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EROSION OF THE TARKIO DRAINAGE SYSTEM, 1845-1976

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SUMMARY:
Historic and geologic evidence indicate that gully erosion was nearly nonexistent when the Tarkio Basin was settled about 1845. Channel enlargement during the years 1845-1976 is quantified and channel changes during 1939-1976 are reconstructed. Channel scour is tentatively explained based on geomorphic principles and subsoil erodibility differences.

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R. F. Piest, L. S. Elliott, and R. G. Spomer[2]

ABSTRACT

Historic and geologic evidence indicated that channel and gully erosion was nearly nonexistent when the loess-mantled Tarkio Basin of southwestern Iowa and northwestern Missouri was settled about 1845. The pattern of channel development--gleaned from old land surveys, records from drainage districts, and highway bridge surveys, and other documents--is related to the intensity of agriculture and is complexly linked to the general runoff regimen and to changes in soil-water content along channel boundaries. Some channel enlargement during the post-settlement period, 1845-1976, is quantified. Channel profile changes during recent years, 1939-1976, are reconstructed. The excessive scour in a channel reach of West Tarkio Creek is tentatively explained based on geomorphic principles and differences in substrata erodibility.

1/ Contribution of the Watershed Research Unit, U. S. Department of Agriculture, Agricultural Research Service, in cooperation with USDA Soil Conservation Service and the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa.

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INTRODUCTION

The loess hills region adjacent to the Missouri River between Sioux City, Iowa, and Kansas City, Missouri, is agriculturally productive, even though much of it has experienced severe erosion. About 40 percent of the total area is in rowcrops, including some land slopes as steep as 10 to 15 percent. But much of this clean-tilled land is still inadequately protected from erosive rainstorms, and many fields are presently being dissected wherever surface runoff concentrates to form incised channels (rills and small gullies). The size and growth of these incised upland channels are often influenced as much by the progressive erosion of downstream drainageways as by the water flowing through them. Throughout the region, there is a history of drainageway entrenchment as a consequence of the successive formation and upstream movement of channel scarps. Therefore, any effort to predict future gully erosion rates, or

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to effect gully control measures, must take account of the overall deterioration of the drainage system. The Tarkio River system in southwestern Iowa and northwestern Missouri exhibits erosion problems typical of the region.

Our objective is to trace the development of the Tarkio drainageways in southwestern Iowa and northwestern Missouri (Fig. 1), discussing causes of recent channel erosion. We hope that this study will yield insights into the future course of channel and gully erosion and eventually be of use in devising erosion control measures.

DESCRIPTION AND HISTORY OF THE TARKIO DRAINAGE SYSTEM

The Tarkio River begins in southern Cass County, Iowa, and flows south and southwest through Montgomery and Page counties, Iowa, and Atchison and Holt counties, Missouri. Its confluence with the Missouri River is about 70 miles south of its origin. Little Tarkio Creek, to the east, begins near the Atchison-Nodaway county line in Missouri and flows parallel to the Tarkio River through Atchison and Holt counties. Its confluence with the Missouri River is about 11 miles southeast of the Tarkio River confluence. Drainage areas of the present Tarkio and Little Tarkio watersheds are about 540 and 180 sq. mi., respectively. Before European settlement, both watersheds were considerably larger and included areas of the Missouri River floodplain that have since been lost by the dredging of new channels for the lower reaches of these watersheds and by draining swamps and other floodplain areas directly to the Missouri River.

The extent of channel alteration in downstream sectors of some loess hills drainage basins becomes evident by noting their past and present confluences with the Missouri River. The Tarkio River confluence is now 16 miles upstream from its former location; the Little Tarkio Creek outlet has been moved 9 channel miles upstream; the Nishnabotna River, just north of the Tarkio system, drains into the Missouri River 23 miles above its old confluence. County records throughout this region show that some drainage districts were formed before 1900, and channel straightening operations by individual farmers or small groups occurred even earlier. Most of the lower and middle channel reaches of the Tarkio system were straightened by 1920.

Soils of the area are loessial in origin, and the rolling loess topography is considered to be a subdued expression of the glacial till that underlies the surface to about 80-ft depth. Although no geologically Recent studies of drainageway development are known for these watersheds, Daniels (1966) stated that the last cycle of drainageway incisement in Harrison County, Iowa, (a similar terrain) ended about 1800, when most channels were healed.

This last observation is roughly substantiated by notations made in the original land survey records. For example, the Atchison County surveys, made in 1845-46, recorded narrow channel widths at most locations where they intersected section lines. Survey notes included occasional references to channel depth, swamps, and other drainage conditions. Other 19th Century information included notations on bridges, draining of swamps (St. Joseph, Mo., 1882), straightening of channels, and the formation of drainage districts. Table 1 shows channel widths for selected streams, based on the 1845 survey and the 1882 history, which tabulated data for all existing bridges in Atchison County; these are compared with more recent channel measurements gleaned from state and county bridge records. Comparative cross sections for 1846, 1932, and 1975 are shown in Fig. 2 for one of these locations on Little Tarkio

Creek. Such comparisons show an accelerated channel growth (erosion) during the past half-century at most locations, and an average two- to fourfold increase in channel dimensions (widths and depths) at some locations approximates a tenfold increase in channel cross section (area).

Although it has not been possible to obtain channel profile records from the last century, we usually have been able to determine the changes in streambed elevation during the past several decades by referring to state and county surveys at bridge sections, U.S. Soil Conservation Service surveys, U.S. Geological Survey gaging station measurements, drainage district records, and topographic maps. One source was records obtained from a concerned farmer who periodically plumbed the distance from a bridge deck to the streambed and recorded the dates and depths on his cellar door. Some measurements were recorded from 1916 to the present for nearly all of the more than 100 bridges across Tarkio drainageways. We used this information for the Tarkio River to compile the streambed profiles as they existed in 1939 and in 1976 (Fig. 3). These profiles show the 37-year channel deterioration.

SOME PROBABLE CAUSES OF CHANNEL ENLARGEMENT

Piest et al. (1976) have postulated, based on numerous plot and small watershed studies, that surface runoff from unprotected, row-cropped fields is two to three times surface runoff levels from the natural prairies that existed before European settlement in the region about 1850; peak runoff rates from such fields often are 10 to 50 times presettlement rates.

This increased runoff has resulted in extensive downcutting of these drainage systems, due to interaction of other erosion-causing variables that are peculiar to loessial areas. That is, the thick soil mantle of upland loess and valley alluvium has no base level to which channels can degrade and stabilize, and erosion scarps constantly form in downstream channels and advance upstream. Commensurate with this channel deepening by scarp migration is the weakening and failure of nearly-vertical loess sidewalls. The resulting soil debris is readily entrained and transported through the channel systems by minimal tractive forces of runoff. The consequence of these erosion activities often is a drastically enlarged channel, which is only casually related to the flows conveyed through the system.

Figure 3 shows that the most rapidly eroding portion of channel in the Tarkio drainage system seems to be West Tarkio Creek near the Missouri-Iowa boundary and several miles upstream. We propose three major reasons for the rapid downcutting in this vicinity. First, this is the logical location for maximum downcutting, if we consider the normal sequential aspects of the gullying process and if we consider where the present Tarkio system fits into such an erosion sequence. Second, there is evidence that some of the stratified alluvium through which this channel is presently cutting is more erodible than were overlying substrata and surface alluvium. Third, the longitudinal profile of West Tarkio Creek is steeper than the comparable Tarkio River reach. These reasons are now considered in detail.

A normal erosion sequence, as described by geomorphologists, is initiated when drainageway slopes steepen to a critical value; an erosion scarp then forms in the channel because of local weakening, unusual turbulence, or random disturbance, and advances upstream. Further scarp formation and migration is triggered by the initial instability, and the erosive action continues until land voiding upstream and sediment deposition downstream decrease the channel profile to a stable condition. Many factors noted in the foregoing process are operative in the Tarkio system today. The lower channel reaches are aggrading (Fig. 3), and there is evidence that the deposition tongue has advanced to a location in Atchison County near the town of Tarkio and just below the junction with the West Tarkio River. Therefore, it follows from the natural evolutionary sequence that the "middle reaches" of Tarkio drainageways would be the most deeply incised.

Also, a tentative explanation for excessive scour in West Tarkio Creek can be made based on soil erodibility evaluations of substrata. Five test borings, each to a minimum depth of 50 feet below floodplain, were taken by the Soil Conservation Service and analyzed for texture and other physical properties. The first three borings listed in Table 2 were in the deeply incised reach; the last two borings were upstream. The erosion potential of the strata were based principally on knowledge of the silt plus very fine sand fraction (0.002-0.100 mm) and of the sand fraction (0.100 mm-2.00 mm). Wischmeier, et al., (1971) have derived useful comparative erodibility values obtained by consideration of soil texture and organic matter content, and refined for soil structure and drainage characteristics.

The erodibility index (K) for many of the surface soils in the basin is about 0.30 to 0.35. Table 2 shows that substrata soil erodibility can vary greatly from the norm for surface soils; e.g., strata being deeply incised 4 miles north of the state line is quite erodible, K = 0.40. Possibly, the low erodibility (K = 0.14) indicated for the channel soil 7.5 miles above the state line has slowed the upstream progression of the erosion cycle. We interpret these differing substrata erodibilities as possible causes for rapid migration of scarps and for causing temporary discontinuities in the channel profile. Given the present flow regime and channel slopes, however, none of the strata characterized in Table 2 is capable of creating long-term channel stability.

The slopes of the relatively stable reaches of Tarkio and West Tarkio channels immediately above their confluence are quite similar, about 0.0006; but the gradient on the rapidly eroding portion of West Tarkio Creek is nearly twice as steep. This steeper slope no doubt has contributed to channel incisement in the past, just as even greater slopes farther upstream threaten to create additional erosion in the future.

DISCUSSION

Quantities of soil eroded from the Tarkio drainageways are enormous. The profiles in Fig. 3 show that nearly 100 miles of the main channel of the Tarkio River and West Tarkio Creek have degraded several feet between 1939 and 1976, with commensurate widening. Channel degradation before 1939 was equally devastating. There is no prospect for erosion control of these drainageways, given present land use and conservation resources. At the same time, there is no possibility of reverting to benign pastoral systems while the agricultural productivity remains high. Grade control structures, plus all other presently recommended structural and vegetative conservation treatments, are today's alternatives, albeit costly, to continued deterioration of the loess hills region. There is urgent need for an effective alternative solution to drainageway erosion problems.

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Table 1.--Channel Growth at Randomly-Selected Locations in Atchison County, 1845 to present

Stream	Location			Channel Width, feet			
	Township	Range	Section	1845[1]	1882[2]	present (1975)	other[3]
Little Tarkio Creek	64	39	19/30	40	40	100	60 ft. in 1931
Little Tarkio Creek	65	39	26	17	40	80	65 ft. in 1960
Little Tarkio Creek	64	39	9	26	40	85	70 ft. in 1960
E. F. Little Tarkio Creek	64	39	24/25	27	60	110	60 ft. in 1932
Rock Creek	65	41	2	10	40	120	120 ft. in 1968
West Tarkio Creek	66	40	24	13	40	110	------
West Tarkio Creek	66	40	36/2	33	60	110	90 ft. in 1930
West Tarkio Creek	66	40	12/13	13	60	110	90 ft. in 1930
West Tarkio Creek	65	40	14/23	50	60	110	------

[1]From original land survey

[2]Bridge widths in 1882 are given; actual channel widths were smaller.

[3]From highway department records

Table 2.--Texture and Erodibility of Channel Substrata in Rapidly Degrading Reach of West Tarkio River

Location of Boring	Character of Strata											
	Previously Incised				Being Incised				To be Incised			
	Sa %	Si %	Cl %	K	Sa %	Si %	Cl %	K	Sa %	Si %	Cl %	K
1 mile N. of MO-IA Line	--	--	--	--	8	47	45	.52	22	49	29	.40
2½ miles N. of MO-IA Line	--	--	--	--	22	43	35	.28	--	--	--	--
4 miles N. of MO-IA Line	--	--	--	--	25	51	24	.40	24	56	20	.33
7½ miles N. of MO-IA Line	--	--	--	--	91	7	2	.14	54	31	15	.38
9½ miles N. of MO-IA Line	20	36	44	.24	25	54	21	.45	--	--	--	--

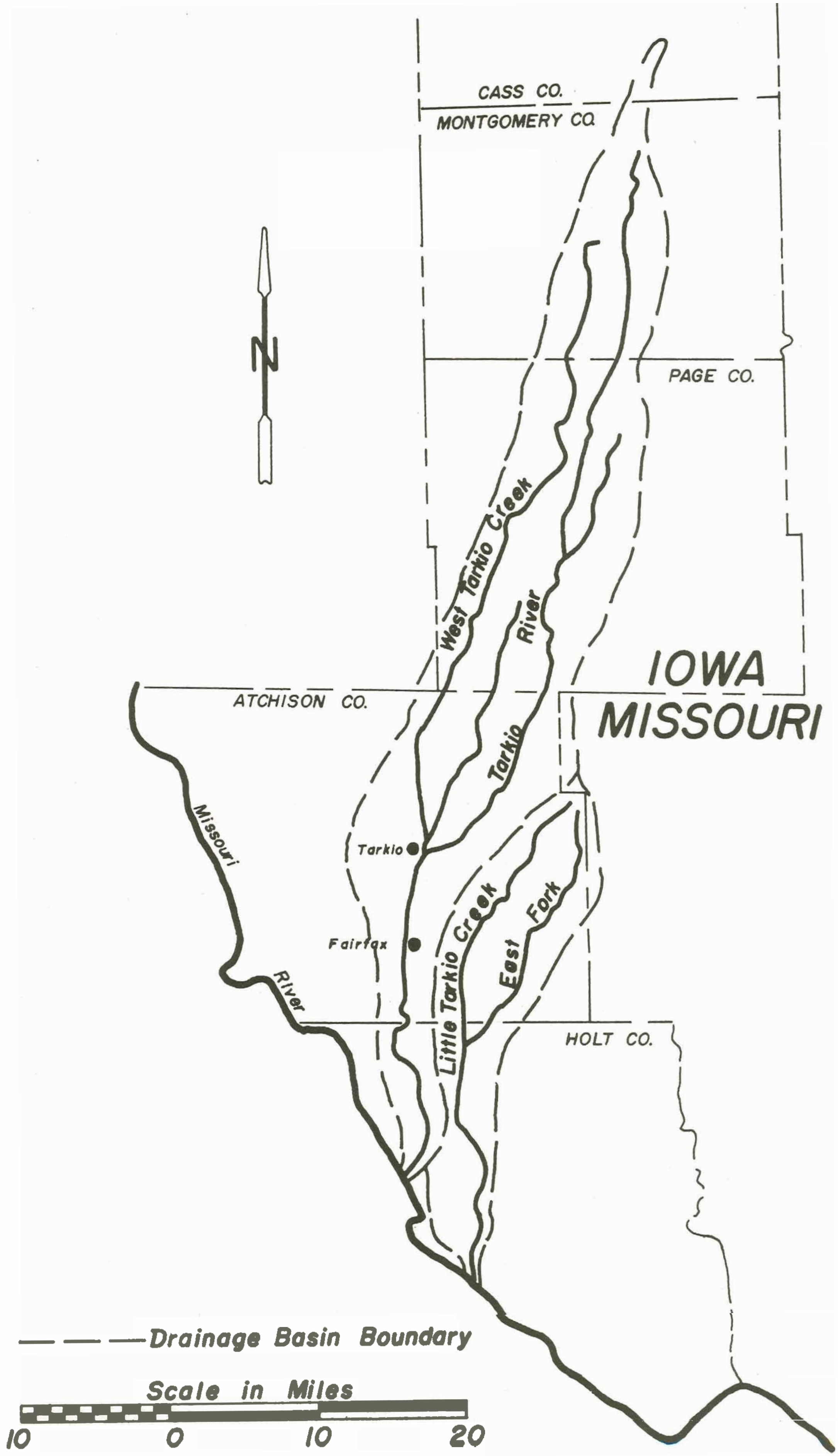
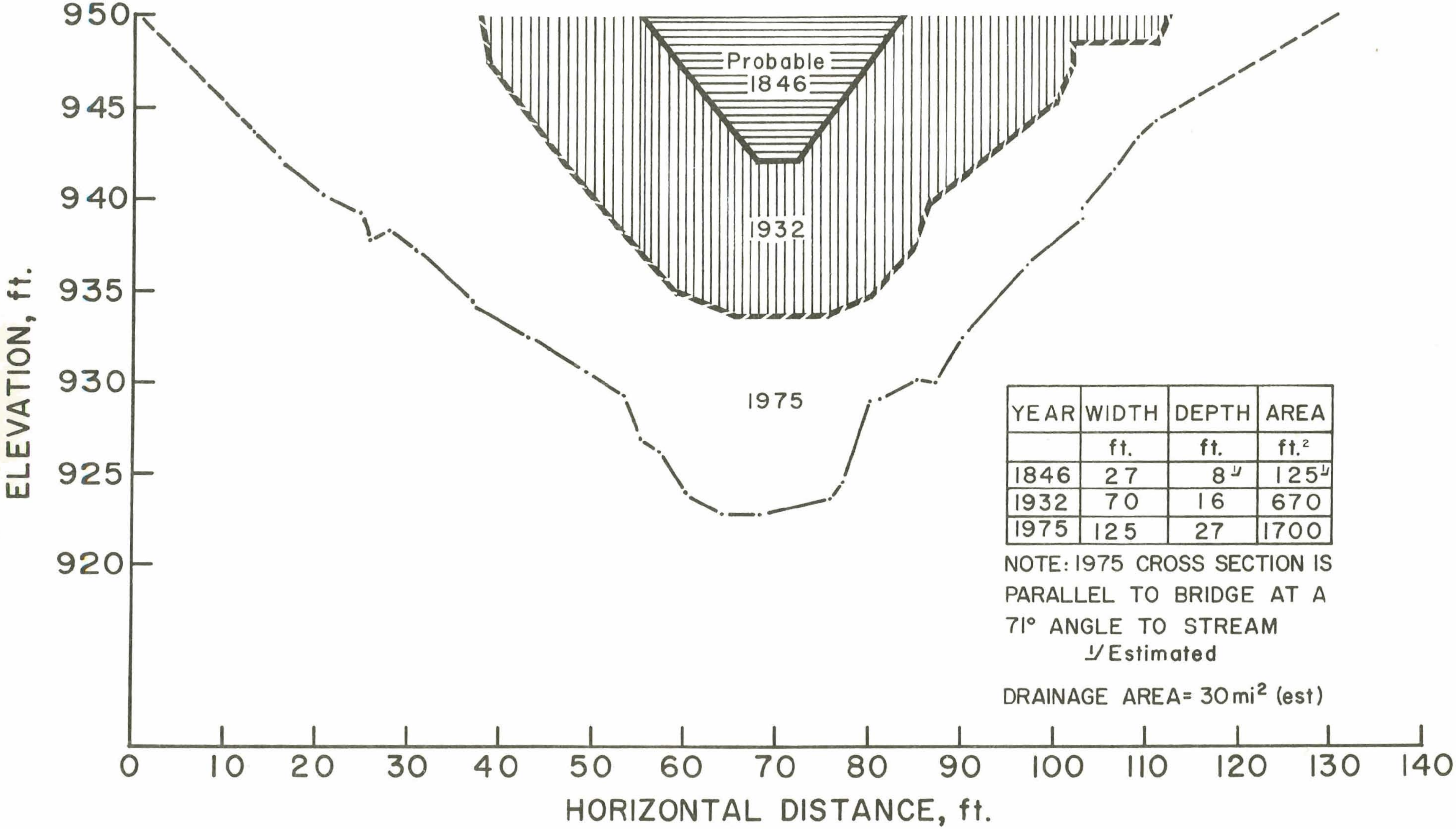


Figure 1.--The Tarkio Drainage Systems



YEAR	WIDTH	DEPTH	AREA
	ft.	ft.	ft.^{2}
1846	27	8[1]	125[1]
1932	70	16	670
1975	125	27	1700

NOTE: 1975 CROSS SECTION IS PARALLEL TO BRIDGE AT A 71° ANGLE TO STREAM

[1] Estimated

DRAINAGE AREA= 30 mi^2 (est)

Figure 2.--Comparison of width and cross section, 1846 to 1975, at location on East Fork Little Tarkio Creek, T64N, R39W, between sections 24 and 25.

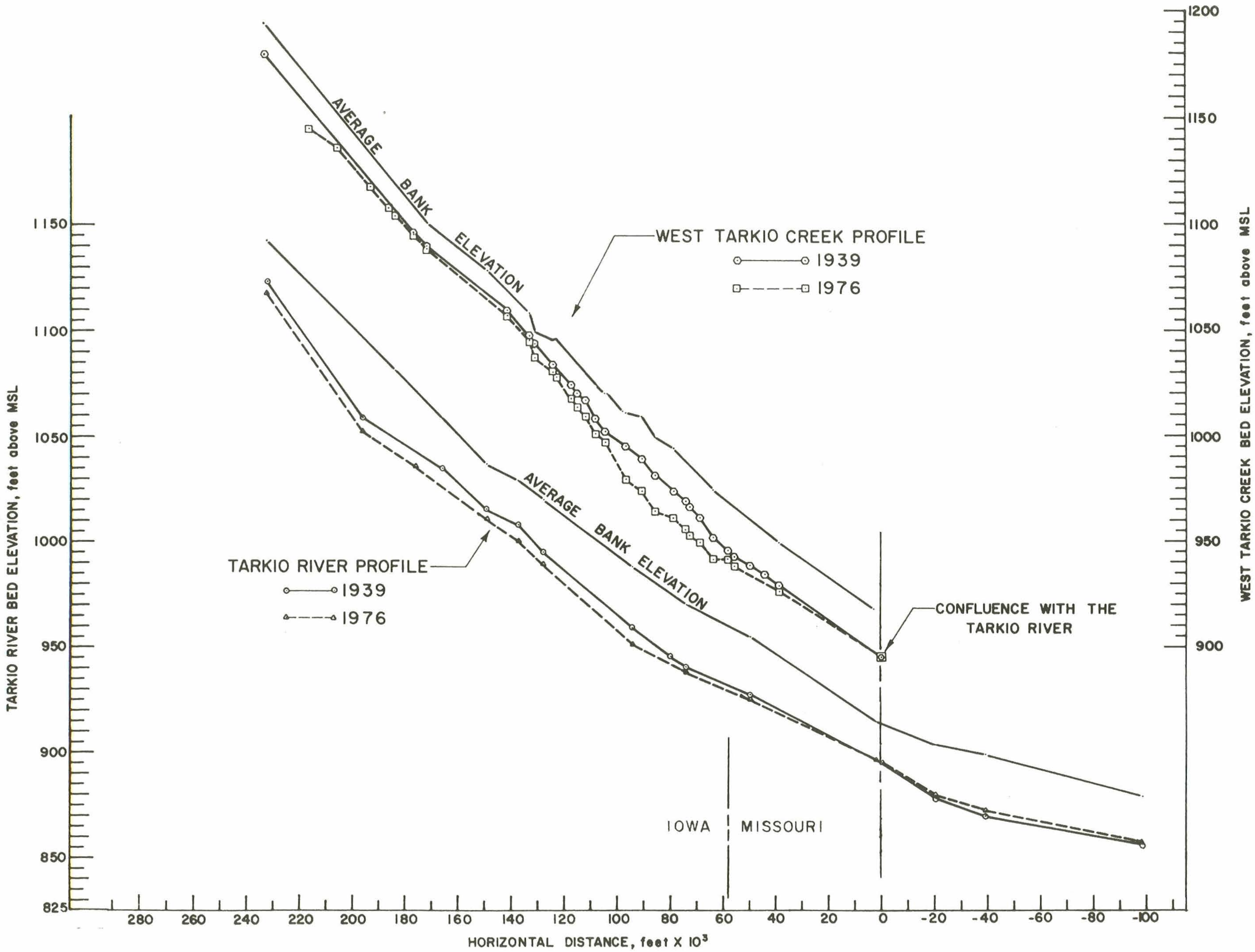


Figure 3.--Profile of Tarkio River and West Tarkio Creek, 1939 vs 1976.