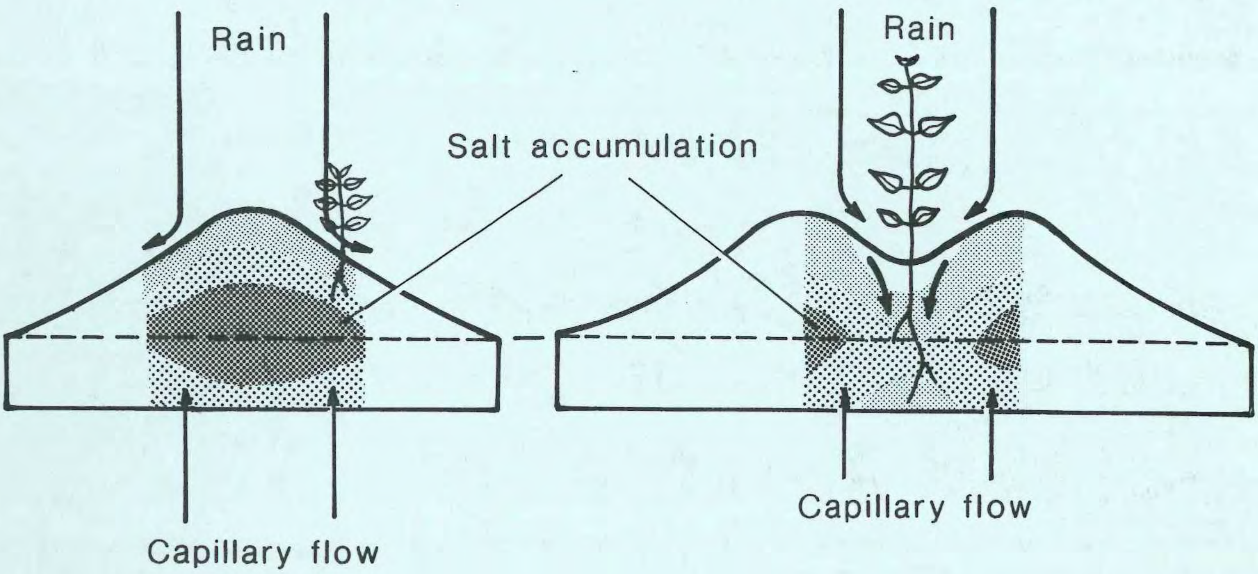
VAUGHN COX

Salt and Water Movement in Single and Double Ridge Mounds

by P. Ritson and N. E. Pettit



Report No. WS 45

April 1989

Water Authority of Western Australia

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ABSTRACT

Soil salt and water content was measured in 0.5 m high single and double ridge mounds formed at two sites in the Wellington Reservoir Catchment. The mounds were formed in an experiment to compare different mound height and shape treatments for tree establishment in saline seeps. Sample times were : mound formation (March/April 1987), planting time (August 1987) and towards the end of the first dry summer/autumn seasons (March 1988).

The double ridge mounds, which were formed with an ~0.7 m wide trough between the ridges, appeared superior to the single ridge mounds (no trough) for tree establishment. This was because the trough collected rain which facilitated salt leaching from the root zone of seedlings planted in the trough bottom as well as watering of seedlings during the dry summer/autumn seasons. Salt accumulated in the surface (0-20 cm) soil layer of both mound types over summer/autumn. However, this may not be critical as, by then, the seedlings which are planted in winter should have extended roots below these depths.

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1. INTRODUCTION

Reforestation programmes for stream salinity control in Western Australia (Loh, 1988; Schofield et al., in press) have necessitated the development of techniques for reforestation of saline seeps. This is because the saline seeps which are typically up to half, sometimes more, of the areas planted are difficult sites for tree establishment mainly due to combined salt and waterlogging stresses (Ritson and Pettit, 1988).

One site amelioration technique being investigated is mounding (bedding or ridging). Details of an experiment to compare the effectiveness of different mound height and shape treatments for Eucalyptus camaldulensis and Eucalyptus largiflorens establishment in saline seep sites in the Wellington Reservoir Catchment (Fig. 1) are given by Ritson and Pettit (1988 and paper in preparation). Nine mound treatments, i.e. standard mounds and 0.25, 0.5, 0.75 and 1.0 m high single and double ridge mounds, were replicated at five sites.

When first formed, standard mounds are 0.15-0.2 m high and have a small (~ 0.1 m wide) trough pressed in the top. However, due to consolidation and erosion the trough is not usually apparent by the end of the first winter. Double ridge mounds have a large (0.5 - 0.9 m wide), long-lasting trough and single ridge mounds have no trough (Fig. 2). Seedlings are planted in the sides of single ridge mounds. This is based on the theory that more salt will accumulate in tops of single ridge mounds than in the sides. Evidence of salt accumulation in the tops of single ridge or flat-topped mounds has been demonstrated in laboratory studies (Bernstein and Fireman, 1957) and found in the field (Bernstein et al. 1955; Fanning and Carter, 1963). This is because these mounds tend to shed rainfall and wet up from the watertable below or from water collected in the furrows formed to make the mounds. Salts accumulate as the water evaporates from the mound surface.

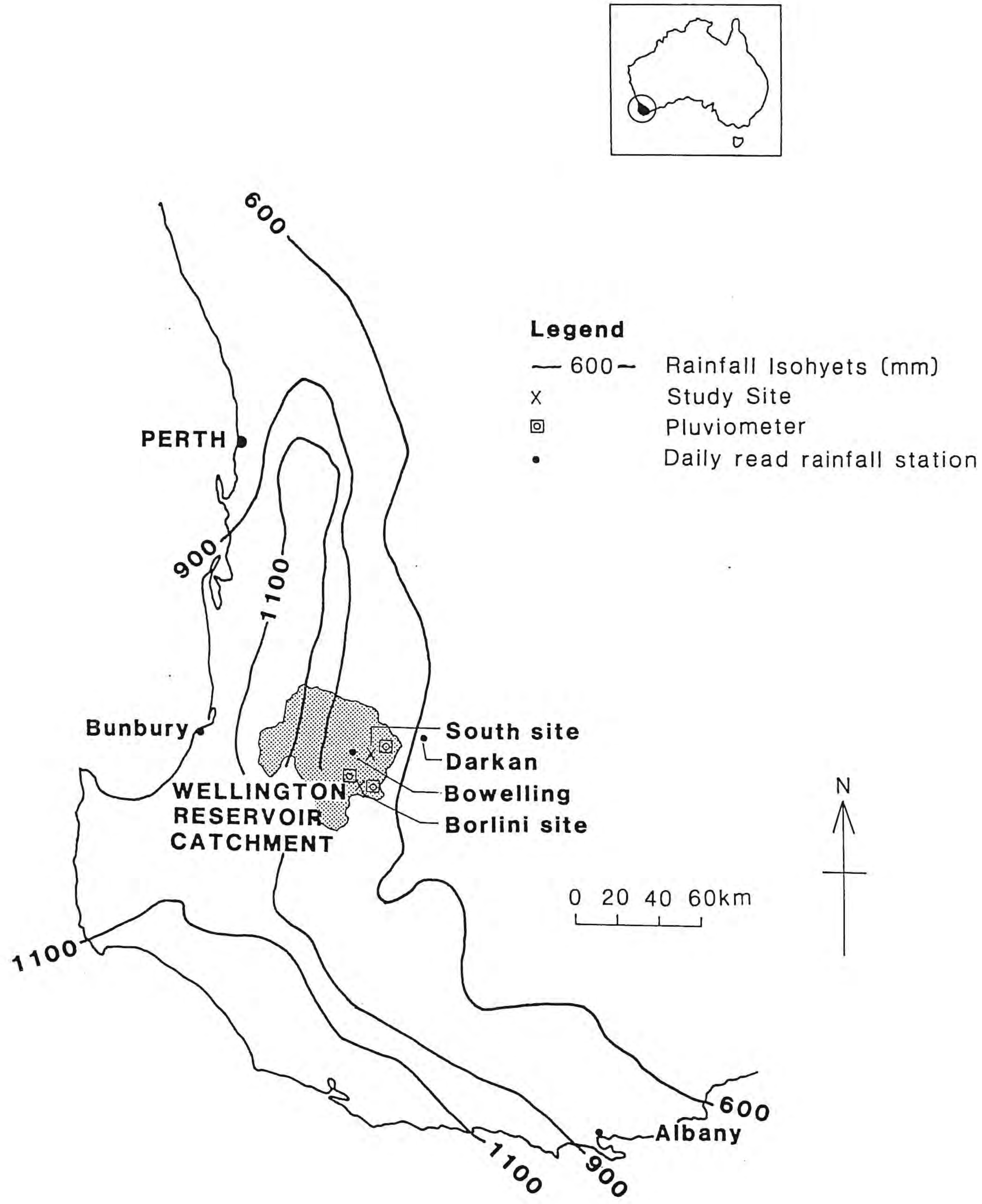

FIGURE 1 Location of the Wellington Reservoir Catchment, study sites and rainfall measurement sites.

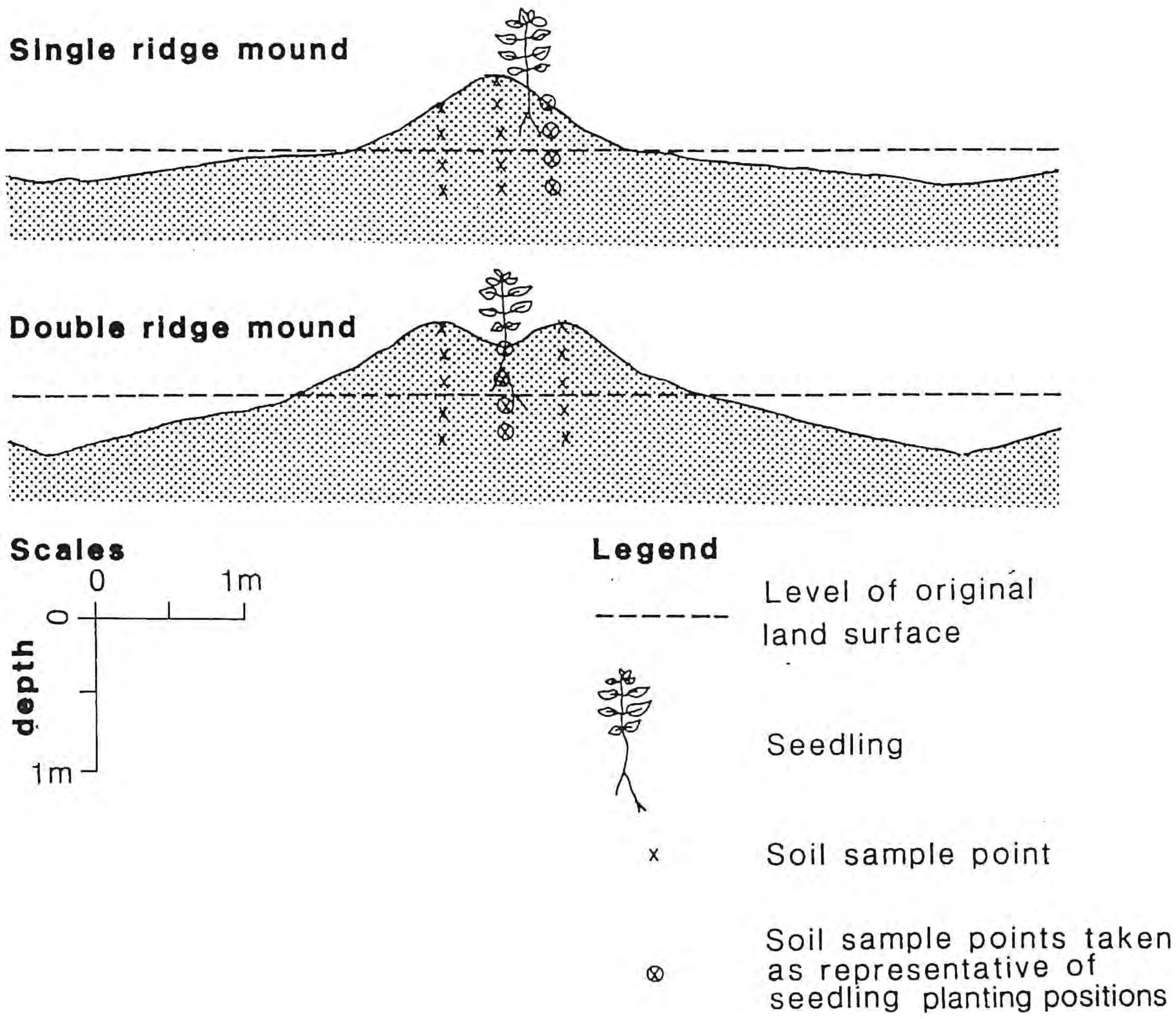

FIGURE 2 Mound cross-sections showing soil sample points.

Seedlings were planted in the trough bottoms of standard and double ridge mounds. This was based on the theory that the troughs would collect rain and leach salt from the seedling root zones. Malcolm and Allen (1981) and Malcolm (1983) applied this theory in designing the Mallen Niche Seeder for seeding saltbushes (Atriplex spp) and other shrubs in saline seeps. Seeds are placed in the trough (niche) which is formed by a press wheel at the rear of the Mallen Niche Seeder.

It was decided to measure salt and water movement in the mounds formed for the experiment in the Wellington Reservoir Catchment to better understand tree performance in those mounds. For logistical reasons sampling was restricted to 0.5 m high single and double ridge mounds at the South and Borlini sites (Fig. 1).

2. SITE DESCRIPTIONS

The South and Borlini sites had been cleared for at least 10 years at the time of mound formation.

Average slopes were 0.2% at the South site and 2.5% at the Borlini site.

Both sites had duplex soils. At the South site there was 0.1 - 0.2 m of clayey fine sand over clay and at the Borlini site there was 0.3 - 0.6 m of coarse sand over clay.

An indication of watertable level and salinity was obtained from observations in 1988 from two shallow (<1.5 m deep) bores in each site. The depth to the watertable at both sites was least in winter (minimum ~0.1 m) and greatest in autumn (maximum >1.0 m). Watertable salinity ranged from 1 000 to 11 000 mg/L total soluble salts (TSS) at the Borlini site and from 5 000 to 21 000 mg/L TSS at the South site.

The South site was nearly all salt scald. It was almost completely bare of pasture cover and was therefore classed as being severely salt/waterlogging affected. The lower one third of the Borlini site had a patchy pasture cover dominated by sea barley grass (Hordeum marinum) and some salt scalds. It was therefore classed as being mildly salt/waterlogging affected. The remainder of the Borlini Site had an almost complete cover of non salt/waterlogging tolerant pasture species including sub-clover (Trifolium subterraneum) and was therefore classed as being non salt/waterlogging affected.

3. METHODS

Mound formation

Mounds were formed in March, 1987. They were constructed 5 m apart and parallel to the direction of maximum slope. Each mound was approximately 70 m long. At each site the mounds were arranged in groups of four according to mound height. Thus at each site there were four 0.5 m high mounds, alternatively single and double ridge mounds, within the group. A road grader was used to form the mounds.

Soil sampling

Soil samples for salt and moisture content analyses were taken at three times: within one day of mound formation (March/April 1987), at planting time in the middle of the wet winter/spring period (August 1987) and towards the end of the dry summer/autumn period (March, 1988).

The soil samples were taken from the middle pair of 0.5 m high mounds (a single and a double ridge mound) at the South and Borlini sites. At each sampling time samples were taken along three transects across the pair of mounds as follows : transect 1 was approximately 15 m from the downslope end of the mounds; transect 2 was approximately across the middle of the mounds and transect 3 was approximately 15 m from the upslope end of the mounds.

Location of sample points within mounds is shown in Fig. 2. It was considered undesirable to sample at exactly the same location each time due to disturbance caused by augering which would have affected salt and water movement in the mounds. Therefore the transects of August 1987 and March 1988 were offset 0.5 m along the line of the mounds from the transects of March 1987.

Laboratory analysis

Soil samples were oven dried for 24 hours at $105^{o}C$ for oven dry weight and gravimetric moisture content determination.

Gravimetric TSS content of soil samples was calculated as the equivalent TSS content of 1:5 soil:water extracts divided by the oven dry weight of soil. The TSS content of the extracts was estimated from equations developed by Johnston et al. (1982) and Stokes (1983) i.e.:

if $29<EC<45$, $Y = 4.796\ EC - 4.83$;

if $45<EC<400$, $Y = 5.126\ EC - 19.81$,

where Y and EC are the total soluble salts concentration (mg/L) and electrical conductivity (mS/m at $25^{o}C$) of a 1:5 soil:water extract. Although the upper bound for the second of the above equations of 400 mS/m (equivalent to 1.0% gravimetric TSS content) was exceeded with many of the extracts, the equation was still applied. This may have introduced bias in absolute determination of TSS content of these soil samples but it was considered adequate for relative comparisons between soil samples.

Solute concentration of soil samples was calculated as the gravimetric TSS content divided by the gravimetric moisture content. (Assuming moisture content (L/Kg) $\simeq$ gravimetric moisture content (kg/kg)). Calculation of solute concentration this way indicates the concentration of salt in the soil water which may, for example, be compared with sea water (solute concentration ~ 33 000 mg/L TSS). It is likely that small errors were introduced by the fact that not all salts dissolved in the 1:5 soil:water extracts would have been dissolved in the soil water of undisturbed samples. In some cases the estimated TSS content of 1:5 soil:water extracts exceeded what could have been dissolved in the soil water (saturation point~370 000 mg/L TSS). In these cases salt must have been present in the soil as a precipitate.

Data analysis

Contour plots of gravimetric TSS content, gravimetric moisture content and solute concentration were produced by interpolation between point values.

The data obtained from the vertical lines of soil samples nearest to the planting positions of seedlings in the two mound types were considered in more detail. These samples were those taken from below the north side of single ridge mounds and from below the trough of double ridge mounds (Fig. 2). Changes in gravimetric TSS content, gravimetric moisture content and solute concentration with depth along these lines were plotted and differences between the two mound types or, in the same mound type, from one sample time to the next were compared using the Wilcoxon paired sample test (Zar, 1984).

Rainfall

Daily and monthly rainfall during the study period was calculated as an average of that recorded in three pluviometers in the vicinity of the trial sites (Fig. 1). Long term records were not available for these pluviometers. Therefore long term average monthly rainfall was estimated from the annual rainfall isohyets and the proportions of total rainfall falling each month at Darkan and Bowelling (Fig. 1). Rainfall records were available for these sites from 1898-1988 and 1919-1984 respectively.

4. RESULTS

The contour plots of gravimetric TSS content, gravimetric moisture content and solute concentration are presented as Appendices 1, 2 and 3. There were large variations in each of these parameters within mounds and between mound types, sites and sampling times. There was also variation between transect positions.

Comparisons of data from planting positions in single and double ridge mounds are made in Figs 3a-f and Table 1. The comparisons made are between mound types (same sample time) and between sample times (same mound type) of gravimetric TSS content, gravimetric moisture content and solute concentration.

Some particular results from Appendices 1-3, Figs 3a-f and Table 1 are noted below.

Gravimetric TSS content

Comparison of gravimetric TSS content below planting positions in the mounds showed that at planting time in August 1987 (late winter) more salt had leached from below the troughs of double ridge mounds than from below the sides of single ridge mounds (Figs 3a, 3b; Table 1). However, by the following March (early autumn) salt had re-accumulated in both mound types in the surface (0-20 cm) soil layer (Figs 3a, 3b).

Salt content was generally much higher at the South site than at the Borlini site (Appendix 1, Figs 3a, 3b).

At the South site the downslope transect (transect 1) contained the least salt whereas the reverse applied at the Borlini site (Appendix 1; Figs 3a, 3b).

Gravimetric moisture content

In both mound types moisture content below planting positions increased from March/April 1987 to August 1987 then decreased by the following March. However the decrease was less in the double ridge mounds. Thus in March 1988 moisture content was higher below the troughs of double ridge mounds than below the sides of single ridge mounds. (Table 1; Figs 3c, 3d).

Solute concentration

The trends were similar to that recorded for gravimetric TSS content i.e. in August 1987 solute concentration below planting positions was less in double ridge mounds than in single ridge mounds but, in both mound types, solute concentration had increased by the following March, mostly in the surface 0-20 cm layer (Table 1; Figs 3e, 3f). Salt must have been present as a precipitate in the surface (0 cm deep) soil samples collected at the South site in March 1988 (Figs 3e, 3f). This was because the soil salt content exceeded what could have been dissolved in the soil water (saturation point ~ 370 000 mg/L TSS).

Rainfall

Fig. 4a shows that rainfall was generally below average from January 1987 to March 1988 when the last soil samples were taken.

Fig. 4b shows daily rainfall recorded in the 2-3 weeks preceding each of the three soil sampling times. Far less rain was recorded in March 1988 than March 1987. However the most rain recorded in the 2-3 weeks preceding sampling was in August 1987.

Fig. 3 Variation in gravimetric total soluble salts (TSS) content, gravimetric moisture content (MC) and solute concentration with depth and time of sampling in seedling planting positions in single and double ridge mounds.

note:

(i) sampling was along three transects across adjacent 0.5 m high single and double ridge mounds at the South and Borlini sites.

(ii) Data are from soil samples taken below both the north side of the single ridge mounds and the trough bottom of double ridge mounds at depths of 0, 0.2, 0.4 and 0.6 m. The original land surface corresponded to a depth of 0.3 m (Fig. 2).

(iii) Graphs presented on the following six pages.

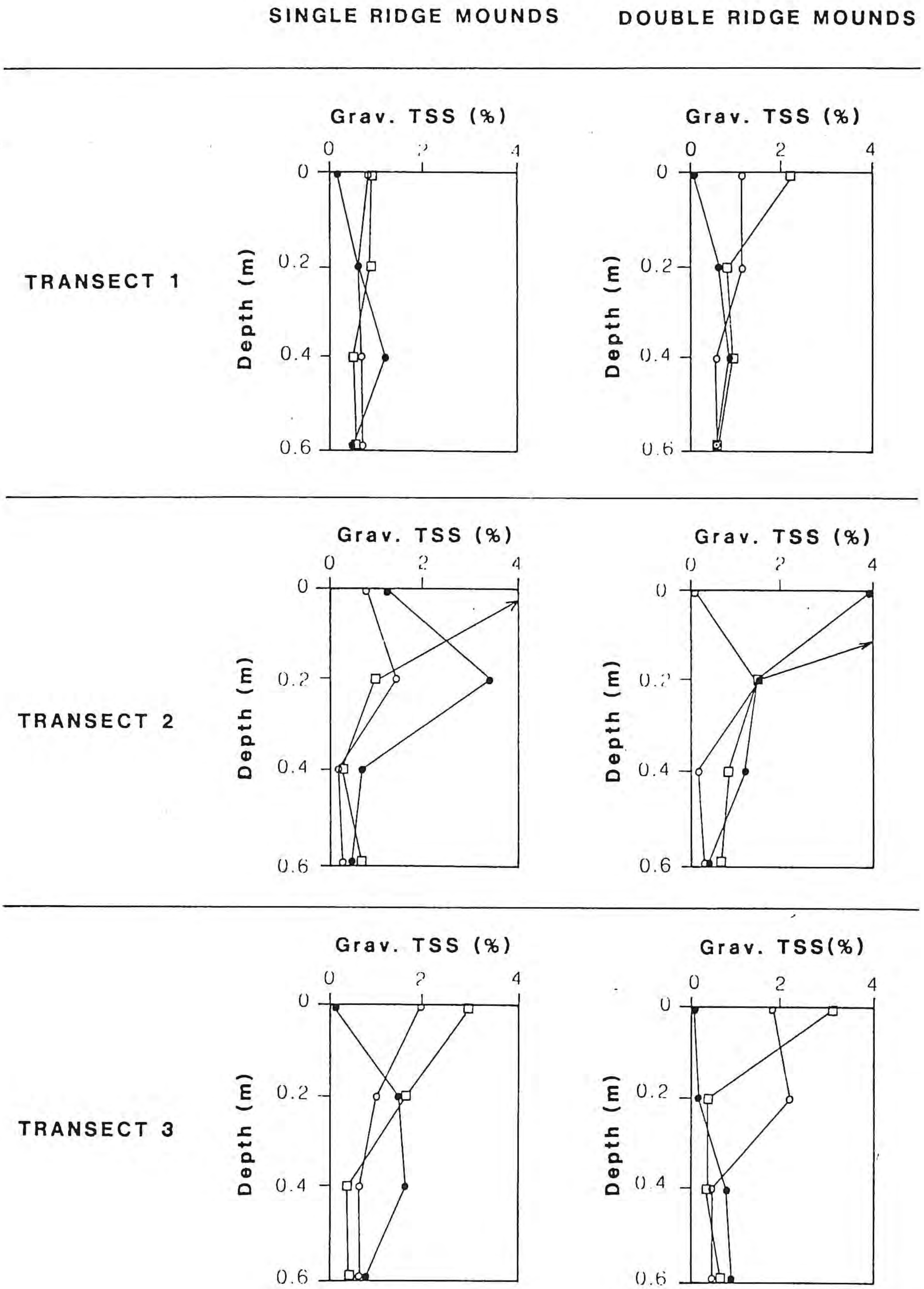

FIGURE 3a Gravimetric total soluble salts (TSS) content, South site: ○ = 24/3/87, • = 3/8/87, □ = 16/3/88.

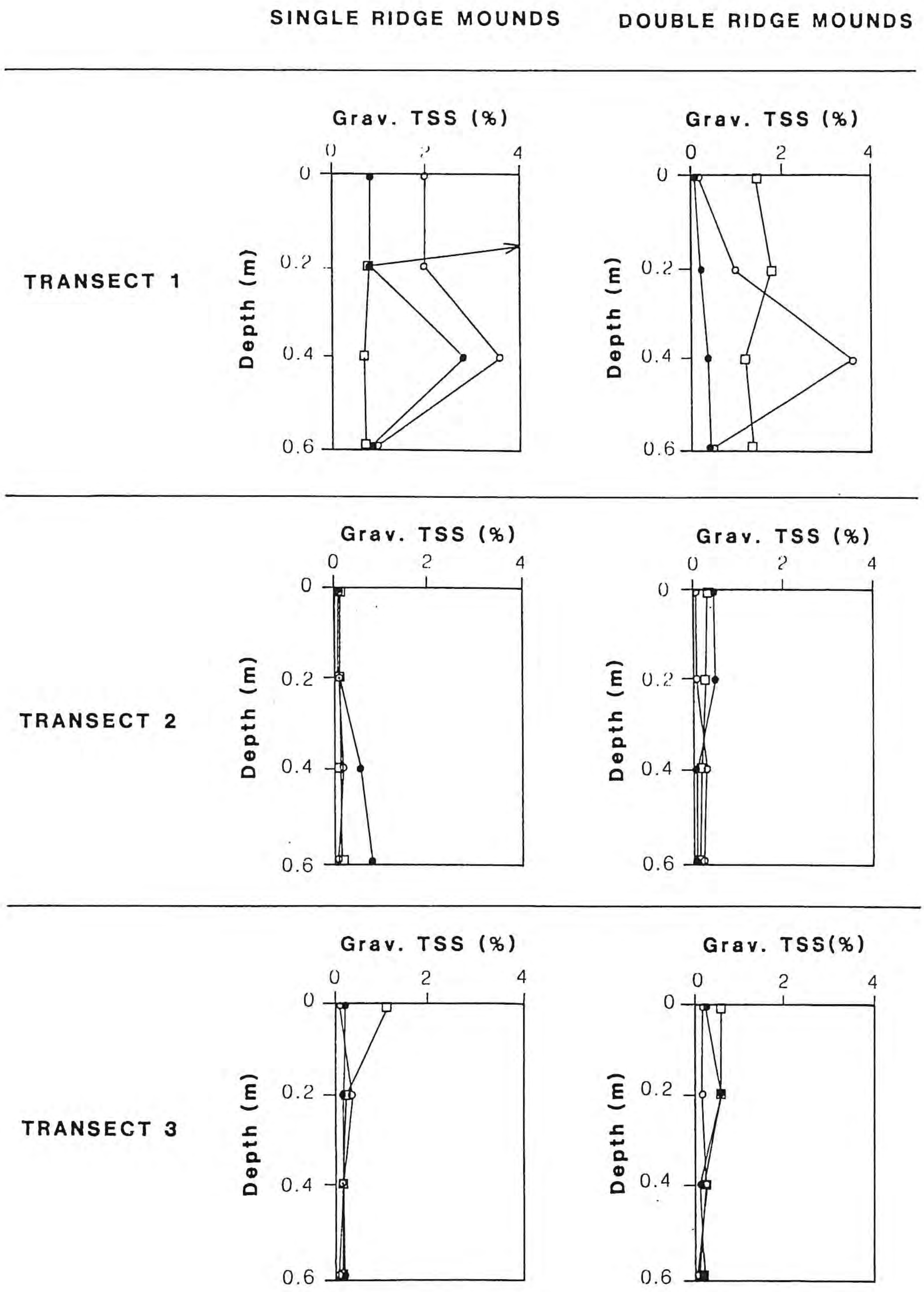

FIGURE 3b **Gravimetric total soluble salts (TSS) content, Borlini site: ○ = 1/4/87, • = 1/8/87, □ = 17/3/87.**

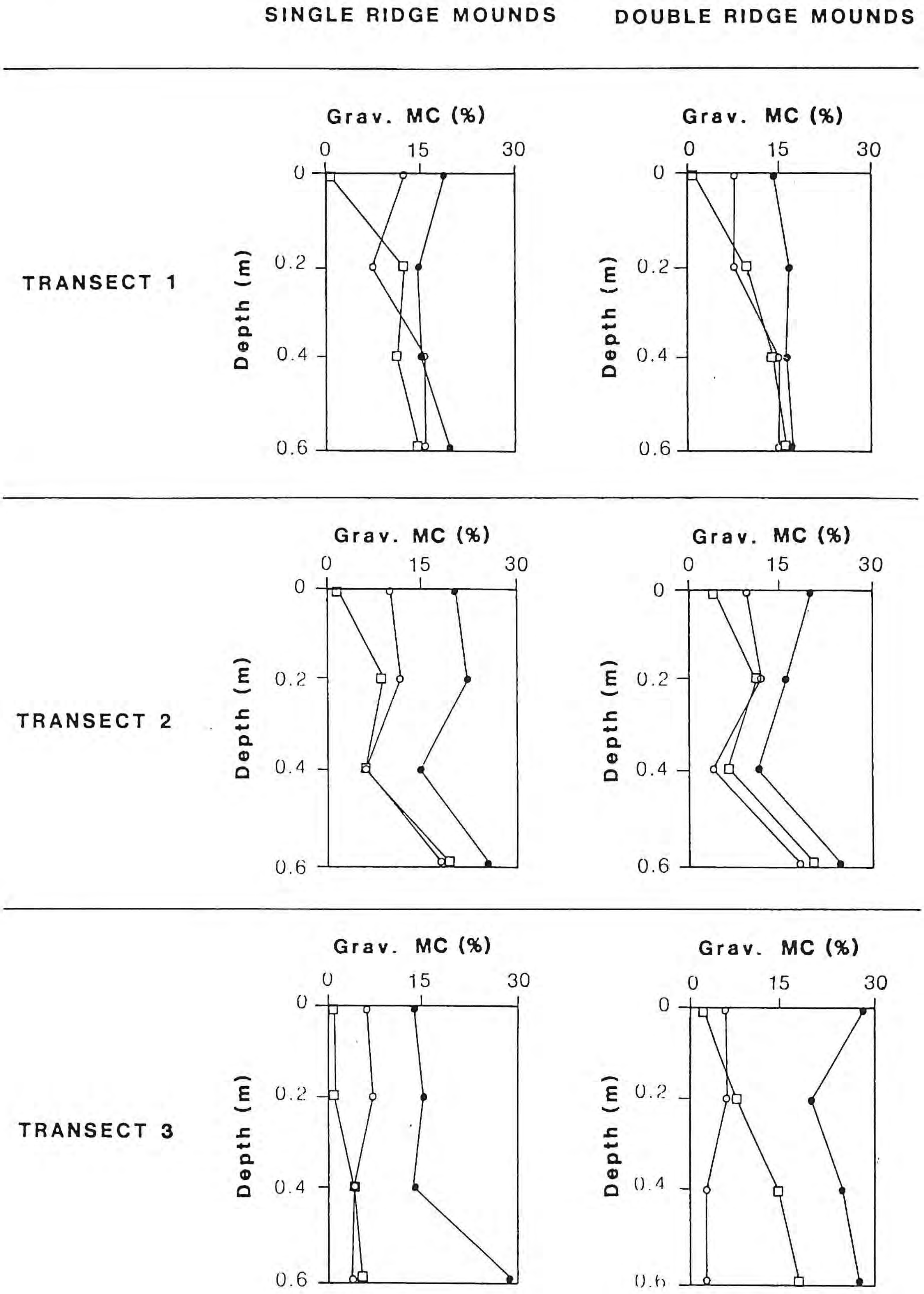

FIGURE 3c **Gravimetric moisture content (MC), South site: ○ = 24/3/87, • = 3/8/87, □ = 16/3/88.**

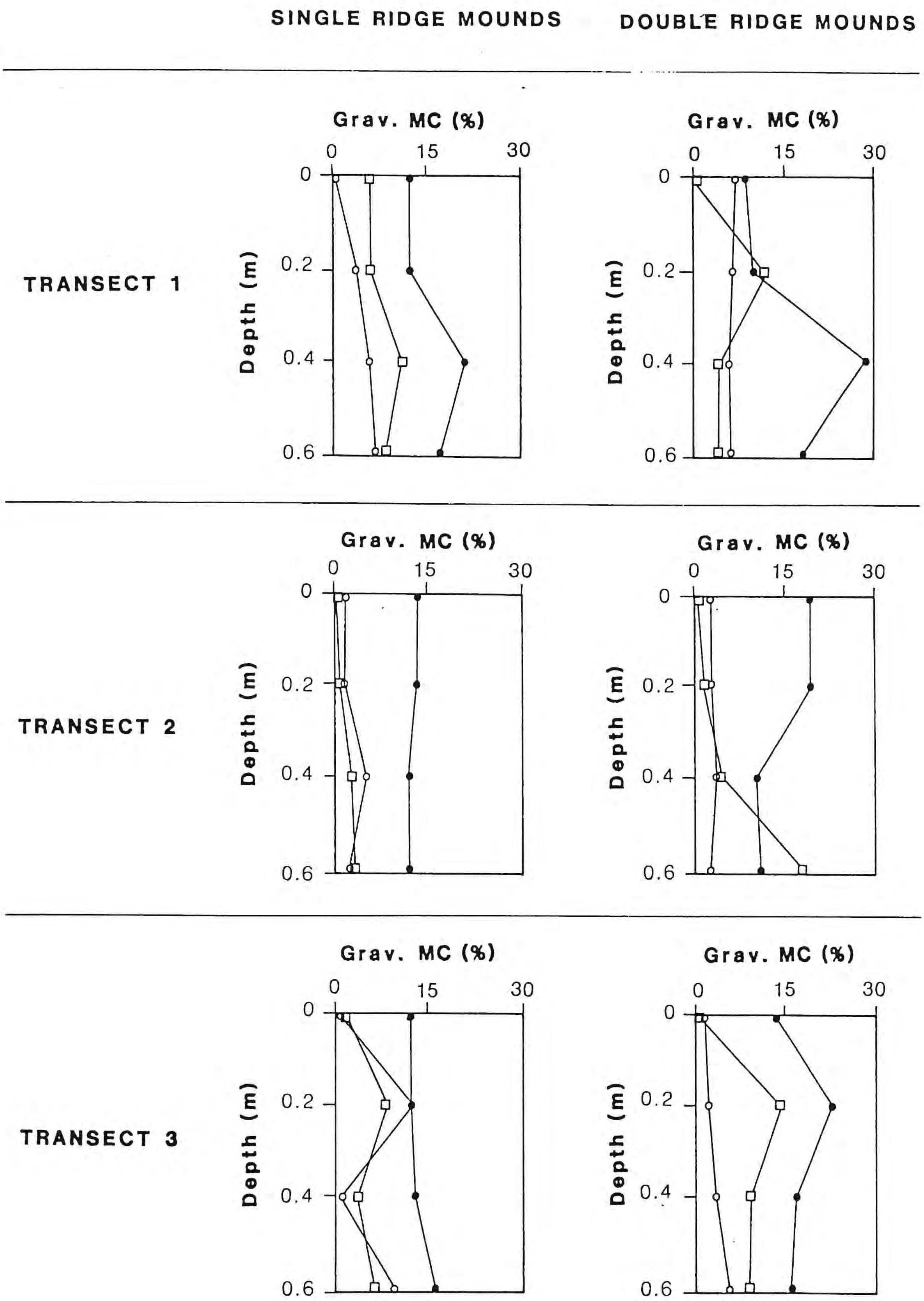

FIGURE 3d **Gravimetric moisture content (MC), Borlini site: ○ = 1/4/87, • = 1/8/87, □ = 17/3/88.**

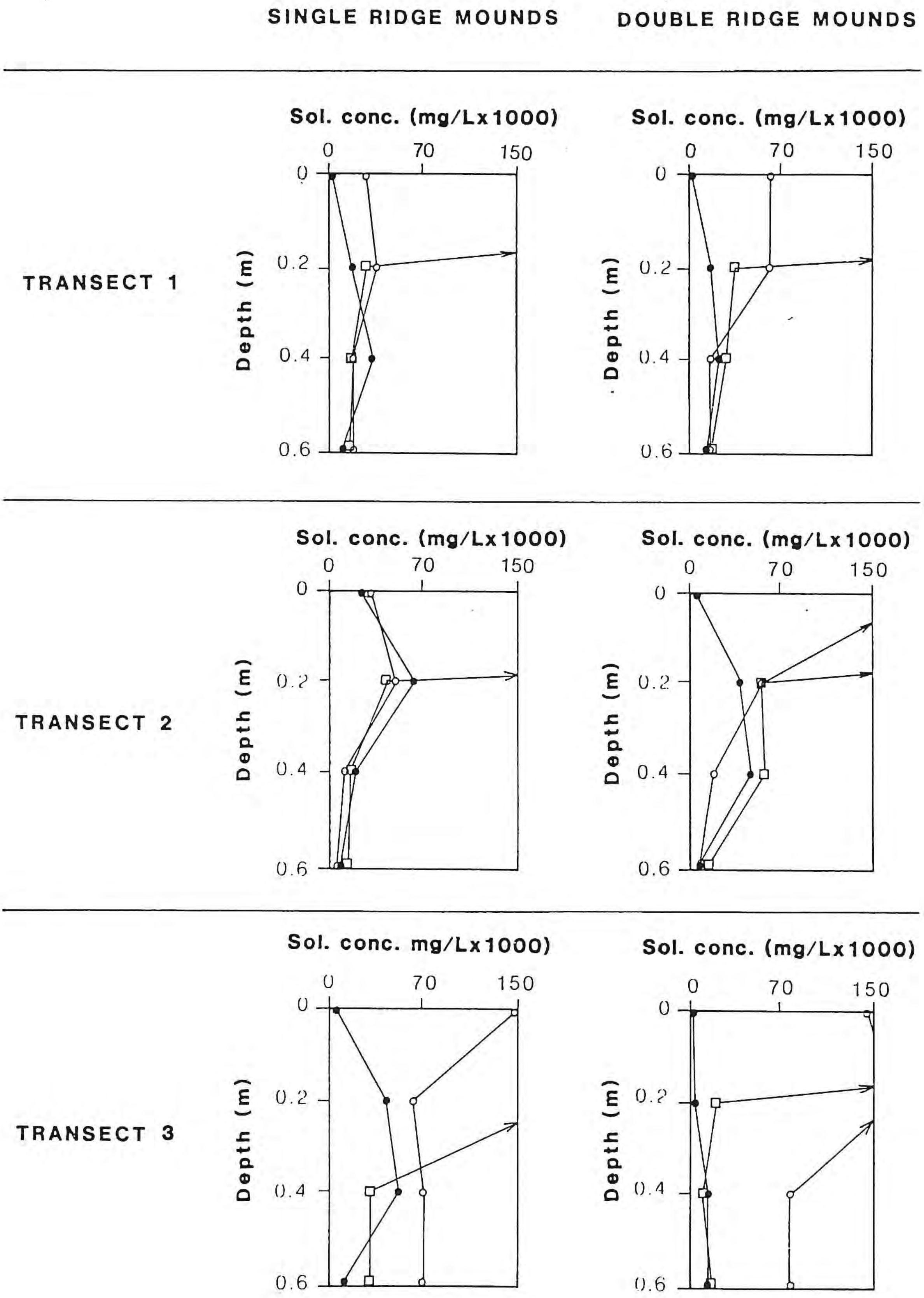

FIGURE 3e **Solute concentration (mg/L TSSx1000), South site: ◦ = 24/3/87, • = 3/8/87, □ = 16/3/88.**

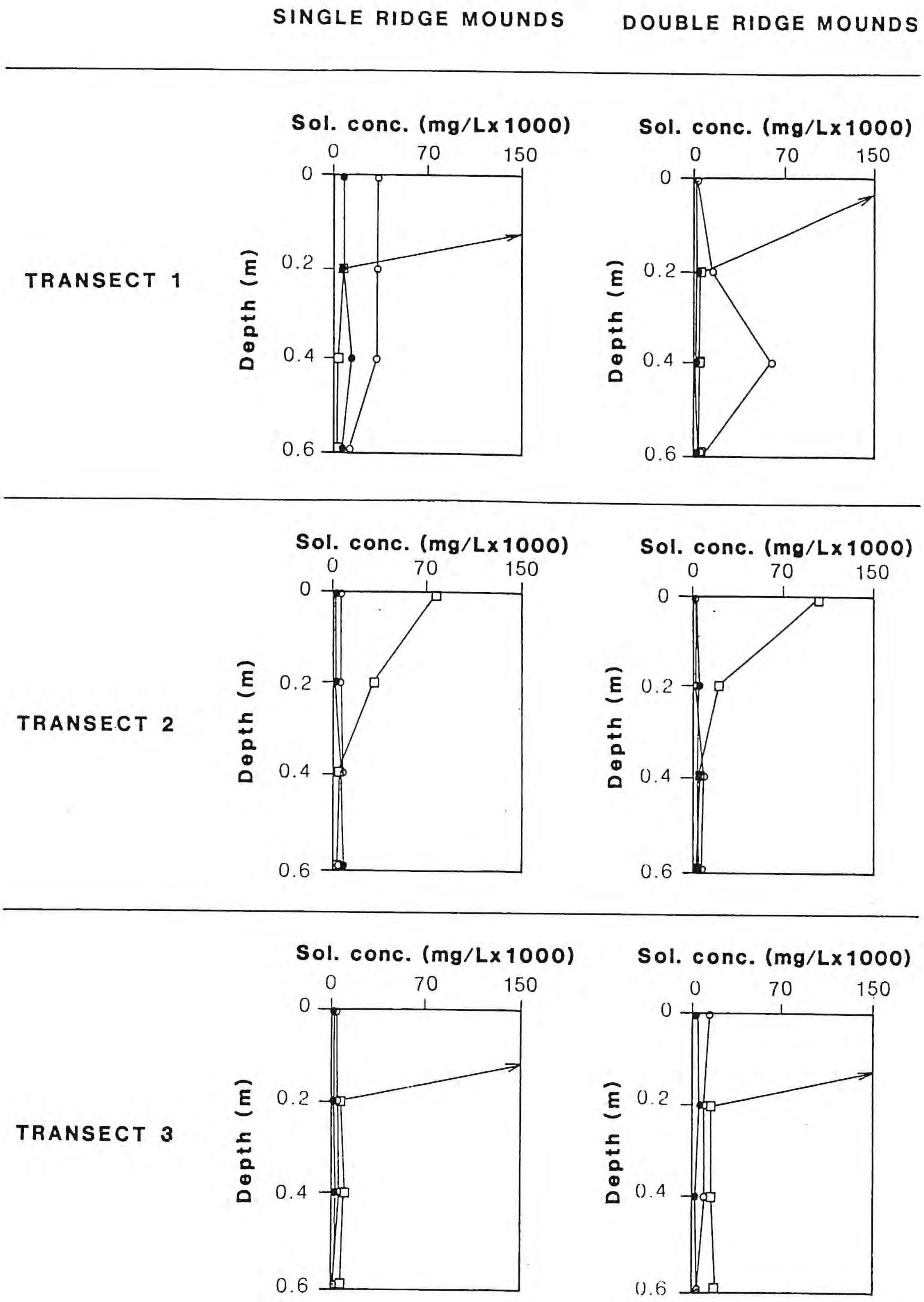

FIGURE 3f **Solute concentration (mg/L TSSx1000), Borlini site: ○ = 1/4/87, • = 1/8/87, □ = 17/3/88.**

Fig. 4. Rainfall measurements

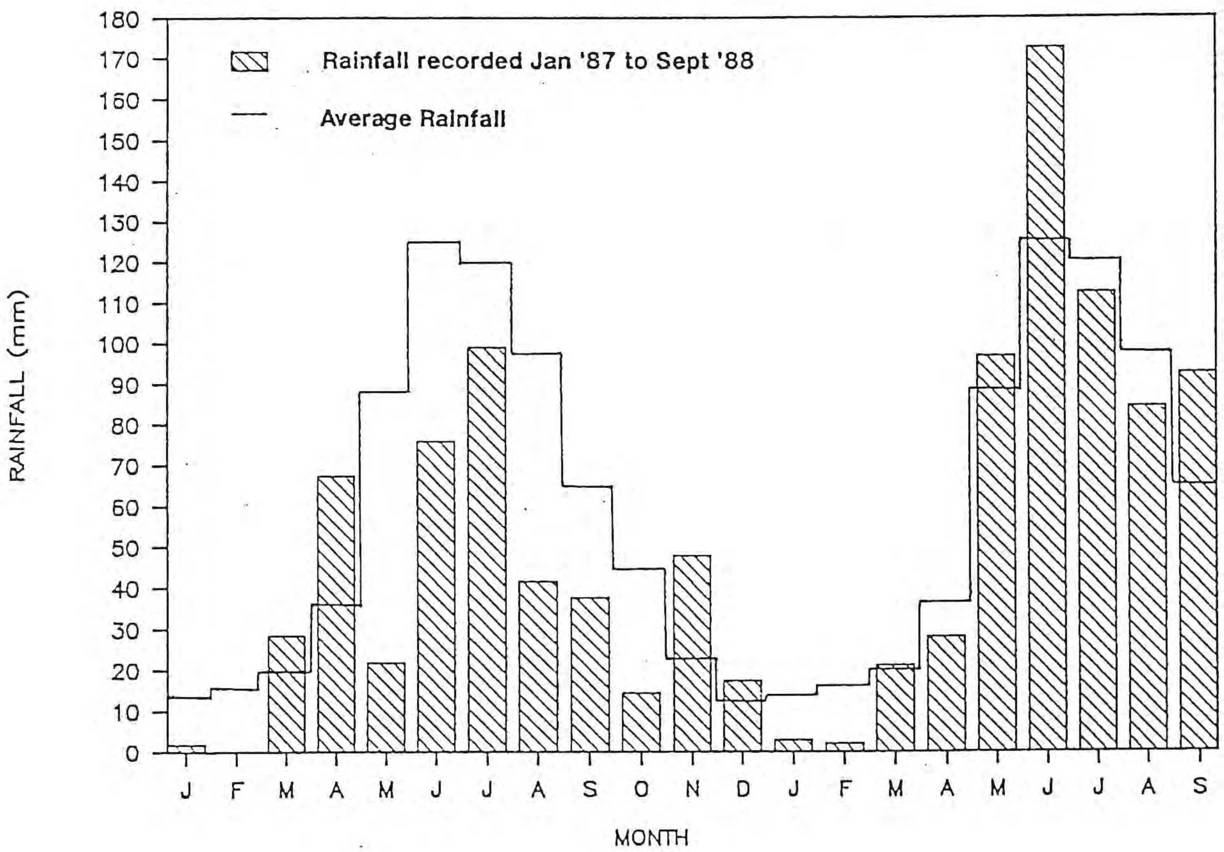

Fig. 4a. Monthly rainfall from January 1987 to September 1988 and average monthly rainfall on the study sites.

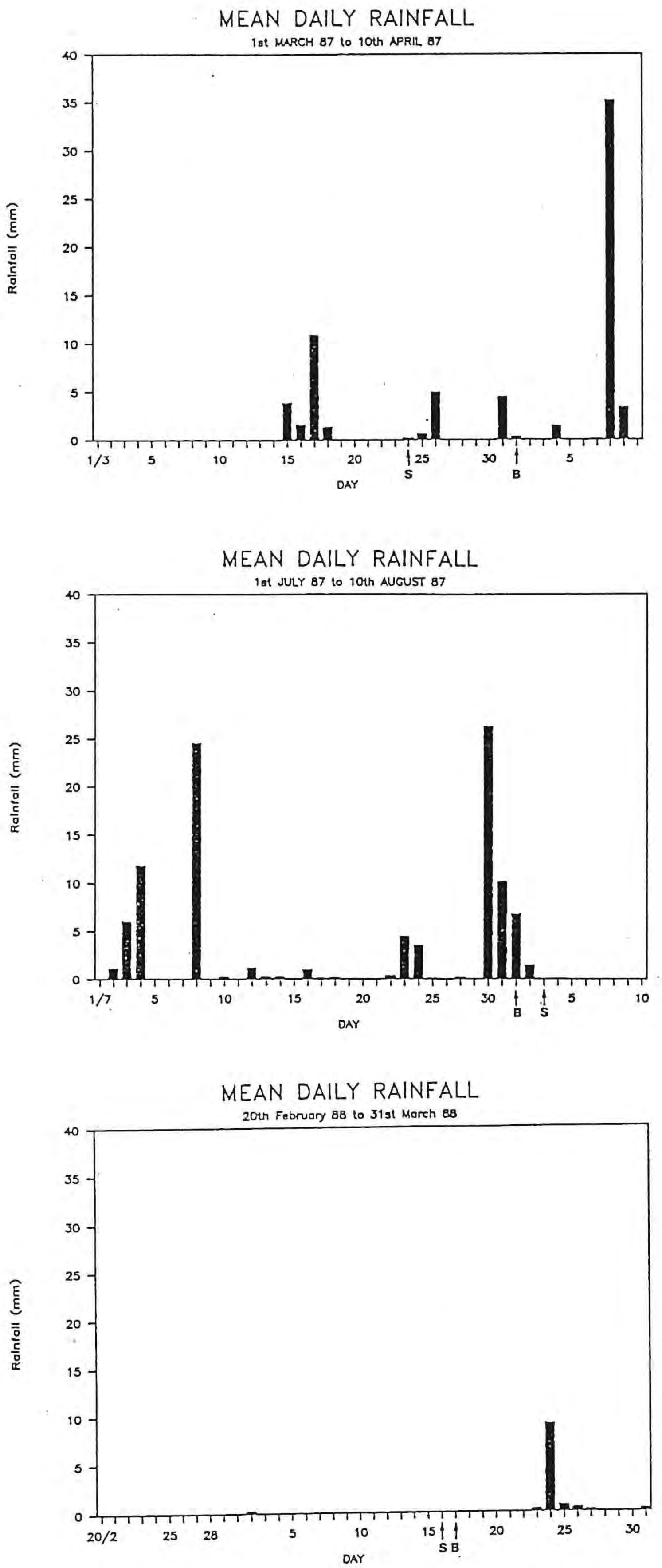

Fig. 4b. Daily rainfall on the study sites in the periods preceding soil sampling. Sample times at the Borlini (B) and South (S) sites are indicated.

Table 1. Significant differences in gravimetric total soluble salts (TSS) content, gravimetric moisture content (MC) and solute concentration

(i) Comparison between single and double ridge mounds

	Grav. TSS content	Grav. MC	Solute concentration
March/April '87	-	-	-
August '87	DR<SR	-	DR<SR
March '88	-	DR>SR	-

(ii) Comparison between sample times

(a) Single ridge mounds

	Grav. TSS content	Grav. MC	Solute concentration
Mar/Apr '87 c.f. Aug '87	-	Aug '87 > Mar/Apr '87	Aug '87 < Mar/Apr '87
Aug '87 c.f. Mar '88	-	Mar '88 < Aug '87	-
Mar/Apr '87 c.f. Mar '88	-	Mar '88 < Mar/Apr '87	-

(b) Double ridge mounds

	Grav. TSS content	Grav. MC	Solute concentration
Mar/Apr '87 c.f. Aug '87	-	Aug '87 > Mar/Apr '87	Aug '87 < Mar/Apr '87
Aug '87 c.f. Mar '88	Mar '88 > Aug '87	Mar '88 < Aug '87	Mar '88 > Aug '87
Mar/Apr '87 c.f. Mar '88	-	-	-

notes. (i) SR = single ridge mound, DR = double ridge mound.
(ii) c.f = abbreviation for 'compare'
(iii) Significant differences ($P<0.05$) noted
(iv) A dash (-) indicates no significant difference.
(v) Based on samples from mounds representative of seedling planting positions i.e. below the north side of single ridge mounds and below the trough bottoms of double ridge mounds.

5. DISCUSSION

Comparison between sites

The TSS content of most of the soil samples from the South site were well in excess of conventional divisions between saline and non-saline soils. These divisions are given by Marshall and Holmes (1979) as 0.15% TSS content for mainly fine textured soils and 0.08% TSS content for mainly coarse textured soils. The high soil salinities at the South site were reflected in the almost complete lack of pasture cover due to salt scalding at that site. Pasture cover on the Borlini site also reflected soil salinity. Though salinities were generally lower than at the South site many of the samples taken along Borlini transect 1 were saline according to the Marshall and Holmes (1979) criteria. The main exceptions along this transect were the samples taken from below the troughs of the double ridge mound in August 1987 which were mostly non-saline. Pasture cover in the vicinity of Borlini transect 1 was patchy (<20% salt scalds) and dominated by sea barley grass (H. marinum). Most of the samples taken along the Borlini transects 2 and 3 were non-saline and, correspondingly, there was an almost complete pasture cover, including sub-clover (T. subterraneum), in the vicinity of these transects.

The situation at the South site, where, in contrast to the Borlini site, soil samples from the upper parts of the site (transects 2 and 3) were more saline than soil samples from the lower part of that site (transect 1), was probably due to a hillside seep above that site. Also evident at the South site was a valley bottom seep which included all of that site. Both seeps would have contributed to the very high soil salinities at the South site. At the Borlini site there was only a valley bottom saline seep which extended part way up the site.

Comparison between mounds

The greater leaching of salts by planting time from below the troughs of double ridge mounds than from below the equivalent planting position of single ridge mounds (the sides) may be very important for tree or other plant establishment. Confirmation of this was obtained by comparing establishment success of *E. camaldulensis* and *E. largiflorens* on the mounds sampled in this study and other single and double ridge mounds. The results of that experiment are described in detail by Ritson and Pettit (1988 and paper in preparation) but, briefly, survival and growth of both species were clearly superior on the double ridge mounds.

The accumulation of salt in the surface (0 - 20 cm) layer of both mound types over the summer/autumn seasons following planting may have been accentuated by the particularly dry conditions then (Figs 4a, 4b). The lack of rain would have decreased salt leaching potential. However, the accumulation that was observed may not have adversely affected the young trees growing in the mounds. From observations of exposed tree roots in mounds that have washed away, it is assumed that by March 1989 (8 months after planting) that the roots of the young trees would have extended well below 20 cm. Thus, although salinity in the surface 20 cm of soil appears to be critical at planting time in winter it may be less critical by the following autumn.

Another advantage of double ridge mounds may be the effect of the trough catching and channelling rain to seedling root zones over the dry summer/autumn seasons when drought stress of seedlings (young trees) commonly occurs. In March 1988 moisture was greater below the troughs of double ridge mounds than below the sides of single ridge mounds. This occurred despite the very low (below average) rainfall in the three months prior to sampling in March 1988 (Figs 4a, 4b). Had rainfall then been equal to, or greater than average, there may have been more difference in moisture content between the planting positions in the two mound types.

6. CONCLUSIONS

Conditions for tree establishment in saline seep areas appeared superior in the double ridge mounds compared with the single ridge mounds. This was attributed to the trough of double ridge mounds which collects rain thus facilitating

(i) salt leaching from the root zone of seedlings planted in the trough bottom

(ii) watering of seedlings during the dry summer/autumn seasons.

Salt accumulated in the surface (0-20 cm) soil layer of both mound types over the summer/autumn season. However this may not be critical as by then seedling (young tree) roots should have extended below this depth.

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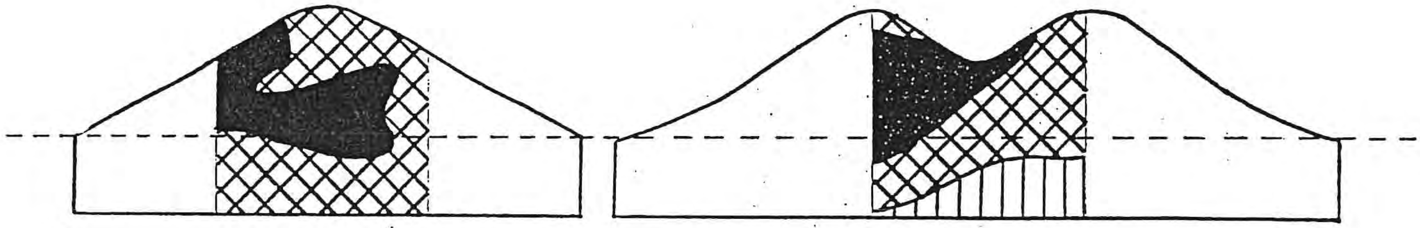
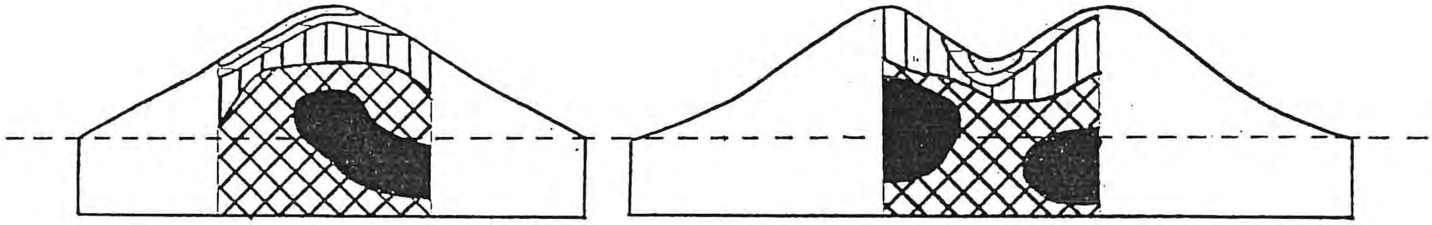
Appendices 1-3. Contour plots of gravimetric total soluble salts content, gravimetric moisture content and solute concentration in single and double ridge mounds.

South, Transect 1

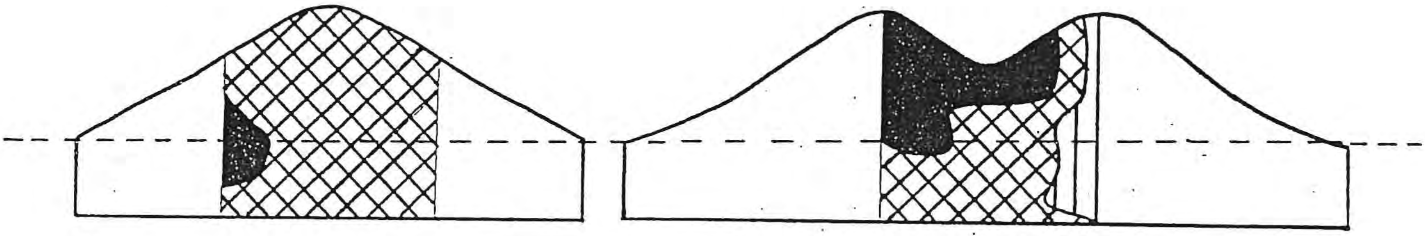
24/3/87



3/8/87

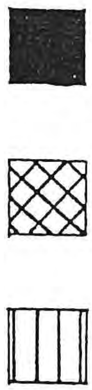


16/3/88



Legend

Gravimetric total soluble salts content (%)



>1.0

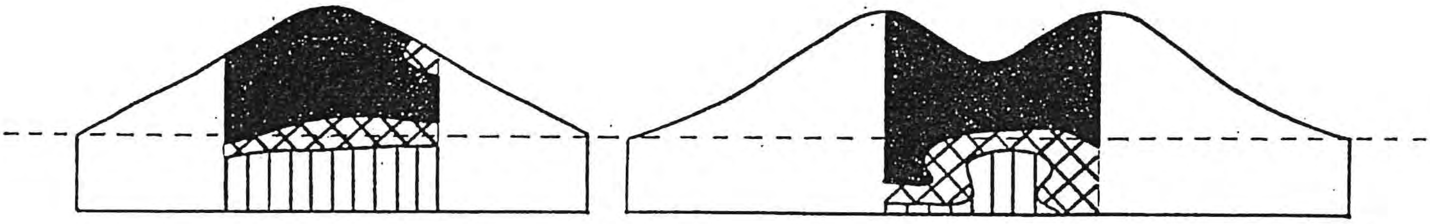
0.6 – 1.0

0.11 – 0.5

App. 1 Gravimetric total soluble salts content

South, Transect 2

24/3/87



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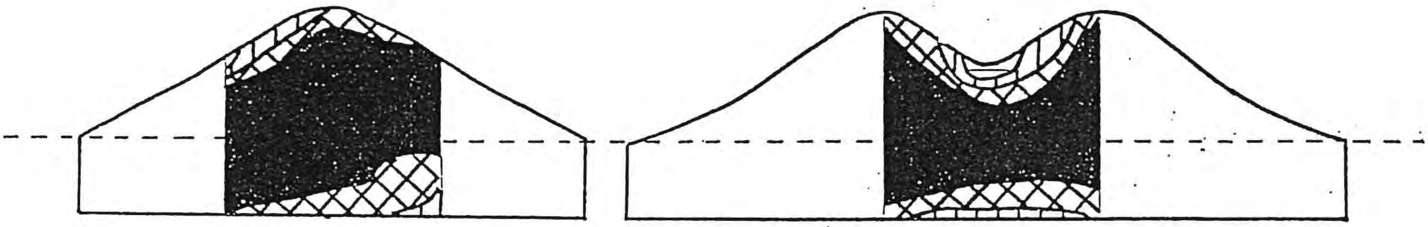
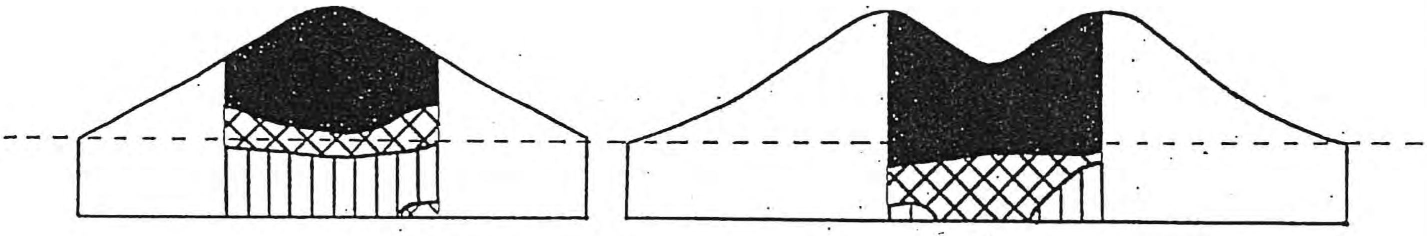
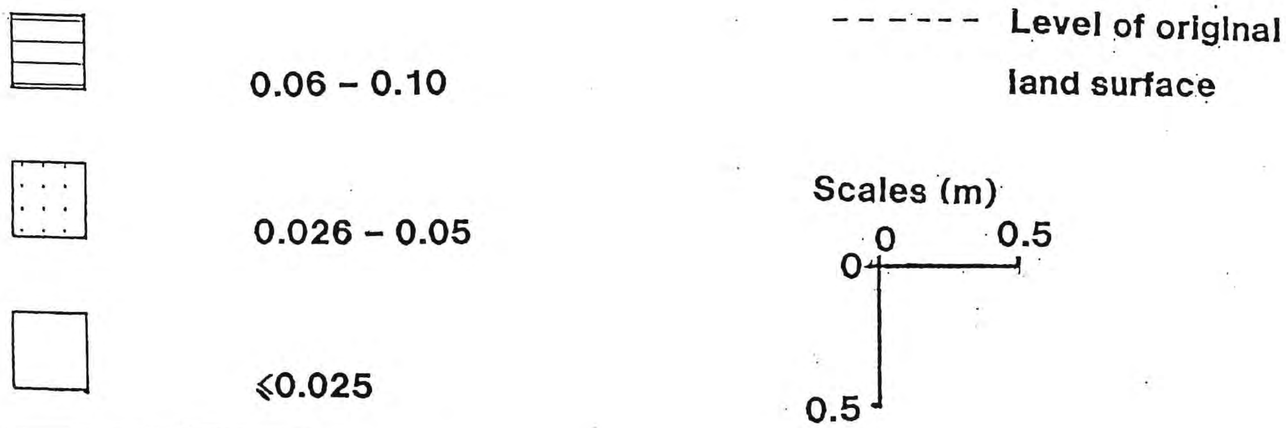


16/3/88





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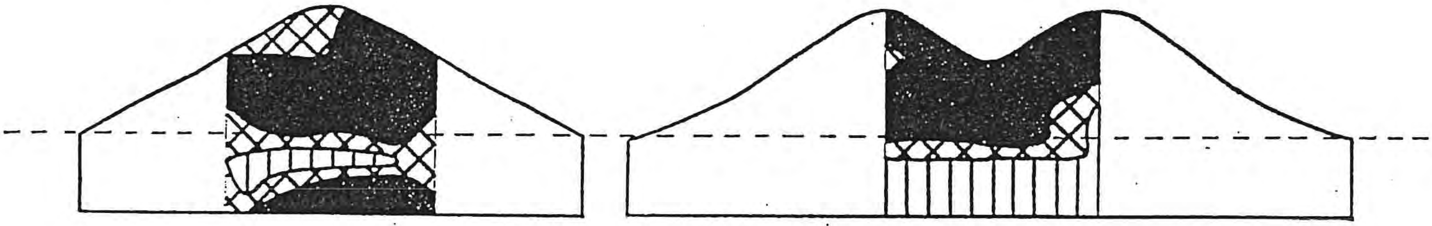
South, Transect 3

24/3/87



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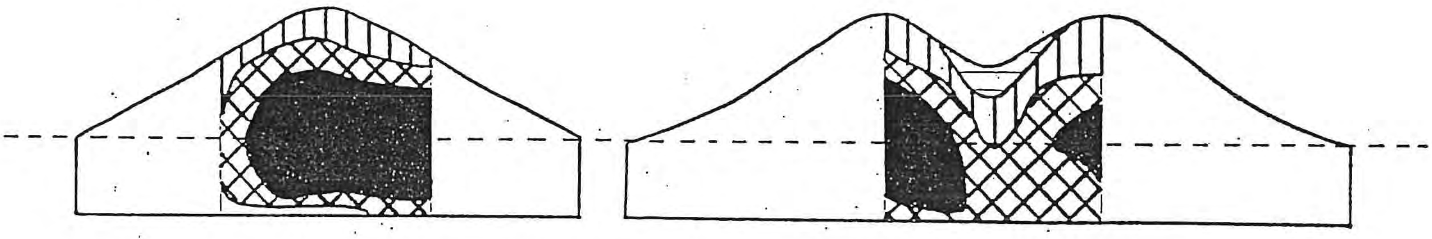
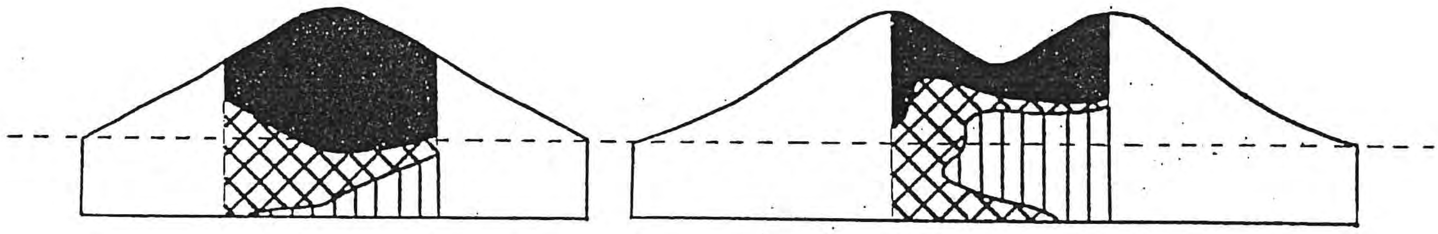
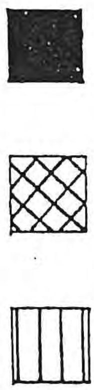


16/3/88



Legend

Gravimetric total soluble salts content (%)



>1.0

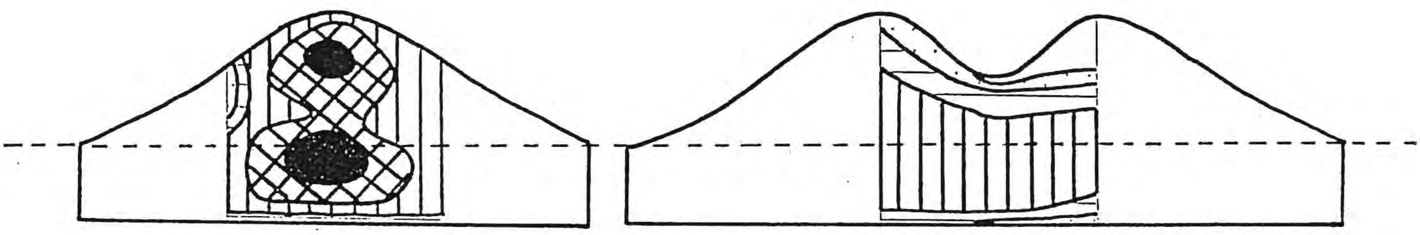
0.6 – 1.0

0.11 – 0.5

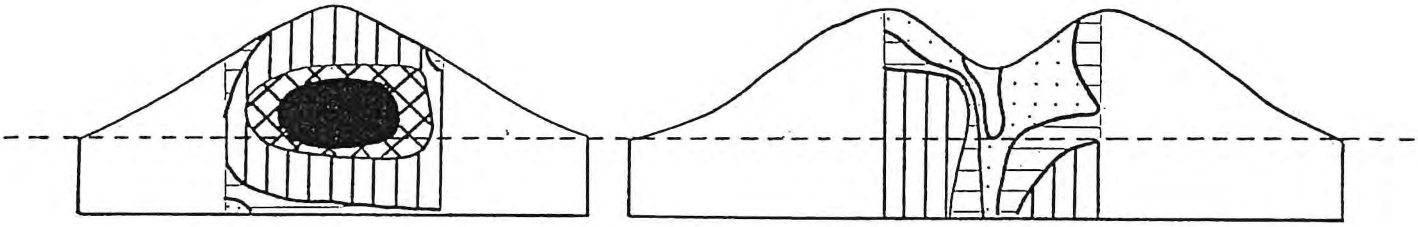
App. 1 cont.

Borlini, Transect 1

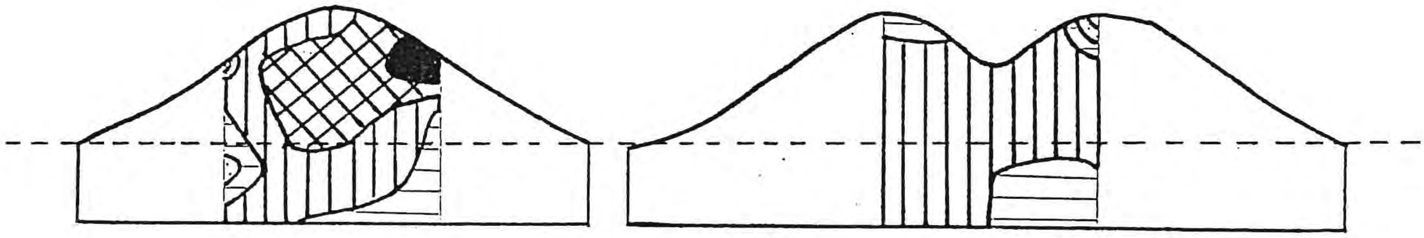
1/4/87

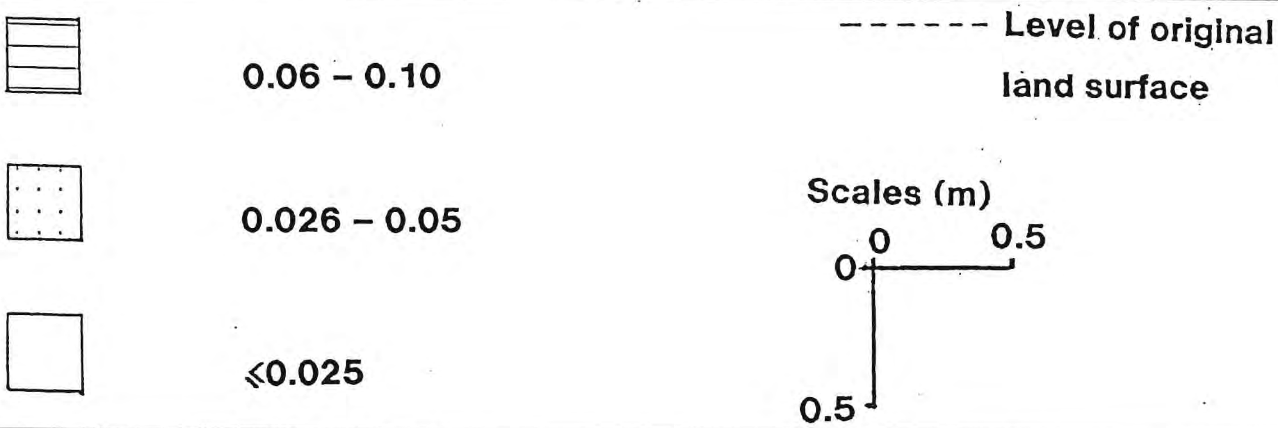


1/8/87



17/3/88

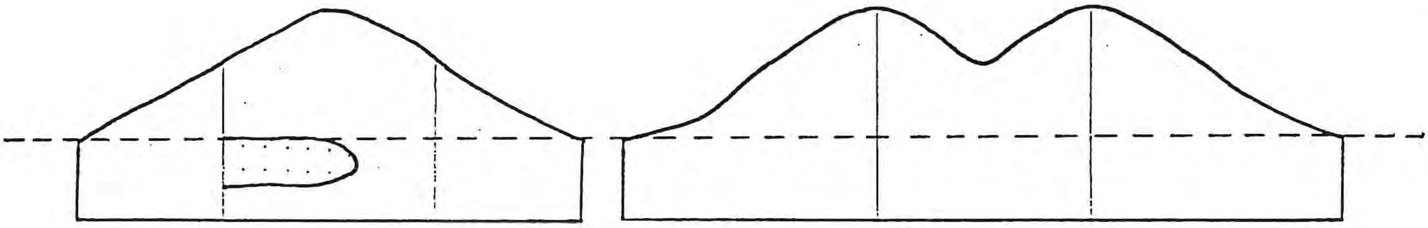




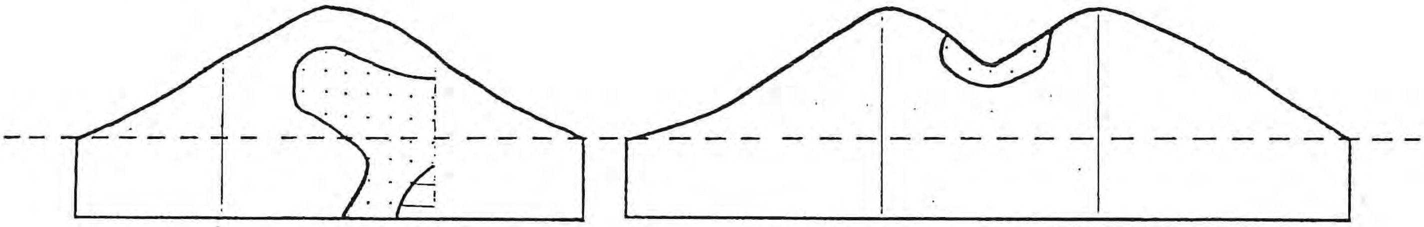
App. 1 . cont. over ...

Borlini, Transect 2

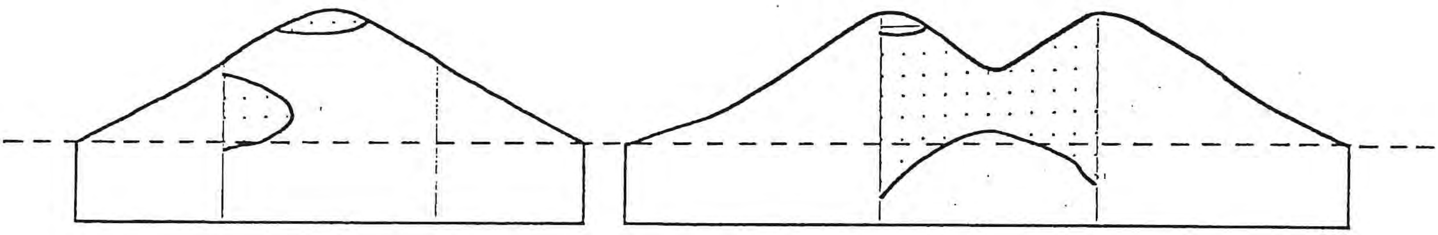
1/4/87



1/8/87

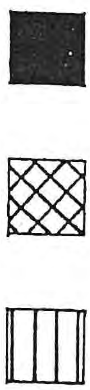


17/3/88



Legend

Gravimetric total soluble salts content (%)



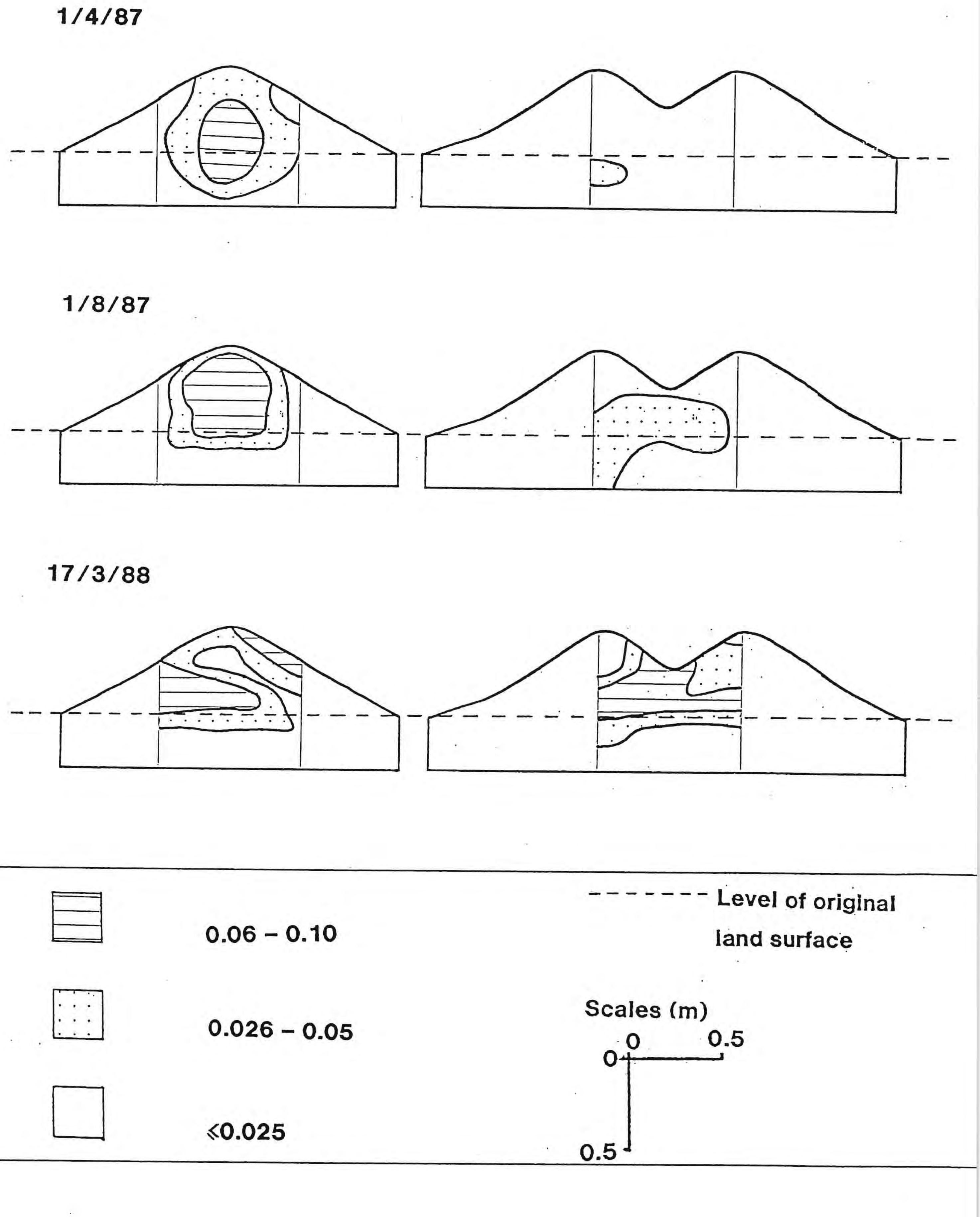
>1.0

0.6 – 1.0

0.11 – 0.5

App. 1 cont.

Borlini, Transect 3



South, Transect 1

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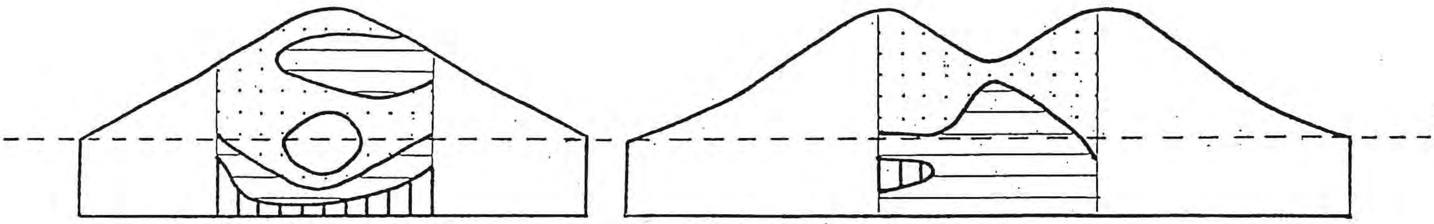
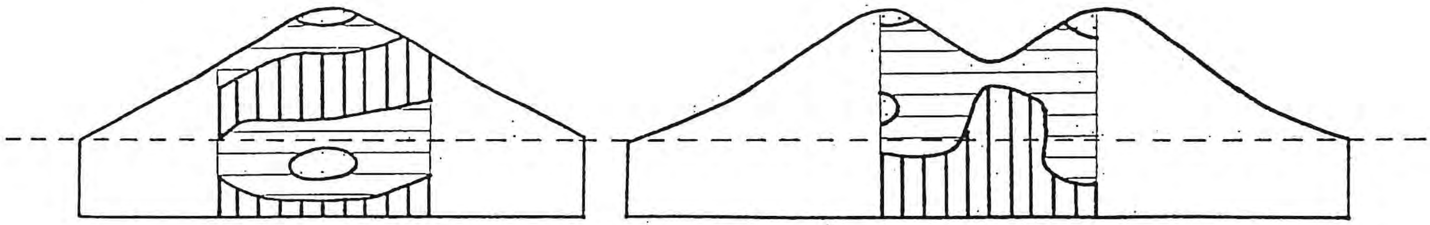
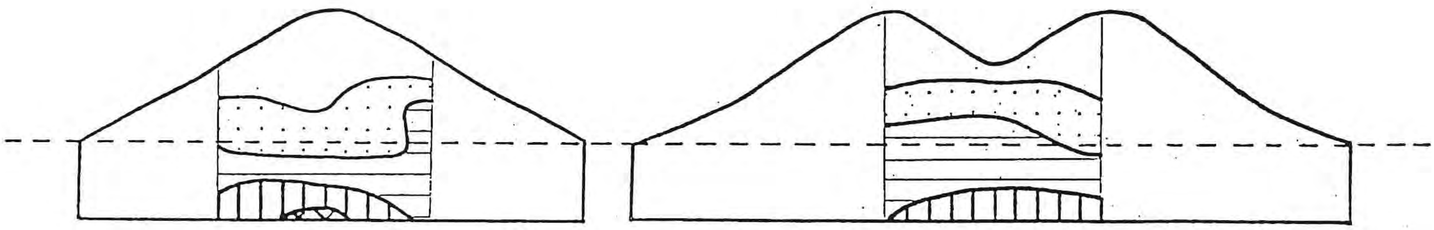


3/8/87

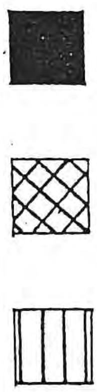


16/3/88



Legend

Gravimetric moisture content (%)



>25

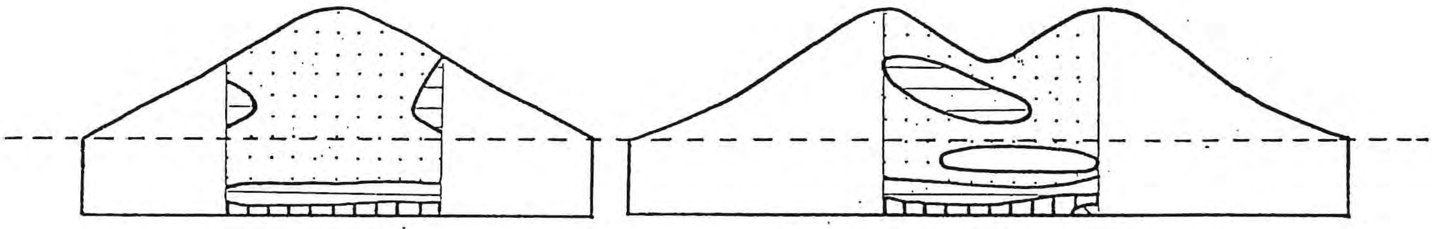
21 – 25

16 – 20

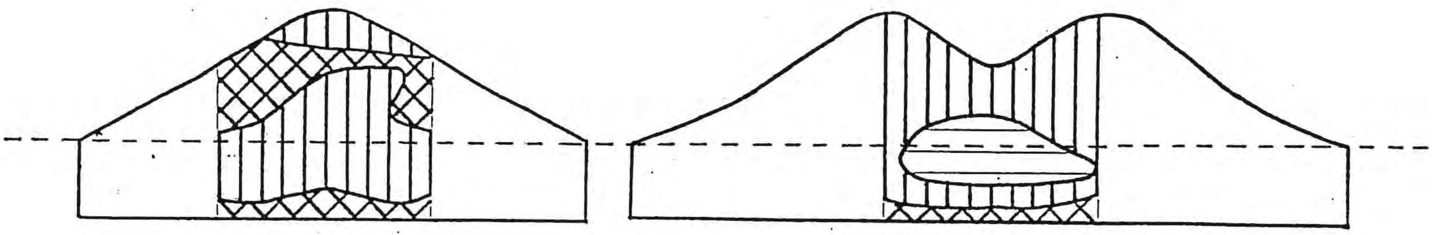
App. 2 Gravimetric moisture content

South, Transect 2

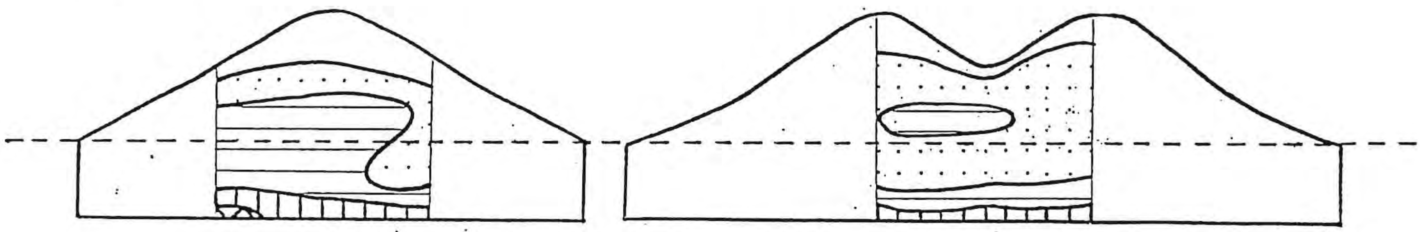
24/3/87

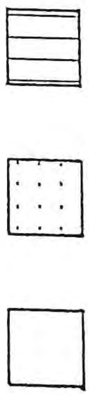


3/8/87



16/3/88





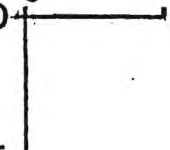
11 – 15

6 – 10

≤5

- - - - - - Level of original land surface

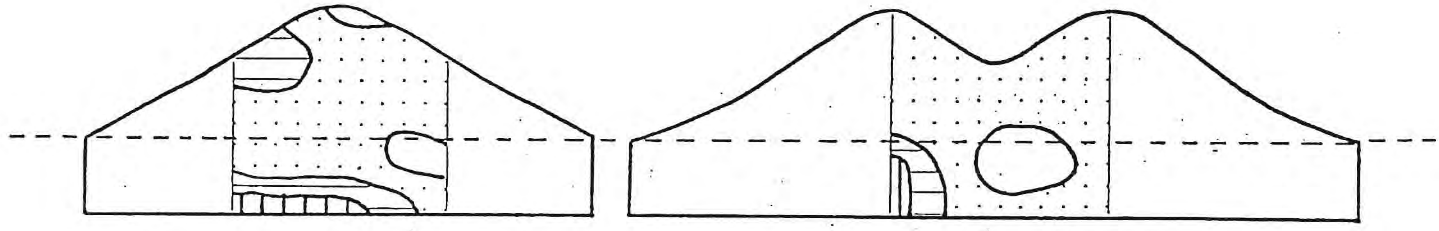
Scales (m)



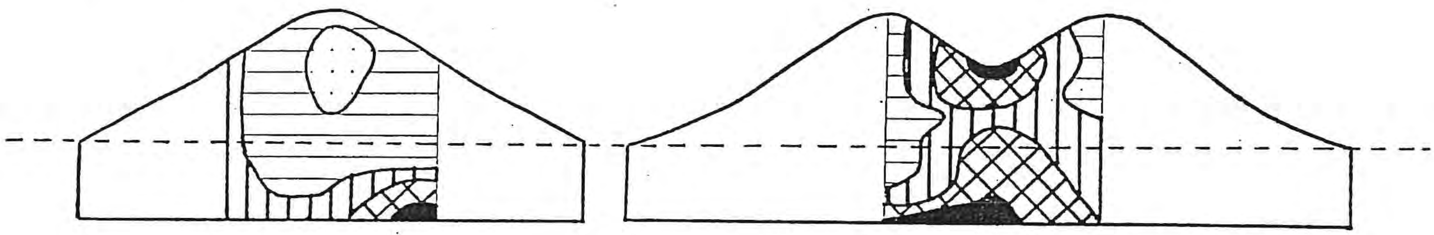
App. 2 cont. over ...

South, Transect 3

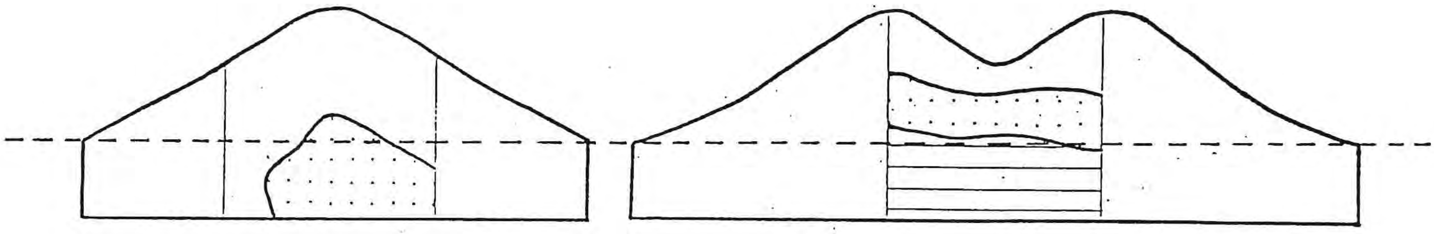
24/3/87



3/8/87

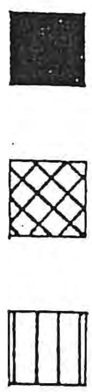


16/3/88



Legend

Gravimetric moisture content (%)

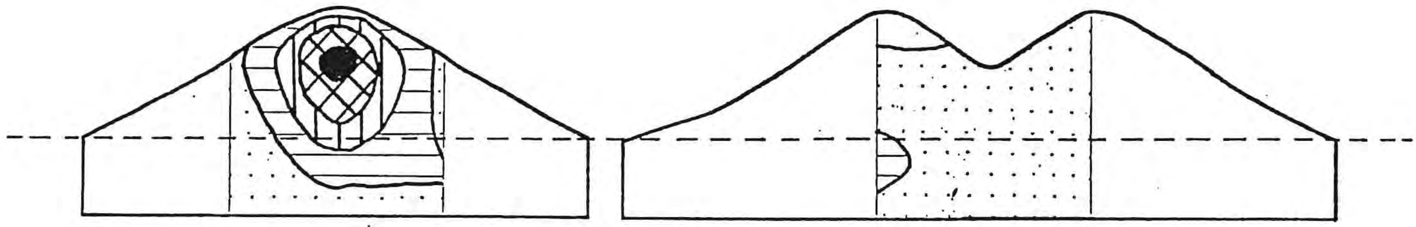


>25	
21 – 25	
16 – 20	

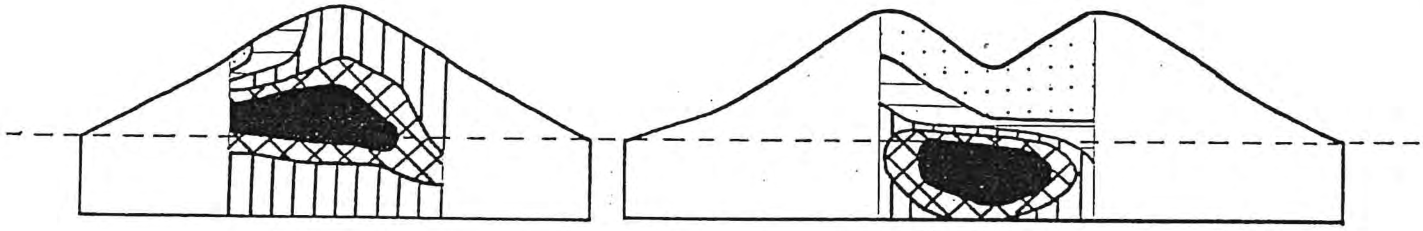
App. 2 cont.

Borlini, Transect 1

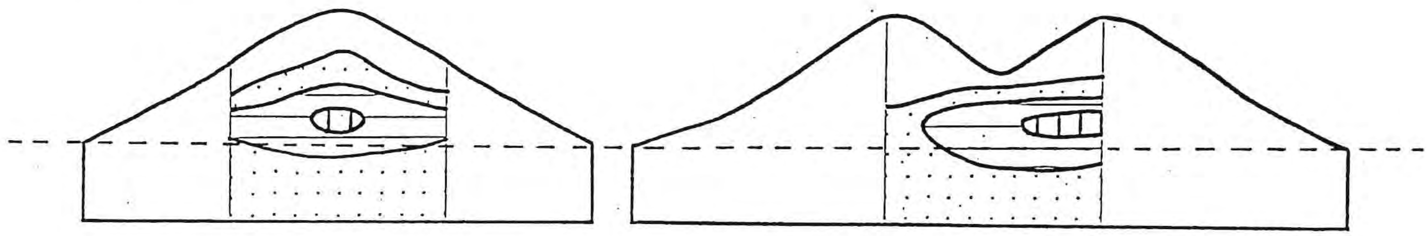
1/4/87



1/8/87

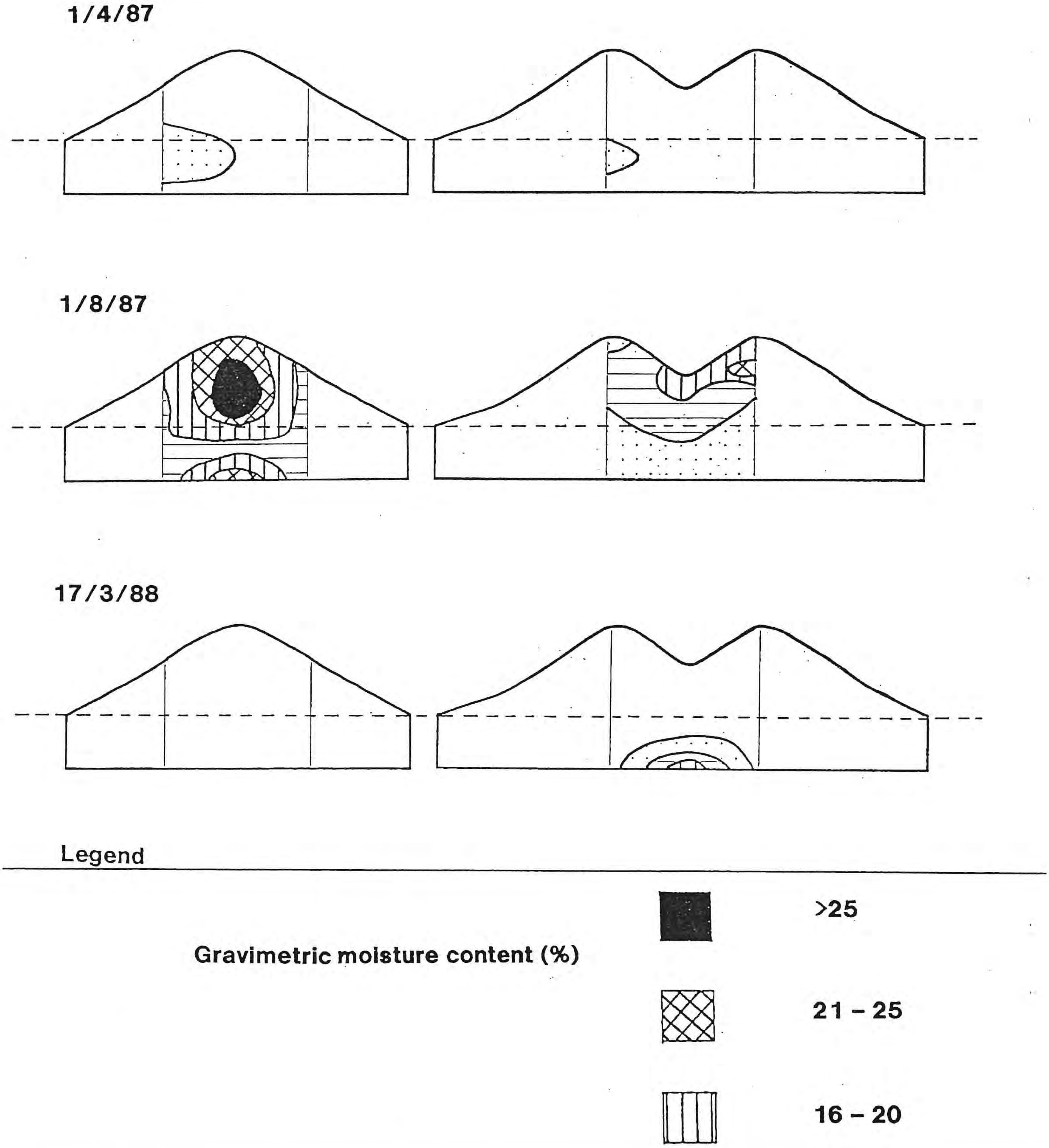


17/3/88



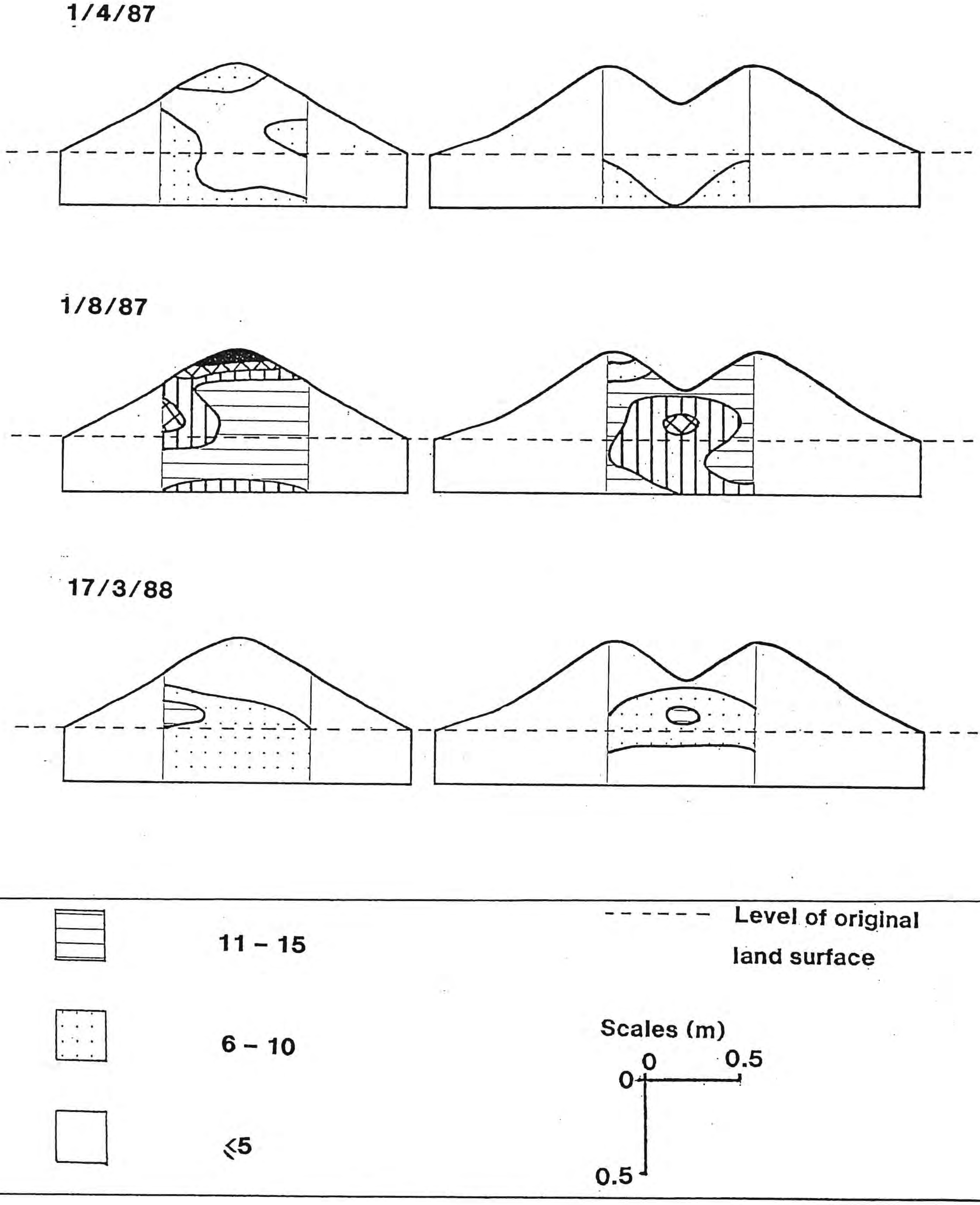
App. 2 cont. over ...

Borlini, Transect 2



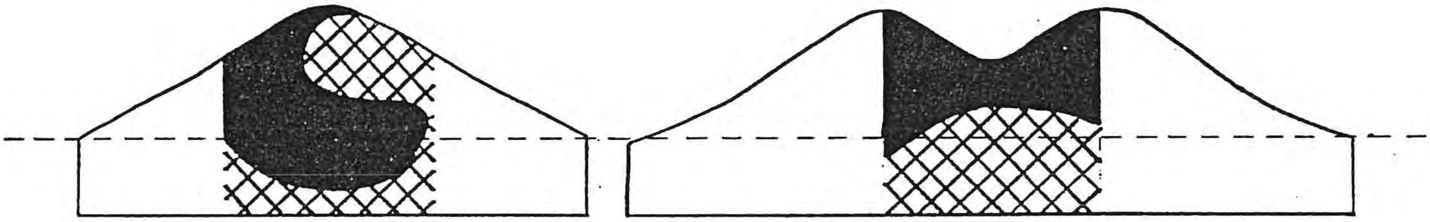
App. 2 cont.

Borlini, Transect 3

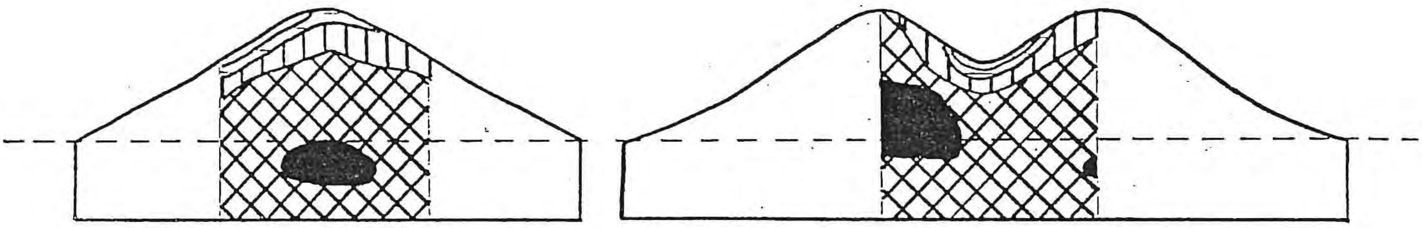


South, Transect 1

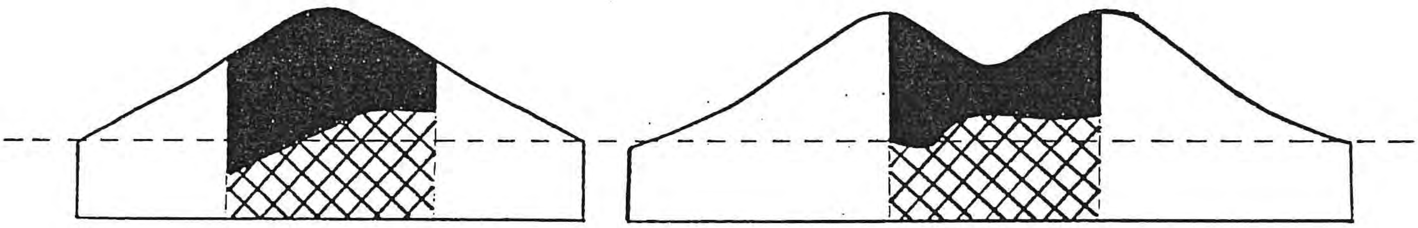
24/3/87



3/8/87

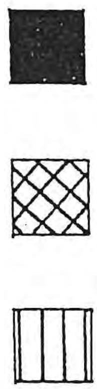


16/3/88



Legend

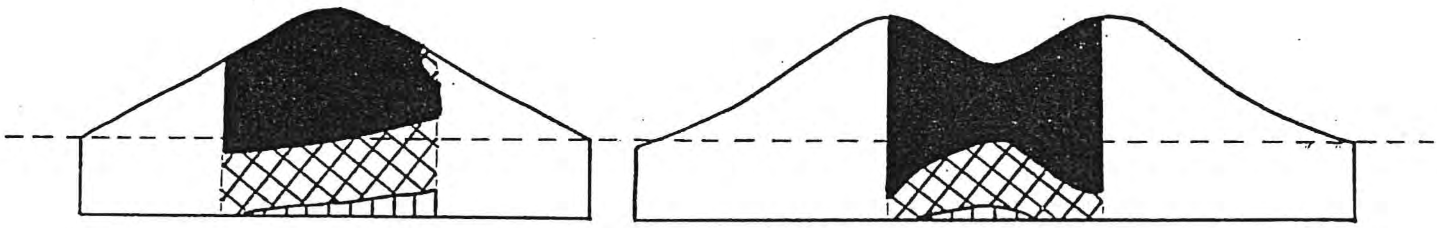
Solute concentration
(mg/L TSS X1000)



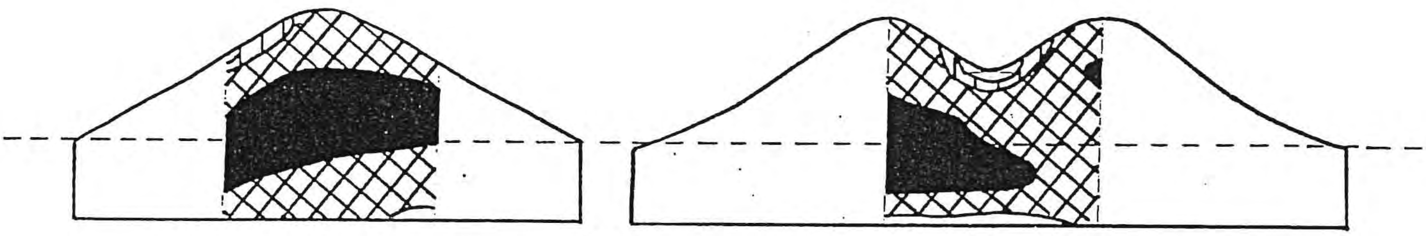
App. 3 Solute concentration

South, Transect 2

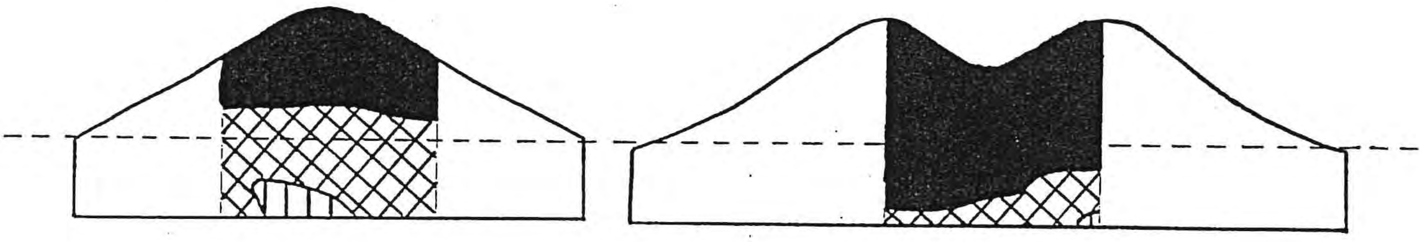
24/3/87

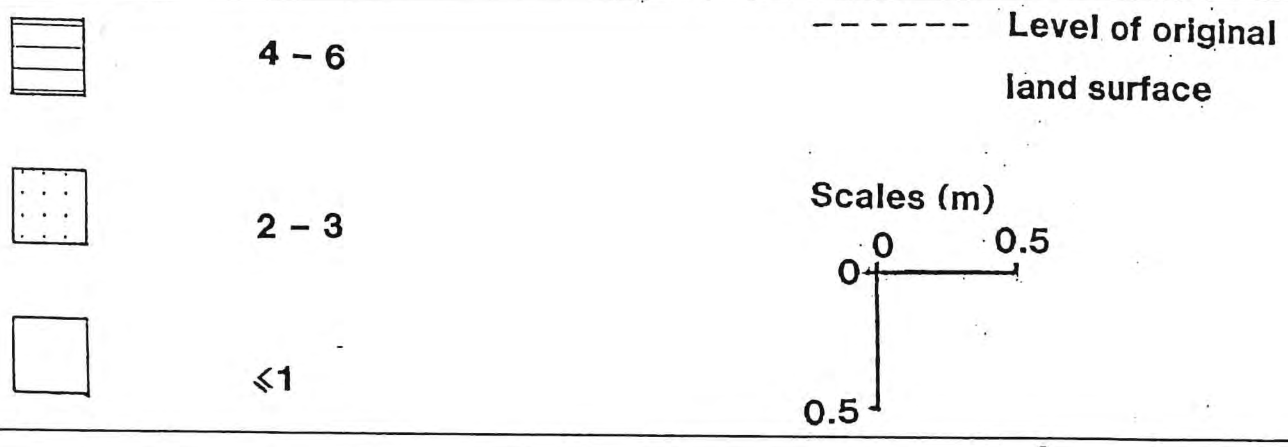


3/8/87



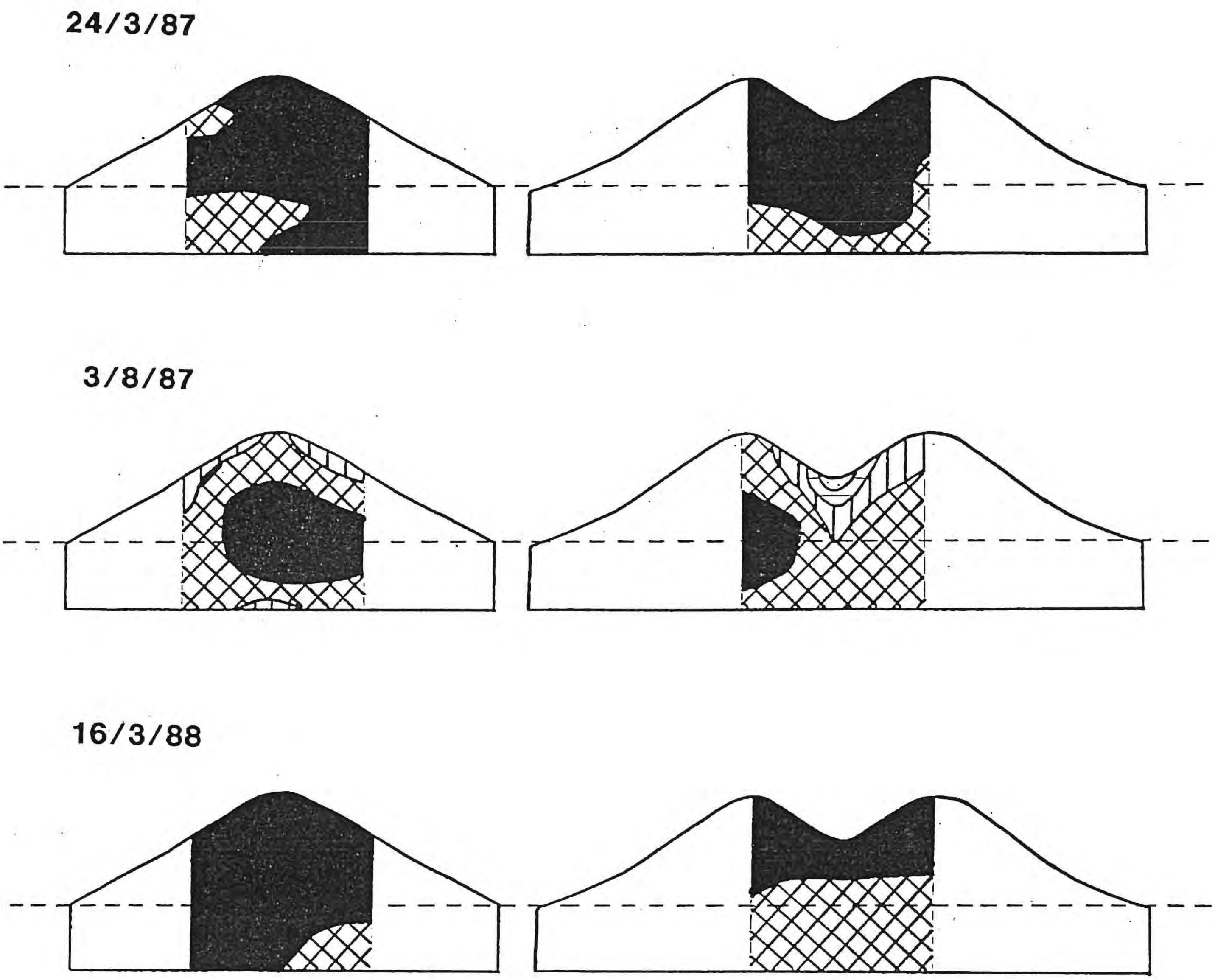
16/3/88



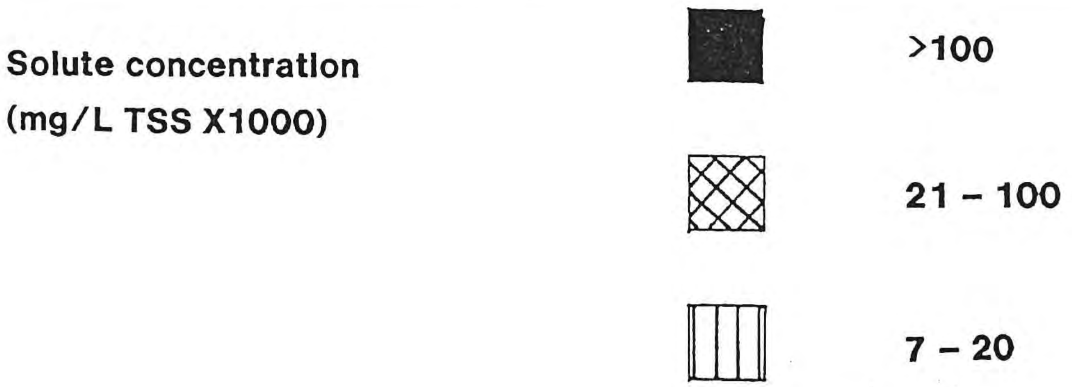


App. 3 cont. over ...

South, Transect 3



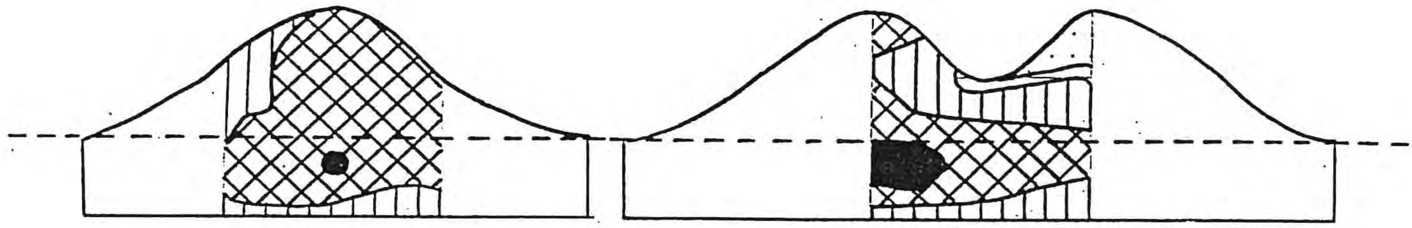
Legend



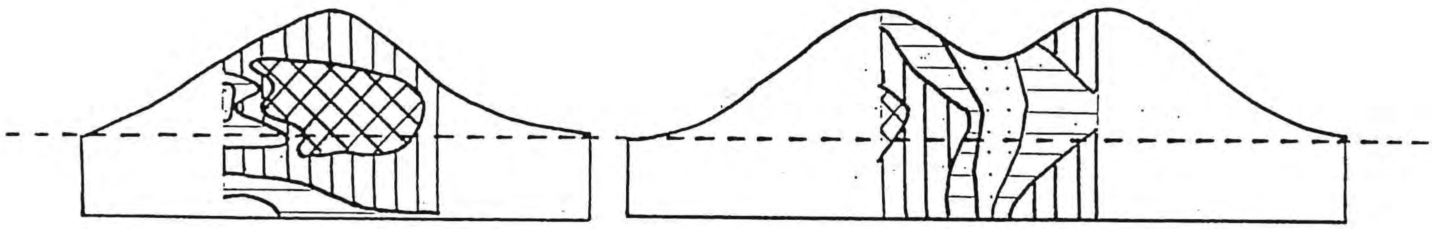
App. 3 cont.

Borlini, Transect 1

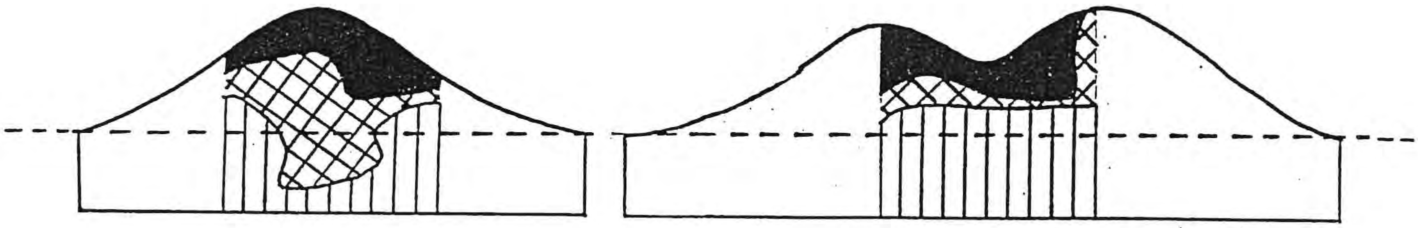
1/4/87

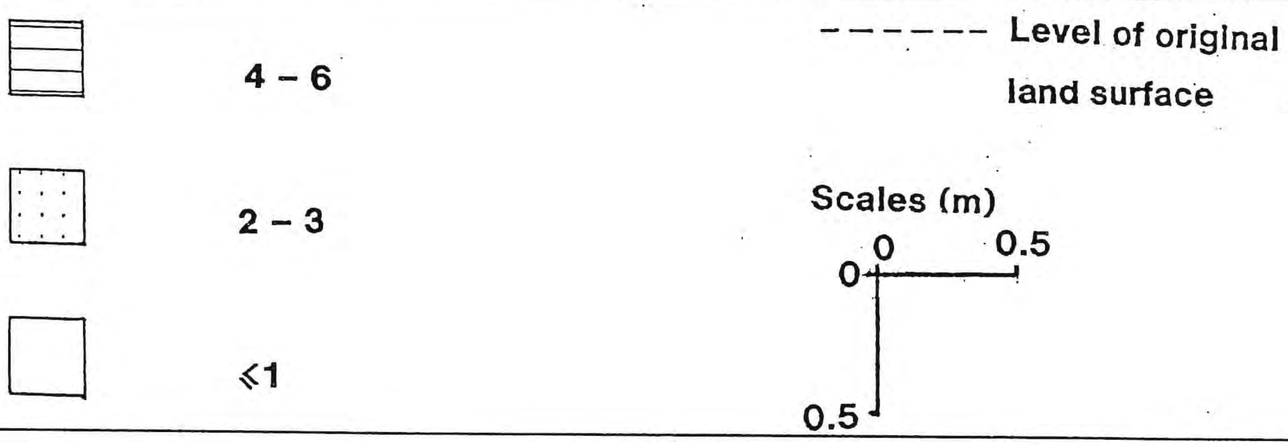


1/8/87



17/3/88

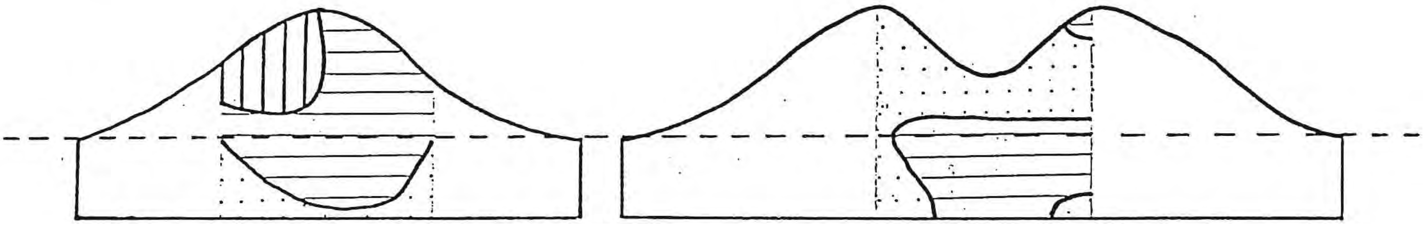




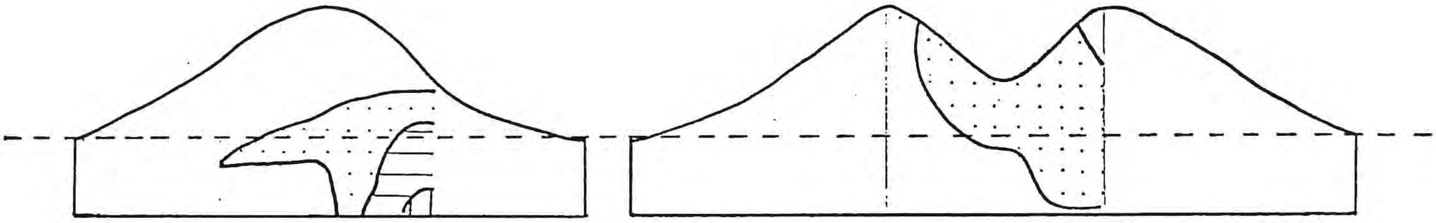
App. 3 cont. over ...

Borlini, Transect 2

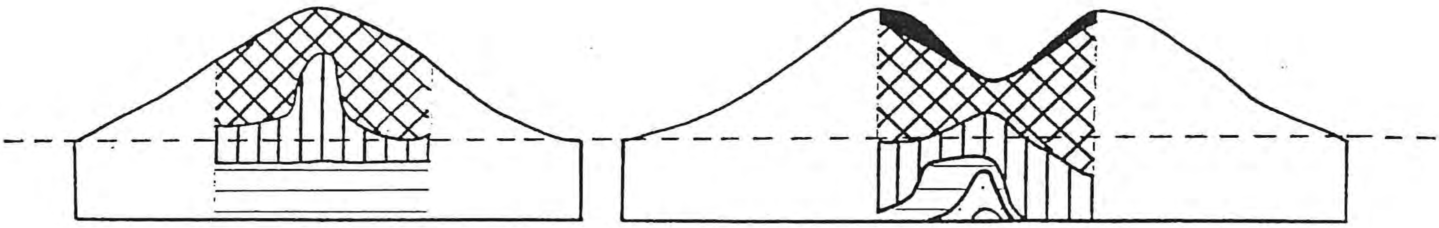
1/4/87



1/8/87

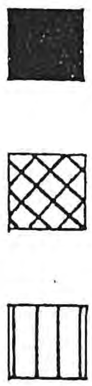


17/3/88



Legend

Solute concentration
(mg/L TSS X1000)



>100

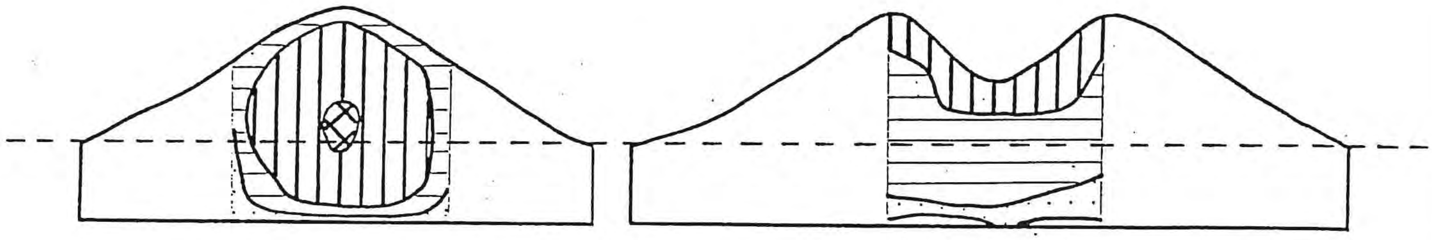
21 – 100

7 – 20

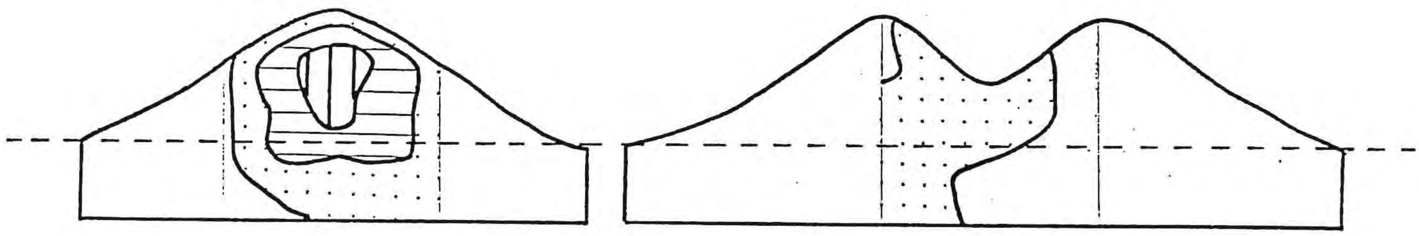
App. 3 cont.

Borlini, Transect 3

1/4/87



1/8/87



17/3/88