Section 684.12

(a) Furrow Design Assumptions

It is necessary to make a certain number of assumptions or approximations in order to prepare design equations and tables for furrow systems. These assumptions must be sufficiently valid so that designs based on them will result in irrigation systems that can be irrigated efficiently and uniformly, with only the requirement of seasonal adjustments in stream size and application time. Design assumptions are made for intake-time relationships, rate of advance, time for recession, opportunity time, retardance coefficient, and intake as related to furrow wetted perimeter. Figure 684-1 illustrates these factors.

(b) Intake-Time Relationship

To theoretically obtain complete intake uniformity along the entire length of a furrow, it would be necessary for the opportunity time for intake at all points along the furrow to be equal. This is not possible with furrow irrigation where water is applied at the upper end and progresses down the furrows over a period of time. The time that water is on segments of the system is, therefore, of different duration at points along the furrows or corrugations. For acceptable uniformity and adequacy of application, the minimum time that water should be on any point along the furrow length should not be less than required for intake of the desired net application. Also, the maximum application time should be such that excessive deep percolation losses will not occur.

The time that water is on a given segment of the furrow is defined as the opportunity time \( T_o \). This "\( T_o \)" is the time duration between the time the furrow stream reaches the furrow stations and the time when water disappears from the surface at these points. This time is defined as the time increment between the advance and recession curves. These two curves are of prime importance in the design of a furrow or corrugation irrigation system as they describe the intake opportunity time for the various segments along the furrow length.

(c) Rate of Advance

The rate of advance is a function of the water flow rate entering the furrow, the soil intake rate, furrow shape, grade length and the roughness of the furrow surface. The relationships involved in the flow of water in furrows are complex. During the irrigation process, water is entered into the upper end and advances along the length of the furrow. The flow rate is largest at the head of the furrow and becomes successively smaller at each point downstream because of the water lost to infiltration into the soil. The result is a reduction in the rate of advance at successive points downstream. If the length is such that the entire stream is absorbed by the soil, the advance stops. For efficient irrigation, a rapid rate of advance throughout the entire length must be obtained.
(d) **Time for Recession**

The time for outflow of water to stop after inflow at the head of the furrow has ended is defined as recession time \( (T_r) \). This time is mostly affected by flow rate, furrow length, shape, and slope. The furrow surface generally becomes relatively smooth during the irrigation period so retardance has less influence on recession. The accumulation of crop residues in the furrows has a marked effect on the rate of recession, but to a lesser extent than on the rate of advance. In graded furrow or corrugation irrigation, the recession curve is relatively flat; and when grades exceed 0.25 percent, the recession time is so short there is little effect on the soil intake. When the grade is .05 percent or less, impoundment of the stream can be used to increase time of recession and, in this manner, balance the advance-recession curve.

Because recession time is relatively short in comparison with needed intake time, it has little influence in graded furrow design. Recession time is taken into consideration in the opportunity time determination for a selected station. It is shown as zero in design equations for gradient furrows. However, a period of time is required for the furrow stream to build to the design flow volume after the advance stream reaches the design station; and this required build-up time and the recession time, for all practical purposes, cancel each other.

(e) **Opportunity Time**

The design of a furrow system is based on opportunity time, \( T_{op} \), or the time that water is on a given station in the furrow. For a constant inflow rate, the infiltration of water into the soil is less at the lower end of the furrow length due to both a reduction in flow rate and opportunity time. A design based on the needed opportunity time at the upper end would result in inadequate intake for all successive stations down the furrow.

A furrow system design based on the needed opportunity time for intake at the end of the furrow results in excessive intake at all stations upstream. Because the rate of advance decreases rapidly with increased length, systems may be designed to provide the opportunity time needed to apply the desired application at a point less than the entire length, for example, approximately 80 percent of the total length from the upper end. The best balance must be determined between excess application at the upper end and insufficient application depth in the section below the design point. This point must be selected after determining the effect of the application deficiency downstream of the design point on specific crops.
(f) Retardance Coefficient

Knowledge of the behavior of water flowing in furrows is essential in developing efficient furrow irrigation system designs. The velocity and depth of flow that will result when a specified flow rate is applied in a furrow of a certain cross section and grade will depend on the roughness or retardance condition in the furrow. This retardance condition is represented by the Manning "n" in the equation

\[
Q = \left(\frac{667}{n}\right) \left(\frac{A^{5/3}}{P^{2/3}}\right) \left(S^{1/2}\right)
\]

where

- \( Q \) = flow in gpm
- \( n \) = retardance coefficient
- \( P \) = wetted perimeter of furrow in feet
- \( S \) = furrow slope in feet per foot
- \( A \) = cross sectional area of water in the furrow, in square feet

The Manning "n" varies with the furrow roughness, shape, and flow rate. Furrow roughness is readily altered by farm tillage equipment. Furrow and corrugation shapes also vary; and therefore, designs are based on the most common shapes. With the retardance and shape standardized, the flow rate becomes the determining factor. Most furrow streams are in the magnitude of 10 to 30 gpm and most corrugations streams 4 to 10 gpm. A study of furrow flows within this range indicates that designs based on retardance "n" value of .04 for furrows; and .10 for corrugations will result in design values most appropriate for these methods of water application.

(g) Wetted Perimeter

The wetted perimeter of a furrow or corrugation at any point is the cross section of the furrow that is in contact with the flowing stream. The rate of infiltration in a furrow or corrugation is a function of this area. This contact area decreases as the distance from the inflow end increases; and therefore the design formulas must take into account this decrease in wetted area to determine the intake at a given point along a furrow.