THE INFLUENCE OF CANAL SEEPAGE ON GROUNDWATER IN LUGERT LAKE IRRIGATION AREA

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Abstract

Seepage from irrigation canals in the Lugert Lake Irrigation area has been considered a major contribution to the perched water table and to soil salinity problems in the area. This research was conducted to quantify water losses from the canals and to determine the influence of the water losses on the soil water. Seepage rates were measured by ponding for canals less than 4 m wide. The rates ranged from 0.35 to 0.78 cm/hr (0.13 to 0.44 ft^3/sec/mi) for canals in regions with clay loam surface soils and from 1.09 to 1.24 cm/hr (0.33 to 0.48 ft^3/sec/mi) for regions with sandy loam surface soils. Seepage rates for the large main canals were measured with seepage meters, but the method proved unreliable. Water losses for the main canals calculated from measured rates on smaller canals were 0.85 to 1.3 ft^3/sec/mi for clay loam soils and 1.3 to 2.0 ft^3/sec/mi for sandy loam soils. Water-table elevations in the vicinity of the canals increased 100 to 200 cm near the canals and 60 to 120 cm at distances greater than 100 m from the canals. The elevations increased rapidly soon after water was placed in the canals and decreased rapidly after the canals were emptied. Water losses from the smaller canals were sufficient to account for up to 50% of the observed change in water-table elevation in the surrounding soil. Water losses from the main canals accounted for up to 100% of the change in the water table elevations.

KEYWORDS: Canal seepage, ponding, seepage meter, soil salinity, drainage, groundwater

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OBJECTIVES AND EXTENT OF ACHIEVEMENT OF THE OBJECTIVES

The objectives of the study were:

1. To quantify water seepage losses from irrigation canals in the Lugert Lake Irrigation Area.
2. To determine the influence of these seepage losses on the groundwater status in fields adjacent to the canals.

The objectives of this study were achieved satisfactorily. Water seepage rates were measured for five canals in two soil types. The canals measured were medium and small in size. Seepage measurements in the large canals were made, but the methods proved unreliable. The results from the small and medium-sized canal were used to calculate seepage rates for the large canals. All of the seepage rates are considered conservative since they were determined at the end of the irrigation season.

Soil water was monitored in fields near the canals. Soil-water content, soil-water potential, and water-table elevations were measured in irrigated and non-irrigated areas. A special piezometer was designed to respond quickly to changes in the soil-water potentials of the slowly conducting soils in the area. The water lost from the canal was compared with the water required to change the water table in the surrounding fields to assess the importance of seepage on groundwater.

Background

Canal losses in the Lugert Lake irrigation area have been estimated to be as great as 25% to 50% of the water entering the irrigation canals. The soils in the area are predominantly poorly-drained clay loam soils. This seepage water is a potential cause of high water tables and soil salinity problems which exist in the area. In Jackson County, Oklahoma, 25,000 acres, or 45% of the irrigated land, is suffering from these problems. Long-term utilization of this irrigation water and these soils necessitates solving these drainage and salinity problems. An understanding of the source of the groundwater and its movement in these soils is needed to enable persons to devise effective methods to eliminate existing problems and to prevent similar ones in the future. This study was conducted to assess canal seepage as a source of groundwater and the contribution of seepage to the elevation and movement of groundwater.

Methods and Materials

Seepage rates were measured from five selected canals in the irrigation district. The ponding method was used for the small and medium-sized canals. A dam was constructed at the downstream end of a selected canal. The dams were constructed of boards covered with plastic sheets. The edges of the plastic were covered with soil to prevent leakage. The boards were supported by existing canal structures. After completing the downstream dam, water was allowed to fill the canal. When the canal was full, a dam was constructed at the upstream end of the canal to prevent inflow of more water. A water stage recorder mounted in a steel stilling well was used to continuously monitor the elevation of water in the canal. Corrections for evaporation were made based on evaporation rates reported by the U.S. Weather Service for Altus, Oklahoma.

The large main canals were too large for the ponding method. Seepage meters as described in Brockway and Worstell (1968) and Kraatz (1977) were used. Since the canals could not by partially filled, the seepage meters were used in canals containing 1.5 m to 2.5 m of water. This necessitated placing seepage meters at the desired measurement locations before the canals were filled. Approximately 70 low-cost seepage meters were constructed and placed carefully in the soil to a depth of 3 cm to 5 cm at 65 m intervals along a 1.5 mile section of the canal.

After the canals were filled, water was supplied to each meter from a floating plastic bag through a flexible plastic tube as described by Kraatz (1977). At the beginning of a measurement period the volume of water was carefully measured into the bag. Eight to twelve hours later the volume of water remaining in the bag was measured. The seepage rate was calculated from the water lost during the period of flow. The floating water bag was used to maintain the same water pressure on the inside and outside of the seepage meter (Kraatz, 1977). Additional tubes connected to the meters indicated the pressure on the inside of the meter differed from that on the outside by less than $\pm$ 0.5 cm of water. No explanation for the small differences could by found.

Seepage meters were used on one small canal measured by ponding to compare the two methods of measurement.

Canals were selected in areas with clay loam surface soils and sandy loam surface soils. The canals were selected in regions where surrounding soil water conditions could be monitored and the necessary dams could be constructed. Locations and descriptions of the canals and the surrounding soils are given in the appendices.

Soil-water potentials were measured by means of rapid response piezometers, as shown in Figure 1. The piezometers with their small

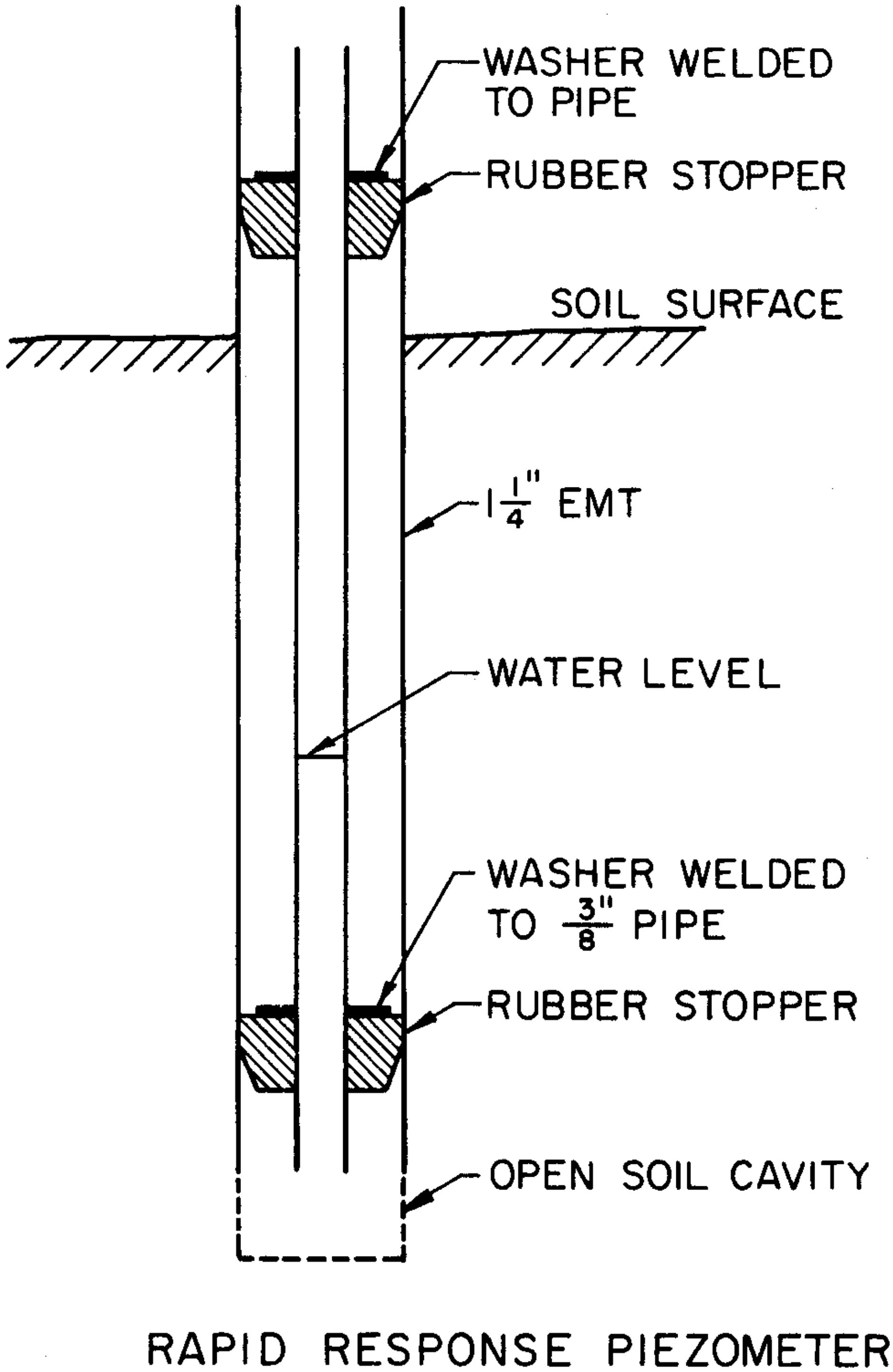

Figure 1. Rapid response piezometer for measuring soil-water potential in soils with low hydraulic conductivity.

center pipe required very little water flow through the soil to move the water up or down in the piezometer as the potential changed. This feature was needed in these soils because of their low hydraulic conductivities. A battery-operated probe was built which could by lowered into the piezometer to measure the water level. An audible sound was emitted when the end of the probe touched the water. The operator then recorded the distance to the water.

Preliminary data suggested that the soil stratification significantly influenced water movement in these soils. The soils were essentially impermeable at a depth of approximately 270 cm. For these reasons the piezometers were installed in sets of 4 at depths of 180, 210, 240, and 270 cm. Forty-two sets of piezometers were installed. Potentials were measured two times each week during and immediately following the irrigation season and one time each week for the remainder of the year. The water content of the soil was measured by means of a neutron probe.

RESULTS AND DISCUSSION

Canal Seepage

Figures 2 through 6 show the seepage rate as a function of the elevation of water in the canal for each canal. These seepage rates are the rate of decrease of the elevation of water in the canal corrected for evaporation. Figures 2, 3 and 4 are for canals in regions with the clay loam surface soils, and Figures 5 and 6 are for canals in regions with sandy loam surface soils. The seepage rates for canals 1, 2, and 4 appear to be independent of the elevation of water in the canal. The seepage rates for canals 3 and 5 decreased approximately 50% as the water elevation changed from its maximum to minimum values. The canals were filled to their operational levels before ponding measurements began so the rates at the high water elevations should be representative of the seepage rates during the operation of the canals.

Repeated measurements in the same canal gave very reproducible results. All of the measurements for a particular canal fell within ± 10% of the mean seepage rates for that canal except for canal 2. The first experiment in canal 2 had a seepage rate approximately 60% greater than experiments 2 and 3 for that canal. Experiment 1 was interrupted by an intense rainstorm which resulted in surface runoff refilling the canal. The decreased rates for the experiments 2 and 3 may be due to sedimentation of soil particles carried into the canal by rainwater. Bouwer and Rice (1969) found sedimentation caused gradual decreases in seepage rates measured by ponding.

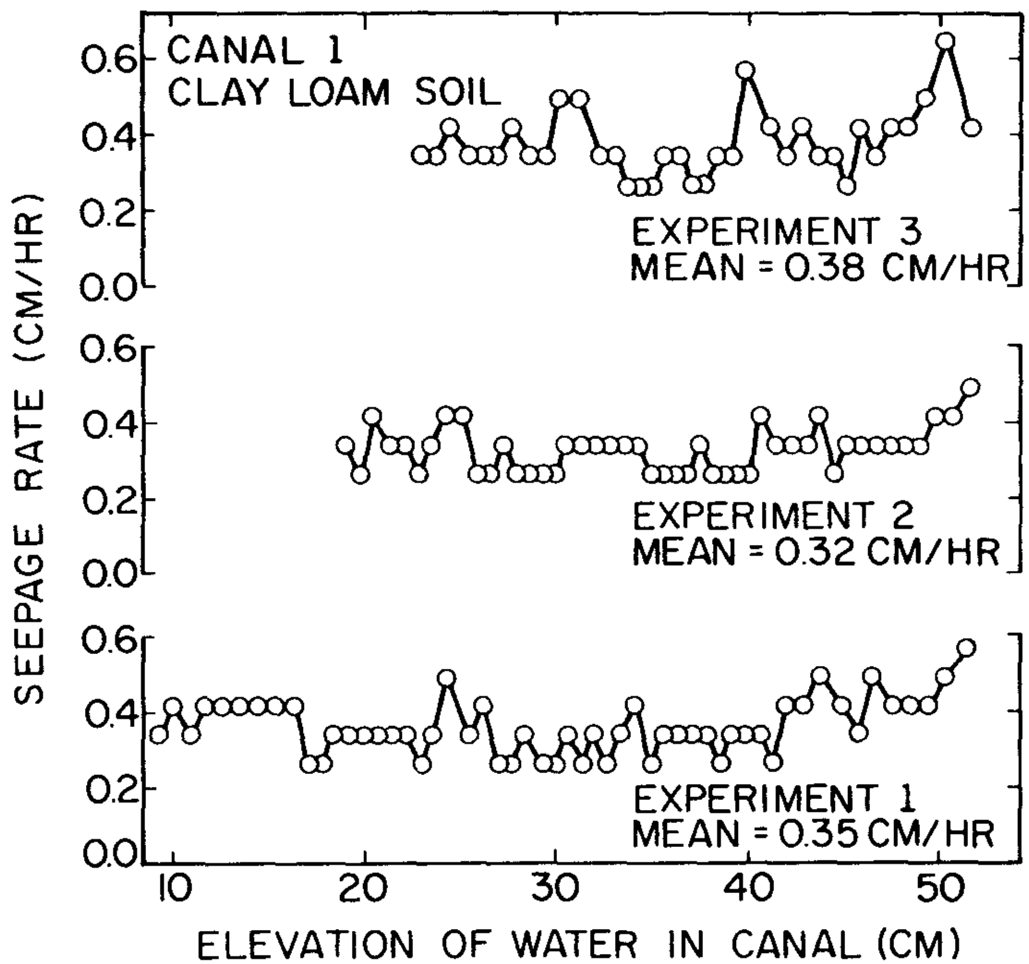

Figure 2. Seepage rate as a function of the elevation of water in the canal as measured by ponding.

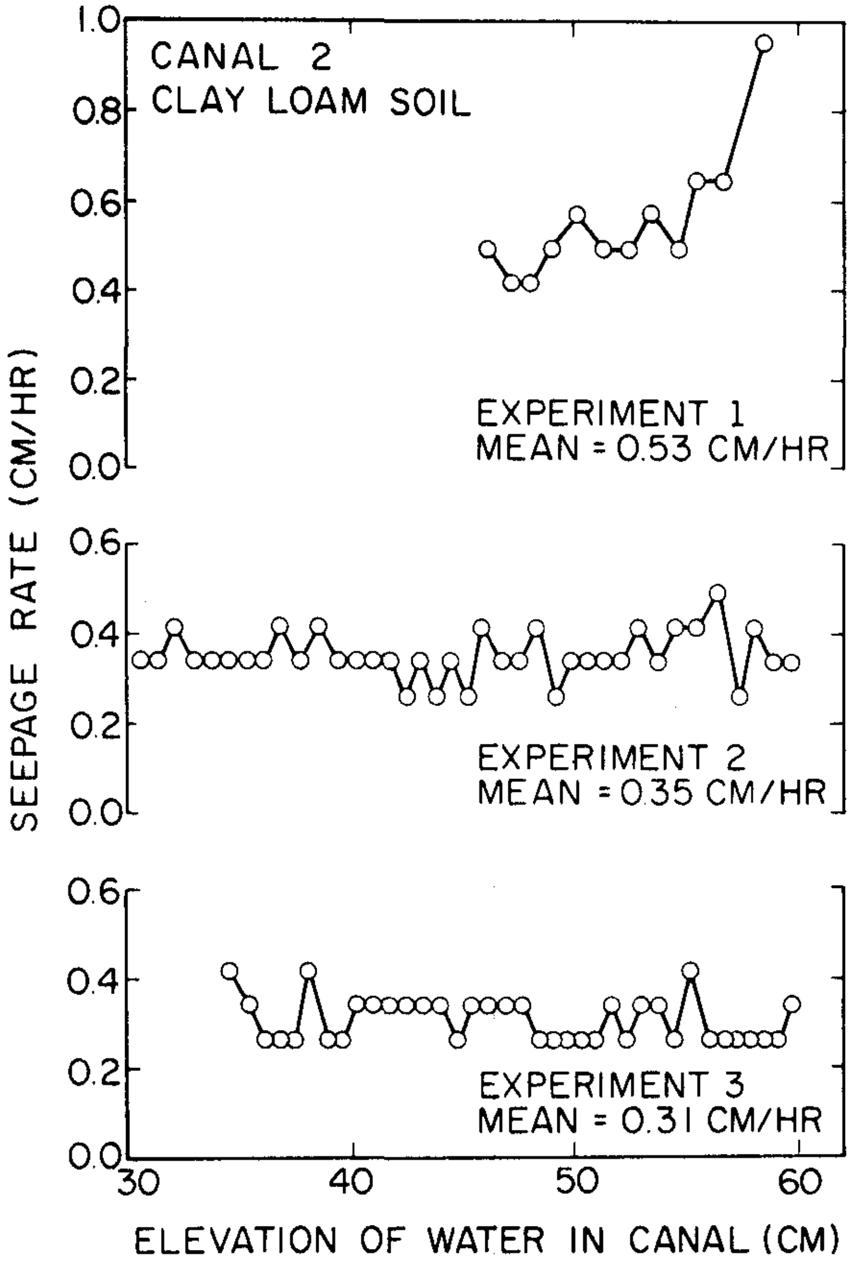

Figure 3. Seepage rate as a function of the elevation of water in the canal as measured by ponding.

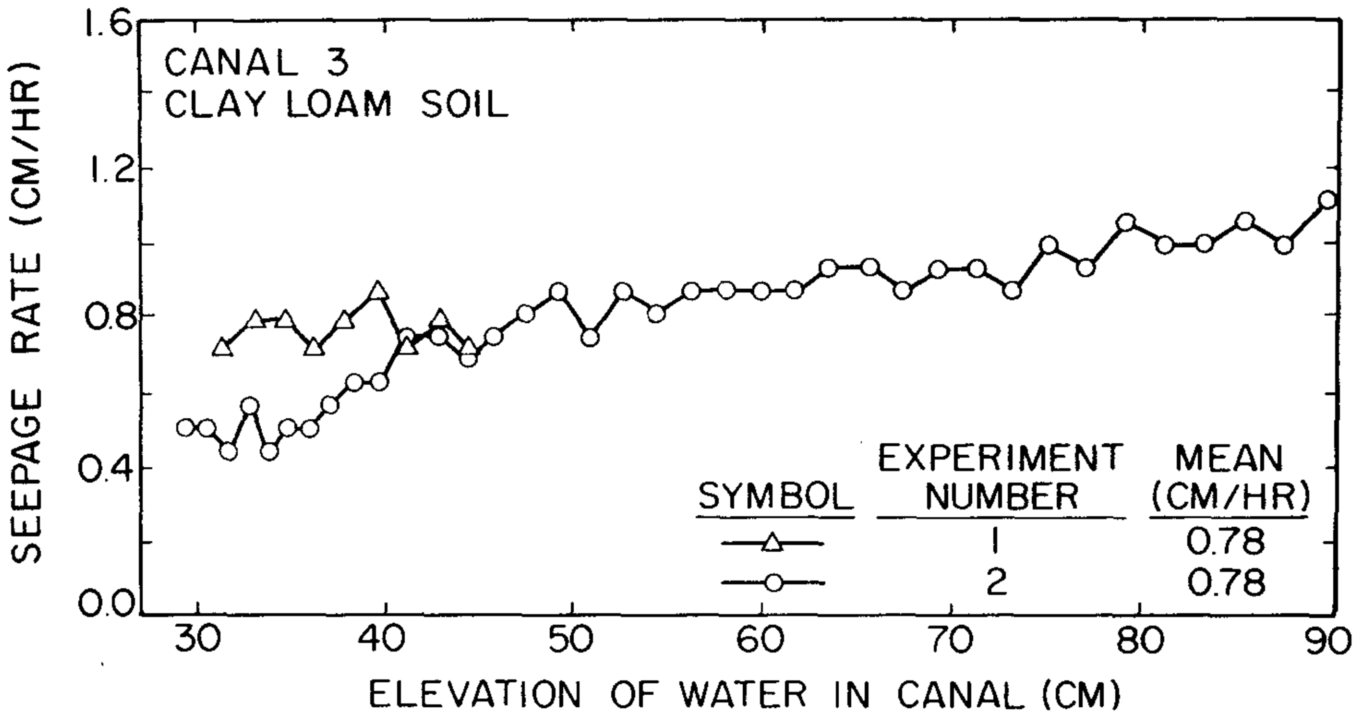

Figure 4. Seepage rate as a function of the elevation of water in the canal as measured by ponding.

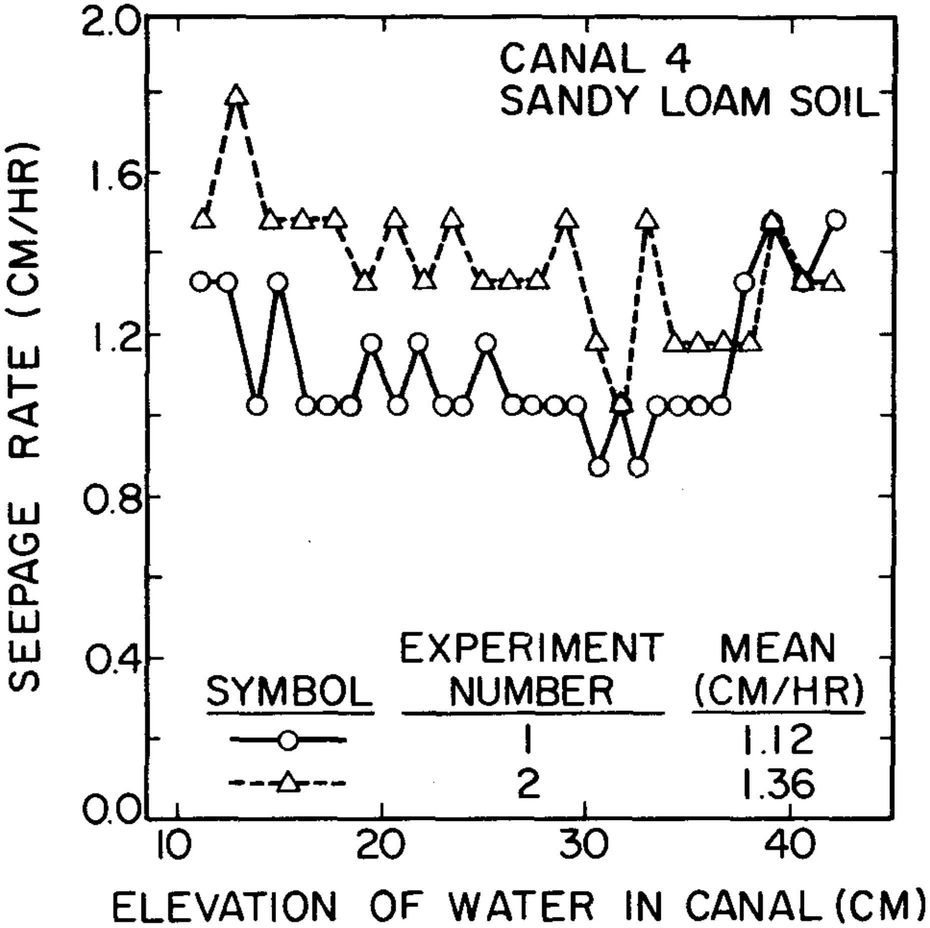

Figure 5. Seepage rate as a function of the elevation of water in the canal as measured by ponding.

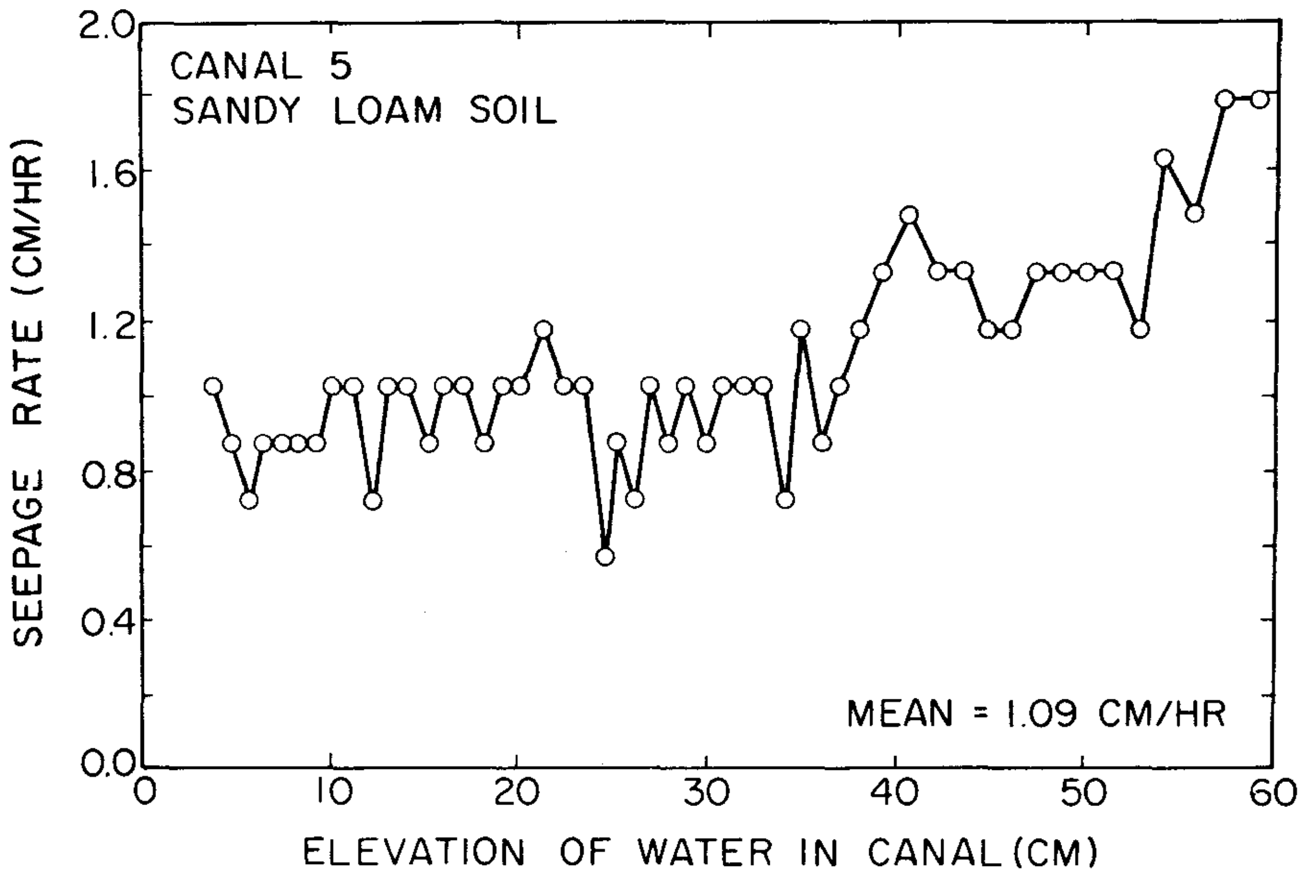

Figure 6. Seepage rate as a function of the elevation of water in the canal as measured by ponding.

Frequently the seepage rate for canals is expressed as the volume of water lost from the canal per unit time per unit area of wetted canal surface. Table 1 contains this information along with the volume of water lost from the canal per unit time per unit length of canal.

The results discussed above are for small and medium-sized canals measured by ponding. Seepage meters were used to measure seepage from the large main canals and from canal 2 presented above. Measurements were made in canal 2 to compare the seepage meter results with those obtained by ponding. Results of measurements at seven locations in canal 2 are shown in Table 2. Four measurements were made at each location. These data indicate that the seepage meter results were extremely variable. Measurements made at one location differed by a factor of 10; measurements during the same time period differed by as much as 14 times across the 7 locations. The mean rate from the positive measurements was only 0.13 cm/hr, while the corresponding rate from the ponding measurements was only 0.13 cm/hr.

In addition to this extreme variability in the results, more than 40% of the measurements resulted in negative seepage rates. That is, the flexible bag contained more water at the end of the 12-hour measurement period than it contained at the beginning. This suggests that the pressure on the water in the seepage meter was less than in the surrounding canal. As stated in the methods, independent measurements of these pressures showed the seepage meter pressure ranged from 0.5 cm of water below that of the canal to 0.5 cm of water above that of the canal. This variation occurred for each meter. Careful and repeated attempts to solve these problems were unsuccessful (Mishu, 1980).

Results for the main canal were similar to those for canal 2. Those data are not presented here but are presented by Mishu (1980). The

TABLE 1

SUMMARY OF SEEPAGE RESULTS OBTAINED BY PONDING METHOD

Canal Identification Number	Avg. Width of Water	Avg. Wetted Perimeter	Avg. Seepage Rate	Avg. Seepage Vol Per Unit Time Per Unit Area of Wetted Surface	Seepage Rate Per Unit Length of Canal
	(cm)	(cm)	(cm/hr)	($cm^3/cm^2/hr$)	
1	240	260	.35	.32	85 $cm^3/hr/cm$ .13 $ft^3/sec/mi$ 58 gal/min/mi
2	300	330	.40	.36	120 $cm^3/hr/cm$ .19 $ft^3/sec/mi$ 85 gal/min/mi
3	360	400	.78	.70	280 $cm^3/hr/cm$ .44 $ft^3/sec/mi$ 197 gal/min/mi
4	170	180	1.24	1.17	210 $cm^3/hr/cm$ .33 $ft^3/sec/mi$ 148 gal/min/mi
5	280	300	1.09	1.02	305 $cm^3/hr/cm$ .48 $ft^3/sec/mi$ 215 gal/min/mi

TABLE 2

SEEPAGE RATES (cm/hr) FOR CANAL 2 MEASURED BY SEEPAGE METERS

	Observation			
Location	1	2	3	4
1	0.02	<0	<0	<0
2	0.07	<0	0.04	<0
3	0.22	0.03	<0	<0
4	0.31	<0	0.58	0.03
5	0.04	<0	0.20	0.03
6	0.02		0.23	<0
7	0.04		0.16	<0

Avg. from Positive Seepage Rates 0.13 cm/hr
Avg. from Ponding 0.31 cm/hr

seepage meter method was considered unsatisfactory for these experimental conditions.

Table 3 shows estimated seepage rates for two large main canals in the clay loam area and two large canals in the sandy loam area. These calculated flow rates are based on the rates through the medium-sized canals in the same soil types. The assumption made in these calculations is that the seepage rate per unit area of wetted surface is constant for all canals in the same soil type.

Underground drainage systems are being installed in these soils to lower the water table and to intercept canal seepage. The seepage rates shown in Tables 1 and 3 provide information on the capacity of drainage systems capable of intercepting all of the canal seepage. They can also be used to estimate the fraction of the canal seepage intercepted by existing drainage systems.

Soil-Water Status

The soil-water potential was measured at various depths below the soil surface by means of the rapid response piezometers. The elevation of water in the most shallow piezometer was taken as the elevation of the water table. Figure 7 shows water table elevations in the vicinity of canal 3 at selected dates in 1978 and 1979. The water table was 200 to 250 cm below the soil surface from October to June. Water was placed in the canals and irrigation began approximately July 1 each year. The water table elevation increased quickly after the canals were filled with water, reached its maximum in early August, and remained near that maximum level until after irrigation stopped in early September. The results shown in Figure 7 are representative of the results obtained at other sites.

TABLE 3

ESTIMATED SEEPAGE RATES FOR LARGE CANALS

Soil Type	Avg. Width Water in Canal	Avg. Wetted Perimeter	Avg. Seepage Volume Per Unit Time Per Unit Area of Wetted Surface	Seepage Rate Per Unit Length of Canal
	(cm)	(cm)	($cm^3/cm^2/hr$)	
Clay loam	1050	1150	.70	805 $cm^3/hr/cm$ 1.3 $ft^3/sec/mi$ 580 gal/min/mi
Clay loam	700	770	.70	540 $cm^3/hr/cm$ .85 $ft^3/sec/mi$ 380 gal/min/mi
Sandy loam	1050	1150	1.1	1265 $cm^3/hr/cm$ 2.0 $ft^3/sec/mi$ 900 gal/min/mi
Sandy loam	700	770	1.1	850 $cm^3/hr/cm$ 1.3 $ft^3/sec/mi$ 600 gal/min/mi

The maximum and minimum water table elevations for the site presented in Figure 7 are shown in Figure 8. Figure 9 shows these elevations for another field with a clay loam soils. The water table elevations increased most near the canals even though none of the measurement sites closest to the canals received surface applied irrigation water. Irrigation began approximately 20 m west of the canal shown in Figure 8 and 100 m west of the canal shown in Figure 9. The land east of both of these canal was not irrigated. At distances greater than 50 m from the canals, the maximum water table elevations were nearly parallel to the elevation of the soil surface. The results for the two years are in good agreement.

Figures 10 and 11 show the maximum and minimum water table elevations for two sandy loam soils. These soils were not irrigated, so all the changes in the water tables must be due to lateral flow of water from the canals or from some other source. Although these results for the sandy loam soils are in qualitative agreement with those of the clay loam soils, several differences exist. Figure 10 indicates the water table elevations for 2 of the 3 sites were lower in 1979 than in 1978. In fact, the maximum at one site in 1979 was below the minimum at that site in 1978. This may be due to improved drainage, since an underground tile drain was installed in this field in the fall of 1978. Figure 11 indicates the water-table elevation in this field increased approximately 200 cm during the irrigation season. The low area near the canal was covered with water; the water table was very close to the soil surface in a large portion of this field. Although this field is part of the irrigation district, it is no longer used for agricultural purposes.

Influence of Seepage on Groundwater

Results shown in Figures 10 and 11 where no water was applied to the

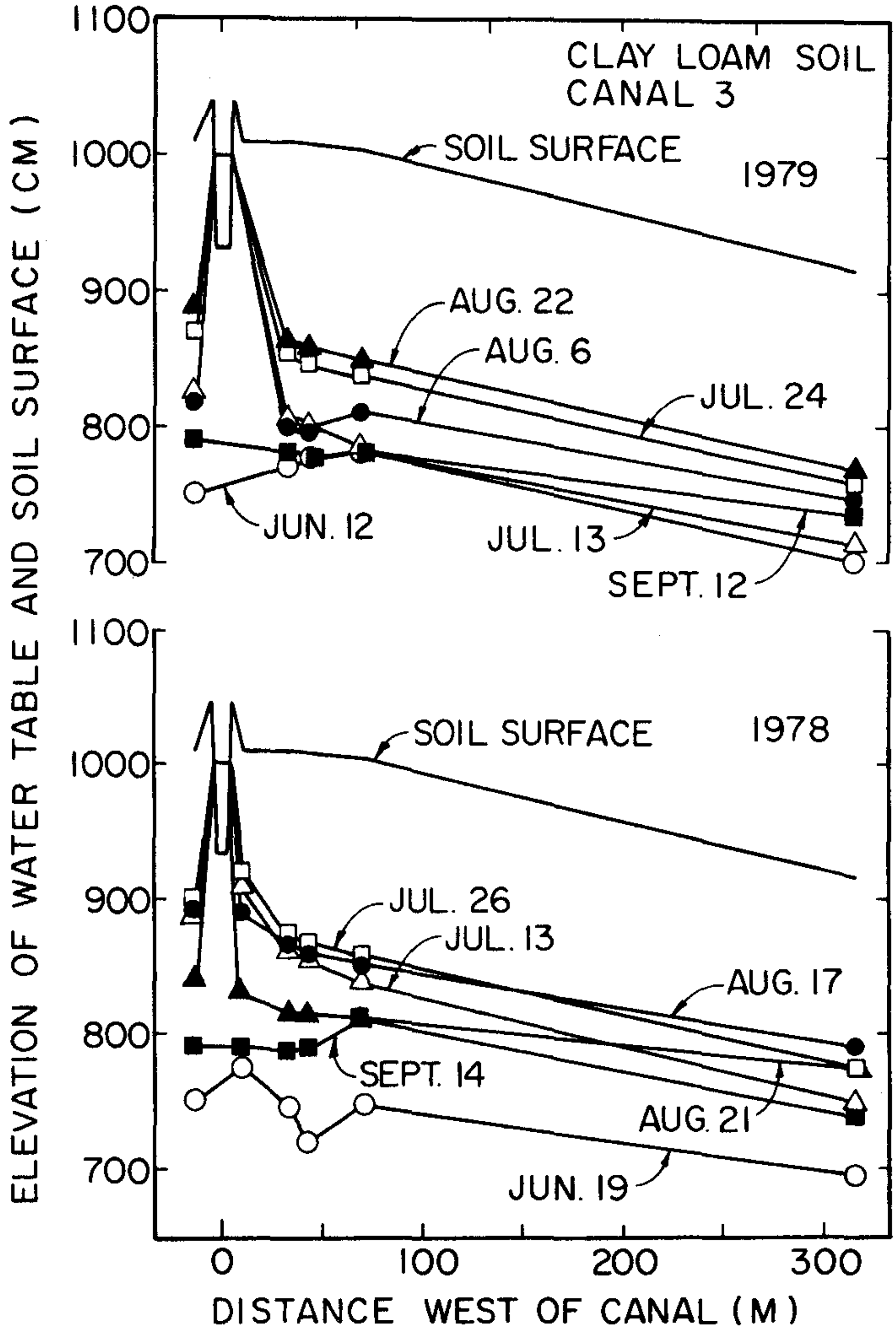

Figure 7. Water table elevations on selected dates in 1978 and 1979.

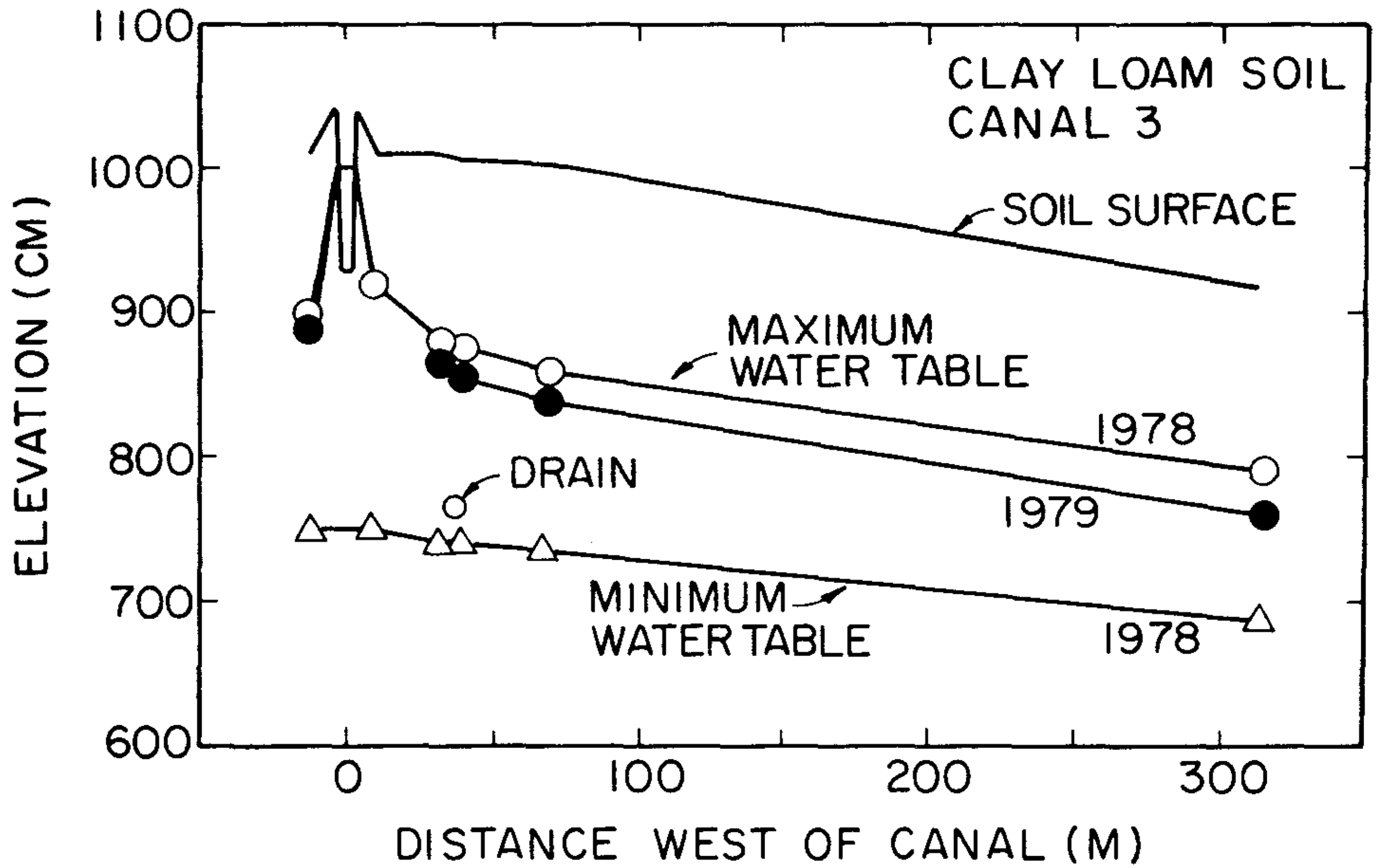

Figure 8. Minimum and maximum water table elevations in 1978 and 1979.

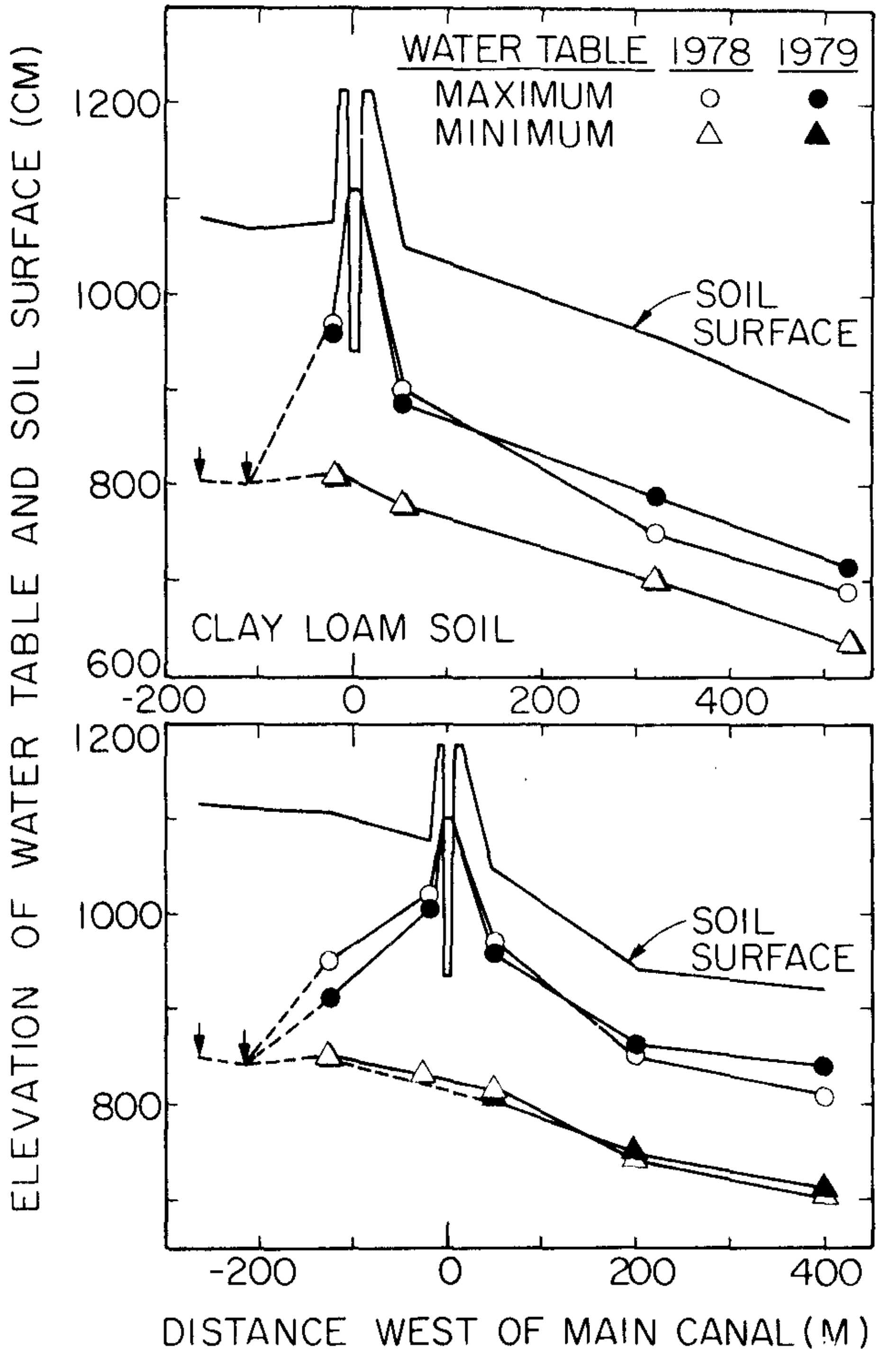

Figure 9. Minimum and maximum water table elevations in 1978 and 1979 for 2 sites 200 m apart. Dashed lines and arrows indicate water table was below deepest piezometer.

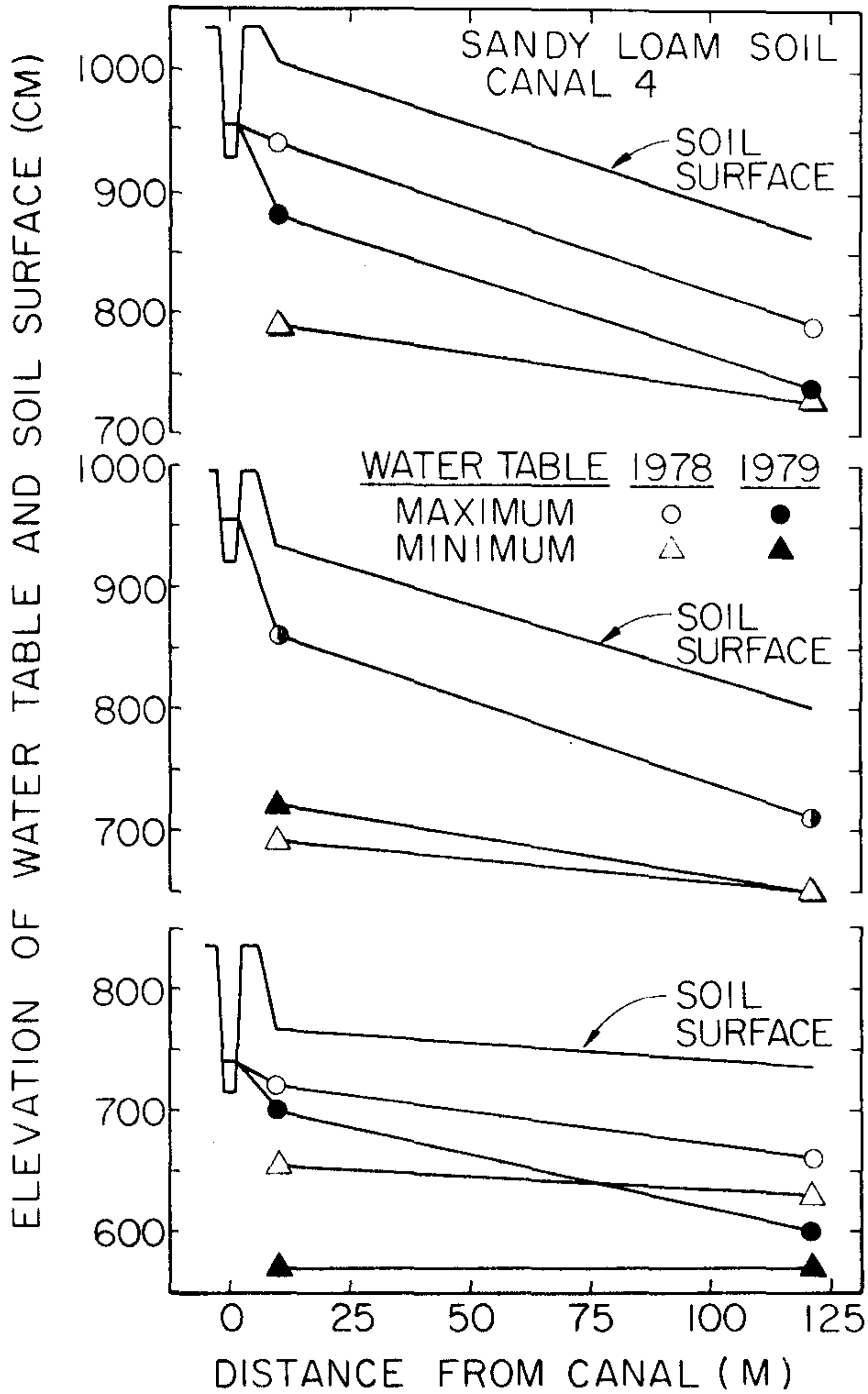

Figure 10. Minimum and maximum water table elevations in 1978 and 1979 for 3 sites approximately 140 m apart. This area was not irrigated.

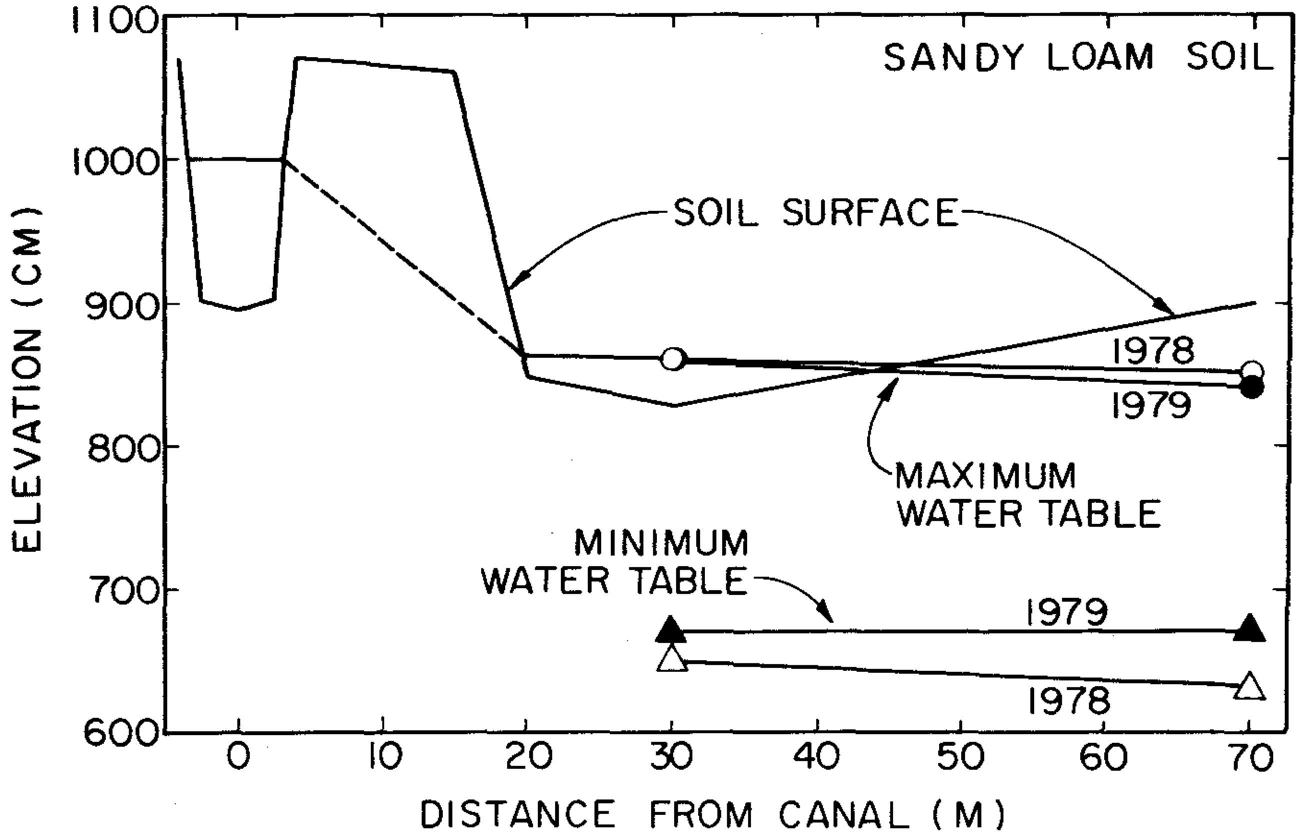

Figure 11. Minimum and maximum water table elevations in 1978 and 1979. This area was not irrigated.

soil surface indicate that canal seepage has very large localized effects on the water tables in the surrounding areas. This is also shown in Figures 8 and 9 for locations near the canal that are not irrigated.

In this section the volume of water seeping from irrigation canals will be compared with the amount of water required to increase the water table elevations as experimentally observed. To make this comparison, the amount of water required to raise the water table a specified amount must be known. Water content measurements just prior to irrigation showed the volumetric water content of these soils ranged from 0.30 to 0.33 cc/cc at depths below 120 cm. At saturation, these soils have a volumetric water content of approximately 0.40 cc/cc. Therefore, approximately 0.08 cm of water is needed to raise the water table 1 cm.

If one assumes that all of the water seeping from a canal remains within 1 mile downslope from the canal and that none of the seepage water drains from the soil, the following results are obtained.

A. For the area downslope from canal 3 shown in Figures 7 and 8:

1. By July 13, the water table had moved up approximately 80 cm. Seepage from the canals surrounding the field could account for only a 13 cm increase.
2. By July 26, the water table had moved up 90 cm. Seepage could account for 26 cm.
3. By Aug. 17, the water table had moved up 100 cm, and canal seepage could account for 48 cm.
4. Canal seepage could account for an average increase in the water table elevation of 60 cm for the entire irrigation season.

B. For the area downslope from the main canal shown in Figure 9:

Canal seepage from the main canal could account for the increase in water table elevation of 60 cm to 100 cm in 35 to 56 days.

These results based on experimental measurements and the assumption mentioned above indicated that seepage from canal 3 is not great enough to account for all of the change in groundwater elevation in the adjacent field. However, seepage from the main canal shown in Figure 9 is adequate to raise the water table the observed amount. In both cases the seepage water contributes a very significant amount to the groundwater of the surrounding soil.

The above calculations are based on the assumption that none of the seepage water drains from the soil. Since some drainage does occur, these calculations suggest that some surface applied irrigation water and rainfall moves through the root zone of the soil and also contributes to the water table. This is encouraging, since some deep movement is necessary to control soil salinity. Research is now underway to develop methods of managing these soils which will control soil salinity and maintain agriculture production on these soils. This research will quantify the movement of water applied to the soil surface by rainfall and by irrigation.

Conclusions

1. Seepage rates for canals in clay loam soils varied from 0.35 cm/hr to 0.78 cm/hr. Seepage rates for canals in sandy loam soils varied from 1.09 cm/hr to 1.24 cm/hr. These results were obtained by the ponding method for canals less than 4 m wide.
2. Water losses for the measured canals in clay loam soil were .13 ft^3/sec to .44 ft^3/sec for each mile of canal. Water losses for the measured canals in the sandy loam soil were .33 ft^3/sec to .48 ft^3/sec./mi.

3. The seepage meter method was found unreliable for measuring seepage from large main canals.
4. Water losses from large canals were estimated using measured seepage rates for smaller canals. The losses for canals 7 m and 10.5 m wide were 0.85 ft^3/sec/mi and 1.3 ft^3/sec/mi, respectively, for clay loam soils and 1.3 ft^3/sec/mi and 2.0 ft^3/sec/mi, respectively, for sandy loam soils.
5. Water table elevations increased 100 to 200 cm near the canals and 60 to 120 cm at distances greater than 100 m from the canals during the irrigation season.
6. Seepage from small canals can account for up to one half of the water needed to change the water table elevations the observed amounts for a region 1 mile downslope from the canal. Seepage from the large canals can account for all of the water required to change the water table the measured amount for a one-mile region.

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APPENDICES

Appendix A

Canal Locations

Canal 1 and 2:

Location: NE 1/4, Sec. 6, T. 1N., R. 20W, Jackson County
Soil: Tillman-Hollister clay loam

Canal 1 runs east and west at south end of this quarter section. Canal 2 runs north and south at north-east corner of the section. Results shown in Figures 2, 3, and 9 are from this area.

Canal 3:

Location: NE 1/4, Sec. 13, T. 2N., R. 21W., Jackson County
Soil: Tillman-Hollister clay loam

Canal 3 runs north and south along east edge of this area. Results shown in Figures 4, 7, and 8 are from this area.

Canal 4:

Location: SE 1/4, Sec. 16, T. 4N., R. 21W., Greer County
Soil: Miles and Altus fine sandy loams

Canal 4 runs north and south along west edge of this area. Results shown in Figures 5 and 10 are from this area.

Canal 5:

Location: SE 1/4, Sec. 19, T. 3 N., R. 20W., Jackson County
Soil: Miles fine sandy loam

Canal 5 (Figure 6) runs north and south along east edge of this area. Results shown in Fig. 11 are for larger canal which runs east and west at north edge of this section.

Appendix B

Description of Soils

Hollister clay loam

A_{1p} 0 to 5 inches, grayish-brown (10YR 5/2, dry; 3/2 moist) clay loam; weak, granular structure; hard when dry, firm when moist; noncalcareous (pH 7.5); abrupt boundary.

A_1 5 to 9 inches, very dark gray (10YR, 3/2, dry; 2/2, moist) clay loam; weak granular structure; hard when dry, firm when moist; many fine pores; peds have a weak shine; noncalcareous (pH 7.5); gradual boundary.

B_2 9 to 28 inches, very dark gray (10YR, 3/1, dry; 2/2, moist) clay; moderate, medium, subangular blocky structure becoming blocky at 16 inches; very hard when dry, firm to very firm when moist; clay skins apparent; noncalcareous to 20 inches (pH 7.5); gradual boundary.

B_2 28 to 36 inches, gray (10YR 5/1, dry; 4/1, moist) clay; weak, blocky structure; very hard when dry, very firm when moist; few whitish spots of soft calcium carbonate; calcareous; gradual boundary.

C_{ca} 36 to 44 inches, gray (10YR 5/1, dry; 4/1, moist) clay; weak, blocky structure; very hard when dry, very firm when moist; more compact than layer above; mixture of soft and hard concretions of calcium carbonate; strongly calcareous; gradual boundary.

C 44 to 60 inches +, gray (10YR 5/1, dry; 5/2, moist) clay, grading to reddish-brown clay. This is apparently red-bed residuum.

From Bailey and Graft (1961)

Soil Descriptions (cont.)

Tillman clay loam

A_1 0 to 10 inches, reddish-brown (5YR 4/3, dry; 3/3.5, moist) clay loam becoming slightly darker in color below plow depth; slightly crusted surface; weak granular structure; hard when dry, firm when moist; noncalcareous (pH 7.5); clear boundary.

B_2 10 to 28 inches, reddish-brown (5YR 4/3, dry; 3/2, moist) light clay that is slightly lighter in color when crushed; moderate, very fine, blocky structure; very hard when dry, very firm when moist; clay skins apparent, but not pronounced; few small, black concretions; noncalcareous (pH 8.0); gradual boundary.

C_{ca} 28 to 50 inches, reddish-brown (5YR 3/4, dry; 3/6, moist) clay; massive (structureless); very hard when dry, very firm when moist; many soft concretions of calcium carbonate; soil mass calcareous; gradual boundary.

C 50 to 60 inches, yellowish-red (5YR 4/6, dry; 3/6, moist) clay containing less calcium carbonate concretions than above.

From Bailey and Graft (1961)

Soil Descriptions (cont.)

Miles fine sandy loam

A_{1p} 0 to 6 inches, brown (7.5YR 5/4, dry; 4/4, moist) fine sandy loam; friable when moist; noncalcareous (pH 6.7); abrupt boundary.

A_1 6 to 10 inches, dark-brown (7.5YR 4/2, dry; 3/2, moist) fine sandy loam; moderate, medium, granular structure; friable when moist; many wormcasts; noncalcareous (pH 6.7); gradual boundary.

B_2 10 to 36 inches, reddish-brown (5YR 4/4, dry; 3/4, moist) sandy clay loam; compound, coarse prismatic, and moderate, medium, granular structure; hard when dry, friable when moist; outside of peds have slight, dark coating; many open pores and wormcasts; moderately permeable; noncalcareous (pH 7.0); gradual boundary.

B_2 36 to 54 inches, yellowish-red (5YR 5/6, dry; 4/6, moist) sandy clay loam that contains less clay and is slightly more friable than the horizon above; same structure as overlying horizon; hard when dry; noncalcareous (pH 7.0); gradual boundary.

C 54 to 72 inches +, yellowish-red (5YR 5/8, dry; 4/8, moist) fine sandy loam; soft when dry, very friable when moist; noncalcareous (pH 7.5).

From Bailey and Graft (1961)

Soil Descriptions (cont.)

Altus fine sandy loam

A_p 0 to 5 inches, grayish-brown (10YR 5/2) fine sandy loam; very dark grayish brown (10YR 3/2) when moist; weak, fine, granular structure; very friable when moist, slightly hard when dry; pH 7.0; plowed boundary. 4 to 10 inches thick.

A12 5 to 15 inches, grayish-brown (10YR 5/2) fine sandy loam; very dark grayish brown (10YR 3/2) when moist; moderate, fine, granular structure; very friable when moist, slightly hard when dry; pH 7.0; gradual boundary. 6 to 12 inches thick.

B1 15 to 21 inches, dark grayish-brown (10YR 4/2), sticky sandy loam; very dark brown (10YR 2/2) when moist; moderate, medium, granular structure; friable when moist, hard when dry; pH 7.3; graudal boundary. 4 to 8 inches thick.

B2t 21 to 35 inches, dark-brown (7.5YR 4/2) sandy clay loam; dark brown (7.5YR 3/2) when moist; moderate, medium prismatic structure; friable or firm when moist, very hard when dry; prominent clay films on faces of peds; pH 7.5; gradual boundary. 12 to 16 inches thick.

B3 35 to 45 inches, reddish-brown (5YR 5/3) sandy clay loam; reddish brown (5YR 4/3) when moist; moderate, medium, subangular blocky structure; friable or firm when moist, very hard when dry; pH 7.5; gradual boundary. 8 to 15 inches thick.

C 45 to 60 inches +, yellowish-red (5YR 5/6) sandy clay loam; yellowish red (5YR 4/6) when moist; 40 percent of layer mottled with gray (N 5/0) or dark gray (N 4/0) when moist, very hard when dry; water table at depth of 50 inches; some iron concretions; calcareous.

Fron Frie et.al. (1967)