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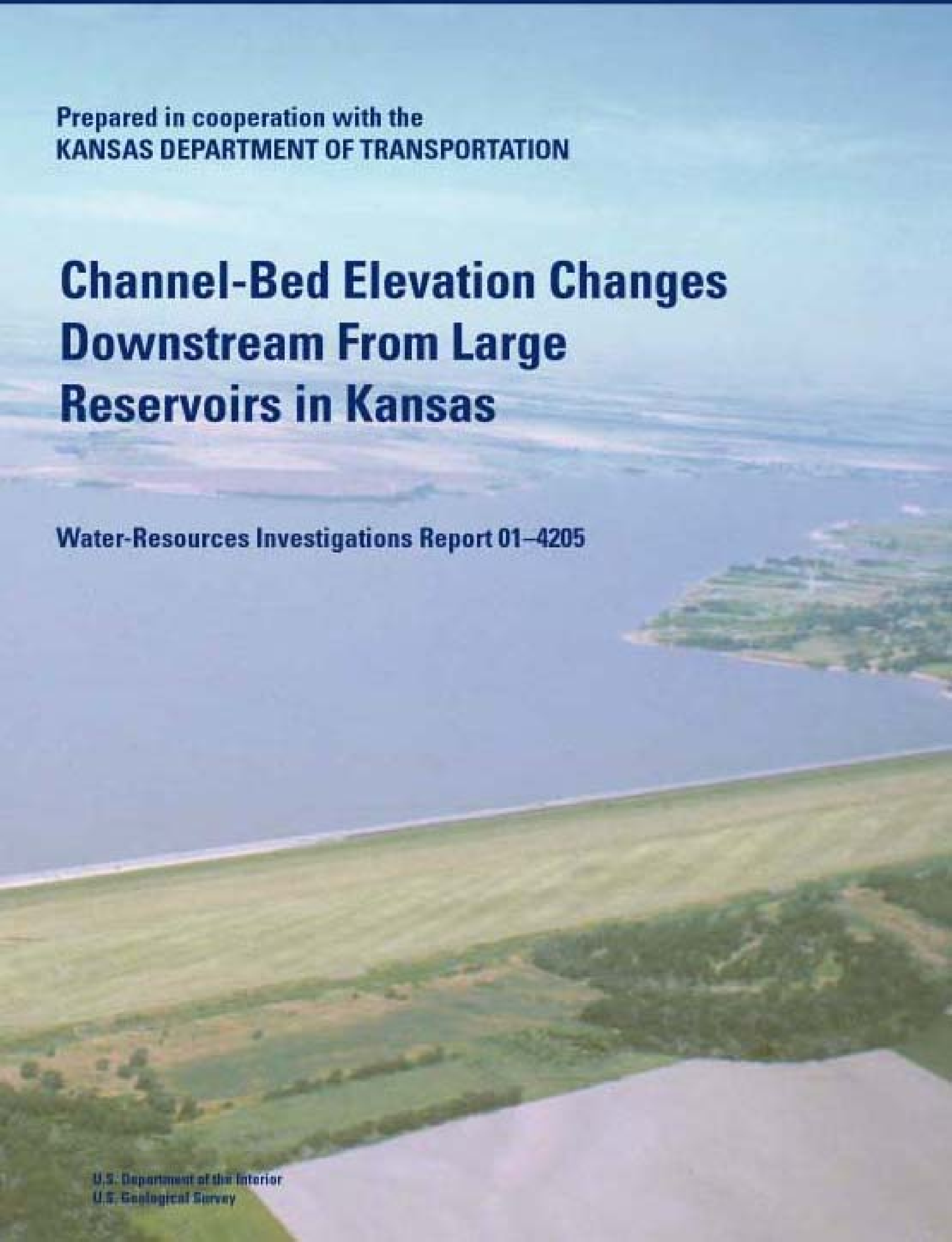

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KANSAS DEPARTMENT OF TRANSPORTATION

Channel-Bed Elevation Changes Downstream From Large Reservoirs in Kansas

Water-Resources Investigations Report 01–4205

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1. Change in river or stream stage for mean annual discharge at U.S. Geological Survey streamflow-gaging stations located downstream from 24 large Federal reservoirs in Kansas for post-dam period of record 4

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter
acre-foot (acre-ft)	43,560	cubic foot
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per year (ft/yr)	0.3048	meter per year
mile (mi)	1.609	kilometer

Channel-Bed Elevation Changes Downstream From Large Reservoirs in Kansas

By Kyle E. Juracek

Abstract

Channel-bed elevation changes were assessed downstream from 24 large Federal reservoirs in Kansas using information from U.S. Geological Survey streamflow-gaging stations. Changes in river/stream stage associated with mean annual discharge indicated that channel-bed lowering had occurred downstream from most of the reservoirs. The net decrease in channel-bed elevation ranged from less than 1 foot to slightly more than 9 feet. The magnitude of channel-bed lowering downstream from the reservoirs likely was related to the composition of the channel bed.

INTRODUCTION

In Kansas, 24 large Federal reservoirs have been constructed, mostly in the eastern two-thirds of the State (fig. 1). The reservoirs, most of which were completed in the 1950s or 1960s, were built by either the U.S. Army Corps of Engineers or the Bureau of Reclamation (U.S. Department of the Interior) initially for the primary purposes of providing flood control and water for irrigation, respectively. Subsequently, the reservoirs have become important for several other uses including public water supply, wildlife habitat, and recreation. Total capacity of the reservoirs ranges from about 40,000 to 3,200,000 acre-ft, with a mean of about 650,000 acre-ft.

The construction and operation of a reservoir can have a substantial effect on the stability of the river or stream channel downstream from the dam. Primary changes introduced by a dam include a reduction in the river's sediment load and an alteration of the flow regime. The ability of dams to trap and permanently store virtually the entire sediment load of the upstream basin has been widely reported (Petts, 1979; Williams and Wolman, 1984). Typical changes in the flow regime include a reduction in the magnitude of peak flows and a possible increase in the magnitude of low flows (Williams and Wolman, 1984). Such artificially introduced changes may trigger an adjustment by the river or stream as it attempts to re-establish an approximate equilibrium between the channel and the discharge and sediment load being transported (Leopold and Maddock, 1953). Channel adjustments, which include such interdependent hydraulic variables as width, depth, and gradient, may be achieved in several ways, including channel degradation [that is, bed and (or) bank erosion], channel aggradation (that is, deposition of material), or changes in channel pattern and shape.

In general, rivers or streams downstream from dams initially adjust by channel degradation. Typically, a river or stream will scour, and thus lower, its channel bed as the sediment-depleted water emerging from the dam attempts to replenish its sediment load. Concurrently, the reduced magnitude of peak flows emerging from the dam eventually may result in channel narrowing as vegetation encroaches. An exception is the case where the channel bed is armored (with coarse material) or situated on bedrock. Unable to effectively scour the resistant channel bed, the river or stream may instead erode laterally and thus widen its channel (Petts, 1977; Bradley and Smith, 1984). Typically, channel degradation begins near the dam following closure and eventually may migrate a considerable distance downstream. Although Williams and Wolman (1984) stated that most channel changes occur during the first 5 or 10 years after dam closure, others have speculated that the complete adjustment of a channel

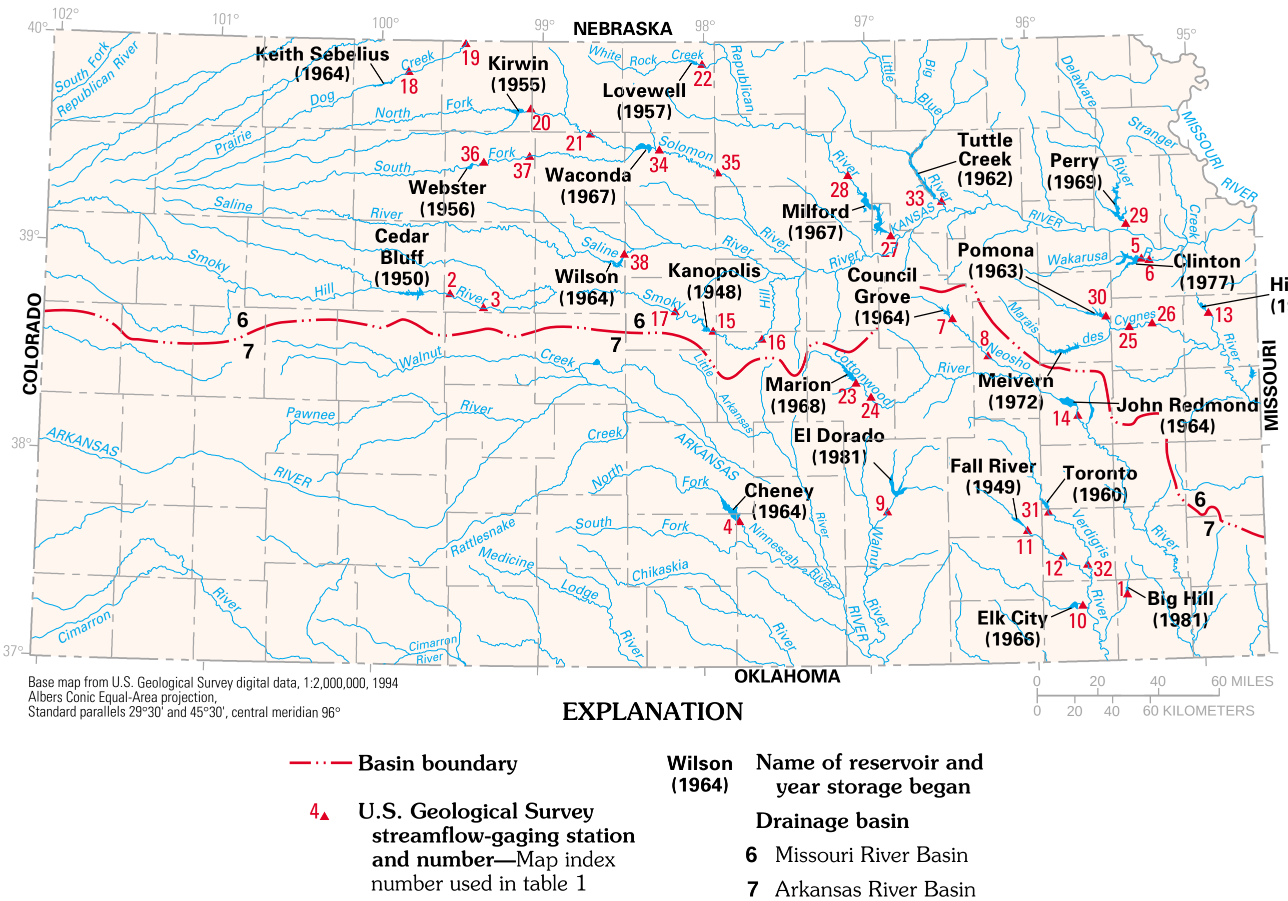

Figure 1. Location of 24 large Federal reservoirs and selected U.S. Geological Survey streamflow-gaging stations in Kansas.

may require 100 years or more (Kellerhals, 1982; Andrews, 1986; Knighton, 1988).

The type, rate, duration, and extent of channel degradation downstream from dams are controlled by many factors, including discharge, sediment load, bed- and bank-material composition, local bed-elevation control (for example, armoring or bedrock), channel geometry, climate, tributary inflow, and vegetation (Simons and Li, 1982; Knighton, 1984, 1987; Williams and Wolman, 1984). Also, human-caused changes such as grade-control structures (for example, weirs) and bank stabilization may affect the geomorphic response of a river or stream. Considerable variation in the type and rate of channel degradation may occur even between sites located close together due to the variability of the controlling factors (Thornes, 1977; Hooke, 1980; Pizzuto, 1994). Downstream from the degradation zone, channel aggradation may result.

Channel change is a concern for several important reasons including bridge-site selection, design, and maintenance; protection of property and structures in and along the affected channel; protection of riparian and aquatic habitat for threatened and endangered species; channel capacity; ground-water levels; general aesthetics; and recreation. A substantial lowering of the channel bed poses a threat to bridge-pier foundations as well as pipelines and cables buried beneath the channel. In addition, bed lowering increases bank height and bank instability. Such instability may trigger bank erosion and channel widening that may pose a threat to bridge abutments and other structures. Channel aggradation raises the bed elevation, reduces channel capacity, and increases the likelihood of flooding. Any channel adjustments that occur on the main-stem rivers or streams also may migrate upstream on the tributaries where additional property and structures may be at risk. Finally, any long-term channel-adjustment processes (such as the downstream response of a river or stream to upstream regulation) also may instigate or worsen local scour problems (Robbins and Simon, 1983).

In addition to reservoirs, several other natural or human factors also may cause changes in channel-bed elevation over time. Examples include regional climate change, a change in base level (level below which erosion cannot occur) of a river or stream, land-use changes within the basin, and channelization. Thus, although upstream regulation may be the primary cause, several causes may combine to account for the changes in channel-bed elevation determined for a given location.

A study by the U.S. Geological Survey (USGS), in cooperation with the Kansas Department of Transportation, was begun in 2000 to assess channel-bed elevation changes downstream from 24 large Federal reservoirs in Kansas (fig. 1). The specific study objectives were to determine the magnitude (and direction) of channel-bed elevation changes as well as the statistical significance of any observed trends in those changes. The purpose of this report is to present the results of the study. From a national perspective, the methods and results presented in this report provide guidance and perspective for future studies concerned with the issue of channel changes downstream from reservoirs.

METHODS

The assessment of channel-bed elevation changes downstream from the 24 reservoirs involved an analysis of available information from USGS streamflow-gaging stations (fig. 1, table 1). The gaging stations provide historical, site-specific information that may be indicative of channel conditions both upstream and downstream of the stations.

At any given time and location along a river or stream, a relation exists between river/stream stage (that is, the height of the water in the channel above a given datum) and discharge. These relations, quantified on rating curves, are updated as necessary to accommodate changes in channel geometry, slope, and other factors that can affect the relation. Each rating curve represents a best-fit line through the measurement data (that is, paired measurements of river/stream stage and discharge). Discharge measurements at, and stage-discharge rating curves for, the streamflow-gaging stations were made using standard USGS techniques (Buchanan and Somers, 1969; Kennedy, 1984) with a typical accuracy of $\pm$ 5 percent (Kennedy, 1983).

By computing the stage that relates to a reference discharge for each rating curve developed during the period of record of a gaging station (and correcting to a common datum, if necessary), trends in the elevation of the channel bed can be inferred by plotting the resulting time-series data. In this assessment, the river/stream stage for the mean annual discharge (rounded to the nearest 10 or 100 ft^3/s, as appropriate) for the period of record was used as the reference discharge (Chen and others, 1999). If the stage for the reference discharge has a downward (negative) trend, it may be inferred that the channel-bed elevation has lowered over time due to erosion. Conversely, if the stage for the reference discharge has an upward (positive) trend, it may be inferred that the channel-bed elevation has risen over time due to aggradation. No trend indicates that the channel bed has been essentially stable.

In addition to the magnitude and trend of channel-bed elevation changes at each gaging station, information derived from the rating curves also was used to assess the rate of channel-bed elevation changes (rating-curve information is on file at the USGS office in Lawrence, Kansas). For a given trend, the rate of channel-bed elevation change was estimated as the net difference in stage between the starting and ending dates that define the trend divided by the length of time between the two dates.

Because channel changes caused by dams are typically greatest near the dam, this study initially focused on the first gaging station located downstream from each dam. Of the 24 reservoirs, 22 had a gaging station located less than 6 mi downstream from the dam. For 16 reservoirs, a gaging station was located 2 mi or less downstream from the dam. Unfortunately, an analysis of channel-bed elevation change at the first gaging station downstream from the dam was not possible for 7 of the 24 reservoirs either due to concrete control in the channel at or near the gaging station or an insufficient post-dam period of record.

For several reservoirs, a second gaging station located farther downstream also was included in the analysis. The inclusion of the second gaging station served two purposes. First, for a few reservoirs it provided some information where otherwise there would have been no information due to the inability to use the first gaging station downstream. Second, it provided some perspective on the downstream extent of the channel-bed elevation changes. Also, for selected reservoirs, an upstream gaging station was included in the analysis to enable a comparison of channel-bed elevation changes upstream and downstream.

A statistical test was used to determine the significance of any observed post-dam trends in channel-bed

Table 1. Change in river or stream stage for mean annual discharge at U.S. Geological Survey (USGS) streamflow-gaging stations located downstream from 24 large Federal reservoirs in Kansas for post-dam period of record

[B, Bureau of Reclamation, U.S. Department of the Interior; C, U.S. Army Corps of Engineers; ft^3/s, cubic feet per second; --, not applicable or not determined]

Reservoir name (agency that built the dam, year storage began)	Map index number for associated USGS streamflow-gaging station (fig. 1)	Associated USGS streamflow-gaging station number	Approximate distance of gaging station downstream from dam (miles)	Period of continuous record at same gaging site (years)	Mean annual discharge for period of record[1] (ft^3/s)	Post-dam net change in stage for mean annual discharge[2] (feet)	Spearman's rho	Trend test at 0.05 level of significance
Big Hill Lake (C, 1981)	1	07170700	0.2	1957–99	30	-2.40	-0.98	negative
Cedar Bluff Reservoir	2	06862500	12.0	1942–52	--	([3])	--	--
(B, 1950)	3	06862700	21.4	1964–99	20	[4]-.65, -.50	-.81, -.81	negative
Cheney Reservoir (B, 1964)	4	07144795	.3	1964–99	100	([5])	--	--
Clinton Lake (C, 1977)	5	06891483	3.7	1972–80	300	-1.10	-.94	negative
	6	06891500	6.0	1929–72, 1980–99	300	+.80	.44	no trend
Council Grove Lake	7	07179500	1.7	1938–99	100	-.70	-.98	negative
(C, 1964)	8	07179730	37.0	1963–99	300	-.35	-.23	no trend
El Dorado Lake (C, 1981)	9	07146830	5.1	1981–98	200	-.25	-.85	negative
Elk City Lake (C, 1966)	10	07170060	.1	1965–99	500	-1.70	-.73	negative
Fall River Lake	11	07168500	.3	1939–89	300	-.30	-.91	negative
(C, 1949)	12	07169500	28.9	1938–99	500	-.30	-.89	negative
Hillsdale Lake (C, 1981)	13	06915000	2.0	1958–99	100	-.25	-.88	negative
John Redmond Reservoir (C, 1964)	14	07182510	5.3	1961–99	1,700	-.15	-.21	no trend
Kanopolis Lake	15	06865500	.8	1940–99	300	-5.80	-.99	negative
(C, 1948)	16	06866000	38.0	1930–65	400	+1.05	-.16	no trend
	17	06864500	--	1928-98	200	+.80	.85	positive
Keith Sebelius Lake	18	06848000	.9	1943–99	20	([5])	--	--
(B, 1964)	19	06848500	48.4	1944–99	30	+1.95	.77	positive
Kirwin Reservoir	20	06871800	.6	1941–99	30	([5])	--	--
(B, 1955)	21	06872500	40.8	1945–99	100	+.45	.40	no trend
Lovewell Reservoir (B, 1957)	22	06854000	.3	1945–99	40	([5])	--	--
Marion Lake (C, 1968)	23	07179795	.25	1968–99	80	-2.15	-.99	negative
	24	07180200	4.55	1984–99	200	+.05	-.23	no trend
Melvern Lake (C, 1972)	25	[6]06913000	[7]13.5, 28.2	1968–99	600	+0.30	.72	positive
	26	[6]06913500	[7]33.5, 48.2	1962–99	700	+.45	.67	positive

Table 1. Change in river or stream stage for mean annual discharge at U.S. Geological Survey (USGS) streamflow-gaging stations located downstream from 24 large Federal reservoirs in Kansas for post-dam period of record—Continued

Reservoir name (agency that built the dam, year storage began)	Map index number for associated USGS streamflow-gaging station (fig. 1)	Associated USGS streamflow-gaging station number	Approximate distance of gaging station downstream from dam (miles)	Period of continuous record at same gaging site (years)	Mean annual discharge for period of record[1] (ft^3/s)	Post-dam net change in stage for mean annual discharge[2] (feet)	Spearman's rho	Trend test at 0.05 level of significance
Milford Lake (C, 1967)	27	06857100	1.7	1963–99	1,000	-9.05	-0.99	negative
	28	06856600	--	1917–99	1,000	-.25	-.34	no trend
Perry Lake (C, 1969)	29	06890900	0	1969–99	700	([5])	--	--
Pomona Lake (C, 1963)	30	06912500	.2	1963–99	200	-.50	-.43	negative
Toronto Lake (C, 1960)	31	07166000	3.5	1939–97	500	-3.35	-.97	negative
	32	07166500	43.6	1938–99	800	-.55	-.79	negative
Tuttle Creek Lake (C, 1962)	33	06887000	2.5	1954–99	2,500	-3.70	-.98	negative
Waconda Lake (B, 1967)	34	06875900	3.6	1964–99	300	([5])	--	--
	35	06876070	57.0	1990–99	600	([5])	--	--
Webster Reservoir	36	06873200	.4	1956–99	40	-1.75	-.74	negative
(B, 1956)	37	06873460	28.3	1978–99	50	-.70	-.70	negative
Wilson Lake (C, 1964)	38	06868200	.5	1963–99	90	-2.20	-.98	negative

[1]Discharges less than 100 ft^3/s are rounded to the nearest 10 ft^3/s, whereas discharges greater than 100 ft^3/s are rounded to the nearest 100 ft^3/s.

[2] In some cases, the period of record does not extend back to the date of dam completion.

[3] Analysis was not possible due to insufficient post-dam period of record.

[4] Gage moved 1.2 miles downstream in 1985. Net changes in stage are for 1964–84 and 1985–98, respectively.

[5] Analysis was not possible due to concrete control at or near gage site.

[6] Gage site located downstream from both Pomona and Melvern Lakes.

[7] Distance downstream from Pomona and Melvern Lakes, respectively.

elevation. For this purpose, a nonparametric Spearman's rho correlation coefficient was computed. An advantage of Spearman's rho is that, because it is based on ranks of the data, it is more resistant to outlier effects than the more commonly used Pearson's r correlation coefficient (Helsel and Hirsch, 1992). Statistical significance of trends was tested using a level of significance of 0.05.

CHANNEL-BED ELEVATION CHANGES

For 15 of the 17 reservoirs for which analysis for the first gaging station downstream from the dam was possible, a statistically significant negative trend (that is, decreasing stage with time) was indicated. Thus, at these locations, channel-bed lowering was indicated by the decreasing stage. The two exceptions were the Neosho River at Burlington downstream from John Redmond Reservoir (fig. 2), which had no statistically significant trend in channel-bed elevation downstream, and the Marais des Cygnes River near Pomona downstream from Melvern Lake (fig. 3), for which a statistically significant positive trend (that is, increasing stage with time) was indicated (table 1). However, for Melvern Lake, the gaging station is located a considerable distance downstream (28.2 mi) and thus may not be indicative of conditions immediately downstream from the dam. Also, artificial control is provided by an overflow dam located 4.7 mi downstream from the gaging station. The presence of the overflow dam may cause backwater effects and deposition of material on the channel bed in the vicinity of the gaging station. In figures 2–31, each data point represents the starting date for an individual rating curve.

For several of the gaging stations for which a statistically significant negative trend was indicated, a

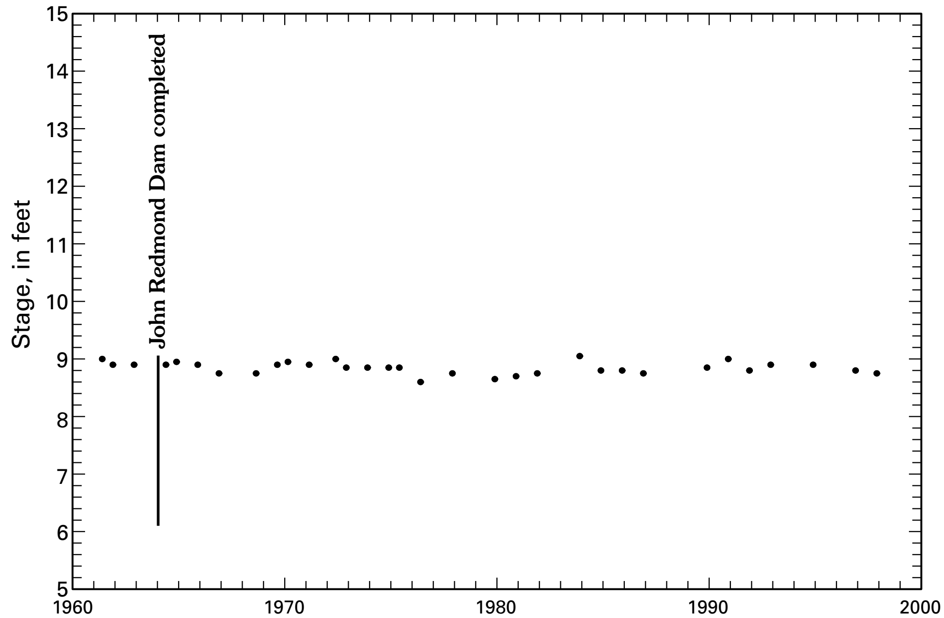

Figure 2. Change in river/stream stage for mean annual discharge (1,700 cubic feet per second) of Neosho River at Burlington (gaging station 07182510, map index number 14, downstream from John Redmond Reservoir), 1961–97.

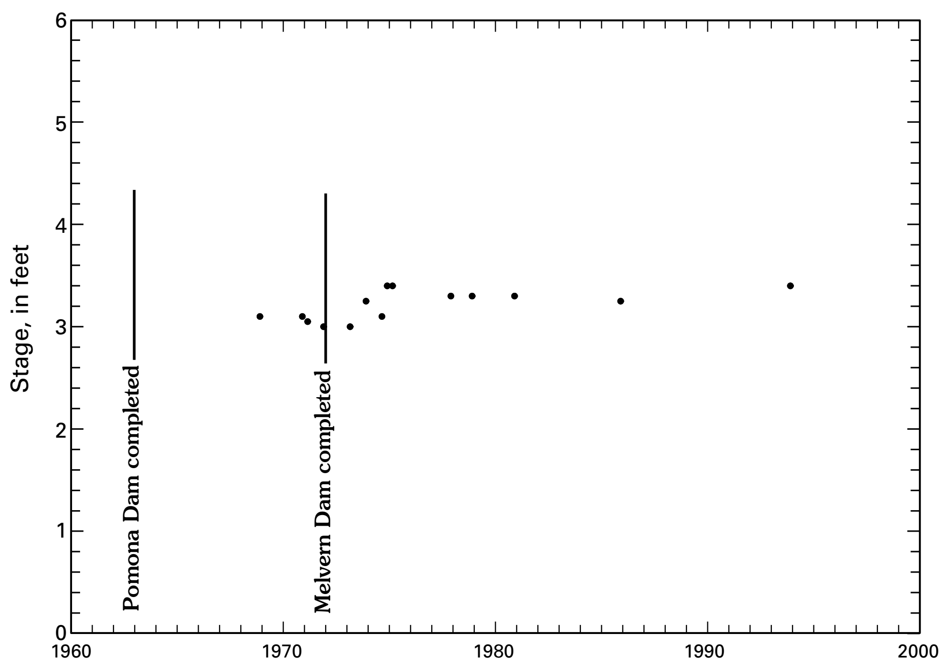

Figure 3. Change in river/stream stage for mean annual discharge (600 cubic feet per second) of Marais des Cygnes River near Pomona (gaging station 06913000, map index number 25, downstream from Melvern and Pomona Lakes), 1968–93.

substantial net decrease in stage was determined. Downstream from Milford (fig. 4) and Kanopolis (fig. 5) Lakes, the net decrease in stage was 9.05 and 5.80 ft, respectively. A decrease in stage of about 3.5 ft was determined downstream from Toronto (fig. 6) and Tuttle Creek (fig. 7) Lakes. Downstream from Big Hill (fig. 8), Elk City (fig. 9), Marion (fig. 10), and Wilson (fig. 11) Lakes, and Webster Reservoir (fig. 12), a decrease in stage of about 2 ft was determined. The decrease in stage determined for the gaging station downstream from Big Hill Lake may be attributable, in part, to other disturbances (bridge construction, channel modifications) that occurred prior to and during the construction of the dam. Also, outflow channel repair in the vicinity of the gaging station downstream from Elk City Lake may have contributed to the decrease in stage determined for this site. With the exception of Clinton Lake (-1.10 ft) (fig. 13), the decrease in stage at the first gaging station downstream from the remaining reservoirs (for which a statistically significant negative trend was indicated) was less than 1 ft (table 1) (figs. 14–18).

The geomorphic response of a channel downstream from a reservoir depends on the local conditions. For example, downstream from Kanopolis and Milford Lakes, the readily erodible sand and gravel channel beds have lowered continuously since the dams were completed in 1948 and 1967, respectively. In comparison, downstream from El Dorado and Hillsdale Lakes, minimal channel-bed lowering has occurred due to bedrock control (information on the composition of the channel bed at gaging stations is on file at the USGS office in Lawrence, Kansas). At the locations where the channel bed is actively lowering, the channel bed eventually will stabilize due to one or more possible causes including armoring, bedrock, flattening of the channel gradient, and downstream base-level control provided by grade-control structures or the confluence with a larger river or stream.

The pronounced lowering of the Republican River channel bed downstream from Milford Lake (fig. 4) began immediately after completion of the dam in 1967. From 1967 to 1997, the channel bed lowered at an average rate of about 0.3 ft/yr. However, as indicated by the slope of the data points (fig. 4), the rate of lowering appears to have slowed in recent years.

Ideally, the period of record for the first gaging station located downstream from a dam would extend back 10 or more years prior to dam construction. Such pre-dam information may be used to help ascertain whether or not the post-dam changes in channel-bed elevation are due primarily to the effects of regulation or to some combination of causes that may include regulation. Unfortunately, in most cases the first gaging station located downstream from a dam was installed to measure the discharge released from the dam. Thus, in such cases, the desired pre-dam information was limited or did not exist.

Such was the case for the first gaging station on the Republican River located downstream from Milford Lake, for which the period of record extended back only 3 years prior to the completion of the dam (fig. 4). Such limited pre-dam information was not sufficient to assess pre-dam changes in channel-bed elevation. However, pre-dam information for a gaging station upstream from Milford Lake at Clay Center (figs. 1 and 19) was available. At this upstream location, the Republican River channel bed has been stable since about 1938, with only minor fluctuations due to scour and fill processes. The stability of the channel bed at this upstream location provided additional evidence that the effects of regulation are a primary, though not necessarily only, cause of channel-bed lowering in the Republican River downstream from Milford Lake.

The lowering of the Smoky Hill River channel bed downstream from Kanopolis Lake (fig. 5) has been ongoing since completion of the dam in 1948. From 1948 to 1952, the channel bed lowered at a relatively rapid average rate of about 0.7 ft/yr. Then, from 1952 to 1997, the channel-bed lowering continued at an average rate of about 0.07 ft/yr. Because only 7 years of pre-dam information was available for this site (fig. 5), pre-dam changes in channel-bed elevation could not be meaningfully evaluated. Upstream from Kanopolis Lake at Ellsworth (figs. 1 and 20), the Smoky Hill River channel bed has been stable or slowly aggrading since 1950. The upstream versus downstream contrast in channel-bed elevation change since completion of the dam indicated that regulation is likely a primary cause of channel-bed lowering downstream from Kanopolis Lake.

The channel bed of the Big Blue River downstream from Tuttle Creek Lake lowered at an average rate of about 0.1 ft/yr from 1962 (year of dam completion) to 1997 (fig. 7). Downstream from Toronto Lake, the channel bed of the Verdigris River lowered at an average rate of about 0.09 ft/yr from 1960 (year of dam completion) to 1996 (fig. 6). The pre-dam period of record for both of these locations was con-

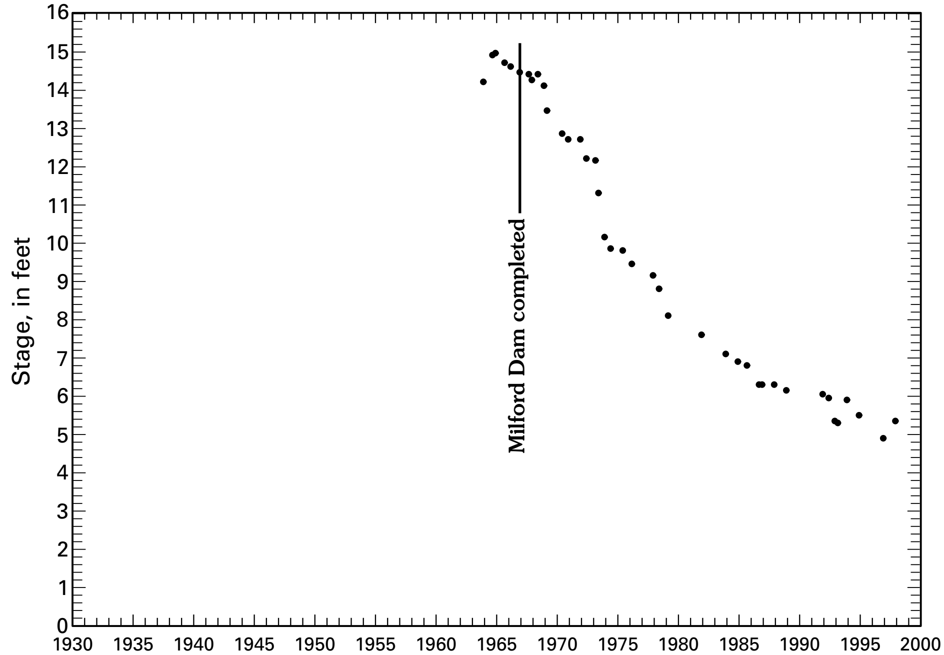

Figure 4. Change in river/stream stage for mean annual discharge (1,000 cubic feet per second) of Republican River below Milford Dam (gaging station 06857100, map index number 27, downstream from Milford Lake), 1963–97.

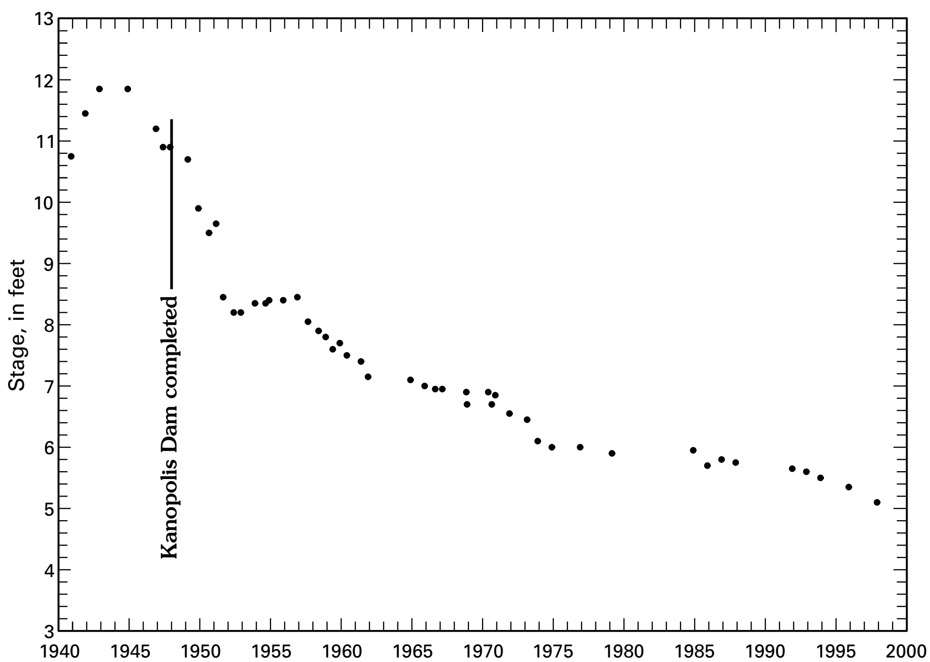

Figure 5. Change in river/stream stage for mean annual discharge (300 cubic feet per second) of Smoky Hill River near Langley (gaging station 06865500, map index number 15, downstream from Kanopolis Lake), 1940–97.

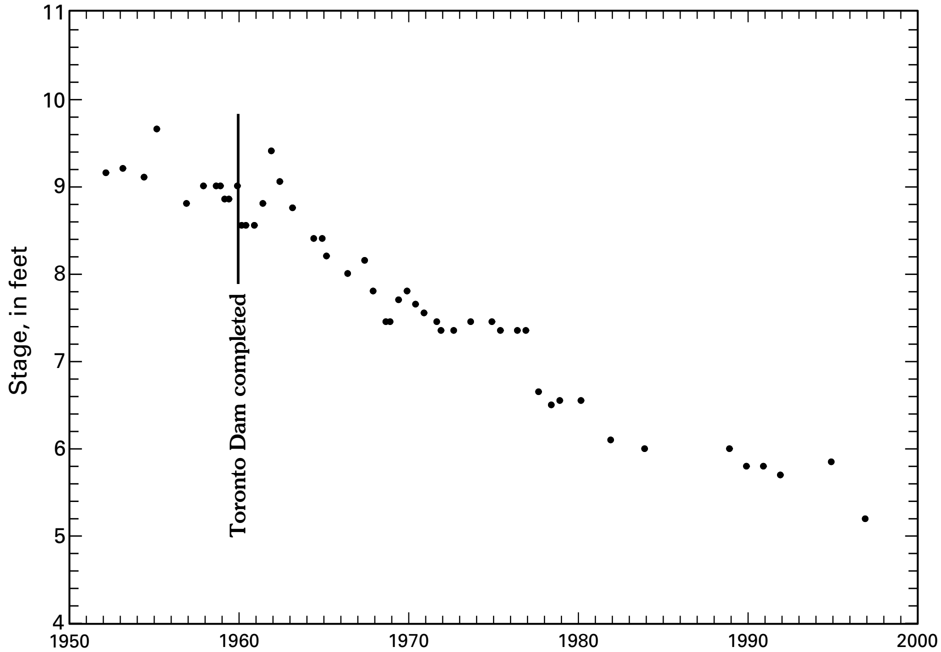

Figure 6. Change in river/stream stage for mean annual discharge (500 cubic feet per second) of Verdigris River near Coyville (gaging station 07166000, map index number 31, downstream from Toronto Lake), 1952–96.

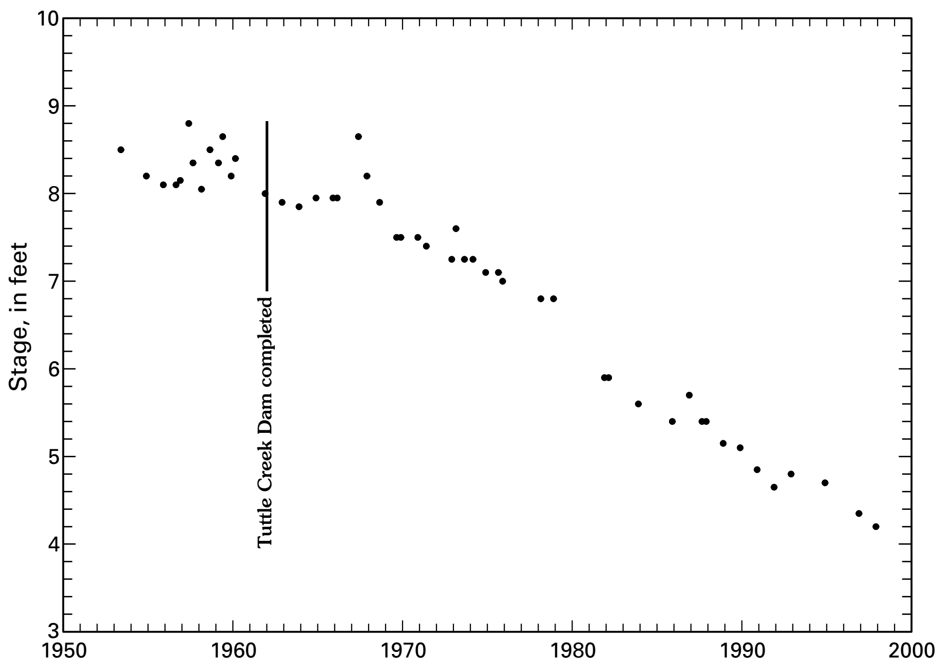

Figure 7. Change in river/stream stage for mean annual discharge (2,500 cubic feet per second) of Big Blue River near Manhattan (gaging station 06887000, map index number 33, downstream from Tuttle Creek Lake), 1953–97.

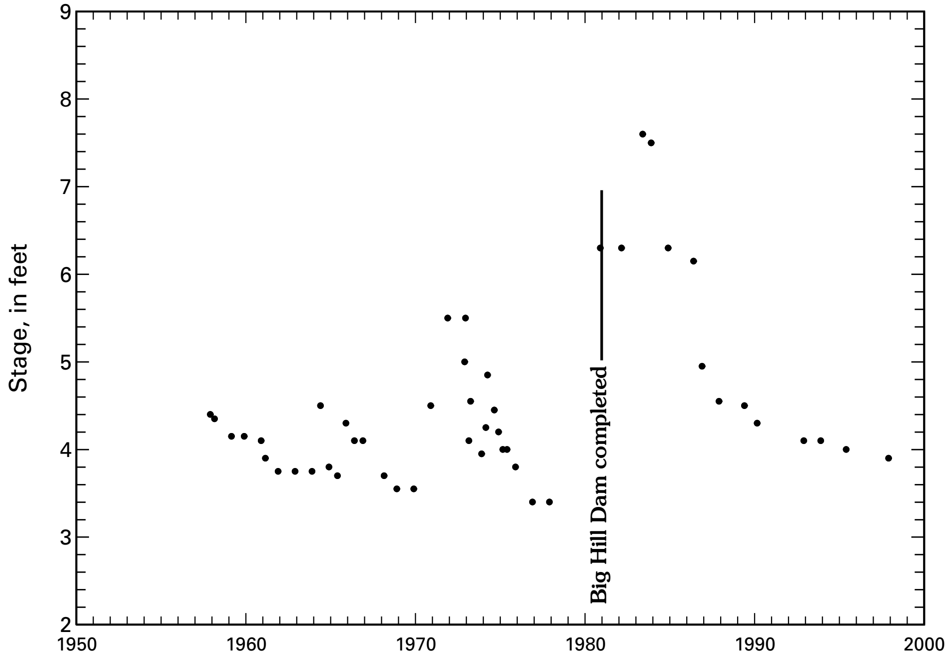

Figure 8. Change in river/stream stage for mean annual discharge (30 cubic feet per second) of Big Hill Creek near Cherryvale (gaging station 07170700, map index number 1, downstream from Big Hill Lake), 1957–97.

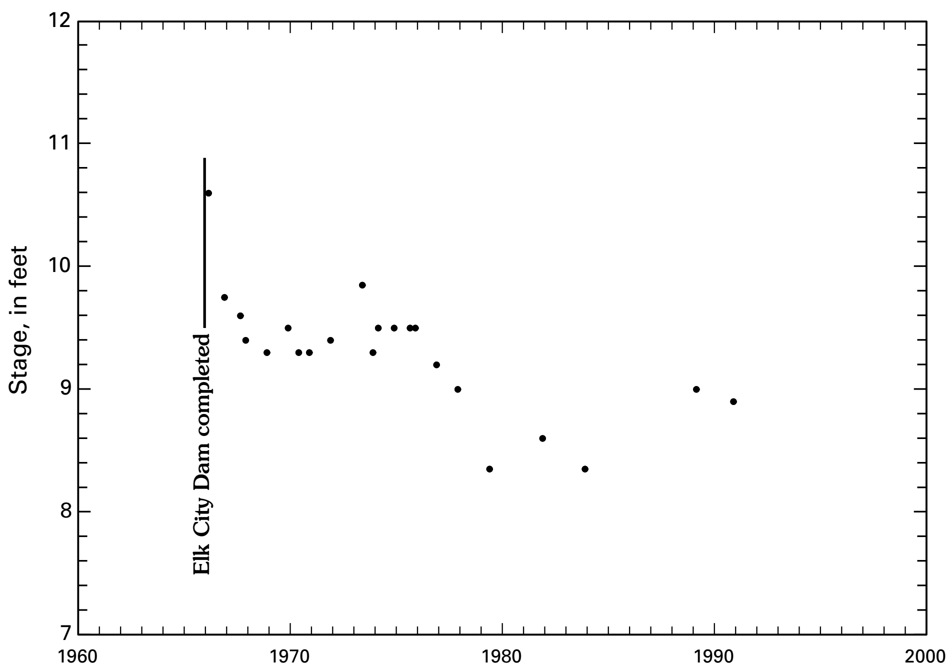

Figure 9. Change in river/stream stage for mean annual discharge (500 cubic feet per second) of Elk River below Elk City Lake (gaging station 07170060, map index number 10, downstream from Elk City Lake), 1966–90.

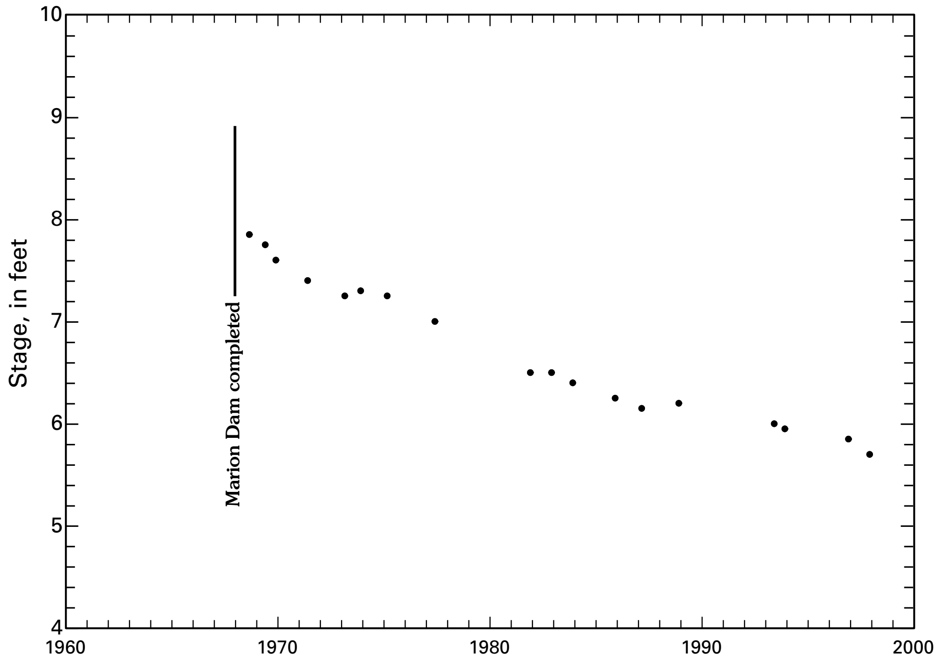

Figure 10. Change in river/stream stage for mean annual discharge (80 cubic feet per second) of North Cottonwood River below Marion Lake (gaging station 07179795, map index number 23, downstream from Marion Lake), 1968–97.

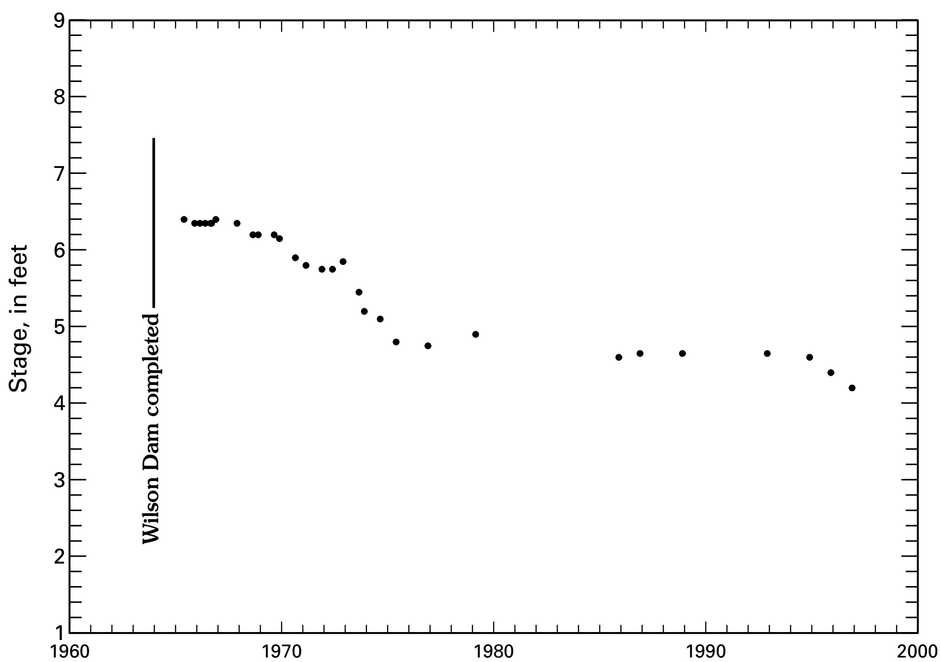

Figure 11. Change in river/stream stage for mean annual discharge (90 cubic feet per second) of Saline River at Wilson Dam (gaging station 06868200, map index number 38, downstream from Wilson Lake), 1965–96.

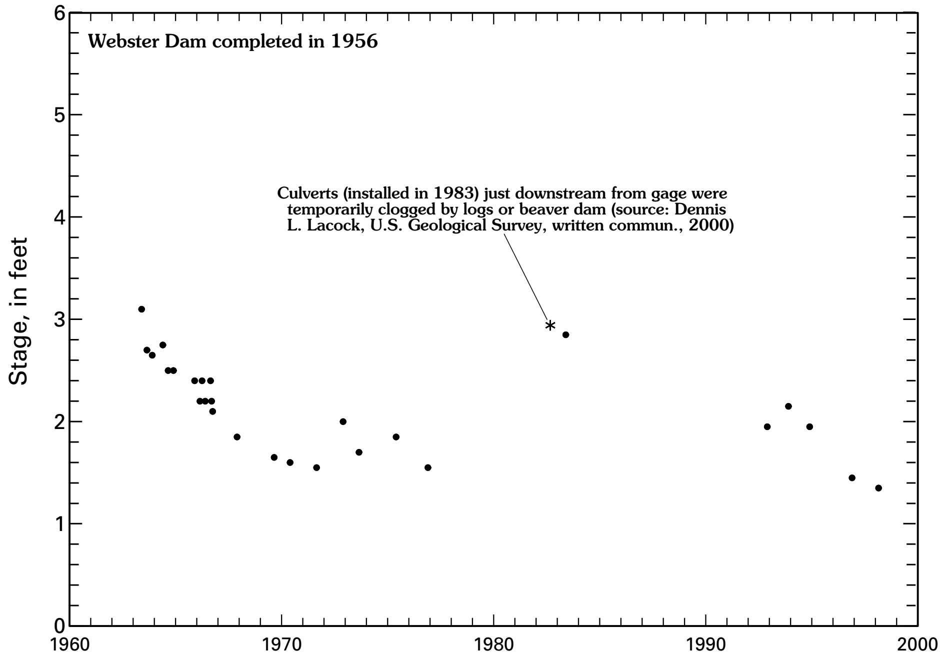

Figure 12. Change in river/stream stage for mean annual discharge (40 cubic feet per second) of South Fork Solomon River below Webster Reservoir (gaging station 06873200, map index number 36, downstream from Webster Reservoir), 1963–98.

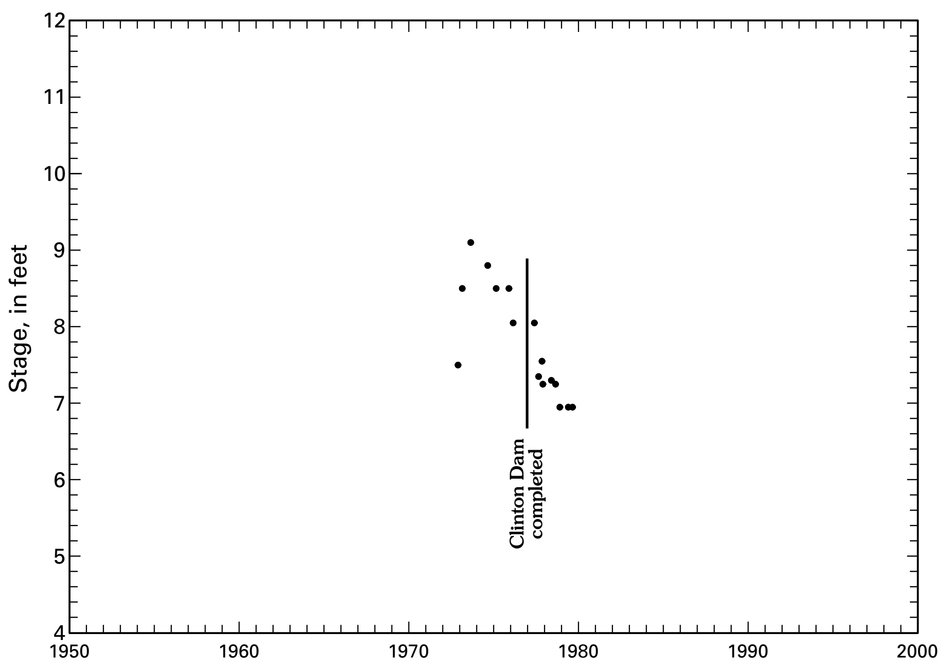

Figure 13. Change in river/stream stage for mean annual discharge (300 cubic feet per second) of Wakarusa River below Clinton Dam (gaging station 06891483, map index number 5, downstream from Clinton Lake), 1972–79.

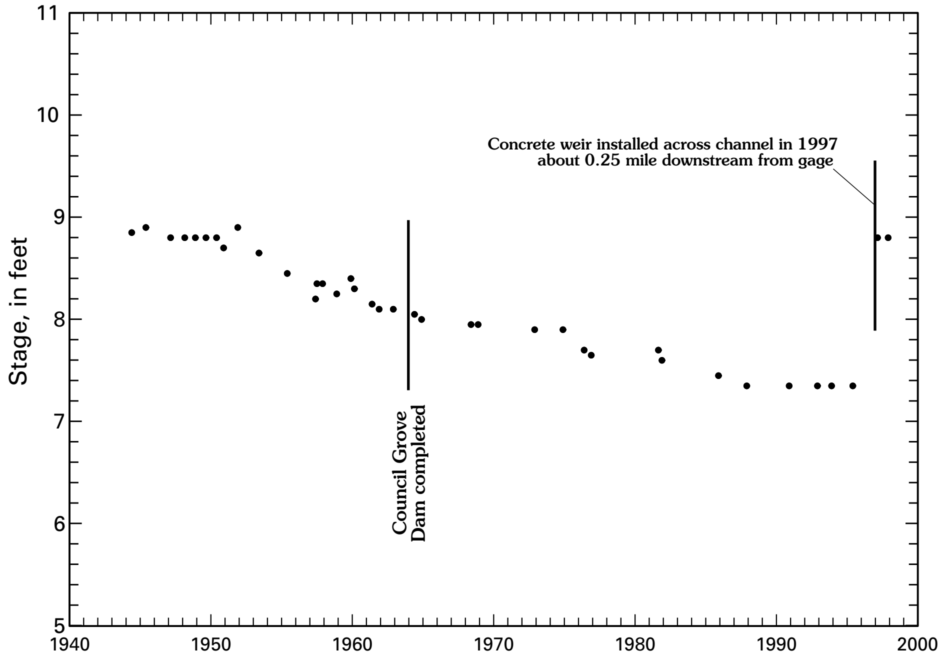

Figure 14. Change in river/stream stage for mean annual discharge (100 cubic feet per second) of Neosho River at Council Grove (gaging station 07179500, map index number 7, downstream from Council Grove Lake), 1944–97.

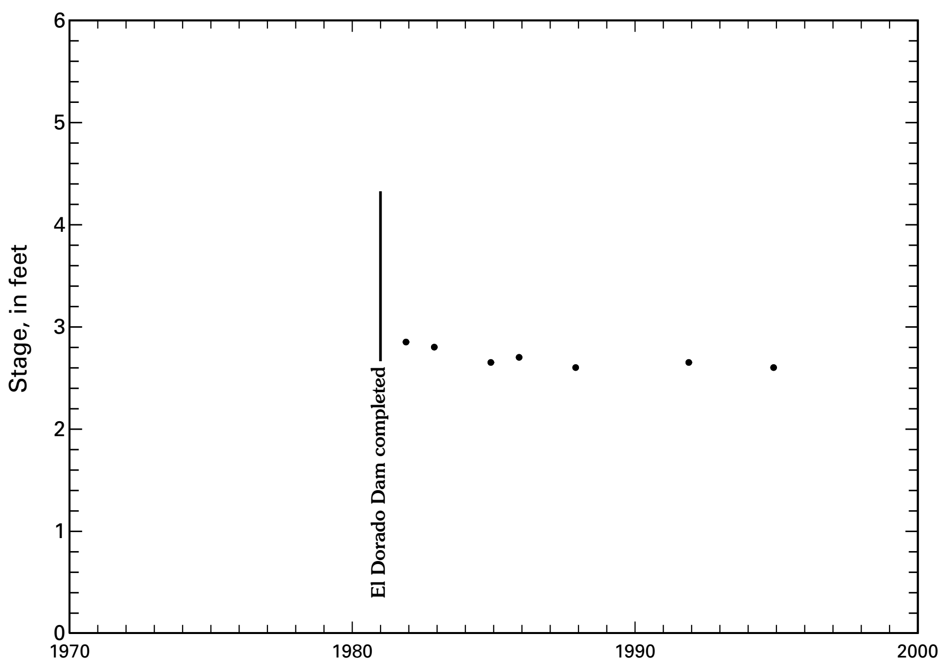

Figure 15. Change in river/stream stage for mean annual discharge (200 cubic feet per second) of Walnut River at Highway 54 east of El Dorado (gaging station 07146830, map index number 9, downstream from El Dorado Lake), 1981–94.

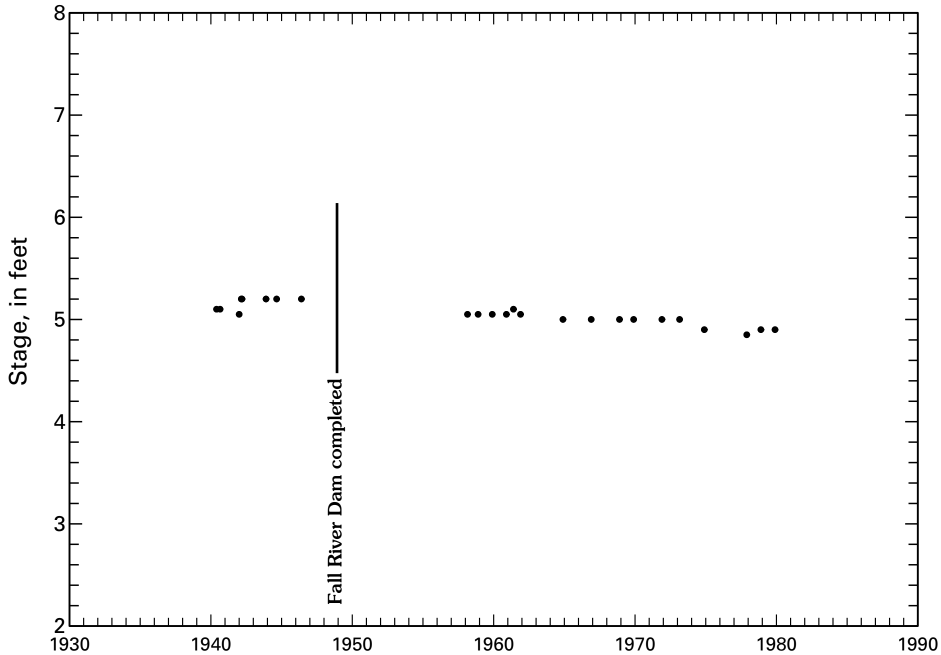

Figure 16. Change in river/stream stage for mean annual discharge (300 cubic feet per second) of Fall River near Fall River (gaging station 07168500, map index number 11, downstream from Fall River Lake), 1940–79.

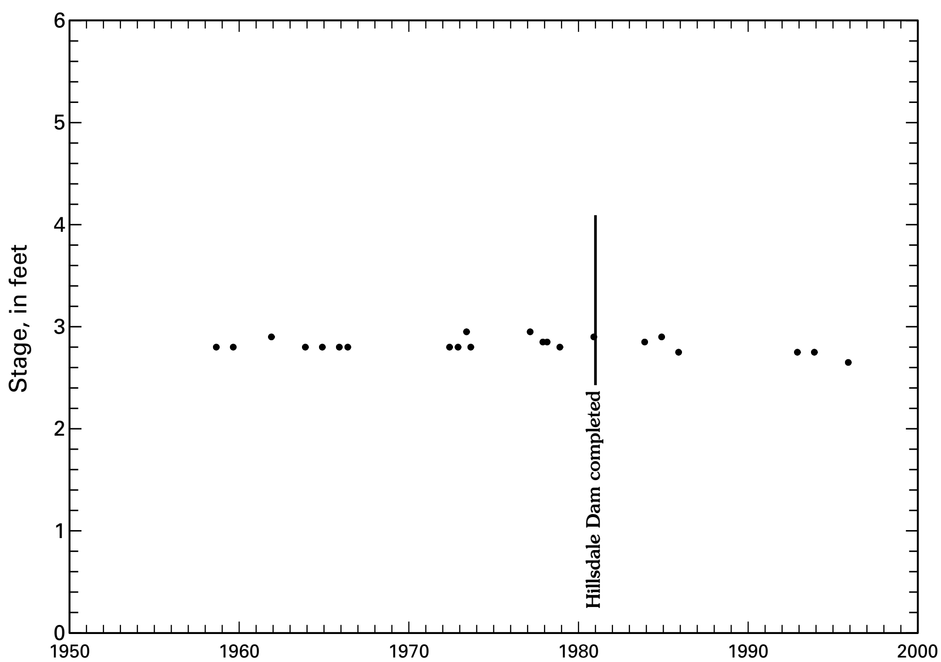

Figure 17. Change in river/stream stage for mean annual discharge (100 cubic feet per second) of Big Bull Creek near Hillsdale (gaging station 06915000, map index number 13, downstream from Hillsdale Lake), 1958–95.

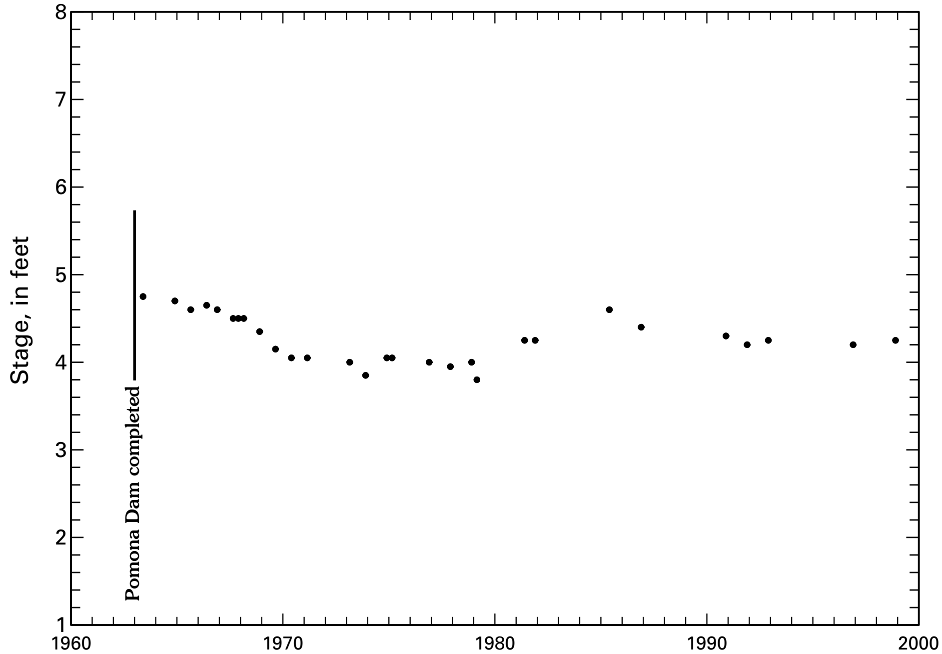

Figure 18. Change in river/stream stage for mean annual discharge (200 cubic feet per second) of Hundred and Ten Mile Creek near Quenemo (gaging station 06912500, map index number 30, downstream from Pomona Lake), 1963–98.

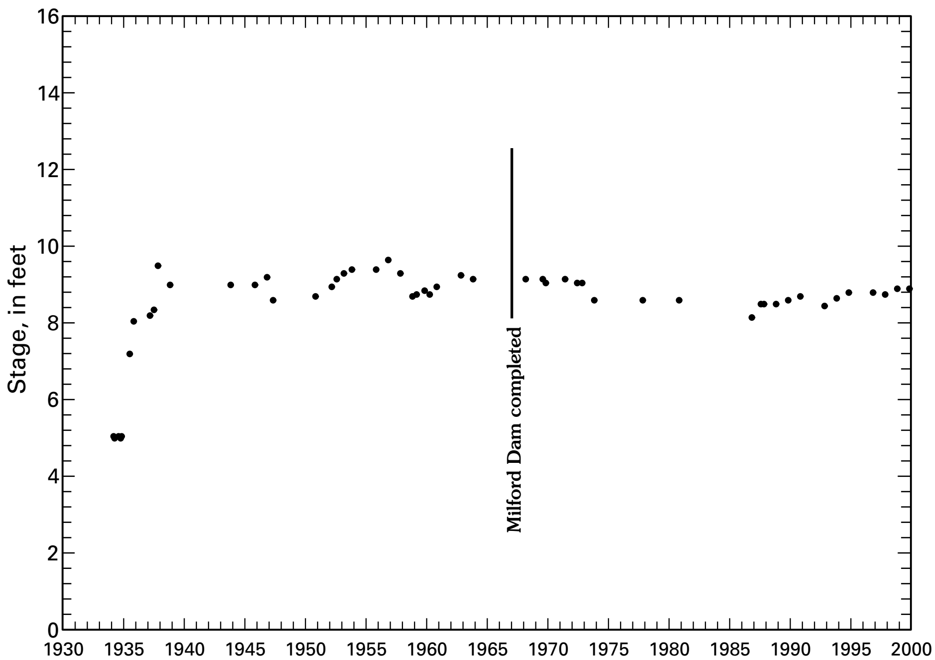

Figure 19. Change in river/stream stage for mean annual discharge (1,000 cubic feet per second) of Republican River at Clay Center (gaging station 06856600, map index number 28, upstream from Milford Lake), 1934–99.

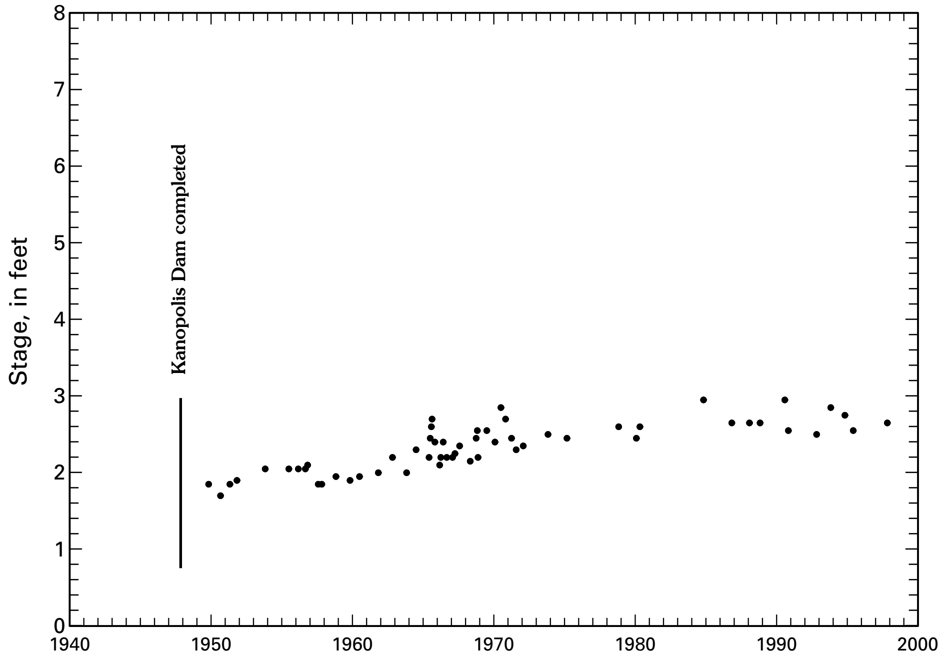

Figure 20. Change in river/stream stage for mean annual discharge (200 cubic feet per second) of Smoky Hill River at Ellsworth (gaging station 06864500, map index number 17, upstream from Kanopolis Lake), 1949–97.

sidered too short (less than 10 years) to meaningfully evaluate pre-dam changes in channel-bed elevation.

Sufficient information to evaluate pre-dam changes in channel-bed elevation at the first gaging station downstream from the dam was available for Hillsdale, Big Hill, and Council Grove Lakes. Downstream from Hillsdale Lake (fig. 17), the stability of the Big Bull Creek channel bed due to bedrock control is evident throughout the period of record. Downstream from Big Hill Lake (fig. 8), pre-dam changes in the Big Hill Creek channel-bed elevation were caused, in part, by multiple disturbances including bridge construction and channel modifications. Downstream from Council Grove Lake (fig. 14), lowering of the Neosho River channel bed was ongoing before, during, and after the construction of the dam. The channel bed has been stable since the late 1980s due to bedrock control.

Changes in channel-bed elevation upstream from most of the reservoirs was not investigated because either the change in channel-bed elevation at the first gaging station downstream from the dam was relatively minor or unknown, no upstream gaging station existed, the upstream gaging station was located upstream from one or more major tributaries, or the period of record for the upstream gaging station was too short.

Although channel-bed lowering was typical at the first gaging station downstream from the dams, the results were more mixed for the second gaging stations located farther downstream. For the second gaging station located downstream from Cedar Bluff Reservoir (fig. 21), Fall River Lake (fig. 22), Toronto Lake (fig. 23), and Webster Reservoir (fig. 24), a statistically significant negative trend in stage was indicated. For these gaging stations, which were located from about 21 to 44 mi downstream from the dams, the net decrease in stage was about 1 ft or less.

No statistically significant trend in stage was indicated for the second gaging station located downstream from Clinton (fig. 25), Council Grove (fig. 26), Kanopolis (fig. 27), and Marion (fig. 28) Lakes, and Kirwin Reservoir (fig. 29). These gaging stations were located from about 5 to 41 mi downstream from the dams. A statistically significant positive trend in stage was determined for the second gaging station located about 48 mi downstream from both Keith Sebelius (fig. 30) and Melvern (fig. 31) Lakes. For Waconda Lake, analysis was not possible for either of the two downstream gaging stations due to concrete control at or near the gage sites. It is uncertain if the trends in

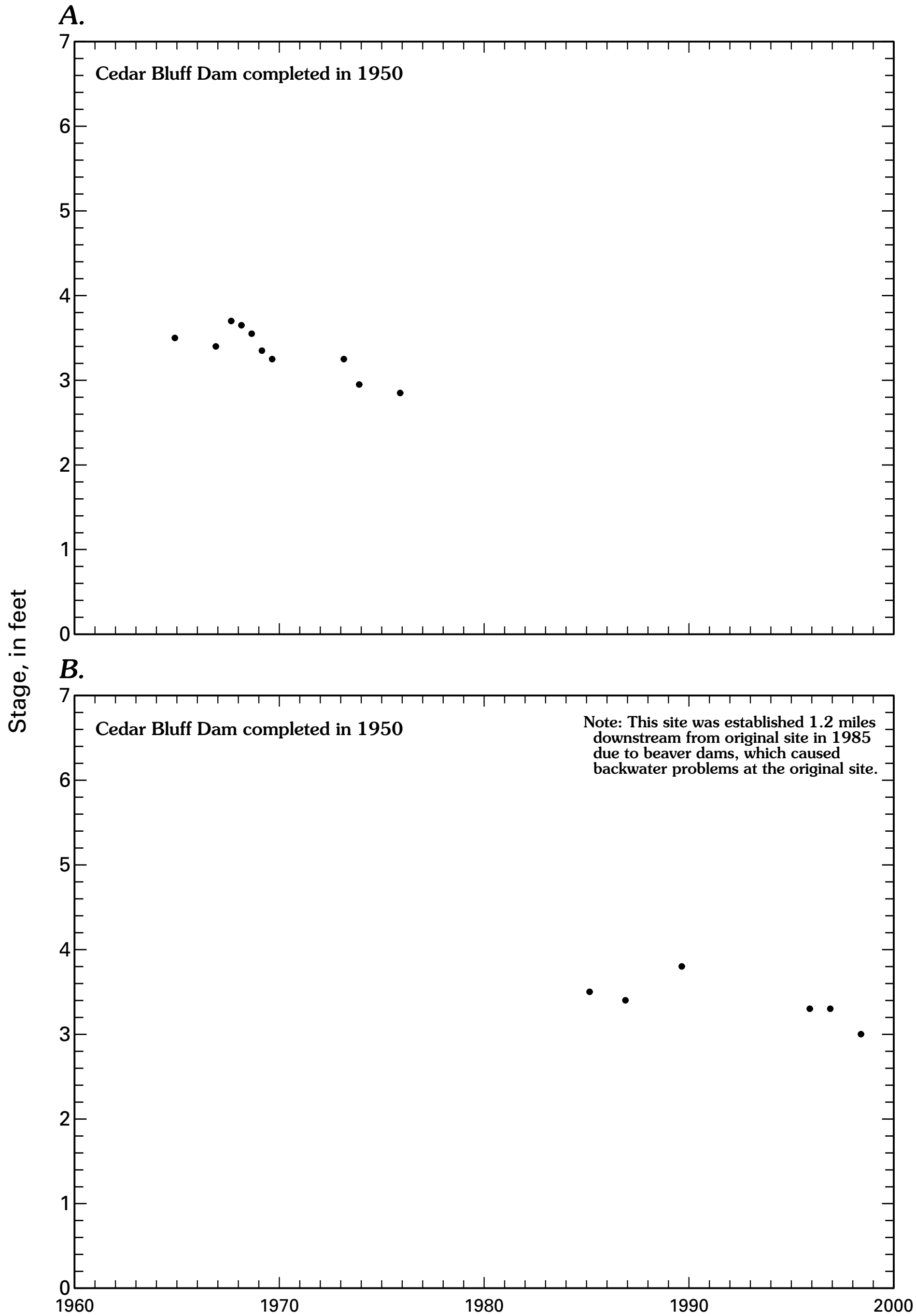

Figure 21. Change in river/stream stage for mean annual discharge (20 cubic feet per second) of Smoky Hill River near Schoenchen (gaging station 06862700, map index number 3, downstream from Cedar Bluff Reservoir), 1964–98.

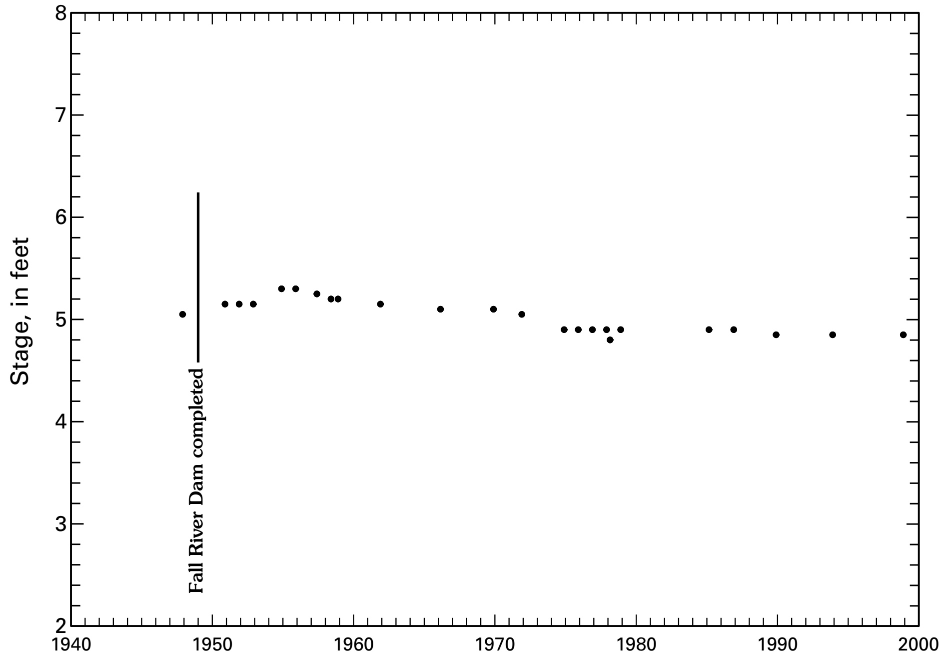

Figure 22. Change in river/stream stage for mean annual discharge (500 cubic feet per second) of Fall River at Fredonia (gaging station 07169500, map index number 12, downstream from Fall River Lake), 1947–98.

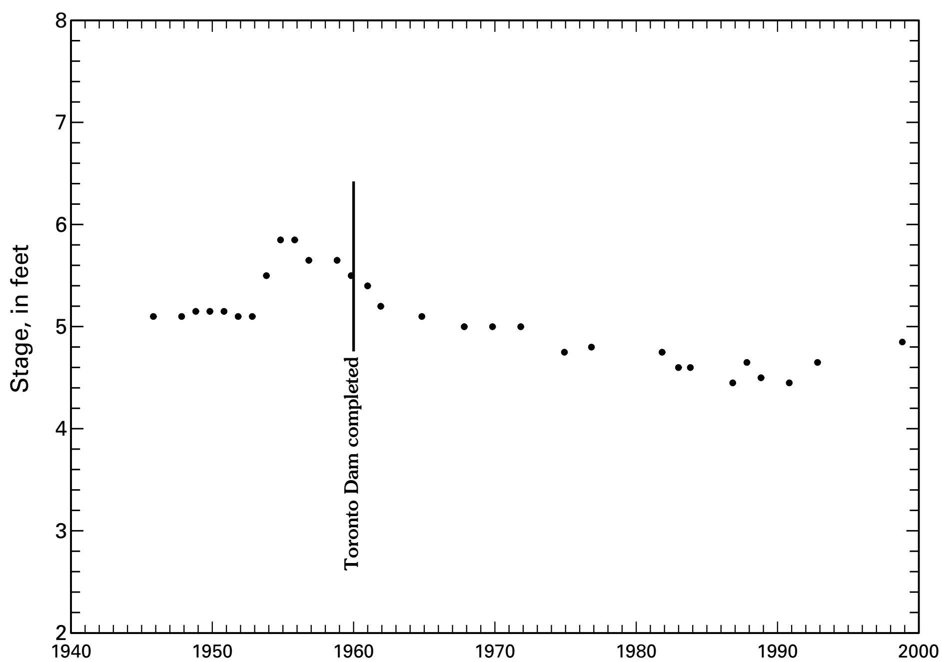

Figure 23. Change in river/stream stage for mean annual discharge (800 cubic feet per second) of Verdigris River near Altoona (gaging station 07166500, map index number 32, downstream from Toronto Lake), 1945–98.

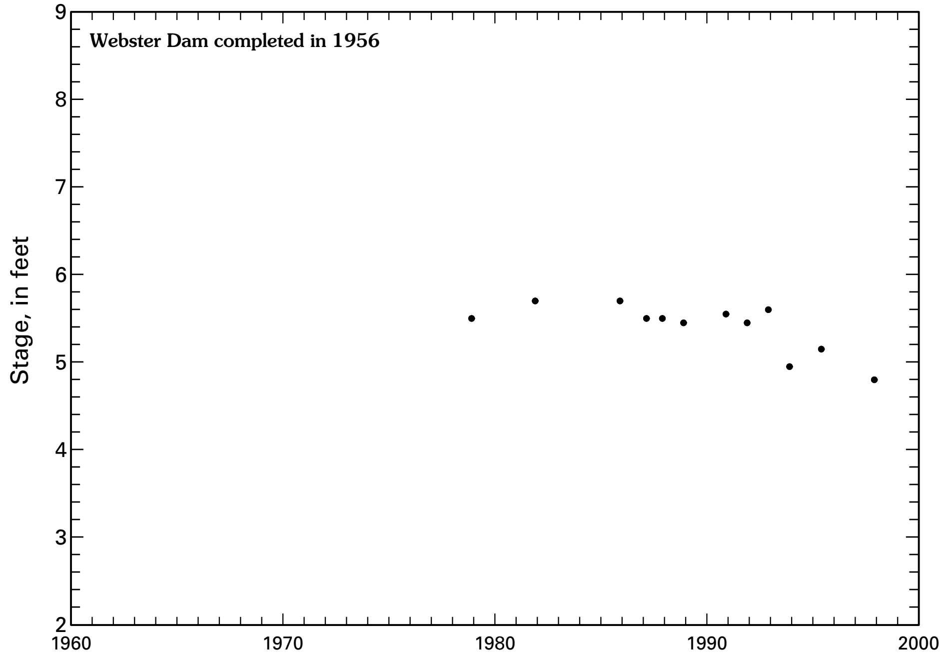

Figure 24. Change in river/stream stage for mean annual discharge (50 cubic feet per second) of South Fork Solomon River at Woodston (gaging station 06873460, map index number 37, downstream from Webster Reservoir), 1978–97.

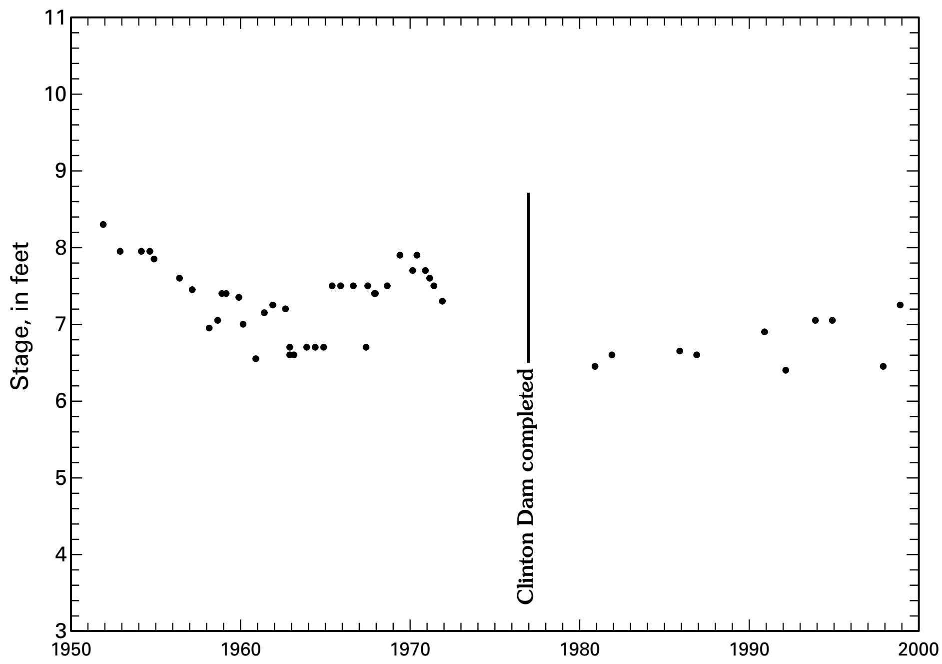

Figure 25. Change in river/stream stage for mean annual discharge (300 cubic feet per second) of Wakarusa River near Lawrence (gaging station 06891500, map index number 6, downstream from Clinton Lake), 1951–98.

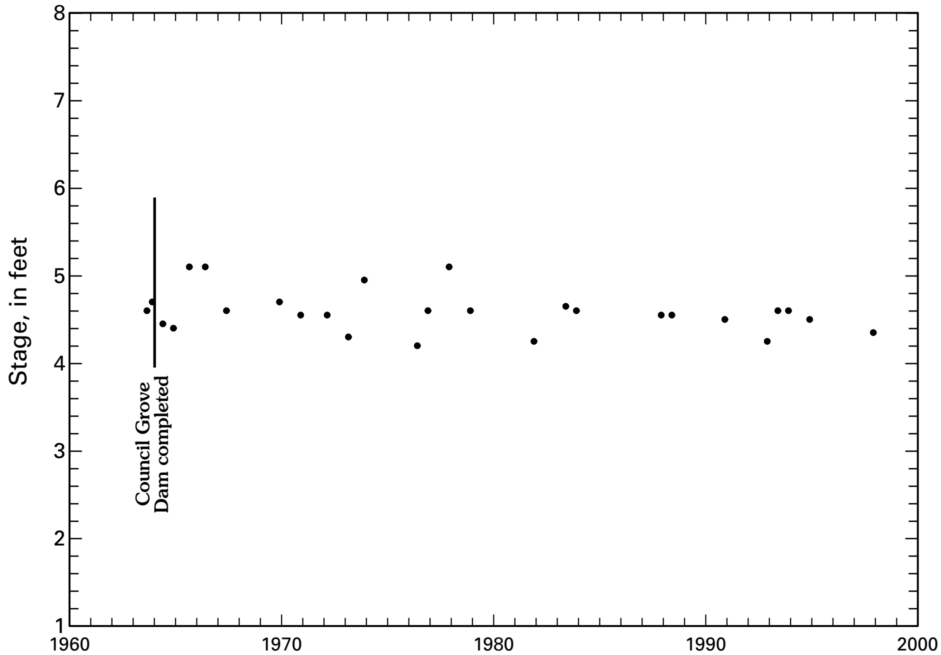

Figure 26. Change in river/stream stage for mean annual discharge (300 cubic feet per second) of Neosho River near Americus (gaging station 07179730, map index number 8, downstream from Council Grove Lake), 1963–97.

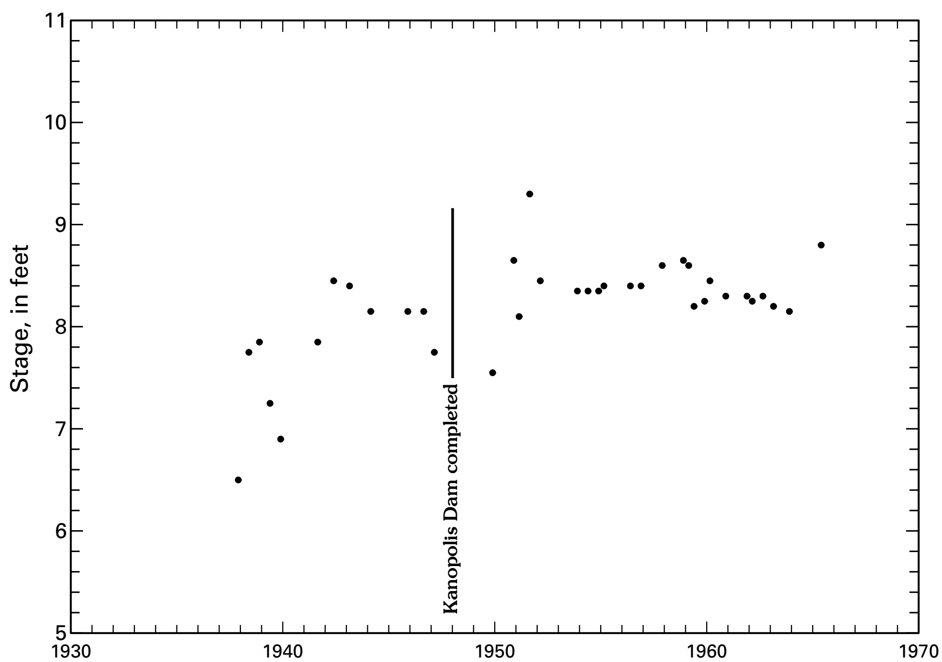

Figure 27. Change in river/stream stage for mean annual discharge (400 cubic feet per second) of Smoky Hill River at Lindsborg (gaging station 06866000, map index number 16, downstream from Kanopolis Lake), 1937–65.

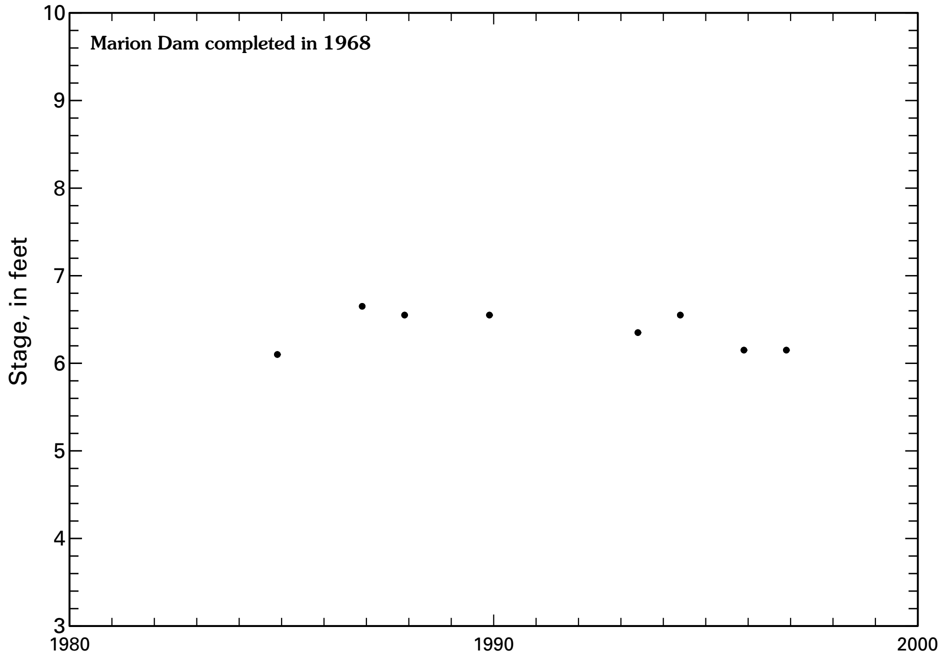

Figure 28. Change in river/stream stage for mean annual discharge (200 cubic feet per second) of Cottonwood River at Marion (gaging station 07180200, map index number 24, downstream from Marion Lake), 1984–96.

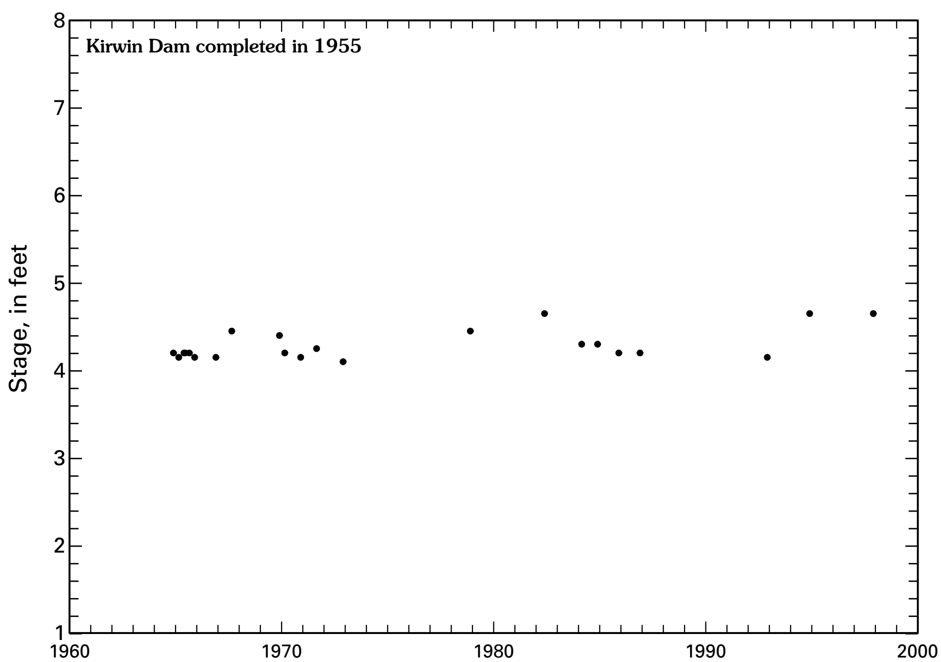

Figure 29. Change in river/stream stage for mean annual discharge (100 cubic feet per second) of North Fork Solomon River at Portis (gaging station 06872500, map index number 21, downstream from Kirwin Reservoir), 1964–97.

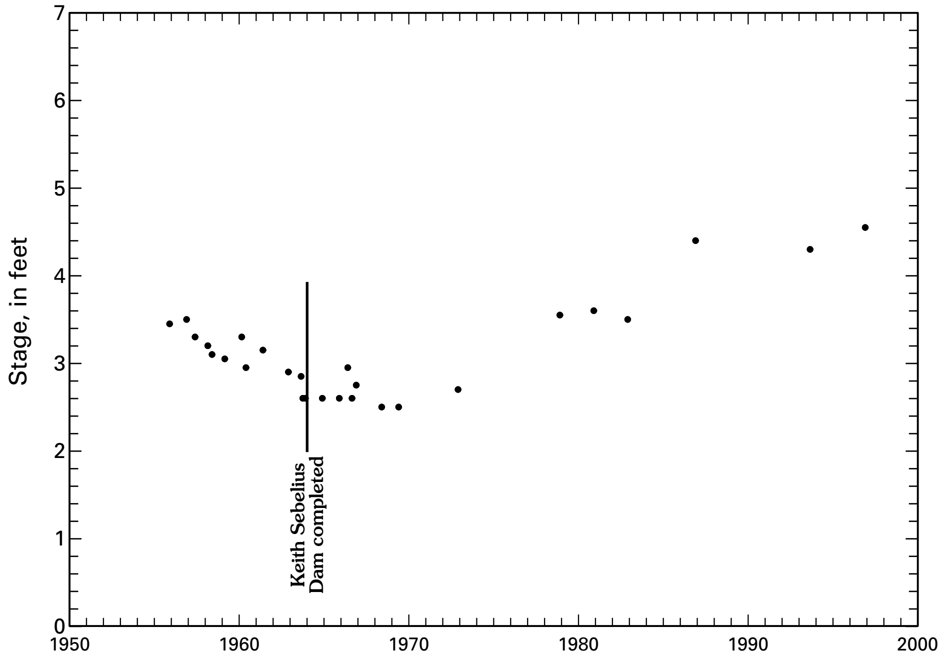

Figure 30. Change in river/stream stage for mean annual discharge (30 cubic feet per second) of Prairie Dog Creek near Woodruff (gaging station 06848500, map index number 19, downstream from Keith Sebelius Lake), 1955–96.

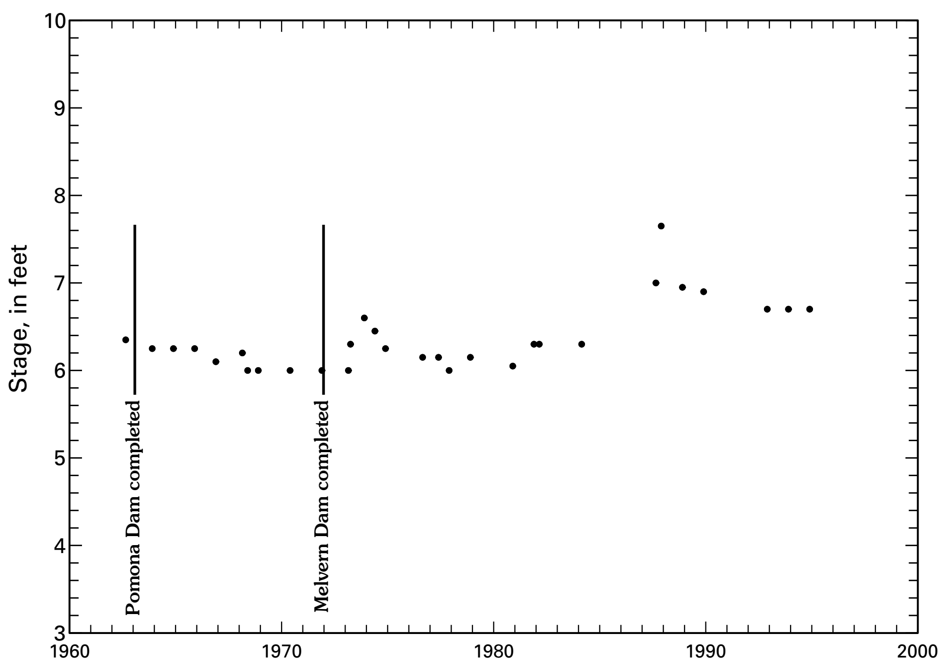

Figure 31. Change in river/stream stage for mean annual discharge (700 cubic feet per second) of Marais des Cygnes River near Ottawa (gaging station 06913500, map index number 26, downstream from Melvern Lake), 1962–94.

channel-bed elevation determined for some of the second gaging stations are related to the upstream dam.

An assessment of the downstream extent of channel-bed elevation changes was limited by a lack of information. For example, downstream from Kanopolis Lake, the first and second gaging stations are located at distances of about 0.8 and 38 mi from the dam. For the first gaging station, a statistically significant negative trend was indicated with a net decrease in stage of 5.80 ft. No trend was indicated for the second gaging station. Thus, the downstream limit of channel-bed lowering was somewhere in the approximately 37-mi-long reach of river channel between the two gaging stations. Williams and Wolman (1984) determined that about 1.6 ft of channel-bed lowering had occurred at a location 3 mi downstream from the dam as of 1971.

Additional information, which may not be available, is necessary to more effectively assess the downstream extent of channel-bed elevation changes. For some reservoirs constructed by the U.S. Army Corps of Engineers (table 1), multiple-date, cross-sectional information may be available for several sites downstream. If available, such information may be used to help assess the magnitude and downstream extent of post-dam changes in channel depth, width, and geometry.

An assessment of the effect of time on channel-bed elevation change was limited to the four reservoirs for which the largest downstream changes in channel-bed elevation were determined. Downstream from Milford Lake, the rate of lowering of the Republican River channel bed appeared to slow about 1980 (13 years after dam closure) but continued at least through 1997 (fig. 4). Eventually, the channel bed at this location will stabilize due to a combination of factors including reduced slope, bedrock control, and base-level control provided by the Kansas River downstream. Downstream from Kanopolis Lake, the rate of lowering of the Smoky Hill River channel bed decreased substantially in 1952 (4 years after dam closure) but continued at least through 1997 (fig. 5). Downstream from Toronto Lake, the rate of lowering of the Verdigris River channel bed has decreased gradually over time but continued at least through 1996 (fig. 6). The rate of lowering of the Big Blue River channel bed downstream from Tuttle Creek Lake showed no indication of slowing as of 1997 (fig. 7). At these locations, the adjustment of the channel bed has been ongoing for several decades and is not yet complete.

SUMMARY AND CONCLUSIONS

Available information from USGS streamflow-gaging stations was used to assess channel-bed elevation changes downstream from 24 large Federal reservoirs in Kansas. For 15 of the 17 reservoirs for which analysis for the first gaging station downstream from the dam was possible, a statistically significant negative trend in channel-bed elevation (represented by the trend in river/stream stage for the mean annual discharge) was indicated. At these gaging stations (typically located 5 mi or less downstream from the dam), the net decrease in channel-bed elevation ranged between 0.25 (El Dorado and Hillsdale Lakes) to 9.05 ft (Milford Lake). The magnitude of channel-bed lowering downstream from the reservoirs likely was related to the composition of the channel bed and may be due, in part, to causes other than upstream regulation. The spatial and temporal variability of channel-bed elevation changes determined in this study were indicative of the variability of the factors that control the geomorphic response of river and stream channels downstream from reservoirs.

A determination of the magnitude and rate of channel-bed lowering downstream from a reservoir is important for understanding the geomorphic response of the channel to the changes imposed by the reservoir and the possible implications. At locations where the channel-bed elevation has decreased several feet and the lowering is ongoing, structures, property, and habitat may be threatened due to channel-bed and bank erosion. At locations where channel-bed lowering has been limited by bedrock, channel widening may be a concern. Thus, the magnitude and rate of channel-bed lowering may provide an indication of actual and potential channel change downstream from a reservoir. Additional investigation, perhaps involving the use of more streamflow-gage information, surveyed cross sections, and aerial photography, as well as a comprehensive analysis of channel-bed and bank composition, may provide a more complete understanding of channel change downstream from reservoirs and help to prioritize and plan channel stabilization and rehabilitation efforts.

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