APPLICABILITY OF DRAINAGE DESIGN EQUATIONS TO FINNISH CONDITIONS

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Abstract

The applicability of some drainage design equations to Finnish conditions was studied. This study encompares the spacings calculated with drainage design equations with spacings in four fields. Both steady state equations and a non-steady state drainage design equation were studied. The soils studied were sandy loam, silty clay, heavy clay and sphagnum peat. The study concluded that the equations are applicable to drainage design in soils where the saturated hydraulic conductivity is moderate to high.

1 Introduction

In Finland the soil and the location of the field determine the drainage design. The common equations for drainage design have not been used in Finland. In order to study the applicability of drainage design equations to Finnish conditions, drain spacings for four fields were calculated. The calculations were compared with the traditional drainage designs.

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2 Experimental fields

The fields represent different types of soil and are located in different areas of Finland. The soils studied and their locations were sandy loam, Muhos (64°3',25°6'); silty clay, Nurmijärvi (60°3',24°5'); heavy clay, Loimaa (60°5',23°5') and sphagnum peat, Jalasjärvi (62°3',22°5'). All the fields have subsurface drains. The drainage has functioned satisfactorily in all fields with the exception of the sphagnum peat.

3 Hydraulic conductivity

The saturated hydraulic conductivity of the soils was measured with the Falling Head Permeameter method. The measurements were made of depths of 30, 60 and 90 cm and at 10 to 20 sample places in the fields. Three replications were made at every place and every depth. The results are presented in Table 1.

Table 1. Hydraulic conductivity values and their coefficients of variation.

Field	Soil type	Saturated hydraulic conductivity (cm/h) mean	geometric mean	Coefficient of variation (%)
Muhos	homogeneous sandy loam	2.9	2.9	15.7
Nurmijärvi	heterogeneous sandy clay	2.8	1.6	88.7
Loimaa	heterogeneous heavy clay	0.53	0.17	124.9
Jalasjärvi	heterog. peat	0.54	0.36	96.5

The distribution of the hydraulic conductivity values was also studied in order to determine the most representative values for the hydraulic conductivity of each field. The saturated hydraulic conductivity of the homogeneous soil was found to be normally distributed and that of the heterogeneous soils log-normally distributed (Fig. 1 and Fig. 2). Consequently both the mean and the geometric mean of the hydraulic conductivity values were used to represent the hydraulic conductivity of the field in the drainage design equations.

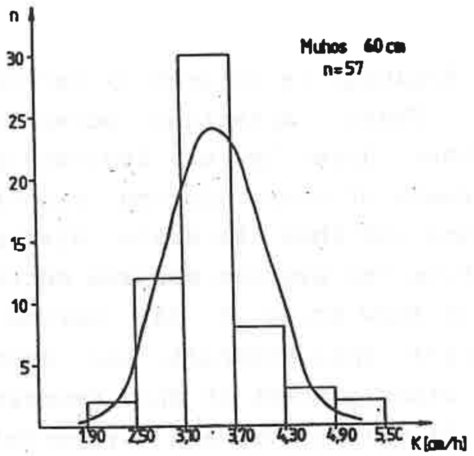

Fig.1. The distribution of saturated hydraulic conductivity in homogeneous soil.

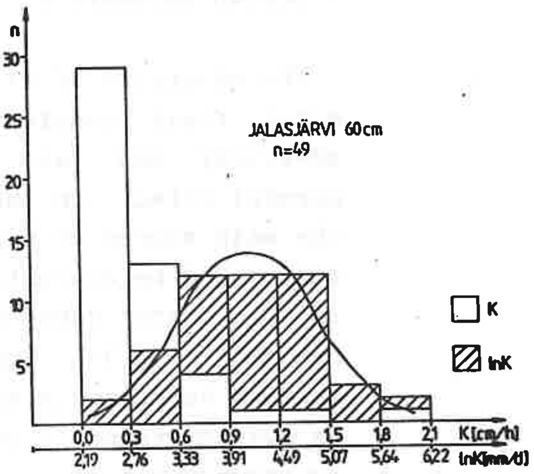

Fig.2. The distribution of saturated hydraulic conductivity in heterogeneous soil.

The variability of the saturated hydraulic conductivity in each field was also studied. The values varied considerably. The coefficient of variation was about 15% in homogeneous soil and 130% at maximum (Table 1) in in heterogeneous soils. Because of the wide variation in the saturated hydraulic conductivity values, the sensitivity of the calculated spacings within these ranges was also studied.

4 Drainage design equation

The applicability of the most common drainage design equations, both steady state equations and non-steady state equation were studied. The steady state equations used in this study were derived by Hooghoudt and by Ernst. The non-steady state equation derived by Kraijenhoff van de Leur and Maasland was used (Wesseling 1973).

5 Design parameters

The objective of field drainage is to prevent excessively moist field conditions. These affecting workability adversely and have -either directly or indirectly- a harmful effect on the growth of crops. Spring runoff is the main source of moisture and thus the drain discharge rate could be evaluated from the avarage maximum decrease in the water content of snow for a 5 day period in Finland (Fig.3). Converted into rainfall, the average maximum decrease in the water content of snow represents an average rainfall of 8.64 mm/day over a 5 day period in southern Finland.

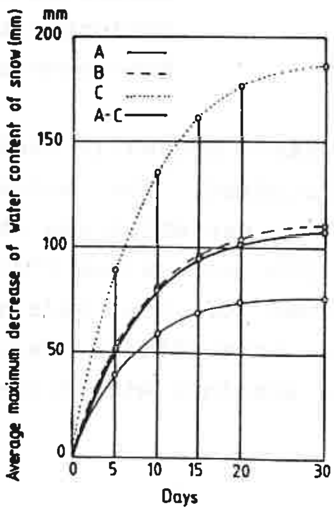

Figure 3. Average maximum decrease in the water content of snow (mm) in different areas of Finland (Kaitera 1939).

Recharge values based on the average maximum decrease in the water content of snow were used calculations made with the drainage design equations. The effects of rainfall during the summer on the depth of water table were also studied (Fig.4).

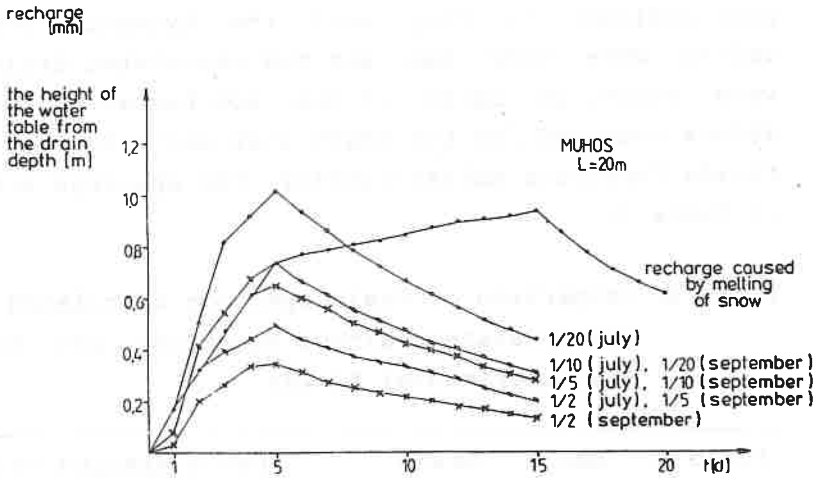

Fig.4. The effect of spring runoff and some summer rainfall on water table fluctuation in the sandy loam field. The non-steady state drainage equation was used in the calculations.

The soil profile of each field was assumed to have uniform structure and hydraulic conductivity down to the impervious soil layer.The mean and the geometric mean of the measured values were used as the hydraulic conductivity values. The drainage depths were the same as those in the experimental fields, i.e. from 1.0 to 1.2 m. The value of 30 cm was used as the permissible depth of the water table. For non-steady state calculations the drainable pore space in soils was determined on the basis of the soil-moisture characteristic curve.

6 Drain spacings with steady state equations

Comparison of the spacings calculated with the steady state drainage equations showed that the calculated drain spacings were almost identical to spacings designed in the traditional Finnish way in soils where the hydraulic conductivity is moderate to high. In sphagnum peat soil the hydraulic conductivity values were low and the calculated drain spacings were only 1/4 or 1/2 of the spacings used in the field. This field has suffered from poor drainage. In clay soil the hydraulic conductivity values were very low and the calculated drain spacings very dense. In spite of the low hydraulic conductivity values measured for the heavy clay soil, drainage in these fields functions satisfactorily. The spacings are compared in Table 2.

Table 2. Comparison of drain spacings calculated with the steady state drainage equations and drainage of the experimental fields.

Field	Soil type	Drain spacing in the field (m)		Drain spacing calculated with equations derived by Hooghoudt (m)	Ernst (m)
Muhos	sandy loam	20		18.2	18.2
Nurmijärvi	sandy clay	20	mean	18.3	17.3
			geom.mean	13.8	12.8
Loimaa	heavy clay	18	mean	9.4	7.2
			geom.mean	4.5	3.2
Jalasjärvi	peat	20	mean	7.8	7.0
			geom.mean	6.6	5.6

7 Drain spacings with non-steady state equations

The drain spacings calculated with the non-steady state equations were found to be similar to the spacings calculated with steady state equations in soils where the hydraulic conductivity values were from moderate to high. With the peat soil data the water table rose very slowly because of the high value of the drainable pore space. This was also the reason for the rate of adjustment in the sinking water table, which was extremely low. When the the drain spacing was 20 m the calculations showed that the water table sank only 1 cm from its maximum height in a 5-day period following after rainfall. The effect of the drain spacing on the water table height in a 20 day period following rainfall calculated with non-steady state equations in peat soil is shown in Figure 5.

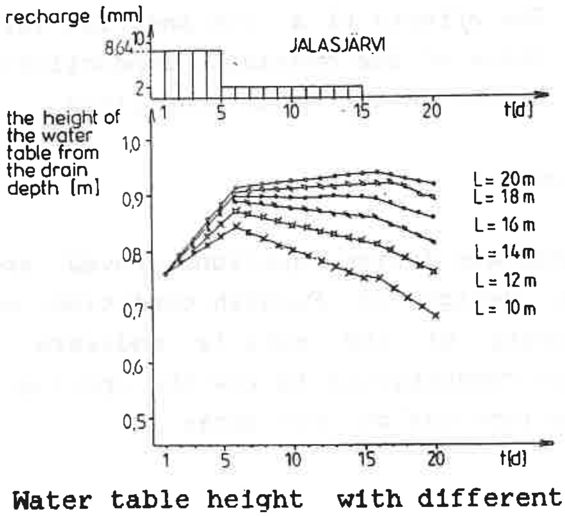

Fig. 5. Water table height with different drain spacings in peat soil.

The sensitiveness of the calculated spacings to the variation in the value of the saturated hydraulic conductivity was also studied. In the case of steady state drainage design equations the variation of 20% in the value of the saturated hydraulic conductivity caused a variation in the drain spacings of 1 to 2 meters. A variation of 20% in hydraulic conductivity caused a variation of 20 cm in the water table height when the non-steady state equations were used (Fig. 6).

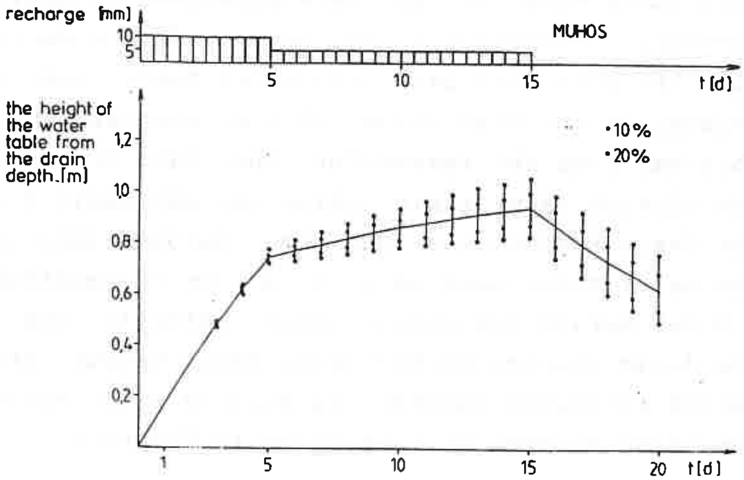

Fig. 6. The effects of a 10% and 20% variation in the value of the hydraulic conductivity on water table height in the sandy loam field.

8 Conclusions

The drainage design equations proved applicable to the drainage design in Finnish conditions when the hydraulic conductivity of the soil is moderate to high. If the hydraulic conductivity is low the spacings calculated with the equations may be too dense.

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