STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 52

SEEPAGE STUDY OF CANALS IN BEAVER VALLEY, BEAVER COUNTY, UTAH

by

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Prepared by
the United States Geological Survey
in cooperation with
the Utah Department of Natural Resources
Division of Water Rights

1976

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Metric (SI) units

Most numbers are given in this report in English units followed by metric units in parentheses. The conversion factors used are:

English Units (Multiply)	English Abbreviation	(by)	Metric Units (to obtain)	Metric Abbreviation
Cubic feet per second	ft^3/s	0.02832	Cubic metres per second	m^3/s
Cubic feet per second per mile	$(ft^3/s)/mi$	.01760	Cubic metres per second per kilometre	$(m^3/s)/km$
Feet	ft	.3048	Metres	m
Miles	mi	1.609	Kilometres	km

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit by the following equation:

$$°F = 1.8(°C) + 32$$

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ABSTRACT

A study of the gains or losses of nine canals near Beaver, Utah, was made to aid in the water allocation of the canal systems. The canals included in this study are Manderfield Ditch, Last Chance Canal, Christiansen Ditch, Mammoth Canal, City Ditch, Owens Ditch, South Field Ditch, Patterson Ditch, and Aberdare Canal. Four sets of seepage measurements were made during 1974, but flow was observed in all nine canals only during the set of measurements made in June. Adjustments for fluctuations in flow in the canals were made from information obtained from water-stage recorders operated at selected locations along the canals during the time of each seepage run.

The canals studied in Beaver Valley have small to moderate gains or losses. The total average loss for all nongaining reaches, which have an aggregate length of 21.2 miles (34.1 kilometres), was 4.8 cubic feet per second (0.14 cubic metres per second). During the seepage runs an average total of 200.6 cubic feet per second (5.68 cubic metres per second) entered the nongaining reaches. The gaining reaches have an aggregate length of 4.1 miles (6.6 kilometres). Most of the water that is lost from canals reappears in lower canals or the Beaver River and its tributaries.

INTRODUCTION

This report gives the results of the second of a series of canal-seepage studies in Utah by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights. The Division of Water Rights, when allocating water along canal systems, needs to know if an individual canal gains or loses water by seepage. It is desirable also to know where water is lost and how much of the lost water returns to the stream system downstream. The information is best obtained by detailed gaging of canals and by a general study of the entire hydrologic system at and near the canals.

This report describes the study of canals in Beaver Valley (fig. 1), Beaver County, Utah. The canals included are Manderfield Ditch, Last Chance Canal, Christiansen Ditch, Mammoth Canal, City Ditch, Owens Ditch, South Field Ditch, Patterson Ditch, and Aberdare Canal (see figs. 2-9).

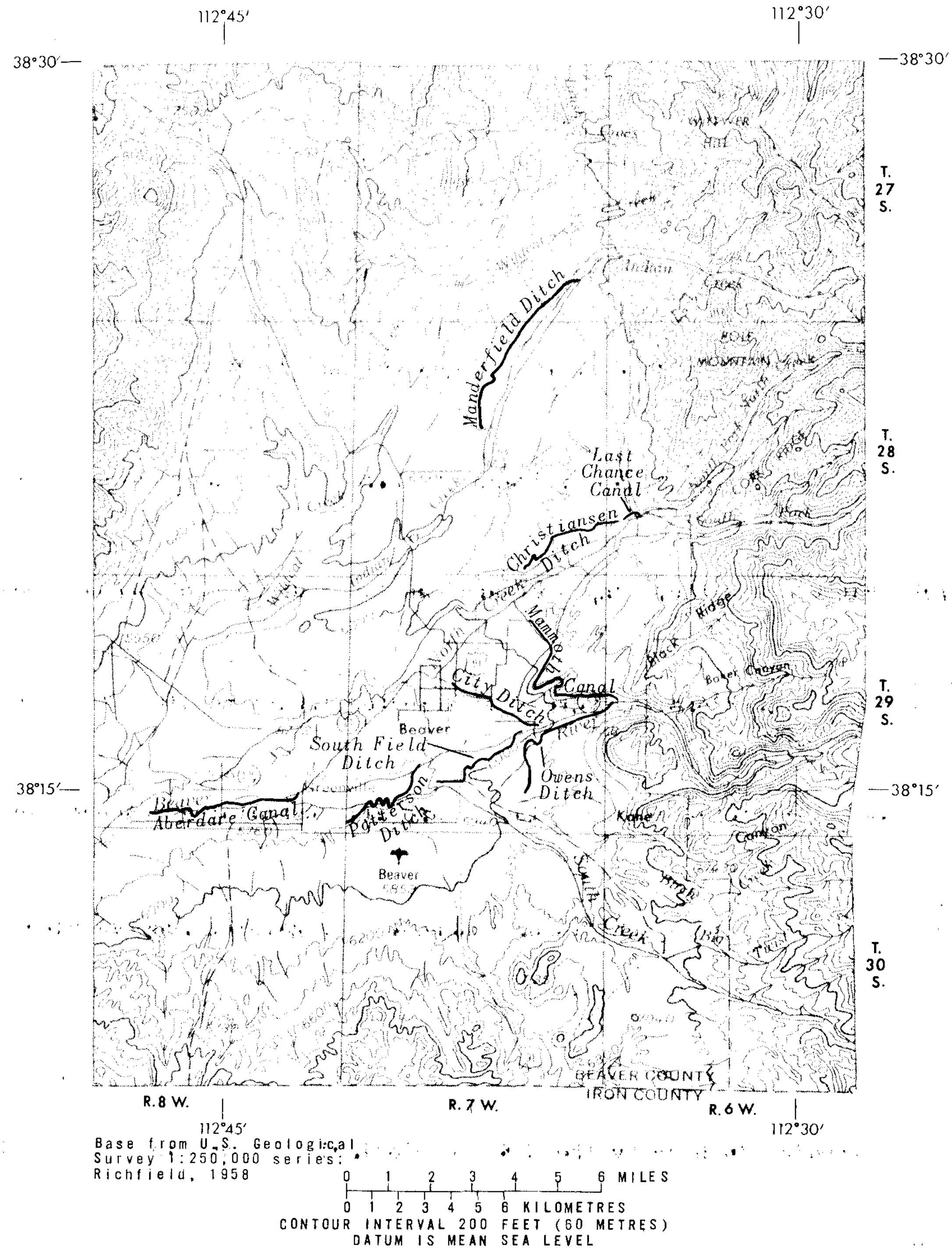

Figure 1.—Map showing location of canals used in this study.

The canal-seepage study was made concurrently with a general hydrologic study of Beaver Valley, the results of which will be published separately. Data obtained for the more comprehensive study were freely used to assist in the preparation of this report.

METHODS OF INVESTIGATION

A reconnaissance was made of all canals in the valley during the fall of 1973. The following items were determined: locations of main canal controls, turnouts, and return flow channels; the nature of the rocks in which the canals are cut; the nature of vegetation above and below the canals; and the land use above and below the canals.

Using the information from the reconnaissance, reaches of nine canals were selected and measuring sites were located within each reach. The reaches were selected to represent typical geologic and hydrologic conditions at the various canals. The reaches selected were between sites M1 and M2 and sites M3 and M7 on Manderfield Ditch (fig. 2), between sites L1 and L2 on Last Chance Canal (fig. 3), between sites M1 and M5 on Christiansen Ditch (fig. 3), between sites M1 and M7 on Mammoth Canal (fig. 4), between sites M1 and M6 on City Ditch (fig. 5), between sites M1 and M7 on Owens Ditch (fig. 6), between sites M1 and M8 on South Field Ditch (fig. 7), between sites M1 and M7 on Patterson Ditch (fig. 8), and between sites M1 and M7 on Aberdare Canal (fig. 9).

Four sets of seepage measurements were made during 1974, covering the periods April 30 to May 2, June 10-13, August 5-7, and September 24 and 25. Flow was observed in all nine canals only during the June set of measurements; therefore, the number of sets of seepage measurements available for any given canal varies from one to four. Measurements were made in each canal at most of the selected measuring sites, turnouts, and inflow points. Figures 2-9 show the sites where measurements were made and the turnouts and inflow points that had flow during at least one of the sets of seepage measurements. The date and time of measurement, the discharge of each measurement, and the temperature and specific conductivity of the water at some of the measurement sites are given in table 2.

Stage recorders were installed at the head of each canal except Christiansen Ditch. The latter was monitored by a recorder that was installed at site L2 on Last Chance Canal, about 300 ft (90 m) upstream from the head of Christiansen Ditch (fig. 3). In addition, continuous water-stage records were obtained at the head of each principal reach. The water-stage records for those sites that had changes in stage during the seepage runs are shown in figure 10.

SEEPAGE MEASUREMENTS

The results, expressed in gain or loss along the canals, are given in table 1. The procedures used to obtain these results are described in the following pages.

A computation was made of the flow that would be expected at each main canal measuring site, assuming no losses or gains. Beginning with the flow at the head of each reach and proceeding in a downstream sequence, all turnout flows were subtracted and all measured or estimated inflows were added. The computed flow at each downstream site was adjusted for fluctuations which originated above the reach being analyzed. Information required to make this adjustment is the change in flow with time at the head of the reach, the time of measurements at the head of the reach and the downstream measuring site, the distance between the head of the reach and the downstream site, and the velocity that the water moves downstream.

The change in flow with time at the head of the reach was determined from the recorded stage and the discharge measurements at the head of the reach. The times of the two measurements are available from table 2. The distance between sites was determined from figures 2-9. The velocity at which the water would be expected to travel downstream was determined from the equation for controlled channel reaches presented by Boning (1974).

As an example, assume that the measurement at the head of the reach was 20.0 ft^3/s (0.57 m^3/s) at 0800 hours, the measurement at the downstream measuring site was made at 1000 hours, the discharge at the head of the canal was dropping at the rate of 0.5 ft^3/s (0.01 m^3/s) per hour, the estimated travel velocity was 1 ft/s (0.3 m/s), and the distance between the two points was 3,600 ft (1,100 m). The travel time would be the distance divided by the velocity:

$$3{,}600 \text{ ft } (1{,}100 \text{ m}) \div 1 \text{ ft/s } (0.3 \text{ m/s}) = 3{,}600 \text{ seconds or 1 hour.}$$

To make the adjustment, the travel time is subtracted from the time of the downstream measurement (1000 hours - 1 hour = 0900 hours) to give a comparable time for flow at the head of the canal. From the water-stage records and the measurements available for the head of the canal, the flow at 0900 hours was calculated as 19.5 ft^3/s (0.55 m^3/s), or an adjustment of -0.5 ft^3/s (0.01 m^3/s). This adjustment was then applied to the computed value of the downstream measuring site.

The computed value was then subtracted from the measured value to determine the amount of gain or loss between the head of the canal and the downstream measuring site. The amount of gain or loss was then plotted as a function of distance downstream from the canal head. This was done for each main canal measuring site for each set of measurements.

Depending on the rate of gain or loss shown on these plots, or if the plotted points showed large amounts of scatter, or if an inflow or turnout was not readily measurable and a main canal measurement had to be made above and below the site, some of the canals were segmented into shorter reaches. The data for each of the newly defined shorter reaches were then plotted in figure 11, with the gain or loss at each main canal measuring site plotted as a function of distance from the head of the reach. A straight line was fitted through the plotted points for each reach, and the amount and rate of gain or loss from the reach was determined from this line. The amount and rate of gain or loss by reach are shown in table 1.

Within a given reach, the amount of gain or loss varied in each set of seepage measurements and among the several sets of measurements. This variation is shown by the scatter of the plotted points in figure 11. The scatter is attributed to one or more of the following: poor measuring conditions, changes in the rate of seepage loss from the canal, changes in the rate of seepage return to the canal of ground and irrigation water, undetected overland flow from nearby irrigated fields, and the inability to adjust completely for fluctuations in the amount of flow within a given reach. At City Ditch, reach M1-M2, and Aberdare Canal, reach M3-M5, the scatter was so large that there was no justification for drawing an average line. For these two reaches, a maximum and a minimum line were drawn and the values noted as such in table 1.

No results are presented for reach M3-M4 on Christiansen Ditch, reach M2-M4 on Mammoth Canal, and reach M5-M6 on Patterson Ditch. Sites M3 and M4 on Christiansen Ditch are above and below a turnout, respectively; thus, the flow of the turnout would be equal to the difference in the two measurements. Only one set of seepage measurements was available for reach M2-M4 on Mammoth Canal, and these measurements were believed to be erroneous. The walls in reach M5-M6 on Patterson Ditch had a number of small breaks that were leaking; but the leaks were not measurable.

GEOHYDROLOGY

The irrigated part of Beaver Valley is underlain by valley fill, which has been derived largely from erosion of the nearby highlands. The valley fill attains thicknesses of several hundred feet, and it may be divided into three general units on the basis of age and permeability.

The oldest material probably is part of the Sevier River Formation of Tertiary and Quaternary age, which has been mapped in detail in a small section of the northern part of the study area by Callaghan and Parker (1961) and by reconnaissance methods at other places in Beaver Valley (Stokes, 1964). Most exposures in the study area are of a fine-grained semiconsolidated material that appears to have relatively low permeability.

The next youngest material forms terraces a few tens to a few hundred feet above the general level of the valley. It is older alluvium of Quaternary age. The upper surface, except for a few inches of soil in most places, consists of as much as 25 ft (7.6 m) of well-cemented coarse gravel, which is generally underlain by an undetermined thickness of loosely cemented finer grained valley fill. The permeability of the older alluvium is probably only slightly greater than that of the Sevier River Formation.

The youngest material covers the main floor of Beaver Valley to a depth of less than 200 ft (60 m) in most places. This younger alluvium of Holocene age is mainly unconsolidated sand and gravel with some discontinuous interbedded unconsolidated to loosely consolidated beds of clay and silt, overlain with a mantle of soil generally less than 2 ft (0.6 m) thick. The relative permeability ranges from low for the silt and clay to high for the gravel.

Most of the canals and irrigated farmlands are on the younger alluvium, although there is a moderate amount of farming on soils derived from the older alluvial terraces. Only a few miles of canal and a small amount of irrigated land are on the Sevier River Formation.

Much of the unconsumed irrigation water seeps to the underlying ground-water reservoir, and water levels rise rapidly in the spring. After peak streamflow and maximum diversions for irrigation, usually in late June or early July, water levels decline as the ground water moves laterally and is intercepted by the lower-lying Beaver River and its tributaries, canals, ditches, and topographically low areas. For this reason, some canals and other streams may lose water at certain times of the year and gain water at other times.

EVALUATION OF CANAL SYSTEMS

Most canals that were studied in Beaver Valley have small to moderate gains or losses. The total average loss for all nongaining reaches, which have an aggregate length of 21.2 mi (34.1 km) during the 1974 seepage runs was 4.8 ft^3/s (0.14 m^3/s) (table 1), and the average unit loss was 0.23 $(ft^3/s)/mi$ or 0.004 $(m^3/s)/km$. During the seepage runs an average total of 200.6 ft^3/s (5.68 m^3/s) entered the nongaining reaches, thus the loss was only 2.4 percent of the available water.

Four canals in Beaver Valley were observed to gain water during the 1974 seepage runs. The gaining reaches have an aggregate length of 4.1 mi (6.6 km), but data are insufficient with which to compute a meaningful average.

Most of the water that is lost from canals reappears in lower canals or the Beaver River and its tributaries, thus once again becoming available for diversion for irrigation. Practically all the remainder is consumed by evapotranspiration in native pastures. The amount of water that returns to canals or the Beaver River and its tributaries versus the amount consumed in pastures is not known.

Manderfield Ditch

Manderfield Ditch diverts from the right bank of Indian Creek in the SW¼ sec. 25, T. 27 S., R. 7 W. (fig. 2), and has a capacity of about 20 ft^3/s (0.6 m^3/s) at the head. Reach M1-M2 of Manderfield Ditch is constructed in older alluvium, consisting of loosely cemented gravel. This material has low permeability when dry, and it becomes even less permeable as water is turned into the canal during the irrigation season. This may account for the slight apparent loss at the beginning of the irrigation season in April and none thereafter. There is no evidence of ground-water inflow in this reach, thus the small apparent gains in June, August, and September may be due to measurement error. For all practical purposes there is no gain or loss in this reach.

Reach M3-M7 of Manderfield Ditch is constructed in younger alluvium derived mainly from the underlying older alluvium. The younger alluvium consists of silty to gravelly materials which have low permeability when wet. This accounts for the relatively low rate of loss during the last three seepage runs.

Last Chance Canal

Last Chance Canal diverts from the right bank of North Creek in the SW¼ sec. 29, T. 28 S., R. 6 W. (fig. 3), and has a capacity of about 30 ft^3/s (0.8 m^3/s) at the head. The first 2,300 ft (700 m) of the canal downstream from site L1 is constructed in younger alluvium. The remaining 2,000 ft (610 m) of the canal to site L2 is constructed in older alluvium.

The younger alluvium is mainly sandy to coarse gravel, which under natural conditions probably has moderately high permeability. The materials along the bed of the canal have become relatively impermeable, however, because of silting and compaction during many decades of use.

The older alluvium is mainly moderately cemented gravel which, where unweathered, has extremely low permeability. In places where the older alluvium is weathered, it has high permeability. Silting and compaction in the canal during many decades, however, has resulted in the older alluvium becoming relatively impermeable also.

The section of the canal that is underlain by older alluvium has shown evidence of at least intermittent leakage. On May 7, 1975, numerous seeps were observed just below the canal bed with discharge rates of as much as 0.01 ft^3/s (0.0003 m^3/s). The numerous cottonwoods on the hillside below the canal also suggest appreciable seepage from the canal. Moist soil areas on the hillside below the canal from about 100 to 500 ft (30 to 150 m) upstream from site L2 were also evident. A considerable amount of ground water is being discharged in marshy areas at the foot of the hill below the canal. The geology and topography suggests that the source of the marsh water is canal seepage.

The bed of the canal had been disturbed by cleaning prior to receiving water in the spring of 1975, an operation that probably is not done every year. This may account for the losses visibly observed in May 1975. Silting of the canal bed between cleaning operations probably greatly reduces the rate of seepage from the canal. This was further indicated on June 2, 1975, when an inspection of this subreach revealed that no water was flowing from any of the seep areas observed during the inspection on May 7. Also, the only moist soil observed was at the site of the largest seep observed on May 7.

Christiansen Ditch

Christiansen Ditch is the leftmost channel of a four-way split of the Last Chance Canal near the center of sec. 30, T. 28 S., R. 6 W. (fig. 3), and has a capacity of about 10 ft^3/s (0.3 m^3/s) at the head. Reach M1-M3 of Christiansen Ditch is constructed in older alluvium or shallow soils derived therefrom on Last Chance Bench. Seepage runs in May and June 1974 show average losses of 0.7 ft^3/s (0.02 m^3/s) (see table 1 and fig. 11). Losses were greatest in May due to the larger flow and probably because water had been in the ditch for only a few days.

Reach M4-M5 runs along the foot of Last Chance Bench and is constructed in younger alluvium derived from the older alluvium of Last Chance Bench. Seepage runs in May and June 1974 show average losses of 0.2 ft^3/s (0.006 m^3/s) (see table 1 and fig. 11). Losses were greatest in May due to the much larger flow and probably because water had been in the ditch for only a few days. The unit loss in both reaches M1-M3 and M4-M5 is 0.3 $(ft^3/s)/mi$ or 0.01 $(m^3/s)/km$ (table 1).

Mammoth Canal

Mammoth Canal diverts from the right bank of the Beaver River in the SW¼ sec. 18, T. 29 S., R. 6 W. (fig. 4), and has a capacity of about 120 ft^3/s (3.4 m^3/s) at the head. Reach M1-M2 of Mammoth Canal is constructed in older alluvium and runs from the base of a terrace at site M1 to a point about midway up the terrace at site M2. The materials are loosely to moderately cemented sandy gravel to coarse gravel, except for small local areas where the material has been weathered and reworked to form a thin mantle of younger alluvium. The unweathered alluvium probably has extremely low permeability, and the weathered alluvium has low to moderate permeability. The materials in the bed of the canal have become relatively impermeable, however, because of silting and compaction during many decades of use.

Seepage runs in August and September 1974 showed small losses. Although the magnitude of the measured loss is within the degree of accuracy of the measuring devices, losses along the reach are confirmed by thickets of willows and areas of moist soil below the canal.

Reach M4-M6 is constructed in older alluvium, and bed conditions are the same as in reach M1-M2. The seepage run in June suggests a slight gain; but as there is no source of inflow above the canal, the apparent gain is probably due to instrument error or undetected fluctuating flow rates in the reach. There are no wet areas, water-loving vegetation, or other visible indications of loss below the canal.

Reach M6-M7 is constructed in younger alluvium; consequently, the permeability of the canal bed and the loss due to seepage are potentially large. A seepage run in June 1974 showed a loss of 0.96 ft^3/s (0.027 m^3/s). The canal was cleaned in the spring of 1974, however, and the seepage rate observed in June probably diminished as time elapsed.

City Ditch

City Ditch heads in the N½ sec. 23, T. 29 S., R. 7 W. (fig. 5), and has a capacity of about 60 ft^3/s ($1.7\ m^3/s$) at the head. It receives water from the Beaver River and(or) the Mammoth Canal. City Ditch is constructed in younger alluvium consisting of a mantle of sandy or gravelly soil generally less than 1 ft (0.3 m) thick underlain by as much as 200 ft (60 m) of unconsolidated sand and gravel. The permeability of the soil mantle in its undisturbed state probably ranges from moderate to high. The permeability of the bed materials of the canal has decreased, however, owing to silting and calcareous deposits.

Seepage measurements show a gain in reach M1-M2. The gain, however, is not from ground-water inflow because the canal is above the water table. The gain may represent undetected direct surface runoff from adjacent fields, undetected change of diversion rates, measurement error, or a combination of all three.

Seepage measurements suggest that the amount of gain or loss is insignificant in reach M2-M6. The small gains or losses observed in this reach may result from the same factors described in the preceding paragraph.

Owens Ditch

Owens Ditch diverts from the left bank of the Beaver River in the SW¼ sec. 18, T. 29 S., R. 6 W. (fig. 6) and has a capacity of about 20 ft^3/s ($0.6\ m^3/s$) at the head. Reach M1-M7 of Owens Ditch runs from the base of a terrace at site M1, near the diversion from the Beaver River, to the top of the terrace at site M5, from whence it runs across the terrace and drops about halfway down the opposite side at site M7. It is constructed in older alluvium; and the materials are loosely to moderately cemented sandy gravel to coarse gravel, except for small local areas where there is a mantle of sandy or gravelly soil about 1-2 ft (0.3-0.6 m) thick that has been derived from the older alluvium. The unweathered alluvium and the soil probably have low permeability. The materials in the bed of the canal have become relatively impermeable, however, through silting and compaction during many decades of use.

The seepage runs showed a loss of 1.3 ft^3/s ($0.037\ m^3/s$) or almost 20 percent of the diverted water (fig. 11). The rate of loss per mile of ditch, however, was only 0.3 $(ft^3/s)/mi$ or 0.005 $(m^3/s)/km$.

A few intermittent wet areas were observed below Owens Ditch. The leakage is probably through burrow holes of rodents in the ditch bed. Phreatophytes were not observed in these areas; thus, it is assumed that the rodent holes are periodically sealed by silting or caving, resulting in intermittent leakage. Above site M4, small patches of cottonwood were observed below the ditch, an indication of a permanent leaky section.

South Field Ditch

South Field Ditch diverts from the left bank of the Beaver River in the SE¼ sec. 22, T. 29 S., R. 7 W. (fig. 7) and has a capacity of about 10 ft^3/s (0.3 m^3/s) at the head. All of South Field Ditch is constructed in younger alluvium consisting of a mantle of sandy loam soil, probably at least 2 ft (0.6 m) thick at most places, underlain by as much as 200 ft (60 m) of unconsolidated sand and gravel. The bottom of the ditch probably is in the soil mantle along its full length. The permeability of the soil and ditch bed is probably low to moderate. The bed is cleaned every year, thus preventing a reduction of permeability by silting.

The water table is above the ditch bed at all times in the general area of reaches M4-M5 and M7-M8. The water table is above the ditch bed during the irrigation season in about three-quarters of the entire canal. A hydrograph for an observation well about 100 ft (30 m) east of the approximate mid-point of reach M5-M6 shows that in 1974 the water table rose rapidly from April 5-27, then rose slowly from April 28 to July 12, then declined slowly through the remainder of the year (fig. 12). This ground-water inflow is the reason for the general gain in South Field Ditch from spring to early fall.

Patterson Ditch

Patterson Ditch diverts from the left bank of the Beaver River near the center of sec. 29, T. 29 S., R. 7 W. (fig. 8) and has a capacity of about 20 ft^3/s (0.6 m^3/s) at the head. All of Patterson Ditch is constructed in younger alluvium overlain by a mantle of sandy loam soil, probably at least 2 ft (0.6 m) thick at most places in reach M1-M5, but less than 2 ft (0.6 m) thick in reach M5-M7. As much as 200 ft (60 m) of unconsolidated materials, ranging from clay to boulders, underlies this mantle. The bottom of the ditch probably is in the soil mantle throughout its full length. The permeability of the soil and ditch bed is probably low to moderate. Drastic disturbance during cleaning operations prevents sealing of the ditch bed.

The ditch bed lies below the water table at intermittent intervals throughout its length, and these intervals expand and contract with the rise and fall of the water table that corresponds approximately with the fluctuations shown by the hydrograph of the observation well in figure 12. When the water table is at its highest level, usually in late June or early July, probably more than 90 percent of the length of the ditch is below the water table; but when the water table is at its lowest level, usually in March or early April, probably less than 50 percent is below the water table. An analysis of the seepage-run measurements suggests a balance between gain and loss in the ditch, but because of poor measuring conditions, an absolute conclusion cannot be determined. The ditch probably has a net gain during certain periods of the year, however, as suggested for the August seepage run by an increase in specific conductance of the water at downstream sites (table 2).

Aberdare Canal

Aberdare Canal diverts from the left bank of the Beaver River in the NE¼ sec. 35, T. 29 S., R. 8 W. (fig. 9) and has a capacity of about 20 ft^3/s ($0.6\ m^3/s$) at the head. All of the Aberdare Canal is constructed in younger alluvium, overlain by a sandy to gravelly soil mantle, probably less than 2 ft (0.6 m) thick in most places. Unconsolidated materials ranging from clay to coarse gravel and having a thickness of 0-100 ft (0-30 m) underlie most of the mantle. There may be short reaches where the soil is underlain by semiconsolidated clay to fine gravel. The permeability of the ditch bed is probably low in reach M1-M3 and extremely low in reach M3-M7.

The ditch bed lies below the water table at intermittent short intervals in the reach from M1 to perhaps 0.25 mi (0.4 km) downstream from M2. Farther downstream, the bed is believed to be above the water table at all times. Occasionally during the irrigation season, however, water may be perched locally beneath fields along the upper side of the canal where the semiconsolidated clay and gravel are at shallow depths.

Aberdare Canal gained in each reach between sites M1 and M5 during the June seepage run, and it gained in reach M1-M2 during all three seepage runs. The gains in reach M2-M5 probably are largely from shallow perched bodies of ground water beneath the adjacent fields at a time when irrigation diversions were at a peak.

SUMMARY

The gains or losses determined for nine canals studied in Beaver Valley were small to moderate. The aggregate length of the canals was 25.3 mi (40.7 km), of which only 4.1 mi (6.6 km) showed gains. The nongaining reaches had an aggregate length of 21.2 mi (34.1 km), with an average total flow of 200.6 ft^3/s ($5.68\ m^3/s$) entering the reaches. The average loss for the nongaining reaches was 4.8 ft^3/s ($0.14\ m^3/s$); thus, the average unit loss was 0.23 $(ft^3/s)/mi$ or 0.004 $(m^3/s)/km$.

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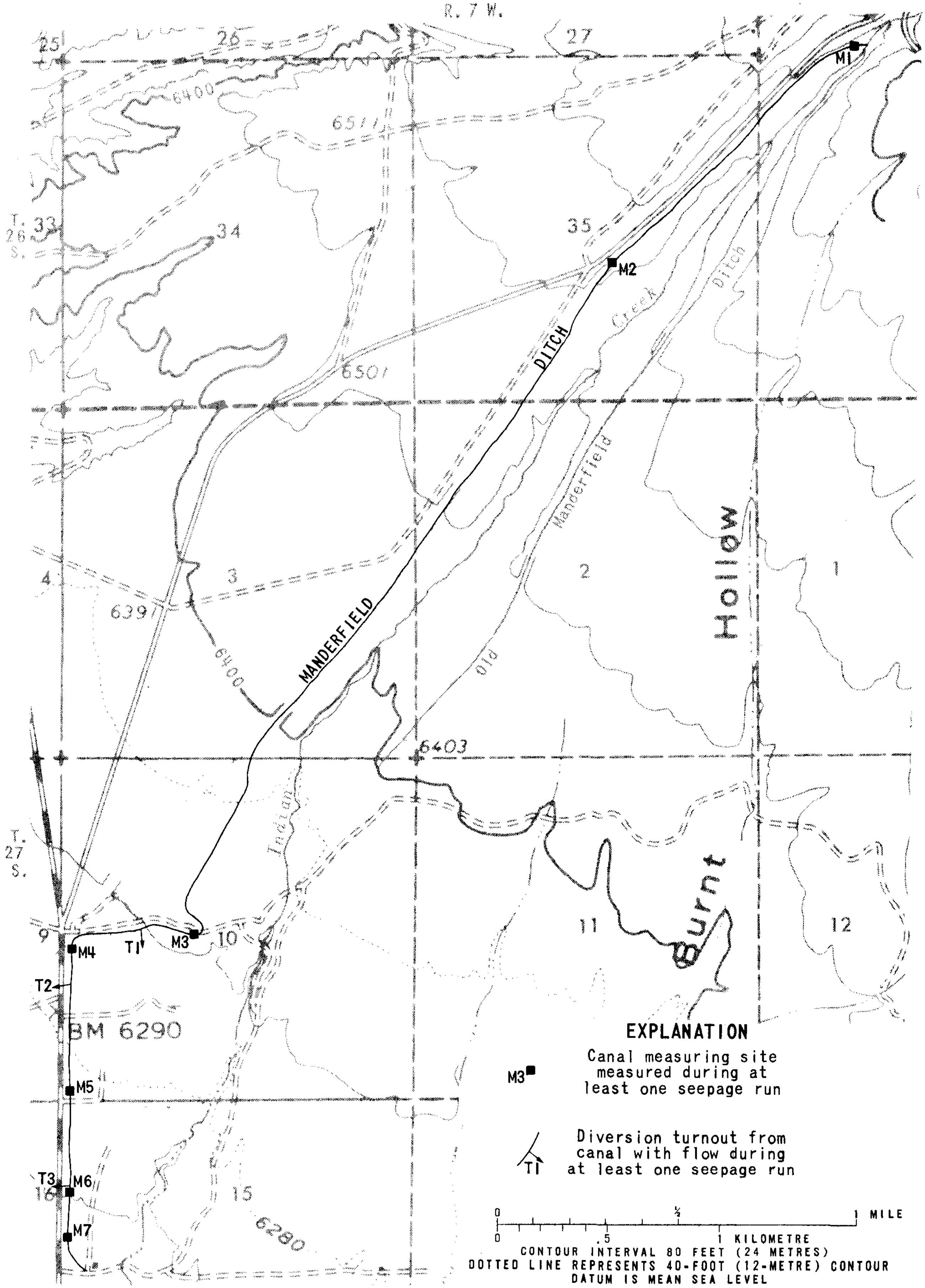
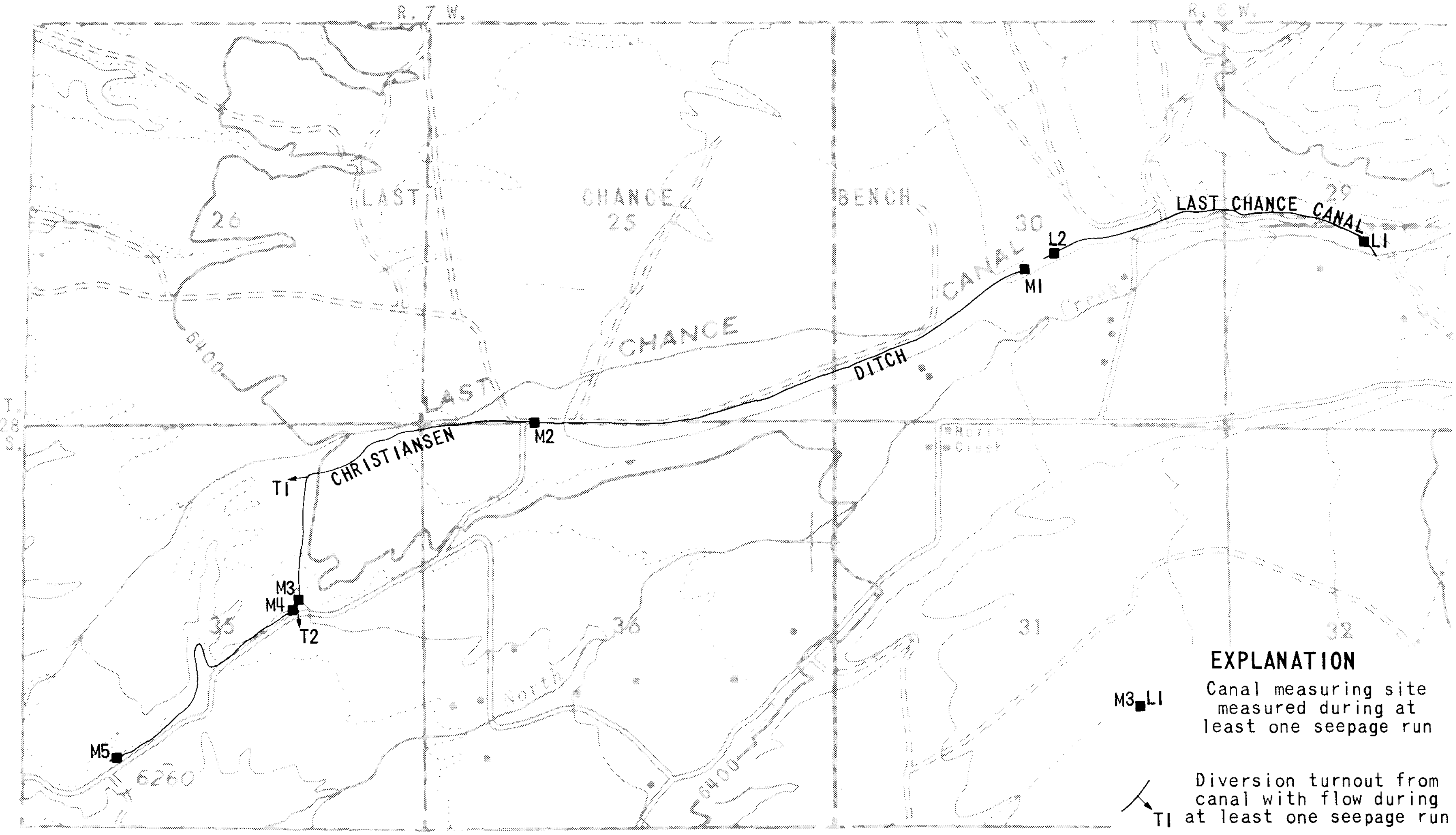


Base from U.S. Geological Survey topographic quadrangle: Beaver, 1958

Figure 2.—Map of Manderfield Ditch showing measuring sites.

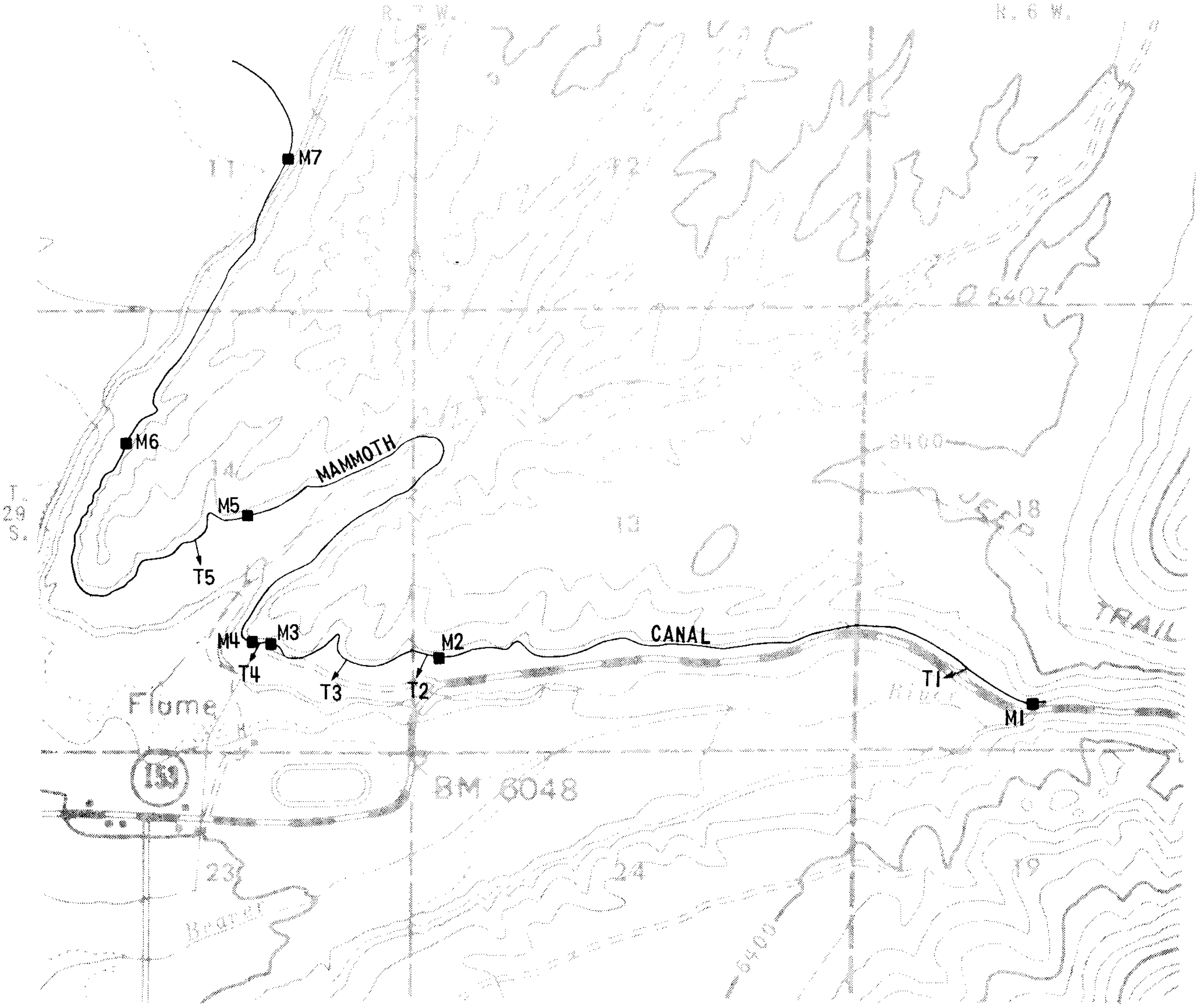


Base from U.S. Geological Survey topographic quadrangle: Beaver, 1958

0 ½ 1 MILE
0 .5 1 KILOMETRE

CONTOUR INTERVAL 80 FEET (24 METRES)
DOTTED LINE REPRESENTS 40-FOOT (12-METRE) CONTOUR
DATUM IS MEAN SEA LEVEL

Figure 3.— Map of Last Chance Canal and Christiansen Ditch showing measuring sites.



Base from U.S. Geological Survey topographic quadrangle: Beaver, 1958

0 ½ 1 MILE
0 .5 1 KILOMETRE

CONTOUR INTERVAL 80 FEET (24 METRES)
DOTTED LINE REPRESENTS 40-FOOT (12-METRE) CONTOUR
DATUM IS MEAN SEA LEVEL

EXPLANATION

M3 ■ Canal measuring site measured during at least one seepage run

T1 Diversion turnout from canal with flow during at least one seepage run

Figure 4.—Map of Mammoth Canal showing measuring sites.

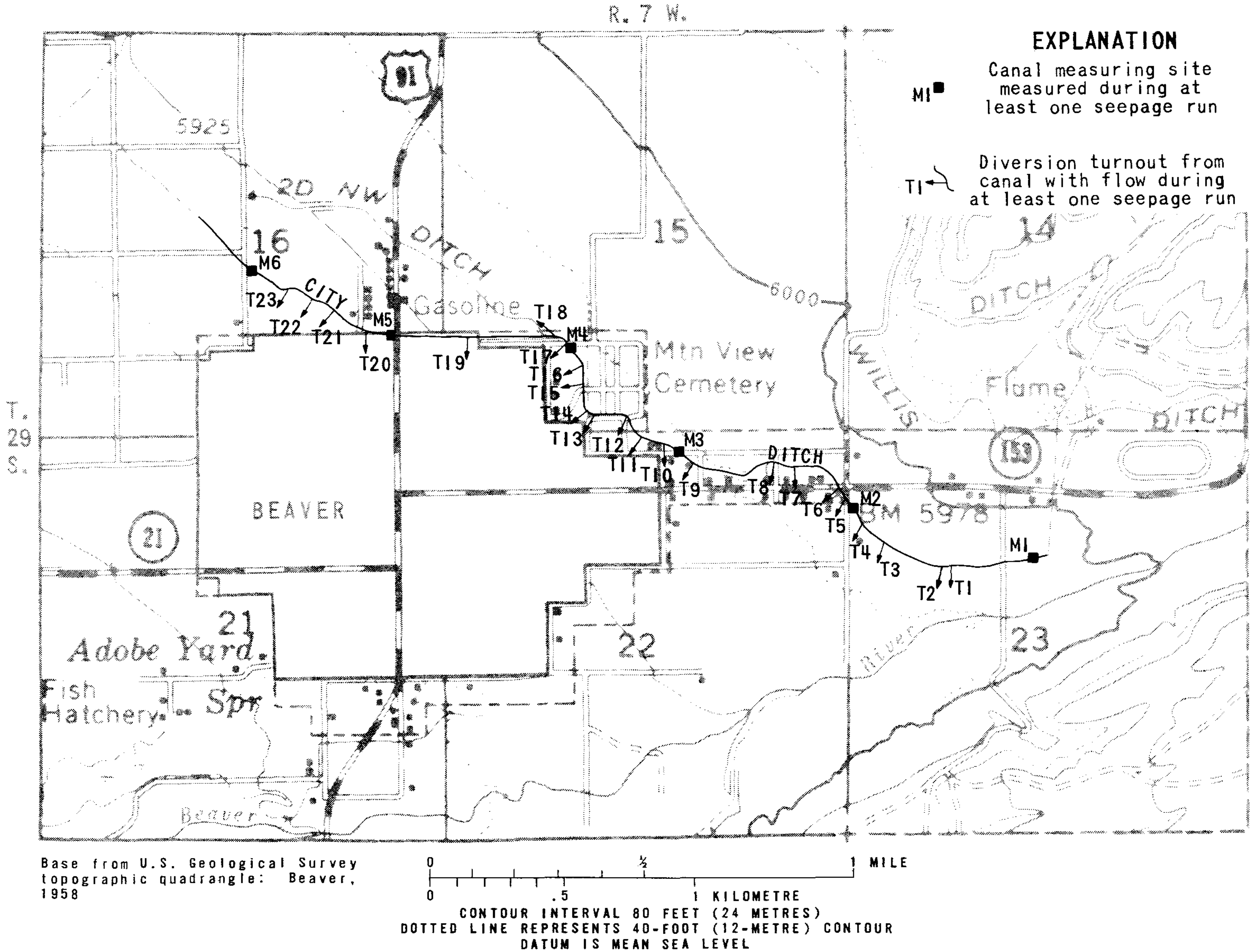


Figure 5.—Map of City Ditch showing measuring sites.

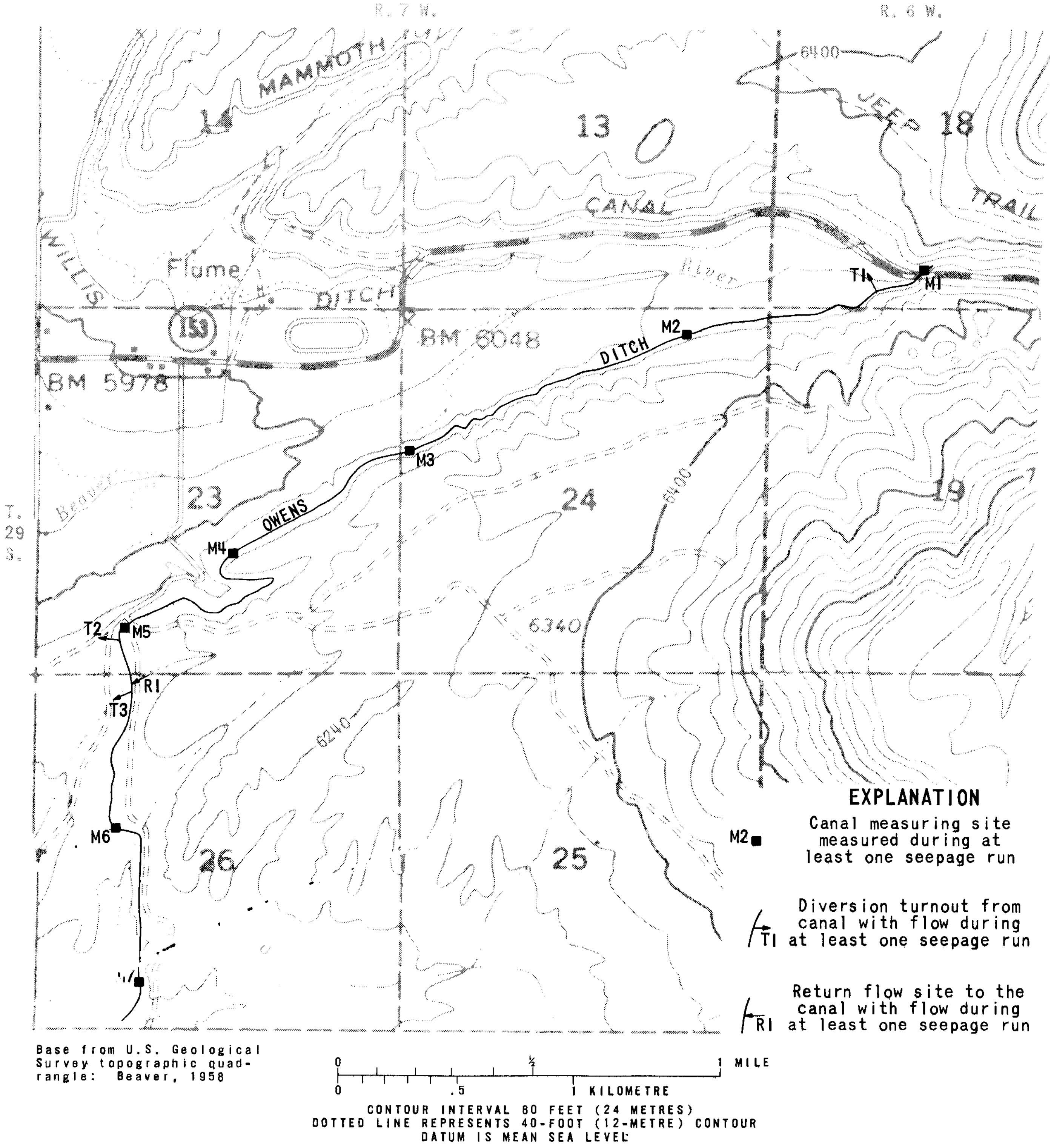


Figure 6.—Map of Owens Ditch showing measuring sites.

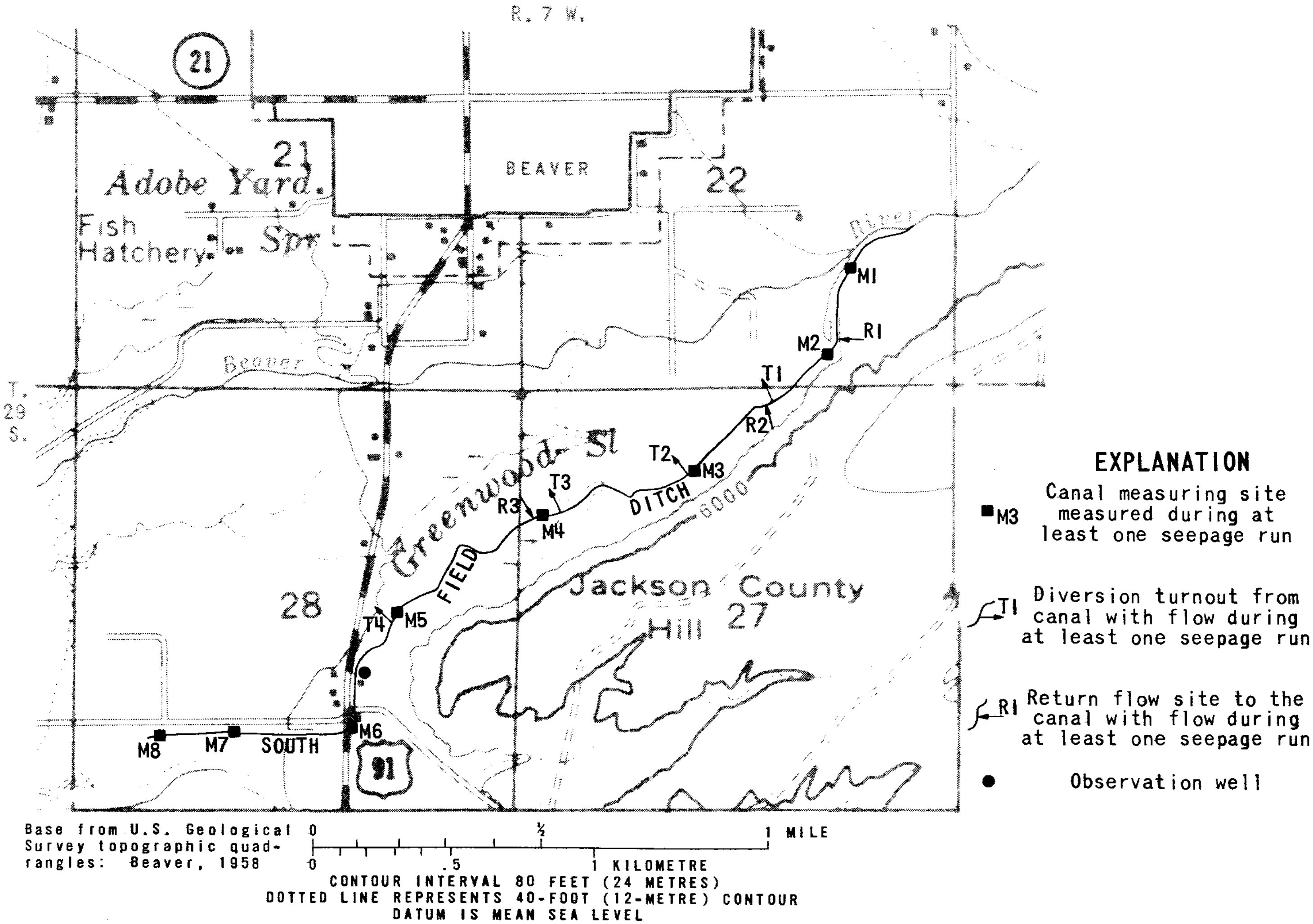
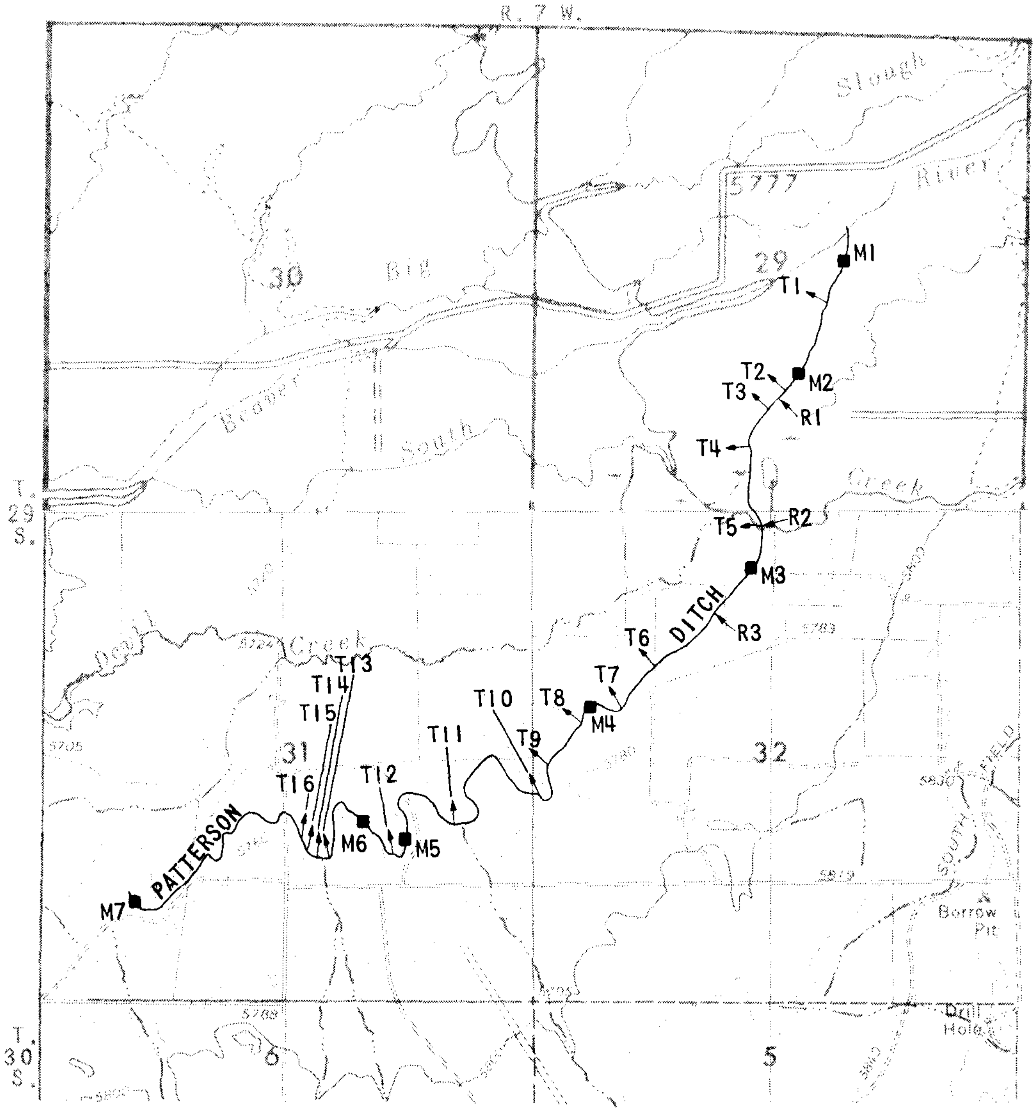


Figure 7.— Map of South Field Ditch showing measuring sites and observation well.



Base from U.S. Geological Survey topographic quadrangle: Beaver, 1958

0 ½ 1 MILE

0 .5 1 KILOMETRE

CONTOUR INTERVAL 80 FEET (24 METRES)
DOTTED LINE REPRESENTS 40-FOOT (12-METRE) CONTOUR
DATUM IS MEAN SEA LEVEL

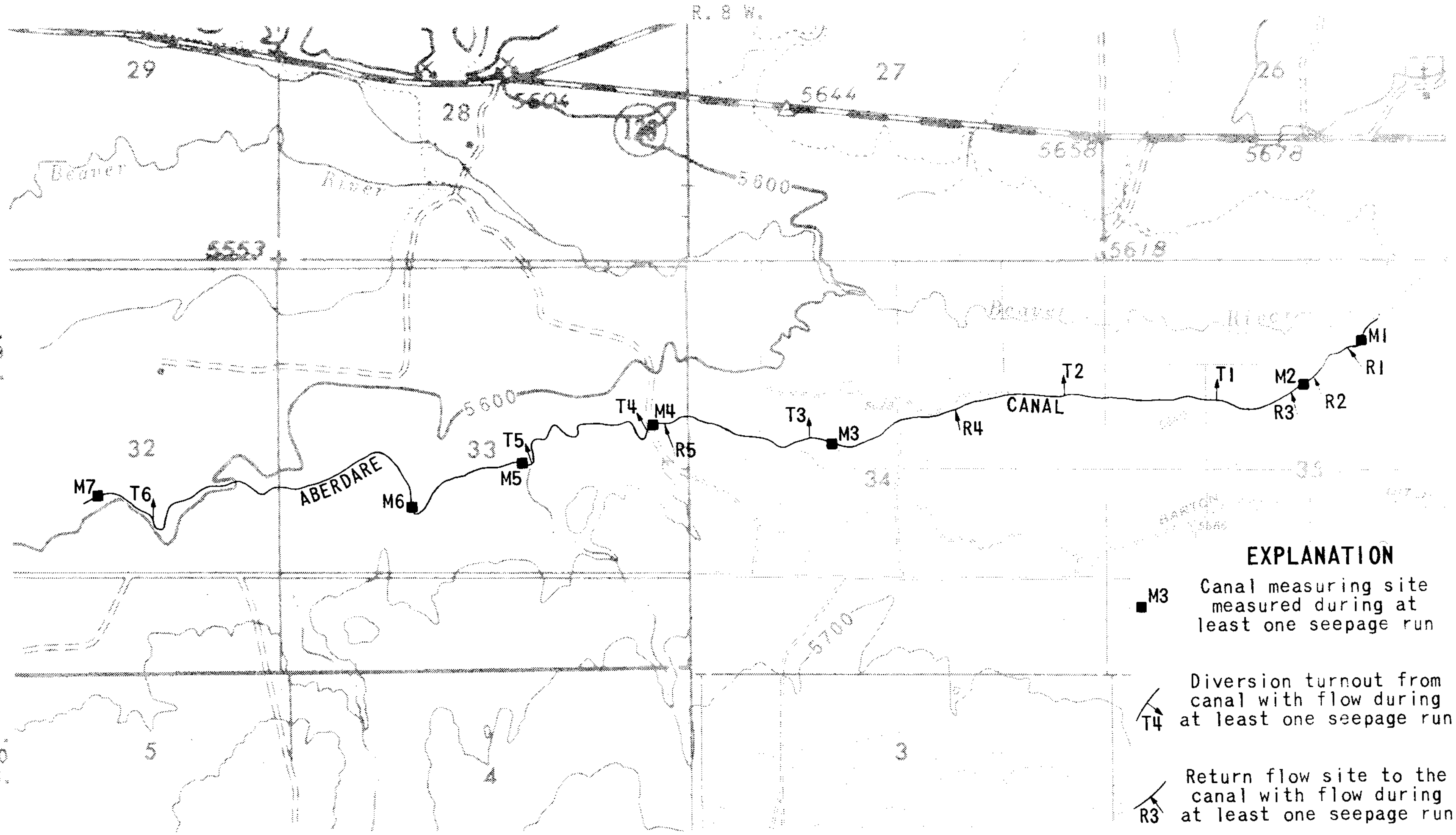
EXPLANATION

M3■ Canal measuring site measured during at least one seepage run

T1 Diversion turnout from canal with flow during at least one seepage run

R1 Return flow site to the canal with flow during at least one seepage run

Figure 8.— Map of Patterson Ditch showing measuring sites.



Base from U.S. Geological Survey topographic quadrangles: Adamsville, 1958; Minersville, 1958; Greenville, 1971; and Beaver, 1958

0 ½ 1 MILE
0 .5 1 KILOMETRE
CONTOUR INTERVAL 80 FEET (24 METRES)
DOTTED LINE REPRESENTS 40-FOOT (12-METRE) CONTOUR
DATUM IS MEAN SEA LEVEL

Figure 9.—Map of Aberdare Canal showing measuring sites.

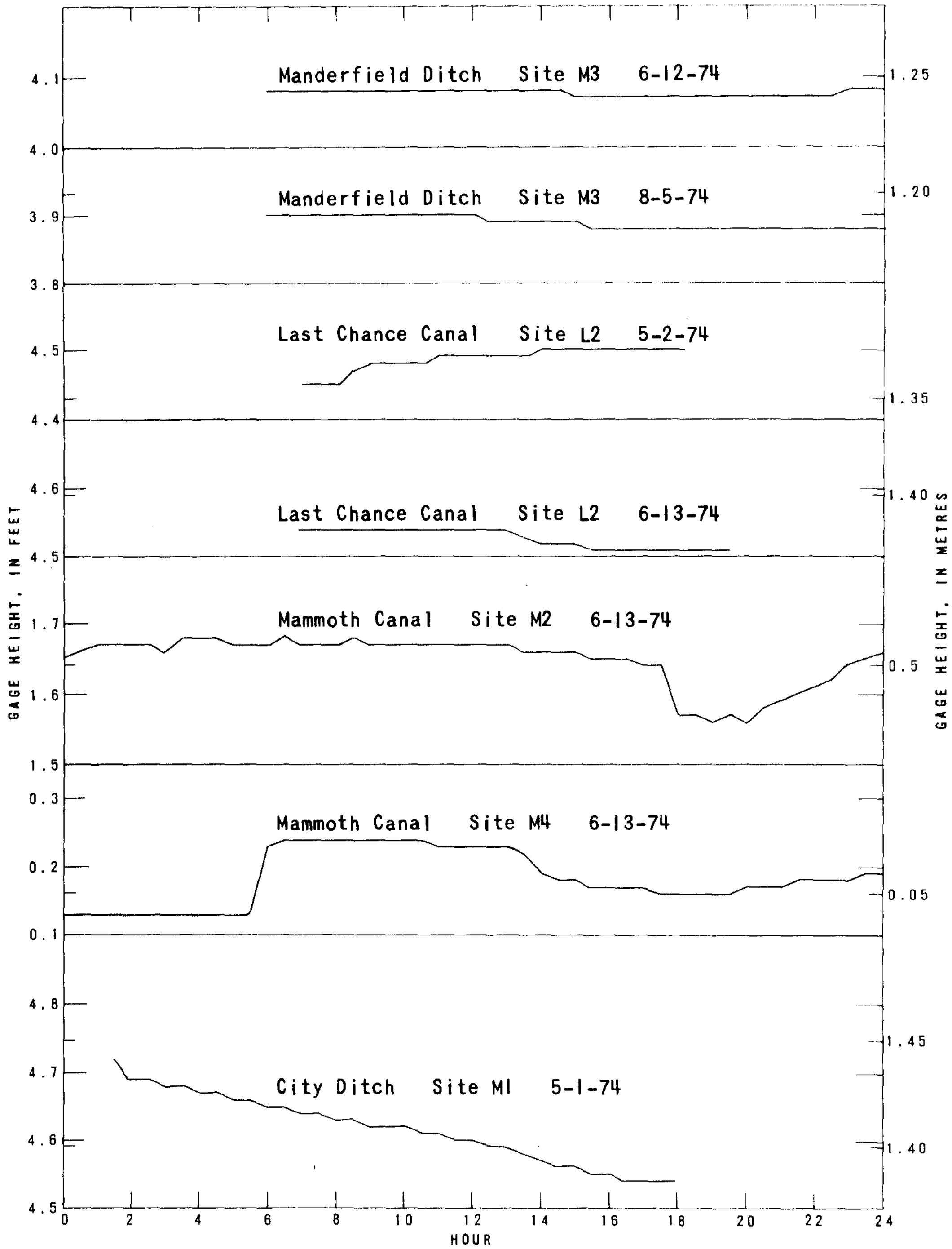


Figure 10.—Gage height at recorders that had change in gage height during seepage run.

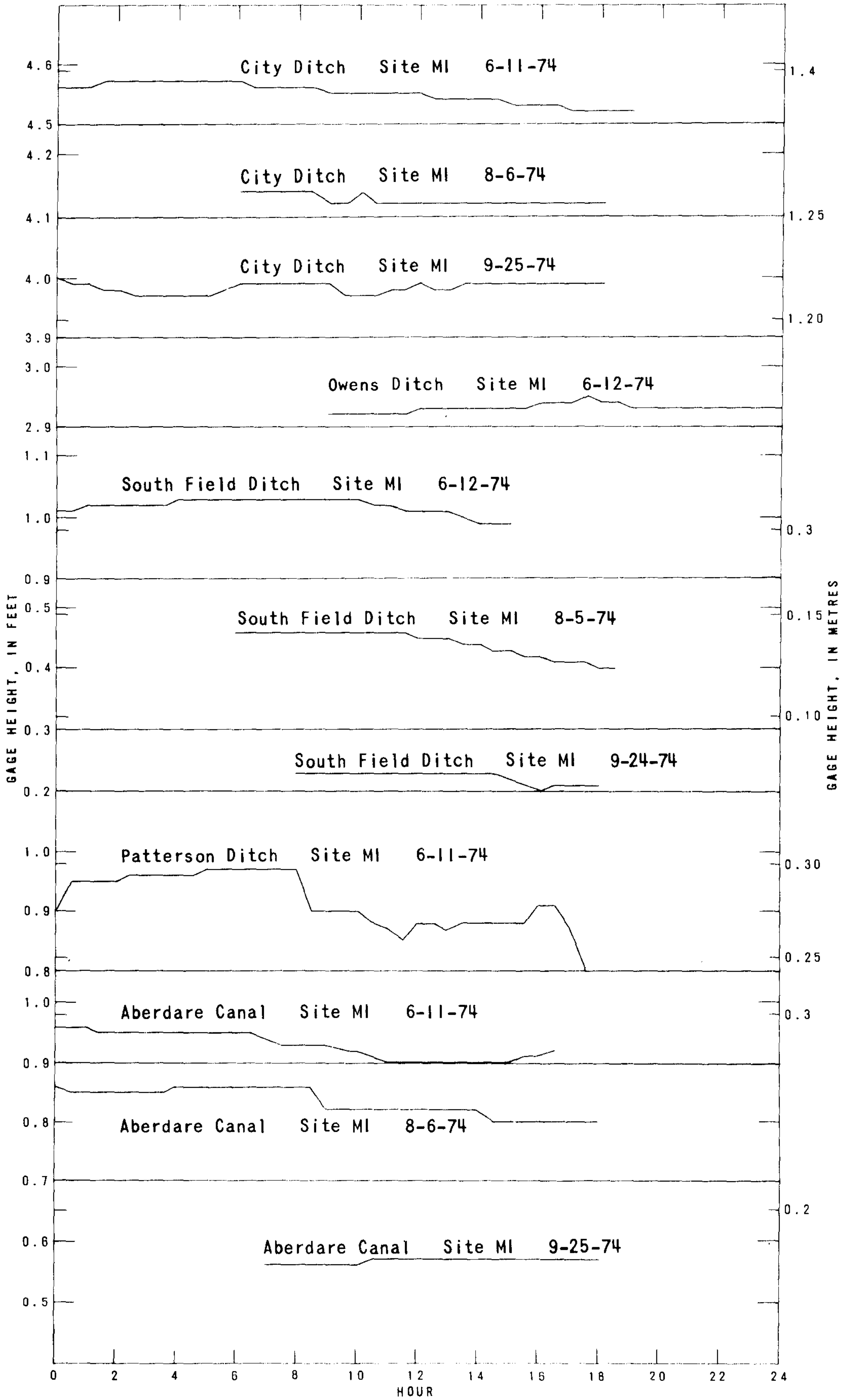


Figure 10.— Continued.

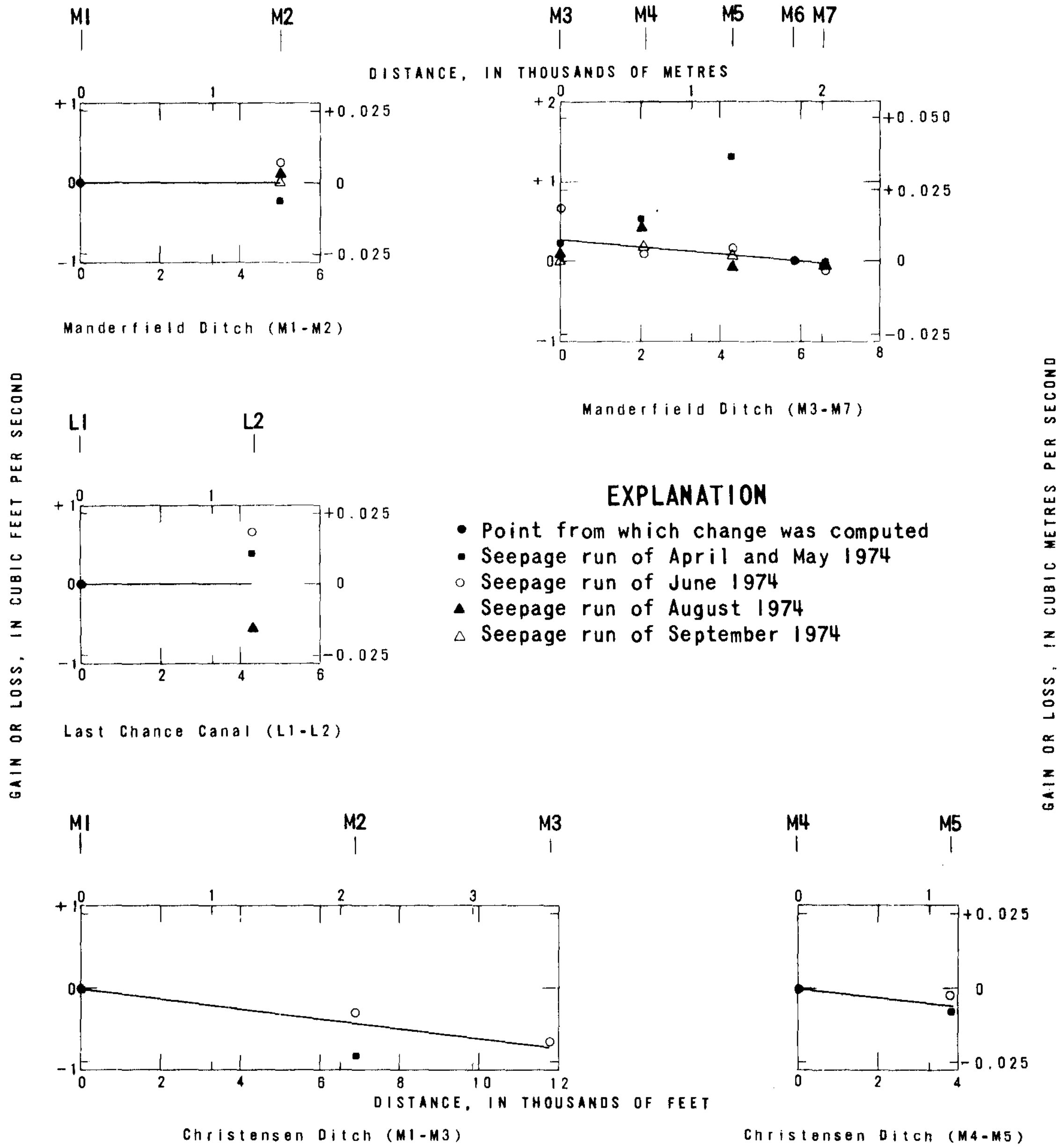


Figure 11.—Gain or loss for reaches of the canals.

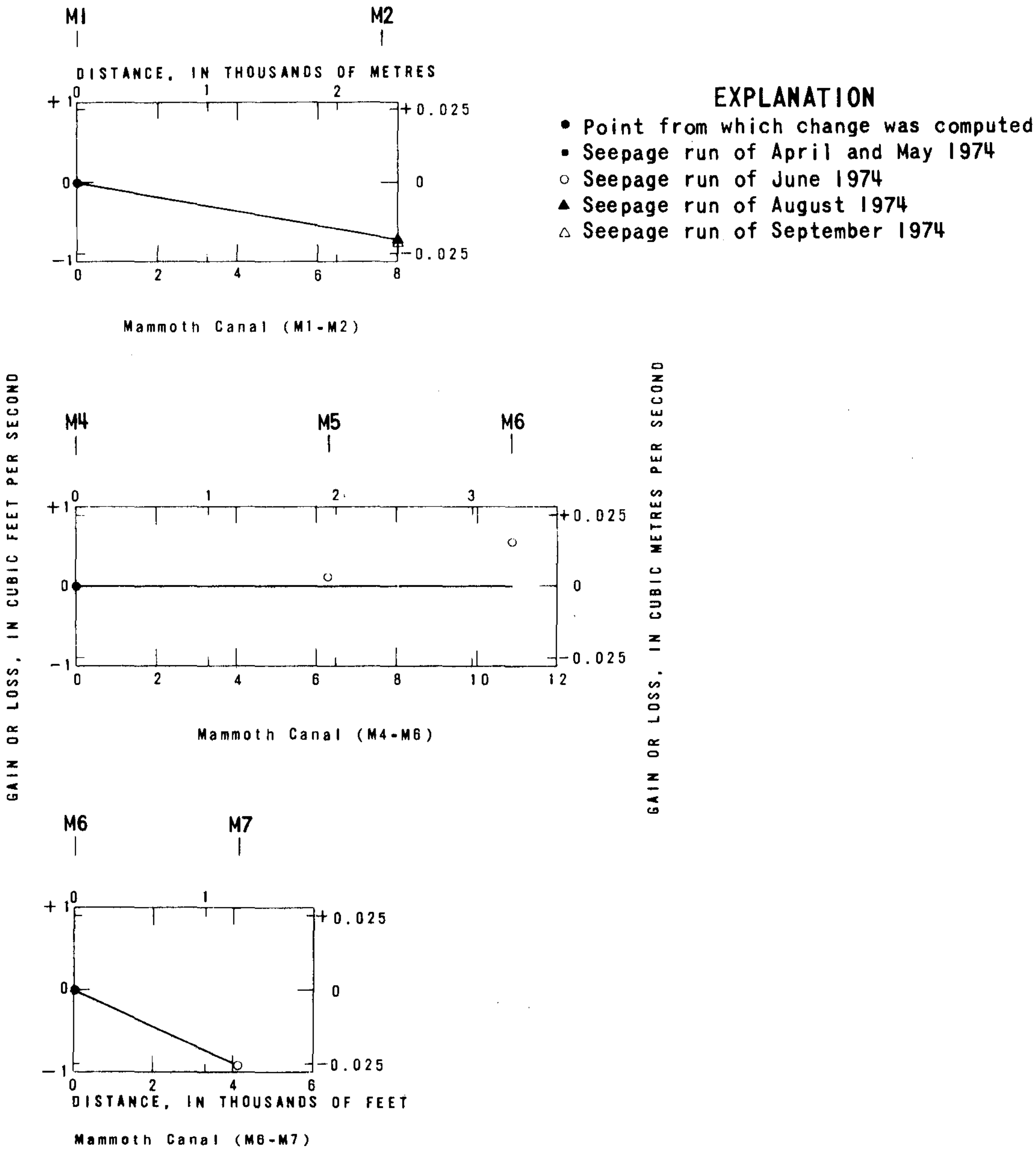
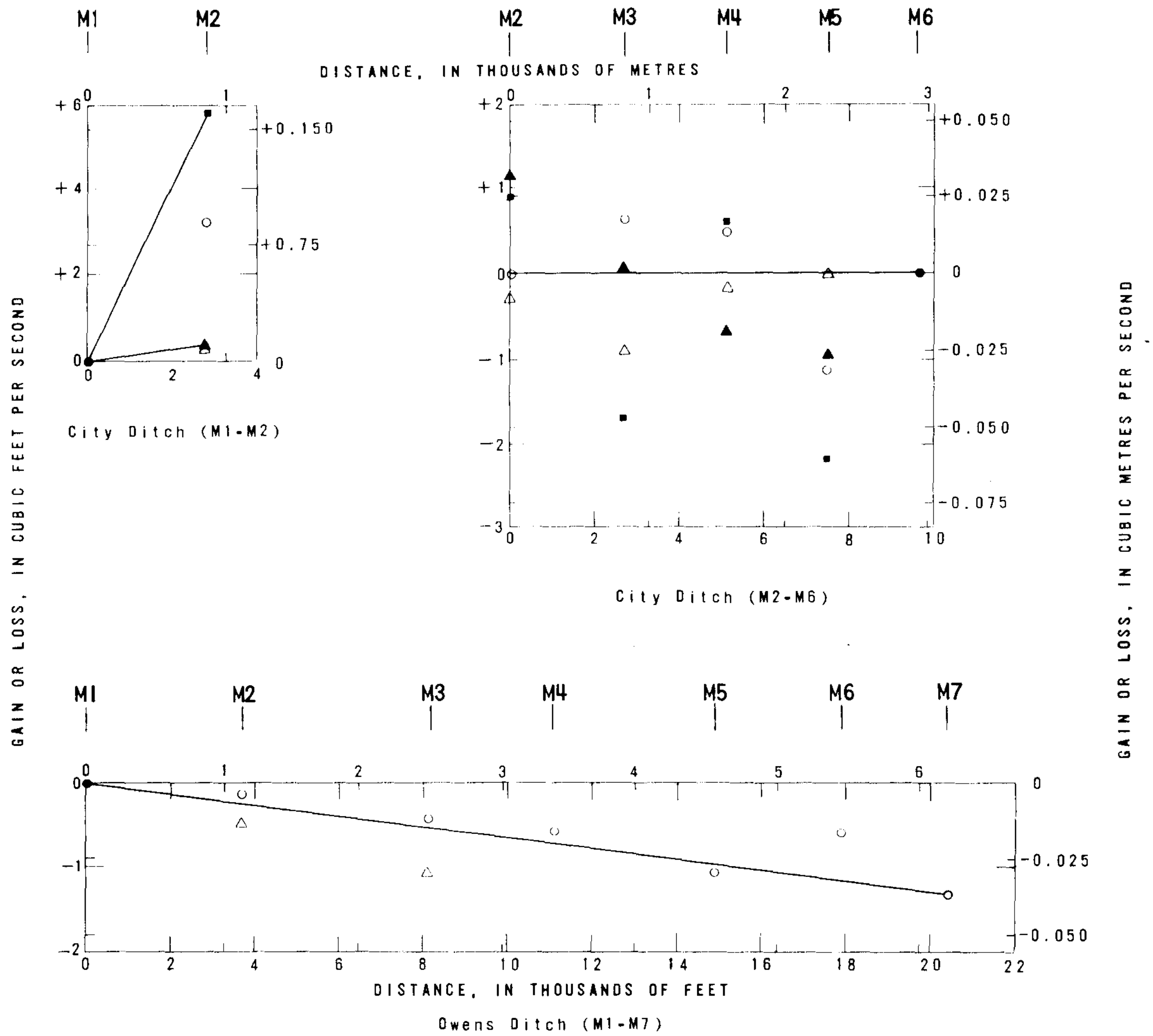


Figure 11.— Continued.



EXPLANATION

- ● Point from which change was computed
- ▪ Seepage run of April and May 1974
- ○ Seepage run of June 1974
- ▲ Seepage run of August 1974
- △ Seepage run of September 1974

Figure 11.—Continued.

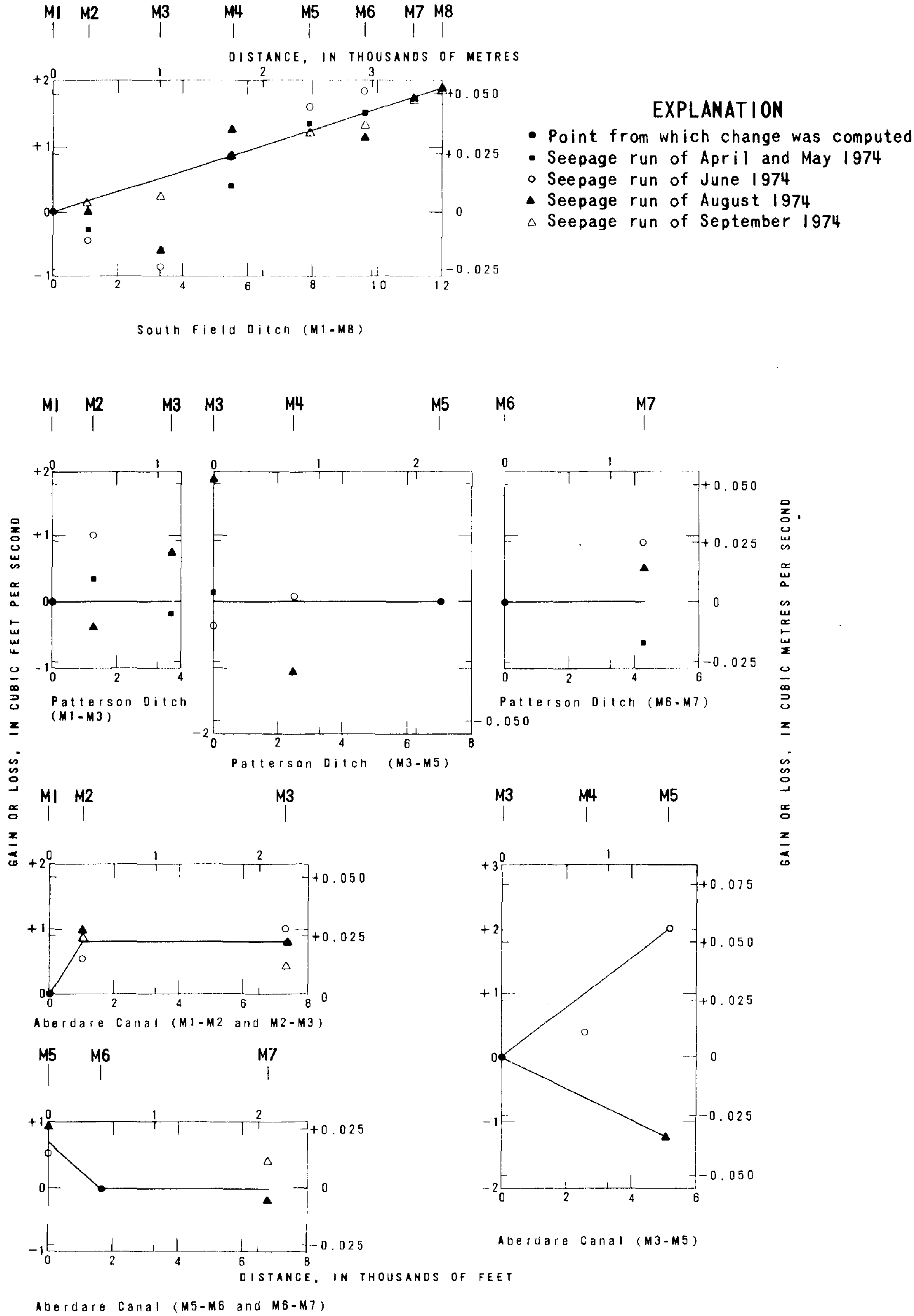


Figure 11.—Continued.

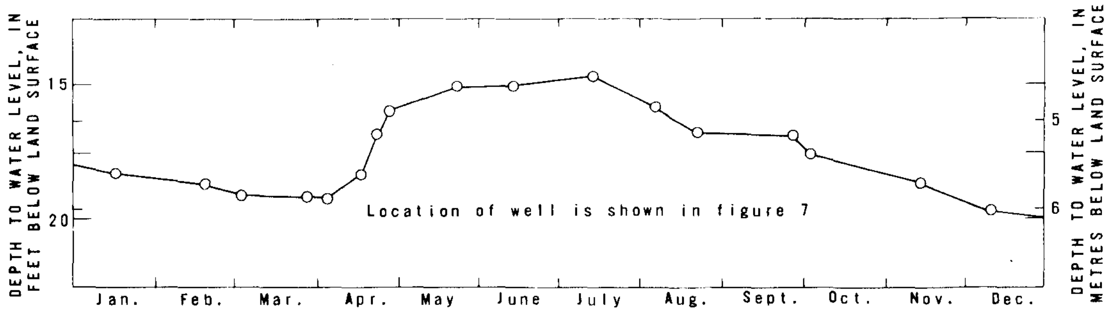


Figure 12.—Seasonal water-level fluctuations in an observation well in Beaver Valley, 1974.

Table 1.--Gain or loss determined from seepage measurements for reaches of canals

Canal	Reach	Lithology	Length (ft)	Number of seepage measurements	Average amount entering reach (ft³/s)	Graphic average (from fig. 11) Gain(+) or loss(-)	
						ft³/s	(ft³/s)/mi
Manderfield Ditch	M1-M2	Older alluvium	5,000	4	6.8	0	0
	M3-M7	Younger alluvium	6,600	4	5.4	-.3	-.2
Last Chance Canal	L1-L2	Younger alluvium in upper third of reach; older alluvium in lower two-thirds	4,300	3	12.7	0	0
Christiansen Ditch	M1-M3	Older alluvium	11,800	2	8.5	-.7	-.3
	M4-M5	Younger alluvium	3,800	2	1.9	-.2	-.3
Mammoth Canal	M1-M2	Older alluvium	7,600	2	41.6	-.7	-.5
	M4-M6	do	10,900	1	13.1	0	0
	M6-M7	do	4,100	1	13.3	-.9	-1.2
City Ditch	M1-M2	Younger alluvium	2,800	4	26.7	(1/)	(2/)
	M2-M6	do	9,600	4	27.1	0	0
Owens Ditch	M1-M7	Older alluvium	20,400	2	6.9	-1.3	-.3
South Field Ditch	M1-M8	Younger alluvium	12,800	4	3.6	+1.9	+.8
Patterson Ditch	M1-M3	do	3,700	3	11.8	0	0
	M3-M5	do	7,000	3	7.1	0	0
	M6-M7	do	4,300	3	4.8	0	0
Aberdare Canal	M1-M2	do	1,000	3	7.3	+.8	+4.2
	M2-M3	do	6,300	3	10.7	0	0
	M3-M5	do	5,100	2	10.7	(3/)	(4/)
	M5-M6	do	1,600	2	10.2	-.7	-2.3
	M6-M7	do	5,200	2	8.0	0	0
Total			133,900		238.2		

1/ Average not determined; minimum and maximum values of +0.4 to +5.8.
2/ Average not determined; minimum and maximum values of +0.8 to +10.9.
3/ Average not determined; minimum and maximum values of -1.2 to +2.0.
4/ Average not determined; minimum and maximum values of -1.2 to +2.1.

Table 2.--Measurements made on the canals

Site: L and M, main canal; R, inflow; T, diversion.
Discharge: e, estimated.

Site	Date	Time	Discharge (ft^3/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
			Manderfield Ditch		
	1974				
M1	Apr. 30	0850	12.92	-	-
M2		0930	12.65	-	-
M3	May 2	0845	8.05	125	5.0
T1		0905	.02e	-	-
M4		0935	8.37	120	6.5
T2		0945	.01e	-	-
M5		1015	9.11	120	7.0
T3		1050	7.76	-	8.5
M6		1110	.04	122	9.5
M7		1125	.06	120	14.0
M1	June 10	1420	8.73	-	-
M2		1510	8.99	-	-
M3	June 12	1020	8.67	93	-
T1		1050	6.01	-	-
M4		1120	1.90	98	-
M5		1200	1.85	93	-
M6		1250	2.00	93	-
M7		1310	1.88	93	-
M1	Aug. 5	1430	3.34	101	16.5
M2		1500	3.45	98	19.5
M3		0945	3.40	105	14.0
T1		1010	.03	-	-
M4		1025	3.61	101	15.5
T2		1040	.01	-	-
M5		1055	3.11	100	17.0
T3		1135	3.01	-	-
M6		1150	.18	100	18.0
M7		1215	.16	100	20.5
M1	Sept. 24	1100	1.74	118	8.5
M2		1135	1.91	112	12.0
M3		1220	1.60	118	15.0
M4		1250	1.68	116	16.5

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft^3/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
			Manderfield Ditch--Continued		
	1974				
M5	Sept. 24	1320	1.52	114	18.0
T3		1350	1.39	-	-
M6		1405	.10	118	19.0
M7		1425	.09	108	20.0
			Last Chance Canal		
L1	Apr. 30	1440	12.50	115	9.0
L2		1535	12.86	113	9.5
L1	June 13	0840	20.46	84	7.5
L2		0920	21.12	88	8.0
L1	Aug. 7	0830	5.18	145	11.5
L2		0910	4.63	145	13.0
			Christiansen Ditch		
M1	May 2	1030	9.83	120	6.0
M2		1155	9.09	120	9.0
T1		1220	.04e	-	-
M4		1250	3.36	130	11.5
M5		1315	3.07	135	13.5
M1	June 13	0820	7.18	-	-
M2		1050	6.88	81	-
T1		1115	.3e	-	-
M3		1145	6.23	88	14.0
M4		1210	.51	-	-
M5		1250	.42	88	24.0
			Mammoth Canal		
M2	June 13	1305	62.90	93	-
T2		1500	.20	-	-
T3		1450	.89	-	-

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft^3/s)	Specific conductance (micromhos per cm at 25°C)	Water temper-ature (°C)
			Mammoth Canal--Continued		
	1974				
M3	June 13	1335	62.97	87	-
M4		1410	13.06	87	-
M5		0855	14.24	87	-
T5		0905	1.34	-	-
M6		1000	13.33	87	-
M7		1030	12.37	-	-
M1	Aug. 5	1410	24.28	125	-
T1		1430	.2e	-	-
M2		1450	23.38	125	-
M1	Sept. 25	1350	12.66	145	16.5
T1		1405	.1e	-	-
M2		1430	11.86	145	16.5
			City Ditch		
M1	May 1	0850	45.24	85	4.0
T1		0925	1.59	-	-
T3		1000	.05	-	-
T4		1005	1.40	-	-
M2		1020	48.05	85	5.0
T6		1040	2.01	-	-
T8		1100	.30	-	-
T9		1120	.52	-	-
M3		1200	41.52	85	6.5
T11		1135	2.94	-	-
T13		1310	20.52	-	-
T14		1305	1.27	-	-
M4		1350	17.61	85	9.0
T17		1325	.72	-	-
T18		1410	.65	-	-
T19		1435	1.24	-	-
M5		1500	12.16	85	10.5
T20		1525	.72	-	-
T21		1545	.07	-	-
T23		1550	.01	-	-

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft^3/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
City Ditch--Continued					
	1974				
M6	May 1	1610	11.89	90	11.5
M1	June 11	0800	42.01	95	-
T1		0825	.94	-	-
T2		0830	.90	-	-
T3		0900	2.10	-	-
T4		0905	.12	-	-
M2		0925	41.14	95	-
T5		0940	2.40	-	-
T7		0950	.67	-	-
T8		0955	.05	-	-
T9		1020	.41	-	-
M3		1040	38.27	93	-
T10		1100	.35	-	-
T11		1110	.87	-	-
T12		1115	1.70	-	-
T13		1145	18.60	-	-
T14		1155	.71	-	-
M4		1250	15.90	95	-
T17		1305	.76	-	-
T18		1310	.77	-	-
T19		1320	1.57	-	-
M5		1325	11.21	94	-
T22		1410	.01e	-	-
T23		1415	.01e	-	-
M6		1520	11.46	95	-
M1	Aug. 6	0915	12.56	125	12.5
T1		0940	.22	-	-
T3		0950	.54	-	-
T4		0955	.03	-	-
M2		1010	12.20	125	14.0
T5		1025	.93	-	-
T7		1035	.49	-	-
T8		1045	.01e	-	-
T9		1055	.39	-	-
M3		1110	10.29	125	15.0

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft³/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
		City Ditch--Continued			
	1974				
T11	Aug. 6	1135	0.32	-	-
T12		1135	.99	-	-
T13		1150	3.99	-	-
T14		1140	.84	-	-
T15		1220	.01e	-	-
M4		1245	3.34	125	17.5
T17		1300	.39	-	-
T18		1305	.27	-	-
T19		1315	.88	-	-
M5		1330	1.58	125	19.0
M6		1435	1.59	125	22.0
M1	Sept. 25	0840	6.96	165	8.0
T1		0855	.01e	-	-
T3		0910	.19	-	-
M2		0930	7.19	150	9.0
T5		0945	.27	-	-
T8		1000	.16	-	-
T9		1020	.12	-	-
M3		1035	6.01	150	10.0
T11		1100	.94	-	-
T12		1100	.01	-	-
T13		1115	2.62	-	-
T14		1105	.43	-	-
T15		1130	.03	-	-
T16		1135	.02	-	-
T17		1145	.03	-	-
M4		1200	1.97	150	12.0
T18		1245	.25	-	-
T19		1305	.55	-	-
M5		1320	1.40	145	15.0
T22		1345	.05	-	-
T23		1350	.01	-	-
M6		1425	1.33	150	16.5

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft³/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
			Owens Ditch		
	1974				
M1	June 12	0950	6.89	88	-
T1		1010	.1e	-	-
M2		1050	6.64	88	-
M3		1140	6.36	88	-
M4		1220	6.22	88	-
M5		1305	5.72	92	-
T2		1330	2.41	-	-
R1		1350	.35	-	-
T3		1405	.32	-	-
M6		1450	3.82	-	-
M7		1535	3.06	92	-
M1	Sept. 25	0945	1.22	140	9.5
T1		1010	.05	-	9.5
M2		1040	.67	140	12.0
M3		1130	0	-	-
			South Field Ditch		
M1	May 1	0855	3.78	105	5.0
M2		0940	3.49	100	6.0
T1		1050	.66	-	7.5
M3		1130	2.58	100	10.0
M4		1235	3.53	155	12.0
M5		1315	4.47	200	13.5
T4		1315	4.47	-	-
M6		1430	.19	605	20.0
M1	June 12	0910	7.49	122	10.0
M2		0955	7.04	118	-
T1		1035	.73	-	11.5
M3		1140	5.89	114	-
T2		1150	.2e	-	-
T3		1200	1.73	-	-
M4		1230	5.61	140	15.0
R3		1240	1.73	-	-
M5		1400	7.98	168	16.5
T4		1400	7.98	-	-

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft^3/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
			South Field Ditch--Continued		
	1974				
M6	June 12	1425	0.22	540	21.0
M1	Aug. 5	1240	1.99	152	20.0
R1		1300	.2e	-	-
M2		1310	2.20	156	20.5
T1		1340	.07	-	-
R2		1350	.5e	-	-
M3		1410	2.04	158	21.0
M4		1450	3.90	195	18.5
M5		1525	4.37	232	18.5
M6		1600	3.79	252	21.0
M7		1640	4.32	252	21.0
M8		1700	4.53	255	21.0
M1	Sept. 24	1150	1.01	160	13.0
M2		1230	1.15	160	14.5
M3		1315	1.24	165	16.5
M4		1400	1.88	200	16.0
M5		1435	2.28	265	15.5
T4		1500	.2e	-	-
M6		1520	2.12	300	15.0
M7		1555	2.51	300	18.0
			Patterson Ditch		
M1	May 1	0920	11.25	190	7.0
T1		0925	.39	-	-
M2		1020	11.18	200	10.0
T2		1050	4.37	-	-
T3		1150	.33	-	-
T4		1210	.63	-	-
R2		1220	.1e	-	-
T5		1220	.12	-	-
M3		1230	5.32	-	-
T7		1240	.01e	-	-
T8		1250	.01e	-	-
T9		1310	.01e	-	-
T10		1320	.01e	-	-

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft^3/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
			Patterson Ditch--Continued		
	1974				
T11	May 1	1345	0.28	-	-
M5		1415	4.86	-	-
M6		1445	2.57	-	-
T13		1505	.01e	-	-
M7		1550	1.95	-	-
M1	June 11	0845	13.58	385	-
M2		0945	14.58	400	-
T2		1005	8.01	-	-
R1		1015	1.0e	-	-
T3		1025	1.60	-	-
T4		1045	1.57	-	-
R2		1055	.2e	-	-
T5		1100	.2e	-	-
M3		1120	7.29	398	-
R3		1135	.1e	-	-
T6		1140	.02	-	-
M4		1200	7.81	398	-
T8		1220	.1e	-	-
M5		1300	7.63	-	-
M6		1330	6.76	398	-
T14		1345	.2e	-	-
T15		1345	.2e	-	-
T16		1350	.2e	-	-
M7		1410	7.05	-	-
M1	Aug. 6	0935	10.64	355	14.5
M2		1010	10.27	360	15.5
T2		1035	3.69	-	-
R1		1050	2.0e	-	-
T3		1100	.75	-	-
T5		1140	.2e	-	-
M3		1210	8.75	395	18.0
M4		1300	5.84	395	18.0
M5		1410	6.89	420	20.5
M6		1440	5.00	415	20.0
M7		1510	5.52	-	-

Table 2.--Measurements made on the canals--Continued

Site	Date	Time	Discharge (ft³/s)	Specific conductance (micromhos per cm at 25°C)	Water temperature (°C)
			Aberdare Canal		
	1974				
M1	June 11	0830	10.84	550	11.0
R1		0850	.7e	-	-
R2		0900	.92	-	-
M2		0950	12.86	560	13.0
R3		1010	.5e	-	-
M3		1150	13.80	565	16.5
M4		1225	14.34	560	18.0
T4		1240	.5e	-	-
T5		1345	5.45	-	-
M5		1425	9.91	565	22.0
M6		1500	9.38	565	24.0
M1	Aug. 6	0855	7.76	520	14.0
R1		0930	.79	375	18.0
R2		1000	4.19	480	18.0
M2		1040	13.30	495	17.0
T1		1110	.42	-	18.0
T2		1140	.2e	-	-
M3		1230	12.43	490	18.0
T3		1250	.66	-	18.0
R5		1310	.2e	-	-
T4		1320	.2e	-	-
T5		1345	.10	-	-
M5		1405	10.46	488	18.5
M6		1440	9.51	485	19.0
T6		1515	5.24	-	19.5
M7		1600	4.08	480	20.0
M1	Sept. 25	0900	3.72	550	9.5
R1		0910	.25e	-	-
R2		0925	1.22	620	10.0
M2		1005	6.04	570	10.0
R4		1045	.25e	-	-
M3		1105	5.85	570	11.0
M6		1240	5.04	560	12.5
M7		1350	5.44	570	16.5

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TECHNICAL PUBLICATIONS

*No. 1. Underground leakage from artesian wells in the Flowell area, near Fillmore, Utah, by Penn Livingston and G. B. Maxey, U.S. Geological Survey, 1944.

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