INFLUENCE OF STRATIGRAPHY ON YIELD OF THE TILE DRAINS IN NORTHEASTERN COLORADO

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CER59NAE65

59-705

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INTRODUCTION

The search for improvements in design criteria for tile drains accelerates when new problems arise which existing practices do not adequately cover. In northeastern Colorado, one particular new problem is the lack of adequate outlet or disposal facilities. In many cases, the most convenient disposal facility is either a lake or natural slough. With the large increase in number of drain systems experienced during the past ten years, such outlets have become overloaded. One result has been inundation of usable land as water levels in the lakes and sloughs has risen. Litigation has been a natural consequence.

The irrigated area of northeast Colorado lies along the river system for the most part; and the drains are almost entirely of the intercept type. A single line of tile--generally six and eight-inch diameter--is laid on impermeable material (shale). Figure 1 illustrates the typical condition. Trenching is done with a dragline and a gravel filter of at least four inches in thickness is placed around the tile.

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NEED FOR STUDY

In order to secure outlet facilities for the drains being constructed at the present time, long tile lines must be designed to carry water to a natural drain way. These lines may be more than a mile long. To be economically feasible, several land owners must share in the cost, and the result is a "community" disposal line.

Design of such disposal lines requires a reasonable estimate of the flow to be obtained from the several drain systems served. In 1956 the State Soil Conservation Service requested assistance in finding a method for predicting the yield of a drain system. This report summarizes the results of studies covering four years time, during which data were collected for correlation analysis. A very limited manpower and expense budget restricted the study to northeast Colorado.

PROCEDURE

Drains were selected for study in consultation with Soil Conservation Service personnel. Selection was made on the basis that the drain represented the predominant type of system being installed. Roughly 85 per cent of the drains in the area can be considered to have common general features.

The discharge, or yield, was measured by one of several devices including Parshall flumes, HS flumes, and slotted pitot tube, (1). During the first three years, recorders were used to obtain records of flow variations. During 1959, only once-a-week readings were made on most of the systems because experience showed that the flows were essentially constant and that no purpose was served by a continuous record. The discharge used throughout this report is that flow which occurs most of the time throughout the irrigation season. Runoff peaks of short duration were cut off in determining the discharge.

The physical features of the drain system were collected from the S.C.S. design surveys. This included the soil logs, topography, and location and construction of drain. Hydraulic conductivity measurements were made by the auger hole method (2). At least two sites in the near vicinity of tile line were used for this data.

It became apparent that the degree of stratification of the soil was related to the yield, so an index was devised to characterize stratification. It was observed that one textural class of soil predominates in the profile, with other textural classes interspersed as layers or lenses. Therefore, the degree of stratification is expressed as a ratio of the total thickness of minor layers to the total depth of soil above the shale base. Figure 2 illustrates the determination of stratification index.

Finally, after the collection of data on 30 systems over the four-year period, several correlation analyses were made in an effort to produce a prediction equation which could be used with some confidence.

RESULTS

Yield and Hydraulic Conductivity--The correlation between yield (cfs per 1,000 ft. of line) and hydraulic conductivity (in./hr.) is illustrated in Figure 3. A correlation coefficient of 0.685 (significant at 99.9 per cent) is obtained and the standard error of estimate is 0.0149 cfs. The prediction equation so obtained is:

$$Q = 0.0228 + 0.00397\ K \text{ - - - - - - - - - - - - } (1)$$

Yield and Stratification--The correlation between yield and degree of stratification (%) is illustrated in Figure 4. The correlation coefficient is 0.683 (significant at 99.9 per cent) and the standard error of estimate is 0.0149 cfs. The prediction equation so obtained is:

$$Q = 0.0495 - 0.00068\ S \text{ - - - - - - - - - - - } (2)$$

Yield and Hydraulic Conductivity plus Stratification--A multiple correlation analysis was made to relate yield to hydraulic conductivity and stratification. The correlation coefficient is 0.776 (significant at 99.9 per cent) and the standard error of estimate is 0.0098 cfs. The prediction equation obtained is:

$$Q = 0.0362 + 0.00217\ K - 0.00042\ S \text{ - - - - } (3)$$

DISCUSSION

The yield of a drain must depend upon several variables in addition to hydraulic conductivity and stratification. One very significant factor must be the water supply. In the area considered, this factor could not be evaluated within the limitations of manpower and finance. If it could have been, the multiple correlation could no doubt be improved. However, the water supply of the area has been somewhat stabilized and equalized by the Colorado-Big Thompson project and for this reason its omission does not appear to be serious.

Stratification alone gives a reasonable correlation with yield. A prediction based on this correlation should result in a yield of $Q_e \pm 0.015$ cfs/ 1000 ft. in 68 out of 100 cases. A yield of $Q_e \pm 0.03$ cfs/1000 ft. should result in 95 out of 100 cases.

Coincidentally, the standard error of estimate for the correlation between yield and hydraulic conductivity was exactly the same as that for yield and stratification, so the same remarks would apply.

The multiple correlation gives a better prediction of yield than either of the two-variable correlations. A prediction based on this correlation should result in a yield of $Q_e \pm 0.0098$ cfs in 68 out of 100 cases or a yield of $Q_e \pm 0.0196$ cfs in 95 out of 100 cases. For a yield of 0.035 cfs/1000 ft., which is about the average, this would represent an error of approximately 25 per cent. Although this is a rather large error, it seems tolerable in view of the many other uncertainties in the design criteria. A qualitative evaluation of the water supply factor should offer a means of reducing the error by applying a judgment correction to the predicted yield.

Influence of Stratification--It would appear that stratification might reduce yield if the interspersed lenses were of low permeability, and on the other hand might have the opposite effect if the lenses were of high permeability. However, considering the possibility that a significant percentage of the flow moves in a partially saturated zone above the water table, it can be postulated that any interface may reduce the rate of flow.

In a flow system such as is considered, the capillary pressure, p_c, must be a continuous function of the distance, r. If this were not true, there would be an infinite pressure gradient at any point of discontinuity. Physically this is impossible, so at any interface between materials of different texture, the p_c must be the same on both sides. Consequently, the side of the interface having the coarser texture will have a lower saturation and consequently a lower permeability. This may be confined to a very thin region; but if it occurs, the flow through the interface will be restricted.

On the basis of the above remarks, one might expect to find a correlation between yield and stratification, especially in shallow systems, as found in this study.

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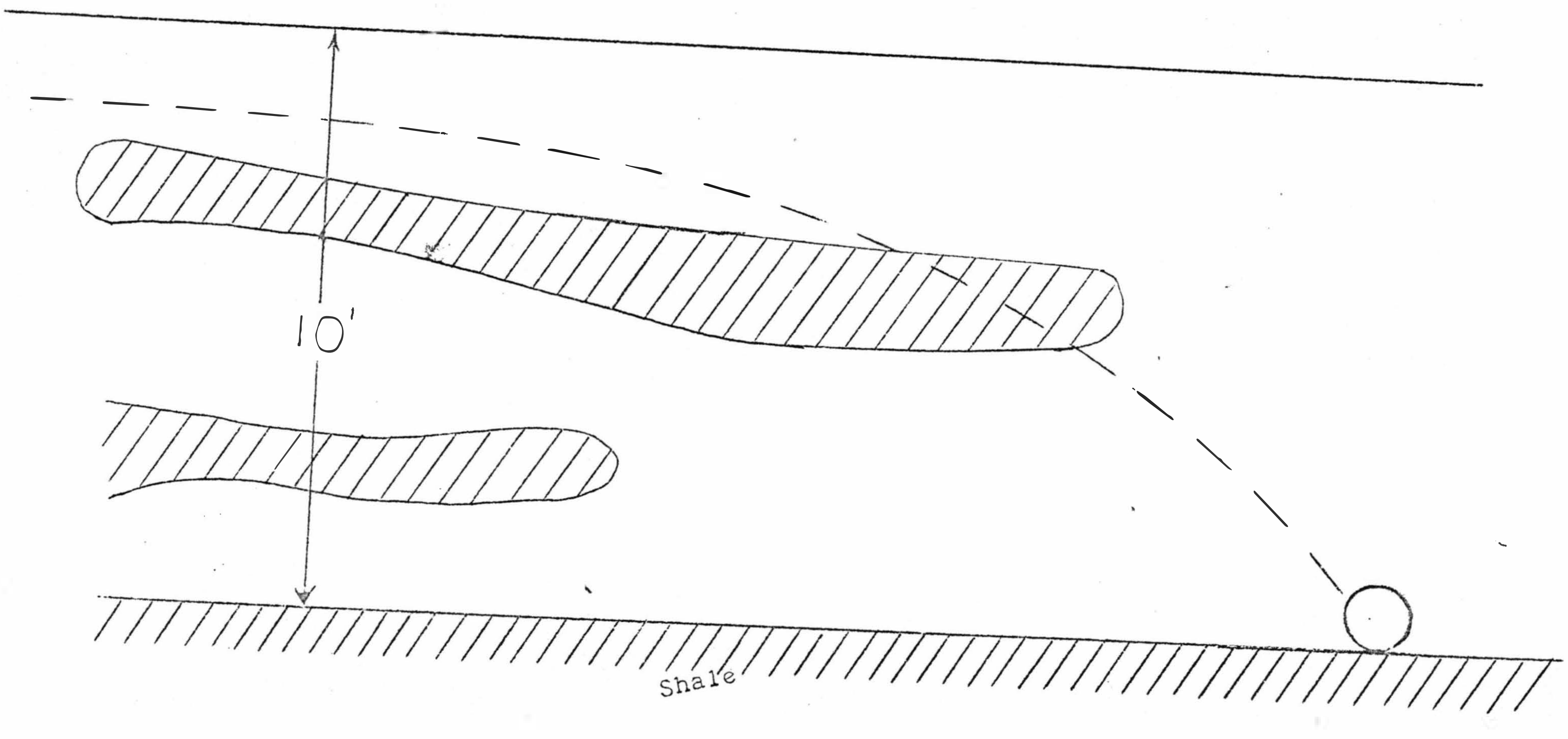
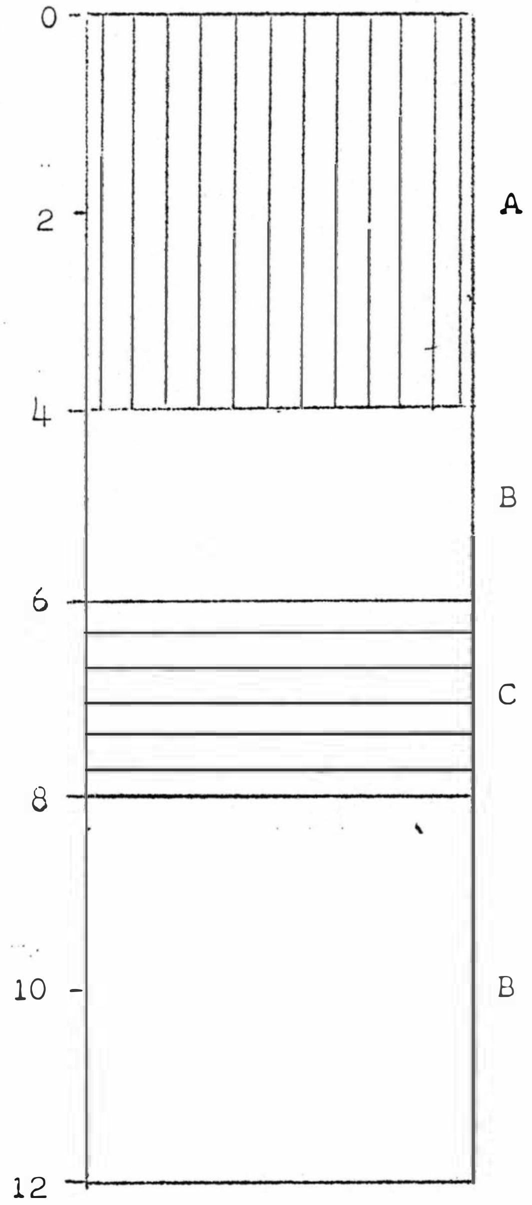


Figure 1. TYPICAL PROFILE



Material	Thickness
A	4
B	6
C	2
	12

$$S = \left(\frac{A + C}{12}\right)100 = \left(\frac{6}{12}\right)100 = (0.5)100$$

$$S = 50\%$$

Figure 2. DETERMINATION OF STRATIFICATION

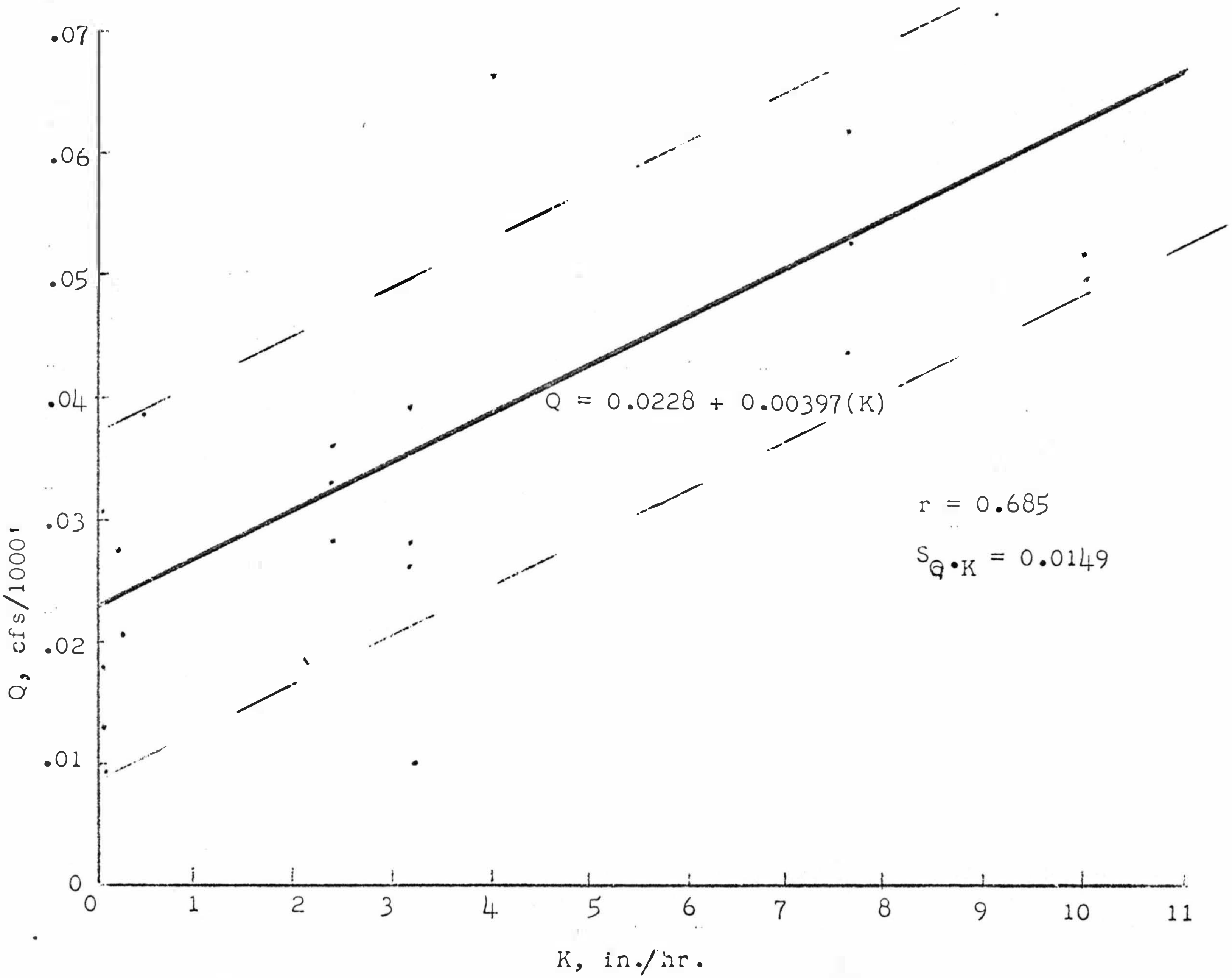


Figure 3, CORRELATION BETWEEN HYDRAULIC CONDUCTIVITY AND YIELD

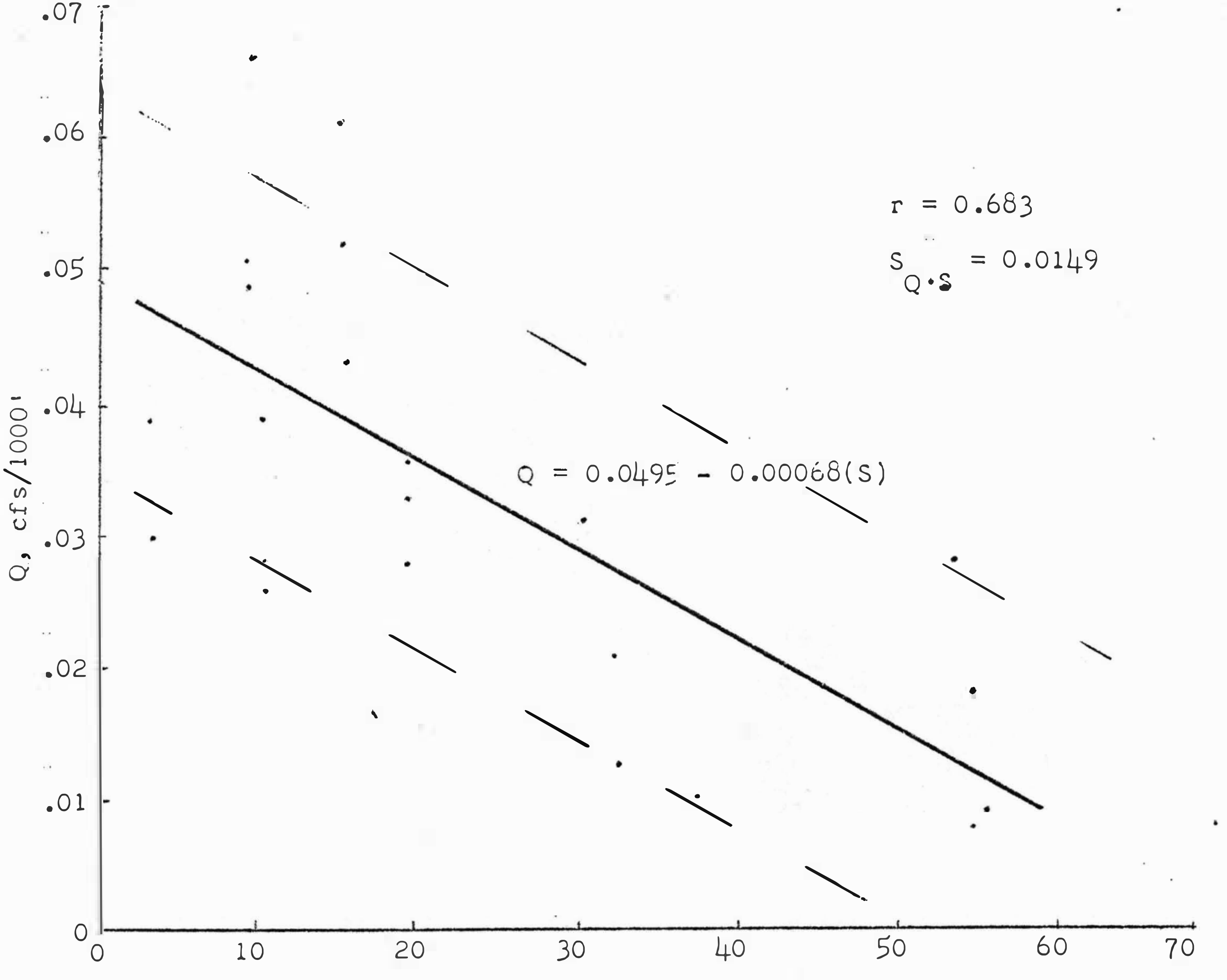


Figure 4, CORRELATION BETWEEN STRATIFICATION AND YIELD