Fluvial Sediment in the Drainage Area of K–79 Reservoir Kiowa Creek Basin Colorado

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1798–D

Prepared in cooperation with the
U.S. Department of Agriculture
Soil Conservation Service

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By JAMES C. MUNDORFF

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FLUVIAL SEDIMENT IN THE DRAINAGE AREA OF K–79 RESERVOIR, KIOWA CREEK BASIN, COLORADO

By JAMES C. MUNDORFF

ABSTRACT

As part of a national investigation of trap efficiency of detention reservoirs, a study was made of fluvial sediment in the drainage area of K–79 Reservoir in north-central El Paso County, Colo. This study by the U.S. Geological Survey was begun in 1956 and terminated in 1965. During this period, the average annual precipitation was near normal, although annual precipitation ranged from much below normal to much above normal. Drainage from most of the area passed through one or more upstream structures before reaching K–79 Reservoir.

From August 29, 1956, when the original survey of the reservoir was made, to July 27, 1965, when the final resurvey was made, observed sediment discharge from the reservoir was about 2,610 tons, or 2.5 acre-feet; sediment deposition in the reservoir was about 7.5 acre-feet. Trap efficiency was 75 percent as computed from computed volume of sediment outflow and measured volume of sediment desposition. Trap efficiency was 83 percent computed from the observed weight of sediment outflow and the computed weight of sediment deposition; the few available data on volume weight and particle sizes of deposited sediment suggest a volume weight of 80 pounds per cubic foot, or about 13,000 tons of sediment deposited in the reservoir.

Most of the sediment that entered K–79 Reservoir during 1956–60 originated in the downstream one-third of the drainage area, and during 1961–65 originated in a small area downstream from hydraulic structures built during 1960. All the bedload discharge and most of the suspended-sediment discharge from a large part of the drainage area were trapped before reaching K–79 Reservoir.

Flocculation of sediment within the reservoir probably is not a significant cause of deposition in the reservoir. The runoff from the area is of low mineralization and is not conducive to rapid flocculation, and the detention time for runoff is only a few hours.

Neither the amount of sediment deposition in, nor the trap efficiency of, K–79 Reservoir should be regarded necessarily as representative of similar but unstructured areas in the Colorado Piedmont or High Plains. Under present structured conditions in the K–79 drainage area, the effective life of the reservoir should be exceptionally long.

INTRODUCTION

A study of the characteristics of fluvial sediment in the drainage area of K–79 Reservoir, which is on Kiowa Creek in north-central El Paso County, Colo., began in April 1956 and ended in September 1965. This study was part of a national investigation of trap efficiency of detention reservoirs and was made by the Water Resources Division of the Geological Survey, U.S. Department of the Interior, in cooperation with the Soil Conservation Service, U.S. Department of Agriculture. The main purpose of the study was to determine the quantity and characteristics of sediment transported into, retained in, and discharged from K–79 Reservoir.

CHARACTERISTICS OF THE DRAINAGE AREA

The drainage area of K–79 Reservoir is the headwaters of Kiowa Creek. That part of the Kiowa Creek basin upstream from K–79 Reservoir has an area of 3.2 square miles. (See fig. 1.)

GEOLOGY AND DRAINAGE

Only two geologic formations have a direct influence on present erosion and sedimentation in the K–79 drainage area. The Castle Rock Conglomerate, of Oligocene age, is a conglomeratic arkose that occurs principally as caprock in the forested divide areas in the southwestern part of the area. The Dawson Arkose, of Late Cretaceous and Paleocene age, is predominantly arkosic sandstone and clay and is the surface material in most of the basin.

Upstream from K–79 Reservoir, Kiowa Creek has an average fall of about 100 feet per mile, and altitudes range from about 7,600 feet in the forested headwaters to about 7,290 feet at the reservoir site. Channels in most of the southwestern half of the K–79 drainage area are broad grassy drains. From the extreme headwaters to State Route 157, the channel generally has a grass cover and shows little evidence of rapid erosion. At the highway, the channel type changes abruptly to a well-defined, actively eroding channel. Bank erosion and bank caving are common between Route 157 and a small reservoir about three-eighths of a mile downstream. Figure 2 shows the channel of Kiowa Creek immediately downstream from Route 157.

Conspicuous erosion immediately downstream from reservoirs commonly is attributed to the "de-silting" of the water and the release of relatively clear water. The channel downstream from K–79 Reservoir has steep banks and has a deep scour area immediately downstream from the outlet tube. The general characteristics of the channel downstream from the reservoir, however, do not appear to be related

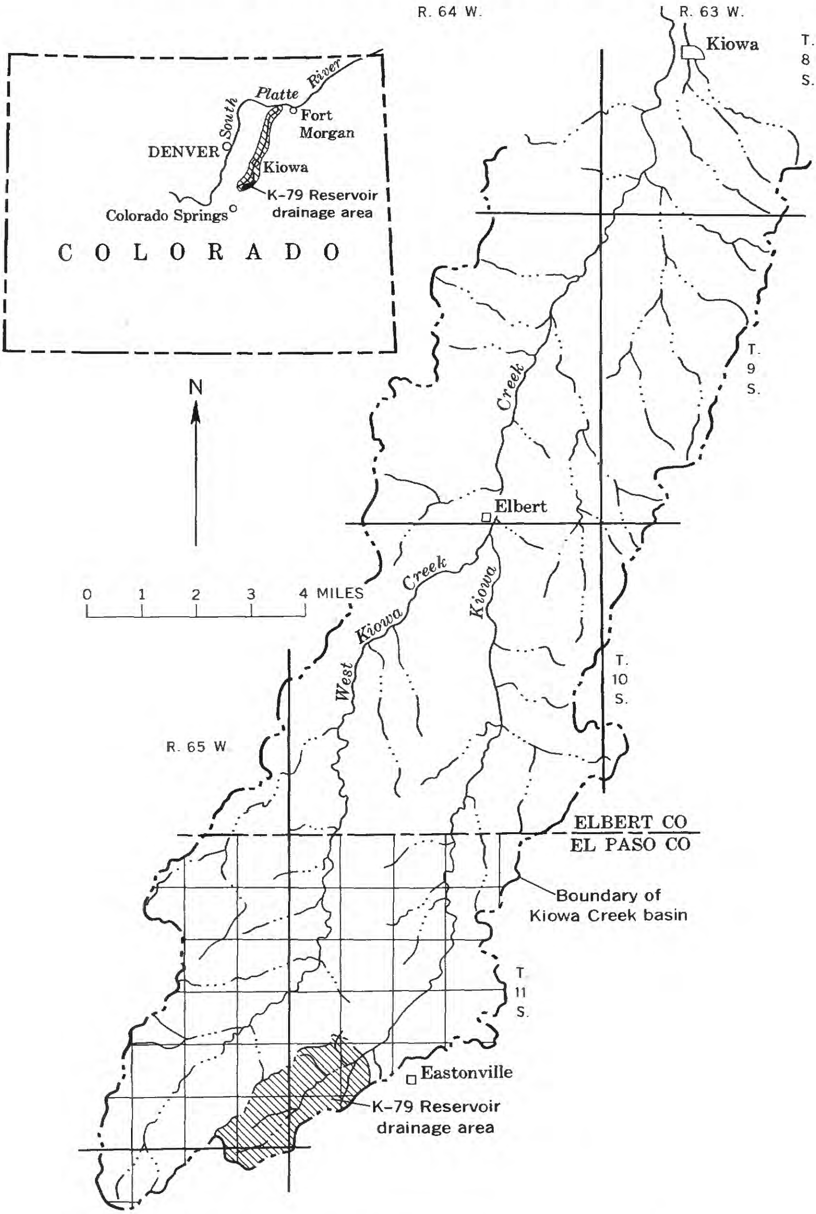

Figure 1.—Drainage area of K–79 Reservoir, upper Kiowa Creek basin.

to the presence of the reservoir. Aerial photographs taken in 1937, 1951, and 1955 give clear evidence that K–79 dam was constructed only a few feet upstream from a major scarp in Kiowa Creek and that this scarp was utilized in reservoir design as the discharge point for

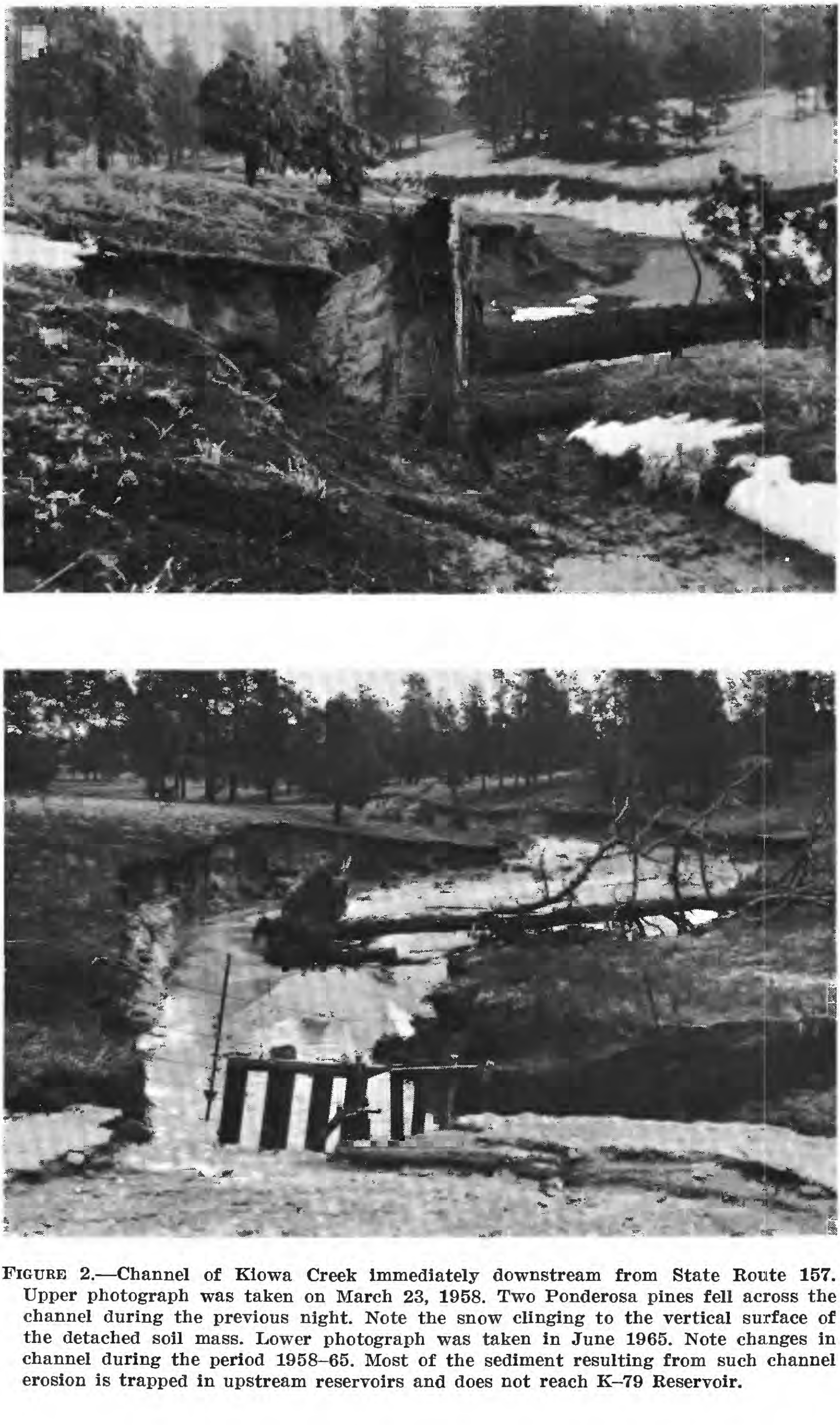

FIGURE 2.—Channel of Kiowa Creek immediately downstream from State Route 157. Upper photograph was taken on March 23, 1958. Two Ponderosa pines fell across the channel during the previous night. Note the snow clinging to the vertical surface of the detached soil mass. Lower photograph was taken in June 1965. Note changes in channel during the period 1958–65. Most of the sediment resulting from such channel erosion is trapped in upstream reservoirs and does not reach K–79 Reservoir.

outflow from the reservoir; as the scarp migrated upstream, the channel deepened accordingly. The dam has prevented normal upstream migration of the scarp, and appreciable scour has occurred just below the discharge tube (fig. 3).

Another scarp extends across the upstream end of the reservoir, and is clearly shown on aerial photographs taken in 1937, 1951, and 1955 and on maps made during the reservoir surveys of 1956 and 1965. The upstream migration of both this scarp and the major scarp at the downstream side of K–79 dam appears to have triggered the development of scarps in tributary channels as the mainstem scarps moved past each tributary. Neither the mainstem scarps nor the tributary scarps resulted from the presence of the reservoir.

VEGETATION AND LAND USE

Vegetation in the K–79 drainage area ranges from dense stands of Ponderosa pine in the southwestern part of the area to sparse short grass on the steep slopes in the northeastern part. Figure 4 shows the distribution of forest and grass within the area.

Stands of Ponderosa pine range from dense to scattered scrub growth. Gently sloping to hummocky meadowland in the west-cen-

FIGURE 3.—Downstream end of discharge tube from K–79 Reservoir, 1965. Dashed line shows location of bank in May 1957.

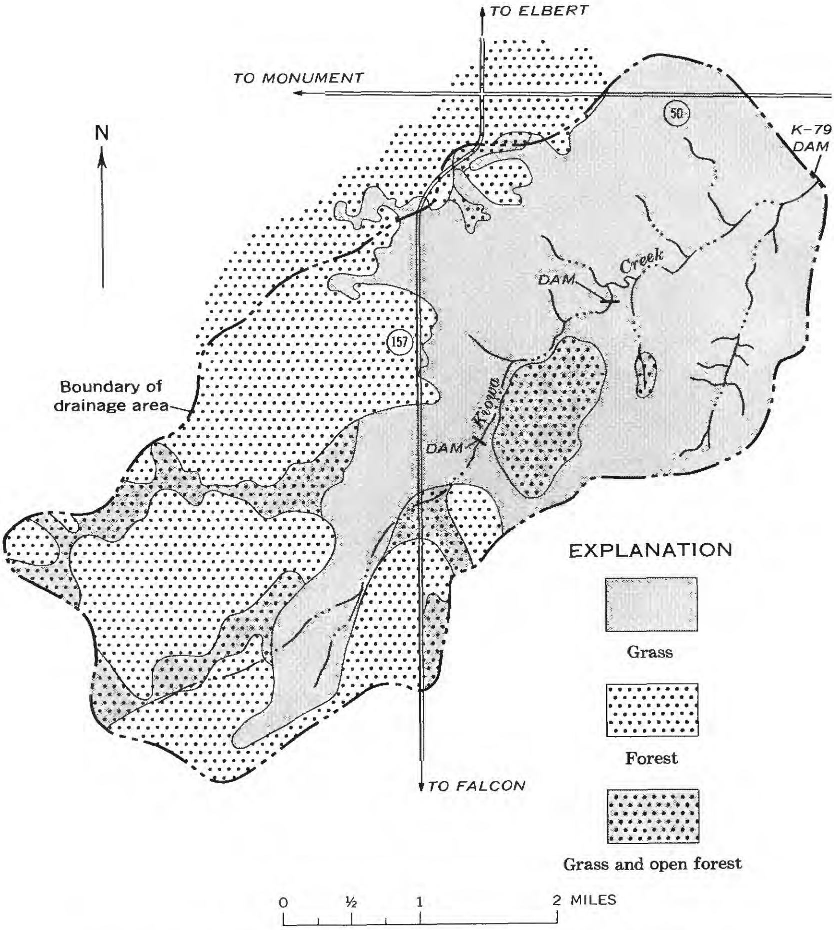

FIGURE 4.—Distribution of vegetation in drainage area of K–79 Reservoir.

tral part of the area grades from grass to a dense pine forest on the west side. Vegetation changes abruptly from short grass in the eastern part of the area to pine forest along the northwest side of the area. Pine forests occupy most of the ridges and divides where the Castle Rock Conglomerate is the surface material.

Land use is restricted to grazing. The climate, slope, and soils are not conducive to grain production.

SOILS

Most soils in the drainage area of K–79 Reservoir have developed on weathered arkosic material in the uplands or on narrow alluvial deposits along the main drainageways. Variations in vegetation, soil slope, microrelief, and moisture conditions commonly result in catenary complexes.

Well-developed podzolic profiles were observed in some of the areas of coniferous forest. These soils, probably of the Kettle series, have an A_{00} horizon about 1 inch thick composed of fresh litter and pine needles grading into the A_0 horizon of partially decomposed litter mixed with mineral particles. The A_1 horizon, a sandy loam, is about 3 inches thick and changes abruptly into the A_2 "bleicherde" horizon that ranges from 8 to 14 inches in thickness and is a very light gray loamy fine sand. The A_2 horizon is underlain by the B_2 horizon, approximately 18 inches thick, which is a compact sandy clay loam. The B_2 horizon is underlain by an undetermined thickness of clayey to gravelly weathered arkose. In some of the forested areas, weakly developed soils do not have the profile typical of the Kettle series. For most of the forested areas, the combination of thick surface litter, relatively gentle slopes, high infiltration rate, and precipitation interception by the forest cover probably results in low overland runoff and low sediment yield. During short periods of early spring, however, some soil frost commonly exists in the shaded forest areas after soil frost has disappeared from the open grassland. During such periods, runoff may be high from the forest areas.

In general, the soils in the eastern half of the area show weaker development and are more erodible than those in the western half.

PRECIPITATION

No long-term precipitation records are available for the immediate vicinity of K-79 Reservoir. For the period 1921–63, unofficial records kept by the Kiowa State Bank at Kiowa, Colo., about 20 miles downstream from K-79 Reservoir, show that average annual precipitation was about 16.0 inches. During the period 1956–65, precipitation records were obtained by the U.S. Weather Bureau at four stations near the drainage area of K-79. Precipitation data for these stations, all of which are within 2 miles of the area, are given in the table below.

Year	Precipitation, in inches			
	Eastonville 1 NNW	Eastonville 2 NNE	Eastonville 3 NW	Eastonville 6 WSW
1956	[1] 11.35	[1] 9.18	9.07	11.06
1957	25.64	23.75	20.28	27.26
1958	20.00	17.87	18.00	18.78
1959	19.67	15.43	12.70	18.34
1960	14.59	13.47	11.06	17.61
1961	18.00	18.14	14.77	19.83
1962	12.59	7.53	10.99	12.09
1963	16.32	14.55	13.15	13.57
1964	12.50	8.65	7.98	9.36
1965	25.61	24.60	[2] 24.6	21.72

[1] April through December.
[2] Partly estimated.

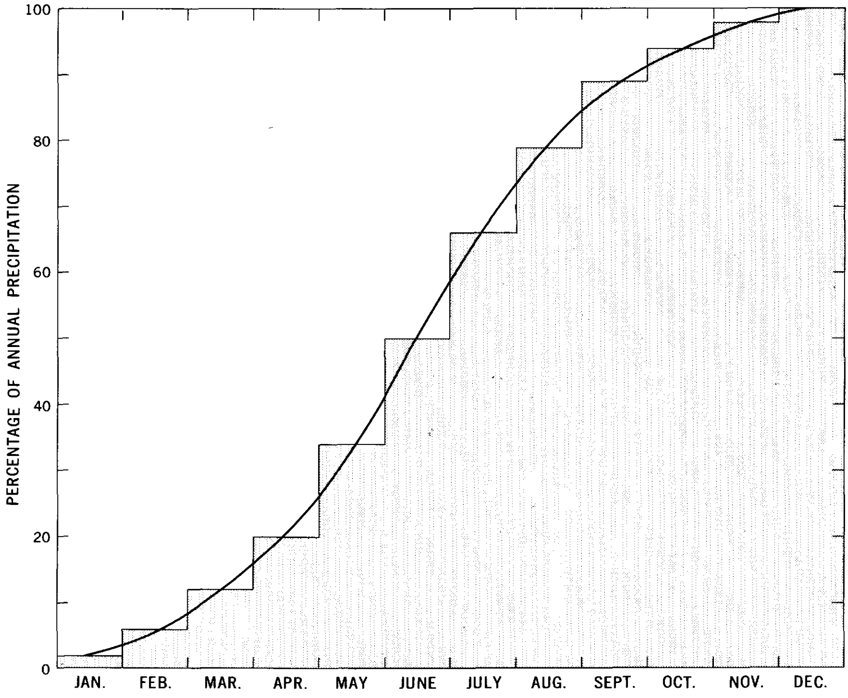

FIGURE 5.—Monthly cumulative percentage of precipitation in the vicinity of K–79 Reservoir, 1956–65.

The data show that average annual precipitation in the vicinity of K–79 Reservoir during 1956–65 was about the same as the long-term average at Kiowa, and that precipitation in the drainage area of K–79 probably was significantly above normal during 4 years, below normal during 4 years, and about normal during 2 years. On the average, about 60 percent of the annual precipitation occurs from May through August (fig. 5). During 1956–65, precipitation for any given month varied greatly; for example, precipitation at Eastonville 1 NNW during June 1964 was only 0.47 inch, but during June 1965 it was 11.46 inches. At the same location, total snowfall ranged from about 35 inches during the winter of 1962–63 to 141 inches during the winter of 1956–57.

HYDRAULIC STRUCTURES

Two reservoirs existed on the main channel upstream from K–79 Reservoir throughout the period of investigation; in 1960 many small hydraulic structures were completed in the downstream half of the K–79 drainage area. (See fig. 6.) After 1960, runoff from only about 15 percent of the drainage area has entered K–79 Reservoir directly without having first passed through one or more upstream structures.

Runoff from about 65 percent of the area has been controlled by the two mainstem reservoirs, and runoff from an additional 20 percent of the area has been controlled by the small structures constructed in 1960. As an emergency spillway is the only discharge arrangement at any of the upstream structures, a high stage is necessary for discharge. Therefore, since 1960 the upstream reservoirs have retained most of the runoff from the upstream part of the area.

Discharge from K–79 Reservoir is through a concrete-box drop structure that is 6 feet square and has an open top and four 1-foot-square ports in the sides. (See fig. 7.) A 24-inch-diameter tube carries the water through the dam. The emergency spillway for the reservoir is about 17 feet higher than the lowest port in the drop structure.

According to the original survey of the reservoir in 1956, all points in the reservoir bottom were higher than the bottom of the lowest port in the drop structure. Thus, the reservoir had no pool except when the lowest port was closed. The lowest port was open continuously from April 1956 to June 1958, from September 1958 to June 1959, from September 1959 to May 1961, and from October 1961 to May 1962. During these periods, the original bed of the reservoir and the sediment deposited during periods when the lowest port was closed were subject to erosion. The amount of sediment removed from the reservoir area during these periods is not known.

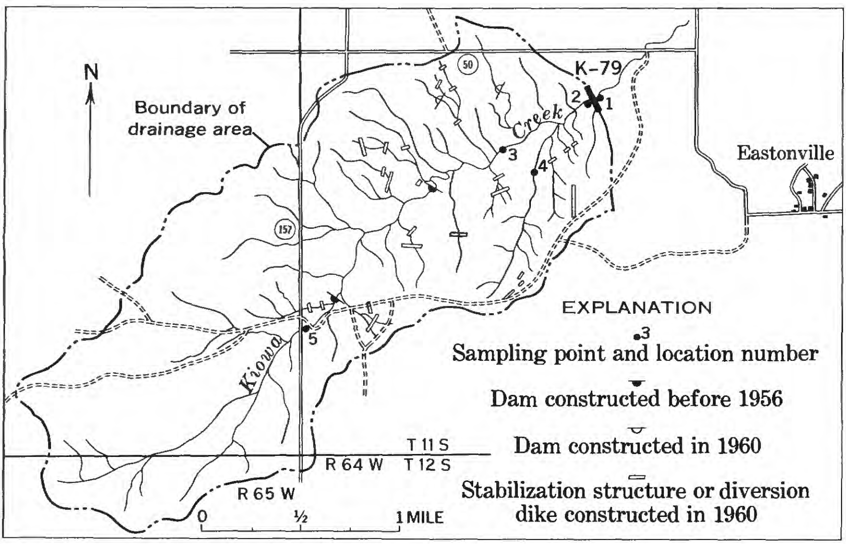

FIGURE 6.—Hydraulic structures in K–79 Reservoir drainage area.

FIGURE 7.—Drop structure at K–79 Reservoir.

FLUVIAL SEDIMENT

METHODS OF COLLECTION AND ANALYSES OF DATA

Data on the quantity and characteristics of sediment transported into and discharged from K–79 Reservoir were obtained by several different instruments and methods. Most of the data on sediment discharge from the reservoir were obtained by standard methods; a U.S. DH–48 suspended-sediment sampler was used to obtain samples of outflow at the downstream end of the outflow tub (figs. 3 and 6). Additional outflow samples were obtained with automatic single-stage samplers near the drop structure in the reservoir (fig. 7) and, during a few short periods, with an automatic continuous sampler at the downstream end of the outflow tube. Reservoir inflow was sampled with a U.S. DH–48 sampler and with automatic single-stage samplers at a few inflow channels.

Problems arose in obtaining reliable outflow samples during some periods when the lowest port of the drop structure was open or when backwater in the channel submerged the lower part of the downstream end of the outflow tube. If the lowest port was open during periods of minor inflow, coarse sediment could be transported directly through the reservoir. This coarse sediment was not uniformly dispersed throughout the depth of flow in the discharge tube, and extreme care was necessary to obtain a representative depth-integrated sample at the end of the outflow tube. During periods when backwater submerged part of the outflow tube, scoured material from the channel tended to mix immediately with water discharging at high velocity from the end of the tube. During such periods, an effort was made to keep the intake nozzle inside the tube although the high outflow velocity tended to force the sampler away from the tube.

Concentration, particle size, and discharge of suspended sediment were determined by the standard methods of the Geological Survey.

BASIC DATA

Monthly summaries of suspended-sediment discharge and tables of particle size analyses of suspended sediment for the period 1956–65 are given in tables 2 and 3. Continuous records of water and sediment discharges were not obtained during winter months, but periodic observations indicated that no major runoff occurred during winter months. Probably less than 5 percent of the water discharge and less than 2 percent of the sediment discharge occurred during periods when records were not obtained. Table 1 summarizes water and sediment discharges during significant observed outflow periods. Limited data on chemical characteristics of inflow and outflow obtained during the study are in table 4.

TABLE 1.—*Summary of water and sediment discharge during major outflow periods at K–79 Reservoir, 1956–65*

Date	Water discharge (cfs-days)	Water discharge (acre-ft)	Suspended sediment	
			Weighted mean concentration (ppm)	Load (tons)
1956				
July 16–17	4.0	7.9	2,270	24.5
Aug. 1–2	2.1	4.1	1,600	9.1
1957				
June 14–15	5.9	11.7	1,910	30.4
July 10–11	6.8	13.5	1,510	27.8
July 23–24	3.0	6.0	1,570	12.7
July 30–Aug. 1	136	270	4,360	1,600
Aug. 6–7	2.8	5.6	1,650	12.5
1958				
Mar. 21–22	5.5	10.9	512	7.6
July 19–21	3.6	7.1	741	7.2
July 25–27	5.4	10.7	665	9.7
Sept. 9–10	6.4	12.7	856	14.8
1959				
July 16–17	9.8	19.4	1,350	35.6
1960				
Mar. 24–31	39.1	77.6	527	55.6
1963				
July 27	23.0	45.6	2,420	150
July 28	7.8	15.5	475	10.0
Aug. 24–25	6.3	12.5	705	12.0
1964				
Aug. 3–6	5.7	11.3	721	11.1
1965				
June 17–18	181	359	1,080	530
June 19	18	35.7	154	7.5
Aug. 4–5	4.7	9.3	400	5.1

SUSPENDED SEDIMENT

Water and sediment discharge into and from K–79 Reservoir occurred mainly during the summer months, and then only occasionally. The outflow periods summarized in table 1 represent about 76 percent of the water discharge, about 97 percent of the sediment discharge, and only about 1 percent of the time during 1956–65. About 80 percent of the sediment discharge from the reservoir during the 10-year period occurred during 5 days—July 30–August 1, 1957, and June 17–18, 1965.

Data on particle size of suspended sediment (fig. 8; table 3) show that nearly all the sand transported into the reservoir was retained there. Probably less than 1 percent of the sediment discharged from the reservoir was sand or gravel. The greatest quantities of sand probably were discharged when the lowest port of the drop structure was open during periods of minor runoff and during the earliest and latest parts of major runoff. Only during such periods were hydraulic conditions at the drop structure suitable for the suspension of sand at the point of discharge from the reservoir. Further, when the lowest port

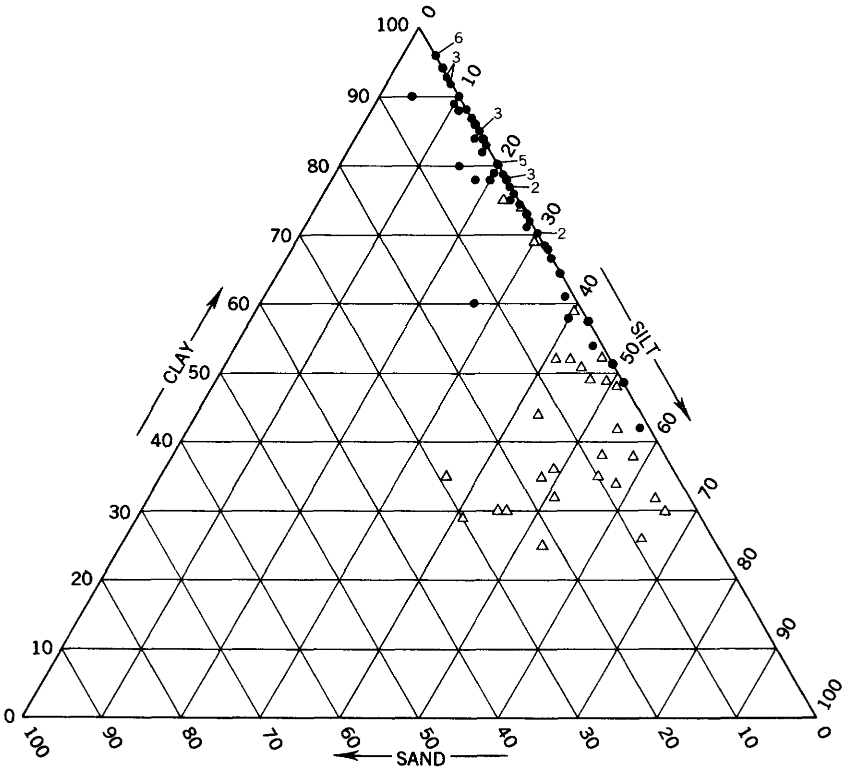

FIGURE 8.—Percentages of sand, silt, and clay in suspended-sediment samples of inflow and outflow, K-79 Reservoir. Δ, inflow; ●, outflow.

was open and inflow to the reservoir did not exceed the discharge capacity of the lowest port, sand may have moved as bedload into the discharge tube and been observed as suspended sediment at the downstream end of the tube.

Neither the quantity nor the particle size of sediment transported into or discharged from K-79 Reservoir is representative of the "sediment yield" of the drainage area upstream from the reservoir. Before reaching K-79 Reservoir, drainage from most of the area must first pass through one or more upstream reservoirs. A small reservoir about three-eighths of a mile downstream from State Route 157 retained much of the sediment from the upstream half of the drainage area. Another small reservoir about 1 mile upstream from K-79 dam probably trapped much of the sediment derived from the central part of the area. Many other small dams and stabilization structures were built in the downstream half of the area in 1960 (fig. 6); these structures undoubtedly trapped appreciable quantities of sediment that otherwise would have been deposited in, or transported through, K-79 Reservoir.

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Maximum observed suspended-sediment concentration of inflow to K–79 Reservoir was 94,000 ppm (parts per million) during the major flood of July 30, 1957. This concentration probably was exceeded in small tributary channels during the early part of several runoff periods, but data could not be obtained from these many small channels during storm periods. Percentage of sand generally was less than 10, although the maximum observed percentage was 29. Most observations, however, were made during the latter part of runoff periods or were obtained by automatic samplers which sample only the extreme upper part of flow where sand concentrations are expected to be less than the mean concentration of sand in the entire depth of flow.

Concentration of outflow from the reservoir was generally less than 3,000 ppm during major runoff periods, and commonly less than 10 ppm during prolonged periods of minor runoff. Sand in the outflow generally did not exceed 1 percent. When the lowest port was open, as on August 1, 1956 (see table 3), significant amounts of sand may have been discharged from the reservoir. The sand probably was transported as bedload across the reservoir and was discharged into the drop structure; the sand would have been measured as suspended sediment at the downstream end of the discharge tube.

During some periods, suspended-sediment concentrations were constant as the water moved through the reservoir. For example, on March 22, 1958, the suspended-sediment concentration at the main inflow point was 1,500 ppm, and the concentration of outflow also was 1,500 ppm. The following excerpts from the author's field notes are pertinent:

> March 22, 1958: "At low discharges, inflow travels straight through the reservoir with no dead-water storage. Low discharges may actually increase in concentration as the water travels across the easily eroded reservoir bottom."
>
> April 2, 1960: "The lower port in the drop inlet is again open, so that a small gully is again being eroded in the reservoir bottom. The water is dropping from the reservoir bottom into the intake structure."

During 1958–60, many small rills and gullies were observed in the reservoir bottom. The largest gully, which in some reaches was 2 feet deep, extended continuously from the main inflow point to within a few feet of the drop inlet. Undoubtedly, a part of the suspended-sediment discharge of the reservoir resulted from erosion of the original reservoir bottom and of temporarily deposited sediment. Figure 9 shows the reservoir and the water level when the lowest port of the drop structure was closed.

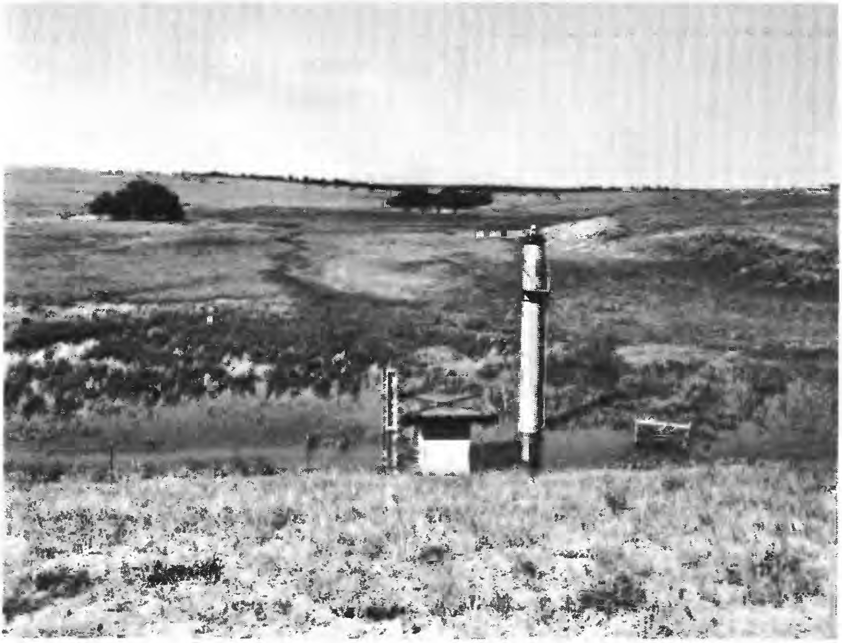

FIGURE 9.—Automatic samplers, drop structure, and water-stage recorder at K–79 Reservoir. Lowest port of the drop structure was closed.

DEPOSITED SEDIMENT AND TRAP EFFICIENCY

After being completed in June 1955, K–79 Reservoir had a gross storage capacity of 134.45 acre-feet. The original survey of the reservoir was made on August 29, 1956; this survey and all subsequent resurveys were made by personnel of the U.S. Department of Agriculture. A resurvey of the reservoir was made on September 25, 1957, about 2 months after the major flood of July 30. The resurvey showed that about 2.4 acre-feet of sediment had been deposited during the period. During the same period about 1,710 tons, or about 1.6 acre-feet, of sediment was discharged from the reservoir. Thus, trap efficiency during the period was about 60 percent. Nearly all the deposition and discharge probably resulted from the flood of July 30, 1957.

A second resurvey was made on October 17, 1961, and showed an additional 1.5 acre-feet of sediment deposition during the period September 1957–October 1961. During this period, suspended-sediment discharge from the reservoir was about 0.15 acre-foot, and trap efficiency was about 90 percent.

A third resurvey was made on July 27, 1965, and indicated that total deposition in the reservoir was about 7.5 acre-feet during the period 1956–65. Total deposition during 1956–61 was about 3.9 acre-feet according to the first two resurveys. Thus, about 3.6 acre-feet of sediment was deposited during the period October 1961–July 1965. During the same period, about 750 tons, or 0.72 acre-feet, of sediment was discharged from the reservoir. Trap efficiency during the period was about 84 percent.

From August 29, 1956, when the original survey was made, to July 27, 1965, when the final resurvey was made, observed sediment discharge from the reservoir was about 2,610 tons, or 2.5 acre-feet; sediment deposition in the reservoir was 7.5 acre-feet. Trap efficiency was 75 percent as computed from sediment volumes. Trap efficiency was 83 percent as computed from the observed weight of sediment outflow and the computed weight of sediment deposition; the few available data on volume weight and particle sizes of deposited sediment suggest a volume weight of 80 pounds per cubic foot, or about 13,000 tons of sediment deposited in the reservoir.

Sediment deposition was not uniform within the reservoir area. The original survey altitudes of 1956 and resurvey altitudes of 1965 were used to prepare a map (plate 1) that shows areas of erosion and of deposition during the study period. For most of the reservoir area, altitudes were determined at 50-foot intervals along the reservoir grid ranges; therefore, details of reservoir topography, including accurate definition of small channels and gullies, could not be determined. The map shows that 0.1–1.0 foot of sediment was deposited over much of the reservoir area; deposition of 1.0–2.0 feet generally was restricted to deltas and channel fill in the main inflow chanels or to small fans immediately below gullies along the margin of the reservoir. At a few points in the reservoir, deposition of nearly 2.5 feet was observed. Deposition of less than 0.1 foot, or erosion, occurred mainly along the margins of the reservoir and especially along the easternmost of the main inflow channels at the upstream end of the reservoir.

The average volume weight of deposited-sediment samples obtained on September 25, 1957, was 77.6 pounds per cubic feet, and on October 17, 1961, was 81.5 pounds were cubic foot; the volume weight of delta deposits was appreciably higher than that of deposits in the main part of the reservoir. Particle-size analyses of delta deposits obtained in 1957 showed 46 percent gravel and 53 percent sand; reservoir deposits showed 1 percent gravel, 45 percent sand, 34 percent silt, and 20 percent clay (U.S. Dept. Agriculture, 1959).

Most of the sediment that entered K–79 Reservoir during 1956–60 originated in the downstream one-third of the drainage area, and during 1961–65 originated in the small area downstream from hyraulic structures built in 1960. Thus, during 1956–60 about one-third of the drainage area contributed significant quantities of sediment to K–79

Reservoir, and during 1961–65 about one-sixth of the drainage area contributed. All the bedload discharge and most of the suspended-sediment discharge from a large part of the drainage area were trapped before reaching K–79. The upstream structures and a decreasing effective-drainage area during the period of investigation probably resulted in a lower trap efficiency than would have resulted from a complete absence of upstream structures. Although much less sediment entered K–79 Reservoir as a result of upstream entrapment, the sediment that was discharged from the upstream reservoirs probably was extremely fine and had little tendency to settle during temporary detention in K–79 Reservoir. Thus, although the trap efficiency of K–79 Reservoir for sediment derived from the upstream two-thirds of the drainage area probably was low, the amount of sediment delivered to K–79 Reservoir from this area probably was small. A low trap efficiency for a reservoir in a basin having many upstream structures may indicate only that the easily trapped coarse sediments were deposited in upstream reservoirs and that the particle-size distribution of sediment that entered the downstream reservoir was finer than it would have been in the absence of upstream structures.

Flocculation of fine sediment within the reservoir probably was not a significant cause of deposition in K–79 Reservoir. The runoff from the area contained a low concentration of dissolved solids (table 4) and was not conducive to rapid flocculation. Detention time for most runoff was only a few hours. Even for the flood of July 30–August 1, 1957, when the total inflow was 270 acre-feet, the detention time was short; more than 50 percent of the total inflow was discharged from the reservoir during the first 6 hours, and about 90 percent was discharged during the first 24 hours. Thus, the combination of water having low dissolved-solids content and of short detention time probably prevented significant deposition caused by flocculation of sediment.

SIGNIFICANCE OF RESULTS

The first data on suspended-sediment discharge from K–79 Reservoir were obtained in April 1956, and the last data, in September 1965. The original survey of the reservoir was not made until August 29, 1956; and the final survey was made on July 27, 1965. Trap efficiency of the reservoir must, therefore, be computed only for the period between the first and last surveys, not for the period of data collection. The trap efficiency of 72 percent represents a period during which average annual precipitation was about normal. About 50 percent of the inflow to the reservoir and about 80 percent of the sediment discharge occurred during only 5 days of a 10-year period, during two extremely intense storms.

Most of the eroded sediment from a large part of the drainage area was deposited in upstream reservoirs. If the two dams on the main channel upstream from K–79 Reservoir had not been present during 1956–60 and if the additional structures had not been present during 1961–65, much more sediment would have been transported into, and deposited in, K–79 Reservoir. Although sediment discharge from the reservoir probably would have been somewhat higher in the absence of upstream structures, it would not have increased as much as sediment inflow. Thus both sediment deposition and trap efficiency of the reservoir would have been appreciably greater in the absence of upstream structures.

Neither the amount of sediment deposition in, nor the trap efficiency of, K–79 Reservoir should necessarily be regarded as representative of similar but unstructured areas in the Colorado Piedmont and High Plains. Under present structured conditions in the K–79 drainage area, the effective life of the reservoir should be exceptionally long. Rapid silting in upstream reservoirs or sudden failure of several of these structures during a short time could markedly alter the present rate of sediment deposition in K–79 Reservoir.

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BASIC DATA

TABLE 2.—*Monthly and annual summaries of water and suspended-sediment discharge, Kiowa Creek at K–79 Reservoir near Eastonville, Colo., 1956–65*

Month	Water discharge (cfs-days)	Number of days when mean discharge was 0.1 cfs or more	Suspended sediment: Weighted mean concentration (ppm)	Suspended sediment: Load (tons)
1956				
April	0	0		0
May	0	0		0
June	.8	3	1,570	3 4
July	4.4	6	2,190	26.0
August	2.2	2	1,530	9.1
September	0	0		0
April–September, 1956	7.4	11	1,930	38.5
October	(1)			
November	(1)			
December	(1)			
1957				
January	(1)			
February	(1)			
March	(1)			
April	5.4	30	137	2.0
May	5.7	30	195	3.0
June	8.0	21	1,440	31.0
July	143.1	15	4,190	1,620.0
August	13.8	31	1,340	50.0
September	2.2	22	252	1.5
Water year 1957	178.2	149	3,550	1,707.5
October	0.5	5	74	0.1
November	(1)			
December	(1)			
1958				
January	(1)			
February	(1)			
March	8.7	31	353	8.3
April	6.3	30	58	1.0
May	5.5	31	256	3.8
June	1.0	10	37	.1
July	10.8	20	590	17.2
August	2.6	15	285	2.0
September	8.2	16	687	15 2
Water year 1958	38.6	158	458	47.7
October	1.6	0	139	0.6
November	(1)			
December	(1)			
1959				
January	(1)			
February	(1)			
March	(1)			
April	6.4	30	40	.7
May	2.6	10	28	.2
June	.8	3	93	.2
July	10.7	2	1,240	35.8
August	1.8	2	164	.8
September	2.0	3	93	.5
Water year 1959	25.9	50	555	38.8
October	3.3	21	11	0.1
November	(1)			
December	(1)			

See footnotes at end of table.

TABLE 2.—*Monthly and annual summaries of water and suspended-sediment discharge, Kiowa Creek at K-79 Reservoir near Eastonville, Colo., 1956-65*—Con.

Month	Water discharge (cfs-days)	Number of days when mean discharge was 0.1 cfs or more	Suspended sediment: Weighted mean concentration (ppm)	Suspended sediment: Load (tons)
1960				
January	(1)			
February	(1)			
March	[2] 40.3	10	519	56.5
April	18.6	30	30	1.5
May	11.0	31	24	.7
June	2.0	1	19	.1
July	2.4	3	664	4.3
August	.9	0	16	(3)
September	.4	0	15	(3)
Water year 1960	78.9	96	297	63.2
October	2.2	3	34	0.2
November	(1)			
December	(1)			
1961				
January	(1)			
February	(1)			
March	(1)			
April	4.3	22	52	0.6
May	2.8	9	132	1.0
June	3.1	10	139	1.0
July	.7	2	53	.1
August	3.2	6	58	.5
September	1.7	4	22	.1
Water year 1961	18.0	56	72	3.5
October	2.7	1	110	0.8
November	(1)			
December	(1)			
1962				
January	(1)			
February	(1)			
March	(1)			
April	3.5	30	42	.4
May	1.0	0	37	.1
June	.3	0	35	(3)
July	.7	0	16	(3)
August	.8	2	93	.2
September	.3	0	34	(3)
Water year 1962	9.3	33	60	1.5
October	0.4	0	25	(3)
November	(1)			
December	(1)			
1963				
January	(1)			
February	(1)			
March	(1)			
April	(1)			
May	0	0		0
June	0	0		0
July	31.8	5	1,870	160.2
August	11.0	15	458	13.6
September	2.3	4	48	.3
Water year 1963	45.5	24	1,420	174.1
October	0.3	0	24	(3)
November	(1)			
December	(1)			

See footnotes at end of table.

TABLE 2.—*Monthly and annual summaries of water and suspended-sediment discharge, Kiowa Creek at K–79 Reservoir near Eastonville, Colo., 1956–65*—Con.

Month	Water discharge (cfs-days)	Number of days when mean discharge was 0.1 cfs or more	Suspended sediment	
			Weighted mean concentration (ppm)	Load (tons)
1964				
January	(1)			
February	(1)			
March	(1)			
April	(1)			
May	1.3	3	342	1.2
June	.5	0	148	.2
July	3.8	2	166	1.7
August	6.4	4	654	11.3
September	.5	2	1,040	1.4
Water year 1964	12.8	11	457	15.8
October	1.0	0	15	(3)
November	(1)			
December	(1)			
1965				
January	(1)			
February	(1)			
March	(1)			
April	2.9	16	51	0.4
May	1.1	2	168	.5
June	194.1	23	1,050	550
July	5.7	11	377	5.8
August	7.8	8	361	7.6
September	.9	0	82	.2
Water year 1965	213.5	60	979	564.5

[1] Streamflow records not obtained. Discharge, if any, not included in annual totals.
[2] Includes discharge only for March 21-31.
[3] Less than 0.05 ton.

TABLE 3.—*Particle-size analyses of suspended sediment in inflow and outflow, K–79 Reservoir*

[Methods of analysis: B, bottom-withdrawal tube; P, pipet; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; M, mechanically dispersed; V, visual accumulation tube]

Date	Sampling location number [1]	Time	Water discharge (cfs)	Water temperature (°F)	Suspended sediment: Concentration (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000	Methods of analysis
1956																		
June 8	1	5:00 p.m.	0.25	---	2,520	3,630	---	94	---	98	---	100	---	---	---	---	---	SPWCM
July 16	3	4:00 [2]	---	---	18,100	4,160	---	29	---	52	---	72	72	92	99	100	---	SPWCM
	2	4:15 [2]	[3] 3.5	---	4,610	4,000	---	61	---	88	---	99	99	100	---	---	---	SPWCM
	2	4:45 [2]	[3] 3.5	---	4,030	2,660	43	52	69	85	97	99	---	---	---	---	---	BWCM
	1	6:30	[3] 3.5	---	2,510	1,750	54	71	85	95	98	99	---	---	---	---	---	BWCM
	1	9:30	[3] 3.5	---	1,430	1,050	66	85	95	98	99	100	---	---	---	---	---	BWCM
July 17	1	10:10 a.m.	.11	---	890	1,380	88	93	96	98	100	---	---	---	---	---	---	BWCM
Aug. 1	4	2:15 p.m. [2]	---	---	7,860	6,130	---	34	---	65	---	96	99	100	---	---	---	SPWCM
	3	2:15 [2]	---	---	10,400	2,860	---	44	---	72	---	90	93	98	100	---	---	SPWCM
	3	2:35	---	---	7,120	4,280	---	51	---	82	---	97	99	100	---	---	---	SPWCM
	4	2:40	---	---	4,050	3,060	---	49	---	90	---	99	100	---	---	---	---	SPWCM
	2	2:45 [4]	6.3	---	3,950	2,600	---	72	---	98	---	100	---	---	---	---	---	PWCM
	1	2:50	7.1	---	4,240	4,570	---	60	---	86	---	87	87	88	90	91	92	SPWCM
	3	3:15	---	---	3,160	1,940	61	74	87	96	99	100	---	---	---	---	---	BWCM
	4	3:20	---	---	2,160	1,340	---	69	---	98	---	99	99	99	100	---	---	SPWCM
	1	3:30	8.0	---	2,290	1,760	63	78	90	96	98	98	---	---	---	---	---	BWCM
1957																		
June 14	4	3:25	---	---	7,950	4,690	---	42	---	69	---	96	99	100	---	---	---	SPWCM
	3	3:30	---	---	15,700	5,650	30	38	48	61	76	92	98	100	---	---	---	VPWCM
	3	3:30	---	---	15,700	5,510	16	26	39	54	71	91	98	100	---	---	---	VPNM
	4	3:30	---	---	7,560	3,040	29	38	51	63	75	96	100	---	---	---	---	VPWCM
	4	3:30	---	---	7,560	2,850	15	30	45	62	81	96	100	---	---	---	---	VPNM
	2	3:45	3.7	---	2,060	1,600	---	88	---	98	---	99	100	---	---	---	---	SPWCM
	1	6:00	17.5	43	2,850	1,640	---	76	---	95	---	100	---	---	---	---	---	SPWCM
July 10	3	3:30	---	---	10,700	5,220	24	30	38	47	57	76	90	98	100	---	---	VPWCM
	2	3:35	2.9	---	7,000	5,510	---	58	---	82	---	98	99	100	---	---	---	SPWCM
	2	4:00	16.1	---	5,000	1,430	60	77	88	96	99	100	---	---	---	---	---	SBWCM
	2	4:25	17.3	---	3,300	1,230	69	83	94	98	99	100	---	---	---	---	---	SBWCM
	1	5:30	22.6	43	2,070	1,310	61	75	87	96	99	99	---	100	---	---	---	SBWCM
July 23	3	4:30	---	---	11,700	6,460	29	36	46	58	70	85	92	98	100	---	---	VPWCM
July 30	3	5:45	---	---	13,500	8,010	19	25	33	44	60	78	85	92	98	100	---	VPWCM
	4	5:45	---	---	4,450	3,300	28	35	42	53	68	90	97	100	---	---	---	VPWCM
	2	5:50	.51	---	6,450	5,440	---	---	54	67	82	98	100	---	---	---	---	VPWCM
	2	5:55	1.7	---	7,000	5,020	33	42	51	64	78	99	100	---	---	---	---	SPWCM
	2	6:00	3.0	---	8,000	3,820	36	44	52	63	80	---	---	100	---	---	---	VPWCM
July 31	1	9:00 a.m.	66.7	48	1,750	1,800	66	84	96	96	96	99	100	---	---	---	---	SPWCM
	1	9:00	66.7	48	1,750	1,790	58	82	99	97	98	99	99	100	---	---	---	SPNM
Aug. 6	2	8:25 p.m.	11.0	---	3,900	2,450	54	68	86	97	97	100	---	---	---	---	---	SPWCM

See footnotes at end of table.

TABLE 3.—*Particle-size analyses of suspended sediment in inflow and outflow, K–79 Reservoir*—Continued

Date	Sampling location number [1]	Time	Water discharge (cfs)	Water temperature (°F)	Suspended sediment: Concentration (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000	Methods of analysis
1958																		
Mar. 21	1	4:00 p.m.	[3] 4.0		1,370	1,670	58	64		97		100						SPWCM
	1	9:00	[3] 4.0		597	724	74	89	96	98	98	99						BWCM
July 19	3	2:15			1,830	1,360	55	64		88		100						PWCM
	4	2:30			3,310	2,470	57	67		89		99	100					VPWCM
	1	2:55	7.5		1,150	3,440	65	79		97		100						SPWCM
	1	8:00	5.0		741	1,450	82	92		96		100						SPWCM
July 25	1	4:35	11.0		845	2,310	65	77		96		100						SPWCM
	1	5:30	11.5		1,060	1,150	69	79				100						VPWCM
	1	7:30	10.0		741	810	77	85		87		100						SPWCM
Sept. 10	1	4:49	.44		361	910	95	96		96		100						SPWCM
Sept. 26	1	9:00 a.m.	.07		149	989	51	54										PWCM
1959																		
July 16	1	2:39 p.m.	16.9	48	2,370	3,300	51	64		88		100						VPWCM
	1	2:45	20.3	45	2,990	4,080	53	64		92		100						VPWCM
	1	3:00	21.6	44	2,820	4,010	57	67		94								PWCM
	1	3:15	22.0	43	2,640	3,320	58	68		94		100						VPWCM
	1	3:30	22.1	42	2,490	3,690	59	70		96		100						VPWCM
	1	3:45	21.9	43	2,230	3,230	61	71		97		100						VPWCM
	1	4:30	20.2	42	2,050	2,570	63	74		96		100						VPWCM
	1	10:45	[5] 10.7	45	1,020	1,430	74	88		99		100						VPWCM
	3	2:25 p.m.		48	1,910	2,840	42	52		78		99	100					VPWCM
	4	2:35		43	7,800	8,930	27	32		47		83	94	99	100			VPWCM
	3	3:00 [2]			15,400	6,520	26	30		46		75	81	82	82	100		VPWCM
Aug. 4	5	1:30 [2]			7,840	3,220	29	35		49		83	93	98	99	100		VPWCM
	4	2:30 [2]			2,240	1,620	44	49		70		96	97	98	100			VPWCM
	4	3:45		68	4,050	4,480	29	35		49		71	78	87	98	100		VPWCM
1960																		
July 3	1	2:10	3.90	[6] 34	1,700	4,380	66	79		98		99	100					VPWCM
	4	2:17			1,010	2,620	63	75		93		98	99	99	100			VPWCM
	3	2:30		[6] 34	2,550	6,350	50	59		82		99	100					VPWCM
	4	2:40		[6] 34	3,430	5,850	44	52		70		95	99	100				VPWCM
	1	2:50	6.66	[6] 37	771	2,010	71	78		91		96	98	99	100			VPWCM
	3	2:50			8,780	6,060	44	52		70		93	97	97	99	100		VPWCM
	1	3:40	8.14	[6] 3	1,170	2,970	70	85		99		100						PWCM

1961																	
Aug. 8	4	4:00	----------	----------	6,540	----------	43	48	61	74	88	99	100	-----	-----	-----	-----	VPWCM
1963																	
July 27	4	----------	----------	----------	8,450	----------	30	32	-----	58	-----	95	98	100	-----	-----	-----	VPWC
	2	----------	----------	----------	4,940	----------	42	49	-----	83	-----	100	-----	-----	-----	-----	-----	SPWC
	2	----------	----------	----------	3,160	----------	42	52	-----	84	-----	100	-----	-----	-----	-----	-----	SPWC
	1	3:15 p.m.	65	[6] 43	3,420	----------	46	58	-----	94	-----	100	-----	-----	-----	-----	-----	SPWC
	1	8:30	46	[6] 41	1,680	----------	60	78	-----	100	-----	-----	-----	-----	-----	-----	-----	PWC
July 28	1	8:15 a.m.	8.9	[6] 43	350	----------	89	96	99	100	-----	-----	-----	-----	-----	-----	-----	BWC
	1	12:10 p.m.	6.0	[6] 38	271	----------	80	86	93	96	99	-----	-----	-----	-----	-----	-----	SBWC
Aug. 17	1	4:15	3.9	65	1,000	----------	68	80	-----	98	-----	100	-----	-----	-----	-----	-----	SPWC
	1	4:45	4.0	65	990	----------	70	80	-----	99	-----	100	-----	-----	-----	-----	-----	SPWC
	1	5:05	3.9	54	820	----------	68	87	98	99	100	-----	-----	-----	-----	-----	-----	BWC
	1	5:35	3.8	54	667	----------	75	92	98	100	-----	-----	-----	-----	-----	-----	-----	BWC
	1	5:50	3.7	65	354	----------	61	78	91	96	100	-----	-----	-----	-----	-----	-----	BWC
	1	9:40	2.0	58	410	----------	84	96	98	98	99	100	-----	-----	-----	-----	-----	SBWC
Aug. 24	1	9:25	14	58	1,330	----------	54	70	-----	98	-----	100	-----	-----	-----	-----	-----	SPWC
	1	10:25	15	58	998	----------	67	80	-----	98	-----	100	-----	-----	-----	-----	-----	SPWC
	1	11:00	14	58	923	----------	64	85	95	99	100	-----	-----	-----	-----	-----	-----	BWC
Aug. 25	1	2:40 a.m.	10	57	606	----------	77	93	98	99	100	-----	-----	-----	-----	-----	-----	BWC
	1	2:10 p.m.	1.8	72	337	----------	83	95	97	99	100	-----	-----	-----	-----	-----	-----	BWC
1964																	
July 25	1	[2] 3:30 p.m.	9	----------	589	----------	63	83	-----	100	-----	100	-----	-----	-----	-----	-----	SPWC
	1	[2] 3:45	9	----------	550	----------	64	84	-----	94	-----	100	-----	-----	-----	-----	-----	SPWC
Aug. 8	1	7:15 [2]	12	----------	1,910	----------	64	79	-----	95	-----	100	-----	-----	-----	-----	-----	SPWC
	1	7:25 [2]	12	----------	1,690	----------	64	83	-----	96	-----	100	-----	-----	-----	-----	-----	SPWC
	1	7:35 [2]	12	----------	1,730	----------	57	74	-----	96	-----	98	-----	-----	-----	-----	-----	VPWC
	1	7:45 [2]	12	----------	1,520	----------	74	79	-----	100	-----	100	-----	-----	-----	-----	-----	SPWC
	1	7:55 [2]	12	----------	1,530	----------	75	77	-----	100	-----	100	-----	-----	-----	-----	-----	SPWC
	1	8:05 [2]	12	----------	1,270	----------	66	79	-----	100	-----	-----	-----	-----	-----	-----	-----	VPWC
	1	11:00	10	57	778	----------	77	93	-----	-----	-----	100	-----	-----	-----	-----	-----	SPWC
	1	11:45	9.5	----------	699	----------	78	94	-----	-----	-----	100	-----	-----	-----	-----	-----	SPWC
1965																	
June 18	1	1:00	65	----------	1,460	----------	68	85	-----	-----	-----	100	-----	-----	-----	-----	-----	SPWC
	1	2:00	64	----------	1,440	----------	-----	-----	-----	-----	-----	100	-----	-----	-----	-----	-----	S
	1	7:30	29	----------	1,260	----------	79	96	-----	-----	-----	100	-----	-----	-----	-----	-----	SPWC
June 19	1	1:00	5.2	----------	662	----------	87	92	-----	-----	-----	100	-----	-----	-----	-----	-----	SPWC
July 3	1	12:05 a.m.	1.8	----------	424	----------	87	96	-----	-----	-----	100	-----	-----	-----	-----	-----	SPWC

[1] See figure 7: 1, downstream end of outlet discharge tube; 2, outlet structure in reservoir; 3, Kiowa Creek about ¾ mile upstream from K–79 dam; 4, channel of right tributary to reservoir; and 5, Kiowa Creek just downstream from State Route 157.

[2] Approximate; time for automatic samplers estimated from reservoir stage and weather records.

[3] Daily mean discharge.

[4] Obtained from gage-height chart.

[5] Mean, 8:00 p.m.–12:00 p.m.

[6] Runoff mostly from melting hail.

TABLE 4.—*Chemical quality of inflow and outflow, K–79 Reservoir*

[Chemical analyses, in parts per million]

Date of collection	Sampling location number [1]	Ca	Mg	Na	K	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH
July 17, 1956	1	5.0	1.3	3.2	6.0	74	0.10	18	79	7.2
August 4, 1959	4	5.3	2.1	1.4	5.1	53	.07	22	81	6.5
	3	7.5	2.5	5.0	10	89	.12	29	113	6.5
	4	4.6	.9	.8	4.5	52	.07	15	46	6.2
	3	6.5	2.6	5.4	4.7	80	.11	27	100	6.4
April 14, 1960	1	12	3.4	3.5	5.4	--------	--------	44	110	7.4
	3	15	3.1	4.9	3.9	--------	--------	50	135	7.6
July 3, 1960	1	5.6	1.0	2.8	7.9	72	.10	18	89	6.7
	3	8.2	1.1	3.2	7.2	86	.12	25	131	6.6
	4	7.6	1.5	1.3	4.9	72	.10	25	90	6.7
June 18, 1965	1	----	----	----	----	--------	--------	--------	28	-----

[1] See figure 7: 1, downstream end of outlet discharge tube; 3, Kiowa Creek about ¾ mile upstream from K–79 dam; 4, channel of right tributary to reservoir.

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