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ESTIMATING CHANGES IN IRRIGATION CANAL SEEPAGE[1]

By

R. V. Worstell and C. E. Brockway[2]

INTRODUCTION

Seasonal changes in seepage losses from canals have been observed by numerous investigators using ponding tests before and after the irrigation season. In general, the fall tests indicate considerably lower seepage rates than the spring tests. The objective of this study was to determine whether the magnitude of changes during the season can be estimated without resorting to expensive ponding tests.

PROCEDURE

In an effort to acquire more knowledge about seepage, sealing layers, maintenance effects, unsaturated flow below the canal, and the effects of microbiological activity, a series of studies were made on the main delivery canal of the A & B Irrigation District in southern Idaho during the 1966 and 1967 irrigation seasons. This canal lies north of

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[2] Research Agricultural Engineer, Snake River Conservation Research Center, Kimberly, Idaho; and Assistant Research Professor, Civil Engineering, University of Idaho, located at Kimberly, Idaho.

the Snake River, midway between Paul and Hazelton. It is 4-1/2 miles long, approximately 25 to 30 feet wide in the area studied, and 5 to 5-1/2 feet deep during the irrigation season. The flow in the canal varies between 75 and 250 cubic feet per second, but the depth is held nearly constant. The normal soil in the area is Portneuf silt loam, which has cemented layers existing at various depths in the profile. There is no water table to a depth of 45 feet except for temporary perched conditions over some of the cemented layers. The canal has been in operation for over 10 years, and some sloughing on the side slopes has caused silt layers to form on the bottom. The canal water is not silty and is not flowing at a velocity that would cause erosion.

From midsummer on, a heavy growth of moss and algae periodically occurs. The irrigation district "demosses" the canal at least twice during the season. In recent years this has been accomplished by adding xylene chemicals to the water.

Preliminary work was initiated in the fall of 1965, at which time ponding tests were run on one mile of the canal. Seepage meter tests also were made for comparison with ponding tests. In preparation for these tests, 1-inch-diameter piezometer tubes were installed at various intervals along the canal. These piezometer tubes went dry within a few days and were replaced by tensiometers installed in the bottom of the tubes. The tensiometers permitted measurement of the soil moisture pressure and hydraulic gradients existing beneath the canal over the entire irrigation season. These measurements could then be combined with laboratory conductivity determinations to estimate changes in seepage rates.

A typical tensiometer installation is shown in Figure 1. A porous ceramic cup was pressed into the mud at the bottom of the piezometer tube. Two nylon tubes led from the ceramic cup — one for a bleed-water supply and the other connected to a mercury manometer. Figure 2 shows the ceramic cup and the nylon tubes leading to it. The ceramic cup is about 3/8 inch in diameter and about 2 inches long.

Figure 3 shows a bank of manometers which was placed across the canal. A footbridge was used to make them accessible. Six tensiometers were installed at this location at one foot and two feet below the canal bottom surface at each side and in the center of the canal.

Five tensiometers and 2 piezometers were installed at one location in the spring of 1966, and 40 more tensiometers were installed in the fall of 1966 and the spring of 1967. Some were installed in piezometers; others were installed in the side of pits when the canal was dry; and some were installed by pushing the tips vertically into the bottom of the dry canal. Nylon tubes leading from the buried tensiometers to the manometer boards were placed in a small trench and backfilled.

The different types of installations were made to determine the most desirable method for future tests. Installation in piezometer tubes was found to be easier and more versatile, except for locations immediately below the canal invert. These tensiometers were usually installed in groups of 9 — 3 at different depths at each of 3 locations across the canal as illustrated in Figure 4. They were installed near the bottom of the canal in order to analyze the effects of the sealing layer on the soil moisture pressure immediately below the canal. Readings were taken weekly during much of the 1966 season and twice a week during the entire 1967 irrigation season.

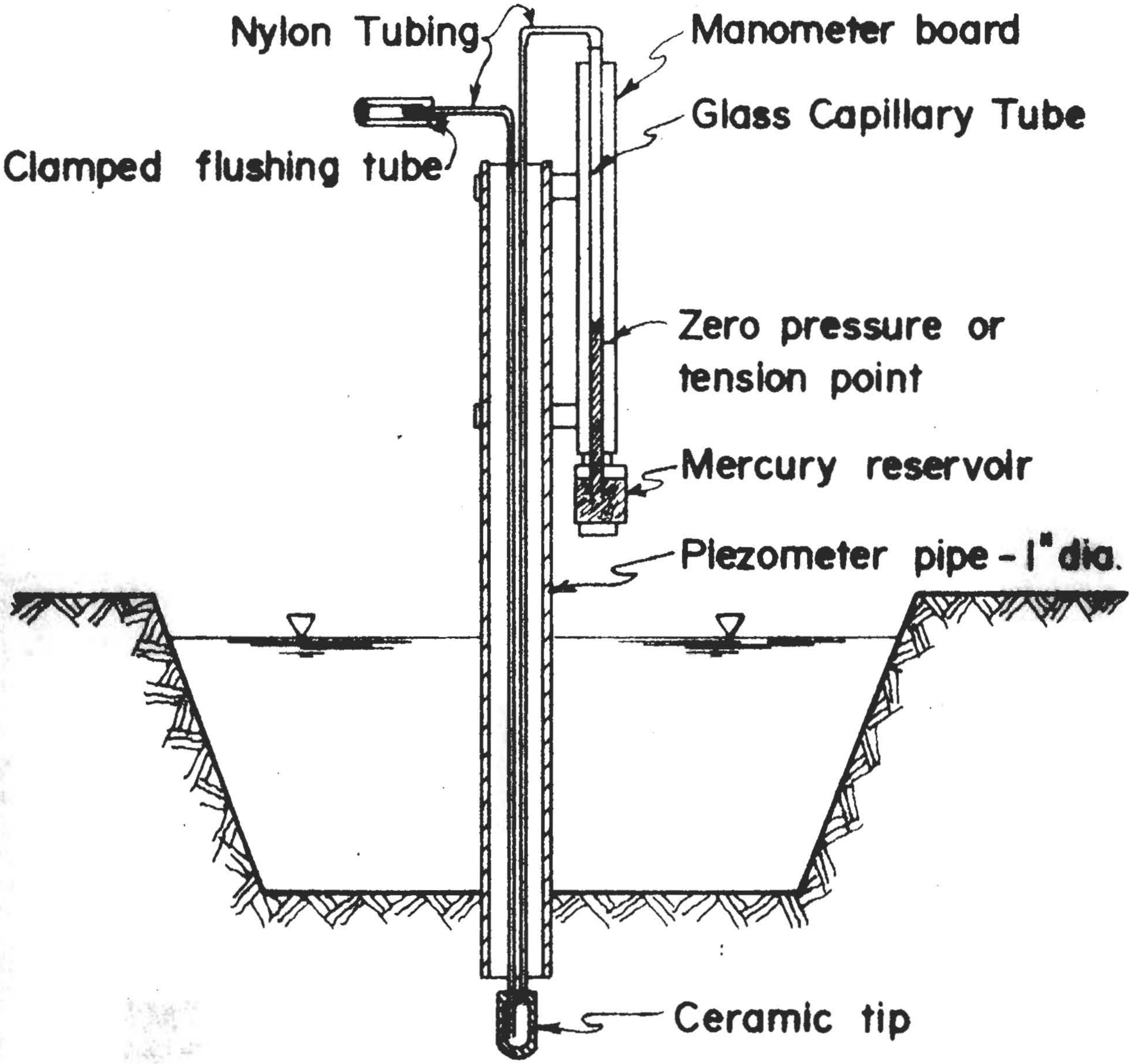

Figure 1. Diagram showing the parts of a field tensiometer installation for studying canal seepage.

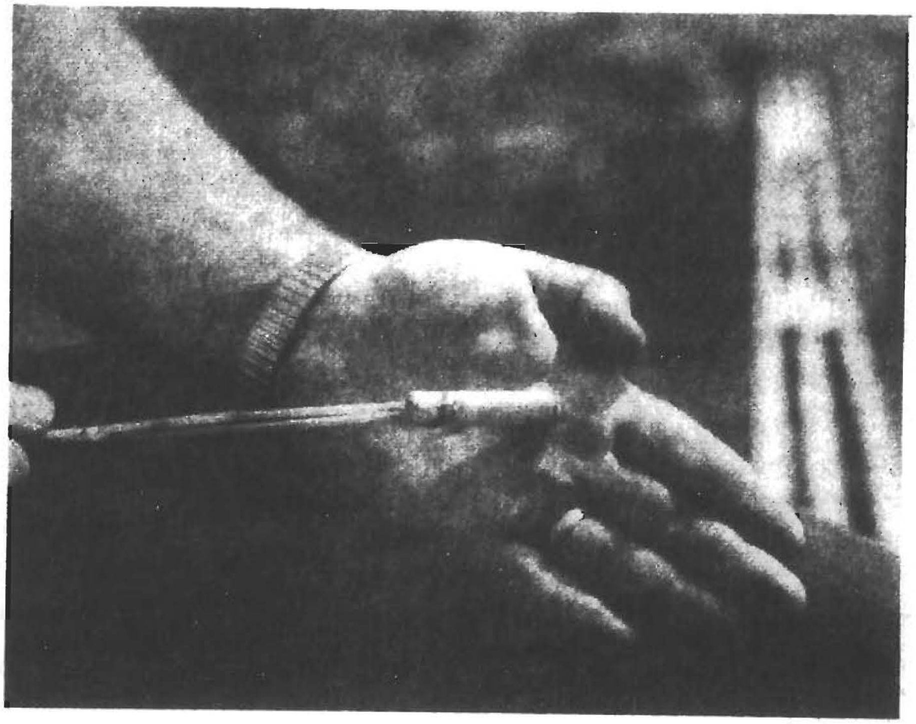

Figure 2. A view of a typical porous ceramic cup and nylon connecting tubes after removal from an installation.

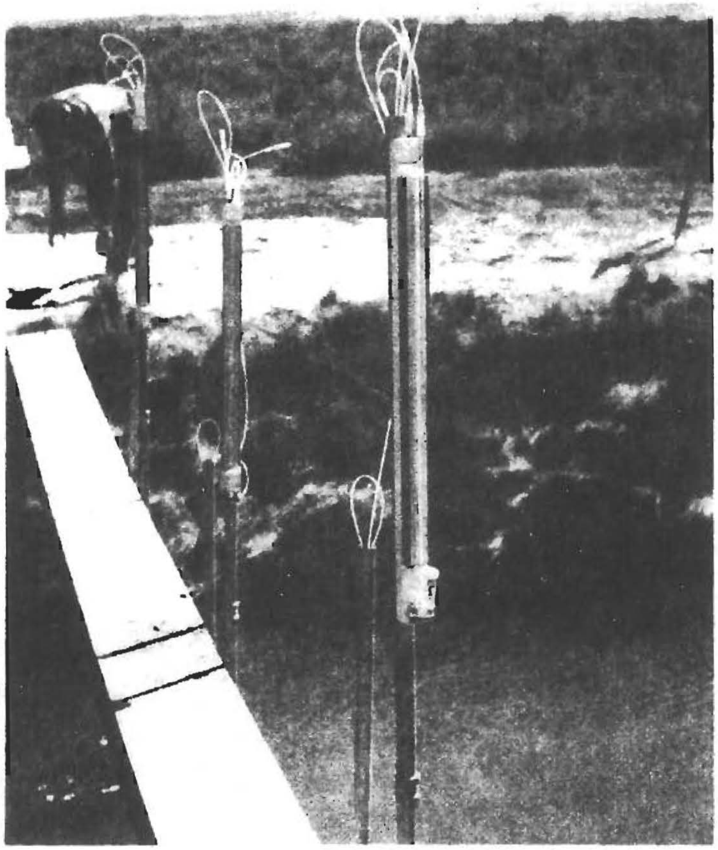

Figure 3. Manometer units mounted at the top of piezometer tubes which are driven into the bottom of an operating canal.

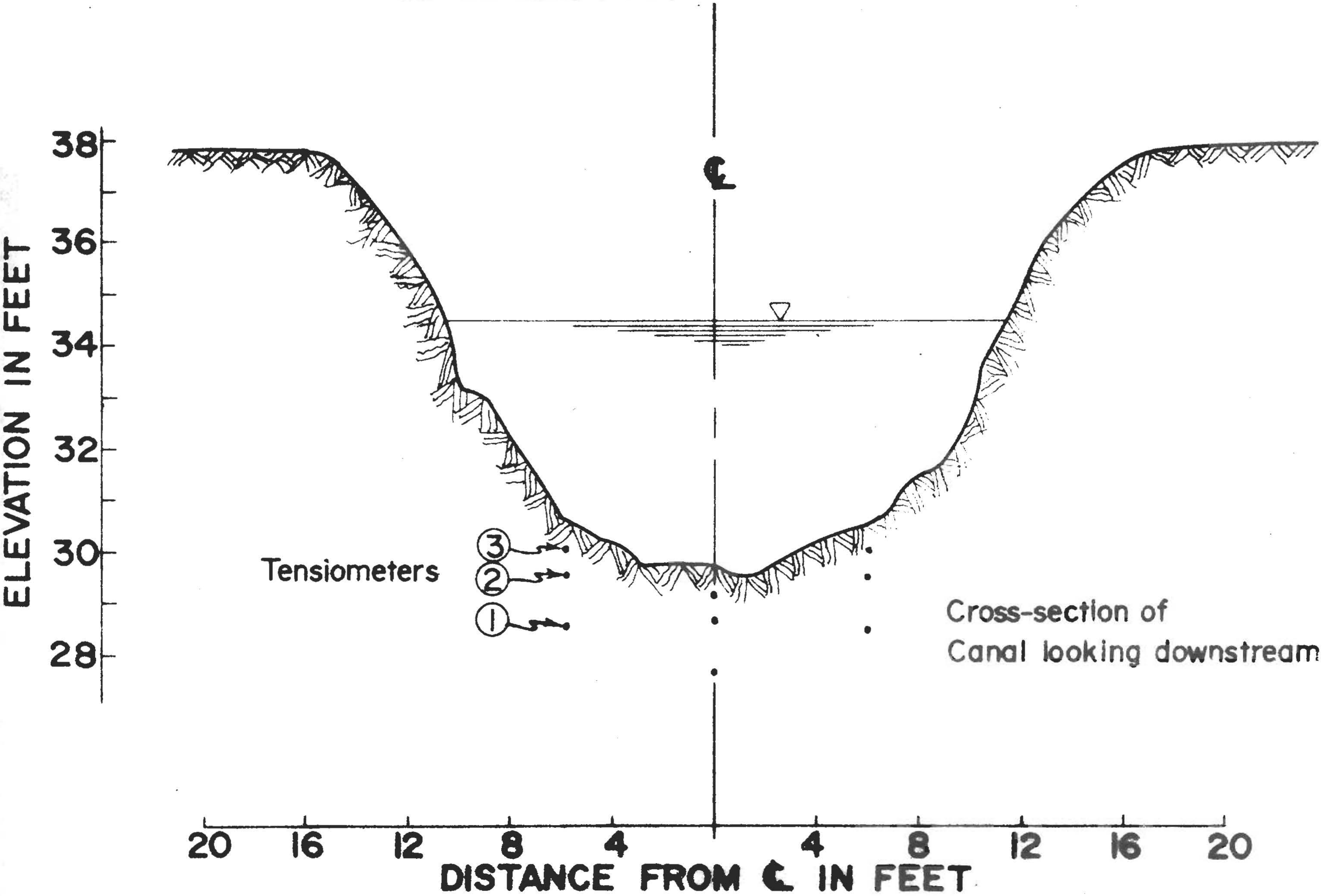

Figure 4. Typical cross-section of the "A Unit" Canal showing locations of the tensiometers below the Canal.

In the fall of 1966, undisturbed soil cores from the bottom of the canal were collected to be studied in the laboratory. The 3.25-inch-diameter cores were placed in 4-inch-diameter shrinkable plastic tubing. The tubing was then heated with a "heat gun," making the tubing shrink around the core and the end caps as shown in Figure 5. The inserted tensiometer units were small glass tubes with a ceramic glass bead tip on the end. The outer end was sealed with epoxy around the two nylon tubes. One nylon tube was used for flushing, and the other was attached to a water column manometer board. The tensiometers were sealed to the shrinkable tubing with a plastic rubber sealant.

Water was applied at the upper end of the soil column at a pressure of at least 3 feet of water and was removed at the lower end through a glass bead plate connected to a negative pressure system which created a vacuum of up to 100 inches of water. These conditions simulated "operating conditions" of the soil below the canal. By measuring the pressure changes and the rates of outflow as the water moved through this column, the hydraulic conductivity of the column was determined. A similar procedure was used to analyze the development of the "sealing layer" with time.

RESULTS AND DISCUSSION

Water potentials measured by the tensiometers installed during the summer of 1966 all decreased in a similar manner. The gradual decline seemed to be due to the "sealing effect" taking place during the season. The sealing effect was also found in laboratory tests of undisturbed core samples taken from the bottom of the canal. Figure 6 shows that after one month of "operation," the first 2 inches of bottom material of the canal had sealed until the hydraulic conductivity was only 20

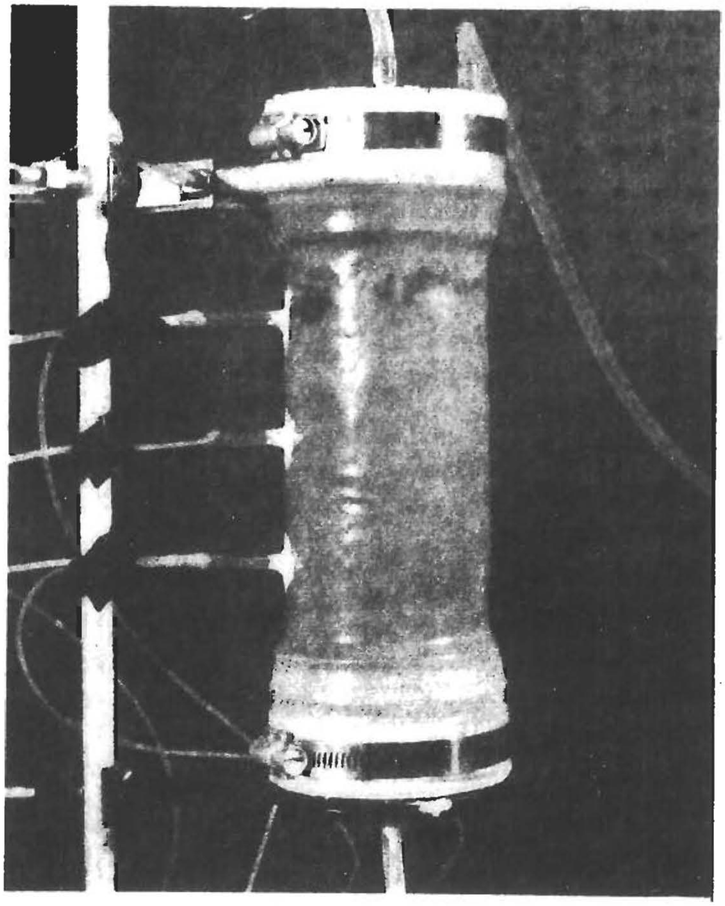

Figure 5. An undisturbed soil core encapsulated in heat-shrinkable tubing and instrumented with tensiometer units.

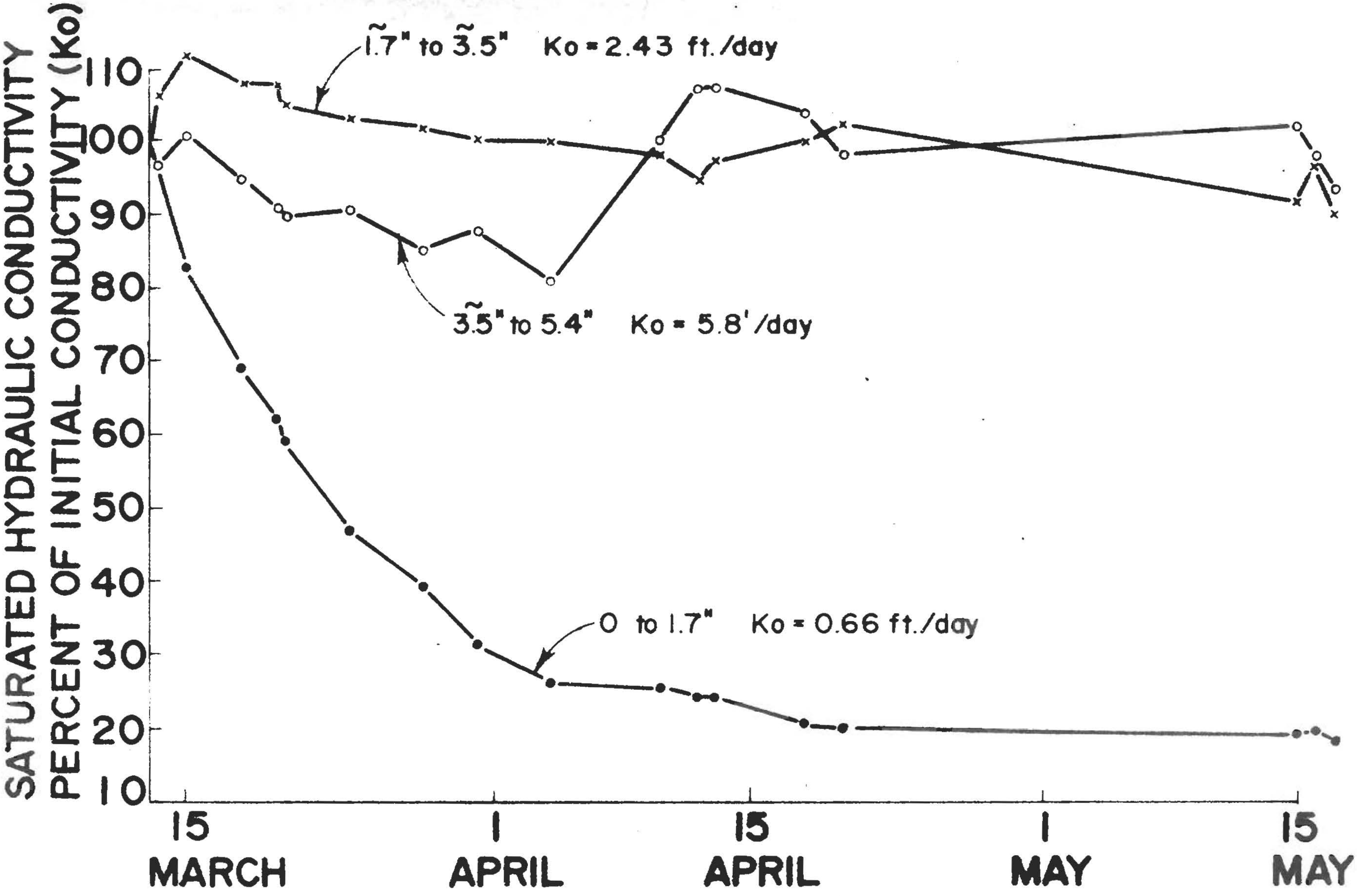

Figure 6. Variation of saturated hydraulic conductivity with time in an undisturbed soil core taken from the "A Unit" Canal in 1966.

percent of its original value. The conductivity of the lower layers in this soil core did not change significantly during this time interval.

The fluctuations in elevation potential as measured by one of the tensiometers in 1966 were compared to the barometric pressure changes, to the air temperature changes, and to irrigation of two nearby fields, as shown in Figure 7. There does not appear to be a significant relationship between these potentials and the barometric fluctuations or the air temperature changes, although there may be some slight relationship between the potentials and nearby irrigations.

A typical series of potentials measured in 1967 by the 3 numbered tensiometers indicated in Figure 4 is shown in Figure 8. Although the elevations of these potentials fluctuated at various times during the season, they gradually declined as the season progressed. Variations in the water surface elevation are shown by the top curve. The dashed line represents the elevation of the canal bottom. The elevations of the 3 tensiometer cups are indicated by the triangular symbols. Whenever the potential curve is below the tensiometer elevation, a tension or negative pressure relative to atmospheric pressure is indicated. When the potential curve is above the tensiometer, a positive pressure is indicated. The hexagonal symbols represent the soil moisture potentials at which a large change in hydraulic conductivity occurs in the soil. The laboratory tests showed that as the potential curve passes below this elevation, the bubbling pressure of this soil is exceeded and the hydraulic conductivity rapidly decreases, indicating a probable significant decrease in seepage.

There appears to be a significant effect of demossing treatments on the seepage rate. After the first and second treatments, the potential

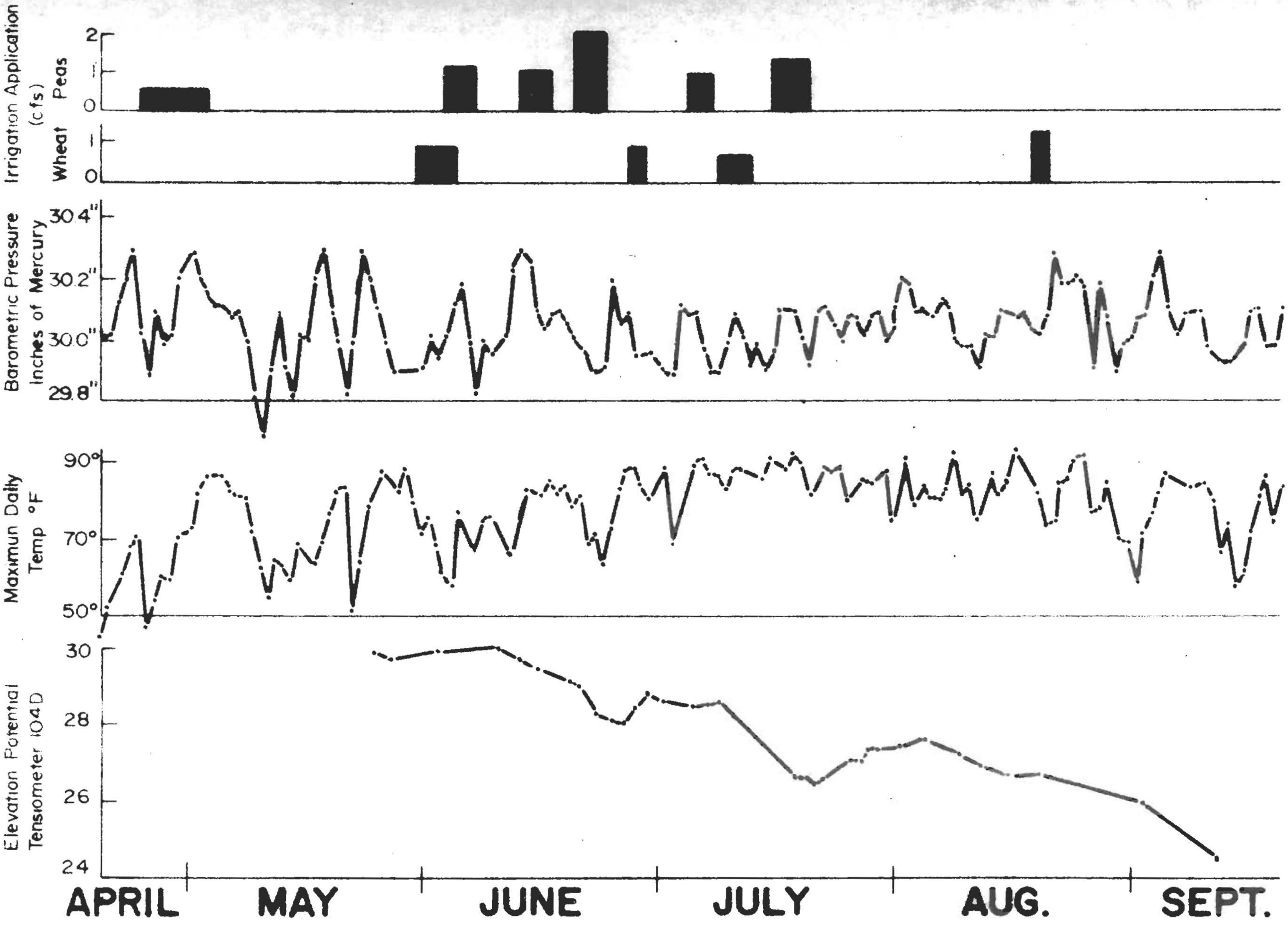

Figure 7. Comparison between elevation potential changes, temperature changes, barometric changes, and time of irrigation of nearby fields during the 1966 irrigation season.

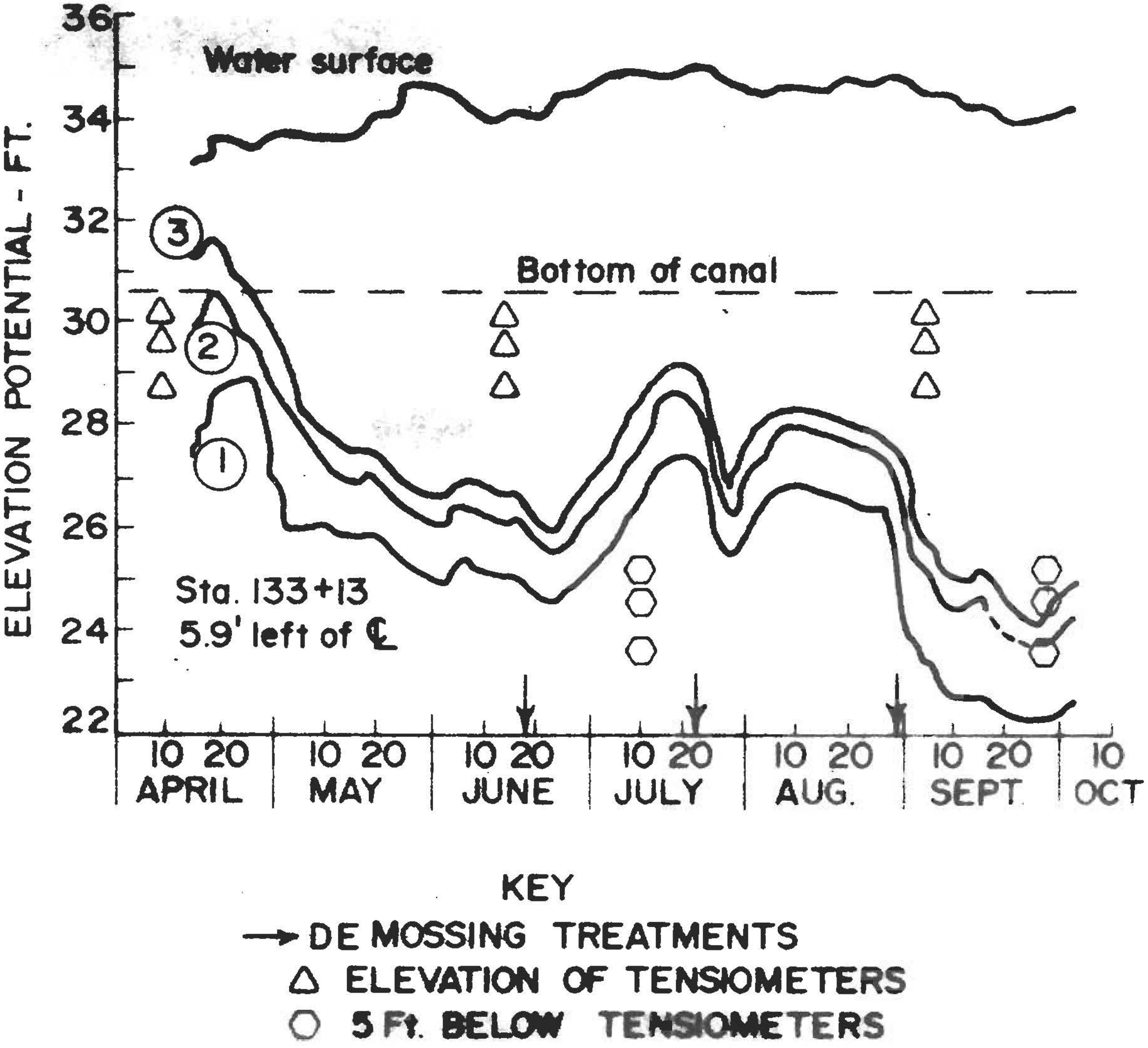

Figure 8. Changes in water potentials found at tensiometers 1, 2, and 3 at Station 133 + 13 during the 1967 irrigation season.

curves declined slightly and then increased, indicating an increase in conductivity in the soil above the tensiometers. There was more delay before this increase in potential was noted after the third treatment.

In order to study the seepage phenomena occurring under this canal, the relationships found between tensiometers 1 and 2 (which were at the 1- and 2-foot depths below the canal bottom) were plotted. Figure 9 shows a typical series of hydraulic gradients and hydraulic conductivity values that occurred between these 2 tensiometers throughout the season. The values before mid-May showed large fluctuations and are not included. After mid-May, the hydraulic gradient became approximately 1. This could be expected with the soil conductivity quite uniform above, below, and in between the tensiometers. However, in late August the gradient rose and stayed above 1.

Figure 10 shows conductivity plotted versus soil moisture tension on a log-log plot. One hundred percent represents a saturated conductivity of approximately 1.4 feet per day. At about 5 feet of water tension, the conductivity drops off sharply to about 25 to 30 percent of the saturated value.

Figure 9 also shows the interaction between changes in gradient, hydraulic conductivity, and seepage rate during the season. When the hydraulic conductivity was at its maximum value, the seepage rate curve represented an amplification of the gradient curve. Late in the season, when the hydraulic conductivity dropped, the gradient curve rose. When the hydraulic conductivity dropped below unity, it caused an attenuation of the gradient curve. This attenuating effect of the lower K values was greater than the increase in the gradient and the seepage rate curve dropped to its lowest value for the season.

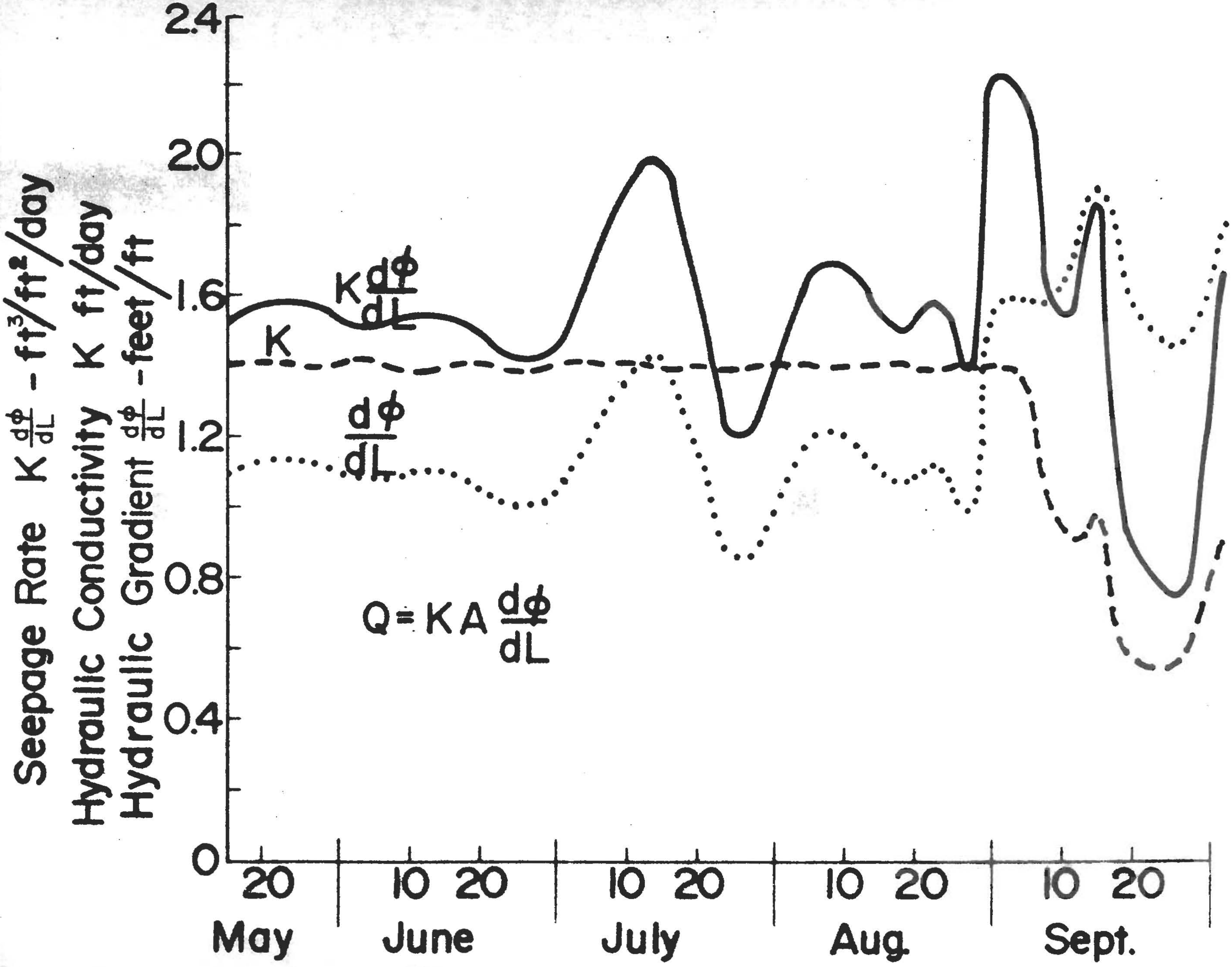

Figure 9. Comparison of hydraulic conductivity, gradient, and seepage rate curves.

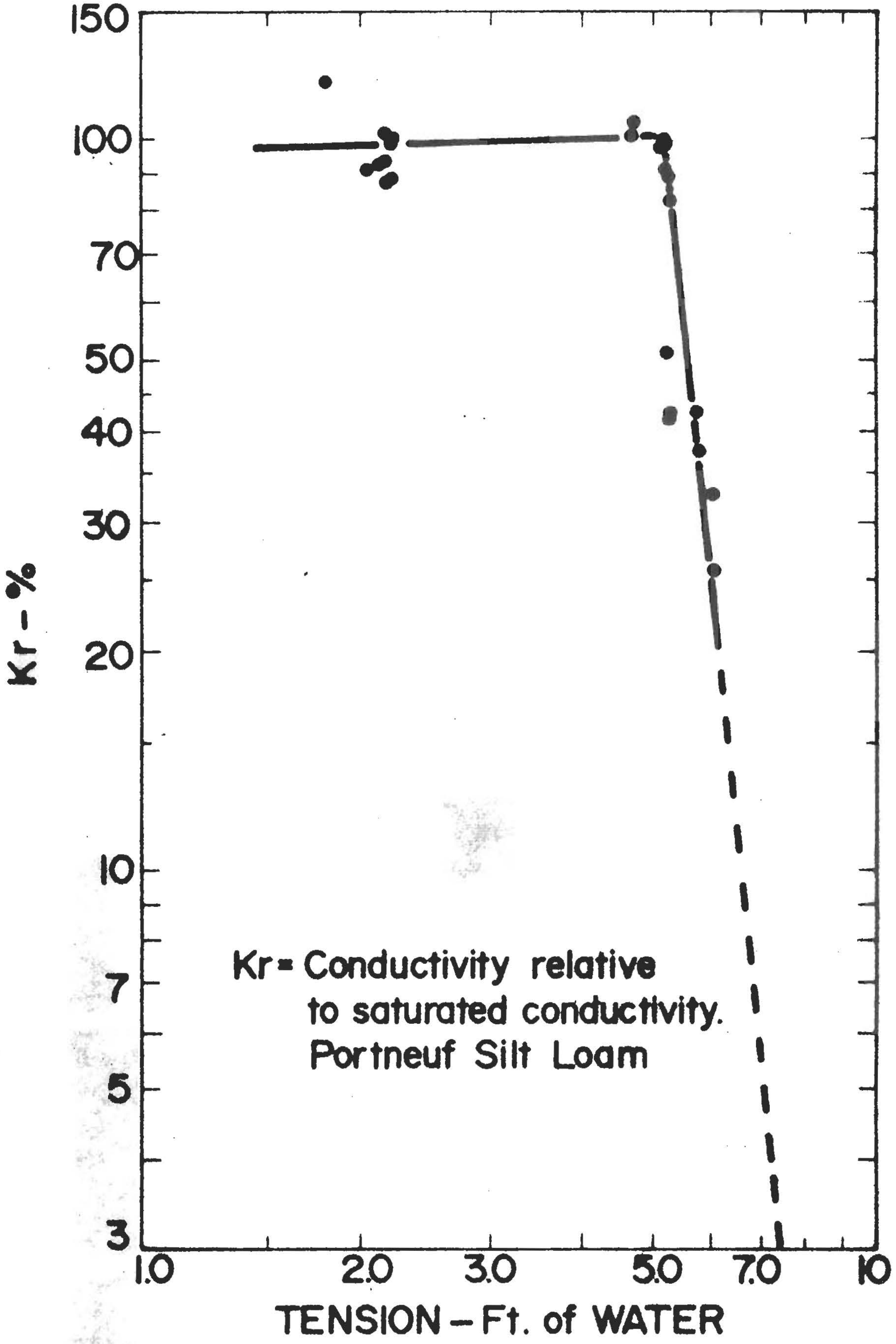

Figure 10. Log - log plot of conductivity-tension relationship of Portneuf silt loam core sample.

CONCLUSIONS

The soil moisture tensions and hydraulic gradients found below a canal in this soil fluctuated considerably during the season, but the hydraulic conductivity remained about the same until September. As the bottom of the canal became less permeable, the tensions at the lower depths became greater than 5 feet of water. At this tension, the conductivity of this soil drops off sharply as shown in Figure 10. The decreased conductivity is caused by air entering the larger capillary pores in the soil, so that they cease to conduct water. The reduced hydraulic conductivity was offset by an increase in the pressure gradient. In time, the gradient should again approach unity.

If the gradient,

$$\frac{d\phi}{dL} = 1,$$

and

$$\text{Area} = 1,$$

and

$$Q = K A \frac{d\phi}{dL},$$

where

$$Q = \text{canal seepage rate},$$

then $Q = K$ and the seepage from the canal as measured by ponding should equal the average K of the soil below the canal.

In ponding four 1/2-mile reaches of this canal in the fall of 1965 and 1966, the seepage rate was found to be approximately 0.60 to 0.75 foot per day per square foot of wetted area of the canal. This seepage rate corresponded to the hydraulic conductivity value for this soil when it was under about 5-1/2 feet of soil moisture tension. This range of tension existed near the bottom of the canal during the latter part of the irrigation season, just before the ponding tests. If the overall gradient was approximately unity, then the seepage rate was about equal to the hydraulic conductivity of the soil just below the canal.

If the sealing phenomena could be caused to occur earlier in the season, the total annual seepage loss could be reduced significantly. This could be done by partially sealing the top layer to restrict the flow of water into the soil. Such sealing might be accomplished by chemical treatments, mechanical compaction, or membrane installations.

Tensiometers can be used to measure the hydraulic gradients and soil moisture potentials existing below a canal. With further development, they might replace expensive ponding or seepage meter tests at the beginning or the end of the irrigation season. They can provide data to evaluate: (1) seasonal seepage changes, (2) the effect of sealing agents, and (3) the rates at which canals lose water. The tension gradients can be measured, and if the soil hydraulic conductivities are known, the seepage can then be estimated at any time during the irrigation season.