RESERVOIR REGULATION MANUAL

FOR

FLOOD-CONTROL STORAGE

AT

TWITCHELL DAM AND RESERVOIR
SANTA MARIA RIVER AND TRIBUTARIES, CALIF.

CONTENTS

TABLES

CONTENTS--Continued

TABLES--Continued

PLATES

CONTENTS--Continued

APPENDIX A

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GENERAL

1. Introduction.--This reservoir regulation manual, which prescribes the use of storage allocated for flood control at Twitchell Dam and Reservoir was prepared in accordance with instructions contained in Engineering Regulation 1110-2-240, dated 8 December 1958, and Civil Works Engineering Manual 1110-2-3600, dated 25 May 1959, issued by the Office, Chief of Engineers. These publications prescribe in part that a reservoir regulation manual will be prepared for each reservoir subject to the provisions of Section 7 of the Flood Control Act of 1944. That Act states that "***Hereafter, it shall be the duty of the Secretary of War to prescribe regulations for use of storage allocated for flood control or navigation at all reservoirs, constructed wholly or in part with Federal funds .***" A copy of the official flood-control regulations for Twitchell Dam and Reservoir is contained in appendix A of this manual.

2. The manual has been divided into a general section containing, descriptive information pertaining to the overall project and an operation section in which details concerning the actual plan of operation are presented. A considerable portion of the material used in the preparation of this manual was supplied by the U. S. Bureau of Reclamation offices in Denver, Colo., and Sacramento, Calif.

3. General description.--Twitchell Dam, and Reservoir (formerly Vaquero Dam and Reservoir) is a multiple-purpose structure for water conservation and flood control, which is located on the Cuyama River, 7 airline miles northeast of Santa Maria, Calif., in the Santa Maria River basin.(see pls. 1 and 2). The dam was completed in December 1958. The drainage area above Twitchell Dam comprises 1,125 square miles of the 1,845 square miles in the Santa Maria River basin. The Santa Maria River is formed by the confluence of the Cuyama and Sisquoc Rivers. All of these rivers flow generally westward. Downstream from the confluence, the basin includes the plain along the Santa Maria River, the Nipomo Upland to the north, and the Orcutt Upland to the south. The Solomon and Casmalia Hills,

ranging in elevation from 500 to 1,600 feet, are along the southern boundary; and a low divide is along the northern boundary. The soil in the valley is composed of alluvium and terrace deposits. The riverwash area, which includes deposits of sand and gravel is very pervious. This area contains irrigated farmland, raising both field and garden crops. The principal cities located below the confluence are Santa Maria, Betteravia, and Guadalupe. The largest of these, Santa Maria, had a population of about 15,000 in 1958. Residential and commercial development is expanding rapidly in the Santa Maria River Valley.

4. The drainage area of the Cuyama River, 1,147 square miles, the larger of the two rivers that combine to form the Santa Maria River, is bounded on the northeast, by the barren Caliente Mountains, whose average crest elevation is about 4,000 feet. The Sierra Madre Mountains on the south and southwest have an average crest elevation of about 5,500 feet, and separate the drainage areas of the Cuyama and Sisquoc Rivers. Scattered conifers are found in the higher elevations, and brush and grass are common on the lower slopes. Parts of the area are frequently denuded by fire. Between these two ranges of mountains is the broad Cuyama Valley. The upper Cuyama area consists of sedimentary and alluvial deposits of gravels, clays, shales, and sandstones. The riverwash area includes deposits of sand and gravel. The valley and riverwash areas are very pervious. About 27 miles downstream of the lower end of the Cuyama Valley proper, the river enters a narrow steep-sided canyon, through which it flows for about 36 miles to its confluence with the Sisquoc River. Alamos Creek and Huasna River, the two largest tributaries of Cuyama River, drain this lower mountainous area.

5. The Sisquoc River (drainage area 483 sq. miles), drains the rugged mountainous area of the Sierra Madre range, which is adjacent to and south of the Cuyama River drainage area. The San Rafael Mountains, forming the southern boundary of the Sisquoc River basin, have an average crest elevation of about 5,000 feet. These mountains, which are mostly sedimentary in origin, consist of shales, gravels, and alluvium. A dense cover of conifers is in the higher elevations; live oak, brush, and grass are common on the lower slopes; and deciduous trees, are along the streams. Parts of the area are frequently denuded by fire.

6. Hydrometeorological characteristics.--The climate of the Santa Maria River basin is generally mild. Extremes of temperature are rare in the valley parts of the basin, but the temperature variation increases with elevation. Prevailing winds, from the Pacific, are generally light to moderate; the highest velocities occur during the spring. Mean seasonal precipitation (July-June), ranges from about 11 inches on the coast to more than 35 inches in the higher mountains (see pl. 3). About 90 percent of the precipitation occurs during the months of November to April, inclusive. Precipitation occurs in the form of rain, except for occasional

light snowfall in mountain areas. Summaries of climatological data for Santa Maria, Calif., And for Cuyama, Calif., are given in tables 1 and 2. The locations of these stations are shown on plate 4.

7. Most storm precipitation in the drainage area results from general winter storms that are associated with extratropical cyclones of North Pacific origin. During the winter season (November-April), such storms move south over the ocean and then inland to southern California, and result in precipitation over large areas. Major storms, which consist of one or more cyclonic disturbances, occasionally last 4 days or more. During major storms, rainfall rates of flood-producing magnitude have extended over periods ranging from a few hours to about 2 days. The greatest floods of record in the drainage area have resulted from this type of storm. Occasionally in the winter season, meteorologic conditions result in random occurrences of unusually heavy but brief rainfall of the thunderstorm type. The duration of-heavy intensities during these occurrences is seldom more than 2 hours and rarely more than 3 hours. In summer, rainfall associated with tropical cyclones has occurred in this region, but such occurrences are infrequent and relatively unimportant in the flood history of the drainage area. Summer thunderstorms are not uncommon, but the amount of rainfall in such storms in the area is relatively minor.

8. Runoff and floods.--Floods resulting from rainfall constitute nearly all of the annual runoff in the Santa Maria River basin. Inasmuch as only occasional snowfall occurs, runoff due to snowmelt is of minor consequence. Records of streamflow in the Santa Maria River basin are incomplete and no records exist for Twitchell dam site. At the present time, seven stream-gaging stations are in operation in the Santa Maria River basin. Table 3 summarizes the extent of available records at these stations, and their locations are shown on plate 4. Runoff data for five of these stations pertinent to the operation of Twitchell Reservoir, are given in tables 4 through 8. The station on the Santa Maria River at Guadalupe, Calif., measures runoff from practically the entire Santa Maria River basin. Peak discharges at this station for the flood years 1941, 1943, 1952, and 1958 were 14,700, l3,800, 23,800, and 21,500 cubic feet per second, respectively. Zero flow has occurred numerous times at this station

9. Historical accounts and records of floods that have occurred in the Santa Maria River basin are lacking. However, a study of historical accounts and records of floods that have occurred in adjacent basins indicate that severe floods occurred in the years 1862, 1868,1884, 1886, 1909, and 1914. The peak discharge for the 1909 flood was estimated at 100,000,cubic feet per second on the Santa Maria River at Guadalupe.

10. Flood damages.--Few monetary estimates of damages from past floods in the Santa Maria River basin are available. Records,

however, indicate that floods have caused extensive damage to agricultural land and to residential, highway, and railroad property. A map of the area subject to overflow for an occurrence of the standard project flood prior to improvements is shown on plate 5. Along the Santa Maria River, floods have caused damage of major proportions by cutting streambanks and changing the shape and location of the channels, damaging, or destroying communication and transportation facilities and inundating rural and urban property. During large floods, the channel has become badly silted, thereby decreasing its carrying capacity. The most recent floods that have occurred in the Santa Maria River basin, those of January 1952 and April 1958, have caused estimated damages of $250,000 and $110,000, respectively.

11. Completion of the plan of flood-control improvements, which comprise flood regulation at Twitchell Dam and Reservoir and the Santa Maria River and Bradley Canyon levees, as subsequently described, provides for nearly complete protection to about 26,000 acres of the 32,400-acre overflow area from floods up to the magnitude of the standard project flood. This area of 26,000 acres, includes about 18,700 acres of cultivated land, most of the city of Santa Maria and part of the city of Guadalupe. An unprotected area of 6,400 acres, including about 1,000 acres of farmland west of Guadalupe, Calif., and downstream from the levees, together with streambed and wasteland along the 22-mile reach of the Santa Maria River from Fugler Point to the Pacific Ocean will exist with the completion of the project. Levee protection was not economically justified for this area.

12. Authorization.--The plan for flood-control improvements in the Santa Maria River was set forth in House Document 400, 83d Congress, 2d session, dated 24 May 1954. This plan provided for a multiple-purpose reservoir for water conservation and flood control at the Vaquero (Twitchell) site, on the Cuyama River, and levee and channel improvements along the Santa Maria River and Bradley Canyon. The construction of Twitchell Dam was authorized by Public Law 774, 83d Congress, 2d session, which was passed by Congress 3 September 1954, and authorized the Secretary of the Interior to construct the project for irrigation and the conservation of water, flood control, and for other purposes, on the Santa Maria River, Calif. The Bureau of Reclamation began construction of Twitchell Dam in July 1956 and completed construction in December 1958. The Board of Geographic Names, Department of the Interior, approved the changing of the name of Vaquero Dam to Twitchell Dam and Vaquero Reservoir to Twitchell Reservoir effective 6 September 1957.

13. The plan for flood-control improvements to protect the overflow areas downstream from Twitchell Dam along the Santa Maria River was approved 3 September 1954 by Act of Congress, Public Law 780, 83d Congress, 2d session. The principal features of this plan are the construction of revetted levees and channel clearing under the supervision of the Chief of Engineers. Construction of this project began in April 1959 and is scheduled to be completed in December 1961.

14. Overall project.--The overall project consists of Twitchell Dam, a multiple-purpose structure for water conservation and flood control, located at river mile 8.0 on the Cuyama River, and levee and channel improvements along the Santa Maria River and Bradley Canyon. Twitchell Dam was designed and constructed by the U. S. Bureau of Reclamation. The flood-control storage allocation and flood-control operation, were prescribed by the Corps of Engineers. Agreement was reached between the Bureau of Reclamation and the Corps of Engineers on the allocation for sediment deposition. The levee and channel improvements along the Santa Maria River were designed by the Corps of Engineers and that organization is the construction agency for these improvements.

15. Twitchell Dam is a zoned-earth dam with a maximum height of 216 feet above the Cuyama River. The crest of the dam at elevation 692 is 1,800 feet long. The embankment is constructed of three zones; an impervious central zone flanked by a pervious zone both upstream and downstream, and a miscellaneous zone in the downstream toe. A 25-foot deep cutoff trench is provided under the impervious zone. The general plan and sections of Twitchell Dam are shown on plate 6. The spillway (see pl. 7), located in the right abutment, is an ungated conduit type and consists of a rounded entrance with a level 50-foot uncontrolled crest at elevation 651.5, connecting with a 23-foot diameter discharge tunnel. The tunnel will flow full when reservoir water surface elevation reaches 618.5. The outlet works (see pl. 8) are located in the right abutment of the dam and discharge directly into the Cuyama River. They consist of (a) an intake structure with invert elevation at 504; (b) a 15.0 foot diameter upstream pressure conduit with a 5.0 by 11.0-foot intake port having an invert at elevation 474; (c) a 15.0-foot diameter upstream pressure tunnel; (d) a gate chamber with access shaft and control house; (e) a 19.0- by 17.0-foot downstream free flow tunnel; and (f) an open chute and stilling basin. Two tandem pairs of 7.0- by 12.0-foot outlet gates are located in the outlet works gate chamber. The upstream gates are normally wide open and function as guard gates. The downstream gates are operated for regulation of flow.

16. The reservoir at spillway crest elevation 651.5 has an area of 3,690 acres and a gross capacity of 240,120 acre-feet. The outlet discharges 12,700 cubic feet per second at spillway crest (low port assumed blocked). At top of dam, elevation 692.0, the reservoir has an area of 5,700 acres and a gross capacity of 426,000 acre-feet. At that elevation, the spillway capacity is 28,000 cubic feet per second and the outlet capacity is 14,000 cubic feet per second. Table 9 lists pertinent data for Twitchell Dam and Reservoir. Curves giving area and capacity, outlet discharge (low-port blocked), outlet discharge (low port open), and spillway discharge are shown on plates 9 through 12, respectively. A tabulation of areas and gross capacities are given in table 10.

17. The Santa Maria Valley improvements provide for about 17 miles of levee along the left bank of the Santa Maria River from Fugler Point to State Highway No. 1 bridge at Guadalupe; about 5 miles of levee along the right bank of the Santa Maria River from a point about 1-1/4 miles downstream from U.S. Highway No. 101 to a point about 1-1/2 miles upstream from the Southern Pacific Railroad bridge at Guadalupe; and channel clearing from Fugler Point to the Pacific Ocean. The Bradley Canyon improvements will consist of about 1.8 miles of channel and revetted levees from the mouth of Bradley Canyon to the Santa Maria River. The left side of the channel would be a revetted levee and the right side would be formed by excavating the natural ground to a slope of 1 on 4. Table 11 lists pertinent data for the Santa Maria Valley levees and channel improvements. The locations of the levees are shown on plate 5 and design discharges are shown on plate 13.

18. Changes to House Document plan.--The current plan for flood-control improvements in the Santa Maria River basin described under "Overall project" differs from the project-document plan given in House Document 400. The principal differences are as follows:

(a) The top of the dam was raised from elevation 660.0 to elevation 692.0 increasing the total storage from 153,250 acre-feet, to 426,000 acre-feet. A 150-foot gated spillway with crest at elevation 609.5 having three 50- by 34-foot radial gates was changed to an ungated tunnel spillway with rounded entrance incorporating a level 50-foot, ogee-type crest at elevation 651.5. In lieu of the gated spillway for control of flood flows, as described in the project-document plan, the outlet works with slide gates are used.

(b) Although the allocation of flood-control storage space in Twitchell Reservoir remains the same at 89,000 acre-feet, the 80,000 acre-feet of capacity for water conservation was increased to 110,000 acre-feet and the sediment storage was reduced from 45,000 acre-feet to 40,000 acre-feet.

(c) The capacity of the downstream levees at Fugler Point was increased from 150,000 cubic feet per second to 160,000 cubic feet per second.

19. Hydrologic basis of design.—The reservoir design flood for Twitchell Dam has an inflow Peak of 95,000 cubic feet per second and a maximum 1-day volume of 107,500 acre-feet. Estimates of the magnitude of the flood were based on the unit-hydrograph method using (a) the runoff that would have resulted from the storm of January 1943 if the center of the storm had occurred over the basin above the dam and if the ground conditions had been conducive to fairly high rates of runoff; (b) an average infiltration rate of 0.30 inch per hour for the upper-Cuyama River basin and 0.20 inch per hour for the remainder of the drainage area; (c) variable base flow for mountain and foothill

areas; (d) channel percolation rate of 1-1/2 cubic feet per second per wetted acre for upper Cuyama River area; and (e) negligible effect from snowmelt.

20. The spillway crest elevation for Twitchell Dam was established at elevation 651.5 by the U. S. Bureau of Reclamation, based on a gross storage requirement of 239,000 acre-feet consisting of 40,000 acre-feet for sedimentation, 110,000 acre-feet for conservation, and 89,000 acre-feet for flood control.

21. The spillway design flood developed by the U. S. Bureau of Reclamation has a peak inflow of 120,000 cubic feet per second and a total runoff volume (72 hours) of 368,000 acre-feet. Estimates of the magnitude of the flood were based on the unit-hydrograph method using (a) runoff that would have resulted from the storm of January 1943 if the center of the storm had occurred over the basin above the dam when the ground conditions were conducive to maximum runoff, and if the observed moisture and wind values were increased to a maximum; (b) an infiltration rate varying from 0.30 inch per hour to 0.20 inch per hour for the upper Cuyama River basin and 0.20 inch per hour to 0.10 inch per hour for the rest of the drainage area; (c) a maximum base flow of 4,000 cubic feet per second; and (d) negligible effect from snowmelt.

22. The height of the dam was determined by the U. S. Bureau of Reclamation after routing their spillway design flood through the reservoir. The routing was based on the assumption that the reservoir water surface was at elevation 623 (conservation pool) at the beginning of the flood. Inflow was passed through the outlets up to 2,000 cubic feet per second and this discharge was maintained until the reservoir reached elevation 649.5. At this elevation, releases were uniformly increased to the capacity of the outlet works. A maximum water-surface elevation of 686.5 was attained and the top of the dam was established at elevation 692.

23. The standard project flood which was used for the design of the Santa Maria Valley levees has a peak flow of 160,000 cubic feet per second. The development of the flood is identical to the development of the reservoir design flood, with the exception that the design storm was centered over the Sisquoc River area and the uncontrolled area below Twitchell Dam.

24. The standard project flood for Bradley Canyon levees has a peak flow of 9,000 cubic feet per second above the confluence with the Santa Maria River. Estimates of the magnitude of the flood were based on (a) runoff that would result from the thunderstorm of March 1943, which occurred in the Los Angeles area, if that storm had occurred over the Bradley Canyon area (on the basis of studies indicating that dewpoint temperature decreases with an increase in latitude, precipitation amounts were decreased 10 percent), and if

the ground conditions had been conducive to fairly high rates of runoff; (b) constant infiltration rate of 0.20 inch per hour; and (c) constant base flow.

25. Sedimentation.--The amount of sediment expected to be deposited in Twitchell Reservoir was determined by the U. S. Bureau of Reclamation on the basis of an analysis of runoff samples. A relationship between sediment load and discharge was developed, and using a flow-duration curve, a long term sediment yield was determined. It was estimated that 400 acre-feet of sediment per year would be deposited. Under the assumption that this rate of deposition would continue during the 100-year period following completion of the dam, 40,000 acre-feet of storage was allocated to sedimentation. It was assumed that this sediment would fill the reservoir to elevation 504 at the end of a 100-year period. It is anticipated that the Regional Director of the Bureau of Reclamation will, at reasonable intervals, make necessary field surveys and office studies to prepare estimates of the volume and location of sediment deposits in the reservoir. If the results of such studies show that the 40,000 acre-feet of storage allocated to sedimentation has been depleted, and the net storage initially allocated to flood control (89,000 acre-feet) or conservation (110,000 acre-feet), respectively, is reduced by an amount exceeding, 10 percent of the allocation for either purpose, the operating plan described herein with respect to storage allocations shall be reviewed with the view of reestablishing an equitable distribution between the primary reservoir uses.

OPERATION

26. Project-document operation plan.--The plan of operation for Twitchell Dam as set forth in House Document No. 400, 83d Congress, 2d session, is described in detail in appendix 3 of the Corps' report titled "Report on Survey, Flood Control, Santa Maria River and Tributaries, California" and dated 10 February 1953. That plan provided for a conservation pool to be developed to elevation 612.0 at the start of a flood. Outflow would then be made equal to inflow to 2,000 cubic feet per second. The outflow would then be maintained at 2,000 cubic feet per second until the water surface reached elevation 641.5. Above this elevation the outflow would be increased 23,700 cubic feet per second for each foot of rise in water-surface elevation. The spillway gates would be wide open at water-surface elevation 646.5. Under this operation plan, the reservoir design flood at Twitchell Dam with a peak inflow of 95,000 cubic feet per second would be reduced to a peak outflow of 43,000 cubic feet per second. The standard project flood on the Santa Maria River at Fugler Point would be reduced from an uncontrolled peak of 230,000 cubic feet per second to a peak of 150,000 cubic feet per second.

27. Flood-operation plan.--Extensive changes in the design of Twitchell Dam since the project was authorized have resulted in

development of a revised flood-operation plan. The gate operation schedule for this plan is given in table 12. In this plan, the low port is assumed blocked and the outlet gates remain closed until a conservation pool is developed to elevation 623. Between elevations 623 and 624, the outlet discharge is increased in steps until the outlet gates are fully opened and discharging 11,630 cubic feet per second. Above elevation 624.0, the outlet gates remain fully opened. For optimum conservation of spillway surcharge space in maximum-type floods, the outlet discharge is not transferred to the spillway. The same schedule is used for rising and falling stages.

28. With the outlet gates fully opened, a discharge of 12,700 cubic feet per second is attained at spillway crest. This discharge causes no damage in flowing through the narrow undeveloped valley extending from the dam to Fugler Point. The unimproved channel reach from Guadalupe to the ocean will also carry the maximum release from the dam without damage. However, as previously stated, it is not economically feasible to improve this reach to carry the 150,000 cubic feet per second peak that would result from a channel design flood.

29. Routing the reservoir design flood.--The reservoir design (standard project) flood developed by the Corps of Engineers was routed through Twitchell Reservoir under the flood-operation plan. It was assumed that the reservoir water surface was at elevation 623 (top of conservation pool) and the low port blocked at the start of the routing. A plot of this routing is shown on plate 14. The peak inflow of 95,000 cubic feet per second is reduced to a peak outflow of 12,700 cubic feet per second and a water-surface elevation of 651.3 is reached.

30. Routing the spillway design flood.--The spillway design flood developed by the U. S. Bureau of Reclamation was routed through Twitchell Reservoir under the flood-operation plan. It was assumed that the reservoir water surface was at elevation 623 (top of conservation pool) and the low port blocked at the start of the flood. A plot of this routing is shown on plate 15. The peak inflow of 120,000 cubic feet per second is reduced to a peak outflow of 39,700 cubic feet per second and a water-surface elevation of 683.9 is reached.

31. Channel design flood at Fugler Point.--For the channel design (standard project) flood at Fugler Point (based on centering the January 1943 storm below Twitchell Dam), the outflow from the dam under the flood-operation plan was routed to Fugler Point and combined with the discharges from the Cuyama River below the dam and from the Sisquoc River as shown on plate 16. A peak discharge of 160,000 cu1bic feet per second was obtained at Fugler Point.

32. Conservation operation.--At the present time the conservation storage in Twitchell Reservoir consists of 151,050 acre-feet below elevation 623 including 40,000 acre-feet for sedimentation.

Floodwaters are retained below elevation 623 for subsequent release at the percolation capacity of the downstream channel, which is estimated to be 300 cubic feet per second or less.

33. Organization for flood-control operation.--The organization for effecting the flood-control operation of Twitchell Dam is shown on plate 17. The names and telephone numbers of key personnel are shown on plate 18. The Regional Director, Region 2, U. S. Bureau of Reclamation, is charged with the responsibility for the actual flood-control operation of Twitchell Dam. He is required to keep the District Engineer, U.S. Army Engineer District, Los Angeles, currently advised of hydrologic and hydraulic data for the Santa Maria River basin and Twitchell Dam. Specifically, such data will include: (a) precipitation amounts, (b) streamflow at critical locations, and (c) reservoir inflow, outflow, and storage. During normal periods, this information is transmitted by mail, but during emergencies, telephone or telegraph is used. The information received from the Bureau of Reclamation is analyzed in the Control Group, under the supervision of the chief, Hydraulic Operations Section.

34. Operation and maintenance of the Santa Maria project were transferred by contract from the U. S. Bureau of Reclamation to the Santa Barbara County Water Agency, which agency in turn transferred the operation and maintenance of Twitchell Dam to the Santa Maria Water Conservation District.

35. Modification of flood-control regulations.--The District Engineer, U.S. Engineer District, Los Angeles, may temporarily modify the flood-control regulations for Twitchell Dam (appendix A), if necessary, in time of emergency. Requests for and action on such modification may be made by any available means of communication to the Regional Director, Region 2, U. S. Bureau of Reclamation, and the action taken shall be confirmed in writing under date of the same day to the office of the Regional Director. In the event of danger of major damage to or failure of the downstream levee system, the Santa Maria Valley Water Conservation District may temporarily adjust releases required by the flood-control regulations upon request of the county of Santa Barbara, pending action by the District Engineer on the request for approval of such adjustment. The county of Santa Barbara is the agency responsible for the operation and maintenance of the levee system. Recommendations for revision of the flood - control regulations will be made to the Secretary of the Army upon mutual agreement of the Corps of Engineers and the Bureau of Reclamation.