4. HYDROLOGICAL CHARACTERISTICS OF THE SOILS

The hydrological characteristics of the clay soils were found to be remarkably consistent throughout, except at a few sites on rocky ridges where infiltration rates were usually high. The results are summarized in Tables II to V and a detailed statistical evaluation will be found in Tables 1 to 19. The data for each of the variables appeared to be normally disturbed and, consequently, are reported as arithmetic means with confidence limits set at 95%. As there is a distinct correlation between geomorphology and soil type, the data area also arranged according to position in the landscape, allowing the comparison of parameters in equivalent situations. Discussion of the results follows.

4.1 Bulk Density

The distribution of bulk density at each geomorphic situation was found to be relatively consistent and uniform. The values showed only minor differences between each catchment, due largely to varying proportions of parent material present as colluvial fragments or weathered in situ rock. In general, the bulk density increased with depth, although the B1 horizons sometimes showed higher values where they were more stony than soil lower in the profile.

The B horizons of the sodic duplex soils tended to be texturally homogeneous and were usually clays or silty clays. As marked variations in texture were not common, the B soil horizons were used for comparisons between different geomorphic situations.

Catenary differences in bulk density also were not great. In Eppalock catchment No. 1 for example, the bulk density ranged from 1.55 on the lower and intermediate slopes, to 1.63 on the upper slopes, and was 1.65 on the valley floor. This higher values for valley floor and upper slope situations were attributed to the presence of slightly higher density alluvial and parent materials respectively.

In general, bulk density indicates the degree of soil homogeneity, although the amount of soil moisture in the profile must also be considered. The forested catchments were sampled at wilting point. Consequently, the bulk density values were higher than those in the adjacent cleared catchments which were sampled at or near field capacity. The difference was approximately 6% and appears to be related to soil shrinkage under very low moisture conditions. However, the layered clay minerals are principally kaolin and potassium mica which do not have the large shrink-swell potential normally associated with the expanding lattice clays such as montmorillonite. The bulk density values for the Kamarooka areas are slightly lower than the Eppalock values owing to their greater degree of textural homogeneity, which is related to more intense weathering. Limited information from the forested catchments, obtained while the soils were at a higher moisture content, gave values consistent with those from the cleared area. The bulk density values are important as they provide an indication of the soil moisture storage capacity. Consistent values throughout the various areas examined suggest that a similar internal consistency applies to other properties related to soil moisture storage. The particle densities varied little, ranging between 2.72 and 2.81, with an average of 2.76.

4.2 Total porosity

The variation in total porosity of the soils is directly related to variation in bulk density, the independent variable. The total porosity for B horizons at or close to field capacity was approximately 40-45%. Results for the forested catchments, sampled at low moisture status, were about 5% lower as a result of soil shrinkage and the presence of more rock material.

Minor differences, which can be explained by textural inhomogeneity related to position in the landscape, occur in Eppalock Catchment No. 1. Total porosities of soils on the valley floors were 2% less than those on the intermediate and lower slopes, and those on the upper slopes were 4% less. A similar distribution occurred in the forested catchments although the values for the upper slopes of the Eppalock No. 2 Catchment appeared to be slightly higher relatively, possibly related to the variable nature of the red-brown gradational soils.

The Kamarooka values were slightly higher than the Eppalock values, again because of the absence there of non-porous rock fragments in the more highly weathered profile.

Total porosity values were determined for a variety of rock samples including weathered sandstone, slate and Shale (Table 19). The results showed that the inherent porosity of such rock is very low, generally much less than 10%. Water storage and transmission must therefore occur mainly in fractures such as joints and shear zones rather than in pores within the rock material itself.

4.3 Field Capacity

Field capacity values varied mostly from 34% to 38%, indicating little variation throughout the landscape. Large numbers of determinations were made for Eppalock Catchment No. 1 and the average difference of values between any of the geomorphic components was generally less than 3%. Field capacity values show a distribution similar to those for total porosity, that is, decreasing with depth in the profile. However, values determined for Kamarooka areas No. 1 and No. 2 were slightly higher (40%), although the populations were not statistically different.

The field capacity values of A and BC horizons were consistently lower than those for the B horizons, undoubtedly due to textural differences. The A horizons are well-drained sandy loams and the BC horizons contain a large proportion of non-porous weathered rock, which reduces the volume of available water storage.

Field capacity values for forested catchments were not determined as this moisture content was not reached throughout the duration of the project, in itself a significant observation. However, limited soil moisture data from earlier work were available for comparison (Jenkin and Irwin, 1976, SCA unpublished). This suggested that field capacity under forest approximates that of cleared areas, although the condition may be of rare occurrence.

4.4 Macroporosity

Macroporosity is defined as the air-filled porosity of the soil at field moisture capacity, that is, it represents the difference in water content between total saturation and field capacity.

Values were quite consistent in all areas sampled, and the detailed sampling in Eppalock No. 1 catchment showed an average range of 6% to 8% for the B horizon throughout the landscape. Slightly higher values were recorded for the more weathered profiles at Kamarooka.

The forested catchment values were lower than those for the cleared catchment. However, this difference was attributed to sampling in the forest at low moisture content and the consequent effects of soil shrinkage. Bulk density, and hence total porosity, has been determined at low moisture content while field capacity was determined, by definition, at high moisture content. The difference between these values is therefore an under-estimate of macroporosity.

4.5 Hydraulic conductivity

Horizontal and vertical saturated hydraulic conductivity values were both determined. Horizontal values for the B and BC horizons were consistently low, and generally ranged from 0.04 m/day to 0.10 m/day, but were mostly about 0.05 m/day. The values were consistent for all areas under both forested and cleared conditions, and in both the Eppalock and Kamarooka sites.

The vertical saturated values were determined as infiltration through the top of the B horizon and, were consistently very low. Exceptions however occurred on the poorly developed red-brown gradational soils on the upper slopes around the rocky ridges. Values for these sites were highly variable and sometimes very high (0.10 m/day). However, low values were also recorded, the rate of infiltration being controlled by the proportion of fine textured material in the B horizon.

The infiltration rates for the A horizons of all soils investigated were exceptionally high and variable compared with those for the B horizons, and often ranged from 0.10 to 3.0 metres per day. This implied that the A horizons were able to absorb rainfall much more readily than the B horizons and may "pond" water over the underlying B horizon for short periods after rain. In addition the upper surface of the B horizon was found to be less permeable than the B horizon proper.

The rate of infiltration through the top of the B horizon was particularly low, seldom greater than 0.005 m/day, for all soils other than those around the rocky ridges. The hydraulic conductivity of the upper B horizon appears to be an order of magnitude less than either the lower B or the BC horizon. As the hydraulic conductivity of the upper B horizon was measured vertically (infiltration) and the lower profile levels horizontally (auger-hole method), it must be assumed, for purposes of comparison, that each profile segment is hydrologically isotropic. Manifest textural and structural homogeneity suggests that this assumption is valid. It appears, therefore, that the upper part of the B horizon acts, at saturation, as a throttle regulating water entry to the deeper parts of the profile, a characteristic also noted by Loveday et al (1978) in Riverine Plain soils.

Although the hydraulic conductivity at saturation was similar for both forested and cleared catchments, the forested areas too much longer time to reach saturation. This was attributed to the initially very low moisture content of the soils and the consequently large volume of water required to fill the available storage, and possibly to the effect of water-repellent fungi.

The permeability results are very significant with regard to the salinisation process. Soils of low permeability are often saline because insufficient water is able to move through the profile and leach the salts which accumulate over long periods of time. Also this process is exaggerated by the relative difference between annual rainfall and potential evaporation. Deep percolation occurring occasionally under wet conditions may then result in accessions to deeper saline groundwater.

4.6 Soil Water

Soil water changes in the two Eppalock catchment through 1980 were found to be significantly different. The forest soils were at or close to wilting point through most of the year, and water which infiltrated after rain was rapidly removed, almost certainly by evapotranspiration, even in winter. By contrast, the soils of the cleared catchment reached field capacity after the first heavy autumn rains, and the subsoils remained at that moisture level until mid spring at least. Furthermore, even during summer, the soil moisture values did not reach the low wilting point moisture level recorded in the forest (Figure 6).

The results show clearly that the trees of the forested catchment are able to remove soil water from the subsoils throughout the year and that the shallow-rooted native pasture and degenerate perennial pasture of the cleared catchment are ineffective in this regard. The forest trees, through evapotranspiration, create the storage required for further water to be absorbed. This storage is not available for at least half the year under cleared conditions, and the chance of saturated flow occurring, either as deep percolation or throughflow, is therefore much greater than under forest.

4.7 Electrical conductivity

The electrical conductivity of the 1:5 aqueous extracts from soils is indicative of the amount of salts stored. In this regard, there are strong contrasts between forested and cleared areas in the same as well as in different climates. The forested catchments at Kamarooka and Eppalock both contain at least twice as much salt as the adjacent cleared catchments, and the Kamarooka localities contain approximately six times as salt as the Eppalock catchments, thus confirming earlier results from the Northern Slopes Deterioration Project by Jenkin and Irwin (1975).

In the solum, most of the salts are stored in the B horizon of the duplex soils, and not in the lower porosity BC and C horizons. The A horizons do not contain large amounts of salt because they have higher permeability and are generally well-leached. The deep kaolinitic palaeosol parent material in the Kamarooka area, however, often contains at depth, concentrations of soluble ions even greater than those of the overlying younger B horizons.

4.8 Relationships

The saturated permeability of the B and BC horizons of sodic duplex soils has been shown to be very low and severely limits the amount of throughflow possible. Darcy’s law, which relates the volume flux density, q, and the gradient of hydraulic potential, can be used to estimate the throughflow velocity as follows:

$$q = K\frac{H}{L} = v\,Pm \text{ (Domenico, 1971)}$$

Where v = Velocity of throughflow
K = Saturated hydraulic conductivity
H = Difference in elevation of watertable between the points considered
L = Length of flow between the points considered
Pm = Macroporosity of subsoils

Therefore assuming a gradient of 0.1 (often much greater than gradients in salt affected areas) and knowing that 0.05 m/day and that Pm 6%, the throughflow velocity becomes 0.08 m/day.

This relatively low value indicates that throughflow is not significant, particularly as local perched watertables are only present within the shallow soil profiles for a few days after extremely wet conditions.

In Ordovician bedrock areas, permanent groundwater occurs in fractures such as joints and shears in both weathered and fresh rock, the soil and vegetation governing the amount of water which reaches such fractures by deep percolation. The higher and more variable permeability of the upper slopes and rocky ridges suggests that these areas are responsible for some direct accession to the watertable, a well-developed soil cover over the fractured rock being absent. However, it is emphasized that recharge occurs over the whole landscape, that this is exaggerated by clearing, and that deep percolation through the fracture network in the underlying rocks is responsible for the principal accessions to the deep, saline groundwater.

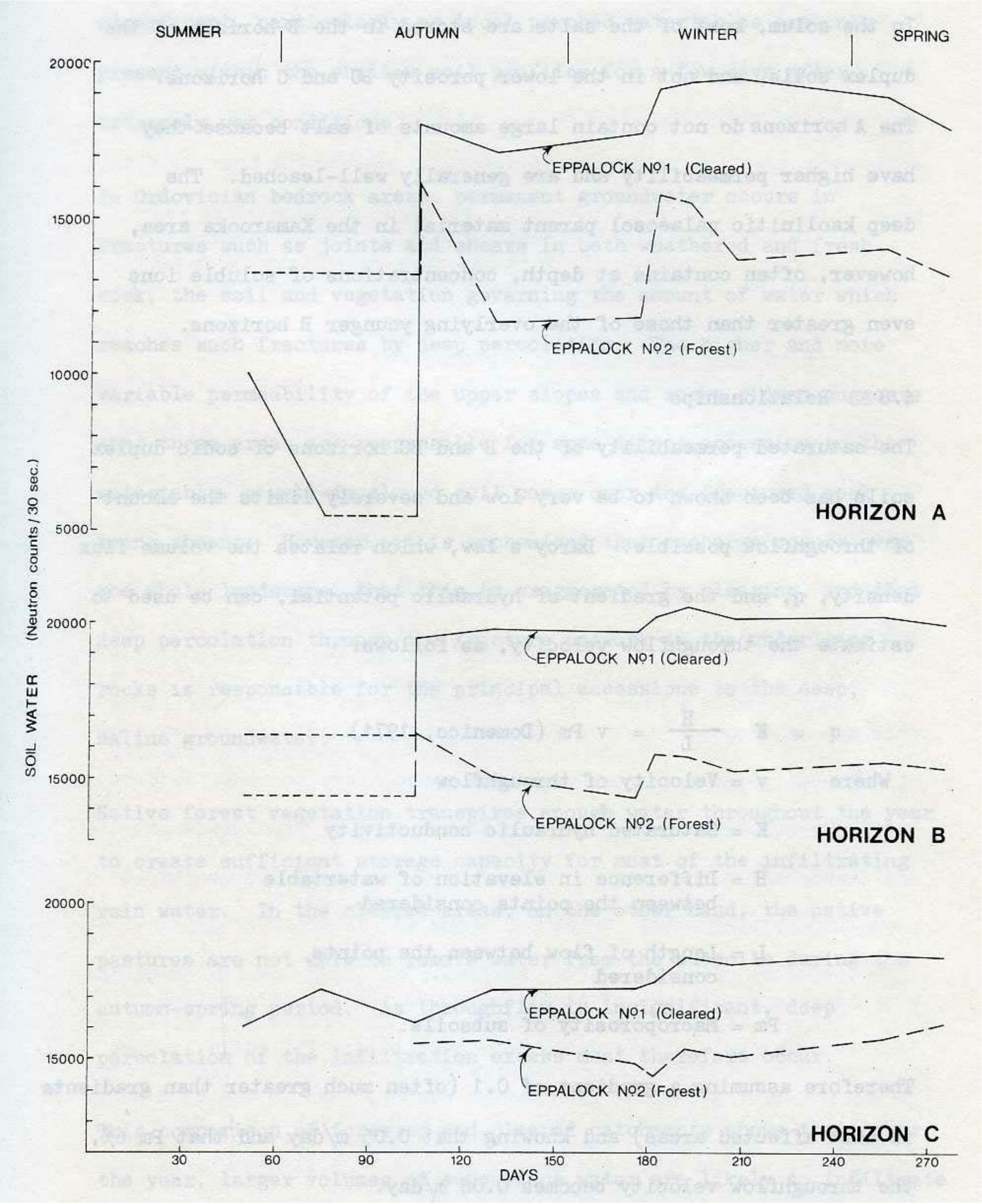

Figure 6 – Changes in soil water content with time for adjacent cleared and forested catchments (1980).

(Approximate field capacity values are: Horizon A 1800 – 1900 counts, Horizon B 2000 counts. Northern Slopes Land Deterioration Project by Jenkin and Irwin (1975)).

Native forest vegetation transpires enough water throughout the year to create sufficient storage capacity for most of the infiltrating rain water. In the cleared areas, on the other hand, the native pastures are not able to remove water from the subsoils during the autumn-spring period. As throughflow is insignificant, deep percolation of the infiltration excess must therefore occur.

This comparison of forested and cleared catchments shows that, over the year, larger volumes of subsurface water are likely to infiltrate the soils of cleared catchments than of forested catchments. In addition, more salts have been leached from the soils of the cleared areas than from those of the forested areas, the permeability results suggesting that this movement occurs vertically as deep percolation through the underlying fractured rock. Furthermore, these results also indicate that the rate of movement and the volume of water involved are both relatively small, accounting for the slow rise of deep, saline groundwater to the point where surface salinisation occurs. Consequently, this may take many years to develop.