982	20	7234	5684	111	24652
1983	33	7494	5397	140	21763
1984	34	6839	5616	115	21915
1985	44	6743	5123	148	22071
1986	40	6662	5118	120	21837

Stene's Valley Plantings

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS) MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1979	14	5494	2417	2966	11441
1980	14	4968	2665	758	10452
1981	14	5130	2815	327	10388
1982	14	3677	2851	390	9844
1983	13	4774	2353	779	8825
1984	8	4563	2830	913	9508
1985	12	3556	2797	284	9543
1986	13	4624	2340	886	9679

Stene's Agroforestry

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS) MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1981	7	6626	4189	248	11554
1982	7	6482	3509	370	11178
1983	7	6003	3396	555	11014
1984	4	4555	997	3678	5680
1985	7	5283	3843	697	11460
1986	7	4781	3484	785	9461

Stene's Arboretum

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS)			
		MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1979	27	5548	3663	261	14052
1980	22	5859	3883	252	14330
1981	28	5366	3751	199	15190
1982	28	2775	3167	85	11953
1983	27	5144	3332	308	13782
1984	16	4075	2653	282	8984
1985	26	3091	2398	226	8342
1986	31	4103	3565	293	15543

Maringee Farms

YEAR	NO. OF OBSERVATIONS	SALINITY (mg/L TSS)			
		MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1982	80	15797	5463	374	22775
1983	77	15520	5370	403	22775
1984	39	14981	6717	337	22541
1985	13	13332	7221	560	19882
1986	26	15222	5612	980	20195