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Sediment Tests on Prototype Diversion Dams


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION


# INTERIM REPORT

# SEDIMENT TESTS ON PROTOTYPE DIVERSION DAMS

# KANSAS RIVER BASIN, KANSAS-NEBRASKA


DIVISION OF RESEARCH
DIVISION OF PROJECT INVESTIGATIONS



OFFICE OF CHIEF ENGINEER
DENVER, COLORADO



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ABSTRACT

Field tests were conducted at Woodston, Bartley, and Superior-Courtland Diversion Dams in the Kansas River Basin during August 1960 to determine the efficiencies of sediment control structures for excluding sediment from the canal system. Data were also obtained at Cambridge Diversion Dam where a sediment problem existed but the dam had no sediment control structure. Sediment samples and hydraulic data were collected for computing the amount of sediment transported in the rivers and the amount of sediment transported through the sluiceway and canal at the headworks of each diversion dam. At Woodston, Bartley, and Superior-Courtland Diversion Dams where curved guide walls were used as a sediment control structure, the sand load of the river was depositing in the river basin above the diversion dam at the time of the tests. Very little sand was entering the guide walls at the canal headworks which did not permit a quantitative evaluation of the amount of sand excluded from entering the canal. However, the operating personnel are extremely satisfied with the curved guide walls. The curved guide walls provide an efficient means for flushing sediments deposited above the dam into the downstream river channel either by continuous sluicing or by intermittent sluicing.

DESCRIPTORS--*sediment control/ *sediment sampling/ suspended sediments/ sediment concentration/ bedloads/ *diversion dams/ efficiencies/ sluice gates/ sluices/ diversion works

IDENTIFIERS--*Woodston Diversion Dam/ *Bartley Diversion Dam/ *Superior-Courtland Diversion Dam/ *Cambridge Diversion Dam/ sediment excluders/ *guide walls/ sediment samplers

ACKNOWLEDGMENTS

Field tests were conducted by Eugene A. Jarecki from the Regional Office in Denver, Enos J. Carlson of the Hydraulics Branch, Division of Research and Ernest L. Pemberton of the Hydrology Branch, Division of Project Investigations, the latter two from the Office of Chief Engineer. Edward Hlavinka from the McCook Office provided valuable help during the collection of discharge measurements and sediment samples. Personnel of the Kansas River Projects Office and Irrigation District Office cooperated in making the tests possible.

The analysis of the data and the report were prepared jointly by Ernest L. Pemberton and Enos J. Carlson.

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## INTRODUCTION

Field tests were conducted during the period August 1-8, 1960, at four diversion dams in the Kansas River Basin to determine the amount of sediment transported in the rivers and the amount moving through the sluiceway and canal at the headworks of each diversion dam. This information would show the efficiency of the diversions for sluicing sediments at the prevailing river conditions and for the flows tested. Tests in the field on the ability of the diversion structure to exclude sediment from the canal system are important for project investigations, for designs of diversion headworks, and for comparison with the hydraulic model tests.

The tests were conducted with the cooperation of the Kansas River Projects Office, McCook, Nebraska. Water was released from the various storage dams upstream to provide adequate flows in which the tests could be made.

Hydraulic model studies had been made to develop sediment control arrangements for Woodston, 1/* Bartley, 2/ and Superior-Courtland 3/ Diversion Dams, and the resulting designed structures were incorporated in their construction. The test program was established primarily to obtain data at these diversion dams to check the efficiency of the operation of the sediment control structures. During the testing, the Projects Office requested that observations and measurements also be made at the Cambridge Diversion Dam; where a sediment problem had developed. This dam did not have a sediment control structure.

## DESCRIPTION OF TESTS

Sediment samples were taken and discharge measurements or estimates of discharge from a gage height were made at each of the four diversion dams to obtain data which could be used to compute the suspended sediment load and the total sediment load (1) transported by the river upstream of the diversion dam; (2) transported through the guide wall channel; (3) diverted into the canal; and (4) discharged through the sluice gates. The amount of total sediment being transported at each of the four

*Numbers refer to references listed at the end of the report.

discharge measuring stations could be used to compute the sediment excluding efficiency of each diversion dam having a sediment control structure. The location of each diversion dam tested is shown on the map in Figure 1.

The first step in the data collection program consisted of selecting a uniform reach of river far enough upstream to be above any backwater influence of the diversion dam. The cross section selected for sampling within each test reach was suitable for reliable discharge measurements, adequate suspended sediment sampling, and acceptable for computing the total sediment load.

Data collected at the selected river reaches upstream from the four diversion dams consisted of:

1. Discharge measurements.

2. Water surface elevations were measured at 100-foot intervals along the channel midpoint to define the water surface slope. The minimum reach length was 1,000 feet.

3. Equal transit rate (ETR)4/ suspended sediment samples.

4. Five bed material samples.

5. Water temperature.

All suspended sediment samples were collected by using depth integrating samplers. The samplers have an intake or nozzle that points directly into streamflow. An air exhaust tube has an outlet in the side of each sampler's head so that air can escape from the sample container while submerged underwater.

The equal-transit-rate (ETR)4/ sampling procedure was adopted in the investigations. In this procedure the stream cross section is divided into increments of equal width. A depth integrating sampler is lowered and raised throughout the depth, at the center of each increment selected, at a constant rate common to all verticals sampled. Samples collected are mixed together to make a composite sample that represents the average concentration in the total cross section, considering that both the velocity and the sediment concentration are integrated.

Depth integrating samplers used in the tests were the DH-48, D-49, and DH-59, described in Reference 4/. The DH-48 sampler weighs 4-1/2 pounds and is designed to be used at a stream section which can be waded as illustrated in Figure 8A. The DH-48 was also used in sampling from a boat, in front of a sluice gate, Figure 9A; and in the reach between guide walls, Figure 5A. The DH-48 sampler was used in another area below the headworks at the upper end of the canal as shown in Figure 9B for the Courtland Canal. The DH-59 sampler weighing 24 pounds was designed for handline suspension operation and was used from a boat or from the handrail in front of sluice gates or headworks as illustrated in Figure 8B. The D-49 weighs 62 pounds and was used where high velocities were encountered such as in the Woodston Diversion Dam sluiceway shown in Figure 2B.

Sampling procedures for collection of the total sediment load diverted into the canal or discharged through the sluice gates at each diversion dam are described in the section of the report covering the particular diversion dam.

Bed material samples were obtained by using the BMH-60[4] bed material sampler or by hand dipping from the channel bottom with a sample carton. The BMH-60 was a newly developed bed material sampler similar to but lighter in weight than the 100-pound BM-54 bed material sampler. The BMH-60 is presently available in three weights, 30, 35, and 40 pounds, made of cast aluminum and equipped with tail fins. The spring-loaded bucket is cocked when the weight of the sampler is supported from the steel cable. When the tension on the cable is released by resting the sampler on the streambed, a constant torque spring swings the bucket out of the sampler body and it scoops up and completely surrounds a sample of about 160 cc (cubic centimeters) taken from the top 2 inches of the streambed. The bed material sample is enclosed in the bucket so that it is not washed out when the sampler is raised through the water to the surface.

## Woodston Diversion Dam

A plan view, of the location of Woodston Diversion Dam[5] in the South Fork Solomon River and the river measuring reach is shown in Figure 3. Appropriate test data were collected at the representative cross section and the river reach located about 4.1 miles upstream from Woodston Diversion Dam. Suspended sediment samples were collected with a DH-48 sampler by the ETR method. Bed material samples were taken by hand dipping at five locations in the measuring section. Slope measurements of the water surface were made by surveying elevations at about 100-foot intervals throughout a reach which extended 500 feet upstream and 500 feet downstream from the measuring section.

Suspended sediment samples were collected at three locations near the headworks of Woodston Diversion Dam. A DH-48 sampler was used to sample the suspended sediment in the flow at the upstream end of the guide walls, and at the downstream end of the canal headworks closed conduit. Suspended sediment samples were also obtained at a section downstream from the sluice gate with the D-49 sampler as shown in Figure 2B. The samples at all three locations were considered to represent the total sediment in transport, as there was no evidence of any sediments depositing at the sampling locations.

A discharge measurement of the flow in the canal by current meter indicated a diversion of 46 cfs (cubic feet per second). The discharge through the sluice gate was computed from the orifice formula:

$$Q = CA\sqrt{2gH}$$

where:

- A = area of gate opening
- g = acceleration of gravity (32.2 feet per second per second)
- H = head of water acting on the gate
- C = coefficient for the gate

With the sluice gate open 0.156 foot (between the music-note seal and the gate seat) and with a head upstream from the sluice gate of 10.1 feet, the discharge was 22 cfs. The flow over the ogee crest was estimated to be 5 cfs.

Observations made at Woodston Diversion Dam clearly indicated that water and sediment discharge in the river had not stabilized upstream from the dam. Backwater in the river from Woodston Diversion Dam extended upstream approximately 1-3/4 miles. A view of the backwater area near the diversion dam is shown in Figure 2A. At a point about one-half mile above the dam, the water depths along the bank were from 6 to 8 feet. With these conditions, very little of the coarse or sand-size material was reaching the diversion dam, even though the river bottom was in a narrow channel. A profile of the river, including the elevations of the diversion dam and the location of the river measuring reach, is shown in Figure 4.

## Bartley Diversion Dam

Bartley Diversion Dam[5/] is presently being operated to deliver the required irrigation diversion by adjusting the canal headgates and allowing the remainder of the river discharge to flow over the ogee crest as illustrated in Figures 5A and 5B. The sluice gate between the guide walls shown immediately below the boat in Figure 5A is operated at intermittent intervals to sluice sediment in the vicinity of the headworks. At about 7:00 p.m. on the day before sampling, the gate operator opened the right sluice gate (sluice gate between the guide walls) approximately 0.4 foot. Sampling with the right sluice gate opened slightly would represent conditions similar to those in the hydraulic model studies[2/] and permit a comparison of results.

A plan view in Figure 6 shows the location of the Bartley Diversion Dam and the river measuring reach. The reach is about 2.3 miles upstream from the diversion dam. River discharge measurements and sediment samples were taken as described previously. The water surface slope was measured in a 1,000-foot reach by standard survey procedures. The suspended sediment samples were obtained using the DH-48 hand sampler, and bed material samples were hand dipped.

Suspended sediment samples were collected from three locations at the Bartley Diversion headworks. A DH-59 handline sampler was used to take samples from a boat at the upstream entrance to the guide walls and from a handrail at the headworks immediately above the sluice gate. Suspended sediment samples were also taken of canal flows at a point immediately downstream from the closed conduit of the headworks using a DH-48 sampler. Soundings made at all three locations showed the concrete bottom to be free of sediment deposits. Therefore, the sediment samples represented the total sediment in movement at each of the three locations.

The rating curve for the Parshall flume on Bartley Canal had been established by previously plotting current meter measurements with gage height measurements. The canal was flowing at 101 cfs for a gage reading of 2.05 feet on the Parshall flume. A discharge of 58 cfs was computed from the formula:

$$Q = CA\sqrt{2gH}$$

for a sluice gate opening of 0.43 foot and a head of 6.44 feet. The estimated discharge flow over the ogee crest was 80 cfs.

The following summarizes the field observations made for Bartley Diversion Dam. Soundings of the river above the dam showed an average water depth of about 2.5 feet. The depth increased near the guide walls to 6.5 feet at the entrance. Backwater from the dam extended about 1/2 mile upstream. Very little sand was observed in the samples collected at the upstream entrance to the guide walls. Obviously, there was storage of the sand load taking place in the river area above the diversion dam. A profile of the river above and below the Bartley Diversion Dam is given in Figure 7.

Superior-Courtland Diversion Dam

A plan view of the Superior-Courtland Diversion Dam5/ and the river measuring reach is shown in Figure 10. Regular measurements of water discharge, suspended sediment samples, and water surface slope were taken at the river reach which is approximately 3.2 miles upstream from the diversion dam.

Normal operation of Superior-Courtland Diversion Dam is to keep the sluice gate below the guide walls closed, open the canal gates the required amount to deliver water to the canals, and pass the excess water at the diversion over the ogee crest. The sluice gates are then opened periodically and operated for a short period. At the time of the test, soundings between the guide wall and the bank on the Superior side of the diversion disclosed the bed to be free of coarse sediment and just a small amount of fine sediment deposited. However, some sediment was deposited upstream from the guide wall.

Suspended sediment samples were taken at four locations in the vicinity of both the Superior and Courtland Canal headworks and sluiceway. Samples were collected with the DH-48 sampler from a boat at the upstream end of the guide walls (Figure 9A), and from the concrete headwall at the downstream end of the canal headworks tunnels (Figure 9B). The handline DH-59 sampler was used to collect suspended samples upstream and downstream from the sluice gate, Figure 8B.

A flow of 127 cfs was measured in Superior Canal and found to be slightly lower than the discharge of 133 cfs indicated by the Parshall flume rating table.

To obtain conditions in the prototype as nearly comparable to those for which the model was tested, 3/ the sluice gates of the Superior and Courtland diversions were opened 0.2 and 0.3 foot, respectively, during sampling.

River conditions above the Superior-Courtland Diversion Dam were observed, and it was estimated the backwater extended upstream about 1 mile. Although there was an appreciable suspended sand load in the reach of the Republican River about 3.2 miles upstream from the dam, very little of this sand was being transported in the river just upstream from the diversion headworks. There was obviously a storage of sand-size material taking place in the areas above the dam. A small deposit of sediment was found immediately above the sluice gate at the Courtland headworks. A sample of the deposited material was obtained with the handline bed material sampler, BMH-60. This material was mostly finer than sand sizes, which indicated that very little sand was entering the guide wall area at the Courtland headworks. The profile of the Republican River upstream and downstream from Superior-Courtland Diversion Dam is shown in Figure 11.

Cambridge Diversion Dam

A plan view of Cambridge Diversion Dam 5/ and the measuring reach on the Republican River is shown in Figure 14. The river cross section selected for measurements was at the U.S. Geological Survey gaging station about 1.5 miles upstream from the diversion dam. The usual river measurements were taken at the river cross section for use in computing the total sediment transport.

Suspended sediment samples from the Cambridge Canal were collected using the DH-48 sampler in the Parshall flume, on three different occasions. Suspended samples were also taken with the DH-59 sampler at the headworks immediately upstream from the left sluice gate.

Prior to the sluicing operations on August 6, suspended sediment samples were collected upstream from each of the four gates diverting water to the canal. A view of the diversion dam showing the four canal gate entrances is shown in Figures 12A and 13A.

Bed material samples were collected with the BMH-60 in the river upstream from the headworks to the Cambridge Canal.

Prior to the measurements, arrangements were made to release from Medicine Creek Dam on the evening of August 5, a flow of approximately 115 cfs in excess of canal diversions. It took about 12 hours for the additional flow to reach the Cambridge Diversion Dam. The left sluice gate at Cambridge Diversion was opened 0.87 foot for a sluiceway discharge of approximately 97 cfs. The rating tables indicated a discharge in Cambridge Canal of 273 cfs and approximately 10 cfs over the ogee crest. These gate settings had been made on the evening before sampling.

The sluice gates were opened wide about 2 p.m. on August 6, for approximately 30 minutes. At 5:30 p.m. on August 6, the left sluice gate was again opened completely, and the right sluice gate was opened to within about 1 foot from the water surface, Figure 13B. The gates were closed after about 20 minutes of sluicing. At 10 a.m. on August 7, the gates were opened again for about 45 minutes.

Soundings were made upstream from the headworks gates and sluice gates on August 6, while the sluice gate was partially opened, Figure 13A. Depths of water varied from 1.5 feet upstream from the left headgate to 4.5 feet upstream from the sluice gate. With the sluice gates closed, soundings on August 7, showed water depths of about 1 foot upstream from the left headgate to 4 feet upstream from the sluice gate. One noticeable effect of the intermittent sluicing operations was the firmness and stability of the riverbed upstream from the headworks and sluiceway caused by sand movement and increased velocities at the time of sluicing. Very little scour was noted in the riverbed directly upstream from the headworks and sluice gates; however, considerable sand appeared to be moving during the sluicing operation. There was no pool upstream from the Cambridge Diversion Dam such as was observed at the other diversion dams.

The river profile above and below the diversion dam is shown in Figure 15. Figure 12B shows the channel conditions upstream from the diversion dam.

## ANALYSIS OF DATA

Data from the discharge and slope measurements at the river reaches upstream from the diversion dams are summarized in Table 1. Hydraulic data taken at the representative river cross section along with the suspended sediment sample data were used in the computations of total load. The water surface slope for a 1,000-foot reach of river was measured 500 feet upstream and downstream from the sampling cross section.

## Laboratory Analysis

Table 2 gives a list of all suspended sediment samples taken during these field measurements giving type of sampler used, methods of sampling, number of verticals in the cross section used for sampling, average water depth, and discharges either computed from measurements or estimated.

About 33 samples of bed material were collected at the diversion dams, and at other areas in the Kansas River Basin. These bed material samples were analyzed in the laboratory for size gradation and the results are shown in Table 3. The individual or average values for all locations are plotted in Figures 16, 17, and 18. The bed material samples taken at locations other than at or upstream of the diversion dams are not pertinent to this report, but are included as general information.

Laboratory analyses using the bottom withdrawal tube method were made of the 30 suspended sediment samples to determine both concentration and size analysis. The results of the suspended sediment analyses are shown in Table 4 with the appropriate breakdown by the clay, silt, and sand size fractions. Plots of the size analyses of suspended sediment samples obtained from the river reaches upstream of the diversion dams are shown in Figure 19.

## Sediment Load Computations

Computations were made of the total sediment transported in the river by use of the modified Einstein formula. The hydraulic data taken at the discharge measuring section, along with suspended and bed material samples, were used in these computations performed on the IBM 650 computer. The results of total load computations for the four river sections are shown in Table 5.

The data obtained on all suspended sediment samples collected at the diversion dams were analyzed by size fractions as shown in Table 4. A breakdown of the suspended load into clay, silt, and sand at various sampling points near the diversion dams is tabulated in Table 6. The concentrations shown are expressed in percent as well as in ppm (parts per million). For the four river cross sections the tons per day from the total load computations were converted to parts per million.

Sediment Exclusion at Diversion Dams

The curved guide wall type of sediment control arrangement was developed to control the movement of the sand load moving on or near the streambed (bedload) and through a curved guide wall channel. The flow in the curved guide wall channel would cause the coarse sand to move to the inside (concave side of the flowing water) of the curve because of the secondary currents produced by super elevation of the water surface as it flowed around the curve. Probing in the curved channels revealed that there was no sand load moving in contact with the channel bottoms. It was obvious that the coarse sand was depositing before it arrived at Woodston, Bartley, or Superior-Courtland Diversion Dams.

The operational efficiency of each sediment control structure could not be determined because almost all the sand load in the river moving in suspension and as bedload was depositing upstream from the three diversion dams. An evaluation of such efficiencies can be made at some future time when conditions indicate the pools above the dams have filled with sediment and the sand load is transported into the vicinity of the sediment control facilities.

Samples were collected to determine if the sediment control arrangements at the three diversion dams would cause more of the suspended load, particularly the coarser (sand) fractions, to go to the outside (concave side) of the flow in the curved channels and through the sluiceway. This type of study (suspended sediment load transported into the headworks and sluiceway) was not made in the model studies.

The data shown in Table 6 were analyzed in a study of the sediment exclusion actually taking place at various diversion dams. At the Woodston, Bartley, and Superior-Courtland Diversion Dams which included sediment control structures there was very little sand load in the flow at the dams for a quantitative evaluation of the structure in excluding sediment from the canals. Observations of upstream river conditions showed that most of the sand load was being deposited above the diversion dam.

Figure 20 shows a plot of the observed concentrations in the river above Woodston Diversion Dam in the flow between guide walls upstream from the headworks, in the canal, and in the sluiceway. The concentrations are broken down into clay, silt, sand, and total sediment. At Woodston Diversion Dam, the concentration of sand in the river was very low and was even lower in the vicinity of the headworks.

Sediment concentrations at Bartley Diversion Dam are shown in Figure 21. The plot shows that the sand concentration in the river was higher than that on the South Fork of the Solomon River at Woodston, but there was almost no sand reaching the guide walls at the headworks.

Therefore, these conditions preclude making a computation of the efficiency of the sediment control structure for excluding sand from the canal.

A comparison of concentrations at the Courtland Canal headworks and the Superior Canal headworks of the Superior-Courtland Diversion Dam is shown in Figures 22 and 23. Here again the sand concentration in the river upstream from the diversion dam was very low and there was little sand observed at the guide walls in front of the headworks. In the case of the Courtland Canal headworks, the sand concentration in the canal was lower than at a point 10 feet upstream of the sluiceway gate, which would indicate the arrangement was efficient in transporting suspended sand through the sluiceway. The true efficiency could not be determined from these extremely low sand concentrations.

For Cambridge Diversion Dam the concentration of the sand fraction in the water flowing through the headworks and sluiceway remained about the same or was even higher than the concentration of the sand fraction measured in the Republican River upstream. Observations and probings of the riverbed upstream from the headworks and sluiceway gates revealed that there was considerable coarse sediment moving on or near the bed. The samples collected at the dam verified the observations and the problems encountered with sediment. The concentrations of sand in the vicinity of the headworks were even higher than those observed in the upstream river. Although no sediment control structure was built into the Cambridge Diversion Dam, the results shown on Figure 24 are presented for comparison purposes and to illustrate what can happen when sediment causes a problem. From Figure 24 it is noted that the sand concentration in the sluiceway was much higher than either in the canal or above the headworks. The sluiceway was operated on an intermittent basis, and to some extent on a continuation basis both before and after the observations. Operations at Cambridge Diversion Dam do show that even when no excluding device is incorporated in the dam and when water is available for sluicing some sand can be sluiced into the downstream river channel.

## SUMMARY AND CONCLUSIONS

Field tests were made to determine the sediment being transported in the river and in the vicinity of the headworks at Woodston, Bartley, Superior-Courtland, and Cambridge Diversion Dams. Measurements of the sediment load above the headworks, in the canals, and in the sluiceways were made to determine the efficiency of the sediment control structures in excluding the heavier sand load of the stream. At three diversion dams--Woodston, Bartley, and Superior-Courtland--where sediment control structures had been built, all of the bedload and most of the river sand load was depositing in the river basin above the diversion dam. Very little sand was entering the guide walls at the headworks and therefore it was not possible to make a quantitative evaluation of the amount of sand sluiced on down the sluiceway and excluded from entering the canal.

Curved guide walls do provide a means of sluicing bedload sediment past the headworks, through the sluiceway and into the downstream river channel. Model studies show they work well for controlling sediment on a continuous basis. Field personnel have also found that they work well when operated on an intermittent basis. Observations by operating personnel have shown that sediment will build up in front of the headworks, and by sluicing on an intermittent basis, much of the sediment in the fine sizes as well as sand is moved on down the river through the sluiceway. Based on the success of those operations, the structures are effective in excluding sediment from the canal. Although the diversion dams were designed to operate with the sluiceway continuously open for sluicing sediment, the intermittent sluicing is an effective method of operation.

It is desirable that, in the future, tests similar to those performed in August 1960 be made again at these diversion dams. This interim report represents an initial step in outlining the field procedures and data reduction analyses for use as guides in performing future tests at the diversion dams in the Kansas River Basins. Information on the amounts of sediments that can be excluded from canals by various sediment control structures is of value in project investigations stages as well as in the design of a diversion dam and for making hydraulic model studies.

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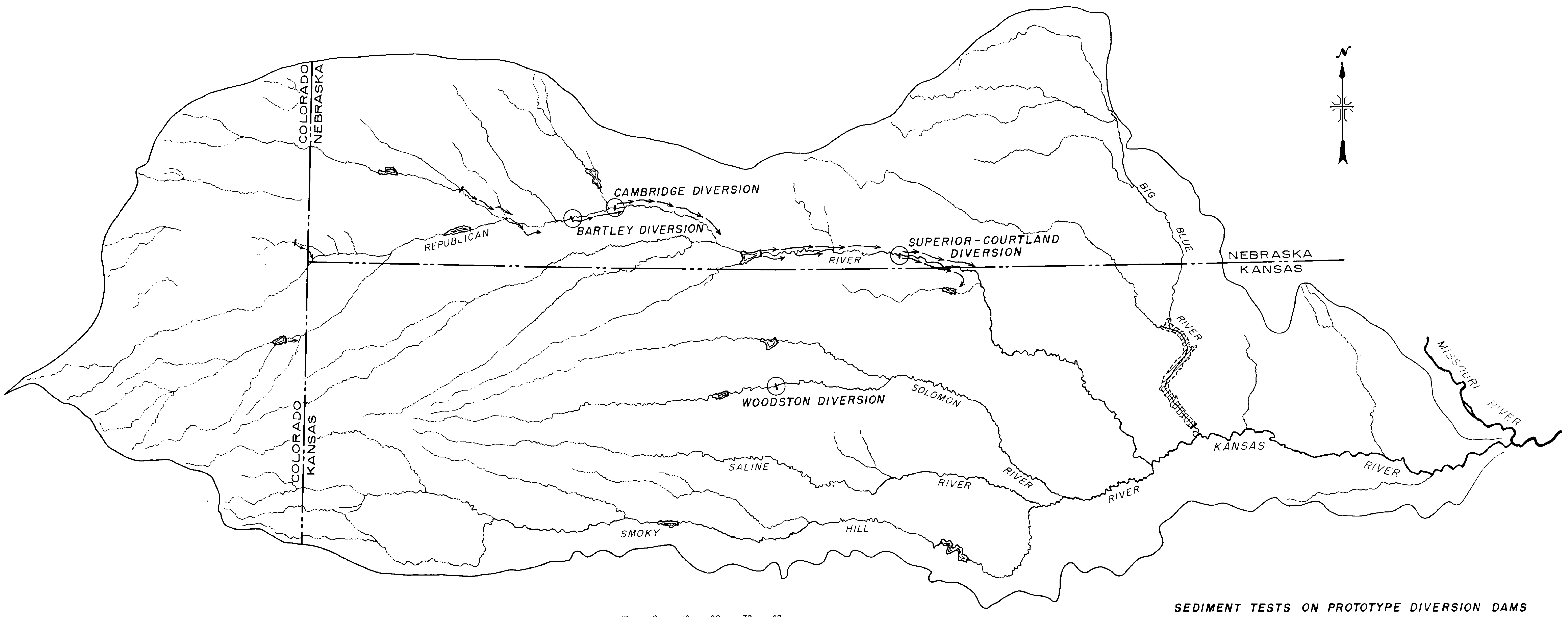



**SEDIMENT TESTS ON PROTOTYPE DIVERSION DAMS**
**IN KANSAS RIVER BASIN**
**GENERAL LOCATION MAP**

FIGURE 1

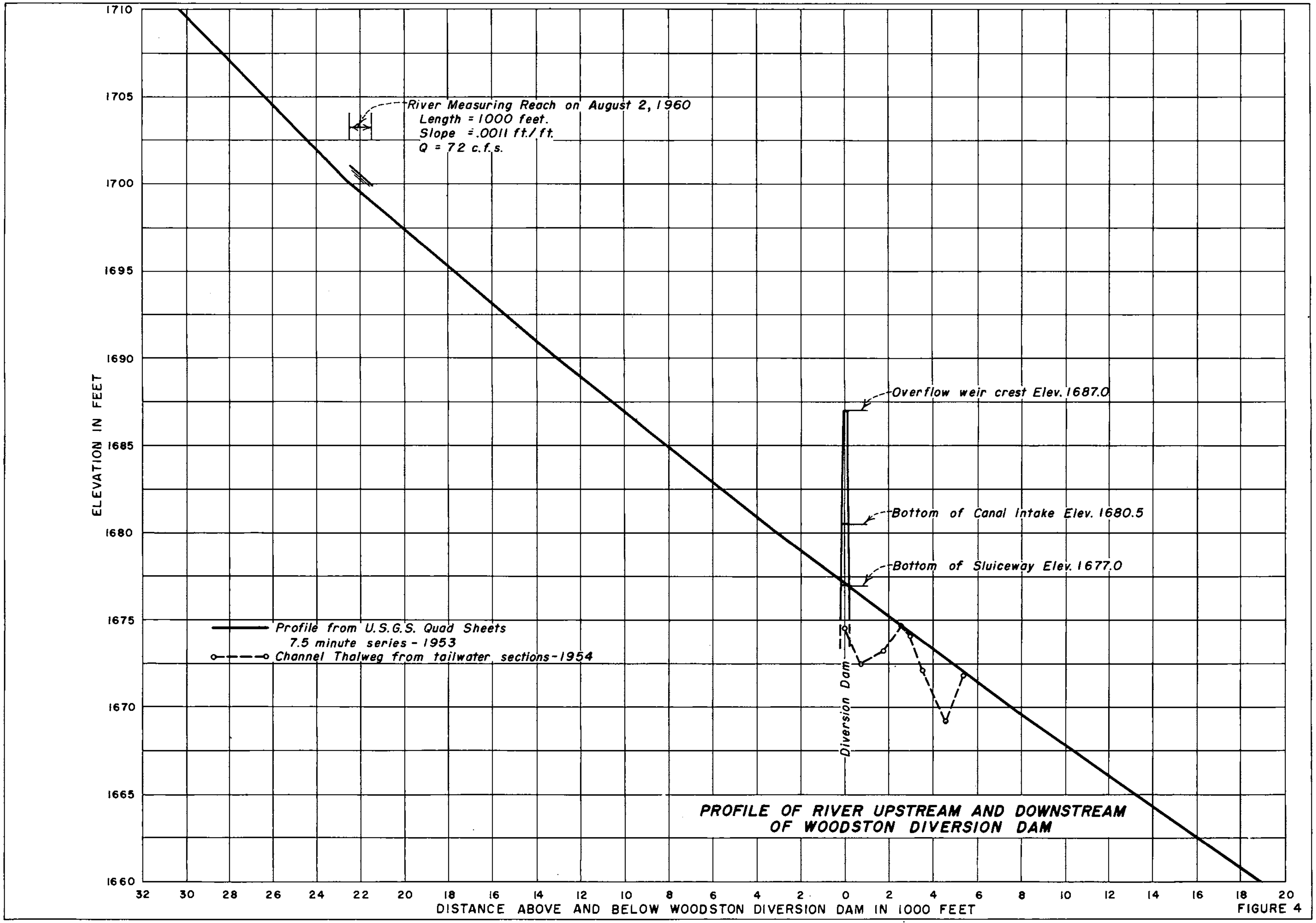
WOODSTON DIVERSION DAM

A. Photograph showing backwater upstream of Woodston Diversion Dam on South Fork Solomon River.

B. Obtaining suspended sediment sample in sluiceway with D-49 sampler.

U.S. 24
MISSOURI PACIFIC RAILROAD
SLUICEWAY
HEADWORKS
WOODSTON DIVERSION DAM
DIKE
OSBORNE CANAL
Woodston
Douglas Creek
Jim Creek
SOUTH FORK SOLOMON RIVER
RIVER MEASURING REACH
Medicine Creek
R.17 W.
R.16 W.
Topography taken from USGS Quad sheets 7.5 minute series - 1953
SCALE OF FEET
SEDIMENT TESTS ON PROTOTYPE DIVERSION DAMS
PLAN VIEW OF WOODSTON DIVERSION DAM AND SURROUNDING AREA
E.L.P.
5-31-61

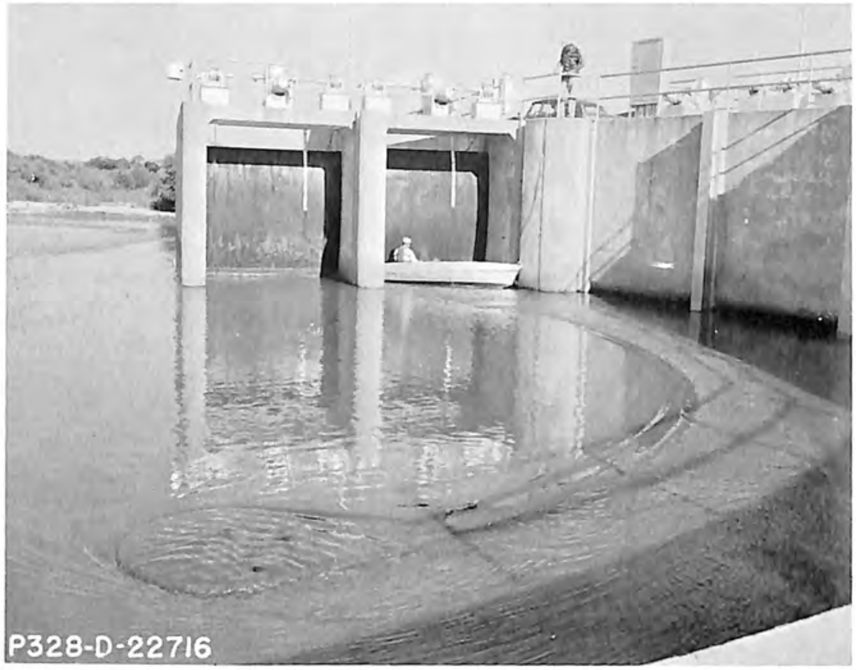

FIGURE 3




PROFILE OF RIVER UPSTREAM AND DOWNSTREAM OF WOODSTON DIVERSION DAM

FIGURE 4

BARTLEY DIVERSION DAM

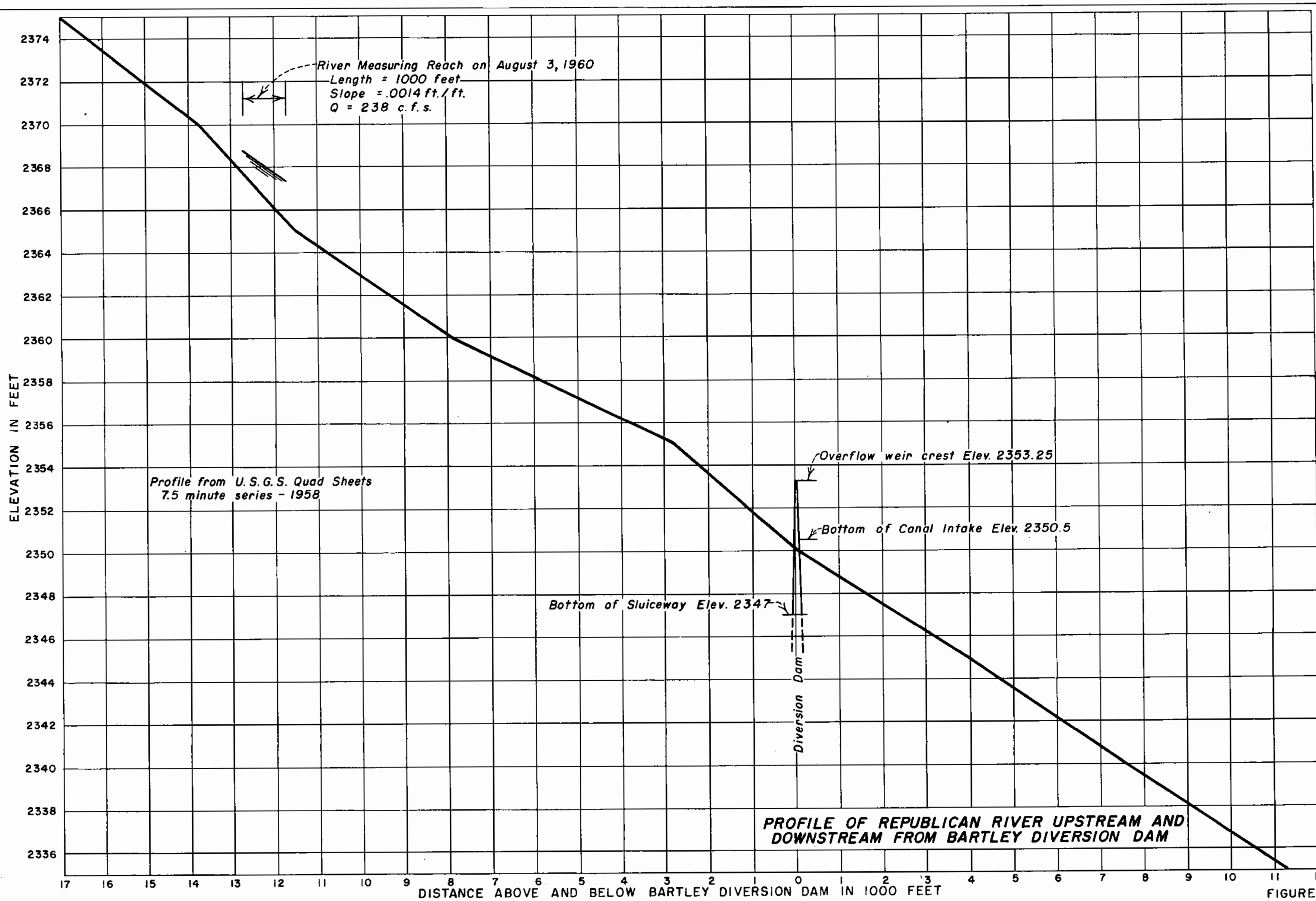



A. Obtaining suspended sediment sample from a boat upstream of the right sluice gate, using a DH-48 sampler.

B. Photograph looking upstream toward Bartley Diversion Dam.


Indianola
CHICAGO
BURLINGTON
AND
QUINCY
U.S. 6-34
SPOIL BANK
RIVER MEASURING REACH
REPUBLICAN
RIVER
BARTLEY DIVERSION DAM
HEADWORKS
SETTLING BASIN
BARTLEY CANAL
Berger Creek
Topography taken from USGS Quad sheets
7.5 minute series-1958
SCALE OF FEET
SEDIMENT TESTS ON PROTOTYPE
DIVERSION DAMS
PLAN VIEW OF BARTLEY DIVERSION
DAM AND SURROUNDING AREA
D.L.K.
5-25-61

FIGURE 6




PROFILE OF REPUBLICAN RIVER UPSTREAM AND DOWNSTREAM FROM BARTLEY DIVERSION DAM

FIGURE 7

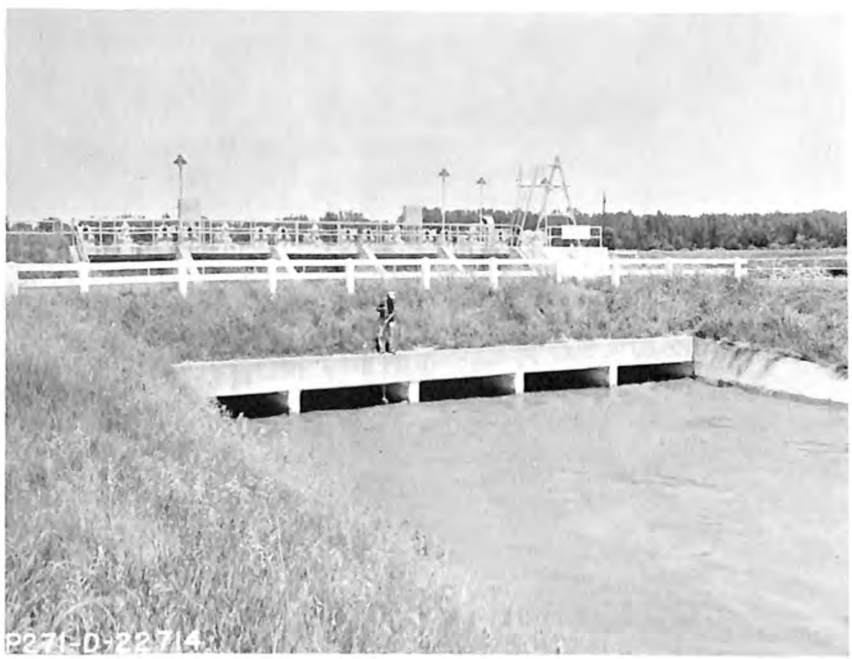
SUPERIOR-COURTLAND DIVERSION DAM


A. Sampling with DH-48 sediment sampler in Republican River upstream from Superior-Courtland Diversion Dam.


B. Sampling with suspended sediment sampler DH-59 at entrance to sluiceway--Superior Canal headworks.

SUPERIOR-COURTLAND DIVERSION DAM


A. Obtaining suspended sediment sample using DH-48 sampler from a boat.




B. Obtaining suspended sediment sample with DH-48 sampler downstream of Courtland headworks.


**SEDIMENT TESTS ON PROTOTYPE DIVERSION DAMS**

**PLAN VIEW OF SUPERIOR-COURTLAND DIVERSION DAM AND SURROUNDING AREA**

E.L.P. 6-1-61

FIGURE 10

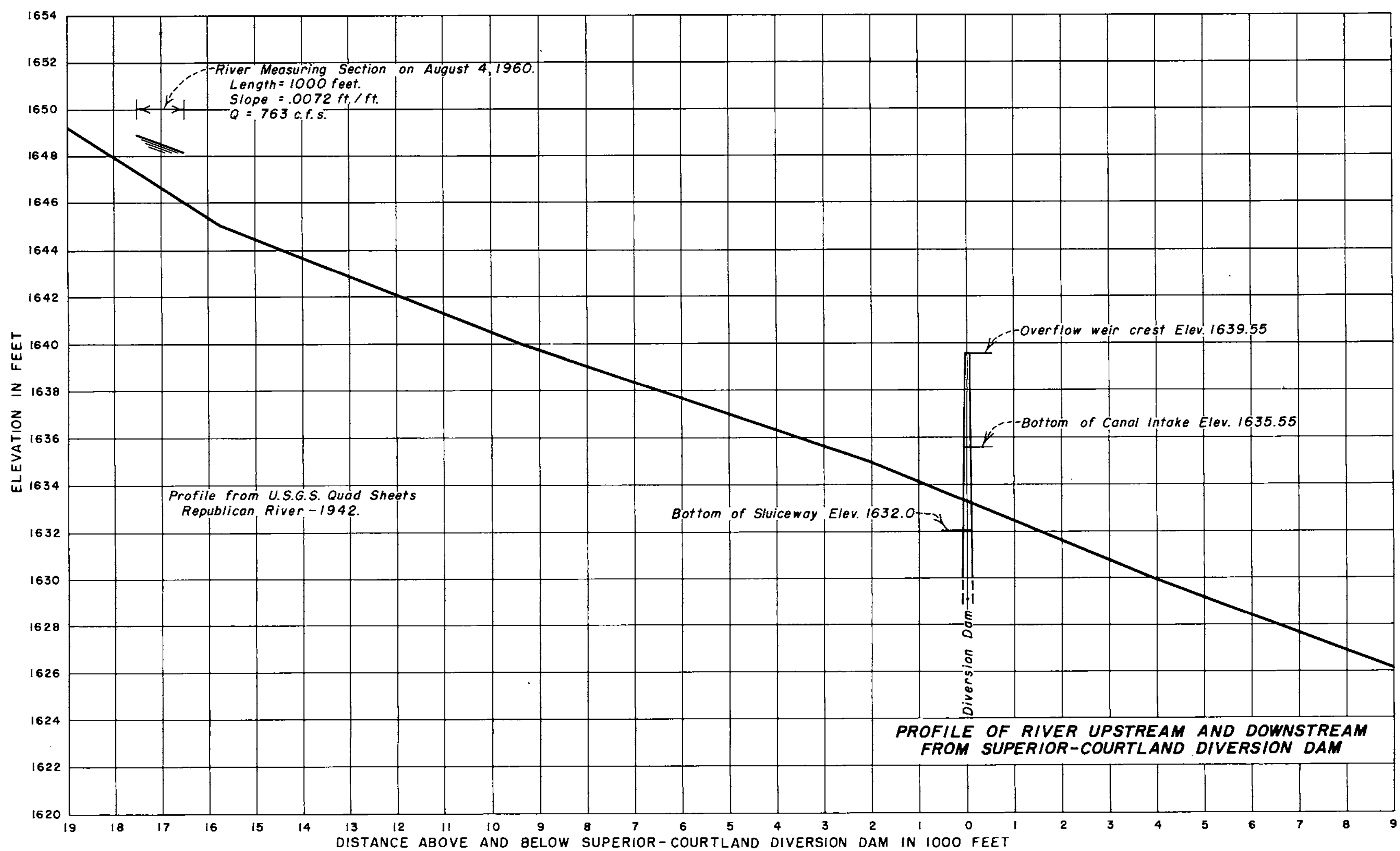

River Measuring Section on August 4, 1960.
Length = 1000 feet.
Slope = .0072 ft./ft.
Q = 763 c.f.s.
Profile from U.S.G.S. Quad Sheets
Republican River - 1942.
Overflow weir crest Elev. 1639.55
Bottom of Canal Intake Elev. 1635.55
Bottom of Sluiceway Elev. 1632.0
Diversion Dam
ELEVATION IN FEET
DISTANCE ABOVE AND BELOW SUPERIOR-COURTLAND DIVERSION DAM IN 1000 FEET
PROFILE OF RIVER UPSTREAM AND DOWNSTREAM FROM SUPERIOR-COURTLAND DIVERSION DAM

FIGURE 11

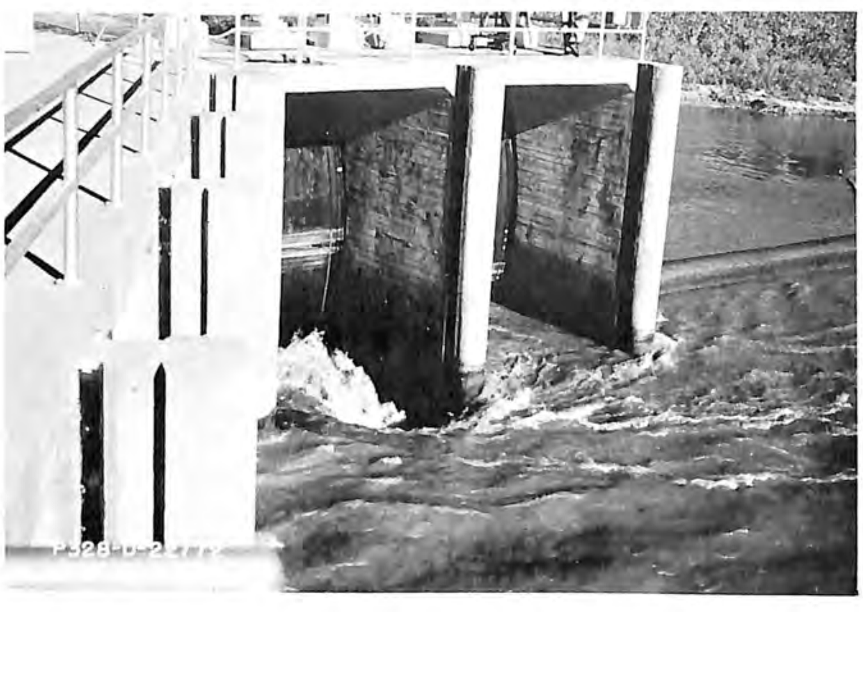
CAMBRIDGE DIVERSION DAM


A. Photograph looking toward headworks and sluiceway on the left bank.

B. Photograph of Republican River upstream.

CAMBRIDGE DIVERSION DAM


A. Measuring water depth and sediment deposit upstream from headworks and sluiceway.



B. Photograph showing sluicing operation.

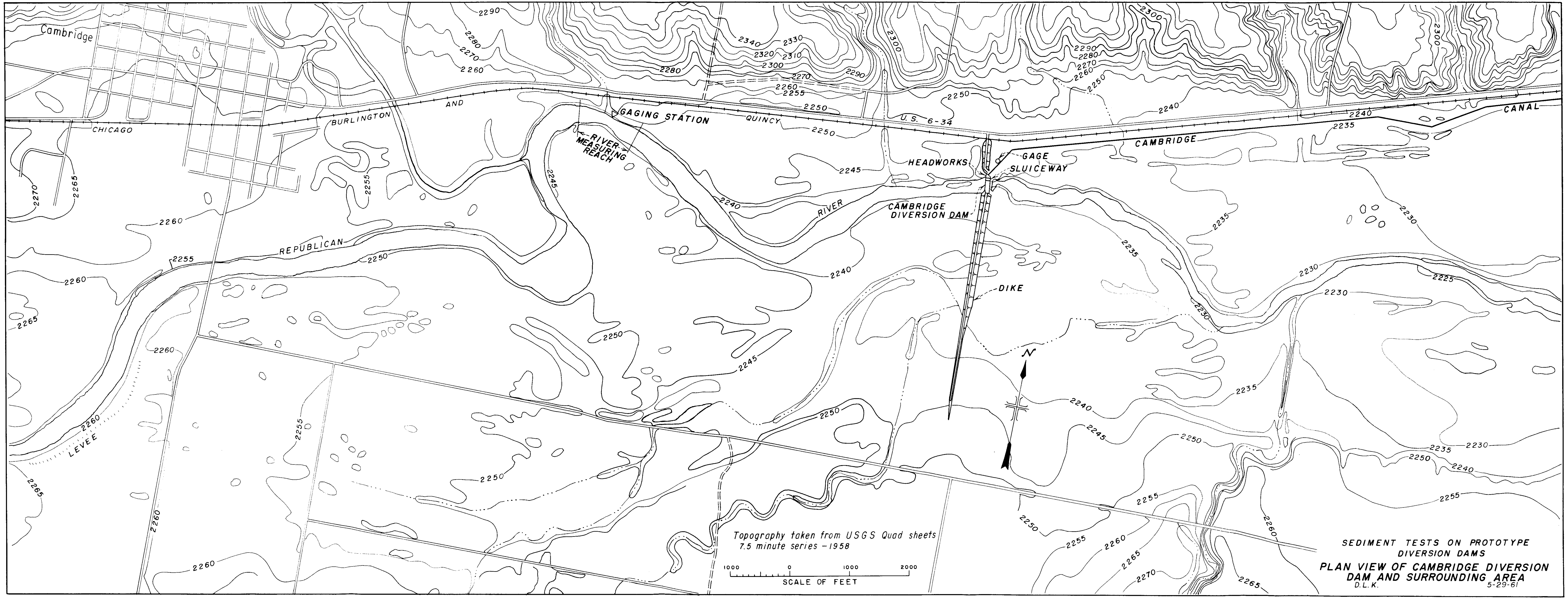
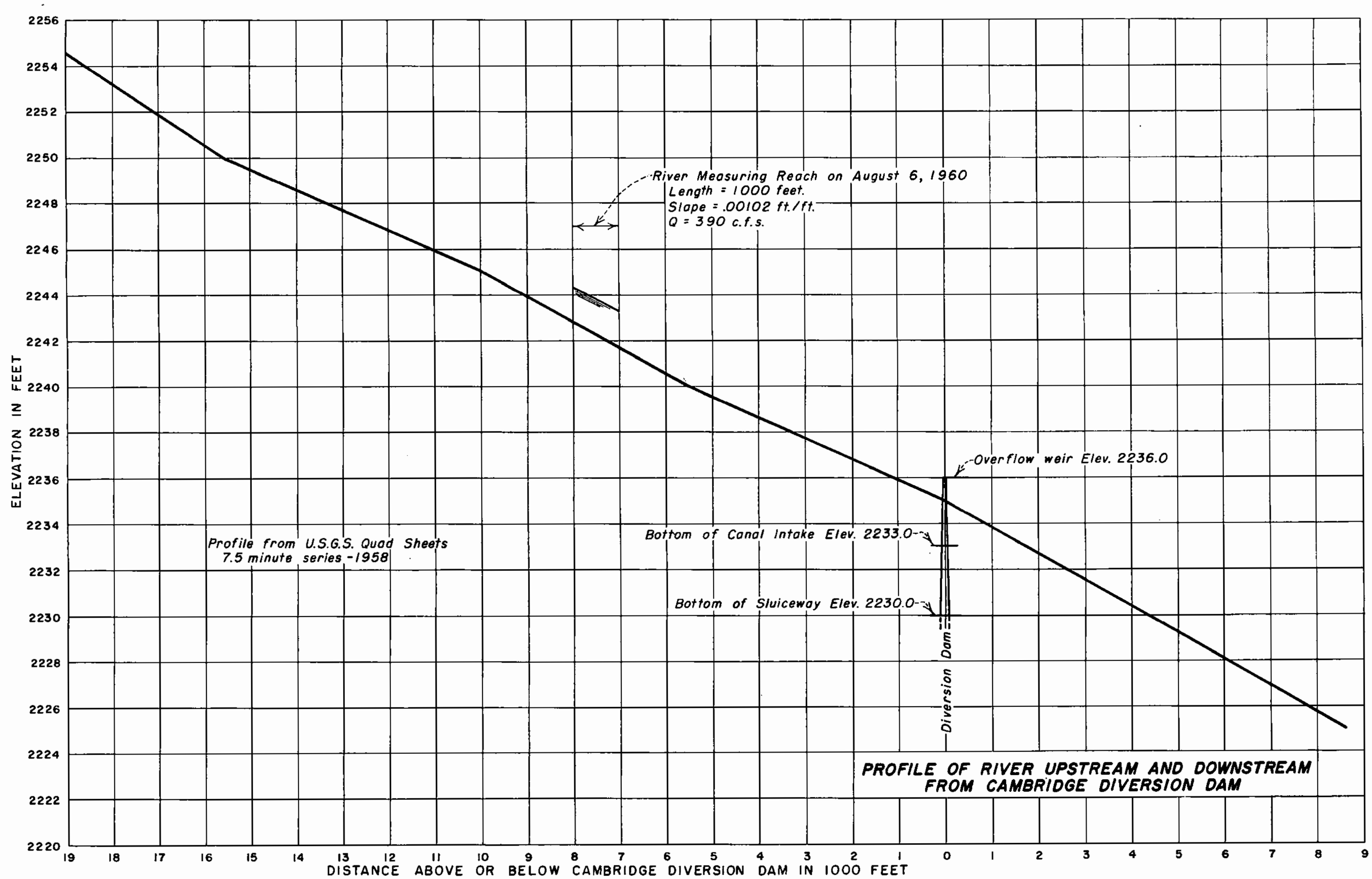

Cambridge
CHICAGO
BURLINGTON
AND
QUINCY
U.S. 6-34
GAGING STATION
RIVER MEASURING REACH
HEADWORKS
GAGE
SLUICEWAY
CAMBRIDGE
CANAL
REPUBLICAN
RIVER
CAMBRIDGE DIVERSION DAM
DIKE
LEVEE
N
Topography taken from USGS Quad sheets
7.5 minute series - 1958
1000 0 1000 2000
SCALE OF FEET
SEDIMENT TESTS ON PROTOTYPE
DIVERSION DAMS
PLAN VIEW OF CAMBRIDGE DIVERSION
DAM AND SURROUNDING AREA
D.L.K.
5-29-61

FIGURE 14



2256
2254
2252
2250
2248
2246
2244
2242
2240
2238
2236
2234
2232
2230
2228
2226
2224
2222
2220
ELEVATION IN FEET
River Measuring Reach on August 6, 1960
Length = 1000 feet.
Slope = .00102 ft./ft.
Q = 390 c.f.s.
Overflow weir Elev. 2236.0
Bottom of Canal Intake Elev. 2233.0
Bottom of Sluiceway Elev. 2230.0
Diversion Dam
Profile from U.S.G.S. Quad Sheets
7.5 minute series - 1958
PROFILE OF RIVER UPSTREAM AND DOWNSTREAM
FROM CAMBRIDGE DIVERSION DAM
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
DISTANCE ABOVE OR BELOW CAMBRIDGE DIVERSION DAM IN 1000 FEET


FIGURE 15

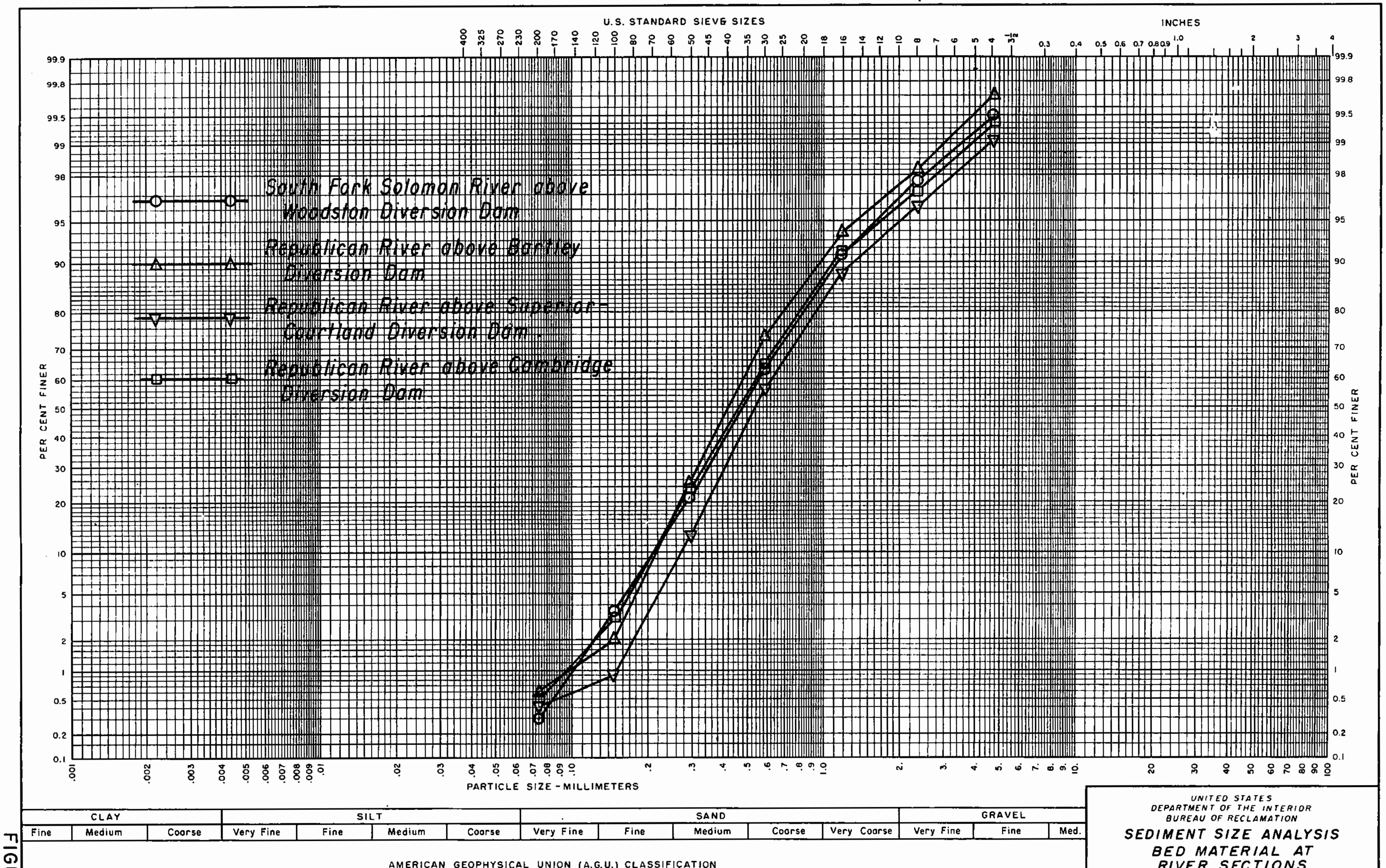


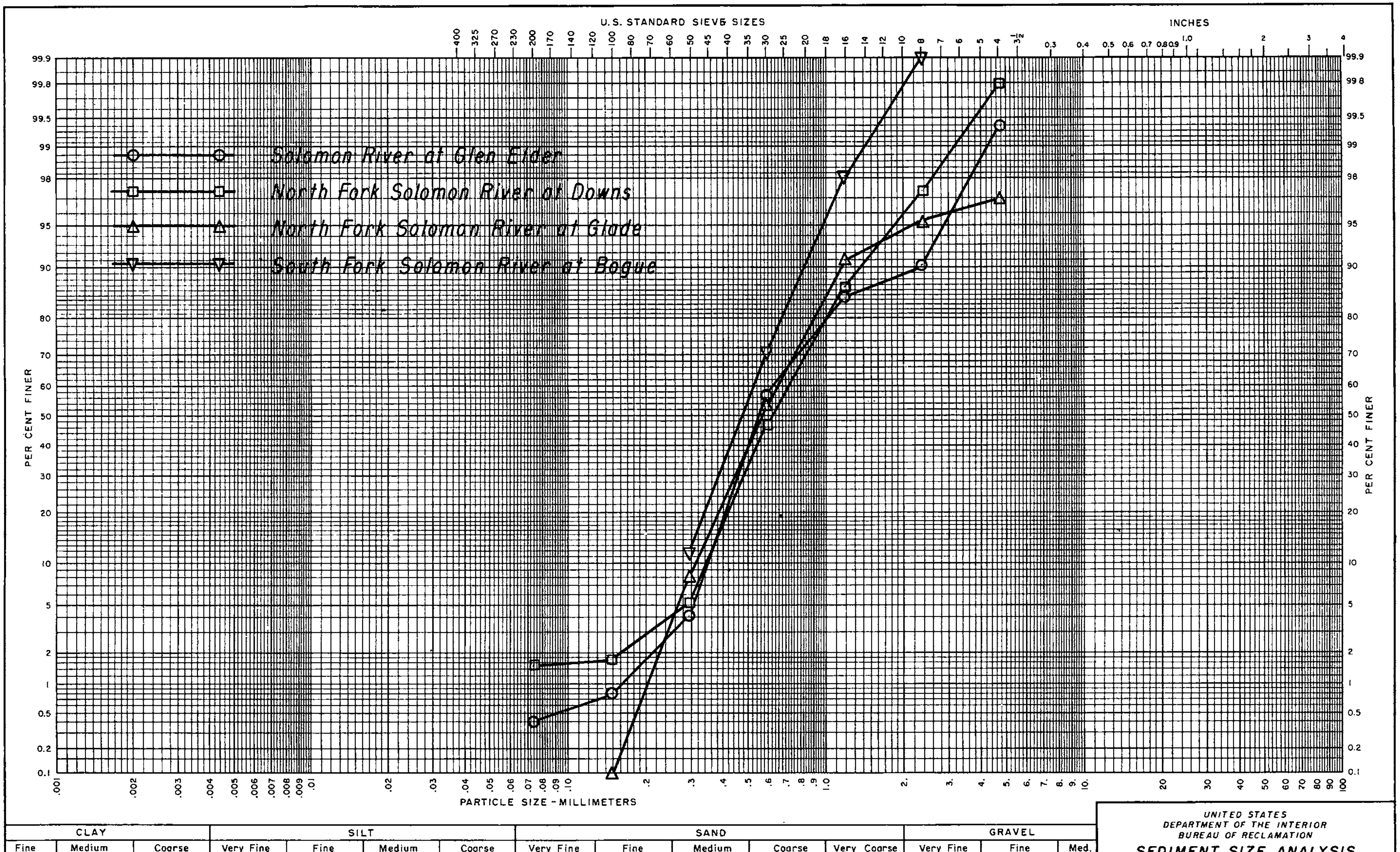

FIGURE 16

**SIZE ANALYSIS OF BED MATERIAL SEDIMENT TAKEN AT RIVER REACHES UPSTREAM FROM THE FOUR DIVERSION DAMS TESTED**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

**SEDIMENT SIZE ANALYSIS BED MATERIAL AT RIVER SECTIONS**

DRAWN............ SUBMITTED............
TRACED............ RECOMMENDED............
CHECKED............ APPROVED............




AMERICAN GEOPHYSICAL UNION (A.G.U.) CLASSIFICATION

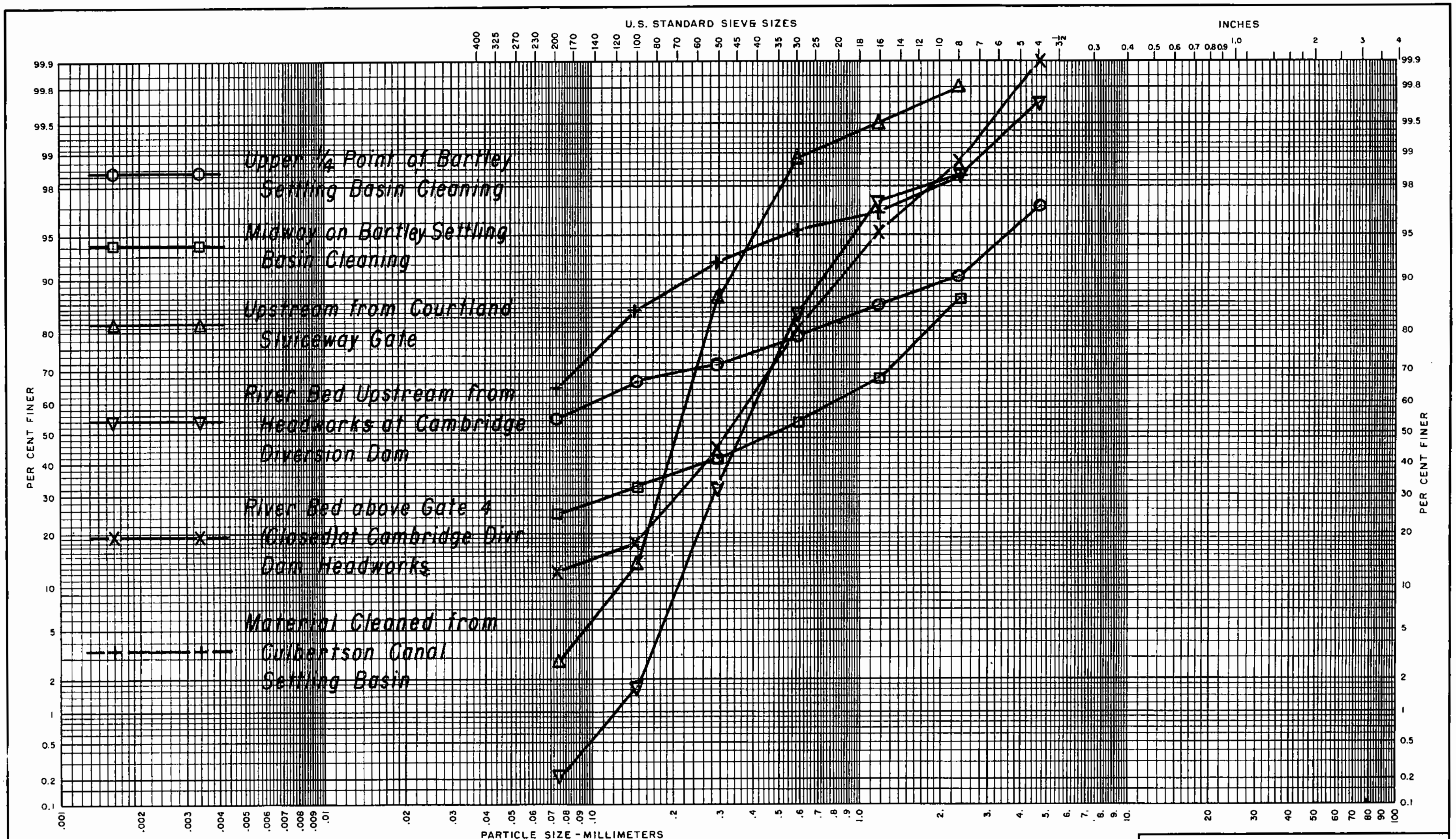
**SIZE ANALYSIS OF MISCELLANEOUS BED MATERIAL SAMPLES FROM THE SOLOMON RIVER, NORTH FORK SOLOMON RIVER, AND SOUTH FORK SOLOMON RIVER**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

**SEDIMENT SIZE ANALYSIS**
**BED MATERIAL**
**MISCELLANEOUS RIVER SAMPLES**

DRAWN............ SUBMITTED............
TRACED............ RECOMMENDED............
CHECKED............ APPROVED............

FIGURE 17




| CLAY | | | SILT | | | | SAND | | | | | GRAVEL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fine | Medium | Coarse | Very Fine | Fine | Medium | Coarse | Very Fine | Fine | Medium | Coarse | Very Coarse | Very Fine | Fine | Med. |

AMERICAN GEOPHYSICAL UNION (A.G.U.) CLASSIFICATION

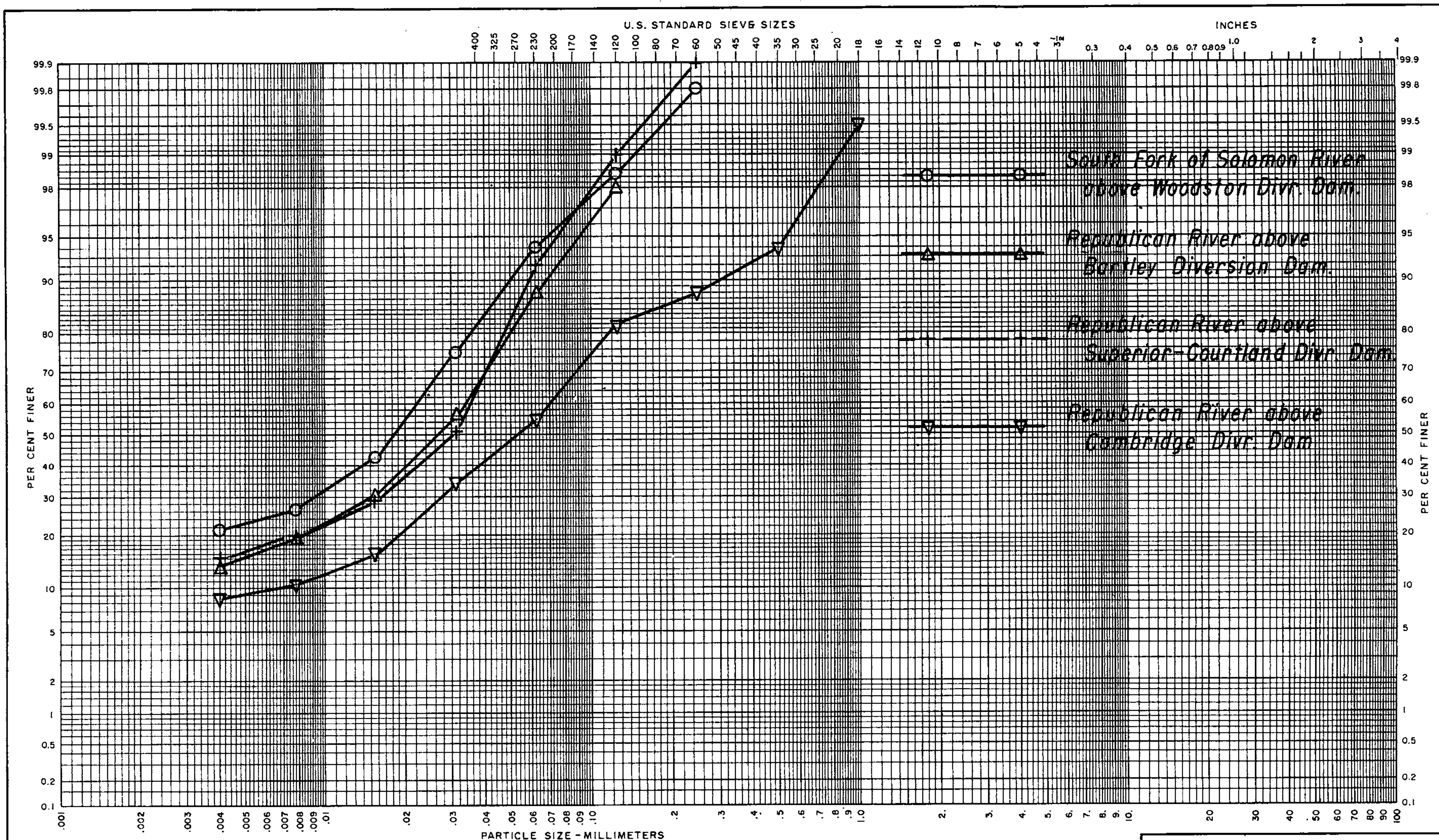
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

**SEDIMENT SIZE ANALYSIS**
**BED MATERIAL**
**MISCELLANEOUS**

DRAWN............ SUBMITTED............
TRACED............ RECOMMENDED............
CHECKED............ APPROVED............

**SIZE ANALYSIS OF BED MATERIAL SAMPLES TAKEN FROM BARTLEY SETTLING BASIN, UPSTREAM OF COURTLAND SLUICE GATE, UPSTREAM OF CAMBRIDGE DIVERSION DAM, AND IN CULBERTSON CANAL SETTLING BASIN**

FIGURE 18




| CLAY | | | SILT | | | | SAND | | | | | GRAVEL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fine | Medium | Coarse | Very Fine | Fine | Medium | Coarse | Very Fine | Fine | Medium | Coarse | Very Coarse | Very Fine | Fine | Med. |

AMERICAN GEOPHYSICAL UNION (A.G.U.) CLASSIFICATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

**SEDIMENT SIZE ANALYSIS SUSPENDED SEDIMENT FOR RIVER SECTIONS**

DRAWN.......... SUBMITTED..........
TRACED.......... RECOMMENDED..........
CHECKED.......... APPROVED..........

**SIZE ANALYSIS OF SUSPENDED SEDIMENT SAMPLES FROM RIVER REACHES UPSTREAM FROM THE FOUR DIVERSION DAMS TESTED**

FIGURE 19

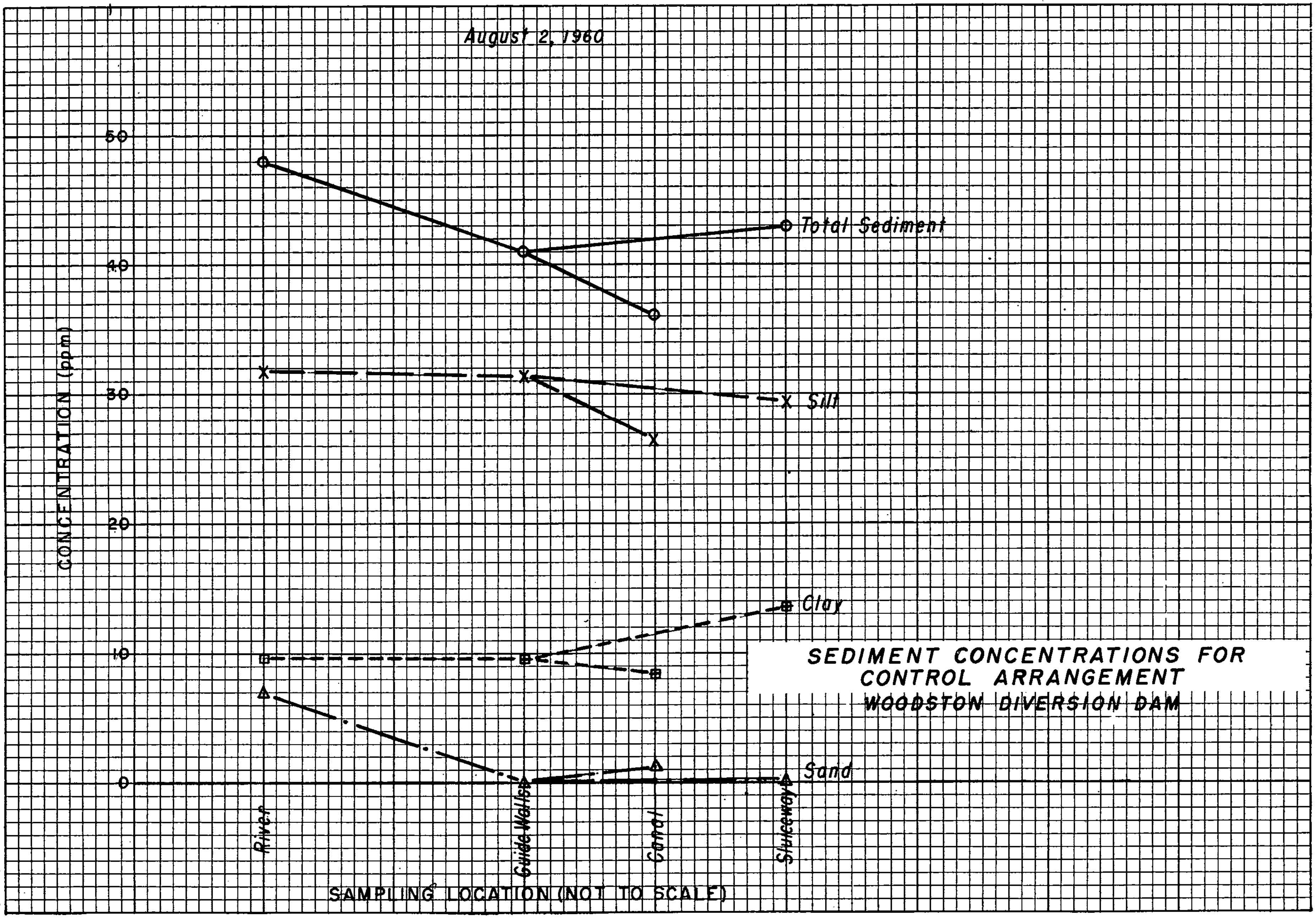

August 2, 1960
50
40
30
20
10
0
CONCENTRATION (ppm)
Total Sediment
Silt
Clay
Sand
River
Guide Walls
Canal
Sluiceway
SAMPLING LOCATION (NOT TO SCALE)
SEDIMENT CONCENTRATIONS FOR
CONTROL ARRANGEMENT
WOODSTON DIVERSION DAM

FIGURE 20

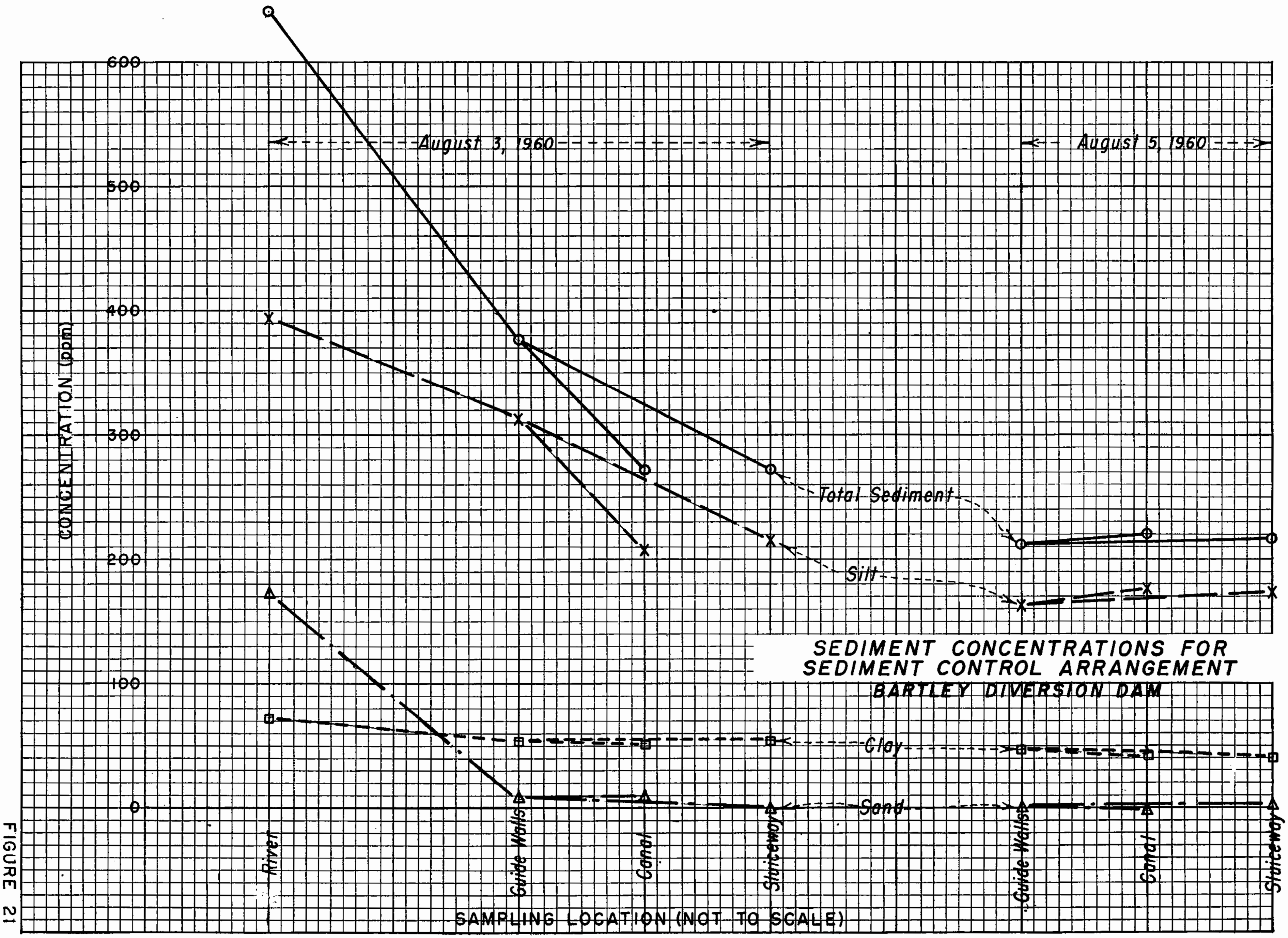
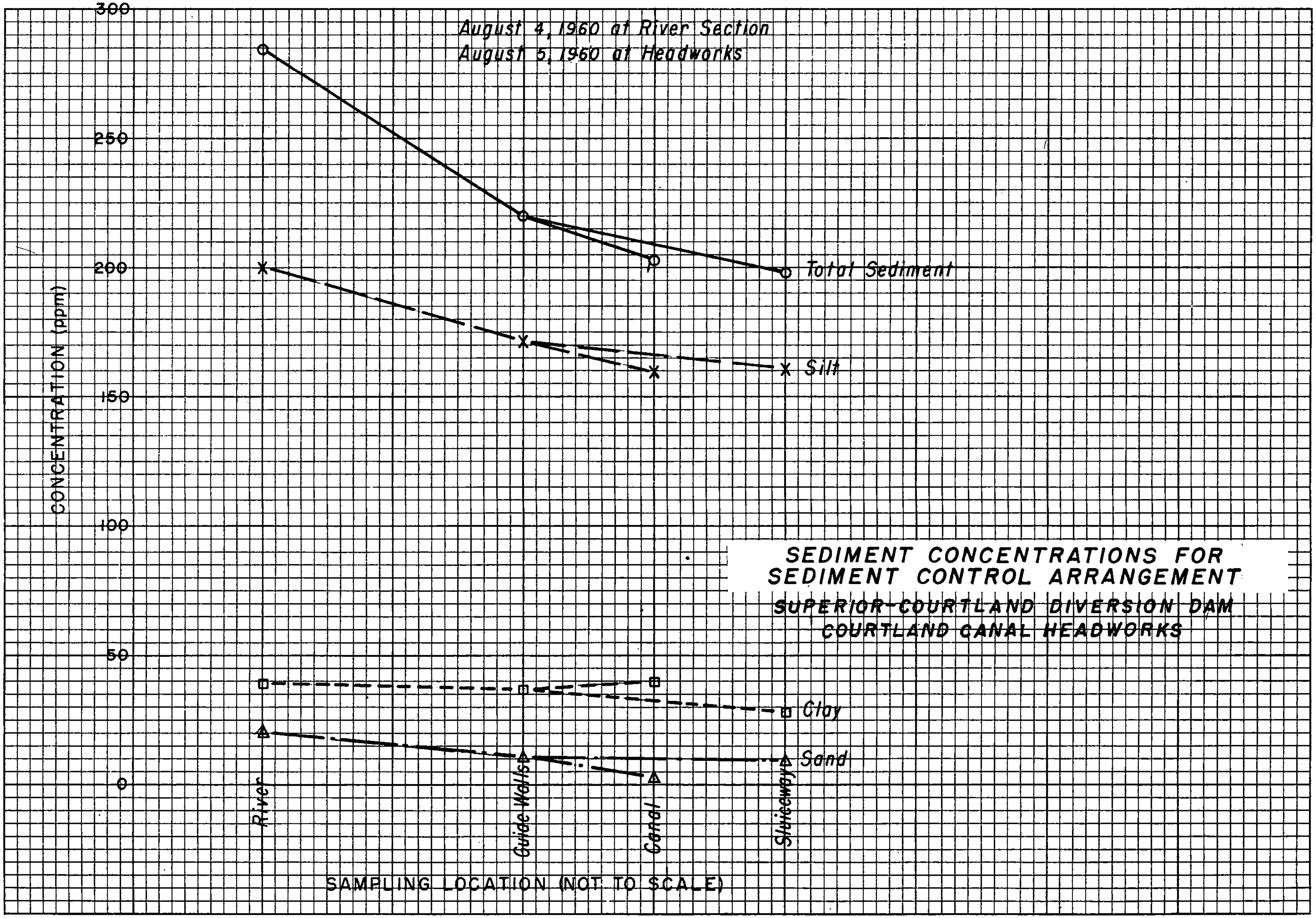
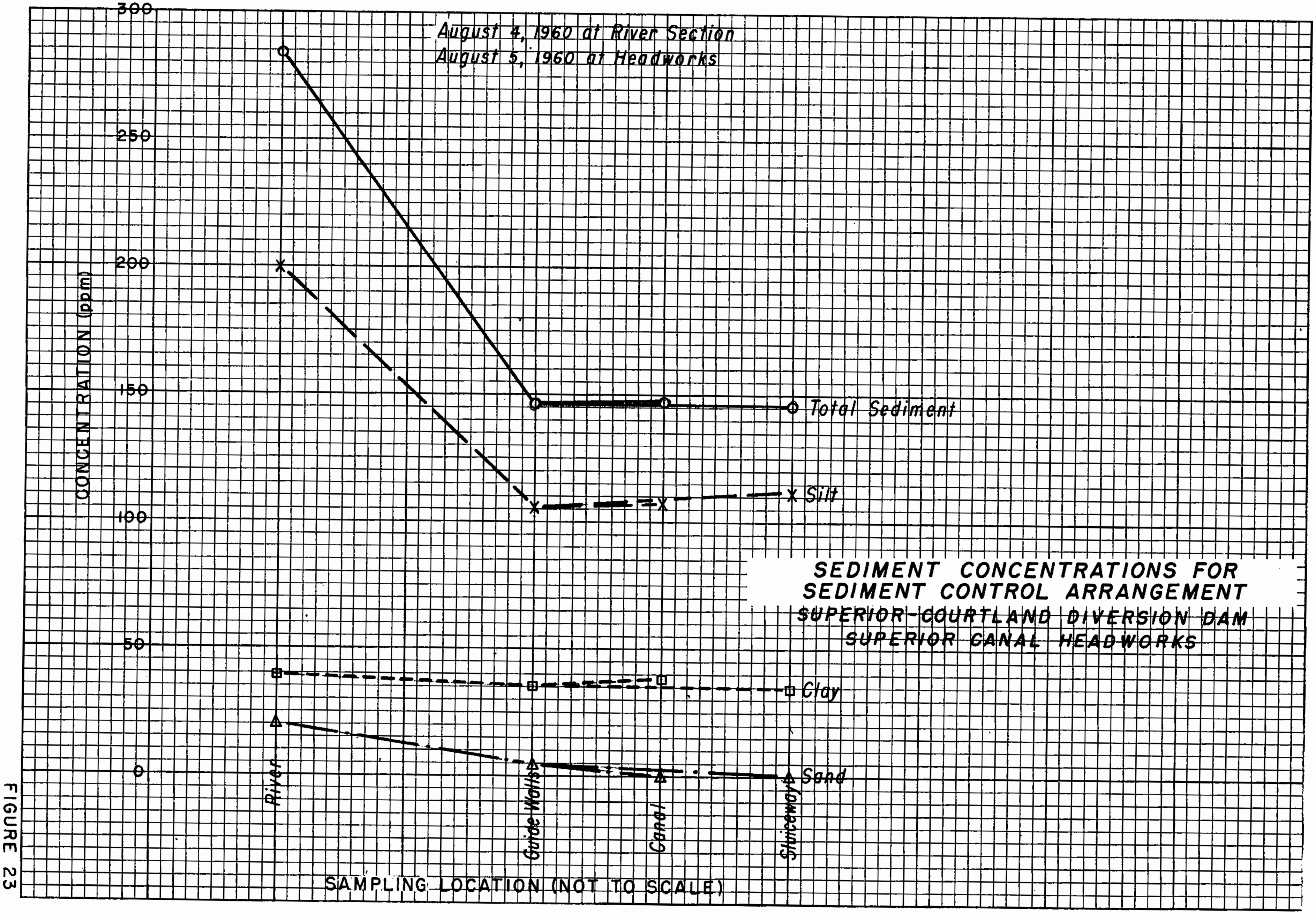

SEDIMENT CONCENTRATIONS FOR
SEDIMENT CONTROL ARRANGEMENT
BARTLEY DIVERSION DAM
August 3, 1960
August 5, 1960
CONCENTRATION (ppm)
600
500
400
300
200
100
0
Total Sediment
Silt
Clay
Sand
River
Guide Walls
Canal
Sluiceway
Guide Walls
Canal
Sluiceway
SAMPLING LOCATION (NOT TO SCALE)

FIGURE 21




SEDIMENT CONCENTRATIONS FOR
SEDIMENT CONTROL ARRANGEMENT
SUPERIOR-COURTLAND DIVERSION DAM
COURTLAND CANAL HEADWORKS

FIGURE 22



August 4, 1960 at River Section
August 5, 1960 at Headworks
300
250
200
150
100
50
0
CONCENTRATION (ppm)
Total Sediment
Silt
Clay
Sand
River
Guide Walls
Canal
Sluiceway
SAMPLING LOCATION (NOT TO SCALE)
SEDIMENT CONCENTRATIONS FOR
SEDIMENT CONTROL ARRANGEMENT
SUPERIOR-COURTLAND DIVERSION DAM
SUPERIOR CANAL HEADWORKS


FIGURE 23

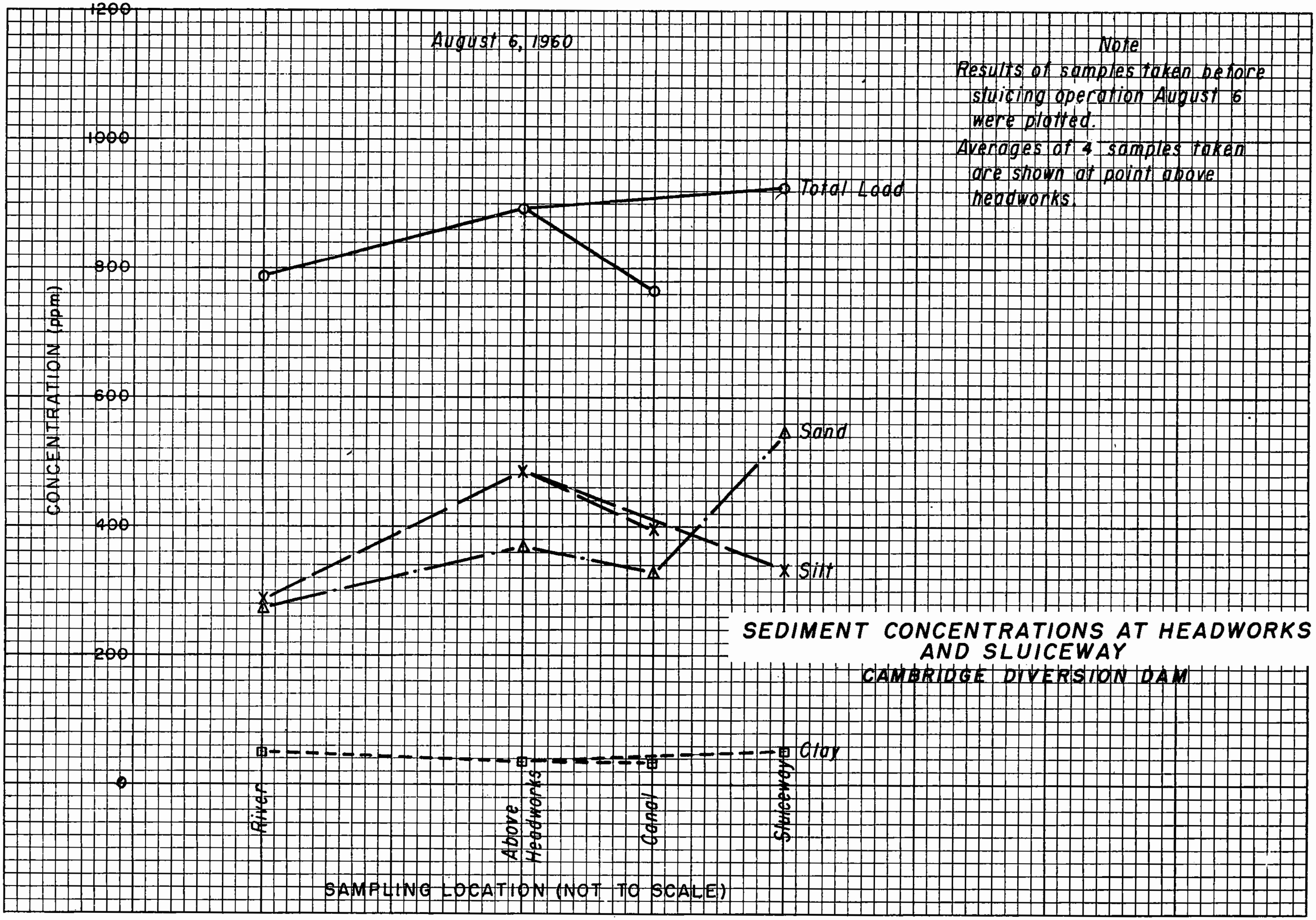

August 6, 1960
Note
Results of samples taken before sluicing operation August 6 were plotted.
Averages of 4 samples taken are shown at point above headworks.
1200
1000
800
600
400
200
0
CONCENTRATION (ppm)
Total Load
Sand
Silt
Clay
River
Above Headworks
Canal
Sluiceway
SAMPLING LOCATION (NOT TO SCALE)
SEDIMENT CONCENTRATIONS AT HEADWORKS AND SLUICEWAY
CAMBRIDGE DIVERSION DAM

FIGURE 24

Table 1

MEASURED HYDRAULIC DATA AT FOUR RIVER SECTIONS TESTED

| Date | River | Station | Width (feet) | Velocity (fps) | Average Depth (feet) | Sample Depth (feet) | Area (sq ft) | Qw Discharge (cfs) | Measured Slope (ft/ft) |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 2, 1960 | South Fork Solomon River | Above Woodston Diversion Dam | 59.0 | 1.31 | 0.94 | 0.77 | 55.33 | 72.26 | 0.0011 |
| Aug. 3, 1960 | Republican River | Above Bartley Diversion Dam | 130.0 | 1.67 | 1.10 | 1.04 | 142.86 | 237.93 | 0.0014 |
| Aug. 4, 1960 | Republican River | Above Superior-Courtland Diversion Dam | 218.0 | 1.93 | 1.81 | 1.73 | 394.41 | 763.14 | 0.00072 |
| Aug. 6, 1960 | Republican River | Above Cambridge Diversion Dam | 138.0 | 1.93 | 1.47 | 1.51 | 202.29 | 389.86 | 0.00102 |

Table 2

SUMMARY OF WATER DISCHARGES AND LOCATIONS WHERE SUSPENDED SEDIMENT SAMPLES WERE TAKEN AT FOUR DIVERSION DAMS TESTED

| Diversion dam | Location | Date | Time | Type of sample 1/ | Sampler | Number of verticals | Average water depth sampled (feet) | Discharge (cfs) 2/ |
|---|---|---|---|---|---|---|---|---|
| Woodston | South Fork Solomon River above Diversion Dam | 8-2-60 | 1:00 p.m. | ETR | DH-48 | 19 | 0.77 | 72 |
| | Upstream end of guide walls | 8-2-60 | 2:30 p.m. | ETR | DH-48 | 3 | 10.0 | 68 |
| | Canal downstream from headworks | 8-2-60 | 3:00 p.m. | ETR | DH-48 | 3 | 2.7 | 46 |
| | Sluiceway downstream from gate | 8-2-60 | 3:30 p.m. | Mid-point | D-49 | 1 | 5.0 | 22 |
| Bartley | Republican River above Diversion Dam | 8-3-60 | 4:30 p.m. | ETR | DH-48 | 13 | 1.04 | 238 |
| | Upstream end of guide walls | 8-3-60 | 5:30 p.m. | ETR | DH-59 | 4 | 6.5 | 159 |
| | Canal downstream from headworks | 8-3-60 | 6:30 p.m. | ETR | DH-48 | 4 | 3.3 | 101 |
| | Sluiceway upstream from gate | 8-3-60 | 6:30 p.m. | ETR | DH-59 | 4 | 6.5 | 58 |
| | Upstream end of guide walls | 8-5-60 | 6:00 p.m. | ETR | DH-48 | 4 | 6.5 | 148 |
| | Canal downstream from headworks | 8-5-60 | 6:15 p.m. | ETR | DH-48 | 4 | 3.3 | 101 |
| | Sluiceway upstream from gate | 8-5-60 | 5:45 p.m. | ETR | DH-48 | 4 | 6.5 | 47 |
| Superior-Courtland | Republican River above Diversion Dam | 8-4-60 | 1:00 p.m. | ETR | DH-48 | 11 | 1.73 | 763 |
| | Courtland Canal Headworks: | | | | | | | |
| | Canal downstream from headworks | 8-4-60 | 6:00 p.m. | ETR | DH-59 | 10 | 7.5 | 561 |
| | Canal downstream from headworks | 8-5-60 | 12:15 p.m. | ETR | DH-48 | 10 | 7.5 | 552 |
| | Sluiceway 10 feet upstream from gate | 8-5-60 | 12:15 p.m. | ETR | DH-59 | 9 | 7.6 | 95 |
| | Upstream end of guide walls | 8-5-60 | 11:30 a.m. | ETR | DH-48 | 8 | 7.6 | 647 |
| | Superior Canal Headworks: | | | | | | | |
| | Upstream end of guide walls | 8-5-60 | 9:30 a.m. | ETR | DH-48 | 7 | 7.6 | 193 |
| | Canal downstream from headworks | 8-5-60 | 9:30 a.m. | ETR | DH-48 | 4 | 4.0 | 129 |
| | Sluiceway upstream from gates | 8-5-60 | 10:00 a.m. | ETR | DH-59 | 8 | 7.6 | 64 |
| | Canal downstream from headworks | 8-4-60 | 4:30 p.m. | ETR | DH-48 | 4 | 4.0 | 127 |
| | Sluiceway downstream from gate | 8-5-60 | 9:30 a.m. | Mid-point | DH-59 | 1 | 0.2 | 64 |
| Cambridge | Republican River above Diversion Dam | 8-6-60 | 10:00 a.m. | ETR | DH-48 | 26 | 1.51 | 390 |
| | Canal at flume | 8-6-60 | Noon | ETR | DH-48 | 9 | 2.8 | 273 |
| | Canal at flume | 8-6-60 | 6:00 p.m. | ETR | DH-48 | 9 | 2.8 | 273 |
| | Sluiceway upstream from gates | 8-6-60 | Noon | ETR | DH-59 | 4 | 5.5 | 97 |
| | Canal at flume | 8-7-60 | 3:50 p.m. | ETR | DH-48 | 4 | 2.8 | 273 |
| | Above Gate 1 at headworks | 8-6-60 | 12:30 p.m. | Mid-point | DH-59 | 1 | 3.0 | 70 |
| | Above Gate 2 at headworks | 8-6-60 | 1:00 p.m. | Mid-point | DH-59 | 1 | 3.0 | 69 |
| | Above Gate 3 at headworks | 8-6-60 | 12:50 p.m. | Mid-point | DH-59 | 1 | 3.0 | 68 |
| | Above Gate 4 at headworks | 8-6-60 | 12:45 p.m. | Mid-point | DH-59 | 1 | 3.0 | 66 |

1/ETR sampling is equal transit rate method.
2/Discharges from current meter measurements together with computed values from gage heights.

Table 3

SIZE ANALYSIS OF BED MATERIAL SAMPLES AT FOUR RIVER REACHES TESTED AND MISCELLANEOUS SAMPLES COLLECTED

| Diversion dam | Location | Station | Percent finer than (sieve size in millimeters) 0.074 | 0.149 | 0.297 | 0.59 | 1.19 | 2.38 | 4.76 |
|---|---|---|---|---|---|---|---|---|---|
| Woodston | South Fork Solomon River above diversion dam | 6 | 0.6 | 1.1 | 36.0 | 87.5 | 99.6 | 100 | 100 |
| | | 18 | 0.4 | 16.0 | 38.5 | 79.7 | 97.8 | 99.6 | 100 |
| | | 30 | 0.4 | 0.5 | 11.6 | 53.2 | 85.5 | 96.7 | 99.7 |
| | | 42 | 0.1 | 0.4 | 11.2 | 46.0 | 84.8 | 95.0 | 98.4 |
| | | 54 | 0 | 0.1 | 8.3 | 51.4 | 87.2 | 97.2 | 99.4 |
| | | Total | 1.5 | 18.1 | 105.6 | 317.8 | 454.9 | 488.5 | 497.5 |
| | | Average | 0.3 | 3.6 | 21.1 | 63.6 | 91.0 | 97.7 | 99.5 |
| Bartley | Republican River above diversion dam | 13 | 0.1 | 0.9 | 17.8 | 67.8 | 92.9 | 98.0 | 99.8 |
| | | 39 | 0.5 | 0.8 | 28.5 | 84.1 | 96.7 | 98.4 | 99.6 |
| | | 65 | 0 | 0.1 | 9.3 | 54.9 | 86.2 | 95.6 | 99.2 |
| | | 92 | 0.8 | 2.6 | 27.0 | 75.3 | 95.5 | 99.3 | 100 |
| | | 102 | 1.7 | 5.7 | 41.7 | 86.9 | 97.8 | 99.7 | 100 |
| | | Total | 3.1 | 10.1 | 124.3 | 369.0 | 469.1 | 491.0 | 498.6 |
| | | Average | 0.6 | 2.0 | 24.9 | 73.8 | 93.8 | 98.2 | 99.7 |
| Superior-Courtland | Republican River above diversion dam | 10 | 0.8 | 1.2 | 12.1 | 58.0 | 87.6 | 96.9 | 99.7 |
| | | 25 | 0.5 | 1.8 | 12.8 | 54.0 | 90.8 | 98.9 | 100 |
| | | 44 | 0.4 | 0.5 | 5.0 | 50.5 | 90.6 | 98.7 | 99.7 |
| | | 100 | 0.3 | 0.6 | 18.5 | 63.9 | 89.8 | 96.5 | 99.2 |
| | | 160 | 0.1 | 0.6 | 15.0 | 55.2 | 81.9 | 91.4 | 96.7 |
| | | Total | 2.1 | 4.7 | 63.4 | 281.6 | 440.7 | 481.5 | 495.3 |
| | | Average | 0.4 | 0.9 | 12.7 | 56.3 | 88.1 | 96.3 | 99.1 |
| Cambridge | Republican River above diversion dam | 14 | 0.3 | 0.6 | 13.3 | 76.8 | 96.1 | 99.2 | 100 |
| | | 40 | 1.3 | 9.8 | 55.7 | 80.7 | 93.6 | 97.3 | 99.0 |
| | | 70 | 0.5 | 2.6 | 11.1 | 53.4 | 99.0 | 99.9 | 100 |
| | | 98 | 0.4 | 2.5 | 30.2 | 76.8 | 94.8 | 97.3 | 98.6 |
| | | 126 | 0.2 | 0.8 | 7.0 | 37.3 | 73.7 | 92.7 | 99.3 |
| | | Total | 2.7 | 16.3 | 117.3 | 325.0 | 457.2 | 486.4 | 496.9 |
| | | Average | 0.5 | 3.3 | 23.5 | 65.0 | 91.4 | 97.3 | 99.4 |
| Miscellaneous bed material samples: | | | | | | | | | |
| Solomon River at Glen Elder--50 feet above Highway Bridge | | | 0.4 | 0.8 | 4.1 | 57.0 | 84.6 | 90.2 | 99.4 |
| North Fork Solomon River at Downs | | | 1.5 | 1.7 | 5.3 | 46.6 | 86.7 | 97.4 | 99.8 |
| North Fork Solomon River at Glade | | | 0 | 0.1 | 8.1 | 53.4 | 91.0 | 95.5 | 97.0 |
| South Fork Solomon River at Bogue | | | 0 | 0 | 11.9 | 70.7 | 98.1 | 99.9 | 100 |
| Upper 1/4 point of Bartley settling basin cleaning | | | 54.2 | 66.1 | 71.5 | 78.8 | 85.5 | 90.3 | 97.0 |
| Midway on Bartley settling basin cleaning | | | 24.5 | 32.4 | 41.4 | 53.8 | 67.5 | 86.9 | 100 |
| Upstream from Courtland sluiceway gate | | | 2.8 | 13.6 | 87.1 | 98.9 | 99.5 | 99.8 | 100 |
| Riverbed upstream from headworks at Cambridge Diversion Dam | | | 0.3 | 2.7 | 37.3 | 95.8 | 99.6 | 99.7 | 100 |
| Riverbed upstream from headworks at Cambridge Diversion Dam | | | 0.2 | 1.5 | 20.4 | 61.7 | 93.5 | 96.2 | 99.4 |
| Riverbed upstream from headworks at Cambridge Diversion Dam | | | 0.2 | 0.9 | 38.3 | 93.9 | 98.9 | 99.3 | 99.8 |

Table 3--Continued

| Diversion dam | Location | Station | Percent finer than (sieve size in millimeters) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0.074 | 0.149 | 0.297 | 0.59 | 1.19 | 2.38 | 4.76 |
| Miscellaneous bed material samples--continued: | | | | | | | | | |
| | Riverbed above Gate 4 (closed) at Cambridge Diversion Dam headworks | | 10.6 | 15.3 | 36.7 | 76.1 | 94.0 | 98.6 | 100 |
| | Riverbed above Gate 4 (closed) at Cambridge Diversion Dam headworks | | 13.8 | 20.8 | 52.3 | 84.9 | 96.6 | 99.0 | 99.8 |
| | Material cleaned from Culbertson Canal settling basin | | 64.2 | 84.2 | 92.3 | 95.2 | 96.7 | 98.4 | 100 |

Table 4

ANALYSIS OF SUSPENDED SEDIMENT SAMPLES AND COMPUTED SUSPENDED SEDIMENT LOADS AT FOUR DIVERSION DAMS TESTED

| Sample No. | Location of sample | Q cfs | Suspended load | | Sediment load--Size fraction in mm: Clay | | Silt | | | | | | | | Sand | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | < 0.004 | | Very fine 0.004-0.0078 | | Fine 0.0078-0.0156 | | Medium 0.0156-0.0312 | | Coarse 0.0312-0.0625 | | Very fine 0.0625-0.125 | | Fine 0.125-0.25 | | Medium 0.25-0.50 | | Coarse 0.50-1.00 | | Very coarse 1.00-2.00 | |
| | | | Conc. ppm | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day | per- cent | ton/ day |
| | **Above Woodston Diversion Dam** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | South Fork Solomon River | 72 | 44 | 8.55 | 21.8 | 1.86 | 4.9 | 0.42 | 15.5 | 1.33 | 33.5 | 2.87 | 18.3 | 1.56 | 4.5 | 0.38 | 1.3 | 0.11 | 0.2 | 0.02 | | | | |
| 2 | Upstream end of guide walls | 68 | 41 | 7.53 | 23.5 | 1.77 | 14.5 | 1.09 | 37.0 | 2.79 | 25.0 | 1.88 | | | | | | | | | | | | |
| 3 | Canal downstream from headworks | 46 | 36 | 4.47 | 23.3 | 1.04 | 14.7 | 0.66 | 22.7 | 1.02 | 17.3 | 0.77 | 19.0 | 0.85 | 2.9 | 0.13 | 0.1 | - | | | | | | |
| 4 | Sluiceway downstream from gate | 22 | 43 | 2.55 | 31.7 | 0.81 | 18.3 | 0.47 | 25.7 | 0.66 | 19.8 | 0.50 | 4.3 | 0.11 | 0.2 | - | | | | | | | | |
| | **Above Bartley Diversion Dam** | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | Republican River | 238 | 532 | 342.0 | 13.6 | 46.5 | 5.9 | 20.2 | 10.5 | 35.9 | 26.0 | 88.9 | 32.0 | 109.5 | 10.0 | 34.2 | 2.0 | 6.8 | | | | | | |
| 6 | Upstream end of guide walls | 159 | 377 | 162.0 | 14.6 | 23.7 | 5.8 | 9.4 | 19.0 | 30.8 | 35.6 | 57.7 | 22.5 | 36.4 | 2.5 | 4.0 | | | | | | | | |
| 7 | Canal downstream from headworks | 101 | 271 | 73.9 | 19.6 | 14.5 | 11.4 | 8.4 | 15.3 | 11.3 | 31.7 | 23.4 | 18.5 | 13.7 | 3.5 | 2.6 | | | | | | | | |
| 8 | Sluiceway upstream from gate | 58 | 272 | 42.6 | 20.7 | 8.8 | 4.7 | 2.0 | 22.9 | 9.8 | 45.7 | 19.5 | 6.0 | 2.5 | | | | | | | | | | |
| 9 | Upstream end of guide walls | 148 | 211 | 84.3 | 22.6 | 19.1 | 9.1 | 7.7 | 27.3 | 23.0 | 38.6 | 32.5 | 2.4 | 2.0 | | | | | | | | | | |
| 10 | Canal downstream from headworks | 101 | 220 | 60.0 | 19.5 | 11.7 | 10.5 | 6.3 | 15.8 | 9.5 | 44.2 | 26.5 | 10.0 | 6.0 | | | | | | | | | | |
| 11 | Sluiceway upstream from gates | 47 | 216 | 27.4 | 18.6 | 5.1 | 8.4 | 2.3 | 19.4 | 5.3 | 39.1 | 10.7 | 13.6 | 3.8 | 0.8 | 0.2 | 0.1 | | | | | | | |
| | **Above Superior-Courtland Diversion Dam** | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | Republican River | 763 | 260 | 536.0 | 15.0 | 80.4 | 5.0 | 26.8 | 8.5 | 45.6 | 22.5 | 120.6 | 41.0 | 219.8 | 7.0 | 37.5 | 0.9 | 4.8 | 0.1 | 0.5 | | | | |
| 13 | Courtland Canal downstream from headworks | 561 | 194 | 294.0 | 21.3 | 62.6 | 3.7 | 10.9 | 15.7 | 46.2 | 45.8 | 134.6 | 12.5 | 36.8 | 1.0 | 2.9 | | | | | | | | |
| 14 | Courtland Canal downstream from headworks | 552 | 203 | 303.0 | 19.8 | 60.0 | 4.2 | 12.7 | 12.7 | 38.5 | 38.3 | 116.1 | 23.5 | 71.2 | 1.5 | 4.5 | | | | | | | | |
| 15 | Courtland sluiceway 10-foot upstream from gates | 95 | 198 | 50.8 | 14.2 | 7.2 | 7.1 | 3.6 | 12.2 | 6.2 | 32.5 | 16.5 | 29.5 | 15.0 | 4.0 | 2.0 | 0.5 | 0.3 | | | | | | |
| 16 | Upstream end of guide walls (Courtland) | 647 | 220 | 384.0 | 16.7 | 64.1 | 7.0 | 26.9 | 12.0 | 46.1 | 31.8 | 122.1 | 27.5 | 105.6 | 3.5 | 13.4 | 1.5 | 5.8 | | | | | | |
| 17 | Upstream end of guide walls (Superior) | 193 | 146 | 76.1 | 25.0 | 19.0 | 11.0 | 8.4 | 16.5 | 12.6 | 31.0 | 23.6 | 14.0 | 10.6 | 2.5 | 1.9 | | | | | | | | |
| 18 | Superior Canal downstream from headworks | 129 | 147 | 51.2 | 26.0 | 13.3 | 11.5 | 5.9 | 17.0 | 8.7 | 41.5 | 21.2 | 3.8 | 2.0 | 0.2 | 0.1 | | | | | | | | |
| 19 | Superior sluiceway upstream from gates | 64 | 146 | 25.2 | 23.5 | 5.9 | 10.5 | 2.6 | 16.5 | 4.2 | 45.5 | 11.5 | 4.0 | 1.0 | | | | | | | | | | |
| 20 | Superior Canal downstream from headworks | 127 | 125 | 42.9 | 22.0 | 9.4 | 12.0 | 5.2 | 13.0 | 5.6 | 48.0 | 20.6 | 5.0 | 2.1 | | | | | | | | | | |
| 21 | Superior sluiceway downstream from gates | 64 | 175 | 30.2 | 40.0 | 12.1 | 7.0 | 2.1 | 24.0 | 7.3 | 16.5 | 5.0 | 11.0 | 3.3 | 1.5 | 0.4 | | | | | | | | |

Table 4--Continued

| Sample No. | Location of sample | Q cfs | Suspended load | | Sediment load--Size fraction in mm | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Clay | | Silt | | | | | | | | Sand | | | | | | | | | |
| | | | | | < 0.004 | | Very fine 0.004-0.0078 | | Fine 0.0078-0.0156 | | Medium 0.0156-0.0312 | | Coarse 0.0312-0.0625 | | Very fine 0.0625-0.125 | | Fine 0.125-0.25 | | Medium 0.25-0.50 | | Coarse 0.50-1.00 | | Very coarse 1.00-2.00 | |
| | | | Conc. ppm | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day | per-cent | ton/ day |
| | **Above Cambridge Diversion Dam** | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | Republican River | 390 | 616 | 649.0 | 8.5 | 55.2 | 2.0 | 13.0 | 5.5 | 35.7 | 18.0 | 116.8 | 21.0 | 136.3 | 27.0 | 175.2 | 6.0 | 38.9 | 6.0 | 38.9 | 5.5 | 35.7 | 0.5 | 3.3 |
| 23 | Canal at Flume | 273 | 767 | 565.0 | 5.0 | 28.2 | 3.5 | 19.8 | 4.5 | 25.5 | 8.0 | 45.2 | 36.0 | 203.4 | 29.0 | 163.8 | 10.0 | 56.5 | 3.5 | 19.8 | 0.5 | 2.8 | | |
| 24 | Canal at Flume | 273 | 557 | 411.0 | 5.5 | 22.6 | 5.0 | 20.6 | 5.0 | 20.6 | 18.5 | 76.0 | 17.5 | 71.9 | 33.5 | 137.7 | 12.0 | 49.3 | 3.0 | 12.3 | | | | |
| 25 | Sluiceway upstream from gates | 97 | 926 | 242.0 | 5.6 | 13.6 | 2.9 | 7.0 | 2.2 | 5.3 | 10.8 | 26.1 | 20.0 | 48.4 | 38.5 | 93.2 | 12.5 | 30.3 | 7.0 | 16.9 | 0.5 | 1.2 | | |
| 26 | Canal at Flume | 273 | 334 | 246.0 | 10.5 | 25.8 | 5.5 | 13.5 | 9.0 | 22.1 | 18.5 | 45.5 | 33.5 | 82.5 | 15.0 | 36.9 | 6.5 | 16.0 | 1.5 | 3.7 | | | | |
| 27 | Above Gate 1 at headworks | 70 | 756 | 143.0 | 6.5 | 9.3 | 6.0 | 8.6 | 6.0 | 8.6 | 22.0 | 31.5 | 30.5 | 43.6 | 24.5 | 35.0 | 3.5 | 5.0 | 1.0 | 1.4 | | | | |
| 28 | Above Gate 2 at headworks | 69 | 861 | 160.5 | 4.5 | 7.22 | 2.5 | 4.01 | 5.5 | 8.83 | 15.5 | 24.9 | 36.5 | 58.6 | 24.5 | 39.3 | 8.5 | 13.65 | 2.5 | 4.01 | | | | |
| 29 | Above Gate 3 at headworks | 68 | 825 | 151.5 | 2.4 | 3.64 | 1.6 | 2.42 | 3.0 | 4.55 | 9.5 | 14.4 | 21.0 | 31.8 | 9.0 | 13.63 | 22.5 | 34.1 | 9.0 | 13.63 | 12.0 | 18.2 | 10.0 | 15.15 |
| 30 | Above Gate 4 at headworks | 66 | 1126 | 200.0 | 3.0 | 6.0 | 2.0 | 4.0 | 3.0 | 6.0 | 12.0 | 24.0 | 23.0 | 46.0 | 17.0 | 34.0 | 15.0 | 30.0 | 2.0 | 4.0 | 2.0 | 4.0 | 3.0 | 6.0 |

Table 5
TOTAL SEDIMENT LOADS AT FOUR RIVER SECTIONS TESTED

| River | Location | Size fractions in millimeters | Measured suspended load tons/day | Modified Einstein computed load tons/day | Total load tons/day | Unmeasured load tons/day | Percent of total load unmeasured |
|---|---|---|---|---|---|---|---|
| South Fork Solomon River | Above Woodston Diversion Dam | Clay and silt: < 0.0625 | 8.04 | 8.04 | 8.04 | | |
| | | Sand: 0.0625-0.125 | 0.38 | 0.47 | 0.47 | | |
| | | 0.125 -0.25 | 0.11 | 0.30 | 0.30 | | |
| | | 0.25 -0.5 | 0.02 | 0.30 | 0.30 | | |
| | | 0.5 -1.0 | | 0.28 | 0.28 | | |
| | | Total | 8.55 | 9.39 | 9.39 | 0.84 | 8.9 |
| Republican River | Above Bartley Diversion Dam | Clay and silt: < 0.0625 | 301.0 | 300.0 | 301.0 | | |
| | | Sand: 0.0625-0.125 | 34.2 | 34.2 | 34.2 | | |
| | | 0.125 -0.25 | 6.8 | 14.4 | 14.4 | | |
| | | 0.25 -0.5 | | 33.5 | 33.5 | | |
| | | 0.5 -1.0 | | 27.3 | 27.3 | | |
| | | 1.0 -2.0 | | 1.0 | 1.0 | | |
| | | Total | 342.0 | 410.4 | 411.4 | 69.4 | 16.9 |
| Republican River | Above Superior-Courtland Diversion Dam | Clay and silt: < 0.0625 | 493.2 | 484.6 | 493.2 | | |
| | | Sand: 0.0625-0.125 | 37.5 | 42.9 | 42.9 | | |
| | | 0.125 -0.25 | 4.8 | 10.2 | 10.2 | | |
| | | 0.25 -0.5 | 0.5 | 12.5 | 12.5 | | |
| | | 0.5 -1.0 | | 20.5 | 20.5 | | |
| | | 1.0 -2.0 | | 5.4 | 5.4 | | |
| | | Total | 536.0 | 576.1 | 584.7 | 48.7 | 8.3 |
| Republican River | Above Cambridge Diversion Dam | Clay and silt: < 0.0625 | 357.0 | 354.9 | 357.0 | | |
| | | Sand: 0.0625-0.125 | 175.2 | 175.2 | 175.2 | | |
| | | 0.125 -0.25 | 38.9 | 60.5 | 60.5 | | |
| | | 0.25 -0.5 | 38.9 | 102.7 | 102.7 | | |
| | | 0.5 -1.0 | 35.7 | 125.5 | 125.5 | | |
| | | 1.0 -2.0 | 3.3 | 8.8 | 8.8 | | |
| | | Total | 649.0 | 827.6 | 829.7 | 180.7 | 21.8 |

Table 6

COMPARISON OF SUSPENDED SEDIMENT LOAD AND TOTAL LOAD AT FOUR DIVERSION DAMS AND RIVER REACHES TESTED

| Diversion dam | Location | Discharge cfs | Measured suspended load: Clay Percent | Clay ppm | Silt Percent | Silt ppm | Sand Percent | Sand ppm | Total ppm | Total at river section: Sand tons/day | Sand ppm | Total tons/day | Total ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Woodston | South Fork Solomon River above Diversion Dam | 72 | 21.8 | 9.6 | 72.2 | 31.8 | 6.0 | 2.6 | 44 | 1.35 | 6.94 | 9.39 | 48.3 |
| | Upstream end of guide walls | 68 | 23.5 | 9.6 | 76.5 | 31.4 | 0 | 0 | 41 | | | | |
| | Canal downstream from headworks | 46 | 23.3 | 8.4 | 73.7 | 26.5 | 3.0 | 1.1 | 36 | | | | |
| | Sluiceway downstream from gate | 22 | 31.7 | 13.6 | 68.1 | 29.3 | 0.2 | 0.1 | 43 | | | | |
| Bartley | Republican River above Diversion Dam | 238 | 13.6 | 72 | 74.4 | 396 | 12.0 | 64 | 532 | 110.4 | 172 | 411.4 | 640 |
| | Upstream end of guide walls | 159 | 14.6 | 55 | 82.9 | 313 | 2.5 | 9 | 377 | | | | |
| | Canal downstream from headworks | 101 | 19.6 | 53 | 76.9 | 208 | 3.5 | 10 | 271 | | | | |
| | Sluiceway upstream from gate | 58 | 20.7 | 56 | 79.3 | 216 | 0 | 0 | 272 | | | | |
| | Upstream end of guide walls | 148 | 22.6 | 48 | 77.4 | 163 | 0 | 0 | 211 | | | | |
| | Canal downstream from headworks | 101 | 19.5 | 43 | 80.5 | 177 | 0 | 0 | 220 | | | | |
| | Sluiceway upstream from gate | 47 | 18.6 | 40 | 80.5 | 174 | 0.9 | 2 | 216 | | | | |
| Superior-Courtland | Republican River above Diversion Dam | 763 | 15.0 | 39 | 77.0 | 200 | 8.0 | 21 | 260 | 91.5 | 44.4 | 584.7 | 284 |
| | Courtland Canal Headworks: | | | | | | | | | | | | |
| | Canal downstream from headworks | 561 | 21.3 | 41 | 77.7 | 151 | 1.0 | 2 | 194 | | | | |
| | Canal downstream from headworks | 552 | 19.8 | 40 | 78.7 | 160 | 1.5 | 3 | 203 | | | | |
| | Sluiceway 10 feet upstream from gate | 95 | 14.2 | 28 | 81.3 | 161 | 4.5 | 9 | 198 | | | | |
| | Upstream end of guide walls | 647 | 16.7 | 37 | 78.3 | 172 | 5.0 | 11 | 220 | | | | |
| | Superior Canal Headworks: | | | | | | | | | | | | |
| | Upstream end of guide walls | 193 | 25.0 | 36 | 72.5 | 106 | 2.5 | 4 | 146 | | | | |
| | Canal downstream from headworks | 129 | 26.0 | 38 | 73.8 | 108 | 0.2 | 1 | 147 | | | | |
| | Sluiceway upstream from gates | 64 | 23.5 | 34 | 76.5 | 112 | 0 | 0 | 146 | | | | |
| | Canal downstream from headworks | 127 | 22.0 | 28 | 78 | 97 | 0 | 0 | 125 | | | | |
| | Sluiceway downstream from gate | 64 | 40.0 | 70 | 58.5 | 102 | 1.5 | 3 | 175 | | | | |
| Cambridge | Republican River above Diversion Dam | 390 | 8.5 | 52 | 46.5 | 287 | 45 | 277 | 616 | 472.7 | 449 | 829.7 | 788 |
| | Canal at flume | 273 | 5.0 | 38 | 52 | 399 | 43 | 330 | 767 | | | | |
| | Canal at flume | 273 | 5.5 | 31 | 46 | 256 | 48.5 | 270 | 557 | | | | |
| | Sluiceway upstream from gates | 97 | 5.6 | 52 | 35.9 | 332 | 58.5 | 542 | 926 | | | | |
| | Canal at flume | 273 | 10.5 | 35 | 66.5 | 222 | 23.0 | 77 | 334 | | | | |
| | Above Gate 1 at headworks | 70 | 6.5 | 49 | 64.5 | 488 | 29.0 | 219 | 756 | | | | |
| | Above Gate 2 at headworks | 69 | 4.5 | 39 | 60 | 517 | 35.5 | 305 | 861 | | | | |
| | Above Gate 3 at headworks | 68 | 2.4 | 20 | 35.1 | 290 | 62.5 | 515 | 825 | | | | |
| | Above Gate 4 at headworks | 66 | 3.0 | 34 | 58.0 | 653 | 39.0 | 439 | 1,126 | | | | |

ABSTRACT

Field tests were conducted at Woodston, Bartley, and Superior-Courtland Diversion Dams in the Kansas River Basin during August 1960 to determine the efficiencies of sediment control structures for excluding sediment from the canal system. Data were also obtained at Cambridge Diversion Dam where a sediment problem existed but the dam had no sediment control structure. Sediment samples and hydraulic data were collected for computing the amount of sediment transported in the rivers and the amount of sediment transported through the sluiceway and canal at the headworks of each diversion dam. At Woodston, Bartley, and Superior-Courtland Diversion Dams where curved guide walls were used as a sediment control structure, the sand load of the river was depositing in the river basin above the diversion dam at the time of the tests. Very little sand was entering the guide walls at the canal headworks which did not permit a quantitative evaluation of the amount of sand excluded from entering the canal. However, the operating personnel are extremely satisfied with the curved guide walls. The curved guide walls provide an efficient means for flushing sediments deposited above the dam into the downstream river channel either by continuous sluicing or by intermittent sluicing.



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