CONTOUR TRENCHING EFFECTS ON STREAMFLOW FROM A UTAH WATERSHED

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INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
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COVER PHOTO

Oblique aerial photograph of the Halfway Creek drainage.

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ACKNOWLEDGMENT

We of the Intermountain Forest and Range Experiment Station acknowledge with appreciation the valuable assistance of personnel of the Wasatch National Forest and the Intermountain Region headquarters in facilitating the design and supervision of the contour trench construction. This assistance substantially expedited the conduct of this study.

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ABSTRACT

Distribution and volume of streamflow from Halfway and Miller Creeks, two drainages on the Davis County Experimental Watershed, were evaluated. In 1964, about 15 percent of the Halfway Creek drainage was contour trenched. Twelve years of streamflow records before trenching and 4 years of records after trenching were analyzed.

Peak spring flow and peak summer storm flow were reduced after trenching. However, neither annual water yields nor snowmelt runoff in spring and early summer were significantly altered in either volume or distribution over time as a result of trenching. This conclusion is substantiated by supplemental data of precipitation, soil moisture, snowpack water equivalent, and vegetation.

INTRODUCTION

Earlier in this century, the deteriorated condition of numerous high, mountain watersheds in the Western United States resulted in devastating mud-rock flows that flooded valuable lowlands, claimed several lives, and caused considerable property damage (Berwick 1962). These floods followed high-intensity summer rainstorms on the badly denuded areas. Overgrazing and burning of the protective vegetation were considered to be the primary causes of this deterioration (Cannon 1931).

To restore the watersheds, a rehabilitation program was undertaken in the early 1930's (Copeland 1960). Contour trenching, one of numerous practices applied, was so successful that it has become widely accepted (Bailey et al. 1947). By 1969, approximately 30,000 acres had been contour trenched in the States of Utah, Idaho, Nevada, Montana, and Wyoming. Through the years, contour trenches have evolved from small, handmade furrows, 1 or 2 feet deep, to large, bulldozed trenches, 3 or 4 feet deep.

It has been contended that annual streamflow is reduced by trenching. This contention is supported by studies of contour terracing and water-spreading techniques on agricultural land (Branson et al. 1966; Mickelson 1968; Zingg and Hauser 1959).

However, little research has been conducted to determine what effects trenching has on streamflow from high, mountain watersheds. Bailey and Copeland (1960) compared streamflow records from a trenched and an untrenched watershed in Utah. The trenches, which were dug in 1935, were spaced about 25 feet apart. Each had a capacity of 1.5 area inches of water. A gradual decrease of 2.7 inches (23 percent) in average annual streamflow from the trenched watershed developed over a 22-year period. Most of this decrease occurred during the high-flow months, March, April, and May. This decrease in annual flow apparently was due to revegetation, resulting from the stabilizing effect of trenches and the prohibition of grazing by domestic livestock.

Contour trenches in the Western United States are designed to regulate the peak streamflow from the high-intensity summer rainstorm by intercepting overland flow and allowing it to infiltrate into the soil mantle. Total streamflow from these storms represents less than 1 percent of the total annual yields. Therefore, the effect of contour trenching on annual yields would be minimal even if all runoff from these storms were trapped on the mountainside and lost to evapotranspiration. However, contour trenches may have influences that extend beyond control of summer torrents. The effects of trenching on snow catch and areal distribution, on snowmelt and runoff, on soil moisture and vegetation, and on runoff from long-lasting, low-intensity rains are integrated and reflected in annual water yields, in spring snowmelt runoff, and in base streamflow.

Comparisons of the effects of contour furrowing, pitting, and ripping on rangelands from Montana to New Mexico were made by Branson et al. (1966). These treatments added to soil moisture and forage production by increasing infiltration and delaying runoff. These rangelands have a low annual precipitation, most of which occurs during summer rainstorms.

The effect that trenches might have on snowpack accumulation was suggested by Martinelli (1965), who showed that natural barriers contribute significantly to snow accumulation in the alpine zone. I followed this up with two winters' measurements of snow accumulation, distribution, and water content in the contour-trenched area of Halfway Creek (Doty 1970). The effect of trenches on wind movement of snow was to increase snow accumulation slightly, which probably affected revegetation more than water yields.

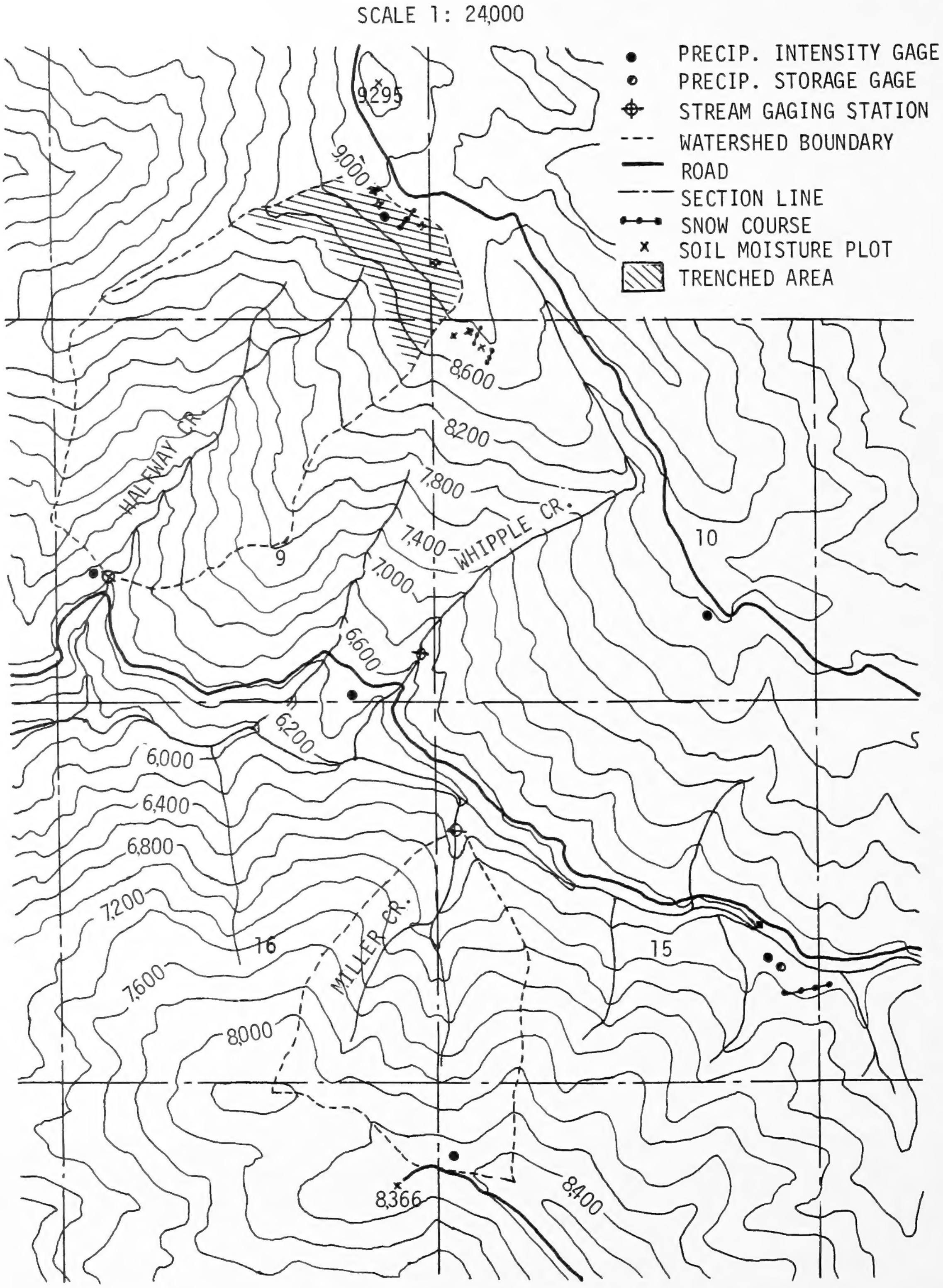

Figure 1.--Topographic map of a portion of the Farmington Canyon watershed showing locations of instruments on the Halfway Creek and Miller Creek drainages.

From this review it becomes apparent that several causal relationships may exist between contour trenching and water yield. A more thorough understanding of trenching effects is necessary to adequately determine what changes, if any, in water yield or water quality occur when a watershed is trenched. The results reported here are the outcome of research conducted on two Utah watersheds, Halfway Creek and Miller Creek. Contour trenching is evaluated in terms of:

(1) Total annual streamflow;

(2) Characteristics of spring streamflow (total and peak volumes and recession); and

(3) Low streamflow (July through February) with respect to total volume of streamflow from these watersheds.

DESCRIPTION OF AREA

The contour trenches used in this study are in Halfway Creek drainage, a tributary of the 10-square-mile Farmington Canyon watershed northeast of Farmington, Utah (fig. 1). Within Farmington Canyon are a couple of snow courses, a network of precipitation gages, and small watersheds which have streamflow records of varying lengths. Of these, Miller Creek drainage was selected as the control. The Halfway Creek drainage produced floods from summer storms in 1926, 1936, and 1947 because of the badly denuded condition of portions of its headwaters area. This drainage and those adjacent to it have been closed to livestock grazing since the late 1930's.

Topography, Geology, and Soils

On this west face of the Wasatch range, the transition is abrupt from the Great Basin valley floor (elevation 4,200 feet) to the peaks of the Wasatch Mountains. Within the 464-acre Halfway Creek drainage, elevation ranges from 6,200 feet at the mouth to 9,000 feet near Francis Peak (9,547 feet). Elevation within the Miller Creek drainage ranges from 6,500 feet to 8,500 feet. The steep stream gradients (approximately 38 percent) for the two drainages are illustrated in figure 2. Halfway Creek's main channel is slightly over 1 mile long, Miller Creek's is approximately two-thirds of a mile long.

A comparison of the Halfway Creek and Miller Creek drainages is given by the dimensionless area-elevation curve (Aronovici 1966) in figure 3. Had the two drainages been similar in configuration, the two curves would have coincided along their entire length. The departure of the curves reflects the greater percentage of Miller Creek drainage at the higher elevations.

Halfway Creek faces southwest and Miller Creek north, and their contrasting aspects contribute to differences in precipitation patterns and vegetation. However, as extremely different as the two watersheds appear to be, their hydrographs react quite similarly as will be shown later in the analysis.

The Halfway Creek drainage has a fine network of tributaries. Many of these are headed by perennial springs that originate along the broad contact zone just below the trenched area. Numerous intermittent stream channels extending into the trenched area are deeply incised. Major channels in the Halfway Creek drainage are V-shaped (10 to 20 feet deep, 40 to 60 feet in width) and usually eroded down to bedrock. Stream channels in Miller Creek do not reflect this degree of cutting, being less than 10 feet deep and 20 feet wide.

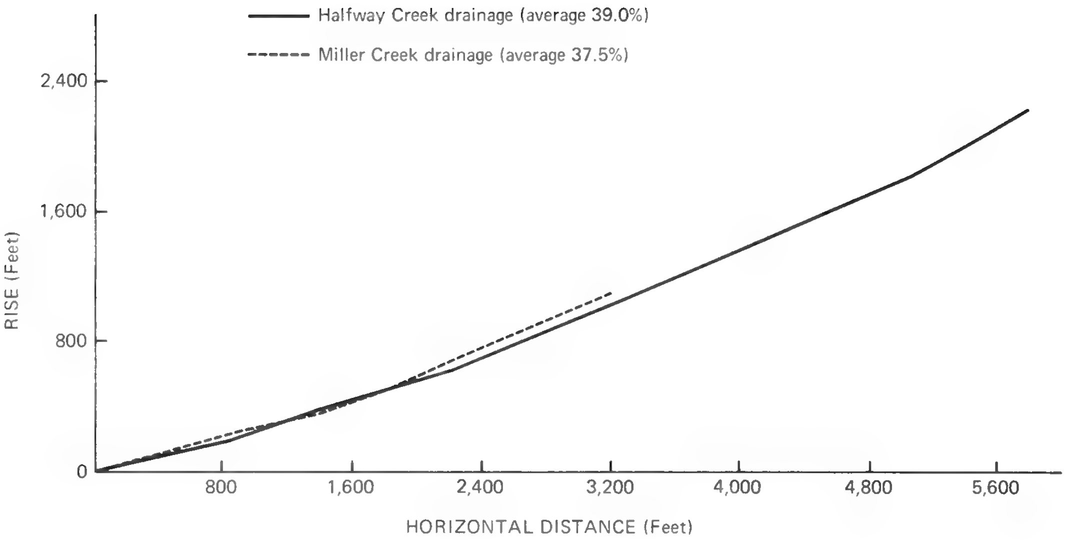

Figure 2.--Stream gradient curves of the Halfway Creek and Miller Creek drainages.

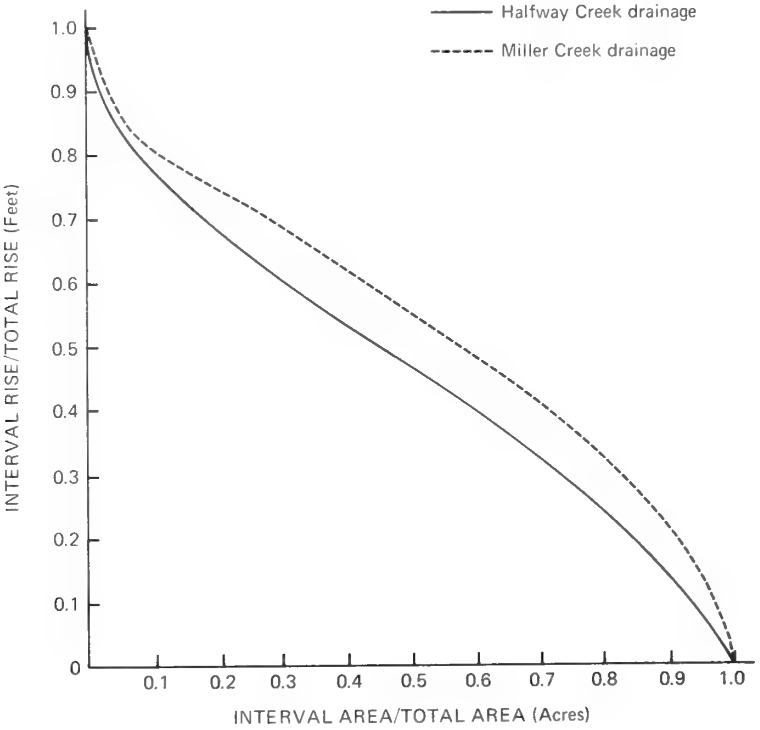

Figure 3.--Dimensionless area--elevation curves for the Halfway Creek and Miller Creek drainages.

Some important geologic features may influence the results of this study. With the use of a detailed geologic map (Bell 1952), a comparison of fault lines with stream locations and strike and dip information with contour lines explains the occurrence of the contact zone in the Halfway Creek drainage. Prevailing winds move considerable snow out of the Halfway Creek drainage. Springs, fed by the large accumulation of snow in the cirque basin immediately to the east and from seepage along the fault zone, return some of this moisture to the Halfway Creek drainage.

Soils are generally coarse textured, immature, rocky, and shallow. Parent material was disintegrated in place by frost action and the resulting surface material in the trenched area is approximately 7 feet thick.

Vegetation

Halfway Creek drainage may be divided into five major vegetation zones (fig. 4). Aspen (*Populus tremuloides)* occupies the wetter sites along stable stream courses just below the contact zone. Adjacent to the aspen, on slightly drier sites, are the ceanothus (*Ceanothus velutinus)* and mixed browse (*Amelanchier utahensis, Prunus virginiana, Symphoricarpos* sp., *Alnus tenuifolia*) zones. The ceanothus and mixed browse zones form dense thickets of brush with little understory. The two are separated because ceanothus completely dominates sites on which it occurs and forms a much shorter type of cover. Along the upper ridges and drier midslopes, two species of sagebrush (*Artemisia tridentata,* and *Artemisia scopulorum*) predominate. A variety of grasses and forbs form the ground cover.

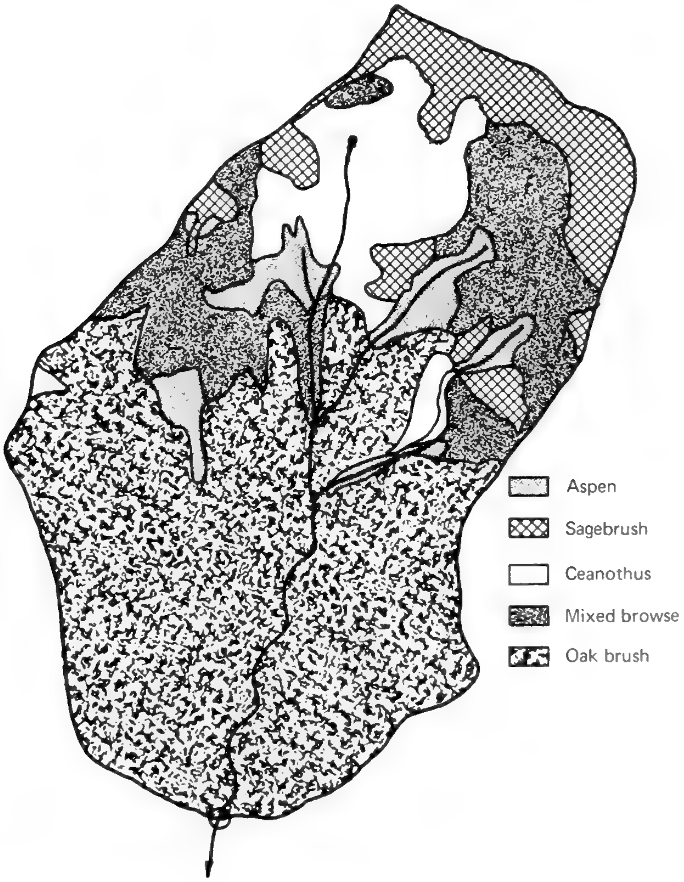

Figure 4.--Halfway Creek drainage showing five major vegetation zones.

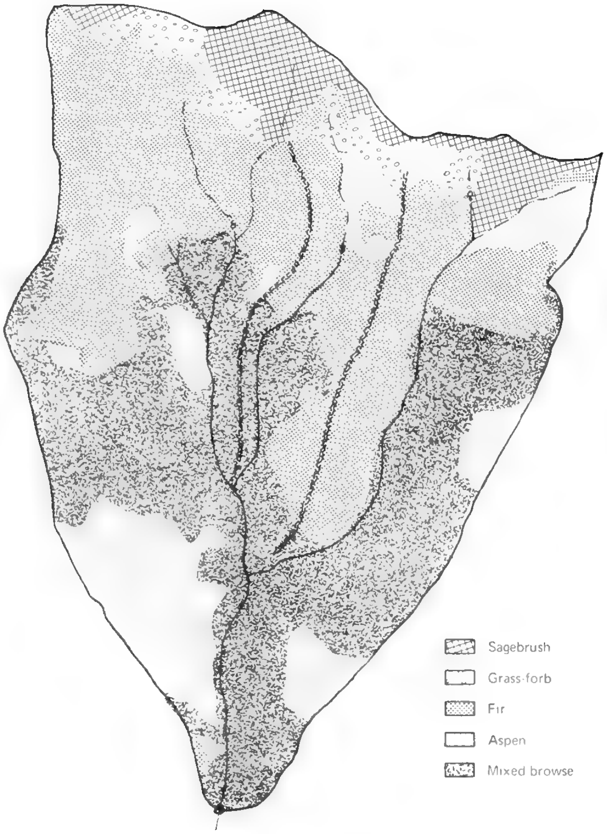

Figure 5.--Miller Creek drainage showing five major vegetation zones.

Because this zone includes the harshest sites and areas of least vegetation, it was the zone trenched for this study. The fifth, or oakbrush (*Quercus gambelii*) zone, occupies more than 50 percent of the drainage. This zone ranges from sparsely vegetated dry slopes where mountain mahogany (*Cercocarpus ledifolius*) also is common to wetter sites, areas covered with dense oakbrush intermixed with maple (*Acer glabrum*).

The Miller Creek drainage tends more toward forest and is generally much more densely vegetated than Halfway Creek drainage (fig. 5). Here, subalpine fir (*Abies lasiocarpa*) occupies much of the upper middle part of the drainage, the ceanothus zone on the Halfway Creek drainage. Fir is interspersed with clones of quaking aspen. Because of the exposure and the wetter site, aspen is also found well down into the bottom of the drainage in the mixed browse zone. Sagebrush grows along the tops of both drainages. An additional zone, the grass-forb, occurs on those areas where snowbanks persist late into the summer.

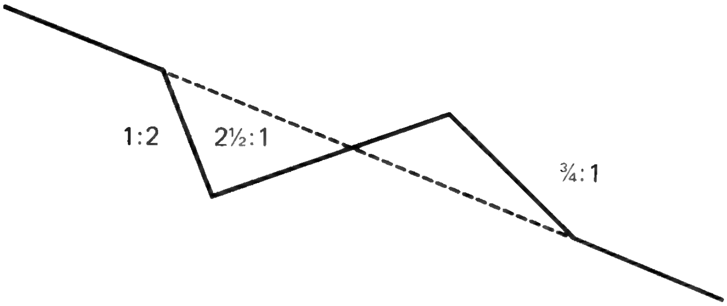

Figure 6.--Typical contour trench cross-section showing cut and fill grade slopes.

METHOD OF INVESTIGATION

Trench Construction

During the summer of 1964, contour trenches were constructed on the upper 15 percent of the Halfway Creek drainage according to standards outlined in Forest Service Handbook 2569.11 (U.S. Dep. Agr. 1959). These trenches were designed to hold 50 percent of precipitation from a 2-inch storm lasting 1 hour, plus allowing an additional 1.5 feet freeboard.

Because of variations in slope gradient, the slope distance between trenches ranges from 40 to 120 feet. The vertical height from trench bottom to fill crest was maintained at 4.5 feet. The profile is shown in figure 6. This gave approximately 10 cubic feet of storage capacity per linear foot.

When the trenches were completed they were seeded with a mixture of yellow clover (*Melilotus officinalis*), smooth brome (*Bromus inermis*), mountain brome (*Bromus carinatus*), intermediate wheatgrass (*Agropyron intermedium*), and tall oatgrass (*Arrhenatherum elatius*).

Instrumentation

The locations of most instruments used in this study are shown in figure 1.

Modified Venturii-trapezoidal flumes were installed on the Halfway Creek and Miller Creek drainages in the 1930's. The trapezoidal section was built into the bottom of a broad-crested weir (fig. 7).

Except for a brief period following the 1947 flood when operation of the Halfway Creek gage was disrupted, both structures have been maintained and continuous strip chart records of streamflow gathered since their construction.

A network of recording precipitation gages has been maintained and operated during the summer months in the Farmington Canyon area since 1942. A comprehensive report on these data has been published by Farmer and Fletcher (1969). In addition, two precipitation storage gages are maintained on the Farmington Canyon watershed, the Rice Climatic Station gage (since 1940), and the Farmington Guard Station gage (since 1951). Summer precipitation intensity data, air temperature data, and snow course data are also available from Rice Climatic Station. Fifteen years of snow measurements can be obtained from the Farmington Guard Station.

Figure 7.--Modified Venturii-trapezoidal flume in a broad-crested weir section constructed in the late 1930's on the Davis County Experimental Watershed.

In addition to the streamflow and precipitation records, other data have been collected in Farmington Canyon that contributed to the conclusions reached here. Soil moisture measurements have been made on the trenched area and on an adjacent untrenched area since 1965. Vegetation measurements were taken as point samples along permanent transects. Two 100-foot transects were located in the trenched area and two others in an adjacent untrenched area. In addition to the regular snow courses, four snow courses were established in conjunction with the contour trenches in the Halfway Creek drainage. Two of the courses were so located in the trenched area that each course crossed one trench.

RESULTS AND DISCUSSION

The relationship of three factors, streamflow from the Halfway Creek drainage, streamflow from the Miller Creek drainage, and precipitation at the Rice Climatic Station, was determined from records for the 12 years immediately prior to trenching. Correlations of these factors for different streamflow and precipitation periods were the basis used to evaluate effects of contour trenching.

The general nature of the relationship before trenching of the Halfway Creek streamflow, the Miller Creek streamflow, and the Rice Climatic Station precipitation is shown in figure 8. Precipitation catch at Rice Climatic Station tended to be greater than that on Halfway Creek drainage and less than that on the Miller Creek drainage. The extent of this error was accentuated in wet years, primarily because wet years are the result of more snow. Wind generally carries snow out of the Halfway Creek drainage but into the Miller Creek drainage. The movement of snow from Halfway Creek drainage into adjoining drainages is a significant factor in the actual distribution of precipitation available for streamflow.

Streamflows from Halfway Creek and Miller Creek drainages are closely correlated. Based on monthly streamflow patterns, the primary difference is a shift in the spring streamflow. Miller Creek streamflow is somewhat delayed relative to Halfway Creek because snowmelt begins later on this north exposure.

DOTY, ROBERT D.

1971. Contour trenching effects on streamflow from a Utah watershed. USDA Forest Serv. Res. Pap. INT-95, 19 p.

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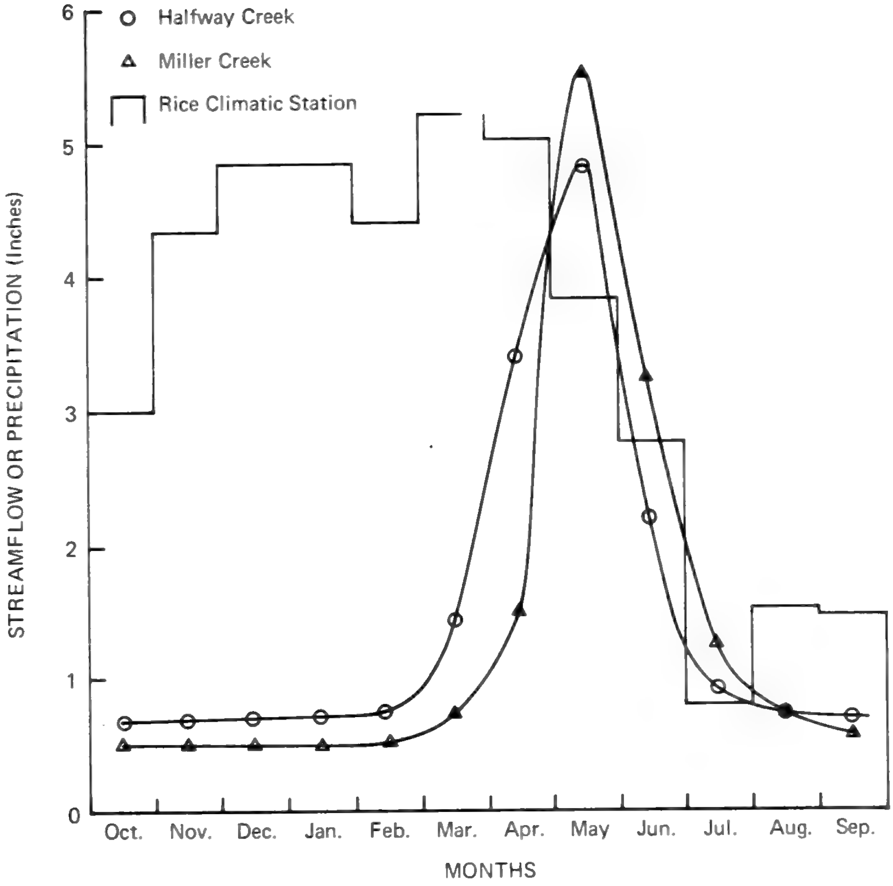
Figure 8.--The 12-year average monthly streamflow from Halfway Creek and Miller Creek drainages and the monthly precipitation at the Rice Climatic Station (1952-1964).

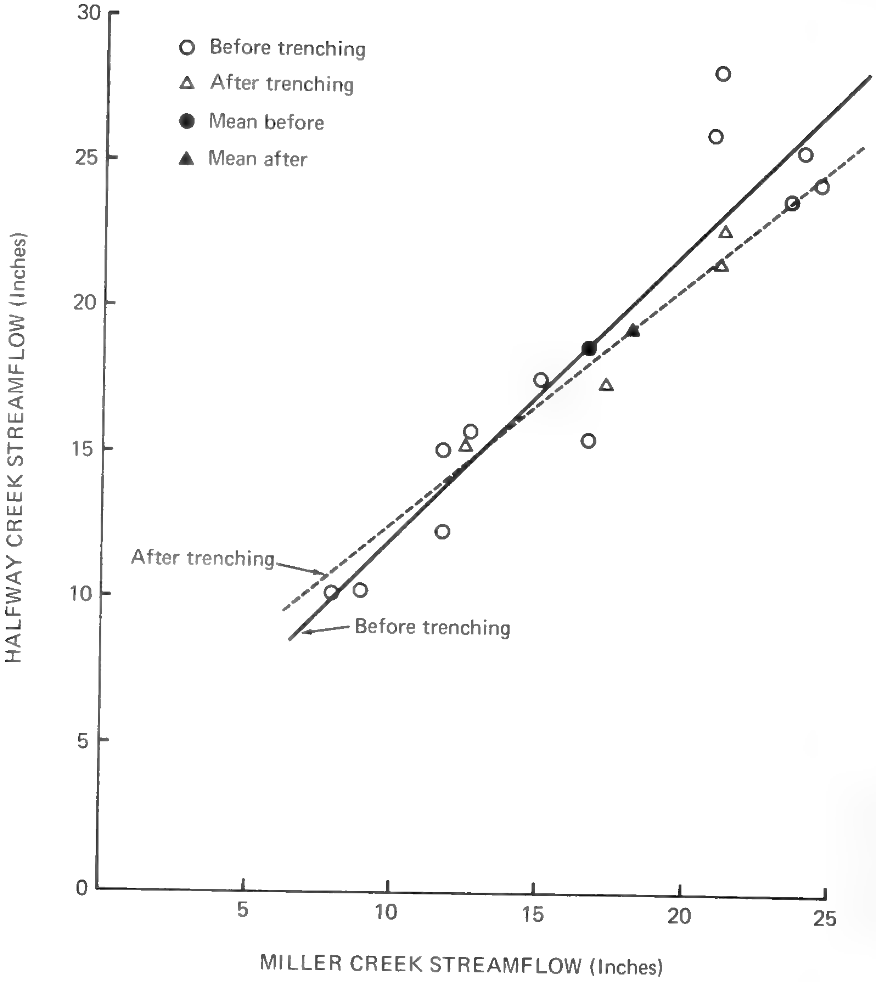


Because of its southwest exposure, the Halfway Creek drainage shows a rapid release of water from the snowpack in the spring. Timing of the peak spring flow fluctuates considerably from year to year, a reflection of the influence of temperature. Table 1 illustrates the relationship between seasonal streamflow from the Halfway Creek and Miller Creek drainages prior to trenching.

Table 1.--*Average streamflow from the Halfway Creek and Miller Creek drainages before trenching*

Streamflow period	Months	Streamflow			
		Halfway Creek		Miller Creek	
		Inches	*Percent*	*Inches*	*Percent*
Low streamflow (July through February)	8	6.25	33.2	5.51	33.1
Spring snowmelt (March through June)	4	12.59	66.8	11.12	66.9
Water year (October through September)	12	18.84	100.0	16.63	100.0

Figure 9.--The regression line comparing annual streamflow from Halfway Creek drainage with that from Miller Creek drainage, 1952-1968.

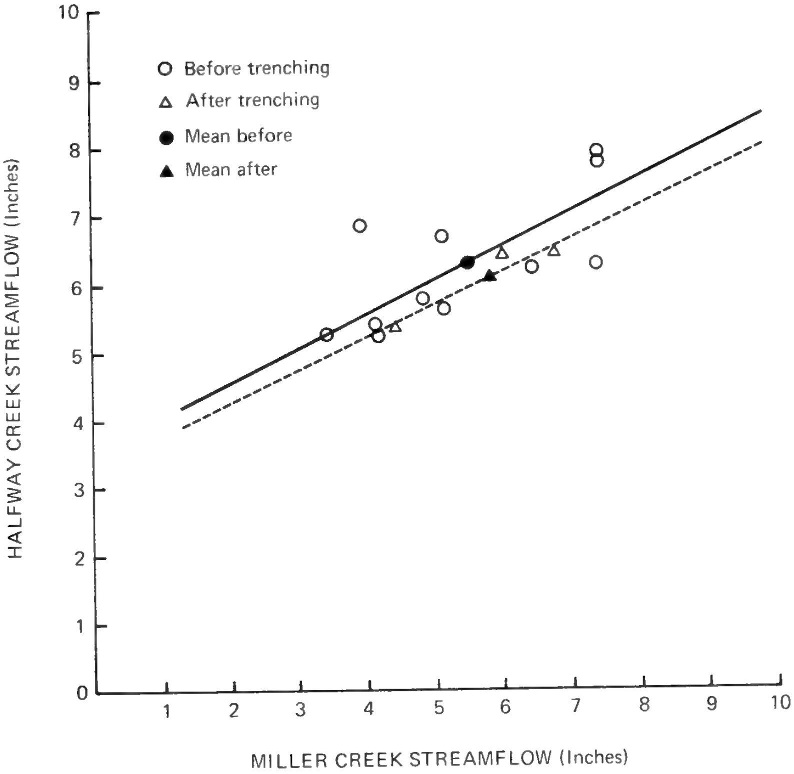


Annual Streamflow

A high degree of correlation ($r^2 = 0.878$) existed between the water-year (October through September) streamflow from the Halfway Creek drainage and that from the Miller Creek drainage prior to trenching. A covariance analysis compared the regression obtained before trenching with that after trenching. That analysis indicated no significant change in the slope of the regression line after trenching and no significant shift in the data either above or below the original regression line (fig. 9). Years of below average streamflow come closer to conforming to the before-trenching regression line than years of high streamflow. Apparently, years of low streamflow are closely alined by such relatively constant factors as consumptive use and watershed characteristics, whereas years of high streamflow are influenced more by such variable factors as precipitation storm patterns and snowpack distribution prior to runoff (Gartska et al. 1958). A slight reduction observed in streamflow from Halfway Creek in wetter years is indicated by triangles that represent the 4 years since trenching.

Some of the scatter of points in figure 9 are explained by multiple regression analysis that includes Rice Climatic Station precipitation data. With this precipitation included, the r^2 increased to 0.932, but did not alter the previous conclusion that trenching had no significant effect on annual flow.

Figure 10.--The relationship between seasonal low streamflow from the Halfway Creek drainage and that from the Miller Creek drainage, 1952-1968.



Low Streamflow Period

As defined for this analysis, the low streamflow period includes the streamflow for July through February. Streamflow during this period is almost exclusively baseflow, water from deep seepage and interflow. Precipitation occurring during the period contributes little water directly to streamflow. Summer storms are generally light and less than 2 percent of their precipitation results in direct runoff (Croft and Marston 1950). Fall and winter precipitation recharge the soil mantle and build the snowpack, but do not appreciably affect streamflow until snowmelt and spring runoff, March through June. Consequently, the low streamflow period reflects the watershed's drainage characteristics while the influence of concurrent precipitation is negligible (Hall 1968).

Soil moisture data collected at various places on the Davis County Experimental Watershed (Johnston, Tew, and Doty 1969) and the fact that two-thirds of the annual streamflow consistently occurs during the spring flow period indicate that the soil mantle is fully recharged at the beginning of each growing season. Fluctuations in streamflow, particularly on Miller Creek, sometimes occur at the beginning of the low flow period due to delayed snowmelt. For the most part, however, this is a rather stable streamflow period.

The relationship between the low flow of Halfway Creek and that of Miller Creek was determined for the pretreatment years (fig. 10). This resulted in an r^2 of 0.46, a low correlation apparently due to events on Miller Creek that effect streamflow while not effecting streamflow on Halfway Creek. The most probable influence was low temperatures, May through June, that delayed snowmelt longer on the Miller Creek drainage with its northern exposure than on Halfway Creek with its southwest exposure. A covariance analysis comparing before and after trenching data indicated no significant change in either the slope of the regression line nor any shift in position of the line. However, a slight decrease in streamflow after trenching is indicated (table 2).

Table 2.--*Annual streamflow during July through February from Halfway and Miller Creeks after trenching*

Year	Halfway Creek Y	Miller Creek	Halfway	
			Predicted ($\hat{Y}$)	Difference ($Y-\hat{Y}$)
	Inches	*Inches*	*Inches*	*Inches*
1965-66	6.39	6.29	6.59	-.20
1966-67	5.31	4.43	5.78	-.47
1967-68	6.35	6.86	6.83	-.48

As already noted, precipitation during the low flow period has little influence on streamflow. Correlations between Halfway Creek streamflow and Rice Climatic Station precipitation, as well as between Miller Creek streamflow and Rice Climatic Station precipitation, verified this lack of relationship. Since the trenches have been completed, summer precipitation amounts have varied from near-record lows to extreme highs, yet streamflow yields do not reflect such extremes.

Spring Streamflow Period

Spring streamflow (March through June) is extremely variable and represents the net effect of many variables (Croft 1944). Total streamflow from Halfway during this period has ranged from a low of 4.78 inches to a high of 19.61 inches in 1964 just before trenching. The extremely variable streamflow from the Halfway Creek drainage is matched by that from the Miller Creek drainage. When streamflows from the two were compared, 88 percent of the variation in Halfway Creek was explained by Miller Creek streamflow (fig. 11). The lack of change in streamflow after trenching was confirmed by a covariance analysis that compared before and after trenching results. This analysis showed no significant change in either the slope nor the position of the regression line.

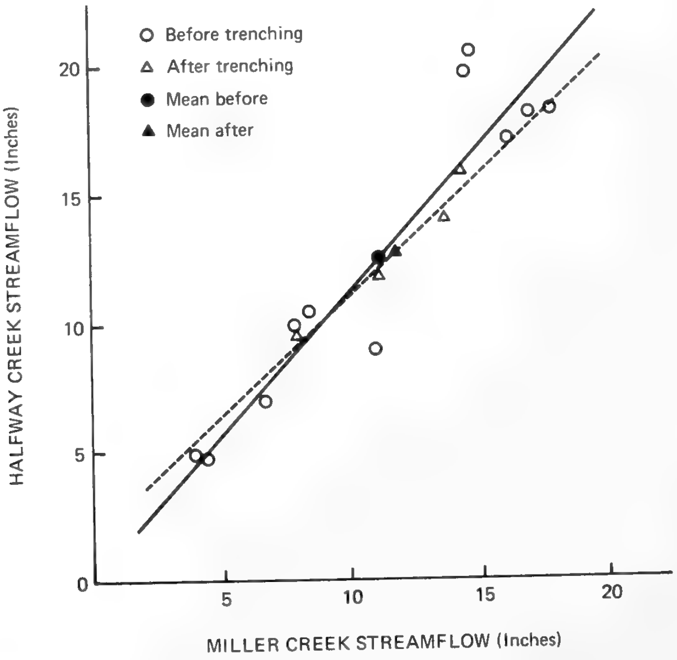
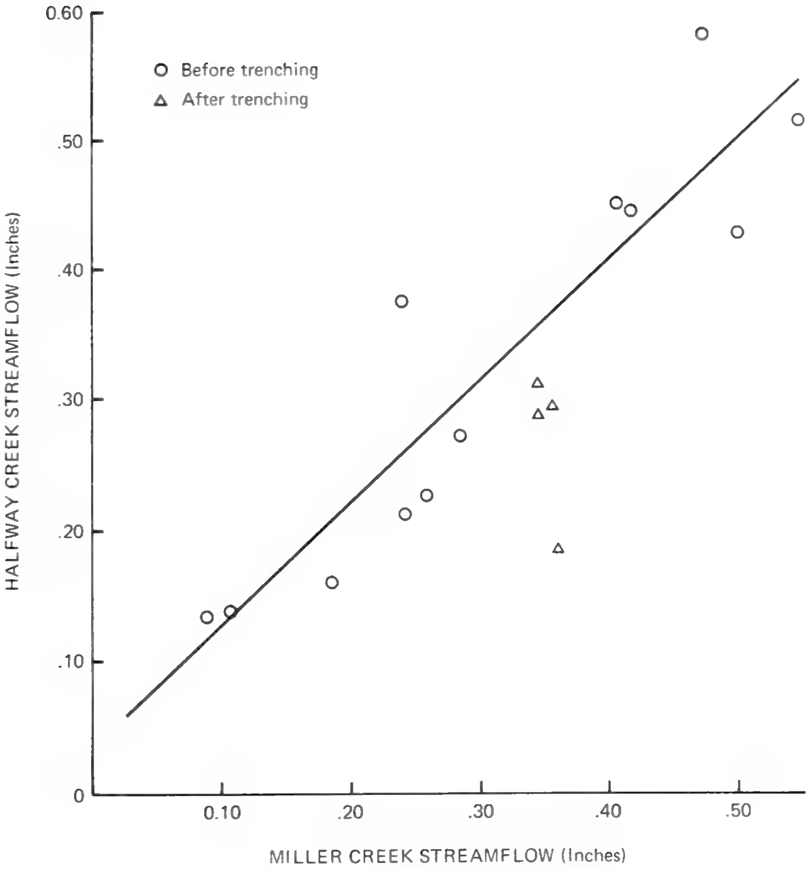


Figure 11.--The relationship between the snowmelt period streamflow from the Halfway Creek drainage and that from the Miller Creek drainage, 1952-1968.

Figure 12.--The relationship between the spring peak streamflow from the Halfway Creek drainage and that from the Miller Creek drainage, 1952-1968.



Although, for this period, no apparent change in streamflow resulted from trenching, it is possible that redistribution of the streamflow did occur. Peak streamflow during the period reflects the most change.

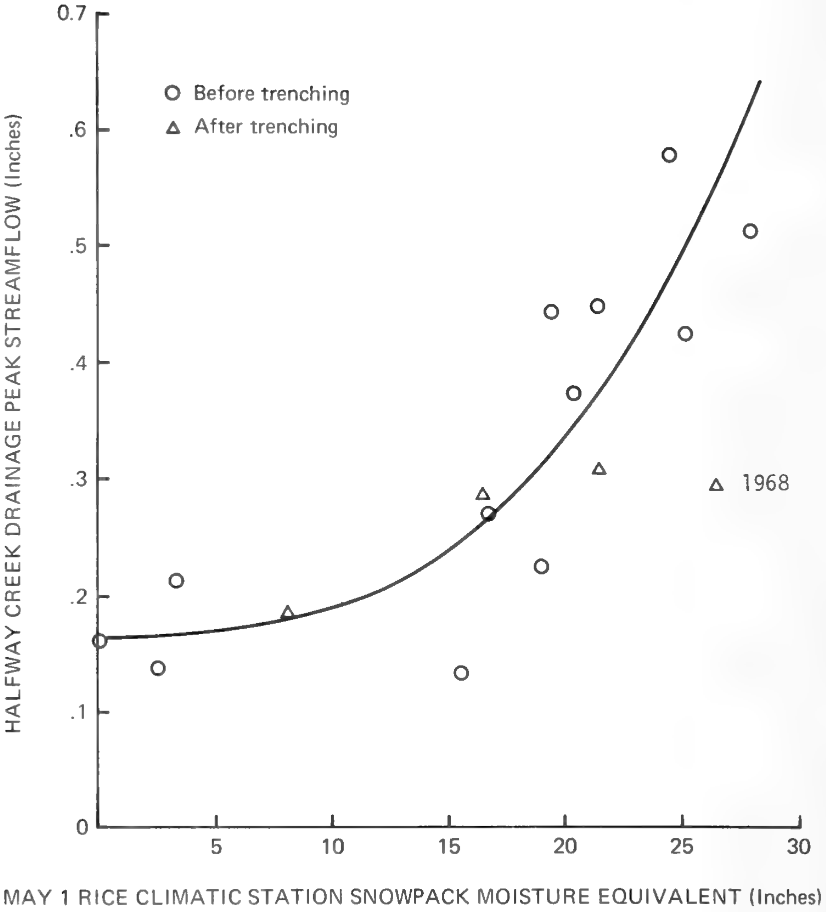
Based on daily streamflow measurements, a comparison was made of the highest single day of streamflow from Halfway Creek each year and the highest single day of streamflow from Miller Creek each year. Thus compared, the 2 days of each year do not necessarily coincide, but do reflect the peak of snowmelt-generated streamflow each year. An analysis of the 12 years of records prior to trenching resulted in 86 percent of the variance of Halfway Creek streamflow being explained by Miller Creek streamflow (fig. 12). After trenching, all peaks were lower than predicted by the regression line.

A comparison of peak flows and snowpack water content indicated that after trenching the peak flows closely followed the regression they followed before trenching; only a slight reduction was noted (fig. 13). For the year 1968, the peak flow, compared to snowpack conditions, was less than expected on both drainages.

Less obvious changes in peak streamflow since trenching include less fluctuation in the peak height and a shift of the peak to a later date. Of interest, too, is the fact that peak flow each year on Miller Creek usually occurs within a week of May 21; on Halfway Creek, it can take place any time between March 24 and May 27 (mean, April 24), nearly a month ahead of the peak Miller Creek flow.

Peak streamflow cannot be influenced without showing some change in the subsequent recession. Recession streamflow is characteristic of a particular watershed and more or less independent of current precipitation. Consequently, a change in the recession

Figure 13.--The annual peak daily streamflow from the Halfway Creek drainage plotted against the May 1 Rice Climatic Station snowpack moisture equivalent, 1952-1968.



flow should be a good indicator of any alteration of watershed characteristics due to trenching. A rapid recession in Halfway Creek streamflow follows the peak. After 60 days, the recession curve flattens to a slight downward gradient until sometime in August or September.

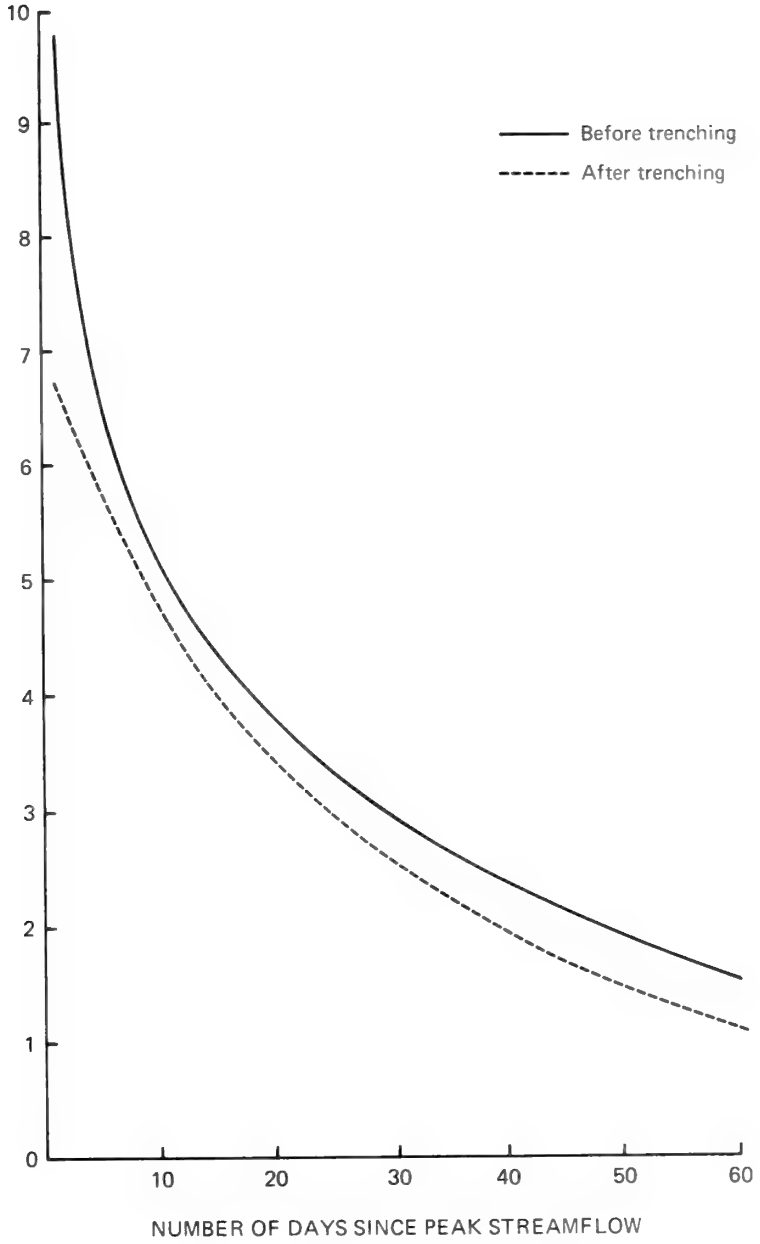
Evaluation of the recession flow was made by plotting daily flows for the 60-day period following the peak. The average of the 12 years prior to trenching was plotted as was the 4-year average after trenching and smooth curves were drawn through these data (fig. 14). A greatly reduced peak and a flattened recession curve followed trenching. Also, a general, but slight, reduction in the flow is shown.

Summer Storms

Runoff from summer storms does not represent a significant portion of the total annual runoff. However, since control of such storms is the primary reason for trenching, a limited analysis of their relationship to trenching was made.

More than 100 storms were studied to determine total surface runoff, time of that runoff, peak flow, and storm patterns. No two storms were alike and, more important, no storm affected the two watersheds in the same manner. However, a few conclusions can be drawn from the precipitation-runoff relationships studied so far. It was noted that less than 2 percent of the precipitation in a storm generally left the watershed as overland flow or was intercepted by the stream channel. Most of the storms analyzed produced less than a half-inch of precipitation each; only a small percentage produced more than an inch.

Figure 14.--The recession streamflow from the Halfway Creek drainage based on daily flow periods before and after trenching.



Hydrographs of two storms are illustrated (figs. 15 and 16) to show the relation between precipitation and runoff from summer storms on the Halfway Creek and Whipple Creek drainages. Figure 15 is the hydrograph of a storm that produced a total of 1.3 inches of precipitation, but had a maximum 5-minute intensity of 6.0 inches. Peak runoff exceeded 18 c.s.m. from Halfway Creek within an hour. Whipple Creek peaked an hour later at 11 c.s.m. The initial smaller peak on Whipple Creek is the result of a rainburst lower on the watershed. This also occurred on Halfway Creek and appeared on that portion of the hydrograph not shown. Figure 16 illustrates a storm 1 year after trenching. This storm produced 1.6 inches of precipitation, but had a maximum 5-minute intensity of 2.5 inches. Halfway Creek peaked at 6.7 c.s.m. Whipple Creek peaked at 7.5 c.s.m. an hour later. In comparison to pretrench conditions, the peak on Halfway Creek was greatly reduced. Also, the flow was distributed over a longer period of time, whereas the untrenched Whipple's flow period was about the same as before. How many of these differences can be attributed to trenching and how many to storm patterns is difficult to say.

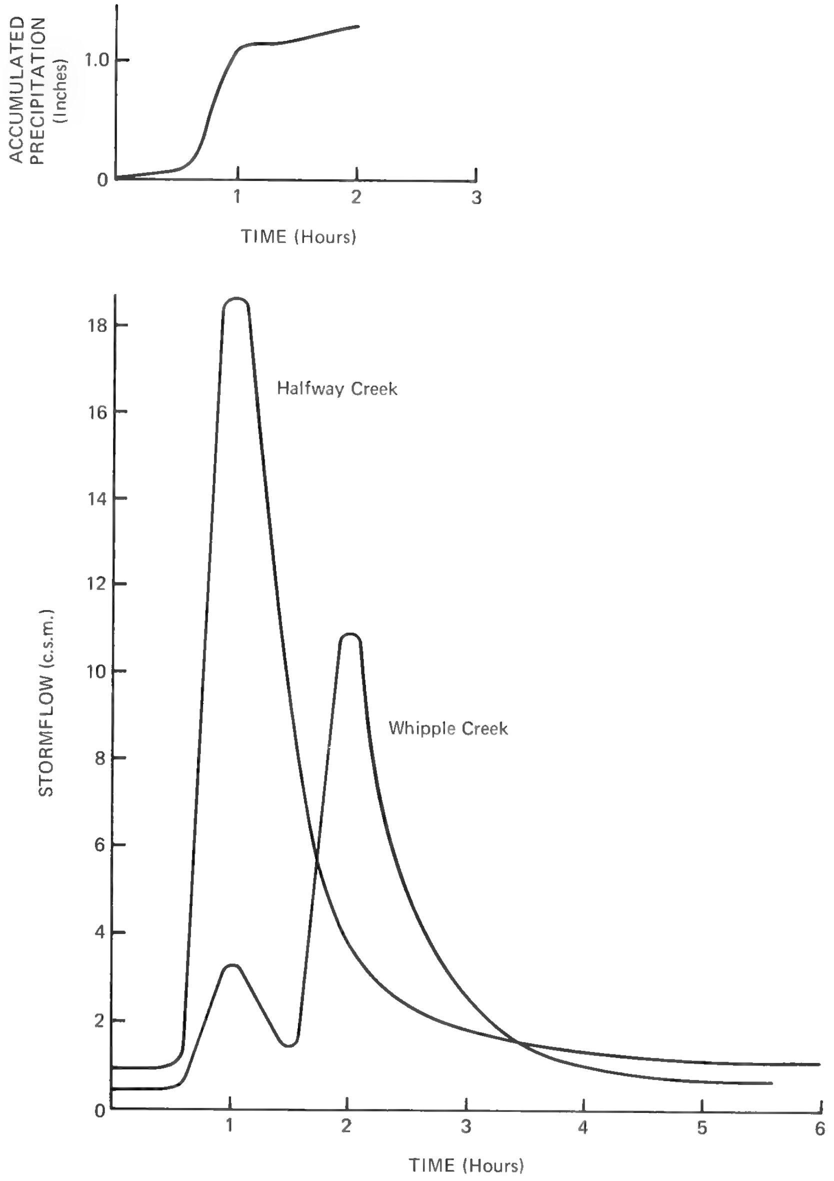


Figure 15.--A hydrograph representing a storm on the Halfway Creek and Whipple Creek drainages before trenching.

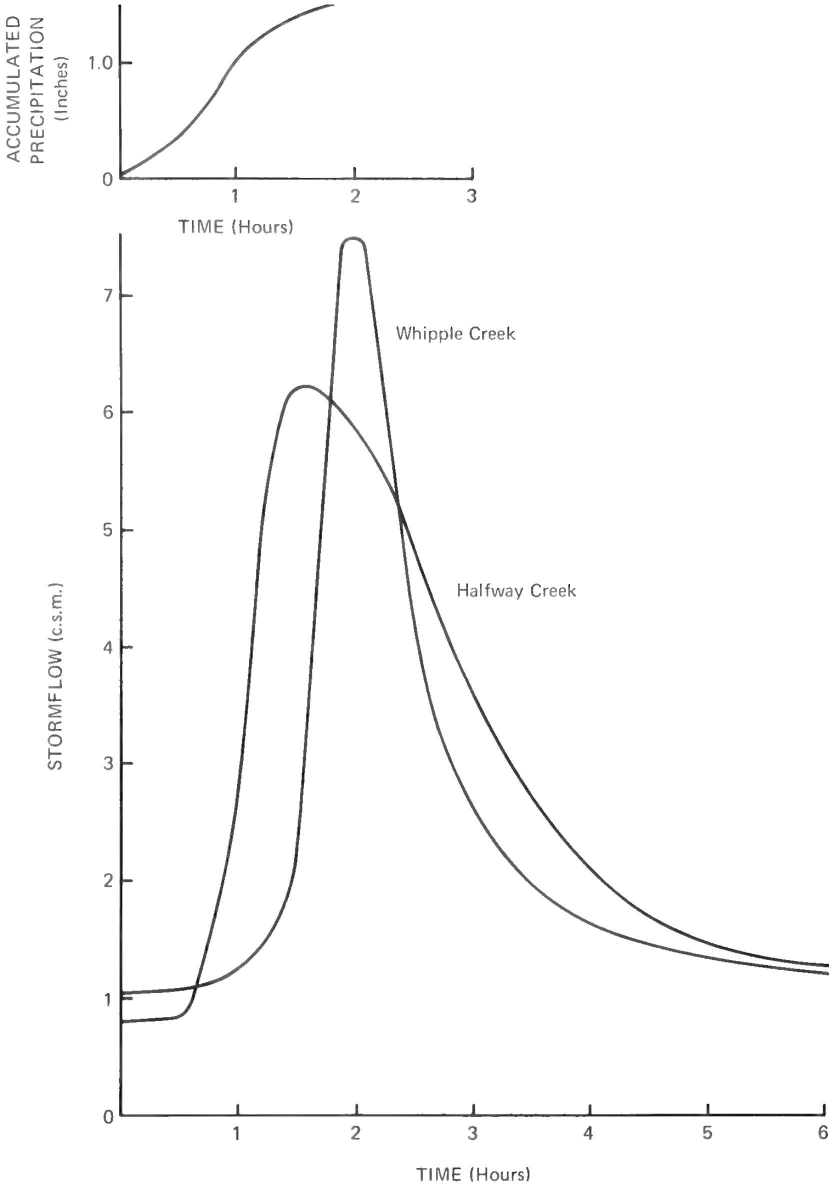


Figure 16.--A hydrograph representing a storm on the Halfway Creek and Whipple Creek drainages after trenching.

CONCLUSIONS

The streamflow and precipitation data analyzed from Halfway and Miller Creek watersheds show no statistically significant change in streamflow patterns as a result of contour trenching. This conclusion is based on 4 years of records after trenching and 12 years of records before trenching. The slight decrease in streamflow since trenching is perhaps due to chance variation in the data or to a slight increase in consumptive use due to a delay in streamflow from the trenched area. The possibility that any change is due to trenching is further reduced by supplemental data that show no appreciable change in the distribution of moisture available as potential streamflow. Snow distribution remains approximately the same, except for some on-site redistribution (Doty 1970). The consumptive use of soil moisture by vegetation has not shown appreciable change to date, although a trend similar to that reported by Bailey and Copeland (1960) may be developing.

The streamflow characteristics of the two drainages before and after trenching are summarized in table 3.

After an examination of streamflow regimen and watershed characteristics, such as soil type and vegetation, it is concluded that contour trenching has not significantly affected streamflow patterns of the Halfway Creek drainage.

Table 3.--*Summary of Halfway Creek and Miller Creek streamflow*

a. AVERAGE STREAMFLOW BEFORE TRENCHING

Streamflow period	Months	Halfway Cr. streamflow		Miller Cr. streamflow	
		Inches	*Percent*	*Inches*	*Percent*
July thru February	8	6.25	33.2	5.51	33.1
March thru June	4	12.59	66.8	11.12	66.9
Water year	12	18.84	100.0	16.63	100.0

b. ANNUAL STREAMFLOW SINCE TRENCHING

Year	Streamflow from Halfway Cr.	Streamflow from Miller Cr.	Predicted* Streamflow Halfway Cr.	Difference (actual-predicted)
	Inches			
1964-65	21.58	21.35	22.04	-0.46
1965-66	15.29	12.45	15.06	+ .23
1966-67	17.30	17.27	21.47	-4.17
1967-68	22.91	21.31	23.23	- .32

*Prediction based on regression: $\hat{Y} = -8.876 + 0.506 X_i + 0.487 X_{ii}$
Where: Y = Halfway Creek streamflow, X_i = Miller Creek streamflow, and X_{ii} = Rice Climatic Station precipitation.

c. SNOWMELT STREAMFLOW SINCE TRENCHING

Year	Streamflow from Halfway Cr.	Streamflow from Miller Cr.	Predicted* Streamflow Halfway Cr.	Difference (actual-predicted)
	Inches			
1965	14.05	13.78	15.52	-1.47
1966	9.42	7.88	9.02	+ .40
1967	11.77	11.24	12.72	- .95
1968	15.80	14.44	16.25	- .45

*Prediction based on regression: $\hat{Y} = 0.325 + 1.103 X$
Where: Y = Halfway Creek streamflow, X = Miller Creek streamflow.

d. LOW STREAMFLOW PERIOD SINCE TRENCHING

Year	Streamflow from Halfway Cr.	Streamflow from Miller Cr.	Predicted* Streamflow Halfway Cr.	Difference (actual-predicted)
	Inches			
1965-66	6.39	6.29	6.59	-0.20
1966-67	5.31	4.43	5.78	- .47
1967-68	6.35	6.86	6.83	- .48

*Prediction based on regression: $\hat{Y} = 3.87 + 0.432 X$
Where: $\hat{Y}$ = Halfway Creek streamflow, X = Miller Creek streamflow.

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