UNITED STATES
DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, SECRETARY

BUREAU OF RECLAMATION

FLOYD E. DOMINY, COMMISSIONER

REGION 3

A.B. WEST, REGIONAL DIRECTOR

REPORT ON
RIVER CONTROL WORK AND INVESTIGATIONS
LOWER COLORADO RIVER BASIN
CALENDAR YEARS 1957 THROUGH 1959

BOULDER CITY, NEVADA

JANUARY 1962

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Boulder City, Nevada
January, 1962

Interior-Reclamation
Boulder City, Nevada

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

LIST OF TABLES

Tables listed below follow Page 24

LIST OF DRAWINGS

LIST OF DRAWINGS (Cont'd.)

PREVIOUS REPORTS

This volume, a report for calendar years 1957, 1958, and 1959, on River Control Work and Investigations, is a continuation of reports on the same subject issued by the Division of River Control of Region 3 for calendar years 1944 through 1956. Prior to calendar year 1944, the reports were issued from Denver and limited to the general subject of retrogression, salinity, and suspended sediment of the lower Colorado River.

INTRODUCTION

With the placing in operation of Hoover Dam, the major flood control problem on the Colorado River was largely solved. The construction of other storage dams on the river and its tributaries will furnish additional security against recurrence of the disastrous floods of bygone years. Reduction of the flood hazard, however, does not mean the elimination of all control problems. There remains the necessity for controlling the river by coordinating the operation of the control structures, and rectifying and maintaining the river channel between structures.

It is desirable that the Federal Government accomplish this control because the Colorado River is not only an interstate stream, but also an international stream. Region 3 of the Bureau of Reclamation is responsible for achieving control of the lower Colorado River.

The Division of Construction and River Control of Region 3 is concerned with all river problems along the main stream of the river from Lee Ferry to the International boundary. The Mexican Water Treaty of 1944 delegated authority to the International Boundary and Water Commission to conduct flood control studies along the river from Imperial Dam to the Gulf of California. Construction of various flood control and river improvement works within the reach from Imperial Dam to the boundary has been done by the Bureau of Reclamation.

COLORADO RIVER BASIN

The River

Location.--The main stream of the Colorado River rises in the high peaks of the Rocky Mountains of northern Colorado near Long's Peak. From its source at Grand Lake, Colorado, the river flows southwest about 1400 miles to the Gulf of California, traversing the mountain valleys of Colorado, the spectacular canyons of southeastern Utah and northern Arizona, of which the Grand Canyon of the Colorado is the outstanding example, and finally, below Lake Mead, it passes through broad alluvial valleys interspersed with mountain chains.

Tributaries.--The principal tributaries are the Green, Gunnison, Dolores, San Juan, Little Colorado, Virgin, Bill Williams, and the Gila Rivers. In its virgin condition, before diversions were made by man, the Colorado River is estimated to have carried an average of 16 million acre-feet of water annually across the international boundary into Mexico. The annual flow varied from about 5 million acre-feet to 27 million acre-feet. The Colorado River carries a tremendous volume of silt, and in its virgin state ranked as one of the greatest silt-carrying streams of the world.

Drainage Area.--That part of the drainage area of the basin lying in this country covers about 242,000 square miles, about one-twelfth of the area of the continental United States. The basin is some 900 miles long and varies in width from about 300 miles in the upper section to 500 miles in the lower section. The drainage area includes parts of seven states and is divided naturally into two parts: (1) the plateau region or Upper Basin, bounded on the north, east, and west by mountain ranges having an elevation from 8,000 to 14,000 feet; and (2) the desert region or Lower Basin, comprising low, hot plains and valleys.

Lower Basin

The Lower Colorado River Basin, shown on Figures 1-A, B, and C, includes a natural drainage area of about 133,500 square miles. Along the river, it extends from Lee Ferry near the Utah-Arizona boundary to the International Boundary below Yuma, Arizona. From Hoover Dam to the point where the Colorado River crosses the International Boundary into Mexico, the river flows generally in a southerly direction for a distance of about 326 miles. Of this distance, about 129 miles are contained within reservoirs and 52 miles are in narrow canyons. The remaining 145 miles traverse broad alluvial valleys. The northern part of the Lower Colorado River Basin receives some precipitation in the form of snow on the high peaks, whereas the southern part of the basin receives very little precipitation, usually in the form of

isolated thunderstorms. The southern part of the basin includes some of the most extreme desert areas within the United States. It is characterized by low humidity and almost complete absence of freezing temperatures.

Existing Dams and Lakes - Lower Basin

Dam	Lake	Storage Capacity Acre-Feet	Remarks
Hoover	Lake Mead	29,827,000 1/	To top of spillway gates in raised position, elevation 1221.4 feet. Includes dead storage, 2,620,000 1/ acre-feet.
Davis	Lake Mohave	1,818,000	To high water elevation 647.0. Includes dead storage, 8,530 acre-ft.
Parker	Havasu Lake	648,000 2/	To high water elevation 450.0. Includes dead storage, 28,600 acre-feet; inactive storage, 439,400 acre-feet.
Headgate Rock	---	None	Indian Bureau structure. Irrigation diversion.
Palo Verde	---	None	Diversion for Palo Verde Irrigation District.
Imperial	---	1,000	To elevation 181.0 (spillway crest) irrigation diversion. Silting has reduced storage capacity from 85,000 to about 1,000 acre-feet.
Laguna 3/	---	None	Obsolete, irrigation diversion. Forms a downstream control for Imperial Dam.
Morelos	---	None	Irrigation diversion to lands in Mexico.

1/ From tables put into use October 1, 1949, based on the Lake Mead Sedimentation Survey made in 1948-49 by the Bureau of Reclamation and Geological Survey of the Department of the Interior, and the Navy Department.

2/ Revised capacity of Havasu Lake based on resurvey of the top 20 feet of reservoir in April 1957. 180,000 acre-feet active space above elevation 440.

3/ No irrigation diversions from Laguna Dam after December 16, 1954.

THE BED OF THE RIVER

Meander

Hoover Dam to Davis Dam.--Below Hoover Dam, the river, prior to the construction of Davis Dam, flowed through a relatively narrow canyon for 67 miles. No meandering was possible within this reach and with the completion of Davis Dam and the filling of Lake Mohave, the reach was mostly inundated and regular river surveys within the reach were discontinued.

Davis Dam to Parker Dam.--Beginning at Davis Dam, the river flows through a naturally confined channel for about 10 miles. Meander within this short section is limited by stable banks composed of heavy gravel and conglomerate. Below this confined channel, the river enters Mohave Valley and has been free to meander up to 4 to 5 miles laterally within the confines of the bluff line surrounding the valley. Aerial photographs depicting the remains of old channels show that the river has moved from the western bluff to the eastern bluff many times; however, within historic times, the river from the northern end of Mohave Valley to Topock on the south (approximately 33 miles) has been located on the western side of the valley.

Parker Dam to Imperial Dam.--Between Parker and Imperial Dams, the river flows through wide valleys for a considerable part of the total distance of about 150 miles. During the years preceding closure of Parker Dam, minor natural channel changes were of frequent occurrence, and occasionally excessive meandering occurred. After closure of Imperial and Parker Dams (in 1938), no major natural channel changes took place until 1942 when a break-through occurred at a wide oxbow about 33 miles downstream from Parker Dam. The river course was shortened approximately four miles by this break. The locations of the old and new channels may be seen on Figure 1-C.

By 1943, the meandering action of the river had begun to threaten property at two locations in the Palo Verde Irrigation District. Cutoffs were constructed during 1943 and 1944 for the purpose of straightening the channel and protecting property. Shortening of the river channel of about 1/2 mile was accomplished at the lower location about 65 miles upstream from Imperial Dam and shortening of about 1-1/2 miles at the other location about 14 miles farther upstream.

The upstream cutoff temporarily relieved the threatened property in that area but did not stabilize the channel. Aerial photographs taken in 1953 show that the river had abandoned the cutoff and had re-established the meander. Since that time, this meander has continued to migrate in a westerly direction apparently following the same course as the older meander. Since 1953, this meander has been eroding its concave bank at a rate of from 20 to 300 feet per year, with the average area of cut amounting to about 40 acres per year.

A pilot cut, 1-1/2 miles long by 40 feet wide, was constructed in 1947 across a bend in the river opposite the mouth of the Palo Verde drain to facilitate drainage of Palo Verde Irrigation District lands. Work on this pilot cut was started with conventional land-operating equipment in January 1947 and was completed in June 1947 when the earth plug left at the lower end of the cut was dynamited. Enlargement and development of the cut has taken place by means of natural erosion and by additional blasting. Additional work by land equipment in June 1953 closed off the upper end of the old channel and directed 100 percent of the river flow through the cut. About one foot of lowering of the water surface at the mouth of the Palo Verde drain resulted from the cut.

Laguna Dam to International Boundary.--Farther downstream between Laguna Dam and the International Boundary, the river apparently meandered considerably during the period 1900 to 1940 as evidenced by the extensive levee system which has been built. Minor meanderings between the levees have occurred since 1940 when regular river surveys were begun, but the scouring action which has taken place has had the general effect of deepening the channel over most of the area rather than causing lateral movement.

Rehabilitation and raising of the levees in the Yuma area were completed during 1952. The work was performed using funds appropriated to Colorado River Front Work and Levee System. Since a portion of the levee construction was chargeable to Mexico under the terms of the Mexican Water Treaty of 1944, reimbursement of the Colorado River Front Work and Levee System appropriation was agreed upon for Mexico's share of the construction cost. Negotiations with the Mexican Government were conducted by the International Boundary and Water Commission. A memorandum of understanding dated January 12, 1951, between the International Boundary and Water Commission and the Bureau of Reclamation, was written for the purpose of governing the activities of the two agencies in the matter.

Erosion and Sedimentation

Surveys.--A system of river surveys and investigations which evolved from the original retrogression work below Hoover Dam has been in effect on the Colorado River for a number of years. This work began immediately after the closure of Hoover Dam in 1935 and was extended to the downstream sections of the river as follows:

Hoover Dam to River Section 19	1935
Hoover Dam to Searchlight Ferry	1936
Hoover Dam to Katherine Wash	1937
Hoover Dam to Fort Mohave	1938
Hoover Dam to Needles, California	1939
Hoover Dam to Havasu Lake	1941
Parker Dam to Imperial Dam	1938
Imperial Dam to International Boundary	1940

Active River Cross Sections.--Following the initial closure of Davis Dam in 1948, the river surveys between Hoover Dam and Davis Dam were abandoned. In 1951, the International Boundary and Water Commission took over the river surveys below Laguna Dam. As of 1959, the Bureau of Reclamation was conducting surveys that included measurements at 183 active river cross sections. These sections are located on the river as shown below:

Division	No. of Sections	Distance
Davis Dam to Havasu Lake	80	59 miles
Parker Dam to Imperial Dam	75	147 miles
Imperial Dam to Laguna Dam	28	5 miles

The cross sections between Davis Dam and Havasu Lake begin with River Section No. 28 immediately below the dam and progress through No. 43.97 located in Havasu Lake. Between Parker Dam and Imperial Dam, the cross sections start with River Section No. 1 just above Imperial Dam and progress upstream to River Section No. 41 immediately downstream from Parker Dam. Between Imperial and Laguna Dams, the cross sections begin with River Section No. 0.1 located in the California sluiceway of Imperial Dam and end with River Section No. 2.6 just upstream from the sluiceway gates at Laguna Dam. In addition to the above, cross sections have been established at 1-mile intervals within the channelized portion of the river in Mohave Valley. These "1-mile" sections are numbered consecutively upstream from Topock.

Cross-Sectional Measurements.--The cross-sectional measurements at these locations are taken each year and data on average bed elevation, adjusted water-surface elevation, and quantities of riverbed material deposited or removed are derived.

Changes in Reporting Procedures.--In earlier reports where mean bed elevation had been computed below an established baseline, the baseline length usually included some river-bottom topography that was not truly a part of the riverbed. Since 1952, the computations avoid this difficulty by eliminating the established baseline and taking the average bed elevation as being the average height of the bed below the adjusted water surface. Also in reports previous to 1952, the water surface corresponding to a flow of 15,000 cfs has been used as the adjusted water surface at all locations below Davis Dam. The present report uses 15,000 cfs as the flow to which the adjusted water surface is set for all cross sections between Davis Dam and Palo Verde Diversion Dam. From Palo Verde Diversion Dam to Imperial Dam, an adjusted water surface corresponding to a discharge of 10,000 cfs is used and below Imperial Dam, adjusted water-surface elevation is taken at a flow of 5,000 cfs. These changes have been made to bring the adjusted water-surface elevation more nearly into agreement with the dominant flows occurring within the particular reach of the river.

Effect of Storage Reservoirs.--Prior to construction of Hoover Dam, the river carried great quantities of sediment brought in from the drainage areas during periods of flood flow. Some of this material was deposited in the river channel, and some was carried to the mouth of the river. During seasons following the flood flows, part of the deposited material was picked up from the riverbed and banks and carried farther downstream. The net result, however, was a gradual rise in riverbed elevation. With the construction of Hoover Dam, the entire sediment load of the river at this point was trapped in Lake Mead, and clear water was released from the dam.

This water, being free of sediment load, began scouring the deposit which had been laid down in earlier years. With completion of Parker and Imperial Dams in 1938, two more depositories for the scoured materials were formed, and two other points on the river became subject to the erosive action of clear water. Following the initial diversions for construction at Davis Dam on June 28, 1948, the main point of scour below Hoover Dam was moved downstream 67 miles. Profiles shown on Figures 2, 3, and 4 illustrate the early rise of the water surface and later changes. The later changes are further illustrated by the variations in average bed and water-surface elevations shown on Figures 5, 6, 6A, and 7 for all river sections. Later changes in the average slopes are shown on Figures 8, 9, and 10. Estimates of volumes of material eroded and deposited are given in Tables 1, 3, and 4.

The Needles Problem.--Particularly worthy of comment is the rise of the river which occurred in the Needles area. The history of changes in water-surface elevation at Needles and Topock highway bridge is shown on Figure 11. The rise which had been taking place at the latter station, prior to construction of Hoover Dam, continued at a gradual rate until Havasu Lake was formed in 1938. Within a short time thereafter, the elevations raised 6 to 10 feet. On the other hand, the rise at Needles was halted almost completely after closure of Hoover Dam, and the elevation remained nearly constant at 470 feet until 1941 when a rapid rate of rise began which continued at an average rate of 1.4 feet per year, reaching elevation 476.5 by the end of 1944. After 1944, the elevation dropped slowly until June 1951 when it was about 3.0 feet lower than at the end of 1944. After the river was diverted into the new dredged channel in June 1951, the elevation dropped by the end of 1951 an additional 5.2 feet to elevation 467.3 as a direct result of opening of the newly dredged channel. However, due to the unabated sediment movement from the unchannelized reach above Needles, the trend of river stage was rising and reached a maximum of 469.5 by 1955. From 1955 through 1959 there has been some variance below the 1955 high but no significant trend developed during this period.

Palo Verde Intake Problem.--Difficulty of a nature opposite to that at Needles developed at the Palo Verde Irrigation District's intake, 65 miles downstream from Parker Dam. That is, scouring action lowered the riverbed to the point at which diversions could not be satisfactorily made. Changes shown on Figure 6 for River Section 30 below Parker Dam are representative of what has occurred at the intake, approximately 1,000 feet downstream from Section 30. The lowering was

arrested in 1945 by construction of a temporary rock weir (see Section "P", Blythe Area--Palo Verde Weir). Future diversion difficulties were solved by the construction of a permanent diversion dam. Authorization by the Congress for a permanent structure was made September 2, 1954. A contract was entered into with the W. E. Kier Construction Company on January 9, 1956, for construction of the permanent structure. Completion of the new diversion structure took place on December 17, 1957, but the temporary rock weir was nullified by removal of a major portion of the rock fill on November 1, 1957.

Rockwood Heading Problem.--Similar scour during the period 1940 to 1947, indicated by Section 12-S (Figure 7), occurred in the vicinity of Rockwood Heading below Yuma, Arizona, where diversions were made for Imperial Irrigation District prior to the construction of the All-American Canal and for the Mexican irrigation operations prior to construction of Morelos Diversion Dam. Morelos Dam was constructed by the Mexican Government to divert Colorado River water into the Alamo Canal for use by Mexico in the Mexicali Valley. The structure was put into operation during November 1950.

Change in Size Composition of Bed Material.--As the riverbed elevations have been raised and lowered, the size composition of the bed material has been changed as illustrated by the size analyses shown on Figures 12, 13, and 14. Also indicated are depths of scour and deposit at the time of each of the observations shown.

THE WATER OF THE RIVER

Sediment Load

Upstream from Lake Mead, the Colorado River carries large quantities of sediment. The major part is washed into the river by flood water from melting snow in the spring and from rains during the summer and fall. Consisting to a great extent of topsoil, the sediment is composed chiefly of very small particles of quartz, feldspar, and mica.

Before construction of Hoover Dam, sediment was transported to the lower reaches of the river in amounts varying from about 20 million to more than 300 million tons per year, part of it being deposited at many points along the river, the remainder being carried to the mouth and deposited at the Gulf. Suspended sediment loads and water discharges at the Yuma station since 1911, as shown in Tables 7 and 7A and Figures 18 and 18A, and at Grand Canyon station since 1926, as shown in Table 8 and Figure 15, are representative of sediment loads carried in suspension by the river.

Below Hoover Dam.--With the construction of Hoover Dam and the formation of Lake Mead, the sediment could no longer be carried downstream, but instead was deposited in the lake with the result that clear water was discharged into the river below the dam. The scouring power of the clear water on the riverbed slope of 1.5 to 2 feet per mile is very great and immense quantities of riverbed material are picked up and

transported farther downstream. In the past years, sediment in amounts averaging as high as 0.17 percent by weight (in 1940-41), or approximately 36 million tons per year, has been eroded from the riverbed. The rate of removal after 1941 gradually reduced and during the period covered by this report, the rate was considerably lower (see Table 2).

Below Davis Dam.--The initial diversion for construction at Davis Dam took place on June 28, 1948, raising the surface of the water approximately 9 feet and backing up about 5000 acre-feet of water. In January 1950 the second-stage diversion took place. Following the initial closure of the dam, the bed immediately downstream was subjected to renewed scouring action, the effect of which can be seen at Section 28 where the average bed dropped 6.5 feet between December 1947 and June 1949 (see Figure 5). By July 1956, the average bed elevation had dropped 15.9 feet. The bed seemed to stabilize near that elevation and, in fact, aggraded somewhat through July 1957. However, the heavy releases during late 1957 and early 1958 nullified the aggradation and caused some additional scour so that the total drop in average bed elevation amounted to 16.2 feet by July 1959. Despite the continued drop in the average bed elevation, changes in slope, channel width, and roughness have compensated in part for the lowered bed so that the total drop in the adjusted water surface was only 11.9 feet by July 1959 and has shown almost no change since July 1956.

Below Parker Dam.--With the closure of Parker Dam in 1938 and the resulting release of clear water the riverbed below the dam was attacked by scouring action. Material at rates up to 200,000 tons per day was eroded (see Figure 16).

Change in Size of Suspended Material.--Size analyses, shown on Figure 17 for the years 1933 through 1958, illustrate how the sediment carried in suspension has become coarser with the passage of time. This is typical of the sampling at all locations on the river below Hoover Dam. The early sampling shown by samples, Series 1 and 2 on Figure 17, is indicative of pre-Hoover Dam conditions. After the closure of Hoover Dam, all of the suspended load from upstream sources was trapped in Lake Mead and the suspended sediment moving in the lower river consisted of recharge from the bed and banks. As the finer sizes were carried away, with no upstream source of replacement, the suspended load has become progressively coarser. However, it is to be expected that the rate of change in size of the suspended material will become progressively slower. Note should be given to the fact that the suspended material sampled at Taylor's Ferry in recent years is coarser than the material sampled at Yuma during the same period (see Figures 17 and 19). This is a normal condition in a fully developed alluvial river showing typical diminishing gradient downstream.

Below Imperial Dam.--Until 1945, the major portion of the material eroded below Parker Dam had been trapped by Imperial Dam, 150 miles downstream. The water leaving Imperial Dam, with a reduced sediment load and renewed scouring power, began attacking the sediment

on the riverbed. Large quantities were removed below Laguna Dam, as indicated in Table 4, and carried downstream past the International Boundary. The relatively flat reach between Imperial and Laguna 1/ Dams account for the small amount of material removed in this 4.7-mile reach of river. By 1945, Imperial Reservoir was essentially filled with sediment and an objectionably high fraction of the load eroded below Parker Dam was arriving at Imperial. In June 1945, the desilting works of the All-American Canal were placed in operation. The increased concentration in the water arriving at Imperial, plus the sediment return from the desilting works, greatly increased the load entering the river below Imperial. This increase in load caused immediate aggradation in the Imperial-to-Laguna reach and slowed the rate of degradation in the river below Laguna. From 1945 until 1953, the river remained about in equilibrium with local areas of fill or scour. The series of low-water years, beginning in 1953, introduced a period of general aggradation that was terminated by the larger release of 1957 and 1958. Rather poor inflows in 1959 curtailed releases during that year and again general aggradation resulted.

Below Morelos Dam.--A special problem area is developing below Morelos Dam. The Alamo Canal immediately below the inlet works at Morelos Dam is maintained as a settling basin and is periodically dredged to remove the deposited sediments. For the first several years, the dredge spoil from the settling basin was piled on land between the canal and the river. By 1956, this spoil area had been built up until the dredge could no longer economically pump sediment to this storage area. In November and December of 1956, the Mexicans dredged 61,000 yards of sediment from the basin and spoiled it into the river immediately below Morelos Dam. The practice of spoiling the dredged material into the river has continued each year since 1956 until a total of 1,470,000 yards has been returned to the river through December 1959.

During periods of relatively high discharge, such as November 1957 through 1959, the river can handle this additional load and still maintain a reasonably good channel. However, with normal or below normal flows expected for the next few years, continued spoiling of sediment into the river below Morelos will cause excessive aggradation that may threaten the Yuma Valley Levee in case a flood flow develops in the channel.

Total-Load Measurements.--During 1956, a system of total-load measurements was initiated using the "Modified Einstein" procedure for computation of the suspended and bed loads. At the end of 1956 indications were that the total load sampling was providing acceptable figures as to the magnitude of the previously unmeasurable bed load. Sampling stations for making total-load measurements were established on the river at Needles, River Section 43, Water Wheel, Palo Verde Gage, Taylor's Ferry, and Adobe Ruin Gage.

1/ With the Laguna sluice gates closed.

Dissolved Solids

In the spring, as the pure water from the melting snow finds its way to the river, it becomes contaminated to some extent by contact with soluble salts occurring in the sediment which is picked up. It reaches the river, however, still in a comparatively pure state, usually carrying only about 200 to 400 parts per million of dissolved matter during the months of May and June. During the fall and winter months, on the other hand, when a large part of the flow comes from ground-water sources, the average dissolved solids content may be as high as 1,000 to 1,200 parts per million. As the water flows down the river, the content of dissolved matter usually is increased, perhaps partly because of dissolution of additional minerals from the bed and banks and partly by mixture with water of high salinity draining from adjacent irrigated land. In recent years, the salinity has been further increased by evaporation from the lake surfaces.

With the closure of Hoover Dam, a huge mixing basin was formed for the inflowing water. By the end of 1936, there was sufficient storage above the dam so that the salinity of the outflowing water remained nearly constant throughout the year. From year to year the concentration of the discharge reflects the runoff conditions during the year. For example, following the high spring inflow of 1952, the mean concentration dropped to 623 parts per million. In each of the succeeding four years of low inflow, the concentration increased until it reached 840 parts per million. The excellent spring inflow in 1957 and 1958 again reduced the concentration to 634 parts per million (see Table 9).

Records of River Flow and Reservoir Operation

Lake Mead.---The principal inflow to Lake Mead is measured by the Geological Survey on the Colorado River near Grand Canyon, Arizona. Daily reports of the 8:00 a.m., MST instantaneous discharge at this station and at the Geological Survey gaging station at Lees Ferry are received at Boulder City, Nevada, via the Geological Survey radio network, thus providing advance information of the inflow. These daily reports provide about 48 hours advance notice of the inflow which will reach Lake Mead. Figure 22 shows records of average monthly flow and maximum and minimum mean daily flows for each month at the gaging station on the Colorado River near Grand Canyon, as published by the Geological Survey, for the period January 1923 through December 1959.

Outflow from Lake Mead is measured by flowmeters in the Hoover Dam Powerhouse and checked about once a month by discharge measurements. Figure 23 shows records of average monthly release from Hoover Dam as published by the Geological Survey and storage contents of Lake Mead for the period 1935 through 1959.

Lake Mohave.--A gaging station to measure the flow of the Colorado River below Davis Dam was installed and placed in operation by the Geological Survey on July 1, 1949. Prior to installation of the Geological Survey station, the water-stage record was obtained by the Bureau of Reclamation at a temporary installation approximately 1/2 mile downstream from the Geological Survey gage. Discharge records for that point were begun March 16, 1949, and discontinued when the Geological Survey station was put into operation. Figure 24 shows records of average monthly releases from Davis Dam, as published by the Geological Survey, and storage contents of Lake Mohave for the years 1950 through 1959.

Havasu Lake.--Inflow to Havasu Lake is measured by the Geological Survey at its gaging stations on the Colorado River near Topock, Arizona, and on the Bill Williams River near Alamo, Arizona.

Outflow from Havasu Lake is measured by the Geological Survey at the gaging station below Parker Dam and also by the Parker Dam Power Project, using records of releases through the turbines and spillway gates. Figure 25 shows records of the average monthly release from Parker Dam, as published by the Geological Survey, and storage contents of Havasu Lake for the period 1938 through 1959.

Special Studies of River Losses.--In order to provide a closer accounting of the water diverted from the river and the drainage returned to it, the Geological Survey operates two gaging stations on the river in Palo Verde and Cibola Valleys. One station, located immediately downstream from the new Palo Verde Diversion Dam, began operations on March 24, 1956. The other station is located in the southern end of Cibola Valley at the Adobe Ruin site. It began operations on February 29, 1956. These stations, along with the Davis Dam and Topock stations, are included in a system of intensified measurements designed to obtain more accurate discharge data for special studies of river losses. The program of intensified measurements is financed by the Bureau of Reclamation 1/.

Below Imperial.--The Geological Survey maintains a gaging station on the Colorado River at Yuma, Arizona, which is below the junction with the Gila River. The total flow crossing the upper International Boundary into Mexico is greater than the flow measured at the Yuma gage by the amounts returned to the river below Yuma. The principal returns are via the California Wasteway of the Yuma Project and through the Pilot Knob Powerplant of the Imperial Irrigation District. Figure 26 shows records of average monthly flow of the Colorado River at Yuma, Arizona, by the Geological Survey for the period 1938 through 1959. The quantities shown on Figure 26 do not include the flow returned to the river below the gaging station.

1/ Operation of the Davis Dam gage is financed by cooperative agreement between the Bureau of Reclamation and the Geological Survey. The Bureau finances the operation of the gage below Palo Verde Diversion Dam and the gage in lower Cibola Valley. The Topock station is operated on Geological Survey funds. The system of intensified measurements at all the above stations is paid for out of Bureau of Reclamation, General Investigation, and Colorado River Front Work and Levee System funds.

THE RESERVOIRS

Storage

Lake Mead.--The original total capacity of Lake Mead to the top of the spillway gates, at elevation 1221.4, was 31,142,000 acre-feet as indicated on the capacity tables compiled from computations made by the Division of Cartography, Soil Conservation Service, dated August 1940. Of this amount, there were 3,207,000 acre-feet of dead storage below the lowest outlet gate sills at elevation 895. The revised capacity table dated October 1949, based upon data collected during the period March 1948 through March 1949 in connection with the sedimentation survey of Lake Mead by the Geological Survey, Bureau of Reclamation, and Navy Department, indicates that the total capacity at elevation 1221.4 is now 29,827,000 acre-feet and the dead storage at elevation 895 is 2,620,000 acre-feet, resulting in a usable capacity of 27,207,000 acre-feet. The revised capacity table has been in use since October 1, 1949.

Storage in Lake Mead was begun with closure of Hoover Dam on February 1, 1935, and not until the spring of 1941 did the water approach the maximum level. The level reached that year was higher than would have occurred if normal operating practices had been followed, but it was deemed advisable to allow the water to rise above the permanent spillway crest, elevation 1205.4, so that tests of spillway gates and tunnels could be made. By the end of the flood season of that year, the water had risen to within a fraction of a foot of the top of the spillway gates (in raised position). In order to prepare for the spring flow of the succeeding year, it was necessary to lower the lake level. Therefore, from May 1941 through July 1942, releases were made for flood control. During most of that period, the excess releases were equal to or greater than those for power production, partially due to the fact that only part of the generating equipment in the powerhouse had been installed. Following a series of dry years, on April 25, 1956, the lake level dropped to its lowest level (1083.2 feet) after the initial filling. Since the runoff was also quite low in 1956, there was only slight recovery with the 1957 low of 1089.5 feet on April 19. The April-July runoff in 1957 was excellent and was followed by an exceptionally high July and August. This large inflow raised the lake level to a maximum of 1184.1 on September 8, 1957. 1958 was also a year of above-average runoff and the lake elevation reached a high of 1205.9 on July 7. 1959 was again a year of low runoff with a maximum level of 1181.4 reached on July 12. Records of the storage content of Lake Mead and releases from Hoover Dam are shown on Figure 23. Figure 22A shows graphically the decreased average annual flow in the Colorado River above Lake Mead during the past 30 years as compared with the previous 17 years.

Lake Mead Water-Loss Investigations.--In storing such vast quantities of water, certain losses are inevitable. For example, at the beginning of storage, a large amount of water is required to prime the ground which had not been previously submerged. During storage, some water may be lost by continuous seepage and some will be lost by evaporation from the surface.

Measurements of evaporation in floating pans on the lake and in land pans, together with precipitation measurements, were made from 1936

until late in 1953 when the floating pans and all land pans except the Boulder City pan were abandoned in favor of a newer approach for determining monthly evaporation from Lake Mead.

A comprehensive study of evaporation losses from Lake Mead was carried out cooperatively by the Navy, Geological Survey, Weather Bureau, and Bureau of Reclamation during 1952 and 1953. Results of this study are published in a Geological Survey Professional Paper No. 298, entitled "Water Loss Investigations, Lake Mead Studies, Technical Report." Records of evaporation from Lake Mead, computed by procedures proven in the above-mentioned comprehensive investigations, are available in provisional reports of the Geological Survey. Final records are published in Geological Survey Water Supply Papers beginning with Water Year 1953.

Lake Mohave.--In January 1950, the diversion openings in the spillway structure at Davis Dam were closed with concrete stop logs and all water passing Davis Dam flowed through the two radial gate openings. In the latter part of November 1950, the radial gates were closed and the river flow was passed over the spillway. This method of bypassing the water at Davis Dam continued until April 1951, at which time the spillway gates were closed and all water was released through the powerplant turbines.

The storage capacity of Lake Mohave, the reservoir above Davis Dam, is 1,809,800 acre-feet between the top of spillway gates (elevation, 647.00 feet) and the lowest outlet. There is an additional 8,530 acre-feet of dead storage below elevation 533.39, the lowest outlet. Storage is used for power head and for meeting treaty requirements with Mexico. Records of the storage content of Lake Mohave and releases from Davis Dam are shown on Figure 24.

Havasu Lake.--Storage in Havasu Lake, the reservoir above Parker Dam, was actually begun in July 1938 although the dam was not officially closed until October 1938. The original storage capacity of this lake, including 28,600 acre-feet of dead storage, was 716,000 acre-feet, somewhat less than the average monthly flow of the river. The water level in the lake is controlled between elevations 440 feet and 450 feet. Except for the flood season on the Bill Williams River, when the level is reduced to provide space for possible flood inflow, the water surface is maintained as high as operational fluctuations will permit. A resurvey of the storage space between elevations 430 and 450 feet was completed in April 1957 and a new capacity table was prepared and placed in use commencing October 1, 1957. This table shows a total capacity of 648,000 acre-feet including 28,600 acre-feet of dead storage, and 180,000 acre-feet of active space above elevation 440.00 feet. Records of storage in Havasu Lake and releases from Parker Dam are shown on Figure 25.

Imperial Reservoir.--Imperial Dam is a diversion structure for the Gila and All-American Canals. Although it held about 85,000 acre-feet of storage immediately after its construction, the space is now almost completely filled with sediment deposit as was anticipated. The present usable capacity is approximately 1000 acre-feet.

Sedimentation in Reservoirs

Lake Mead.--Mention has been made previously in this report of the large sediment load passing the Grand Canyon station that has been trapped in Lake Mead since the closure of Hoover Dam in 1935. Table 8 shows the computed amounts of suspended sediment, in tons, that has passed the Grand Canyon station annually since 1926. The amount of suspended sediment that has been deposited in Lake Mead from the time of the closure of Hoover Dam through September 1958 is about 2.9 billion tons. Soundings have been made in the lake from one to three times per year since 1938 for the purpose of determining depths to the top of deposit (see Figure 27 for profiles), but these soundings have not been sufficiently extensive to permit an accurate determination of volume of sediment deposited.

A report on sediment investigations at Lake Mead was published as part of the "Lake Mead Comprehensive Survey of 1948-49" in February 1954. This report shows that in the period from 1935 to 1948, the capacity of the reservoir below the top of the raised spillway gates was reduced from 31,250,000 acre-feet to 29,825,000 acre-feet. This represents an average annual accumulation during this period of 102,000 acre-feet.

As part of the comprehensive report 1/, an attempt was made to estimate the probable life of the reservoir. By taking into account such contributing factors as compaction of the deposited sediment, increased deposition in the river above the reservoir level, and the decrease in trap efficiency, the probable life of the reservoir would be more than 500 years. None of those studies considered the effect of upstream developments. Glen Canyon Dam and reservoir, now under construction, will reduce the sediment inflow to Lake Mead by an estimated 75 percent and extend its useful life by many centuries.

Havasu Lake.--The level of Havasu Lake is normally maintained between elevations 440 and 450 in order to provide a forebay for the Metropolitan Water District to pump water from the lake into the Colorado River Aqueduct. Since sediment deposited elsewhere in the reservoir does not affect its operation, a resurvey of the reservoir made in 1956 covered only the top 20 feet of the lake between elevations 430 and 450. In the 16 years from the closure of Parker Dam to the time of the resurvey, a total of 58,100 acre-feet of sediment had been deposited in the upper 20 feet. This represents a loss of about 15 percent of the original capacity of the top 20 feet. It is expected that the completion of the present channelization program from Davis Dam to Havasu Lake will materially reduce the future sediment inflow to Havasu Lake.

1/ Page 331, Volume 3, Lake Mead Comprehensive Survey of 1948-49.

Imperial Reservoir.--The primary function of Imperial Dam is to raise the river water to a point at which diversions for irrigation can be made. The quantity of water impounded by this dam, therefore, is not an important consideration. In fact, in the design of the dam it was anticipated that the storage space of approximately 85,000 acre-feet to elevation 181.0 (spillway crest) would be filled with sediment before many years had passed. This expectation has been fulfilled in that a sediment volume equal to about 99 percent of this capacity has been deposited. Tables 3 and 6 show quantities of sediment trapped in the reservoir during various periods since closure of the dam.

USE OF THE WATER

The Boulder Canyon Project Act was passed "* * * for the purpose of controlling the floods, improving navigation, and regulating the flow of the Colorado River, providing for storage and for delivery of the stored waters thereof for reclamation of public lands and other beneficial uses * * *, and for the generation of electrical energy as a means of making the project * * * a self-supporting * * * under-taking, * * *." In achieving the purposes of controlling the floods and regulating the flow, the other two purposes, providing for delivery of irrigation water and generation of electrical energy, are partially achieved. With installation of the necessary appurtenant works, the two latter purposes are accomplished.

Irrigation and Domestic Use

Waters of the lower Colorado have been used for irrigation for many years. The major uses in early times were in the Palo Verde, Yuma, and Imperial Valleys with minor uses in the Mohave and Parker Valleys.

Mohave Valley.--In the Mohave Valley, about 17 miles upstream from Needles, California, irrigation of a small amount of land was begun in 1891. Shortly thereafter, a canal and levee were built. Because of silting difficulty in the canal followed by levee breaks in 1914, irrigation was discontinued. Following the lowering of the river surface in the vicinity of Needles, California, resulting from channelization of the river from Needles to Topock, some of the valley lands were cleared and farming operations started. By the end of calendar year 1953, some 3,300 acres of land had been cleared and leveled for large scale irrigation. Some additional development continued in subsequent years.

Parker Valley.--The Colorado River Indian Reservation in the Parker Valley was established in 1865. Diversion of water from the river was begun soon thereafter (1870), but was not successful and was discontinued in 1876. Beginning in 1889, various pumping installations were made for irrigation purposes. The permanent gravity diversion at Headgate Rock was built in 1939.

Palo Verde Irrigation District.--The first water filing for what is now known as Palo Verde Irrigation District was made in 1877 by the Blythe Rancho. Development was continued, one cooperative company succeeding another, until 1923 when the present Palo Verde Irrigation District was created by Act of the California legislature.

Yuma Project.--In the Yuma Valley, settlement and irrigation of lands actually was begun in 1890. The Yuma County Water Users Association was incorporated in November 1903. Construction of an irrigation system under the Reclamation Act was approved in 1904 and the first portion was completed in 1907. Originally, all diversions for the Yuma Project were made at Laguna Dam. Beginning August 4, 1941, diversions at Laguna Dam for this project were limited to requirements for the Bard District with deliveries being made from the All-American Canal at Siphon Drop for the remainder of the project. Diversions for the Yuma Project at Laguna Dam were entirely stopped on June 23, 1948, and since that date, all water for that project has been delivered from the All-American Canal. The Bard District in California is now served by the Pequod, Yaqui, Titsink, and Reservations Main Turnouts from the All-American Canal. Diversion facilities at the left (Arizona) end of Laguna Dam continued to serve the North Gila Irrigation District in Arizona until December 16, 1954. Since that time, its diversion has been accomplished through the Gila Gravity Main Canal at Imperial Dam.

Imperial Valley.--The Imperial Valley was first irrigated with Colorado River water in 1901. Water was delivered via the Alamo (Imperial) Canal which flowed through Mexico and then into the Imperial Valley of the United States. Deliveries to the Imperial Valley from the All-American Canal were begun in September 1940 and the last delivery to lands in the United States from the Alamo Canal was in February 1942.

Coachella County Water District.--The first water deliveries from the All-American Canal to the Coachella Canal for canal priming and construction purposes were made in 1944. The first deliveries to this canal for irrigation purposes were made on an emergency basis in July 1948. Emergency canal-side deliveries were continued throughout the remainder of 1948 and the first two months of 1949. The first laterals of the distribution system were completed and turned over to the Coachella County Water District for operation on February 28, 1949.

Problems of Irrigation Development.--A detailed history of early irrigation development in the lower Colorado River Basin is given in "The Boulder Canyon Project" by Paul L. Kleinsorge (Stanford University Press, 1941). Many difficulties were encountered in these early years such as those caused by flood flows in the spring and early summer and by shortage of water in the late summer and the early autumn. With completion of Hoover Dam in 1935, the flood flows, as well as water shortages, were largely eliminated.

There still remained the sediment problem at Laguna Dam for the Yuma Project and difficulties of diversion at Rockwood Heading in addition to the sediment problem for the Imperial District. With the commencement of water deliveries from the All-American Canal late in 1940, these problems were solved. The major part of the sediment eroded below Parker Dam was trapped above Imperial Dam during the initial operation, and the quantities carried into the All-American and Yuma Canals did not become objectionable until about 1943. Figure 20 shows the amounts of sediment carried into the former canal and Figure 21 shows percentages of sediment in the Yuma Canal. Operation of the All-American Canal Desilting Works was begun in the fall of 1944 but failure in the riprap of the effluent channels forced its shutdown after a few weeks. Repairs were made and operation was resumed in June 1945.

Deliveries to Mexico.--Deliveries of water to the Alamo Canal from the All-American Canal via Pilot Knob Wasteway, prior to the completion of Morelos Diversion Dam, were made in accordance with interim annual arrangements negotiated by the International Boundary and Water Commission and the Bureau of Reclamation. Initial diversion of water to Mexico at Morelos Dam began on November 8, 1950. All deliveries to the Alamo Canal via Pilot Knob Wasteway were discontinued November 7, 1950.

Power

Hoover Dam.--Generation of power at Hoover Dam was begun officially on October 26, 1936, when installation of the first of the main generating units, N-2, was completed. Two station-service units were completed the previous month. Additional units have been put into service as completed, the last in September 1952, bringing the total installed capacity to 1,249,800 kilowatts, consisting of fourteen 82,500-kw units, one 50,000-kw unit, one 40,000-kw unit, and two 2,400-kw station units. The units are numbered in downstream order, N-0 to N-7 on the Nevada side and A-0 to A-9 on the Arizona side of the river.

The City of Los Angeles and its Department of Water and Power and the Southern California Edison Company, Ltd., acting as agents of the United States, actually operate the various units in Hoover Powerplant. The City of Los Angeles operates ten 82,500-kw units, N-1 to N-7 and A-1 to A-4; one 50,000-kw unit, A-9; and the two 2,400-kw station-service units, N-0 and A-0. The Edison Company operates the remaining three 82,500-kw units, A-5 to A-7, and the one 40,000-kw unit, A-8.

All generating units were designed exclusively for 60-cycle operation except the three 82,500-kw units, A-5 to A-7. In addition, Unit N-7 was operated on 50 cycles prior to April 12, 1947. At present, all generation is on 60-cycle frequency, the last 50-cycle operation having been discontinued on April 8, 1948.

(Unit N-8, 95,000-kw, now installed, is estimated to be in service by December 1, 1961.)

TABLE 3

ESTIMATED QUANTITIES OF RIVERBED MATERIAL REMOVED
AND DEPOSITED BETWEEN PARKER AND IMPERIAL DAMS

(Thousands of Cubic Yards)

Between Stations	Parker Dam to Section 30	Section 30 (Dam) to Section 23	Total Parker Dam to Section 23	Section 23 to Imperial
Miles	59	27	86	61
Sept. 1937-July 1951[1/]	-94,732	-75,012	-169,744	+140,963
Aug. 1951-Dec. 1951[2/]			-1,171	+589
1952			-8,063	+767
1953			-3,639	+1,532
1954			-3,174	+2,021
1955			-2,467	+1,719
1956	-1,371	-436	-1,817	+1,378
1957	-1,635	-630	-2,265	+756
1958	-4,918	+225	-4,693	-922
1959	-1,539	-939	-2,478	+1,647

1/ Computed from change in river section cross-sections.
2/ Computed from total load samples at station below Palo Verde Dam, at Taylor's Ferry, and suspended sediment records and estimated bedloads on the All-American Canal, All-American desilting works, California sluiceway, Gila Gravity Canal, and Gila Gravity desilting basin.

TABLE 4

ESTIMATED VOLUMES OF RIVERBED MATERIAL
REMOVED AND DEPOSITED BELOW IMPERIAL DAM

Between Sections		Imperial Dam to Laguna Dam	Laguna Dam to 6S	6S to 8S	Total Imperial Dam to 8S	8S to Morelos Dam	Morelos Dam to 20S	Total Imperial Dam to 20S
Distance (miles)		6.3	7.7	5.0	-	8.3	19.4	
Period Approx. Dates	Mean Q at Yuma cfs	VOLUME REMOVED OR DEPOSITED (-) Indicates Removal (+) Indicates Deposit Thousands of Cubic Yards						
Nov. 1955 Nov. 1956	1,200	+48	-91	+43	0	-17	+1,187	+1,170
Nov. 1956 May 1957	790	+179	+145	+329	+653	+169	+527	+1,349
May 1957 Nov. 1957	1,590	+125	-169	-629	-673	+143	-334	-864
Nov. 1957 May 1958	6,600	+212	+1,122	+116	+1,450	+653	+1,013	+3,116
May 1958 Nov. 1958	2,030	-33	+338	-90	+215	-490	+417	+142
Nov. 1958 May 1959	1,710	-34	+54	-204	-184	-215	+642	+243
May 1959 Nov. 1959	1,130	+11	+38	+23	+72	-64	+135	+143
Total Nov. 1955 - Nov. 1959		+508	+1,437	-412	+1,533	+179	+3,587	+5,299

1/ For year prior to 1955 see Table 4, of "Report of River Control Works and Investigations, Lower Colorado River Basin", 1952 through 1956.

Data in this table computed from cross-sectional measurements taken by International Boundary and Water Commission.

TABLE 5

ACTIVE SUSPENDED SEDIMENT STATIONS IN THE
LOWER COLORADO RIVER

Name of Station or Group	Approximate Location of Station	Dates of Records	Sampler Used	Frequency of Sampling	Agency Obtaining Samples	Agency Analyzing Samples	Method of size Analyses
Lees Ferry	Just upstream from Colorado River Mile 0.0	Nov. 10, 1942 to Sept. 29, 1944; continuous since Oct. 1, 1947.	"Colorado River" type U. S. D-43	Daily	Geological Survey	Geological Survey	None Sieve and Decantation
Paria River	Just upstream from Junction of Colorado River	Continuous since Oct. 1, 1947.	U. S. D-43	Daily	Geological Survey	Geological Survey	None
Little Colorado River	Near Cameron, Arizona	Continuous since Oct. 1, 1947	U. S. D-43	Daily	Geological Survey	Geological Survey	None
Grand Canyon	Colorado River Mile 87.4	Jan. 1935 through Sept. 1942; continuous since Sept. 1943.	"Colorado River" type to about April 1944 U. S. D-43 thereafter	Daily	Geological Survey	Geological Survey	Sieve and Decantation
Virgin River	Littlefield, Ariz.	Continuous since Sept. 1, 1947.	U. S. D-43	Daily	Geological Survey	Geological Survey	None
Needles Bridge	Needles, California	Continuous since July 1955	U. S. D-49	1 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
River Section 41	Colorado River Mile 470.6	Continuous since Sept. 1955	U. S. D-49	1 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
Near River Section 43	Colorado River Mile 475.8	Continuous since Sept. 1955	U. S. D-49	1 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
Water Wheel	Colorado River Mile 550.6	Continuous since April 1, 1958	U. S. D-49	1 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
Below Palo Verde Weir	Blythe, California	Continuous since Sept. 1955	U. S. D-49	2 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
Taylor's Ferry	Colorado River Mile 597.5	Continuous since May 9, 1939	U. S. D-49 2/	2 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
Adobe Ruins	Near Cibola	Continuous since Nov. 1956	U. S. D-49	2 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
Imperial Dam Sludge Pipes	Colorado River Mile 658	Continuous since Nov. 7, 1945	Special	1 or 2 per Mo.	Imp. Irrig. District	Imp. Irrig. District	
Imperial Dam Sluiceway	Colorado River Mile 658	Continuous since June 14, 1938	U. S. D-43	6 to 48 per Yr.	Bureau of Reclamation	Bureau of Reclamation	Sieve
Yuma	Colorado River Mile 676.7	May 1909 to Oct. 1909 April 1910 through Dec. 1942	"Yuma" type	1 per Mo. to 3 per Wk.	Geol. Survey & Recla.	Bureau of Reclamation	None "
		April 1933 to June 1934. Continuous since June 1938.	U.S. D-43 2/		Bureau of Reclamation	Bureau of Reclamation	Sieve
Sta. 61		Jan. 27, 1939 to Mar. 1, 1939; Continuous since Oct. 26, 1940					Sieve
Sta. 1080		Continuous since July 9, 1947.	U. S. D-43 2/	1 or 2 per Mo.	Imp. Irrig. District	Imp. Irrig. District	None
Sta. 1115		Continuous since June 20, 1945.					"
Sta. 1973		Continuous since Mar. 29, 1948 1/					"
Sta. 2963	East Highline	Mar. 22, 1941 to June 17, 1947; Continuous since April 13, 1948 1/					"
Sta. 3256	At Alamo River Crossing	Continuous since Feb. 25, 1946 1/					"
Yuma Main Canal	Siphon Drop Laboratory	Continuous since Aug. 1941 Continuous since Jan. 6, 1943	U. S. D-43 2/ U. S. D-43 2/	1 or 2 per Mo.	Bureau of Reclamation	Bureau of Reclamation	None "
Gila Gravity Canal	Sta. 144+50	Continuous since Sept. 1952	U. S. D-43	2 per Mo.	Bureau of Reclamation	Bureau of Reclamation	Sieve
East Highline Canal	At All-American Canal	Continuous since Feb. 7, 1946		1 or 2 per Mo.	Imp. Irrig. District		None
Central Main Canal	At All-American Canal	Continuous since Feb. 28, 1946		1 or 2 per Mo.	Imp. Irrig. District		None
West Side Main Canal	At All-American Canal	Continuous since Feb. 7, 1946		1 or 2 per Mo.	Imp. Irrig. District		None

1/ Samples obtained by Imperial Irrigation District.
2/ Tait-Binckley used prior to Oct. 1, 1947.

TABLE 5A

SUSPENDED SEDIMENT RECORDS FILED IN OFFICE OF BUREAU OF RECLAMATION
REGION 3

INACTIVE STATIONS

	Name of Station or Group	Approximate Location of Station	Dates of Records	Sampler Used	No. of Samples	Government Agency Obtaining Samples	Government Agency Analyzing Samples	Method of Size Analyses
	Escalante River	Escalante, Utah	May 3 to Aug. 24, 1940	Qt. Jar, Fig. 8 hole in lid	8	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
	Kanab Creek	Near Glendale, Utah	March 21 to April 18, 1940 and April 30, 1941	Qt. Jar, Fig. 8 hole in lid	5	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
	Johnson Creek	Skutumpah, Utah	March 4, 1940 to Sept. 17, 1940	Qt. Jar, Fig. 8 hole in lid	12	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
Virgin River Basin	Virgin River	Virgin, Utah	Jan. 13, 1936 to Nov. 1, 1936		181			
			Jan. 13, 1939 to June 3, 1944		543			
		Near St. George	One sample, March 2, 1941		1			
	Virgin, N. Fork	Near Springdale Utah	Oct. 10, 1936, May 6 and July 25, 1941		3			
	La Verkin Creek	Near La Verkin, Utah	Jan. 29, 1941 to May 19, 1942		71			
	Ash Creek	Near New Harmony	April 7, 1939 to Jan. 25, 1943		58			
	Big Creek	At Reservoir Site	Sept. 29, 1939 to Sept. 17, 1940		22			
			May 15, 1941 to Aug. 6, 1941					
	Kanara Creek	Near Kanara	April 15 and Sept. 4, 1940; April 30 to Aug. 6, 1941: April 15 to 28, 1942	Quart Fruit Jar, Fig. 8 hole in lid	19	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer Analyses of Certain Combined Groups
		Near N. Harmony	April 1 and Sept. 4, 1940; March 3, May 7 and 14, 1941; April 15 and July 22, 1942		7			
	Santa Clara R.	Gunlock, Utah	April 17, 1939 to July 25, 1941 (intermittent)		21			
		Near Santa Clara, Utah	May 8, 1939 to April 7, 1944		60			
	Moody Wash	Near Veyo, Utah	April 17, 1939 to Feb. 28, 1941 (intermittent)		10			
	Ivins Dry Wash	Near Santa Clara, Utah	Jan. 24, 1941 to July 26, 1941		9			
	Kanab Creek	Near Glendale, Utah	March 29, 1944 to May 6, 1944		50			
	River Section 33	Colorado River Mile 447.3	July 5, 1944 - Sept. 17, 1958	US D-49	23	Bureau of Reclamation	Bureau of Reclamation	Sieve
	Red Cloud Cable	Colorado River Mile 635.4	Feb. 8, 1936 to Aug. 29, 1939	1,000 c.c. Tait-Binckley	96	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
	Imperial Dam Site	Colorado River Mile 657.8	May 15, 1933 to Jan. 22, 1934	500 c.c. Tait-Binckley	69	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
			May 15, 1935 to July 26, 1935	500 c.c. " "	10			
			Aug. 2, 1935 to Jan. 24, 1936	1,000 c.c. " "	18			
All-American Canal	Sta. 598	Unnamed Wash	Nov. 2, 1940 to Jan. 14, 1941		4			None
	Sta. 810		Jan. 28, 1941 to Apr. 22, 1942		36			"
	Sta. 1173		Feb. 12, 1941 to July 16, 1946		101	Bureau	Bureau	"
		At Pilot Knob	July 22 to Dec. 30, 1947 1/		10			"
	Sta. 1900	Above Drop No. 1	June 17, 1942 to June 17, 1947	Tait Binckley	83	of	of	"
			July 23 and Aug. 14, 1947 1/		2			"
		Below Drop No. 1	Sept. 10 to Dec. 30, 1947 1/			Reclamation	Reclamation	"
	Sta. 1950		Mar. 6, 1941 to Apr 7, 1942		32			"
	Sta. 2180		May 6 and 25, 1942		2			"
Laguna Dam	Tailwater	Colorado	April 1933 to Oct. 1933	500 c.c.	54	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
	Crest	River	April 1933 to July 1934		110			
	Sluiceway	Mile 662.5	June 1933 to July 1934	Tait-Binckley	78			
	Yuma Main Canal	R. C. Check	April 1933 to July 1934	500 c.c. Tait-Binckley	120	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
		R. C. Check	June 1938 to July 1941	500 c.c. Tait-Binckley	88			
Alamo Canal	Hanlon Heading	Approx. 1 mile below intake	Sept. 28, 1935 to Feb. 11, 1942	Tait-Binckley	167	Bureau of Reclamation	Bureau of Reclamation	Sieve and Hydrometer
	Alamo Mocho	Approx. 36 miles below intake	Nov. 30, 1935 to March 22, 1941	Tait-Binckley	139			
	Dogwood Canal	At Highway 80	May 10 and 24, 1948		2	Imp. Irrig. District		None
	Central Main Canal	At Dogwood Road	May 10 and 24, 1948		2	Imp. Irrig. District		None
	Coachella Canal	Station 10	April 1945 to Sept. 1952	Tait-Binckley & US D-43	61	Bureau of Reclamation	Bureau of Reclamation	None

1/ Samples obtained by Imperial Irrigation District

TABLE 6

ESTIMATED AGGRADATION ABOVE IMPERIAL DAM
Based on suspended sediment tonnage

(Sediment inflow computed from samples at Red Cloud Cable, Taylor's Ferry or Adobe Ruin; sediment outflow computed from samples in Imperial Dam Sluiceway, Desilting Works, All-American Canal, and Gila Gravity Canal)

Year	Average Parker Release cfs	Sediment Inflow	Sediment Outflow	Aggradation	Cumulative Aggradation
		Thousands of tons			
1938 (Apr.-Dec.)	7,400	10,760	535	10,225	10,225
1939	11,600	25,350	2,070	23,280	33,505
1940	10,600	15,430	620	14,810	48,315
1941	20,400	41,010	3,645	37,365	85,680
1942	21,000	29,745	10,845	18,900	104,580
1943	16,700	15,955	2,135	13,820	118,400
1944	19,100	14,045	4,315	9,730	128,130
1945	16,600	10,180	3,330	6,850	134,980
1946	14,000	5,450	1,495	3,955	138,935
1947	14,700	5,655	2,115	3,540	142,475
1948	17,400	6,050	3,510	2,540	145,015
1949	18,000	6,325	4,705	1,620	146,635
1950	14,500	3,735	2,475	1,260	147,895
1951	12,000	2,237	1,143	1,094	148,989
1952	21,200	6,753	7,366	- 613	148,376
1953	14,700	3,048	2,049	999	149,375
1954	13,400	2,658	1,076	1,582	150,957
1955	11,300	2,066	832	1,234	152,191
1956	9,500	1,522	490	1,032	153,223
1957	11,100	2,225	1,475 1/	750	153,973
1958	15,100	3,793	5,492	- 1,699	152,274
1959	11,300	1,957	813	1,144	153,418

Imperial Dam closed April 16, 1938.
First irrigation water delivered to All-American Canal October 1940.
Desilting works placed in operation June 1945.

1/ 1957 and thereafter includes sediment sluiced from Imperial Reservoir.

TABLE 7

SUSPENDED SEDIMENT LOAD - YUMA GAGING STATION
("Yuma" type sampler)

Calendar Year	Discharge Thousands of Acre-Feet	Load 1/ Thousands of Tons	Calendar Year	Discharge Thousands of Acre-Feet	Load 1/ Thousands of Tons
1911	17,800	250,700	1927	17,100	242,500
1912	18,400	187,900	1928	12,800	114,800
1913	11,700	119,600	1929	17,500	289,000
1914	20,700	265,400	1930	10,600	183,900
1915	14,600	235,300	1931	4,800	52,100
1916	23,100	348,700	1932	14,200	184,200
1917	20,600	160,300	1933	8,000	92,200
1918	13,200	112,900	1934	2,400	17,800
1919	10,700	154,000	1935	4,000	21,600
1920	21,400	220,800	1936	3,500	14,000
1921	19,400	221,700	1937	4,000	15,800
1922	17,000	192,500	1938	4,200	12,500
1923	17,800	250,300	1939	6,600	12,100
1924	11,300	127,500	1940	5,400	3,800
1925	12,400	163,200	1941	11,700	19,900
1926	12,200	130,800	1942	10,500	13,500

1/ Determined from 52 to 66 samples per year, 1911-1913; 94 to 105, 1914-1933; 63 in 1935; 99 to 105, 1936-1942.

TABLE 7A

SUSPENDED SEDIMENT LOAD - YUMA GAGING STATION

Calendar Year	Discharge Thousands of Acre-Feet	Load Thousands of Tons	No. of Samples From Which Determined
1939	6,600	13,000	26
1940	5,400	3,500	28
1941	11,700	14,100	31
1942	10,500	8,800	18
1943	7,300	3,000	21
1944	8,600	4,800	21
1945	6,500	4,400	18
1946	3,800	1,700	19
1947	4,200	2,000	22
1948	6,300	6,700	22
1949	6,600	7,800	12
1950	3,500	3,500	54
1951	2,800	1,100	147
1952	9,200	10,500	143
1953	4,100	1,900	175
1954	3,200	1,300	168
1955	2,100	828	155
1956	881	264	155
1957	1,171	656 1/	156
1958	2,945	3,940	253
1959	935	561	142

Tait-Binckley sampler used through September 30, 1947. D-43 sampler used after September 30, 1947.

1/ Since 1957, includes suspended portion of Imperial Dam sluices passing this station.

TABLE 8

SUSPENDED SEDIMENT LOAD - GRAND CANYON STATION

Water Year Ending Sept. 30	Discharge Thousands of Acre-Feet	Load 1/ Thousands of Tons
1926	14,400	225,000
1927	17,300	398,000
1928	15,600	172,000
1929	19,400	480,000
1930	13,400	235,400
1931	6,720	68,810
1932	16,000	261,400
1933	10,000	178,100
1934	4,656	50,080
1935	10,216	122,300
1936	12,322	157,600
1937	12,410	191,300
1938	15,630	232,400
1939	9,618	86,320
1940	7,435	75,410
1941	16,940	270,100
1942	17,260	229,600
1943	11,430	58,760 2/
1944	13,530	97,790
1945	11,870	83,631
1946	9,089	65,970
1947	13,740	136,000
1948	13,870	144,100
1949	14,370	118,900
1950	11,080	59,780
1951	9,839	48,729
1952	18,160	148,500
1953	8,879	48,814
1954	6,229	40,674
1955	7,580	83,132
1956	8,860	76,132
1957	17,500	155,438
1958	14,550	132,495
1959	6,935	23,618

1/ From U.S. Geological Survey Water Supply Papers "1926-1942, 1944-1953. 1957-1958 from Geological Survey provisional data.

2/ Estimated by applying mean monthly concentrations of suspended sediment in the Colorado River at Lees Ferry gaging station to discharge at Grand Canyon.

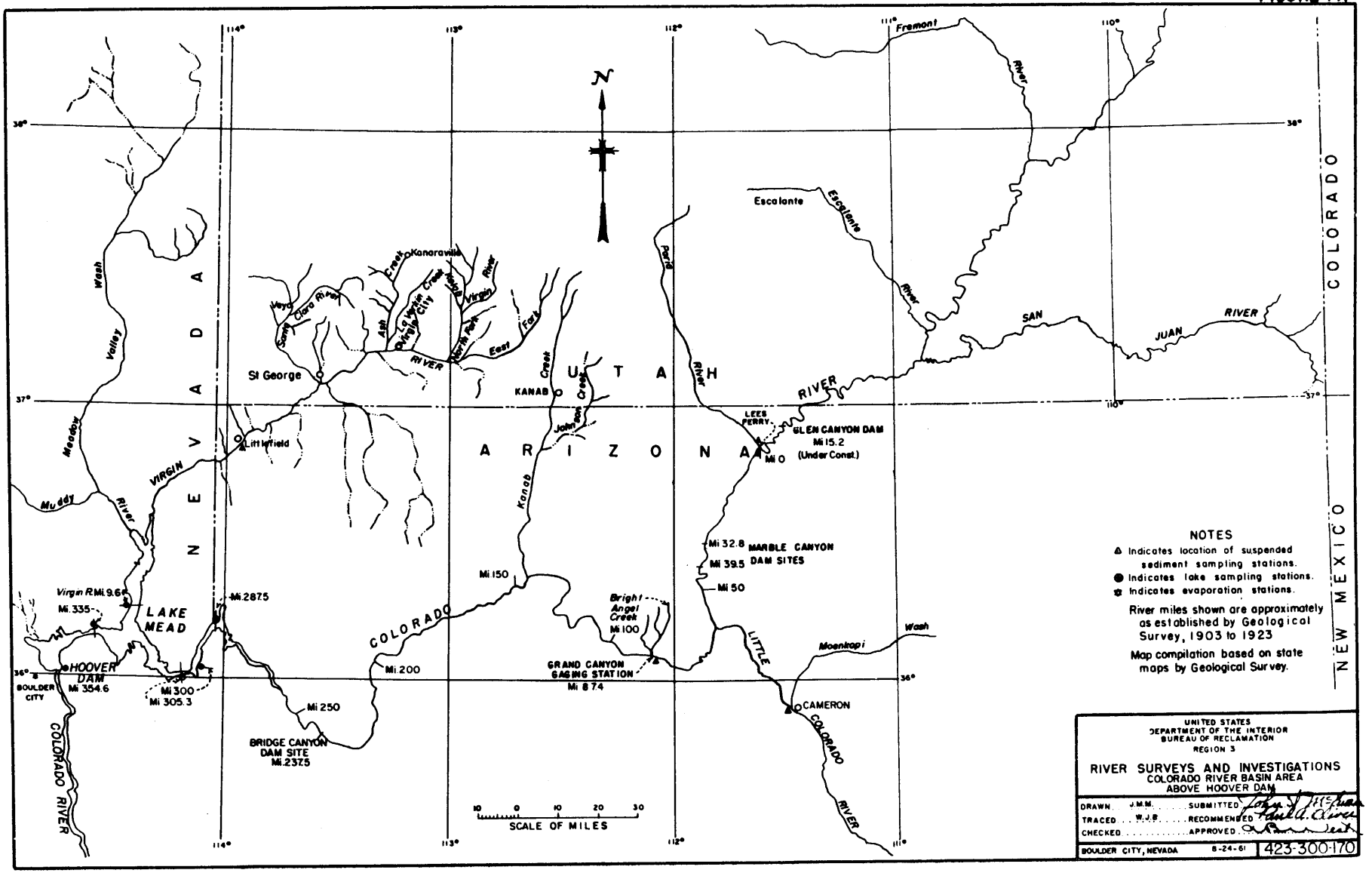
Table 9

WEIGHTED AVERAGE SALINITY OF COLORADO RIVER WATER

Year	Grand Canyon Station		Hoover Dam Station		Yuma Station	
	Wt. Avg. Salinity ppm	Annual Discharge maf	Wt. Avg. Salinity ppm	Annual Discharge maf	Wt. Avg. 1/ Salinity ppm	Annual 2/ Discharge maf
1935	545	10.6	555	6.3	643	4.0
1936	586	12.5	570	5.9	647	3.5
1937	608	12.5	742	6.0	753	4.0
1938	529	15.9	674	6.8	737	4.2
1939	670	9.1	742	8.6	769	6.6
1940	749	8.0	771	8.0	849	5.4
1941	566	18.8	739	14.9	783	11.7
1942	505	14.9	717	15.8	794	10.5
1943	607	11.6	667	12.7	687	7.3
1944	552	13.3	681	14.4	696	8.6
1945	614	12.2	679	12.4	702	6.4
1946	710	9.1	673	10.6	694	3.8
1947	578	14.3	685	11.1	698	4.2
1948	552	13.0	664	13.2	687	6.3
1949	568	14.6	619	13.4	636	6.6
1950	638	10.8	627	12.0	654	3.5
1951	657	9.9	651	9.8	691	2.7
1952	557	18.1	623	15.8	666	9.2
1953	726	8.8	658	11.3	670	4.1
1954	839	6.3	693	10.5	730	3.2
1955	708	6.7	805	8.6	817	2.1
1956	569	8.7	840	7.8	917	0.9
1957	523	18.9	768	9.3	871	1.2
1958	549	13.5	634	11.9	727	3.0

1/ Yuma Main Canal Below Siphon
2/ Colorado River at Yuma, Arizona

FIGURE 1 A



NOTES

△ Indicates location of suspended sediment sampling stations.

● Indicates lake sampling stations.

☆ Indicates evaporation stations.

River miles shown are approximately as established by Geological Survey, 1903 to 1923

Map compilation based on state maps by Geological Survey.

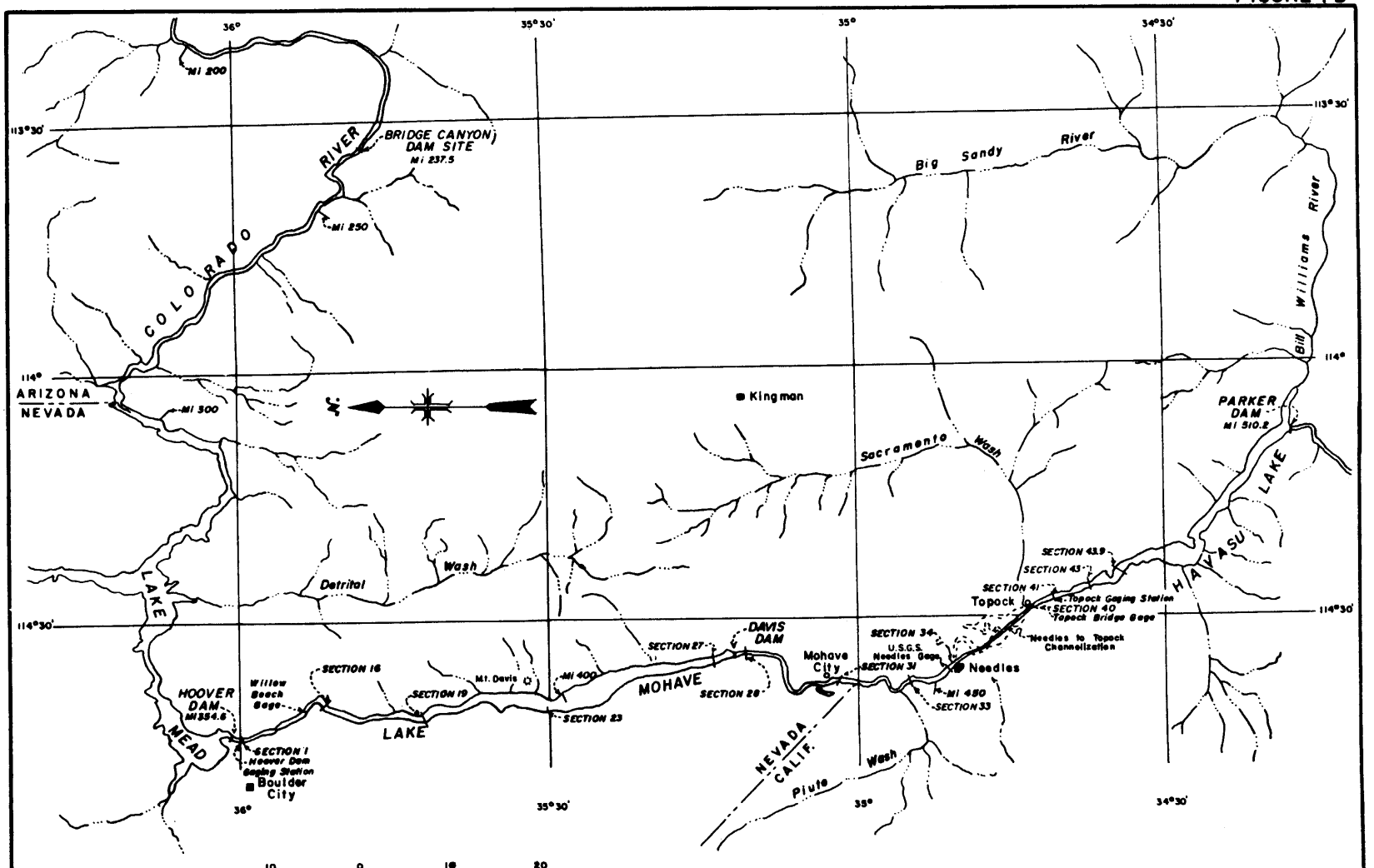
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS
COLORADO RIVER BASIN AREA
ABOVE HOOVER DAM

DRAWN J.M.M. SUBMITTED John J. McGuan
TRACED W.J.B. RECOMMENDED Paul A. Lewis
CHECKED APPROVED Chief Engineer

BOULDER CITY, NEVADA 8-24-61 | 423-300-170

FIGURE 1 B



NOTES

Map compilation based on Sectional Aeronautical Charts by Coast and Geodetic Survey.

River course shown is approximately as of 1942. River miles shown are approximately as established by Geological Survey 1902 and 1920.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

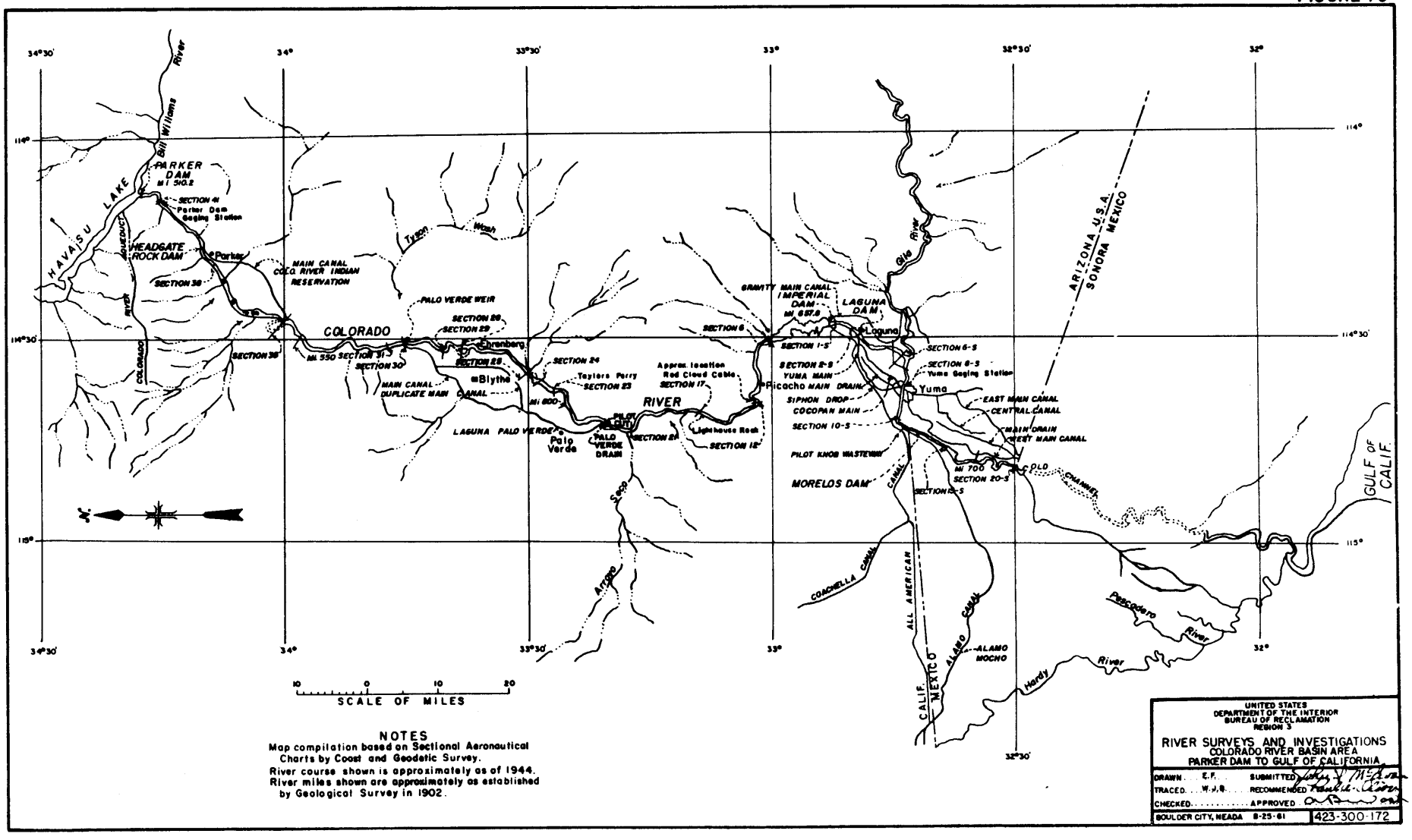
RIVER SURVEYS AND INVESTIGATIONS
COLORADO RIVER BASIN AREA
HOOVER DAM TO PARKER DAM

DRAWN	E.F.	SUBMITTED	
TRACED	W.J.B.	RECOMMENDED	
CHECKED		APPROVED	

BOULDER CITY, NEVADA 8-25-61

423-300-171

FIGURE 1C



NOTES

Map compilation based on Sectional Aeronautical Charts by Coast and Geodetic Survey.
River course shown is approximately as of 1944.
River miles shown are approximately as established by Geological Survey in 1902.

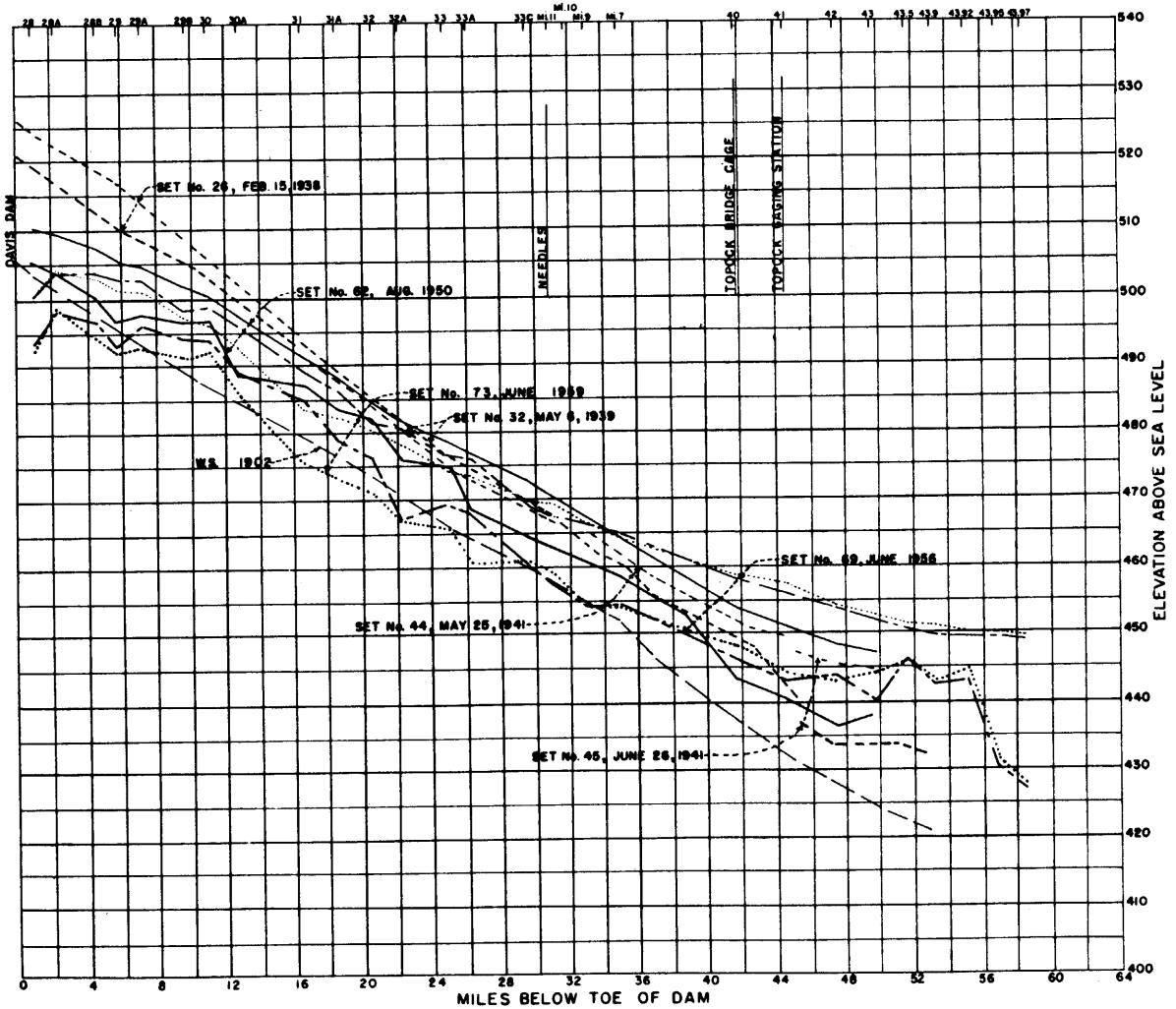
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS
COLORADO RIVER BASIN AREA
PARKER DAM TO GULF OF CALIFORNIA

DRAWN E.F. SUBMITTED
TRACED W.J.B. RECOMMENDED
CHECKED APPROVED
BOULDER CITY, NEVADA 8-25-61

423-300-172

FIGURE 2



NOTES

Locations shown for river sections are approximate locations according to river course in 1959.

Light line indicates water surface (Water surface elevations adjusted to discharge of 15,000 c.f.s., except those for Sections 40 to 43.97 which are measured elevations at time of survey and are influenced by Havasu Lake elevations).

Heavy line indicates average bed elevation. Average bed elevation is computed from area below adjusted water surface.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
OFFICE OF RIVER CONTROL

RIVER SURVEYS AND INVESTIGATIONS

COLORADO RIVER PROFILES
DAVIS DAM TO HAVASU LAKE

DRAWN		SUBMITTED	
TRACED		RECOMMENDED	
CHECKED		APPROVED	

BOULDER CITY, NEVADA, 423-300-144

As the new units have been put into service, the amount of water used for power has increased. Shown on Figure 29 is the total amount of water passing the dam each month, the amount used for power, and the power generation in kilowatt-hours.

Davis Dam.--Generation of power at Davis Dam was officially begun on January 5, 1951, when installation of generating Unit G-1 was completed. Units G-2 and G-3 were completed during April 1951, Unit G-4 went on the line May 12, 1951, and Unit G-5 was completed June 18, 1951. With the completion of Unit G-5, the total installed capacity was 225,000 kva. Gross generation in kilowatt-hours per month and water releases are shown on Figure 30.

Parker Dam.--Parker Dam was closed October 16, 1938. Generation of electrical energy was begun by Units 1 and 3 on December 13, 1942. Unit 2 was put into service on January 3, 1943, and Unit 4 on May 28, 1943, making the total installed capacity 120,000 kva. Gross generation in kilowatt-hours per month and water releases are shown on Figure 31.

Siphon Drop Powerplant.--The Siphon Drop Powerplant on the Yuma Main Canal began operation on July 26, 1926, with an installed capacity of 2,000 kva. Since August 4, 1941, all water for the Siphon Drop Powerplant has been delivered from the All-American Canal via the Siphon Drop turnout. Originally, the plant operated under a head of between 10 and 14 feet; however, since the connection was made to the All-American Canal, the head has been about 16 feet.

Imperial Irrigation District Powerplants.--The Imperial Irrigation District placed two powerplants in service on the All-American Canal in February 1941. One is located at Drop No. 3 (Station 2470+69) and the other at Drop No. 4 (Station 2755+09). A third unit located at Drop No. 2 (Station 2178+09) was placed in service in December 1953. On January 14, 1957, the first delivery of water for testing purposes was made to Pilot Knob Powerplant.

STREAMFLOW FORECASTING

To meet flood-control requirements and to insure efficient use of water for irrigation and power, it is necessary to have timely, accurate, and reliable forecasts of seasonal inflow to Lake Mead. Since from 65 to 70 percent of the annual runoff from the upper Colorado River basin results from snowmelt runoff during the April-through-July period, most of the forecasting research efforts of the Bureau of Reclamation, Region 3, have been concerned with that 4-month period. This research, carried on during the years covered by the previous report, resulted in continued changes and improvements in the forecasting procedures. At the present time, January 1, February 1, and March 1 forecasts of April-through-July inflow are based on accumulated precipitation at selected index stations. April 1, May 1, and June 1 forecasts of April-through-July inflow are based on multiple correlation using precipitation, snow, and antecedent runoff.

Forecast Based on 13-Station Precipitation Index Data

This forecast is derived from a correlation of accumulated precipitation at 13 index stations in the upper Colorado River watershed with April-through-July runoff of the Colorado River near Grand Canyon, Arizona, (adjusted for major diversions and storage change).

Figures 32 and 32A show comparisons of the various streamflow forecasts as issued by this office during calendar years 1952 through 1956 and the observed runoff in each of those years.

Forecast Based on Multiple Correlation Using Precipitation, Snow, and Antecedent Runoff Data

This forecast is derived from a summation of forecasts for three tributaries:

The Green River at Greenriver, Utah

The Colorado River near Cisco, Utah

The remaining drainage areas of the Colorado River Watershed above Grand Canyon, Arizona

Each of the tributary-forecast equations is derived by multiple correlation analysis involving records of precipitation, antecedent runoff, April 1 water equivalent of snow, and April-through-July runoff (adjusted for major diversions and storage change). Consideration has been given to nearly all precipitation stations and snow courses that have sufficient length of record. Records from a total of 72 precipitation stations and 49 snow courses are used for the tributary forecasts. The precipitation stations and snow courses have been assigned weights which give consideration to each station's representative catchment area, elevation, and in some cases to the station's distance from the mouth of the tributary basin. Instead of using the accumulated precipitation for the effective season, it has been separated into three periods (fall, winter, and spring) serving as independent variables. This forecast procedure was used for the first time in predicting the 1955 spring inflow to Lake Mead. Indices calculated for this forecast indicate improved statistical reliability and consistency over other forecast procedures. Future research will probably be directed toward refinement of this basic procedure.

PHYSICAL CONTROL OF THE RIVER

Needles Area

Emergency work.--The work accomplished under the emergency program at Needles, California, was substantially completed by January 1948. The completed work is described in the "Report of River Control

Work and Investigations, Lower Colorado River Basin," for calendar years 1948 and 1949, and previous reports. During the period covered by this report, the completed works were maintained.

Permanent Corrective Work.--The initial channelization of the Colorado River, Needles to Topock, began on January 31, 1949. This program had for its objective the relief of flood or high water damage and the prevention of a threatened increase of flood damage. The channelization work, if properly maintained and extended upstream to a logical conclusion, will provide permanent flood protection to the Needles area, including valley lands adjacent to the river.

The dredge completed the first cut of the Needles-to-Topock channel on April 21, 1951, and was returned to the Needles operating yard where it was secured pending opening of the dredged channel to river flow. By dynamiting the land plug at the head of the new channel, June 25, 1951, the river was allowed to enter the dredged channel.

The operations at the channel entrance consisted of straightening the approach and removing the sand bars blocking the entrance to the dredged channel. At this time, the channel levee along the Arizona bank was extended upstream across the old channel of the river to divert 100 percent of the flow through the new channel. Maintenance dredging in the new channel was necessary to clear river-borne sand and other debris from the channel and to re-establish channel banks in areas where alignment was lost through destructive bank erosion. Considerable bank protection work in the form of jetties and bank riprapping was necessary along the raw, unconsolidated banks of the new channel. Conventional land equipment was used to a large extent in this work.

Within a week after the opening of the channel plug in June 1951, there was a change in water-surface elevation at the Geological Survey's river gage at Needles from 472.5 feet to 469.0 feet (river discharge of 15,000 cfs), for a downward change of 3.5 feet. This downward change continued until January 1952 and reached a low of 467.3. However, starting in 1953, an upward trend set in which returned the water-surface elevation to 469.5 by December 1954 (river discharge of 15,000 cfs). After 1954, the upward trend leveled off and as of December 1959, the water-surface elevation at Needles was still 469.5 feet (see Figure 11).

The dredge completed the channel excavation between Needles and Topock on January 5, 1953. Up to that time, it had removed some 15,548,000 cubic yards of material. The average cost, including administrative overhead, of moving this material was $0.091 per cubic yard for excavation, and $0.029 per cubic yard for disposal of dredge spoil, making a total cost of $0.120 per cubic yard.

Following the completion of the Needles-to-Topock channel, the dredge was assigned the task of extending the rectified channel upstream from Needles to Big Bend (8 miles downstream from Davis Dam). This work

was necessary in order to protect the channelization already accomplished and to prevent the movement of an unlimited amount of sediment into the channelized river from sources in the northern half of Mohave Valley. The dredging extended upstream to Station 1663+50 and was completed during July 1960.

The activities of dredge "The Colorado" after January 5, 1953, are summarized in the following tabulation showing the area of dredging activity and the dates involved:

Dredge Activity	Date
Channelization--Big Bend to Needles ...	Jan. 1953 to May 1953
Overhaul	June 1953
Maintenance--Needles to Topock	July 1953 to Oct. 1953
Channelization--Big Bend to Needles ...	Oct. 1953 to May 1954
Overhaul	June 1954
Dredge immobilized 1/.....	July 1954 to Aug. 1955
Maintenance--Needles to Topock	Aug. 1955 to May 1956
Overhaul	June 1956 to July 1956
Channelization--Big Bend to Needles ...	Aug. 1956 to July 1960

Blythe Area

Palo Verde Weir.--The First Deficiency Appropriation Act, approved April 1, 1944, provided funds for the construction, operation, and maintenance of a temporary weir in the Colorado River for the purpose of restoring and stabilizing the water-surface elevation at the water intake of the Palo Verde Irrigation District. Work of erecting a cableway started soon after passage of the Act. Placement of rock began January 16, 1945, and was completed about April 1, 1945. The amount of rockfill originally placed in the weir and in the various strengthening programs which followed totaled 191,850 cubic yards in the structure and 7,296 cubic yards on the banks. The rock was obtained from local quarries and placed in the river by means of an overhead cableway.

The Act of August 31, 1954 (Public Law 752, 83rd Congress, 2nd Session), authorized construction of work to re-establish for the Palo Verde Irrigation District, California, a means of diverting its irrigation water supply from the Colorado River and for other purposes, and authorized appropriations of $7,099,000. The Act provided for an earth-and-rockfill diversion dam and a concrete spillway. In accordance with the terms of the Act, the temporary rock weir was removed and its effects nullified as of November 1, 1957, when construction of the permanent diversion structure had progressed to the point where it could assume the diversion function.

1/ No funds allocated for dredging activities, Fiscal Year 1955.

Pilot Cut.--The Pilot Cut opposite the mouth of the Palo Verde Drain was constructed as a temporary solution to the problem of a rising water surface in the river at the outfall of the Palo Verde Drain. The high water surface in the river interfered with functioning of the drain and in order to lower the river water surface, a 1-1/2-mile-long pilot cut was constructed across a bend in the river. The cut was excavated by dragline and a total of 102,000 cubic yards of material was moved. The pilot cut was opened by blasting on June 20, 1947. A solid earth plug was completed across the old channel in June 1953, and subsequent to that time all of the flow of the river has passed through the Pilot Cut.

River Channelization.--Channelization of the Colorado River through Palo Verde and Cibola Valleys in California and Arizona has been proposed in a report 1/ covering this reach of the river. The report was approved April 8, 1960.

Yuma Area

Rehabilitation of Yuma Levee System.--The 1944 Treaty with Mexico authorized construction of a diversion dam on the Colorado River below Yuma and provided for construction, at the expense of Mexico, of flood protective works necessary to protect lands in the United States against flood hazards that might be caused by the structure. The United States Section of the International Boundary and Water Commission administers the Treaty for the United States. The Bureau of Reclamation has, through a series of agreements, taken over the responsibility for the construction work involved. Surveys for the purpose of gathering data began during June 1948. The surveys resulted in the Colorado River Front Work and Levee System Report No. RC-3-1.1, "Improvement of Levee System Near Yuma, Arizona, Preliminary Survey," dated July 1950. This report included data on requirements for rehabilitating the existing levees and concurrently providing the additional protection necessitated by construction of Morelos Dam. The rehabilitation of the levees was done at the expense of the United States up to the height of levee necessary to pass the design flood without considering the effect of Morelos Dam. Mexico paid for the additional height of levee made necessary by Morelos Dam.

The Gibbons and Reed Contract for work on the Yuma Levee was completed September 4, 1952, and the R. P. Shea Contract on the Reservation Levee was completed November 30, 1952.

The work planned for the protection of the Gila Valley below Dome, Arizona, from floods in the Colorado River was not done because of the lack of rights-of-way. In order to satisfactorily tie the Colorado River levees back to high ground and provide a means of exit to the river for floods originating in the Gila River, it was necessary to plan levees

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1/ Colorado River Front Work and Levee System Report on "Comprehensive Plan--Colorado River Channelization--Palo Verde and Cibola Valley Divisions", dated December 1959.

that paralleled the Gila River up to Dome. Also, a floodway was planned to guide such flows through the valley to the Colorado River. Local interests (North Gila Irrigation District and Yuma Irrigation District) were approached with the plan that the proposed levees and floodway would be built if rights-of-way could be obtained by the beneficiaries of the project. Insufficient interest on the part of the local residents and land owners brought about the decision to temporarily abandon plans for the work.

Imperial Dam to International Boundary.--Below Imperial Dam the principal problem is that of maintaining a reasonably clear channel. Demands upon the river water at Imperial for irrigation and power production have increased to the point where they equal or exceed the flow in the river. This is especially true during years of comparatively low release (such as June 1955 through October 1957, and again in 1959) when the inflow is equal to or only slightly greater than the total irrigation and domestic water demand. Two powerplants, Siphon Drop and Pilot Knob, divert water at Imperial Dam for power production. This water is then returned to the river to fill the Mexican irrigation requirement. These two plants have adequate capacity to use more than the largest Mexican orders so that it is entirely possible to use the entire flow at Imperial for irrigation and power production when the flow is about equal to the total irrigation demand.

While it is possible to divert the entire flow at Imperial Dam for economic use, it is not practical to do so. The desilting basin of the All-American Canal is constantly returning sediment to the river and sufficient flow in the river must be assured to prevent excessive accumulation of the sediment return. Even if there was no sediment return to be considered, it would still be necessary to maintain a channel below Imperial to provide drainage for the valley and as a pilot channel for flood flows.

Since January 1957, when Pilot Knob Powerplant first received water for testing, it has been necessary to schedule water for river regulation to maintain the channel below Imperial Dam. The amount so scheduled does not represent an added demand upon the flow since it is available after it crosses the International Boundary to be diverted by Mexico as part of their order. However, since it could otherwise be used for power production, river regulation releases are scheduled in the minimum amount necessary to move the sediment return at Imperial on downstream and maintain the channel in a reasonably good condition.

TABLE 1

ESTIMATED VOLUMES OF RIVERBED MATERIAL REMOVED AND DEPOSITED - DAVIS DAM TO SECTION 43.9[1]

Between Sections			Davis Dam to 29	29 to 30	30 to 33	33 to Mile 12	Mile 12 to 40	40 to[2] 43.9
Distance (miles)			5.7	5.2	14.4	5.3	12.1	11.2
Period Approx. Dates	No.[3] of Mos.	Approx. Mean Q - cfs	VOLUME REMOVED OR DEPOSITED (-) Indicates Removal (+) Indicates Deposit Thousands of Cubic Yards					
Sept. '51 Aug. '52	11.4	18,700	-1,217	-1,317	-5,843	-1,624	-62	+963
Aug. '52 July '53	10.7	18,900	-601	-274	-934	-314	-668	+151
July '53 June '54	11.1	14,300	-287	-290	-4,277	+648	+2,472	+1,842
June '54 July '55	12.7	13,800	-266	-1,104	-3,611	-726	+600	+1,171
July '55 July '56	12	11,000	-266	-556	-1,948	+141	+535	+368
July '56 July '57	12	10,500	-468	-294	-3,758	-43	+744	+961
July '57 July '58	12	16,500	+125	- 5	-2,930	-382	-210	-369
July '58 July '59	12	11,521	-373	-2,855	-358	+599	+374	+1,254
Total			-3,313	-6,695	-23,659	-1,701	+3,785	+6,341

1/ For years prior to 1951 see Table 1, Volume 1, of "Report of River Control Works and Investigations, Lower Colorado River Basin", 1950-1951.

2/ Sections downstream from R.S. 43, 7.8 miles below R.S. 40, were first measured in 1952.

3/ Time in months between observations.

Data in this table computed from cross-sectional measurements.

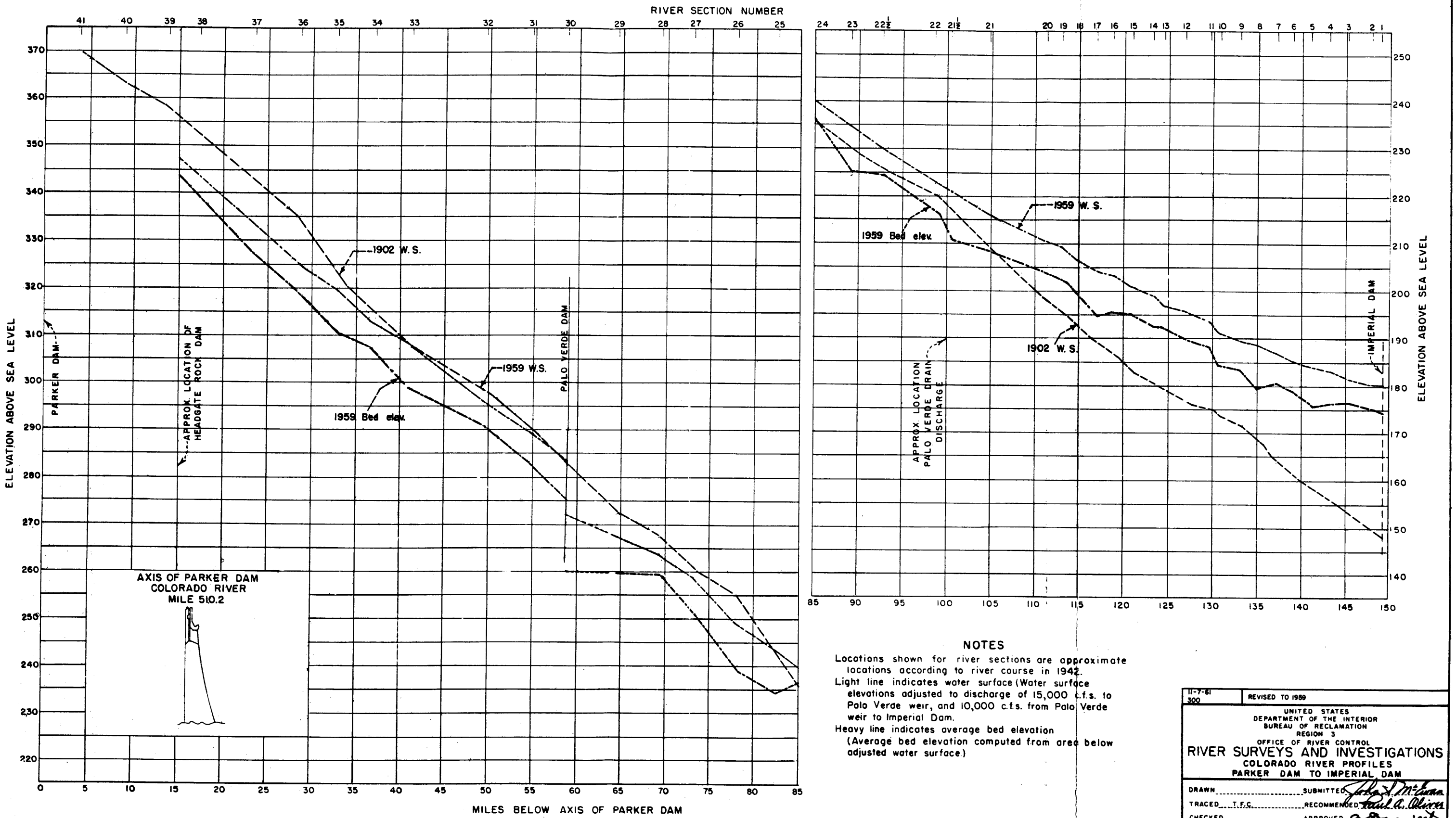
TABLE 2 [1/]

MEAN SUSPENDED SEDIMENT CONCENTRATION
AT SAMPLING STATIONS BELOW DAVIS DAM

Station		RS 33	Needles Bridge	RS 41	Above RS 43
Miles Below Davis Dam		25.3	33.2	45.3	50.3
Year	Mean Q	Mean Concentration in PPM			
1956	11,000	232	249	249	131
1957	10,500	222	243	239	105
1958	16,500	323	310	393	325
1959	12,600	-	392	167	114

1/ For years prior to 1956 see Table 2 of "Report of River Control Works and Investigations. Lower Colorado River Basin". Calendar Years 1952 through 1956.

FIGURE 3



NOTES

Locations shown for river sections are approximate locations according to river course in 1942.

Light line indicates water surface (Water surface elevations adjusted to discharge of 15,000 c.f.s. to Palo Verde weir, and 10,000 c.f.s. from Palo Verde weir to Imperial Dam.

Heavy line indicates average bed elevation (Average bed elevation computed from area below adjusted water surface.)

11-7-61 300	REVISED TO 1959

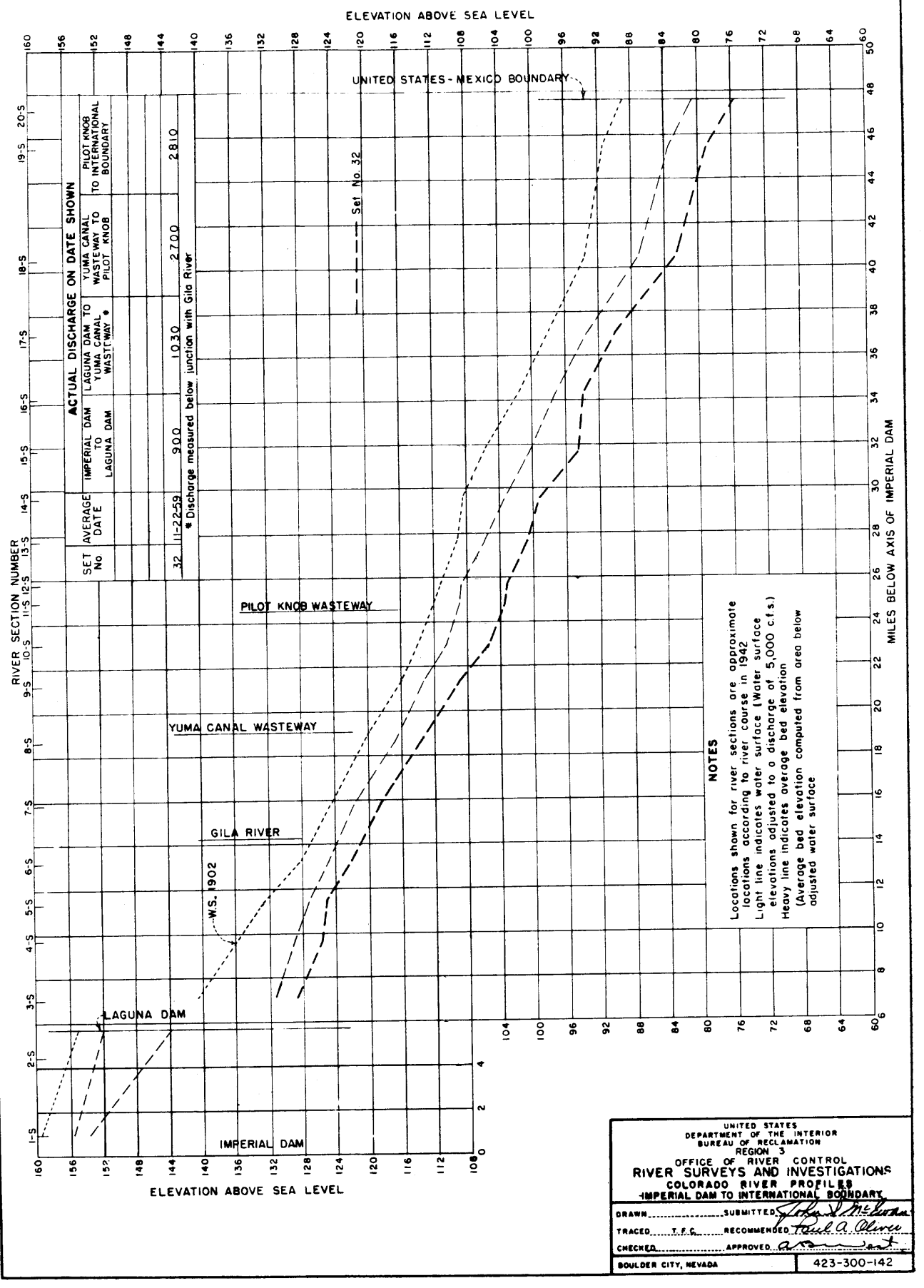
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
OFFICE OF RIVER CONTROL

RIVER SURVEYS AND INVESTIGATIONS

COLORADO RIVER PROFILES
PARKER DAM TO IMPERIAL DAM

DRAWN		SUBMITTED	John F. McEwan
TRACED	T.F.C.	RECOMMENDED	Paul A. Oliver
CHECKED		APPROVED	
BOULDER CITY, NEVADA		423-300-66	

FIGURE 4



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
OFFICE OF RIVER CONTROL
RIVER SURVEYS AND INVESTIGATIONS
COLORADO RIVER PROFILES
IMPERIAL DAM TO INTERNATIONAL BOUNDARY

DRAWN _____ SUBMITTED John D. McLaren
TRACED T.F.C. RECOMMENDED Paul A. Alves
CHECKED _____ APPROVED A. Dimmock

BOULDER CITY, NEVADA | 423-300-142

FIGURE 5

CHANGE IN ELEVATION - FEET

SEC. 28, Mi. 0.0 (W.S., Bed)
SEC. 28A, Mi. 2.1
SEC. 28B, Mi. 4.4
SEC. 29, Mi. 5.7
SEC. 29A, Mi. 7.1
SEC. 29B, Mi. 9.7
SEC. 30, Mi. 10.9
SEC. 30A, Mi. 12.8 (W.S., Bed)
SEC. 31, Mi. 16.6
SEC. 31A, Mi. 18.9
SEC. 32, Mi. 21.1
SEC. 32A, Mi. 22.6 (W.S., Bed)
SEC. 33, Mi. 25.3
SEC. 33A, Mi. 26.6
SEC. 33C, Mi. 30.4
SEC. 40, Mi. 42.7 (W.S., Bed)
SEC. 41, Mi. 45.3
SEC. 42, Mi. 48.3
SEC. 43, Mi. 50.5
SEC. 43.5, Mi. 52.5
SEC. 43.9, Mi. 53.9

CHANGE IN ELEVATION - FEET

NOTES

Davis Dam initial diversion June 28, 1948.

Solid lines show changes in water surface elevation adjusted for discharge of 15,000 c.f.s., dash lines show changes in average bed elevation. (Average bed elevation computed from area below base line from 1947 to 1954 and from area below adjusted water surface from 1952 to date.)

Miles shown with section numbers indicate distances below Davis Dam.

Change in water surface at sections 41 through 43.9 was not computed as the water surface at these sections is influenced by Havasu Lake elevation.

Zero is elevation at time of initial survey as shown by "W.S." and "Bed".

UNITED STATES
DEPARTMENT OF THE INTERIOR
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REGION 3

RIVER SURVEYS AND INVESTIGATIONS

CHANGE IN WATER SURFACE AND BED ELEVATIONS DAVIS DAM TO HAVASU LAKE

COLORADO RIVER

DRAWN _____ SUBMITTED John D. McBurney
TRACED W.J.B. RECOMMENDED Paul A. Oliver
CHECKED _____ APPROVED _____

BOULDER CITY, NEV. 423-300-68

CHANGE IN ELEVATION - FEET

SEC. 41, Mi. 3.9

SEC. 40, Mi. 8.9

SEC. 39, Mi. 13.7

SEC. 38, Mi. 17.4

SEC. 37, Mi. 23.6

SEC. 36, Mi. 28.6

SEC. 35, Mi. 32.7

RIVER CHANNEL LOCATION CHANGED MAY 1942, SEE MAP DWG. 423-306-120 (FIG. 1-C)

SEC. 34, Mi. 37.1

SEC. 33, Mi. 41.1

SEC. 32, Mi. 49.7

SEC. 31, Mi. 54.9

SEC. 30, Mi. 58.9

SEC. 29, Mi. 64.5

SEC. 28, Mi. 68.6

SEC. 27, Mi. 71.4

SEC. 26, Mi. 76.3

SEC. 25, Mi. 80.9

SEC. 24, Mi. 83.0

SEC. 23, Mi. 86.4

SEC. 22A, Mi. 90.7

SEC. 22, Mi. 96.5

RIVER CHANNEL LOCATION CHANGED IN JUNE 1947, SEE DWG. 423-306-120 (FIG. 1-C)

SEC. 21A, Mi. 98.6

SEC. 21, Mi. 103.0

SEC. 20, Mi. 109.6

SEC. 19A, Mi. 110.4

NOTES

Parker Dam closed Oct. 1938. Imperial Dam closed April 1938.

Headgate Rock Dam, between sections 38 & 39 closed June 1942.

Solid lines show change in water surface elevations (water surface elevations adjusted to 15000 c.f.s. from 1938 to 1954, from 1952 to date water surface elevation adjusted to 15000 c.f.s. for sections 41 through 30 and 10,000 cfs for sections 29 through 1)

Dash lines show change in bed elevation (average bed elevation computed from area below base line 1938 to 1954 and from area below adjusted water surface from 1952 to date)

Miles shown with section numbers indicate distances below Parker Dam

This drawing supersedes Drawing No. 423-306-262

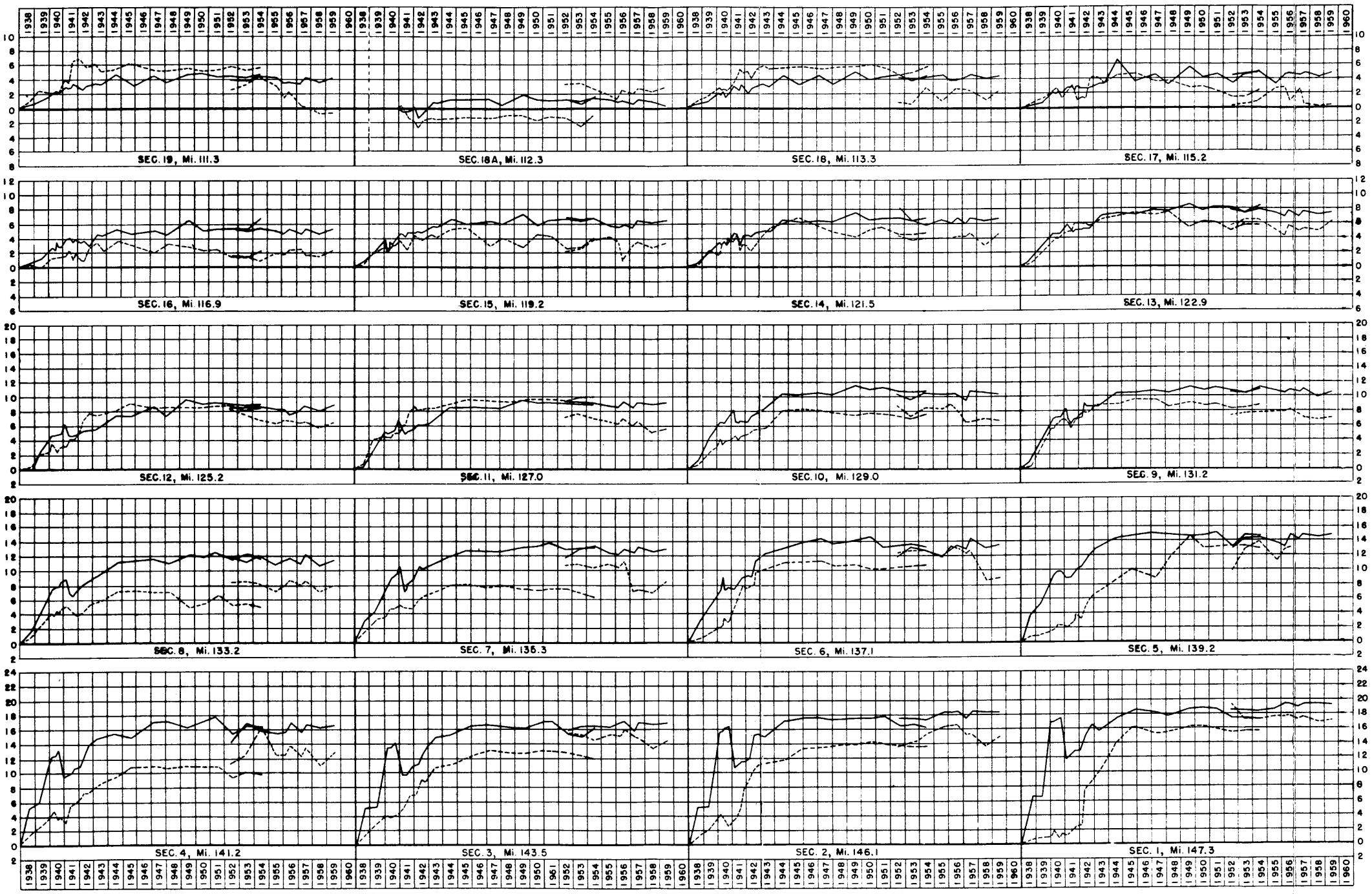
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS

CHANGE IN WATER SURFACE AND BED ELEVATIONS
PARKER DAM TO IMPERIAL DAM

DRAWN P.C.	SUBMITTED		
TRACED W.J.B.	RECOMMENDED		
CHECKED J.M.M.	APPROVED		
BOULDER CITY, NEVADA	11-7-57 SHEET 1 OF 2	423-300-69	

CHANGE IN ELEVATION - FEET



CHANGE IN ELEVATION - FEET

NOTES

Parker Dam closed Oct. 1938. Imperial Dam closed April 1938.

Headgate Rock Dam, between sections 38 & 39 closed June 1942.

Solid lines show change in water surface elevations (water surface elevations adjusted to 15000 c.f.s from 1938 to 1954 from 1952 to date water surface elevation adjusted to 15000 c.f.s. for sections 41 through 30 and 10,000 cfs for sections 29 through 1)

Dash lines show change in bed elevation (average bed elevation computed from area below base line 1938 to 1954 and from area below adjusted water surface from 1952 to date)

Miles shown with section numbers indicate distances below Parker Dam

This drawing supersedes Drawing No. 423-306-262

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

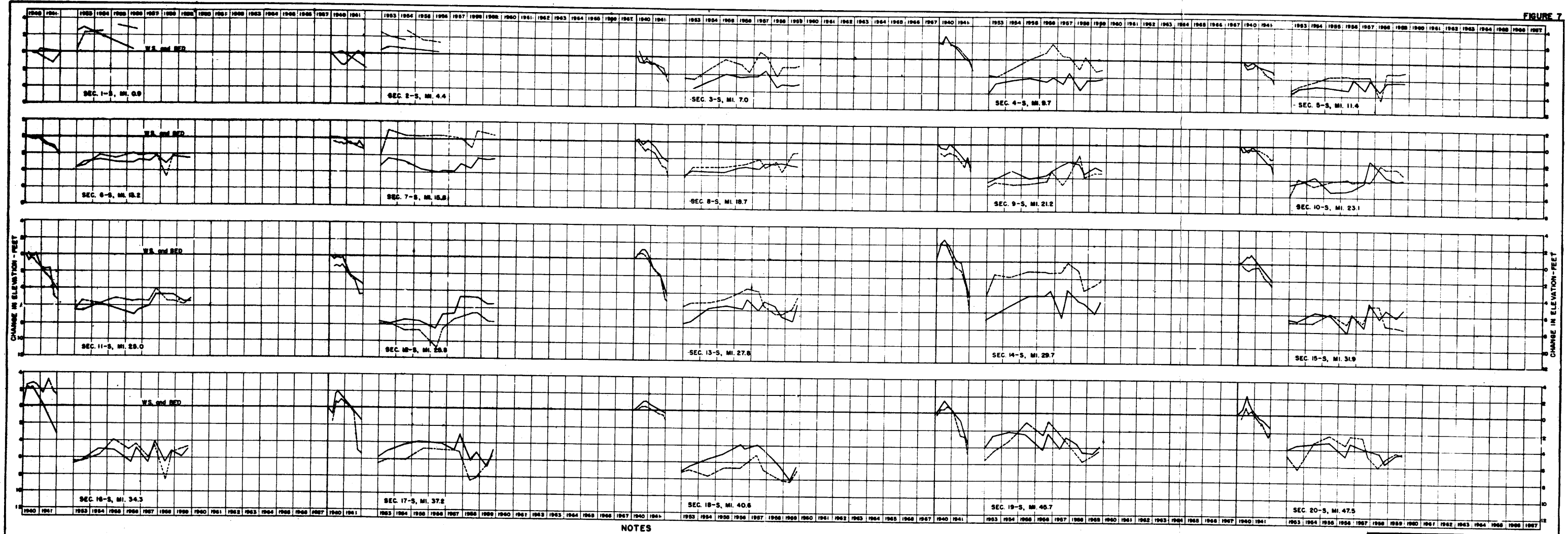
RIVER SURVEYS AND INVESTIGATIONS

CHANGE IN WATER SURFACE AND BED ELEVATIONS PARKER DAM TO IMPERIAL DAM

DRAWN P.C.	SUBMITTED John L. McEwen		
TRACED W.J.B.	RECOMMENDED Frank A. Oliver		
CHECKED J.M.M.	APPROVED		
BOULDER CITY, NEVADA	11-7-57 SHEET 2 OF 2	423-300-70	

11-7-60 300 — ADDED 1957 THRU 1959

FIGURE 7



NOTES

Data shown indicates changes from original measurement (1940)

Data is plotted as change in elevation rather than elevation above datum

Solid lines show change in water surface elevation (discharge adjusted for 5000 s.f.s.)

Dash lines show change in bed elevation (bed elevation computed from area below adjusted water surface.)

Miles shown with section numbers are distances below Imperial Dam

Zero is elevation at time of initial survey as shown by "W.S." and "Bed."

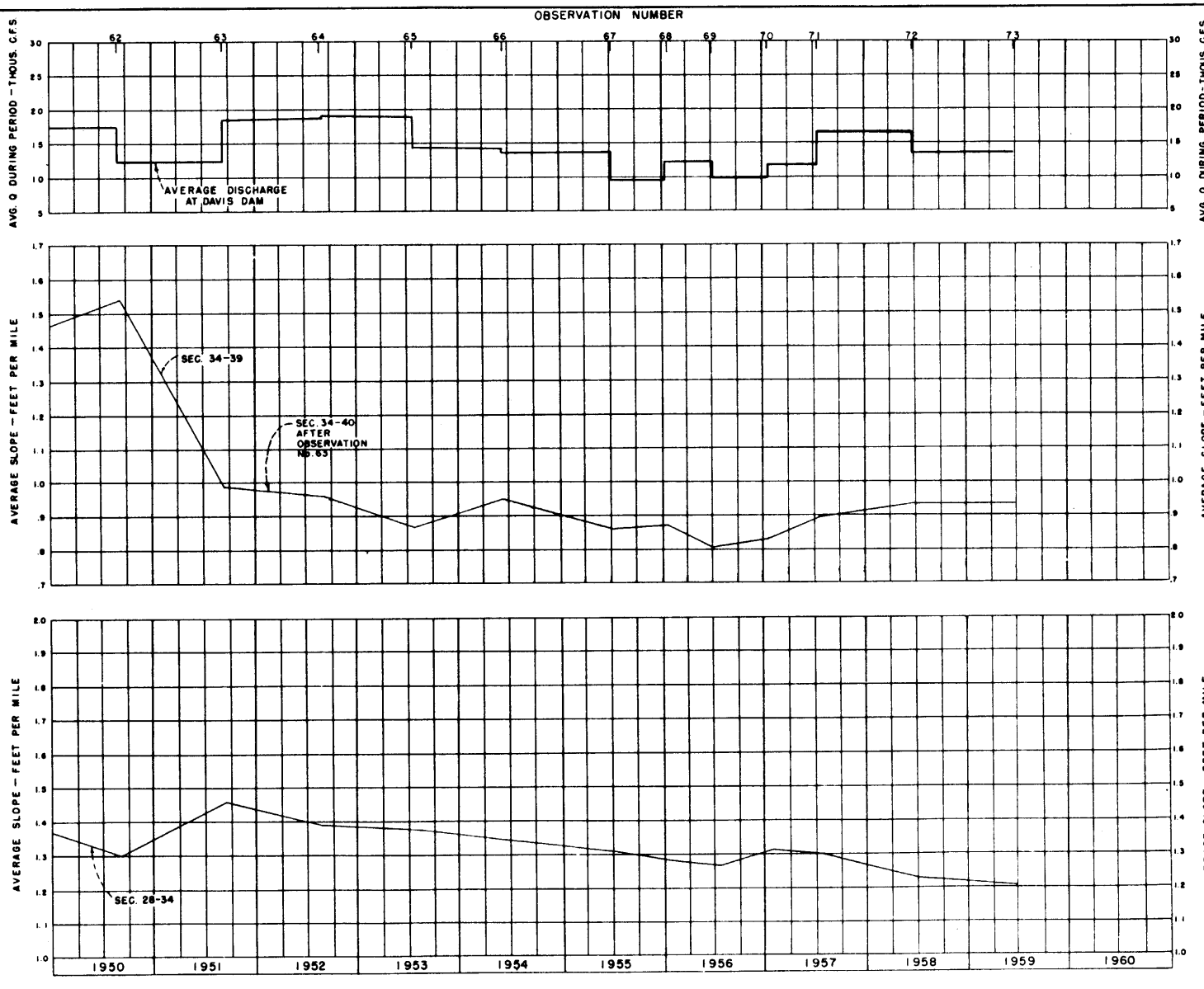
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
OFFICE OF RIVER CONTROL

RIVER SURVEYS AND INVESTIGATIONS

CHANGE IN WATER SURFACE AND BED ELEVATIONS
IMPERIAL DAM TO INTERNATIONAL BOUNDARY

DRAWN: SUBMITTED: John D. McShane
TRACED: T.F.S. RECOMMENDED: Mark A. Skinner
CHECKED: APPROVED:
BOULDER CITY, NEVADA 423-300-132

FIGURE 8



NOTES

Water surface elevations adjusted for discharge of 15000 c.f.m.

For years previous to 1950 see Figure 9 Report for Calender years 1950 and 1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS
VARIATION IN AVERAGE SLOPE
DAVIS DAM TO SECTION 40

DRAWN J.M.M.	SUBMITTED		
TRACED P.V.B.	RECOMMENDED		
CHECKED	APPROVED		
BOULDER CITY, NEVADA		423-300-72	

FIGURE 9

OBSERVATION NUMBER

25 26 27 28 29 30 31 32 33 34 35 36

AVERAGE Q DURING PERIOD THOUS OF C.F.S.

30 26 22 18 14 10 6

Average Discharge During Period

AVERAGE SLOPE - FEET PER MILE

1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2

SEC. 29-24

SEC. 38-30

SEC. 29-24

WS SEC. 29-24

SEC. 38-30

SEC. 41-39

SEC. 41-39

1.6 1.4 1.2 1.0 0.8 0.6

SEC. 24-21

SEC. 24-21

SEC. 21-12

SEC. 21-12

SEC. 12-2

SEC. 12-2

1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960

NOTES

Broken lines - Water surface elevation adjusted for discharge of 15,000 c.f.s.

Solid lines - Water surface elevation adjusted for discharge of 10,000 c.f.s.

Parker Dam closed October 16, 1938

Imperial Dam closed April 17, 1938

For years previous to 1950 see Figure 10, -

Report for Calendar years 1950 - 1951

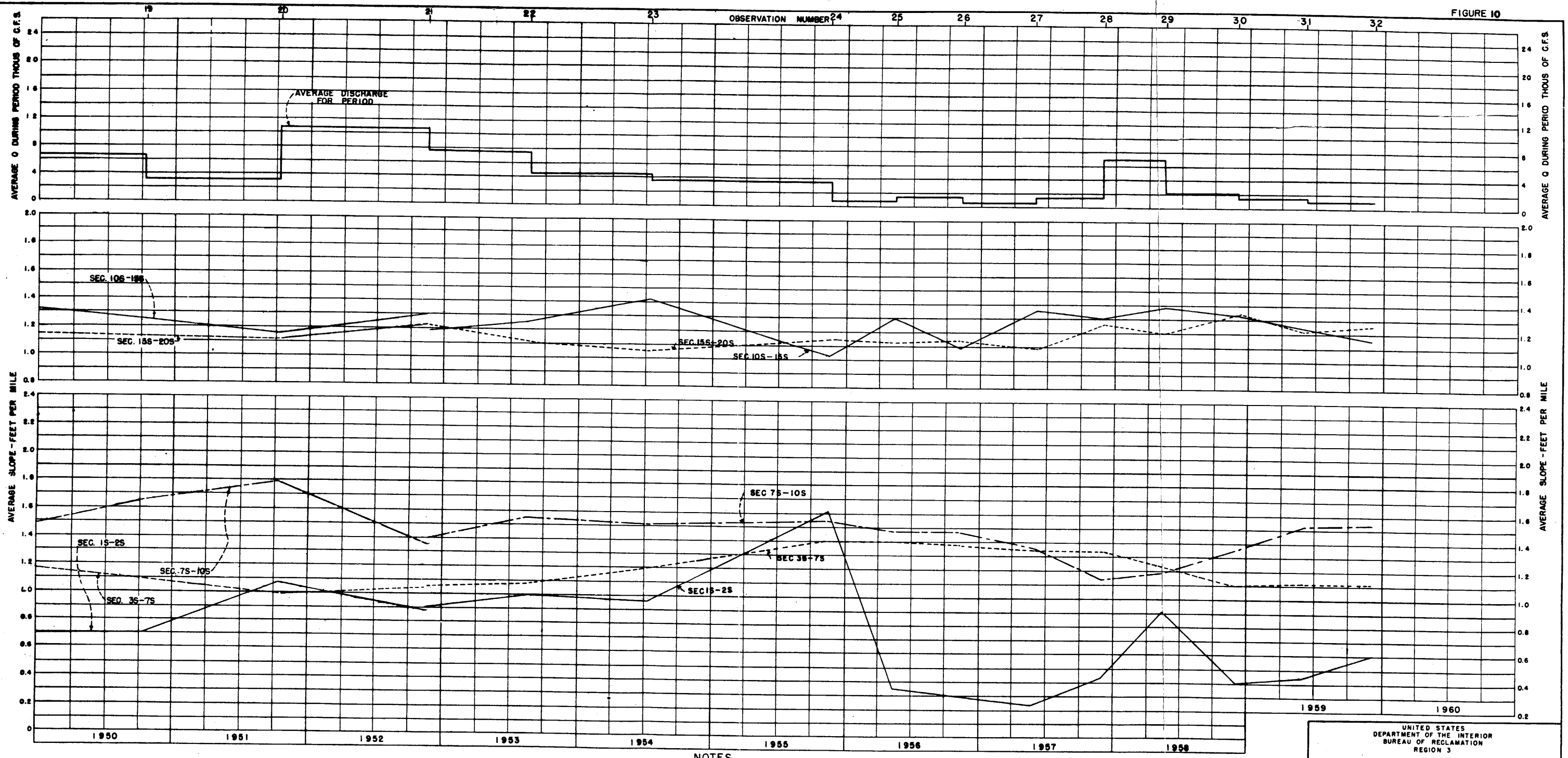
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS
VARIATION IN AVERAGE SLOPE
PARKER DAM TO IMPERIAL DAM

DRAWN	J.M.M.	SUBMITTED	John L. McClure
TRACED	W.J.B	RECOMMENDED	Paul A. Oliver
CHECKED		APPROVED	

BOULDER CITY, NEVADA | 423-300-73

FIGURE 10



NOTES

Water surface elevations adjusted for discharge of 1500 c.f.s. from 1950 to 1952 and discharge of 5000 c.f.s. from 1952 to date.

For years previous to 1950 see figure 11 report for calender years 1950–1951.

11-6-57 J.M.M.	DELETED BED SLOPES ADDED 1957–1959
	CONTINUATION OF GRAPH 1952, 1953, 1954

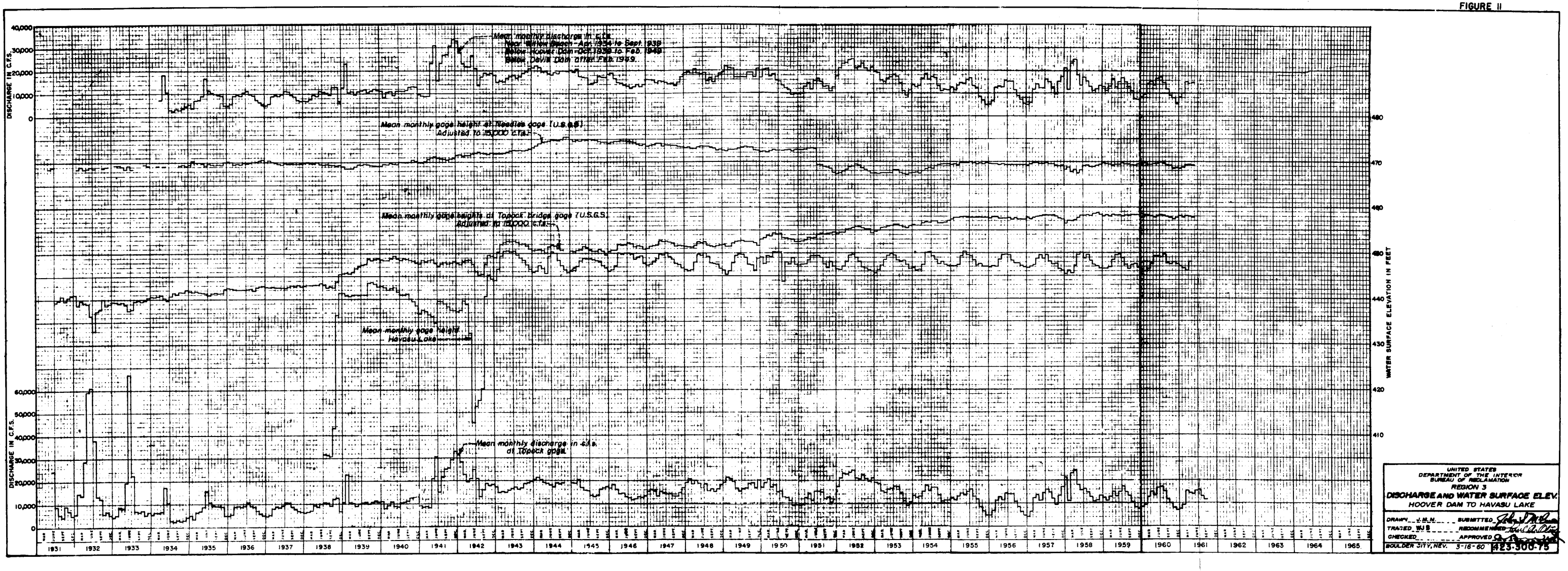
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS
VARIATION IN AVERAGE SLOPE
IMPERIAL DAM TO INTERNATIONAL BOUNDARY

DRAWN _____ SUBMITTED John L. McLaughlin
TRACED _____ RECOMMENDED Paul A. Olivas
CHECKED _____ APPROVED _____

BOULDER CITY, NEVADA 4-13-55 | 423-300-74

FIGURE II



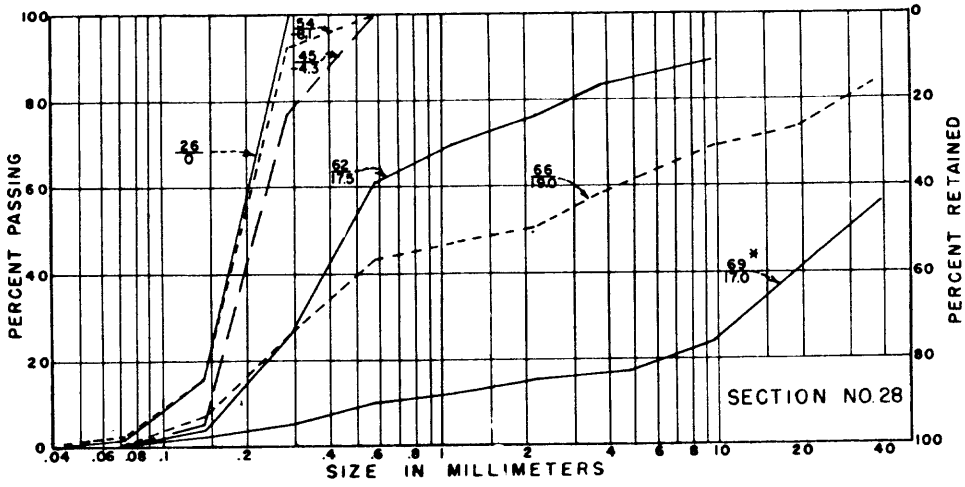
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

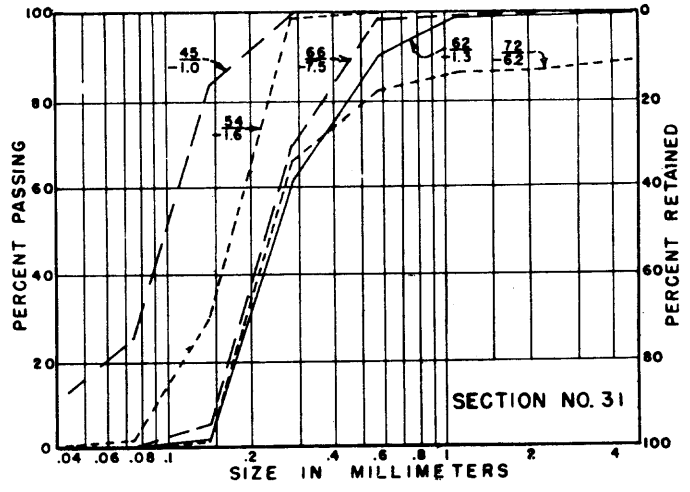
DISCHARGE AND WATER SURFACE ELEV.

HOOVER DAM TO HAVASU LAKE

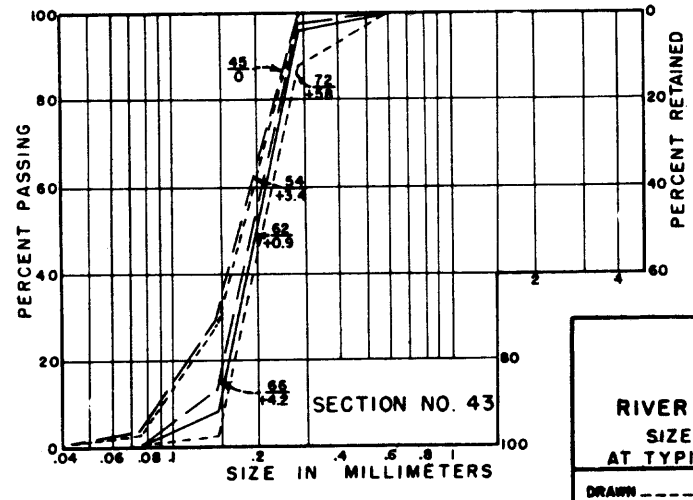
DRAWN U.S.B.R. SUBMITTED
TRACED WJB RECOMMENDED
CHECKED APPROVED
BOULDER CITY, NEV. 3-16-60 423-300-75

FIGURE 12





NO. OF OBSERVATION	DATE OF OBSERVATION
26	2-15-38
45	7-8-41
54	4-5-44
62	8-23-50
66	6-15-54
72	6-24-58



NOTES

$\frac{\#45}{-1}$ Denotes an average scour of 1 ft. at time of observation #45

$\frac{\#45}{+1}$ Denotes an average deposit of 1 ft. at time of observation # 45

* No samples taken since June 1956, material too course for bed sampler.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

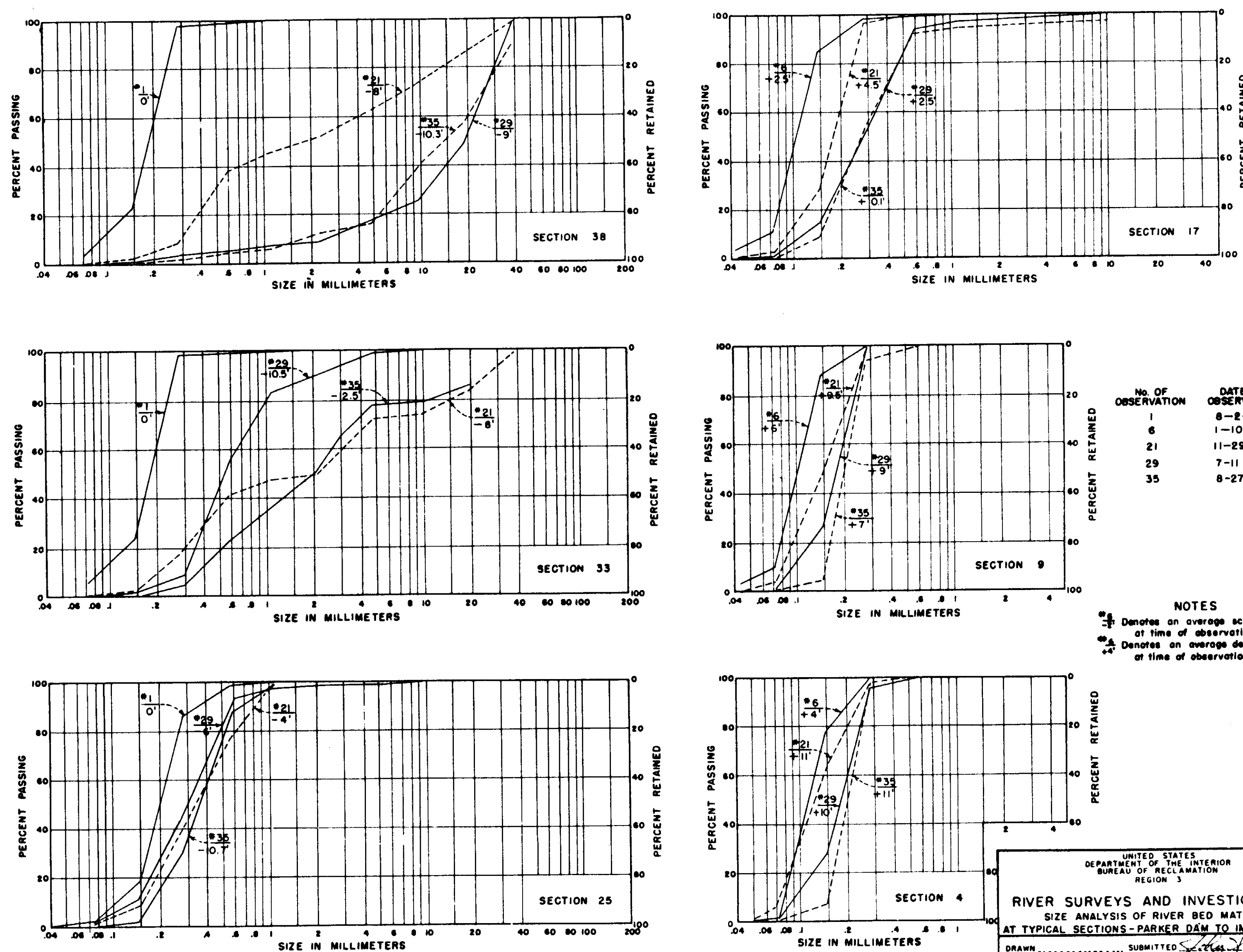
RIVER SURVEYS AND INVESTIGATIONS

SIZE ANALYSIS OF RIVER BED MATERIAL
AT TYPICAL SECTIONS BELOW DAVIS DAM

DRAWN _____ SUBMITTED John L. McLaren
TRACED R&E RECOMMENDED Paul A. Olsen
CHECKED _____ APPROVED _____

BOULDER CITY, NEVADA 10-24-60 | 423-300-146

FIGURE 13



No. OF OBSERVATION	DATE OF OBSERVATION
1	8-2-38
6	1-10-40
21	11-29-45
29	7-11-54
35	8-27-58

NOTES

#6 / −2' Denotes an average scour of 2 ft. at time of observation 6.

#6 / +4' Denotes an average deposit of 4 ft. at time of observation.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

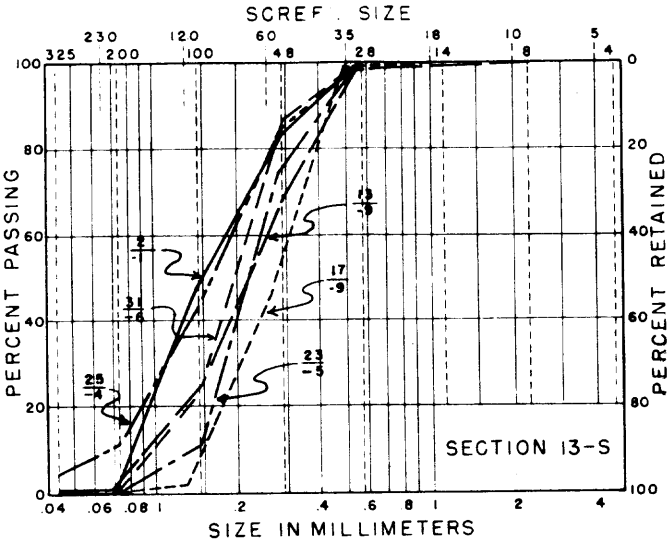
RIVER SURVEYS AND INVESTIGATIONS

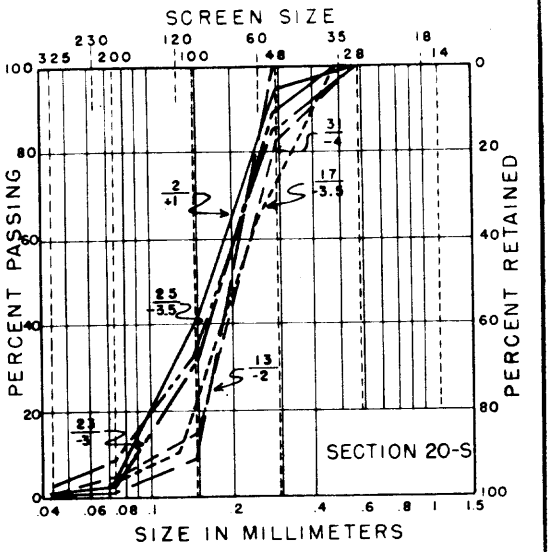
SIZE ANALYSIS OF RIVER BED MATERIAL
AT TYPICAL SECTIONS - PARKER DAM TO IMPERIAL DAM

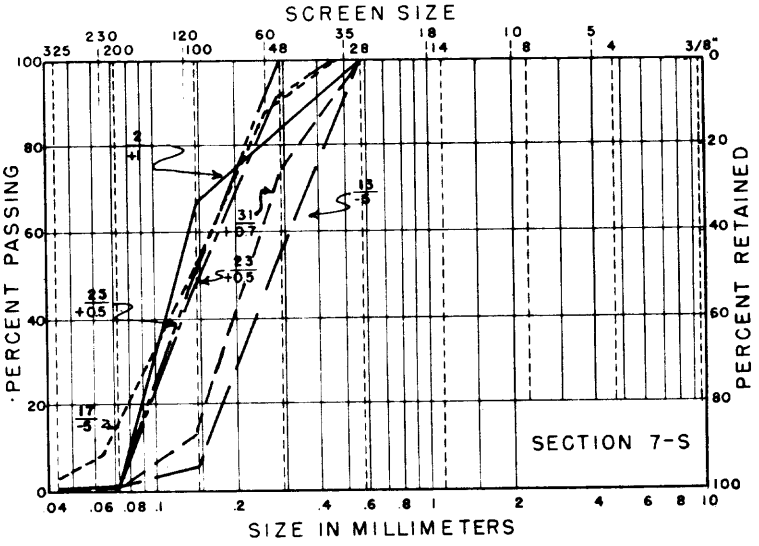
DRAWN .... SUBMITTED [signature]
TRACED .... RECOMMENDED [signature]
CHECKED .... APPROVED [signature]

BOULDER CITY, NEVADA | 423-300-143

FIGURE 14





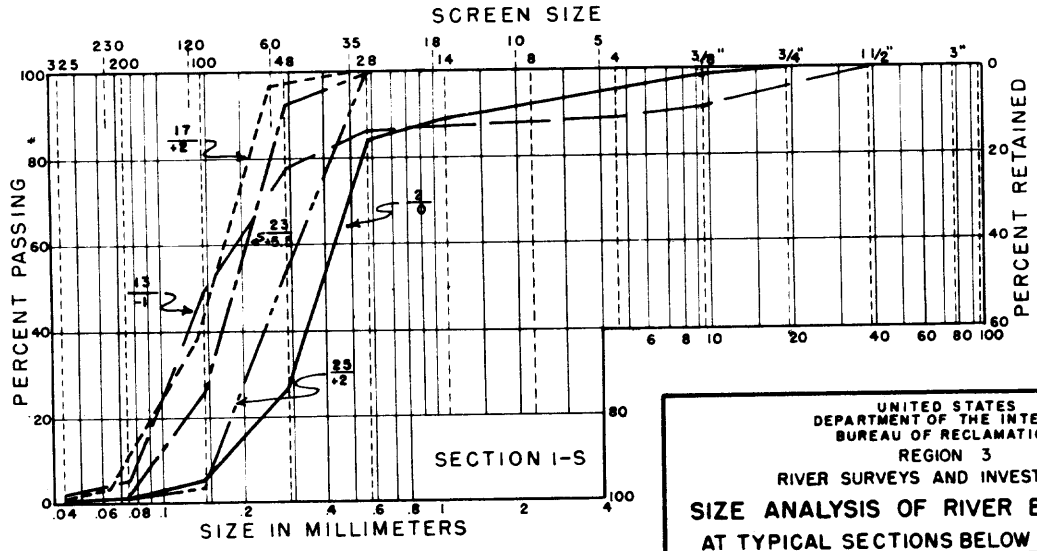


NOTES

$\frac{2}{-1}$ Denotes an average scour of 1 ft at the time of observation 2.

$\frac{2}{+1}$ Denotes an average deposit of 1 ft at the time of observation 2.

NO. OF OBSERVATION	DATE OF OBSERVATION
2	3-24-40
13	7-22-44
17	2-18-48
23	7-14-54
25	5-20-56
31	5-22-59



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
RIVER SURVEYS AND INVESTIGATIONS

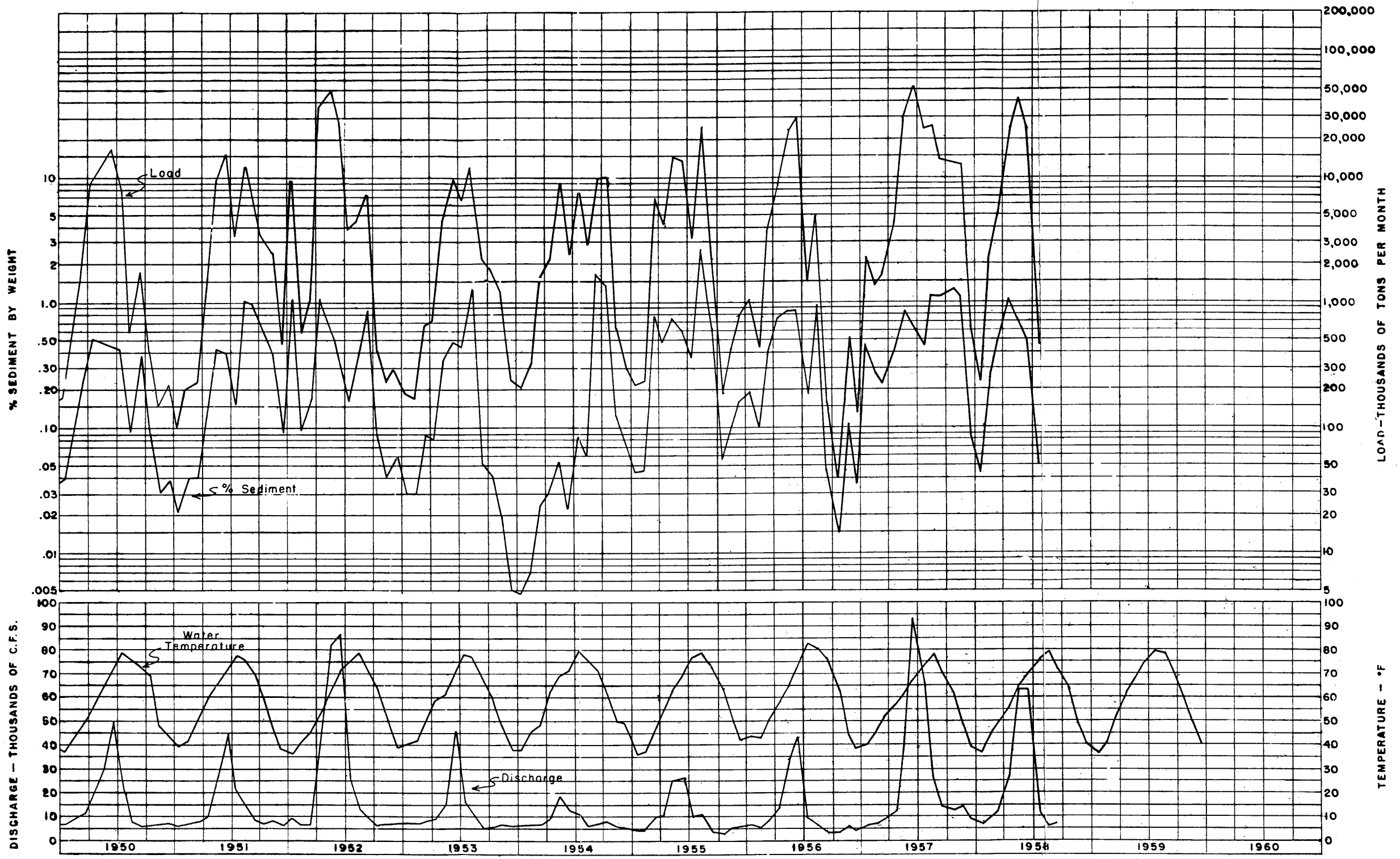
SIZE ANALYSIS OF RIVER BED MATERIAL
AT TYPICAL SECTIONS BELOW IMPERIAL DAM

DRAWN DAD SUBMITTED John L. McGuigan
TRACED WJB RECOMMENDED Rudd A. Oliver
CHECKED APPROVED A. Burnett

11-8-60 300 ADDED OBSERVATION NO. 31

BOULDER CITY, NEV. 8-8-57 423-300-78

FIGURE 15



NOTES

Samples obtained and analyzed by Geological Survey,

Loads are total loads per month.

Percentages are weighted monthly averages.

Discharges and temperatures are monthly averages.

For years previous to 1950 see Figure 23, report for Calendar years 1950 — 1951.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

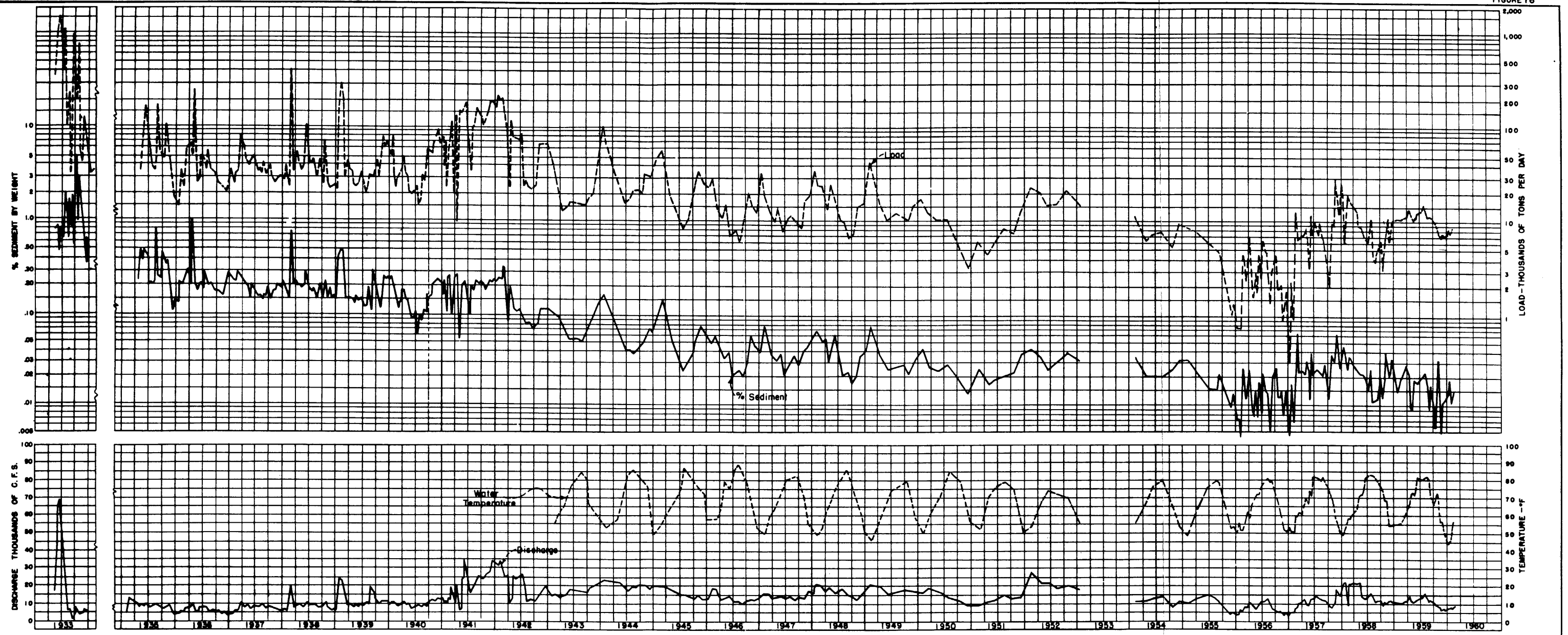
RIVER SURVEYS AND INVESTIGATIONS

SUSPENDED LOAD AT GRAND CANYON

DRAWN	D.A.D.	SUBMITTED	John L. McGrew
TRACED	W.J.B.	RECOMMENDED	Paul A. Olivier
CHECKED		APPROVED	

BOULDER CITY, NEVADA — 423-300-79

FIGURE 16



This drawing supersedes Drawing No. 423-306-315

NOTES

Inflow computed from samples taken at Imperial Damsite 1933 and 1935, at Red Cloud cable 1936 through April, 1939, Taylors Ferry 1939 through 1956 and Adobe Ruin since 1956.

Samples obtained by Bureau of Reclamation, Tait—Binkley Sampler used prior to Oct. 1, 1947. D-43 sampler used after Oct. 1, 1947.

Loads, percentages, temperatures, and discharges are values on sampling dates.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

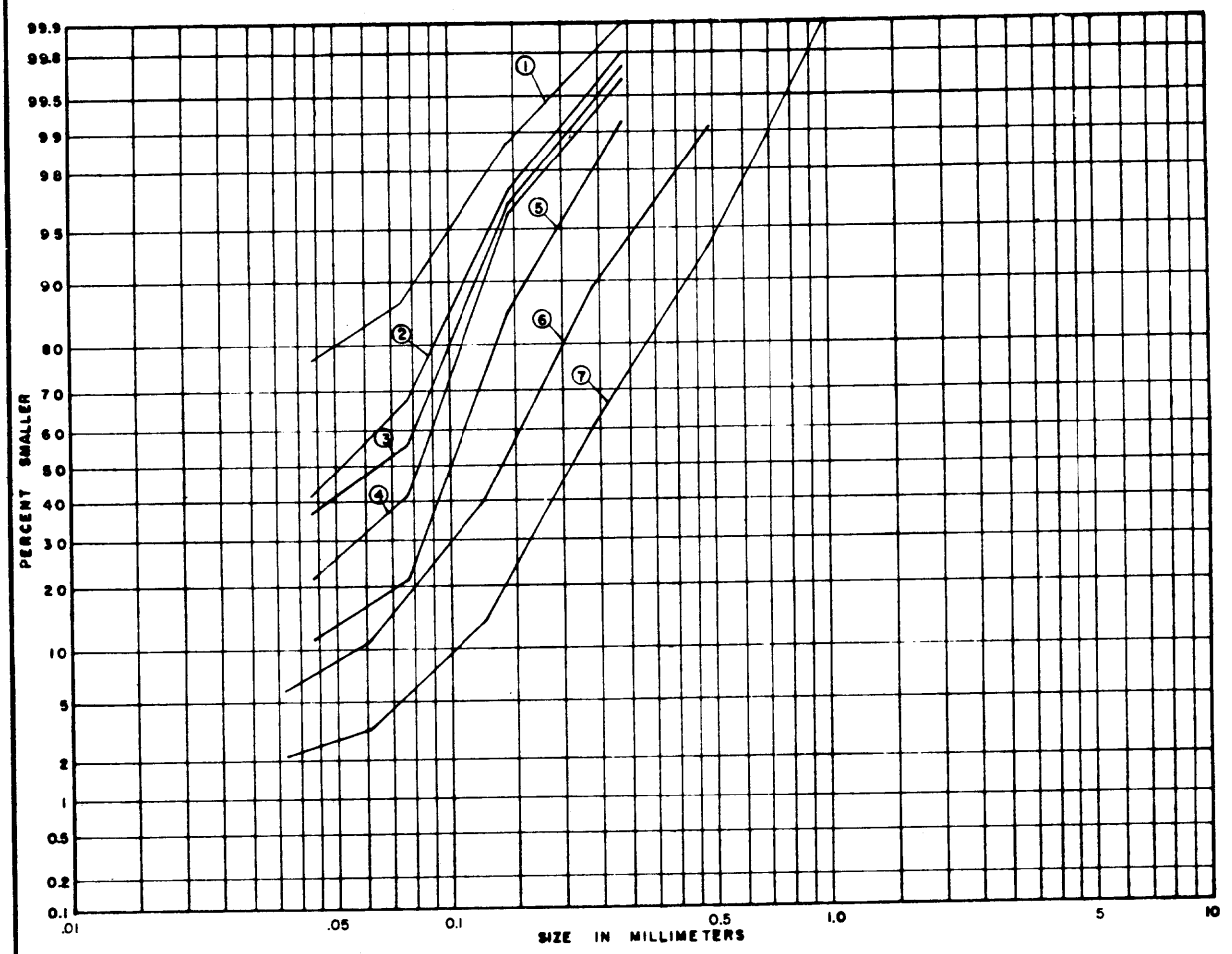
RIVER SURVEYS AND INVESTIGATIONS

SUSPENDED SEDIMENT INFLOW TO IMPERIAL RESERVOIR

DRAWN	DJC	SUBMITTED	John L. McClure
TRACED	WJB	RECOMMENDED	Paul A. Oliver
CHECKED		APPROVED	

BOULDER CITY, NEV. 423-300-80

FIGURE 17



① May 1933 to Jan. 1934, from Imperial Damsite

② May 1935 to Jan. 1936, from Imperial Damsite

③ Year 1936 from Red Cloud Cable

④ Year 1939 from Red Cloud Cable

Samples taken at Taylors Ferry from 1940

⑤ Years 1940 – 1941

⑥ Years 1946 thru 1951

⑦ Year 1959

NOTES

Analysis shown is average for period

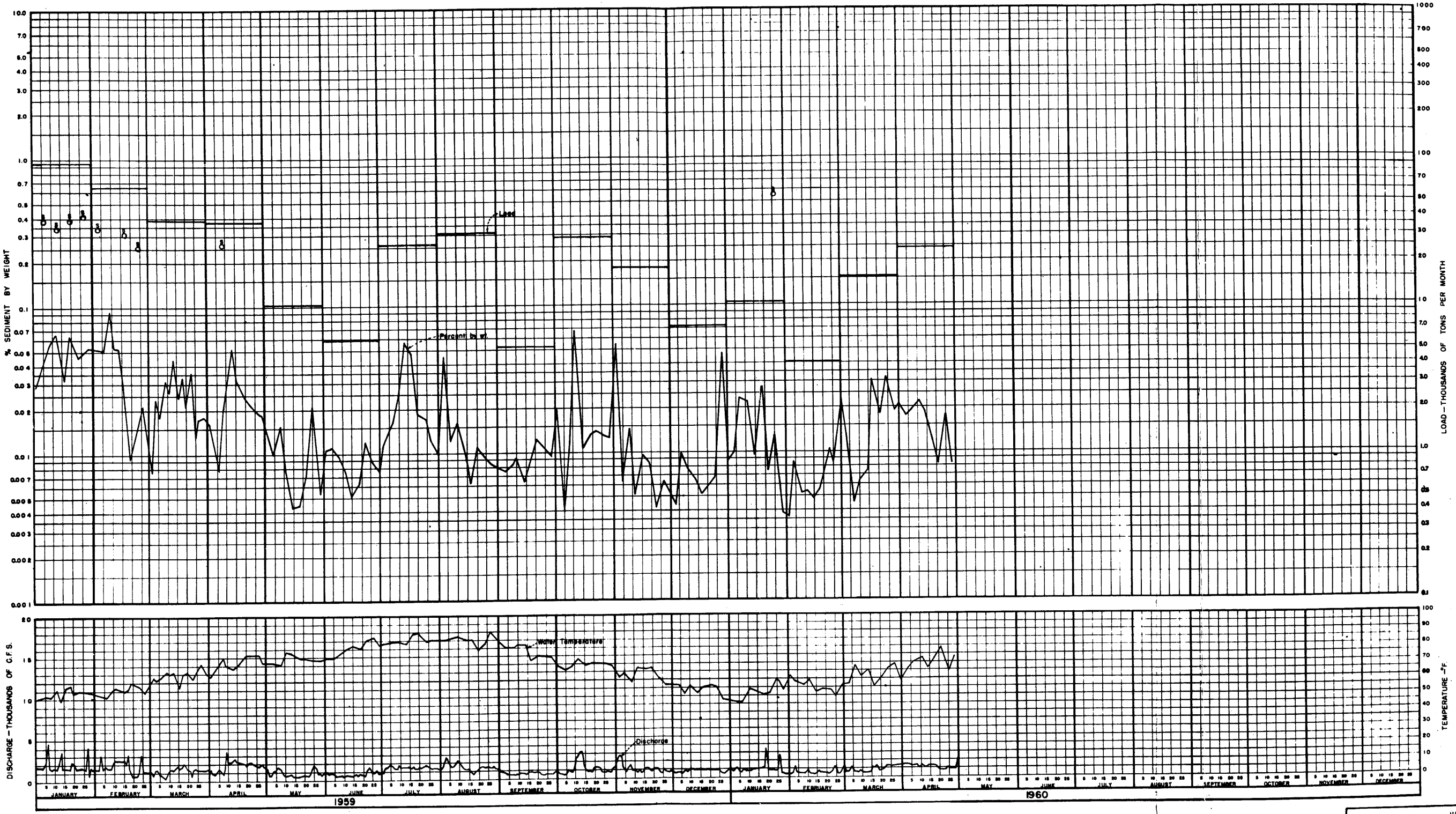
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS

SIZE ANALYSIS — SUSPENDED LOAD
IMPERIAL DAMSITE-RED CLOUD CABLE-TAYLOR'S FERRY

DRAWN	SUBMITTED	J. Ray D. McLaughlin
TRACED R.B.E.	RECOMMENDED	Frank A. Wilson
CHECKED	APPROVED	A. D. Foster
BOULDER CITY, NEV. 10-24-60		423-300-145

FIGURE 10



NOTES

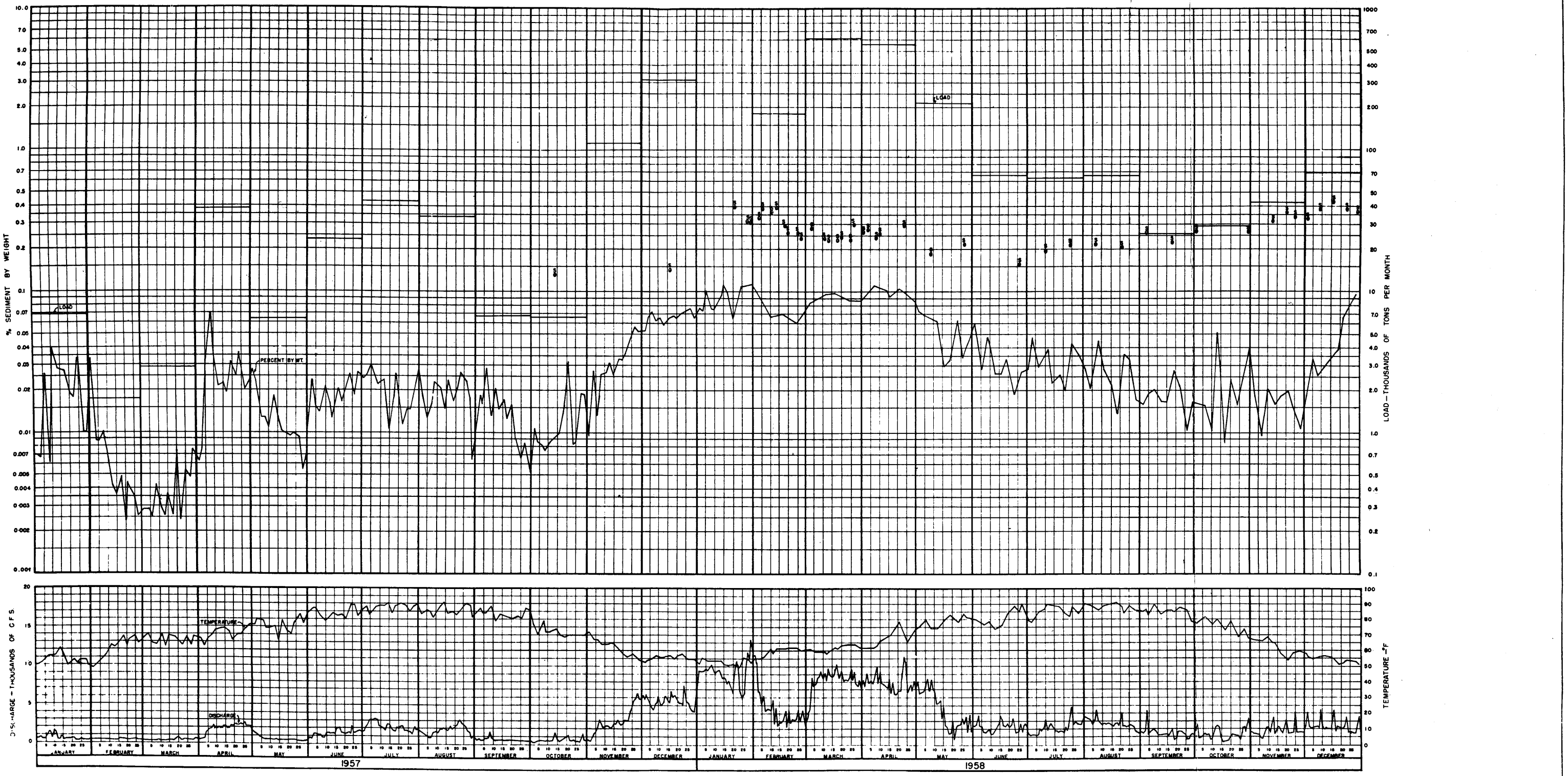
Samples taken by Bureau of Reclamation, D-43 sampler used.
Flow at Yuma is mean daily.
$\frac{3}{8}$ Indicates weighted average concentration during passage of sluicing flows from Imperial Dam.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS
SUSPENDED LOAD IN COLORADO RIVER AT YUMA 1959-1960

DRAWN _____ SUBMITTED John F. McEwan
TRACED R.R.E. RECOMMENDED Paul A. Olsen
CHECKED _____ APPROVED
BOULDER CITY, NEVADA OCTOBER 31, 1960 423-30[illegible]-52

FIGURE 18A



NOTES

Samples taken by Bureau of Reclamation,
D-43 sampler used.
Flow at Yuma is mean Daily

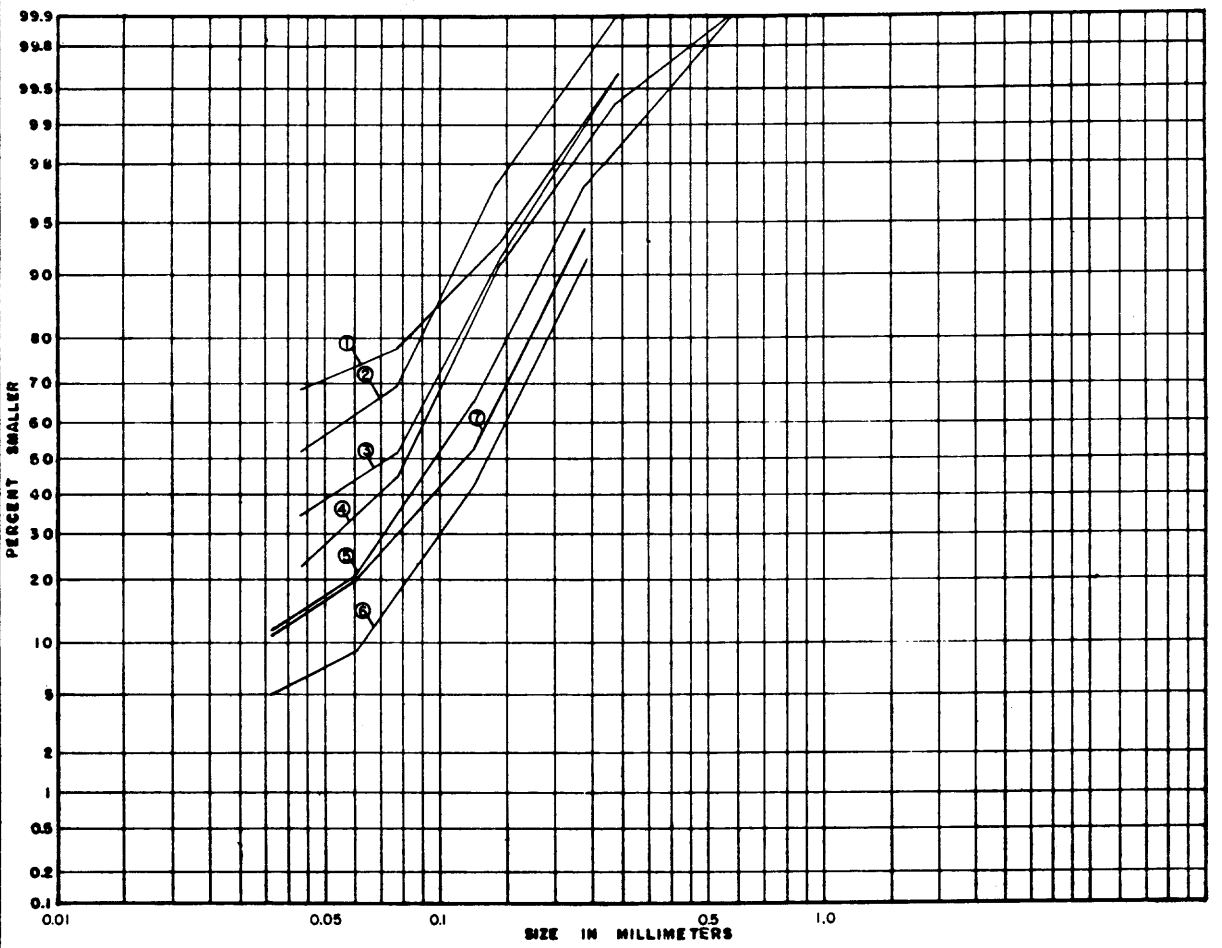
δ Indicates weighted average concentration during passage of sluicing flows from Imperial Dam.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS
SUSPENDED LOAD IN COLORADO RIVER AT YUMA 1957–1958

DRAWN _____ SUBMITTED John A. McClean
TRACED W.J.B. RECOMMENDED Paul A. Olivier
CHECKED _____ APPROVED _____
BOULDER CITY, NEVADA 423-300-52

FIGURE 19



① April 1933 to June 1934

② Sept to Dec. 1935 *

③ Year 1936 *

④ Year 1937 *

⑤ Oct. 1947 thru Dec. 1951

⑥ Year 1956

⑦ Year 1959

NOTES

* Samples obtained at Hanlon Heading on Alamo Canal.

Tait-Binkley Sampler used thru Sept. 1947. D-43 Sampler used thereafter.

Analysis shown is mean of all samples taken during period.

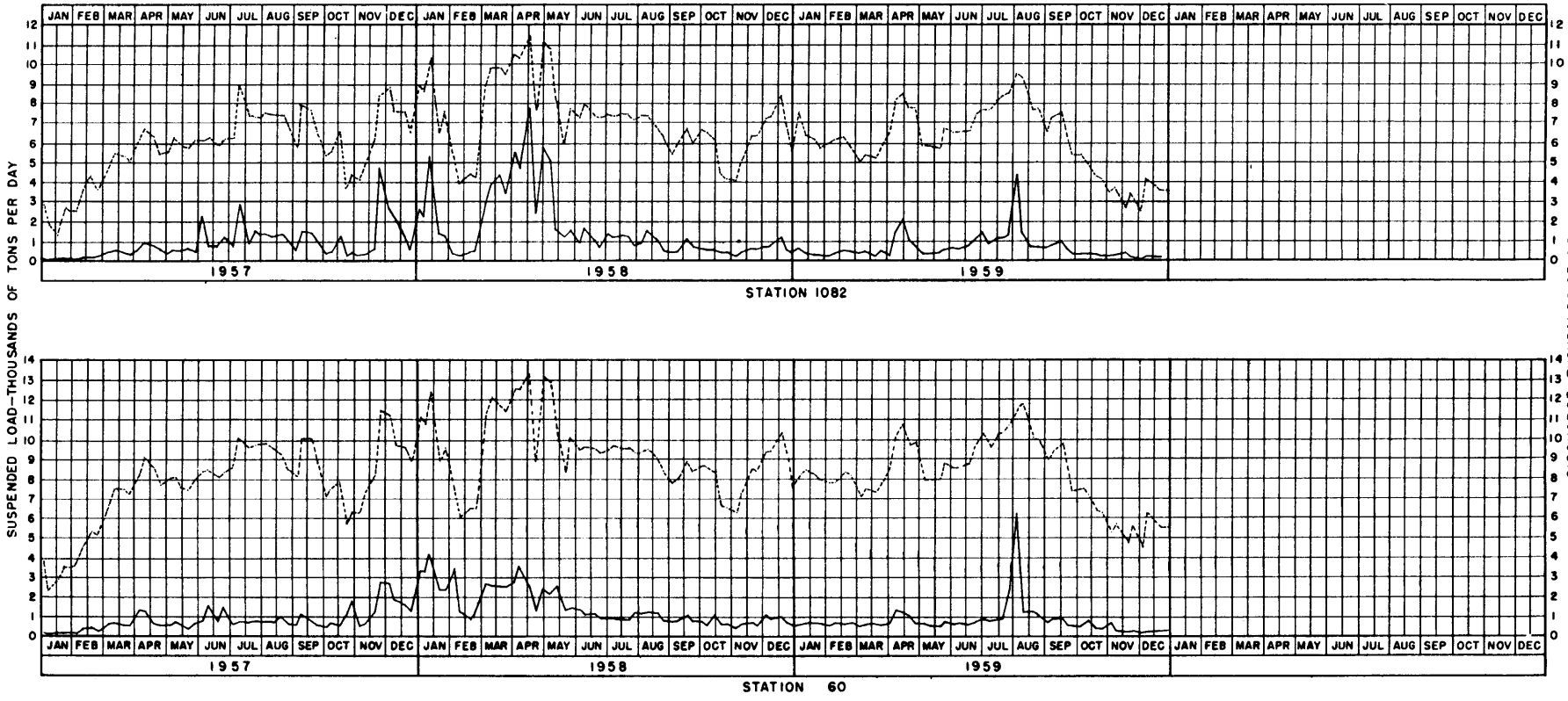
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS

SIZE ANALYSIS CHART
SUSPENDED LOAD AT YUMA

DRAWN	SUBMITTED
TRACED R.B.E.	RECOMMENDED
CHECKED	APPROVED
BOULDER CITY, NEV. 10-24-60	423-300-147

FIGURE 20



NOTES

For locations of stations see figure 1—C
Solid lines (———) show suspended load.
Dash lines (– – – –) show discharge.
Plotted points indicate values on sampling dates.
D-49 Sampler used after Aug. 1, 1956.

11-Y-81 300	REVISED TO 1959

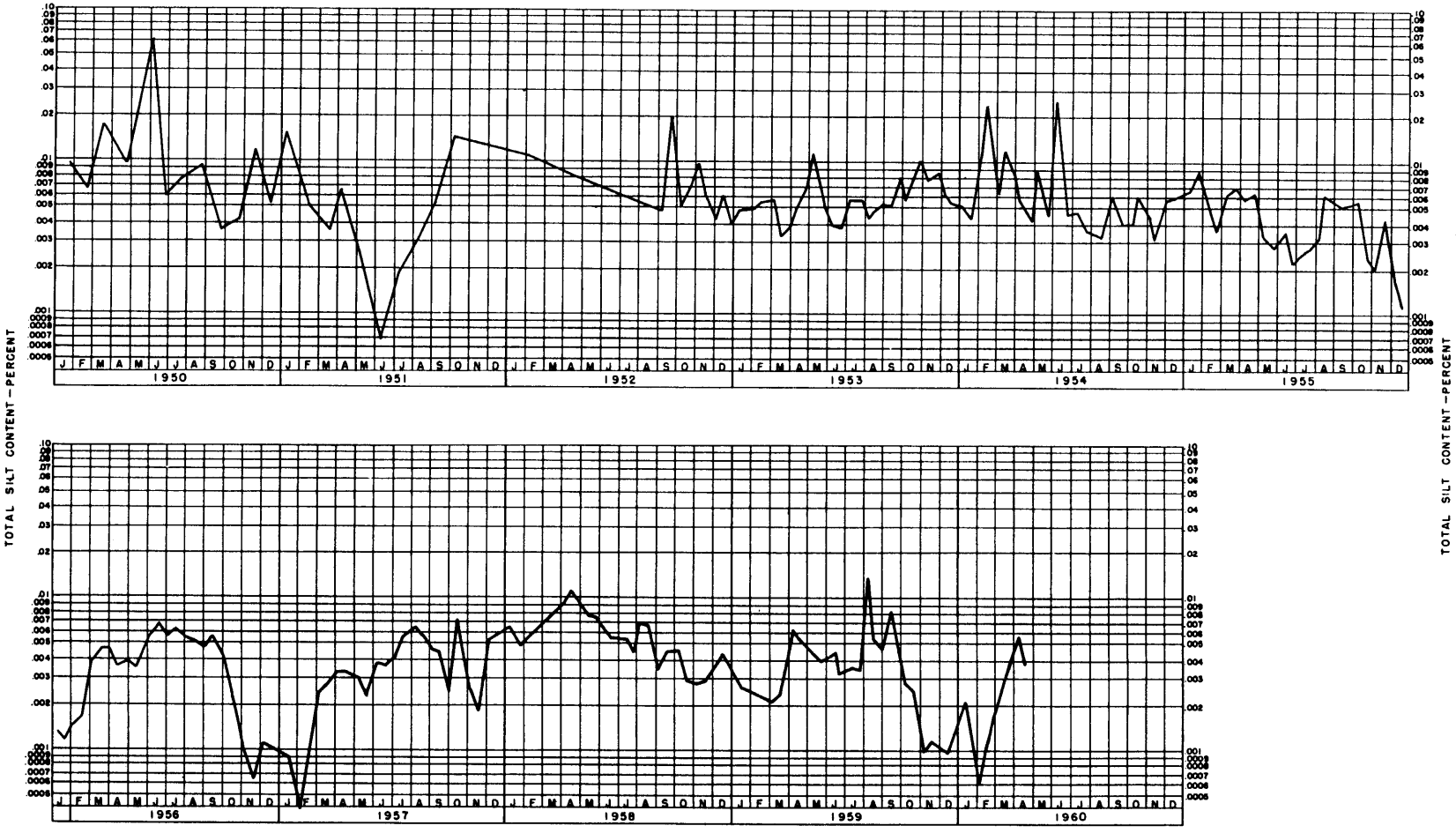
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
OFFICE OF RIVER CONTROL

RIVER SURVEYS AND INVESTIGATIONS

SUSPENDED LOAD
IN ALL-AMERICAN CANAL

DRAWN	SUBMITTED John L. McEwen
TRACED R.B.E.	RECOMMENDED Paul A. Oliver
CHECKED	APPROVED
BOULDER CITY, NEVADA.	212-306-2

FIGURE 21



NOTES

Samples taken at Siphon Drop.

See Figure 1 for location of stations.

For years previous to 1950 see Figure 35 for Calendar years 1950 and 1951

10-12-60 300	ADDED 1957 — 1960

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER SURVEYS AND INVESTIGATIONS

SUSPENDED LOAD
YUMA MAIN CANAL

DRAWN	SUBMITTED John S. McLean
TRACED W.J.B.	RECOMMENDED Paul A. Olivier
CHECKED	APPROVED
BOULDER CITY, NEVADA 8-1-57	423-300-86

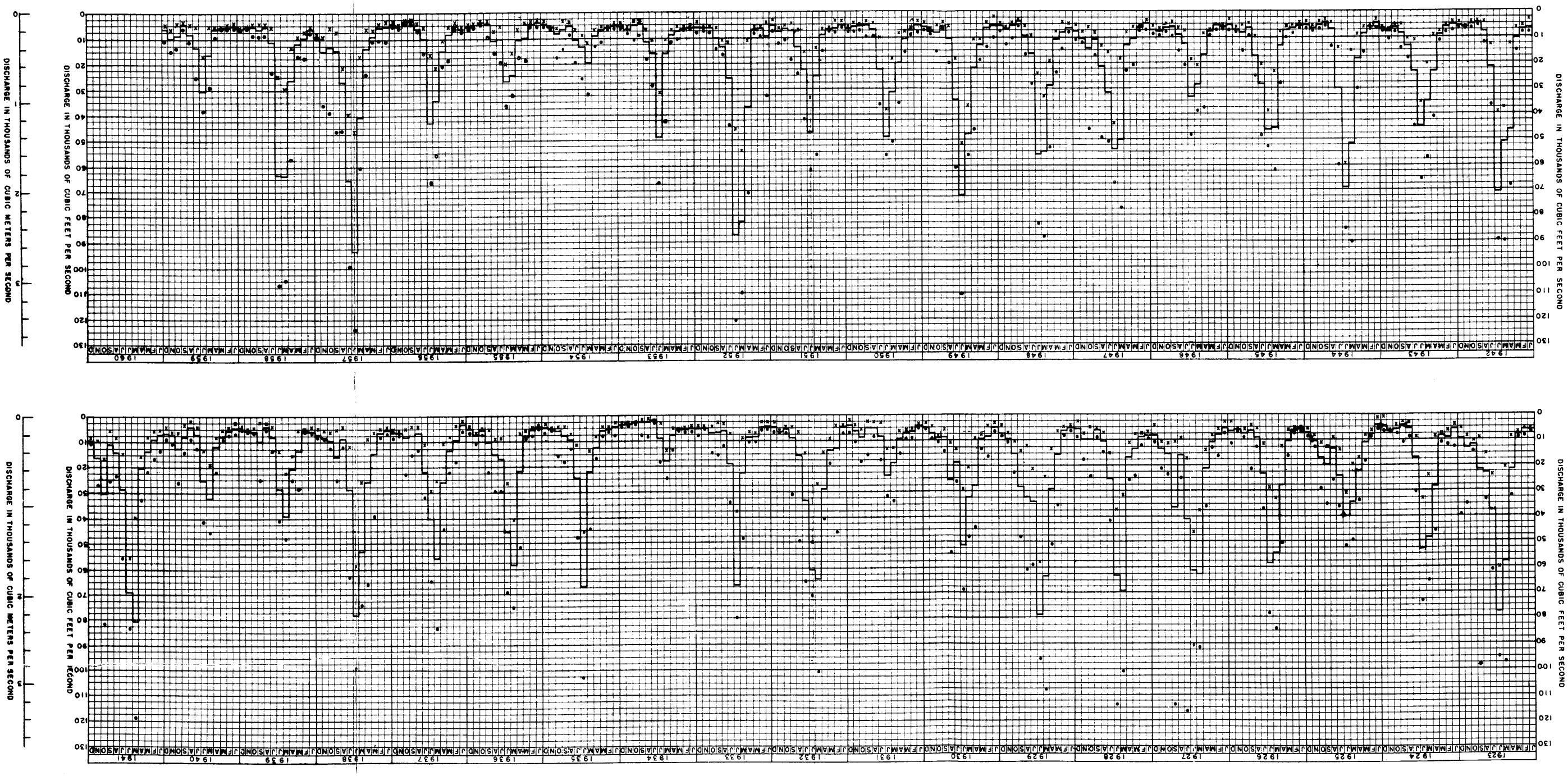


FIGURE 22

NOTES

Data shown hereon were obtained from Water Supply Papers published by the Geological Survey for the periods prior to October 1958. Data since that time were obtained from provisional records of the Geological Survey and are subject to revision.
For convenience, the maximum and minimum mean daily discharge for each month were plotted at the middle of the month, rather than on the day when the discharge occurred.

SYMBOLS

⎍ – Average monthly discharge.
• – Maximum mean daily discharge for month.
▪ – Minimum mean daily discharge for month.

This drawing supersedes drawing No. X-306-11

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COLORADO RIVER BASIN

RIVER OPERATION DATA

AVERAGE MONTHLY DISCHARGE OF THE
COLORADO RIVER NEAR GRAND CANYON, ARIZONA

DRAWN P.C.	SUBMITTED		
TRACED K.J.S.	RECOMMENDED		
CHECKED E.B.M.	APPROVED		

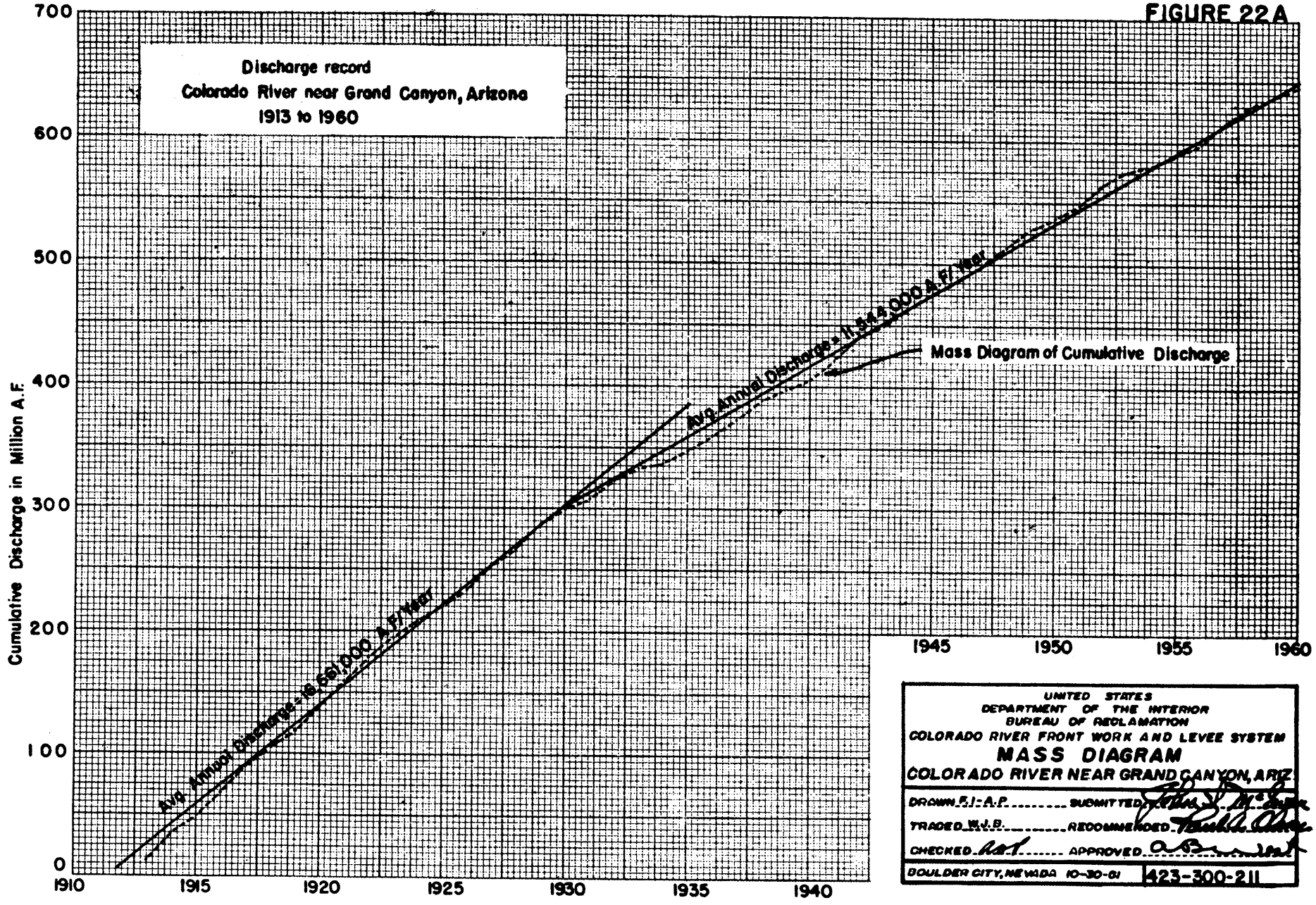
BOULDER CITY, NEV. 11-13-57

ADDED 1957 THRU 1959

11-3-60

423-300-87

FIGURE 22A



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

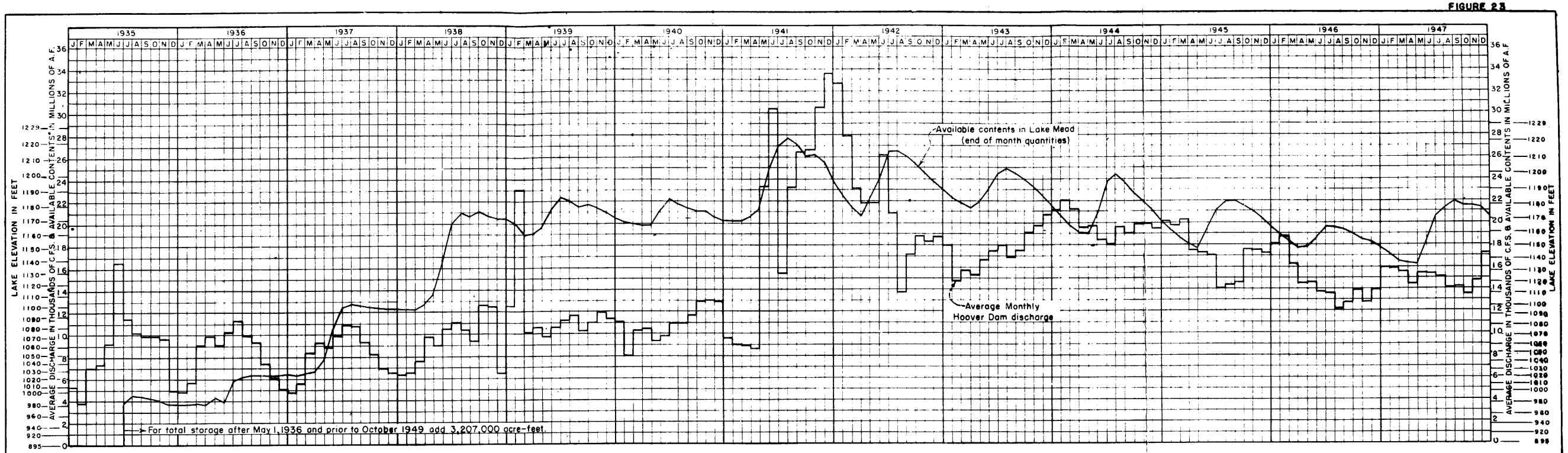
MASS DIAGRAM

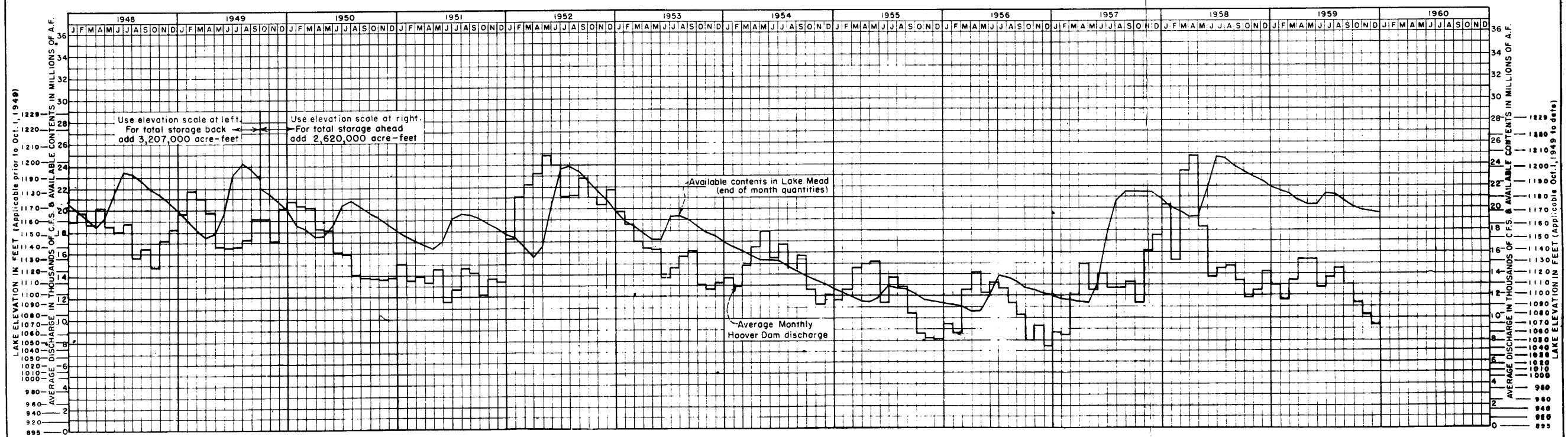
COLORADO RIVER NEAR GRAND CANYON, ARIZ.

DRAWN E.J.-A.P. SUBMITTED
TRACED W.J.B. RECOMMENDED
CHECKED APPROVED

BOULDER CITY, NEVADA 10-30-61 423-300-211

FIGURE 23





NOTES

Data shown hereon were obtained from water supply papers published by the Geological Survey for the period prior to October, 1958.

Data since that time were obtained from provisional records of the Geological Survey and are subject to revision.

New capacity table based on sediment surveys of 1948-49 put into use October 1, 1949.

For total storage between May 1, 1936 and October 1949 add 3,207,000 A.F. to available contents. For total contents after October 1949 add 2,620,000 A.F.

11-4-60 300 — ADDED 1957 THRU 1959

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

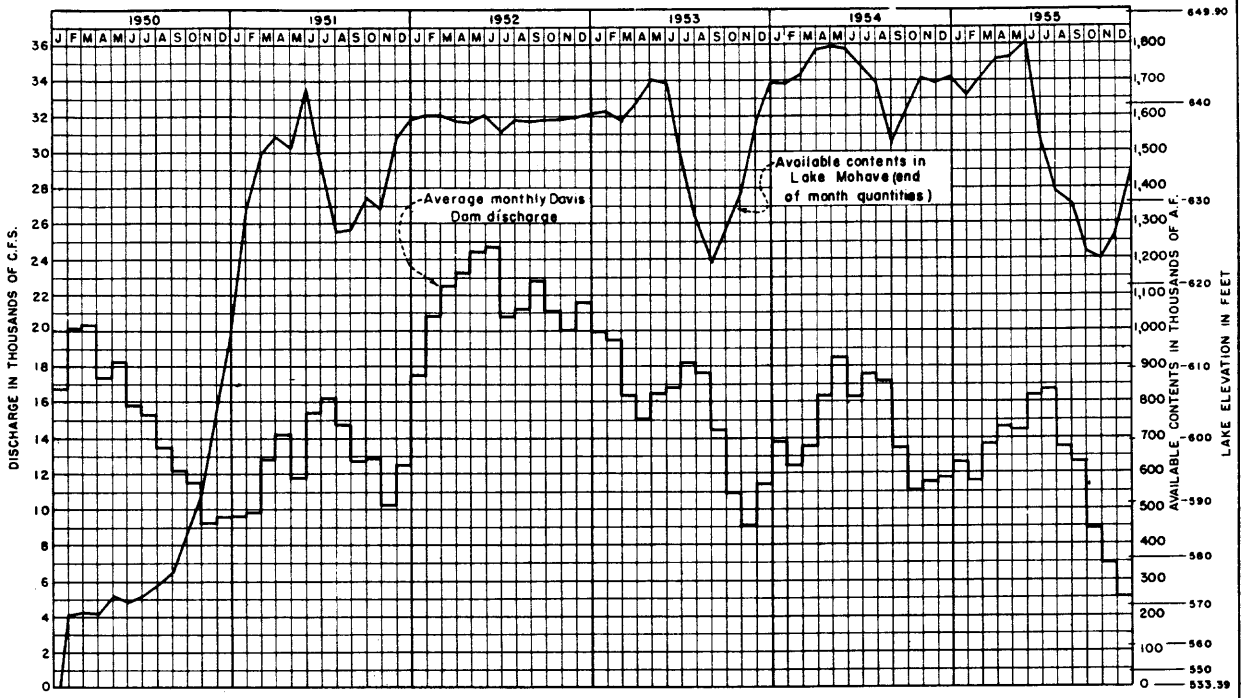
RIVER OPERATION DATA
HYDROGRAPHS
HOOVER DAM AND LAKE MEAD
COLORADO RIVER

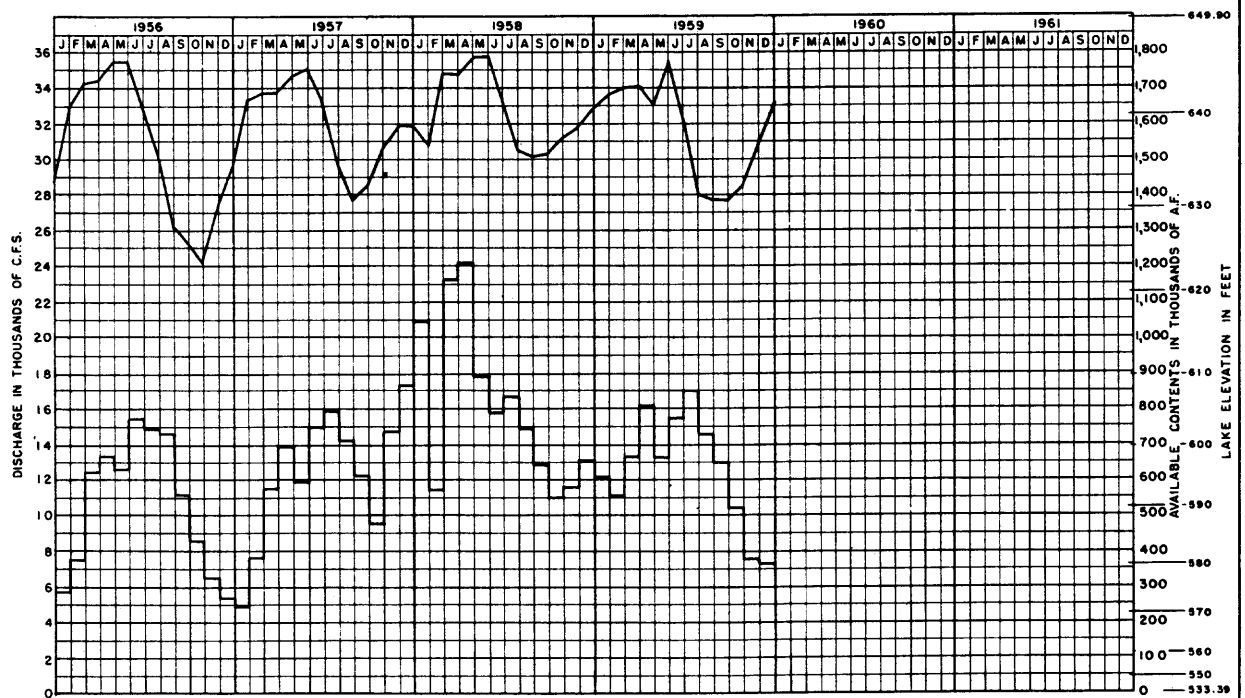
DRAWN T.F.C. SUBMITTED C. M. Smith
TRACED W.L.B. RECOMMENDED Paul A. Rhoads
CHECKED F.R.M. APPROVED A. P. Davis

BOULDER CITY, NEV. 10-11-57

45-300 90

FIGURE 24





NOTES

Data shown hereon were obtained from water supply papers published by the Geological Survey for the period prior to October, 1958.

Data since that time were obtained from provisional records of the Geological Survey and are subject to revision.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

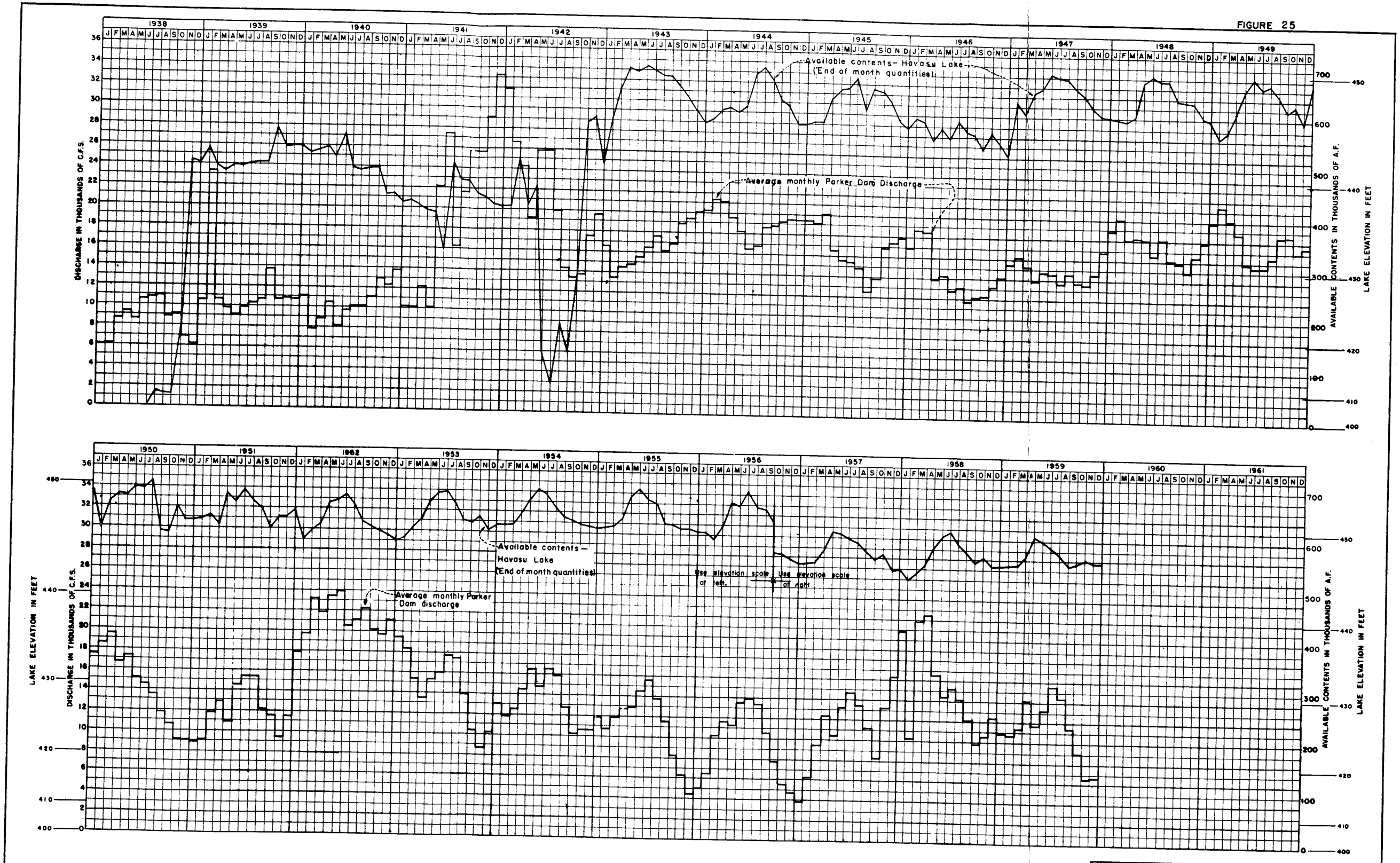
RIVER OPERATION DATA
HYDROGRAPHS
DAVIS DAM AND LAKE MOHAVE
COLORADO RIVER

DRAWN E.F. SUBMITTED
TRACED RRR RECOMMENDED
CHECKED W.O.S. APPROVED

BOULDER CITY, NEV. 11-1-60

351-300-123

FIGURE 25



NOTES

Data shown hereon were obtained from water supply papers published by the Geological Survey for the period prior to October, 1958.

Data since that time were obtained from provisional records of the Geological Survey and are subject to revision.

Elevations shown are based on Geological Survey adjustment of 1912.

New capacity table based on sediment survey of April 1957 was placed in use October 1, 1956 for records purposes.

11-4-60 300 REVISED AND ADDED 1957 THRU 1959

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

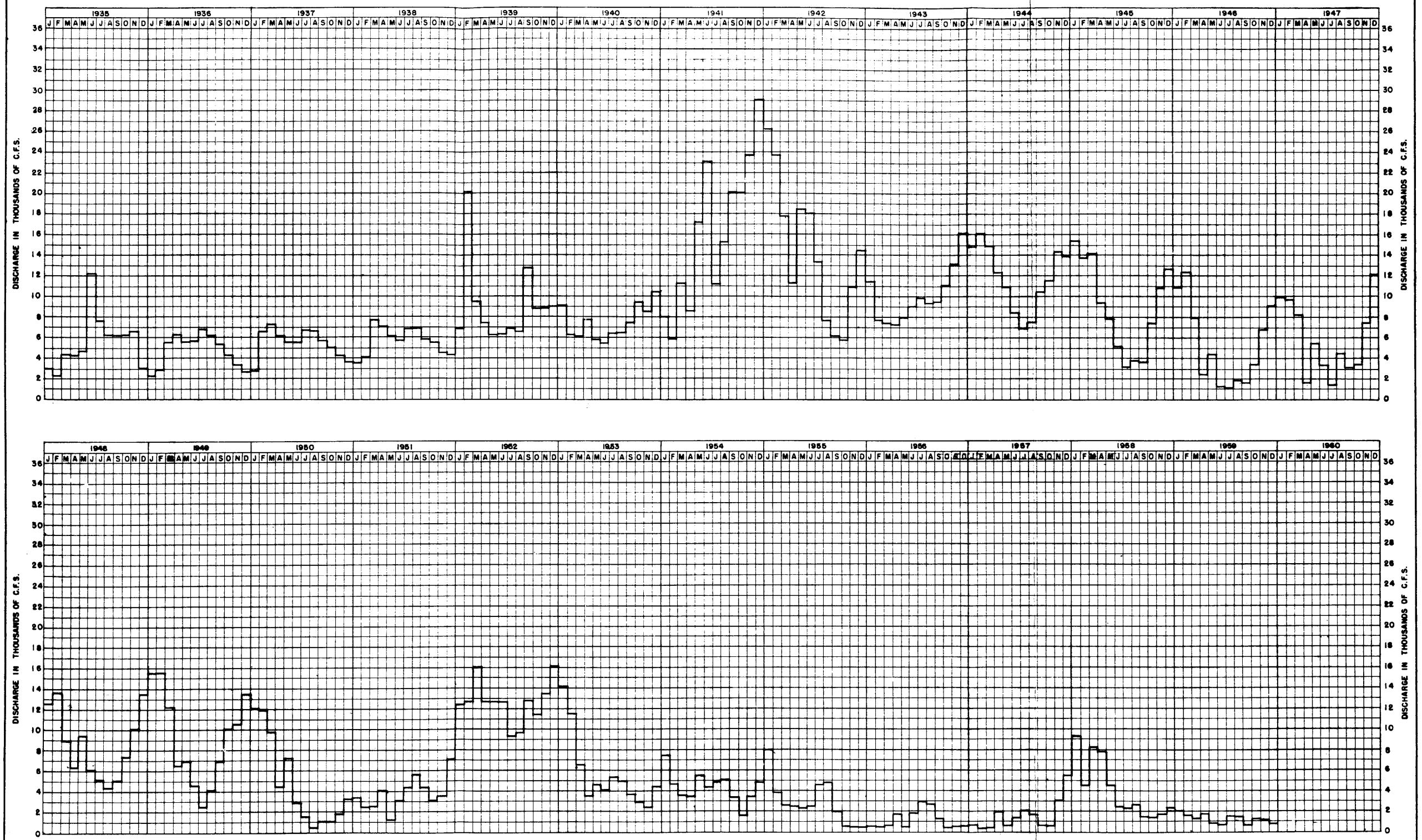
RIVER OPERATION DATA
HYDROGRAPHS
PARKER DAM AND HAVASU LAKE
COLORADO RIVER

DRAWN E.F. SUBMITTED C. Myhrwold
TRACED [illegible] RECOMMENDED Paul A. Olive
CHECKED APPROVED

BOULDER CITY, NEV. 11-13-57

231-300-59

FIGURE 26



NOTES

Data shown hereon are based on figures published by the Geological Survey.
Data shown for period after Sept. 30,1958 are based on Geological Survey provisional records and are subject to revision upon publication of final records by that agency.

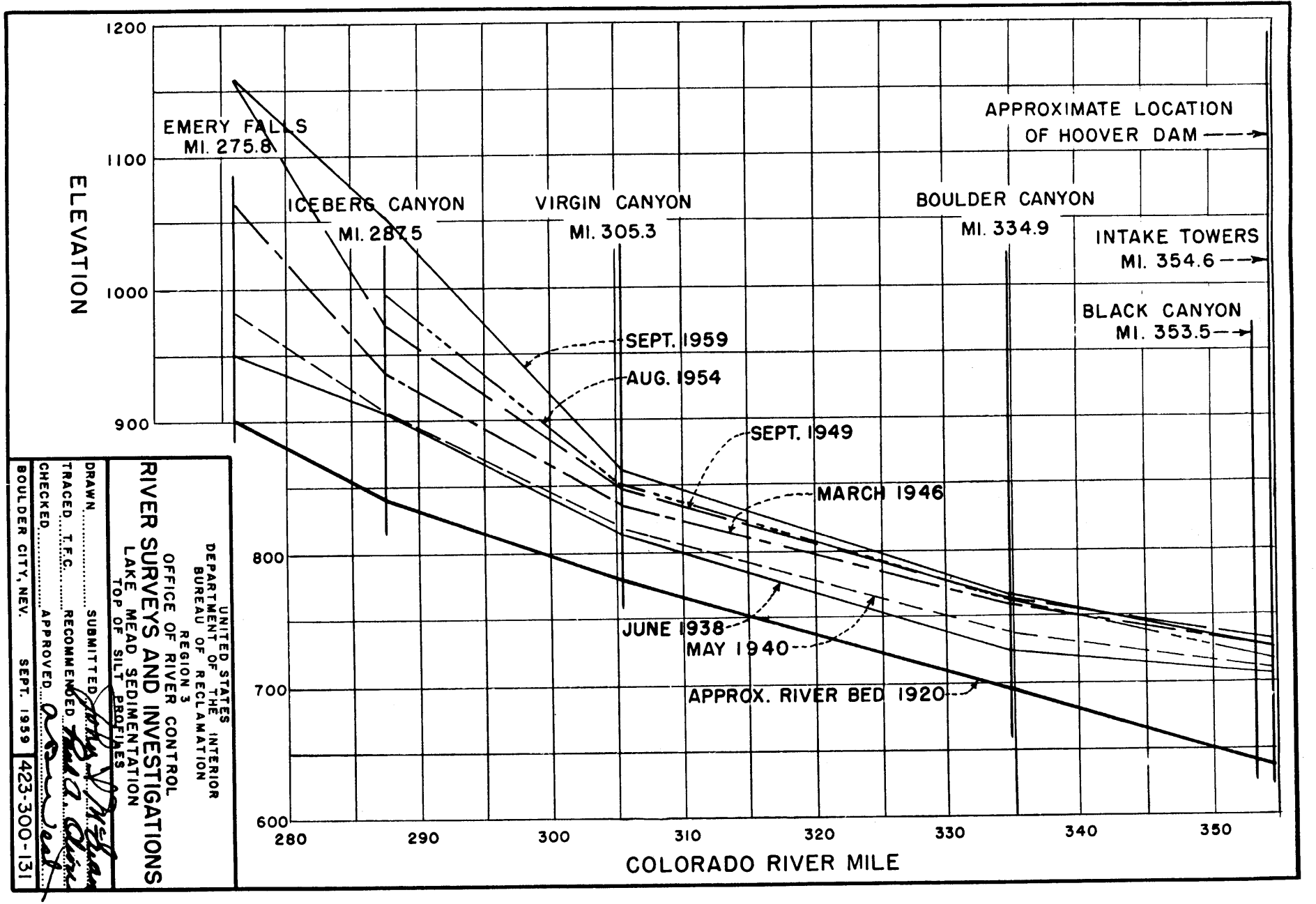
11-1-60 300 JMM	ADDED 1957 THRU 1959	

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER OPERATION DATA
HYDROGRAPHS
COLORADO RIVER NEAR YUMA, ARIZ.

DRAWN E.E	SUBMITTED C.W. Lauritzen
TRACED O.L.S	RECOMMENDED Paul A. Olsen
CHECKED	APPROVED
BOULDER CITY, NEV. 11-14-57	423-300-91

FIGURE 27



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
OFFICE OF RIVER CONTROL
BOULDER CITY, NEV.

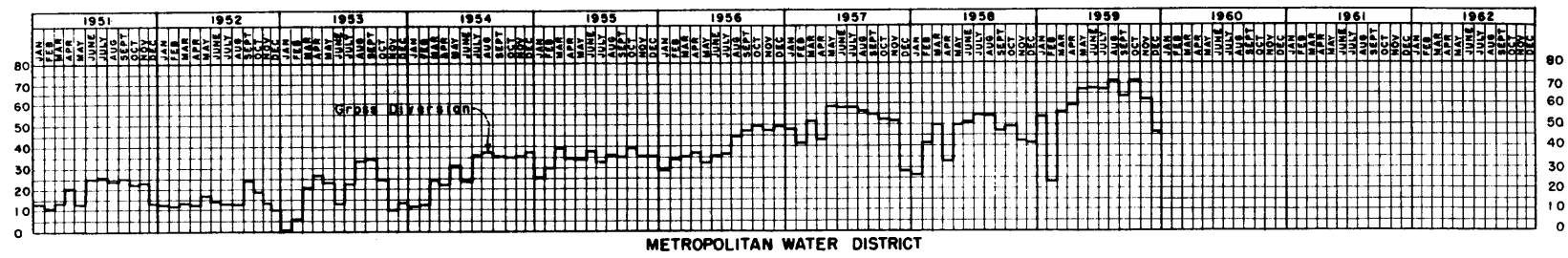
RIVER SURVEYS AND INVESTIGATIONS

LAKE MEAD SEDIMENTATION
TOP OF SILT PROFILES

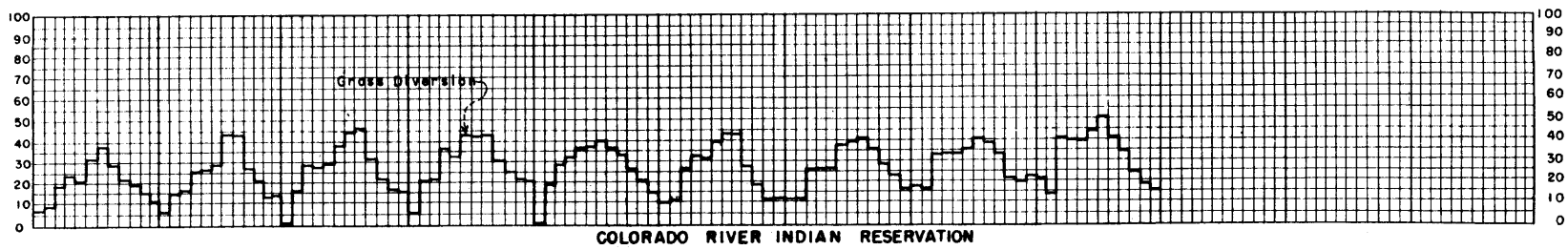
DRAWN
TRACED T.F.C.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED

SEPT. 1959

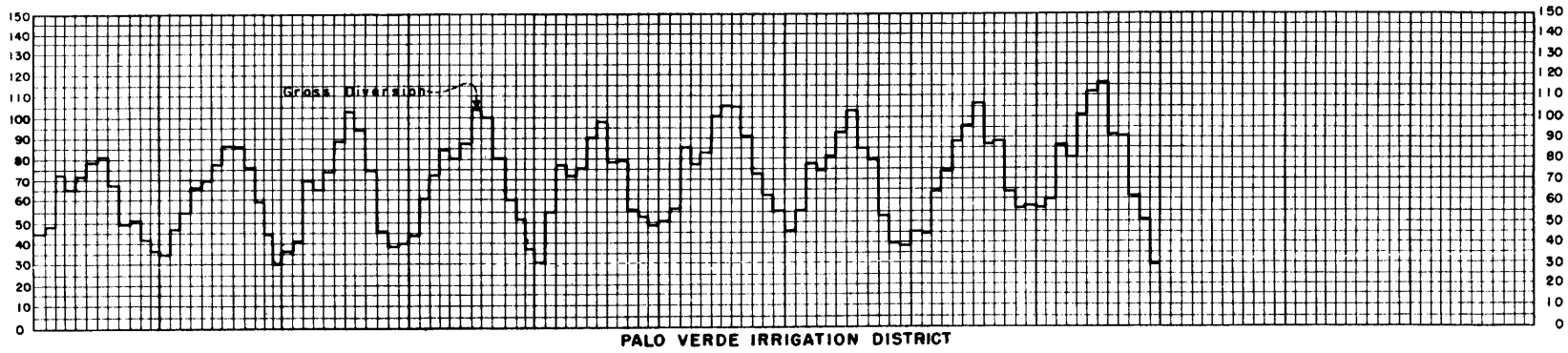
423-300-131



METROPOLITAN WATER DISTRICT

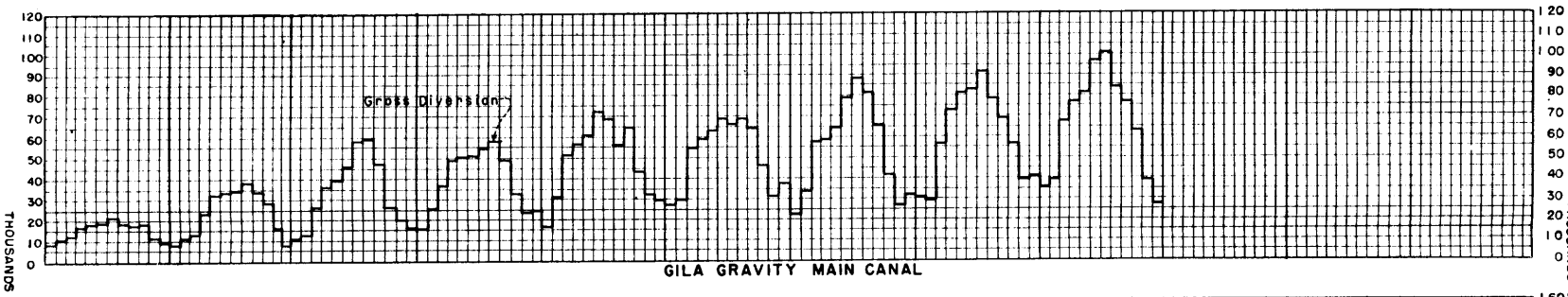


COLORADO RIVER INDIAN RESERVATION



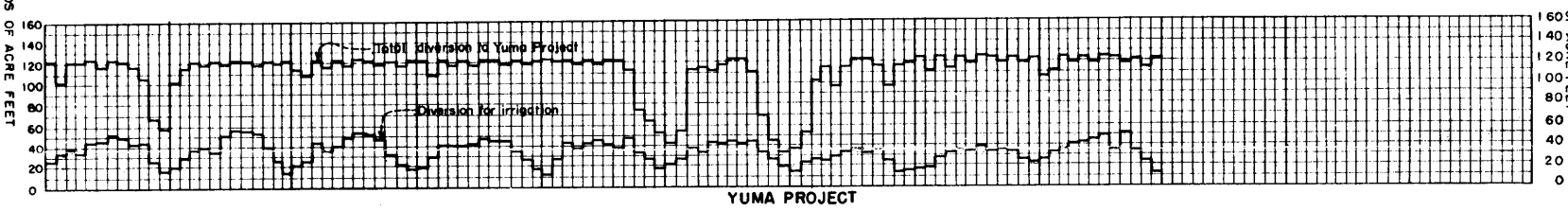
PALO VERDE IRRIGATION DISTRICT

NORTH GILA CANAL

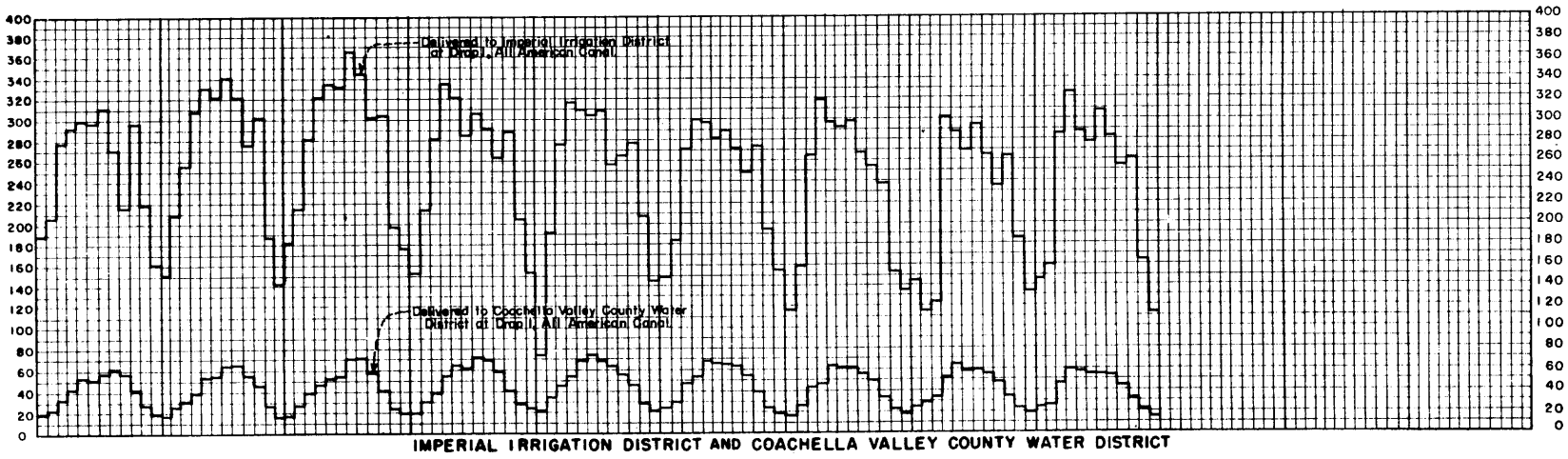


GILA GRAVITY MAIN CANAL

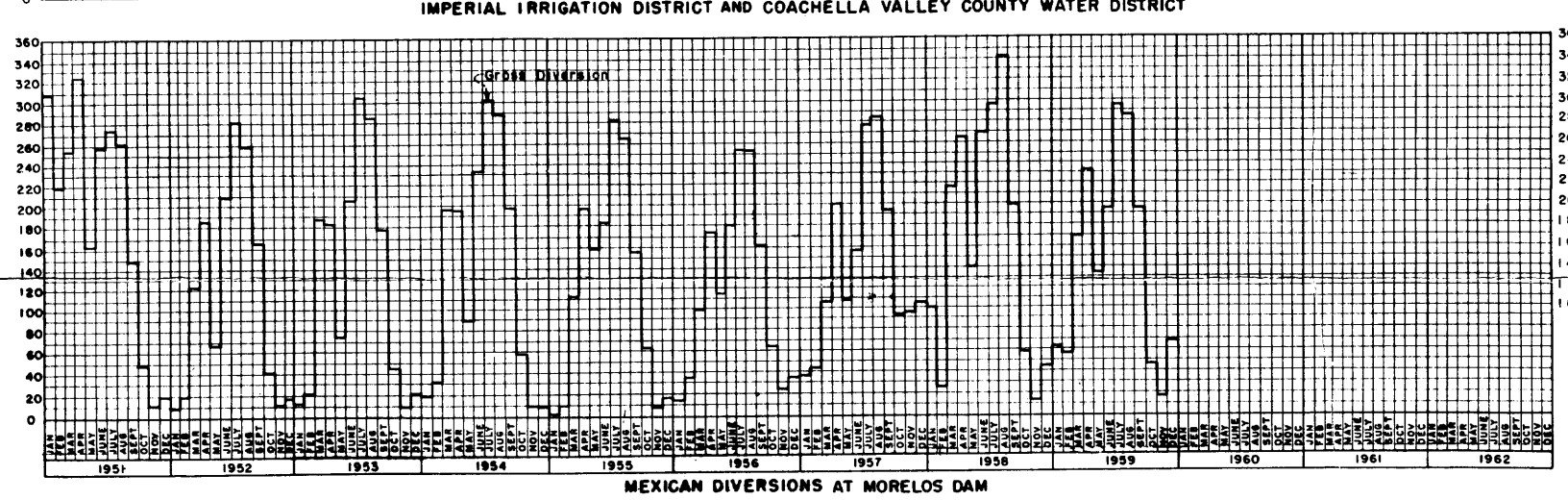
THOUSANDS OF ACRE FEET



YUMA PROJECT



IMPERIAL IRRIGATION DISTRICT AND COACHELLA VALLEY COUNTY WATER DISTRICT



MEXICAN DIVERSIONS AT MORELOS DAM

NOTES

Data shown for period through September 30, 1958 on charts for Metropolitan Water District, Colorado River Indian Reservation, Palo Verde Irrigation District, Gila Project, and Yuma Project are based on figures published by the U.S. Geological Survey.

Data shown for period after September 30, 1958 on the above listed charts and all data shown for Mexican Diversions at Morelos Dam are based on figures from the Water Log of The Colorado River compiled by the U.S. Bureau of Reclamation.

Data shown for Imperial Irrigation District and Coachella Valley County Water District are supplied by Imperial Irrigation District.

For records prior to 1951 see figure 36, report for calendar years 1950–1951.

This drawing supersedes drawing No. X-306-7

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COLORADO RIVER BASIN
ARIZONA AND CALIFORNIA

OPERATIONAL DATA
DIVERSIONS
HAVASU LAKE TO INTERNATIONAL BOUNDARY

DRAWN P.C. SUBMITTED C. Bradshaw
TRACED F.R.M. RECOMMENDED Paul C. Clarke
CHECKED APPROVED A. Peterson

BOULDER CITY, NEVADA 11-14-57

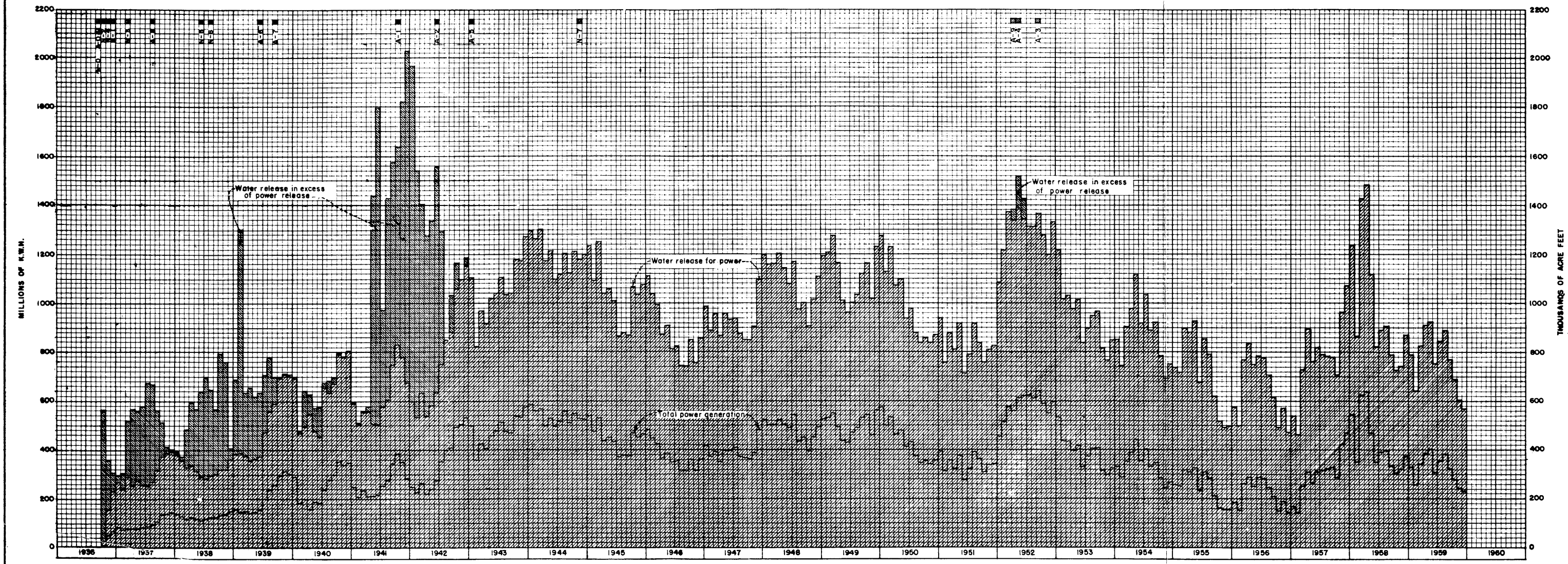
57-300-184

11-7-80 300 DMa

ADDED 1957 THRU 1959

FIGURE 28

FIGURE 29.



NOTES

Only water passing Hoover Dam in excess of releases shown has been seepage and testing water, and has amounted to approximately 4000 acre feet per month.

N-7 ■ Indicates month in which unit was put in service.

All data shown hereon are based on Bureau of Reclamation records.

This drawing supersedes drawing No. 45-306-34

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3

RIVER OPERATION DATA

WATER RELEASES AND POWER PRODUCTION AT HOOVER DAM

COLORADO RIVER

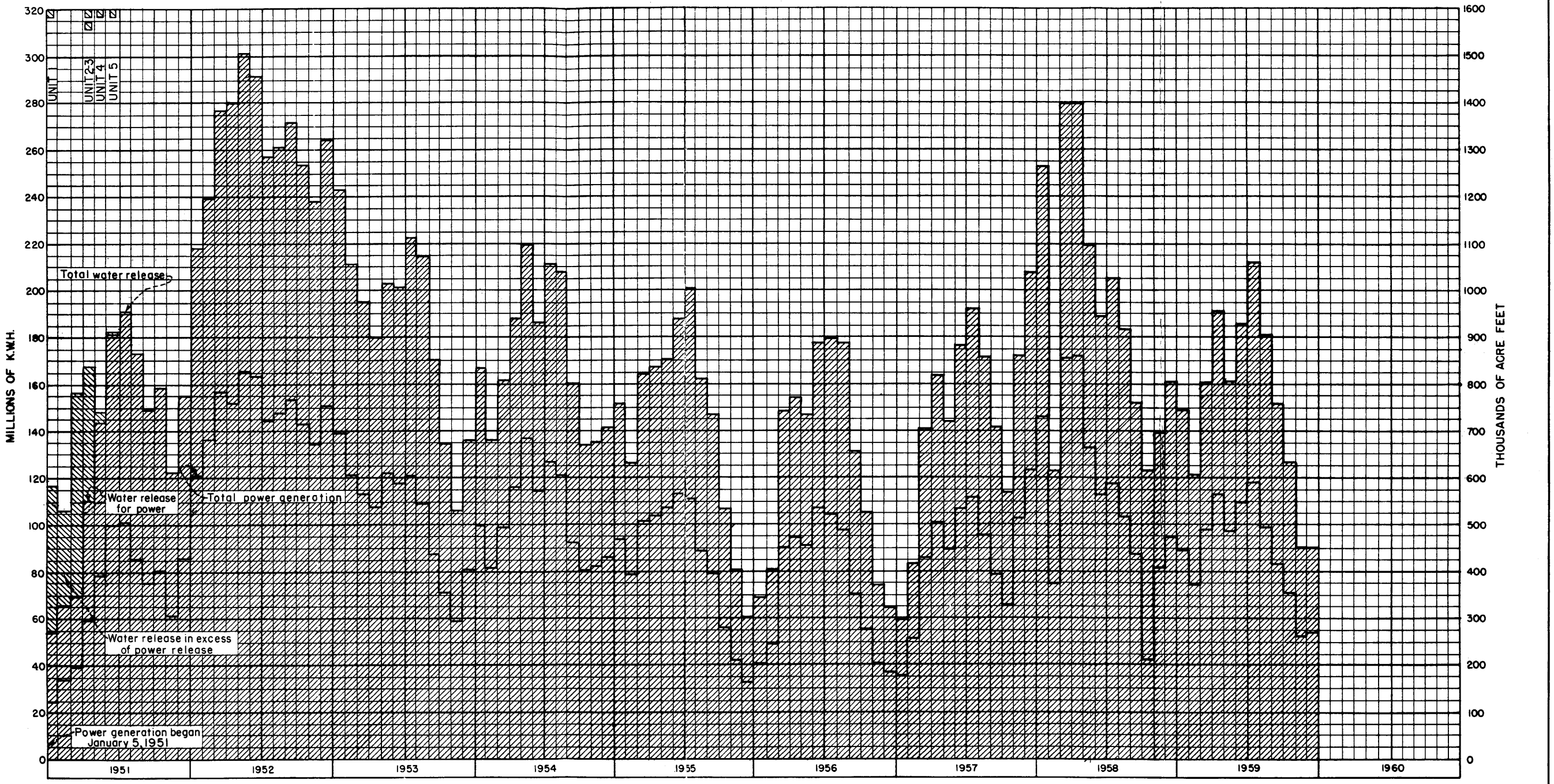
DRAWN K.F. SUBMITTED C.M. Smith
TRACED M.H.C.-O.L.S. RECOMMENDED Paul A. Wiss
CHECKED W.O.E. APPROVED

11-7-60 1900 ADDED 1957 THRU 1959

BOULDER CITY, NEV. 11-14-57

45-300-89

FIGURE 30



NOTES

■ Indicates months units were put in service.

All data shown hereon are based on Bureau of Reclamation records.

THIS DRAWING SUPERSEDES DRAWING. 351-306-20

11-6-80 300 ADDED 1957 THRU 1959

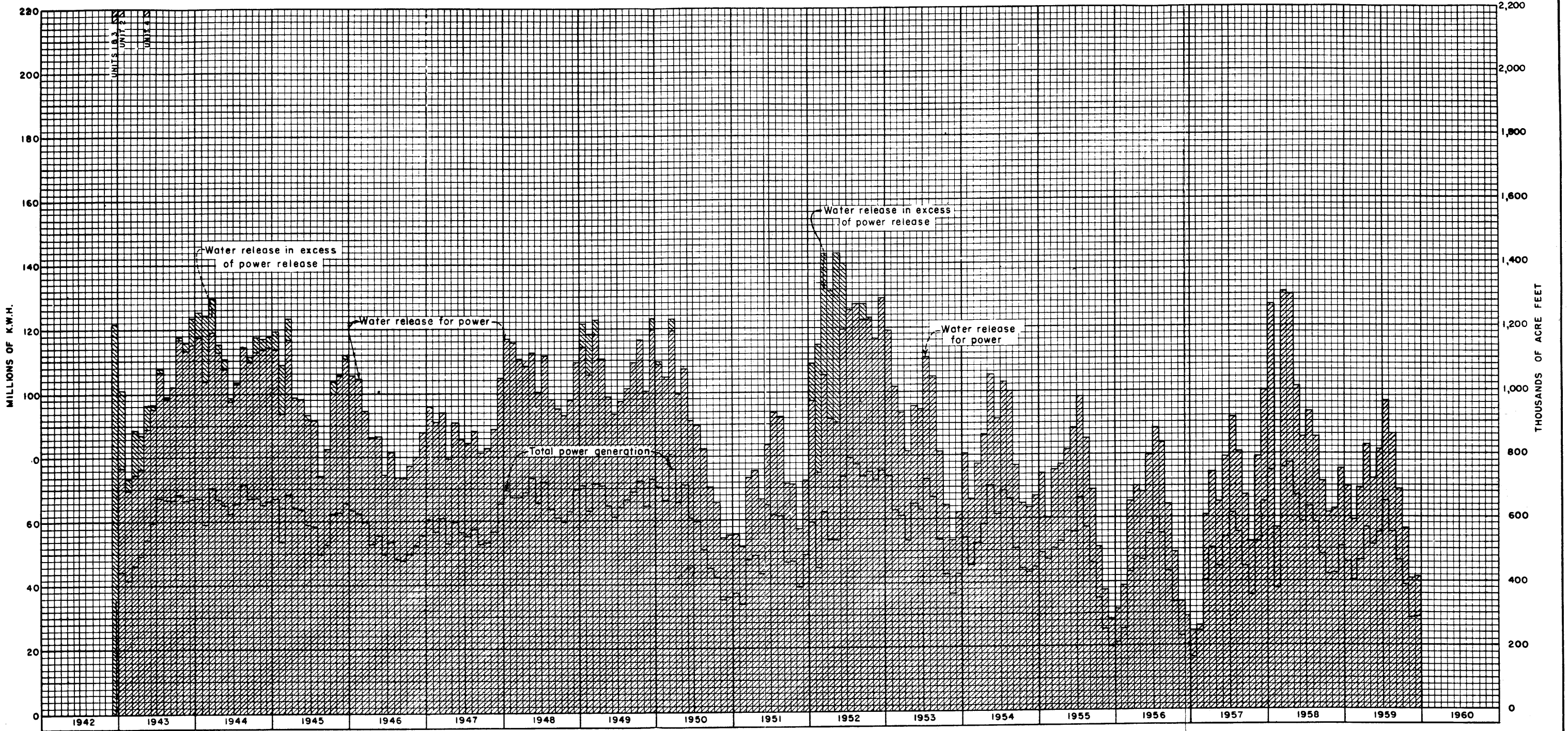
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
OFFICE OF RIVER CONTROL

OPERATIONAL STUDIES
WATER RELEASES AND POWER
PRODUCTION AT DAVIS DAM

DRAWN: E.G.C. SUBMITTED: C.M. Smith
TRACED: RECOMMENDED: Paul A. Wiese
CHECKED: APPROVED:

BOULDER CITY, NEVADA 11-14-57 351-500-122

FIGURE 31.



This drawing supersedes drawing No. 231-306-3

NOTES

▨ Indicates month units were put in service.

All data shown hereon are based on Bureau of Reclamation records.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

REGION 3

RIVER OPERATION DATA
WATER RELEASES AND POWER PRODUCTION AT PARKER DAM
COLORADO RIVER

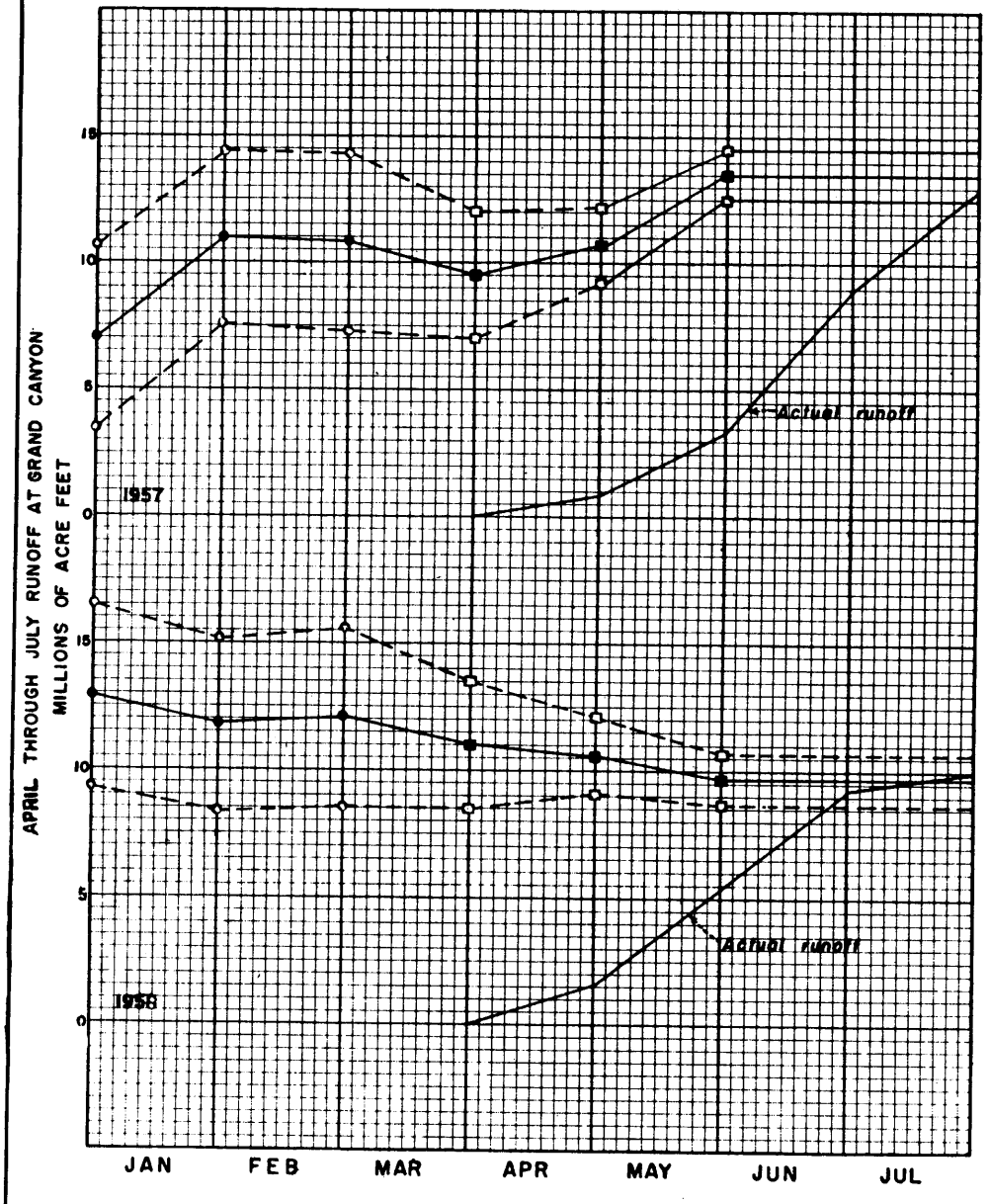
DRAWN E.F. SUBMITTED C.W. Smith
TRACED T.F.C. - O.L.S. RECOMMENDED Paul A. Rivera
CHECKED W.D.S. APPROVED A.B. West

10-31-60 300 Jmm. ADDED 1957 THRU 1959

BOULDER CITY, NEV. 11-14-57

231-300-58

FIGURE 32



NOTES

Solid symbols are mean forecast.
Clear symbols are 9 out of 10 probability limits.

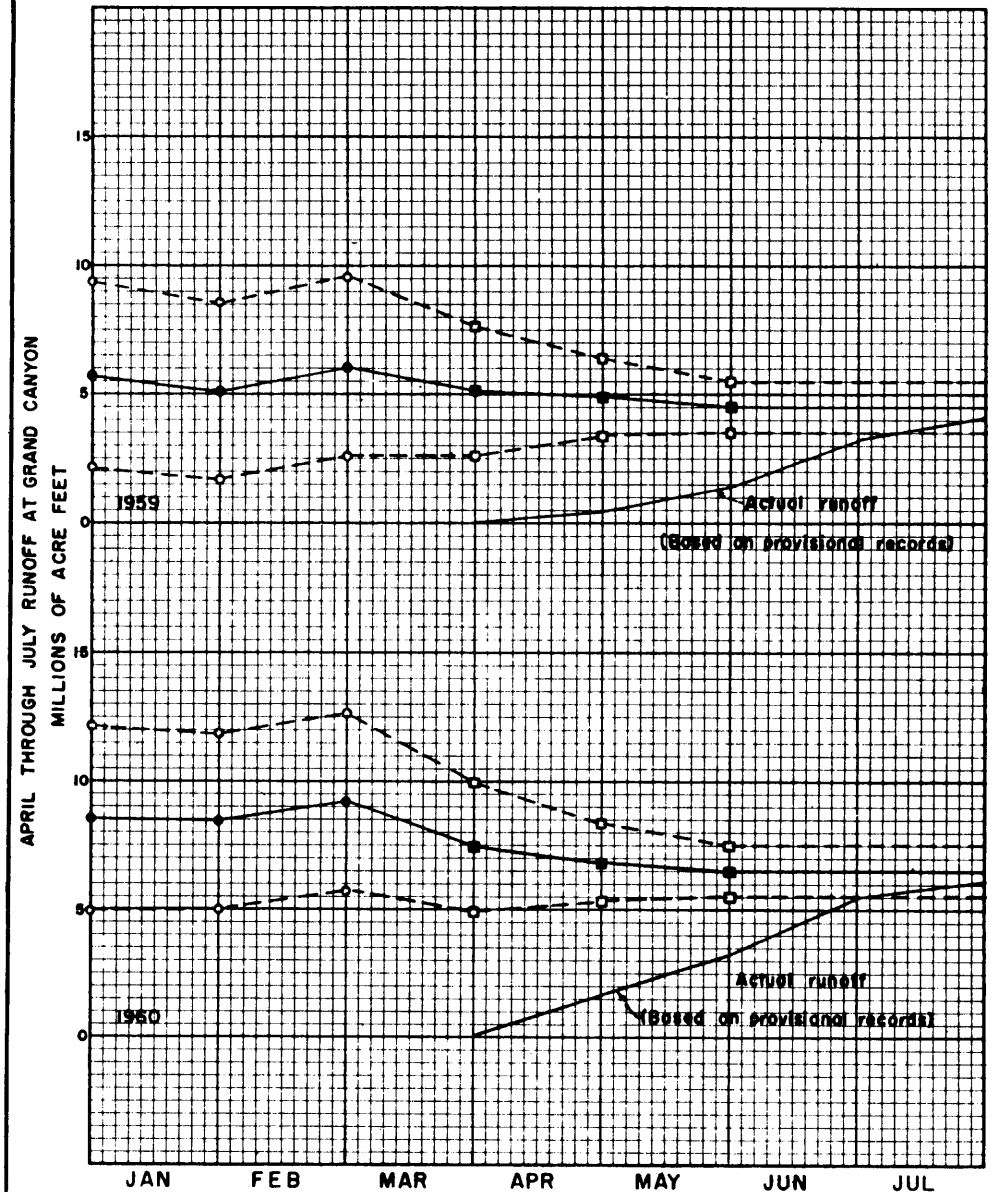
- *Forecast based on precipitation data.*
- *Forecast based on multiple correlation using precipitation, snow and antecedent runoff.*

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COLORADO RIVER BASIN
COMPARISON OF FORECAST
1957-1958

DRAWN E.W.L. SUBMITTED
TRACED R.P.E. RECOMMENDED
CHECKED R.R.M. APPROVED
BOULDER CITY, NEV. 9-30-60

57-300-387

FIGURE 32A



NOTES

Solid symbols are mean forecast.
Clear symbols are 9 out of 10 probability limits.

- *Forecast based on precipitation data.*
- *Forecast based on multiple correlation using precipitation, snow and antecedent runoff.*

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COLORADO RIVER BASIN

COMPARISON OF FORECAST
1959–1960

DRAWN E.W.L. SUBMITTED C.L. Whitworth
TRACED R.P.E. RECOMMENDED Paul A. Olson
CHECKED F.R.M. APPROVED
BOULDER CITY, NEV. 10-3-60

57-300-388