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GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1329-A

A discussion of potential development of power and reservoir sites on East and West Forks, Carson River

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Douglas McKay, *Secretary*

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WATER-POWER RESOURCES IN THE UPPER CARSON RIVER BASIN, CALIFORNIA-NEVADA

By H. L. PUMPHREY

ABSTRACT

West Fork Carson River offers the best opportunity for power development in the Carson River basin. The Hope Valley reservoir site could be developed to provide adequate storage regulation and concentration of fall would permit utilization of 1,400 feet of head in 5½ miles below the dam site, or 1,900 feet of head in about 9½ miles below the dam site; however, the average annual runoff susceptible of development is only about 70,000 acre-feet which limits the power that could be developed continuously in an average year with regulation to about 8,700 kilowatts utilizing 1,400 feet of head, or 12,000 kilowatts utilizing 1,900 feet of head. The method and degree of development will be determined to large extent by the method devised to supplement regulated flows from the Hope Valley reservoir to supply the water already appropriated for irrigation. If the Hope Valley site and the Watasheamu site on East Fork Carson River were developed coordinately water could be transferred to the West Fork for distribution through canals leading from that stream thus satisfying the deficiency due to regulation at Hope Valley and release of stored water on a power schedule. This would permit utilization of the entire 1,900 feet of fall.

Independent development of the West Fork for optimum power production would require re-regulation of releases from Hope Valley reservoir and storage of a considerable part of the fall and winter flow for use during the irrigation season. Adequate storage capacity is apparently not available on the West Fork below Hope Valley; but offstream storage may be available in Diamond Valley which could be utilized by diversion from the West Fork near Woodfords. This would limit the utilization of the stream for power purposes to the development of the 1,400 feet of head between the Hope Valley dam site and Woodfords.

In a year of average discharge East Fork Carson River and three of its principal tributaries could be developed to produce about 13,500 kilowatts of firm power upstream of the Watasheamu site, which has been proposed as the location of a storage reservoir, the principal use of which would be for irrigation and flood control purposes. Substantial storage regulation would be required because of the seasonal variation in flow; and while sufficient storage capacity is available for such regulation, its value for power development is limited because of the lack of concentration of fall below the storage sites where head could be economically developed.

The Watasheamu reservoir with a powerplant near the Horseshoe Bend site could be operated to develop about 5,400 kilowatts of continuous power in a year

of average discharge; however, priority to use of water for irrigation purposes would undoubtedly require operation of the Watasheamu reservoir on a schedule unfavorable to the production of firm power. It is estimated that 47 million kilowatt-hours represents the maximum generation capability of a plant at the Horseshoe Bend site in year of average discharge and a large proportion of this amount would be generated during the period of peak irrigation demand and would be seasonal in nature. Installation of about 7,000 kilowatts of capacity in a plant at the Horseshoe Bend site appears feasible. Annual energy generation would probably be less than the maximum represented by streamflow, depending on the magnitude of releases from the Watasheamu reservoir for irrigation and the demand for seasonal power.

It is judged, from a general consideration of the probable cost of the required structures in relation to the benefits which would accrue from the power that could be produced, that development of East and West Forks Carson River for power purposes only would not be feasible.

INTRODUCTION

Certain lands in the Carson River basin were withdrawn as potential reservoir sites under the authority contained in the legislation of 1888. This act was repealed in 1890 but the withdrawals are still in force. This report presents the results of a study that had been made to review these withdrawals and the relation of the reserved lands to possible water-power development, and to determine if retention of these reserves is justified when judged in the light of information, particularly maps and streamflow data, which has become available since the lands were withdrawn.

The power possibilities of the basin are discussed on the basis of regulated flow only. No estimates of power from unregulated flow are given because the runoff characteristics indicate that run-of-the-river plants would not be feasible because of the long periods of low flow.

Plans of development discussed herein are provisional and intended only as a device for presenting the basic data which has accumulated and estimating the potential power of the streams in the basin.

PREVIOUS INVESTIGATIONS

Potentialities for storage of water on tributaries of the Carson River have long been recognized as evidenced by the early withdrawals of reservoir sites under the Act of 1888.

Water-Supply Paper 300 (p. 156, 171, 175) of the Geological Survey refers to the cooperation of the Stone and Webster Engineering Corporation in furnishing records of streamflow in the upper Carson River basin for the years 1910–11, indicating that sites in the basin were being investigated as possible sources of electric power early in the history of the industry.

The Corps of Engineers, U. S. Army, has congressional authorization to investigate storage possibilities in the basin for flood control purposes. Their progress report dated Feb. 7, 1953, lists the District submission date of the report as indefinite.

F. E. Bonner (1928, p. 150) briefly mentions the East and West Forks of Carson River. He concluded that physical conditions were not favorable for power development on the East Fork, but went on to describe the Hope Valley site on the West Fork where he estimated the average usable water supply from unregulated flow would be about 50 cfs and average power output about 4,000 kilowatts.

The Bureau of Reclamation instituted investigations in the basin soon after the origin of its predecessor, the Reclamation Service, and has conducted them intermittently since that time. The Hope Valley dam site on West Fork Carson River was mapped by that organization in 1903.

An application for Project 127 was filed with the Federal Power Commission on Dec. 3, 1920, but was later withdrawn. This plan, as delineated on project diagrams, featured diversion of the flow of West Fork Carson River near Hope Valley dam site, apparently with some storage regulation. Water so diverted would have been conducted by conduit along the north side of the West Carson Canyon about 8½ miles to a forebay in SW¼ sec. 14, T. 11 N., R. 19 E.; then by penstock another 3 miles to a powerhouse on West Fork Carson River in the NW¼ sec. 8, T. 11 N., R. 20 E., near the California-Nevada State line. The head between the proposed forebay and powerplant was reported to be 2,077 feet.

MAPS AND PHOTOGRAPHS

A set of maps entitled "Carson River and East Fork from Dayton, Nev., to mile 80, and West Fork to mile 30" was prepared by the Geological Survey during the period 1934–36. This set of maps is on a scale of 1:31,680 (2 inches=1 mile) with a contour interval of 5 feet on the river surface and 20 feet on land, with a supplementary interval of 10 feet on land in the very flat areas. Topography in general is shown to an elevation of about 200 feet above the river surface. Several dam sites were mapped in detail on scales of 1:2,400 or 1:4,800 and have been combined with the river plan and profile to form the complete map set.

Topographic maps of Markleeville and Dardanelles quadrangles, scale 1:125,000, contour interval 100 feet, prepared by the Geological Survey, by reconnaissance methods, cover the portion of the upper Carson River basin discussed herein. The basin is also covered by U. S. Forest Service planimetric maps of Otts Creek, Freel Peak, Silver Lake, Ebbet Pass, Topaz Lake, Sonora Pass, and Dardanelles Cone quadrangles, scale 1:31,680.

Aerial photographs of the entire area are available from the U. S. Forest Service.

GEOGRAPHICAL FEATURES

LOCATION OF AREA

The Carson River is formed in Carson Valley, Nev., by the union of its East and West Forks. These drain the section of the steep eastern slope of the Sierra Nevada lying between the Lake Tahoe and the West Walker River basins in California.

East Fork Carson River drains the larger area and is considered to be the continuation of the main stream. It rises in sec. 23, T. 6 N., R. 21 E., Mount Diablo baseline and meridian (Calif.-Nev.), at an elevation of 10,000 feet, and flows in a general northerly direction to a point in sec. 14, T. 13 N., R. 19 E., near Minden, Nev., where it is joined by the West Fork Carson River. The length of the East Fork above the junction is 52 miles and the total fall in that distance is 5,300 feet, of which 3,000 feet is in the upper 13 miles. The principal tributaries are Pleasant Valley, Silver, Wolf, and Silver King Creeks. These, with the exception of Silver King Creek, rise on the east side of the Sierra Nevada divide at an elevation of 9,000 feet and drain the west side of the East Fork Carson River basin. Silver King Creek rises to the east of the headwaters of East Fork Carson River and drains the southeastern part of the basin. Monitor and Bryant Creeks, relatively unimportant tributaries, drain the east side of the basin.

West Fork Carson River rises in sec. 7, T. 9 N., R. 19 E., at an elevation of 8,500 feet. It flows north and east through Hope Valley and West Carson Canyon to its junction with the East Fork. The length of the West Fork is 32 miles and the fall above the junction is 3,900 feet of which 3,600 feet is in the upper 22 miles.

The Carson River flows northward from the junction of its East and West Forks to a point near Carson City, Nev., where it turns to the northeast and flows into the Lahontan reservoir in T. 19 N., R. 26 E., where storage capacity of 294,400 acre-feet (with flash-boards) has been developed to regulate water from the Carson and Truckee Rivers for irrigation of lands in Carson Valley. Many diversions for irrigation are made directly from the river above the Lahontan reservoir. Water in excess of that used for direct diversion or subject to capture in Lahontan reservoir wastes into Carson Sink.

The part of the Carson River basin discussed in this report consists of 472 square miles in Alpine County, Calif., and Douglas County, Nev. East Fork Carson River drains 347 square miles lying above the gaging station "East Fork Carson River near Gardnerville, Nev.," and West Fork Carson River drains 125 square miles lying above the California-Nevada State line. All the sites which appear to be favorable for storage development and all the withdrawn lands considered herein are located above these points.

At several places, streams of the upper Carson River basin flow through short, broad valleys, probably of glacial origin, ranging in elevation from 7,000 feet at Hope Valley on the West Fork to 5,900 feet at Pleasant Valley on Pleasant Valley Creek. These valleys were long ago recognized as potential storage sites and were the subjects of several of the withdrawals under the Act of 1888. (See pl. 1.) With the exception of these valleys the streams in the basin are largely confined to canyons in the upper reaches; however, as they approach the plain at the eastern base of the Sierra Nevada the steep-walled canyons open into narrow, terraced valleys with lower dividing ridges. Small areas of arable land occur in these foothill valley bottoms.

LAND USE

Agriculture consists for the most part of the raising of forage crops in the arable areas and summer grazing of livestock in the high mountain meadows and valleys and on the foothill ridges.

Mining enterprises were active in the past and several small hydroelectric plants were constructed on streams in the basin to serve the industry. Mining has now been reduced to the operation of a few lode claims and the powerplants are no longer in operation.

Land in the basin not privately owned is within the Toiyabe National Forest. Merchantable timber is scattered along the eastern slope of the Sierra Nevada where soil conditions will support growth. This timber is now being logged to some extent (1953).

Low flows of most of the streams in the basin are adequate to sustain fish life and trout fishing is reported to be good. Deer hunters throng the area during the open season.

TOWNS AND ROADS

The area is accessible by good motor roads. California State Highway 88, a paved road that joins Nevada State Highway 37 near Fredricksburg, follows West Fork Carson River through West Carson Canyon and into Hope Valley where it leaves the river and goes over the crest of the Sierra Nevada, and out of the basin, through Kit Carson Pass.

California State Highway 4, also paved, leaves State Highway 88 at Woodfords and leads south to Markleeville, thence up East Fork Carson River and Silver Creek and leaves the basin over the Sierra Nevada through Ebbett Pass. State Highways 4 and 88 both terminate at Stockton, Calif.

State Highway 89, another paved road, joins State Highway 88 in the lower end of Hope Valley, goes north through Luther Pass into the drainage basin of Lake Tahoe and joins U. S. Highway 50, near Meyers, near the south end of Lake Tahoe. These roads are usually closed during the winter by snow in the passes.

A new California State Highway (number as yet unassigned) leaves State Highway 4 at the mouth of Monitor Creek and goes southeast past Heenan Lake and Leviathan Peak and into Antelope Valley where it joins U. S. Highway 395 near Coleville, Calif.

A secondary road joins State Highway 88 in Hope Valley and follows West Fork Carson River for about 5 miles, crosses the divide into the drainage basin of East Fork and continues southward to the Pacific Gas and Electric Company camp near the crest of the Sierra Nevada at lower Blue Lake reservoir in the drainage basin of Mokelumne River. Other secondary roads of relative unimportance have been constructed in the basin and are mentioned in subsequent discussions if their locations affect sites which appear to have possibilities for storage development.

Markleeville with a population of less than 250 is the only town in the area and is also the county seat of Alpine County. At the junction of State Highways 4 and 88 is Woodfords, which now consists only of a combination service station and general store and a highway maintenance station. Paynesville with a few similar buildings is also located at crossroads. Several similar places are shown as towns on recent maps. These may have been substantial settlements when mining operations were extensive but practically all evidence of former activity has disappeared.

GEOLOGIC FEATURES

The geology of the Markleeville quadrangle is described briefly by Lindgren (1911), who reports that the mapping was based on reconnaissance work by Herbert C. Hoover and Lindgren in 1895 and earlier work by H. W. Turner.

Two types of rock occur extensively in the upper Carson River Basin. The granitic rocks which form the core of the Sierra Nevada are exposed in an area roughly paralleling the rim of the basin on the west and south and extending northward on the east side of the basin to the vicinity of Leviathan Peak. The central part of the basin is largely covered with volcanic rocks consisting of andesite breccias, in places tuffaceous, similar to the andesite flows and tuffs which are exposed so extensively on the western slope of the Sierra Nevada. Scattered patches of this andesite rest on the granite which forms the crest of the Sierra Nevada suggesting that this rock can be correlated across the break of the Sierra Nevada and indicating that it is older than the beginning of the mountain-building process.

The elevation of the Sierra Nevada mountains has been accomplished by the westward rotation of the Sierran block associated with extensive block faulting along the eastern face of the range. This faulting is expressed by the impressive scarps which face to the eastward on the west side of the Carson, Antelope, and Owens Valleys and to somewhat lesser extent elsewhere. The scarps on the east and west sides of Lake Tahoe are also associated with this eastern zone of faulting.

Lindgren mapped a fault from the vicinity of Markleeville northward, crossing West Fork Carson River near Woodfords, and continuing along the eastern base of Jobs Peak and the Carson Range to Genoa and Carson City (the Genoa scarp). West Fork Carson River rises in the granitic areas above Hope Valley and crosses this fault scarp in West Carson Canyon. The vertical displacement of about 2,000 feet is reflected in the cascades and rapids which occur in the stream in its course through the canyon. According to Lindgren (1911, p. 190):

> The East Fork traverses from south to north the entire volcanic area, and so far as can be seen, has not been affected by later faulting . . . . At first glance it is difficult to understand why a postandesitic depression of 2,000 feet should not have affected the volcanic area drained by the East Fork. The answer is that it undoubtedly did affect that area, but that the dislocation along the scarp passed into a gradual flexure in the andesite.

The faulting, which caused a rejuvenation of the West Fork creating a section of concentrated fall and thus enhancing its value for power development, has not produced a similar result on the East Fork, which has no sections of concentrated fall in the lower reaches.

EARTHQUAKES

Lindgren (1911, p. 189) speculated that movement had occurred along the Genoa fault north of Woodfords within the last 50 years. This conclusion was based on the occurrence of:

> A distinct fault line at the foot of the escarpment which can be traced for 2,000 feet, within which distance the small debris fans at the mouth of the gulches are faulted with scarp being about 40 feet high. Between the little gullies the fault cuts the solid rock...

According to Louderback (1924, p. 30):

> The evidence, both stratigraphic and physiographic, as obtained from various localities along the east front of the Sierra Nevada, all consistently points to the conclusion that the faulting that produced the present scarps and that was the primary tectonic agent which has determined the physiographic characteristics of the eastern range slopes and flanking valleys was the product of one period of faulting which began not earlier than late Tertiary time (Pliocene); that the

bulk of the work was done before the late Pleistocene, but that some movements have continued down to a very recent date, and further action is to be expected in the future.

The earthquake of 1872, which centered in the Owens Valley area, was one of the most severe that the Pacific Coast has ever experienced, although there was less destruction of life and property than caused by the San Francisco earthquake of 1906. The shock was felt over the greater part of California and Nevada and southward far into Mexico; at one place about 3 miles east of Independence, Calif., a road was cut off by a fissure 12 feet wide and displaced about 18 feet horizontally (Whitney, 1872).

Lindgren's description of the Genoa region, Whitney's description of the Owens Valley earthquake, and Louderback's general remarks on the age of the fault scarps in the Great Basin, indicate that it is not unlikely that movements in the fault zone along the eastern side of the Sierra Nevada are still in progress. Recent earthquakes along the southern edge of the Sierra Nevada near Tehachapi may possibly be associated with movements of the Sierran block and if so will serve further to confirm the activity of the eastern Sierra Nevada faults.

FACTORS AFFECTING HYDRAULIC STRUCTURES

In the upper Carson River basin, where hydraulic structures might be built, elevation ranges from about 5,000 to 7,000 feet. The average annual temperature at the 7,000-foot level is estimated to be about 44° F. Ice conditions are general during the winter and all structures would be subjected to periods of freezing weather.

In view of the occurrence of recent fault zones running through the area and the possibility of future earthquakes, consideration in the planning of hydraulic structures, particularly dams, should be given to providing a design that will resist seismic forces.

HYDROLOGIC FEATURES

CLIMATE

Precipitation records have been maintained in or adjacent to the basins of the East and West Forks for varying periods. Rainfall is heavy at the crest of the Sierra Nevada but drops off sharply to the east as the eastward-moving storms precipitate most of their moisture in passing over that barrier. Stations at Twin Lakes and Tamarack, near the crest of the divide, have an average annual rainfall for the periods of record of 43 and 47 inches respectively, while Markleeville and Woodfords, about 10 miles to the east, have averages for periods of record of 19 and 18 inches. Shields Ranch, about 20 miles to the east of the divide, has an average of only 11 inches. A summary of the records is given below.

Station	Elevation (feet)	Period of record	Average rainfall (inches)	Normal by comparison with Placerville 1874–76, 1879–1950 (inches)
Twin Lakes	7,970	1920–21, 1923–50	43.4	48.6
Tamarack	8,000	1899–1902, 1906–27	46.8	49.2
Markleeville	5,526	1910–27	18.8	21.0
Woodfords	5,625	1939–50	18.3	19.3
Shields Ranch	5,300	1910–45	11.3	12.5

Snowfall records for three of the above stations through the year 1931 are summarized below.

Station	Elevation (feet)	Period of record	Average snowfall (inches)
Twin Lakes	7,970	1920, 1923–31	331
Tamarack	8,000	1906–27	451
Shields Ranch	5,300	1914–31	44

The average annual temperatures range from 39° F at Twin Lakes to about 48° F at Woodfords.

RUNOFF

Runoff is derived largely from snow accumulated at the higher elevations during the winter months. May and June are usually the months of heaviest runoff, and in an average year approximately 80 percent of the total occurs in the period April through July. On rare occasions in the past the combination of high temperature and rain have caused unseasonable winter floods such as occurred in December 1937 and November-December 1950. In the 1950 flood 41 percent of the total annual runoff occurred in this 2-month period.

Discharge records for stations in the upper Carson River basin, as listed in table 1, are available in water-supply papers of the U. S. Geological Survey (1913–50) relating to the surface water supply of the Great Basin.[1] The record for the West Walker River near Coleville also is given, since it was used indirectly to estimate the runoff of West Fork Carson River for periods when no records were obtained thereon.

WEST FORK CARSON RIVER

WATER-SUPPLY CHARACTERISTICS

A gaging station has been maintained intermittently at the station at Woodfords since 1890. (See table 1.) The average annual runoff for the 50-year period, 1891 and 1902–50, is estimated to have been 79,000 acre-feet. (Missing records were estimated from the more com-

[1] Records prior to 1911 are summarized in Water-Supply Paper 300. A list of miscellaneous discharge measurements is included in each volume cited.

TABLE 1.—*Records for gaging station in the upper Carson River basin*

Stream	Station	Drainage basin	Drainage area (sq. mi.)	Period for which records are available	Average discharge for years indicated
West Fork Carson River	Near Woodfords	West Fork Carson River.	66	Oct. 1900–May 1907, 1910–11 (fragmentary); Oct. 1938 to date. Apr. 1890–Mar. 1892 and June 1907–Sept. 1920, at site 0.7 mile downstream.	27 years (1901–03, 1905–15, 1916–20, 1939–50), 124 cfs.
Do	Above Woodfords	do	53	Dec. 1946–Oct. 1950.	
East Fork Carson River	Near Gardnerville, Nev	East Fork Carson River.	344	May 1939–Sept. 1950, Apr. 1890–Dec. 1893, Oct. 1900–Dec. 1906, June–October 1917, Dec. 1924–Sept. 1929, and Oct. 1935–Dec. 1937, at site 2 miles downstream. Mar. 1908–Dec. 1910, at site 2 miles upstream.	23 years (1890–93, 1901–03, 1908–10, 1925–28, 1935–37, 1939–50), 399 cfs.
Do	Above Soda Springs ranger station.	do	30	Sept. 1946–Sept. 1950.	
Pleasant Valley Creek	Above Raymond Canyon	do	16	Oct. 1946–Sept. 1950.	
Hot Springs Creek	Above Grover Hot Springs	do	14	Oct. 1946–Sept. 1950.	
Silver Creek	Below Pennsylvania Creek	do	20	Dec. 1946–Sept. 1950.	
Wolf Creek	Near Markleeville	do	9.8	Sept. 1946–Sept. 1950.	
Silver King Creek	Near Coleville	do	30	Sept. 1946–Sept. 1950.	
West Walker River	do	West Walker River	182	Apr. 1938–Oct. 1950 and Oct. 1902–July 1908 at site 9½ miles downstream.* Mar. 1909–Aug. 1910 and June 1915–Mar. 1938, at site 10 miles downstream.*	11 years (1938–49), 246 cfs.

*Records are reported to be equivalent.

plete data for West Walker River near Coleville.) The maximum recorded discharge was 4,730 cfs on Nov. 20, 1950, and the minimum was 8.4 cfs on Nov. 21, 1948. The average annual runoff for the 7 water years 1928–34, a period of low flow, was estimated to be about 40,000 acre-feet.

An additional gaging station was established on West Fork Carson River about 4 miles west of Woodfords in December 1946. (See table 1.) This station is a short distance downstream from the Hope Valley dam site and no doubt was located to furnish a measure of the runoff at that site. Comparison of the records for the 4 water years 1947–50 indicates that the discharge was 88 percent of that at the station at Woodfords. The duration characteristics of annual discharge at the station "West Fork Carson River at Woodfords" are shown on figure 1.

Figure 1 shows that the mean discharge for the 50-year period of record was 79,300 acre-feet per year and this occurred 42 percent of the time; that for 25 years of the period, or 50 percent of the time, the annual value was 76,000 acre-feet; and for 45 years, or 90 percent of the time, it was 37,600 acre-feet. The minimum annual, or 100 percent of the time, value was 14,200 acre-feet. Assuming a ratio of 88 percent, the corresponding values for the station at the Hope Valley dam site would be 70,000, 67,000, 33,100, and 12,500 acre-feet per year.

Water now appropriated from West Fork Carson River for irrigation is equal to an annual flow equivalent of 55 cfs or about half the average annual runoff of the stream. This is diverted during the irrigation season as available. A plan to develop power on the stream would accordingly have to provide a means of satisfying these prior rights to the use of water. Either importation of water from an outside source or re-regulation of upstream power releases would provide a solution to the problem.

DEVELOPED STORAGE

The flow of West Fork Carson River is slightly regulated by storage at Crater, Red, and Lost Lakes where combined capacity of about 1,500 acre-feet has been provided to supplement the supply of water available for irrigation late in the season.

UNDEVELOPED RESERVOIR SITE—HOPE VALLEY

The Hope Valley reservoir site to which reference has already been made is located on West Fork Carson River just above West Carson Canyon. The dam site, stream elevation 7,000 feet, is in lot 2 sec. 25, T. 11 N., R. 18 E. This and part of the reservoir area are shown on the Geological Survey map of Carson River. The dam-site area was mapped on a scale of 1:2,400 to an elevation of 7,200 feet, and the reservoir site was mapped on a scale of 1:31,680 to an elevation of 7,120 feet. The capacities above the 7,120 contour in the table below

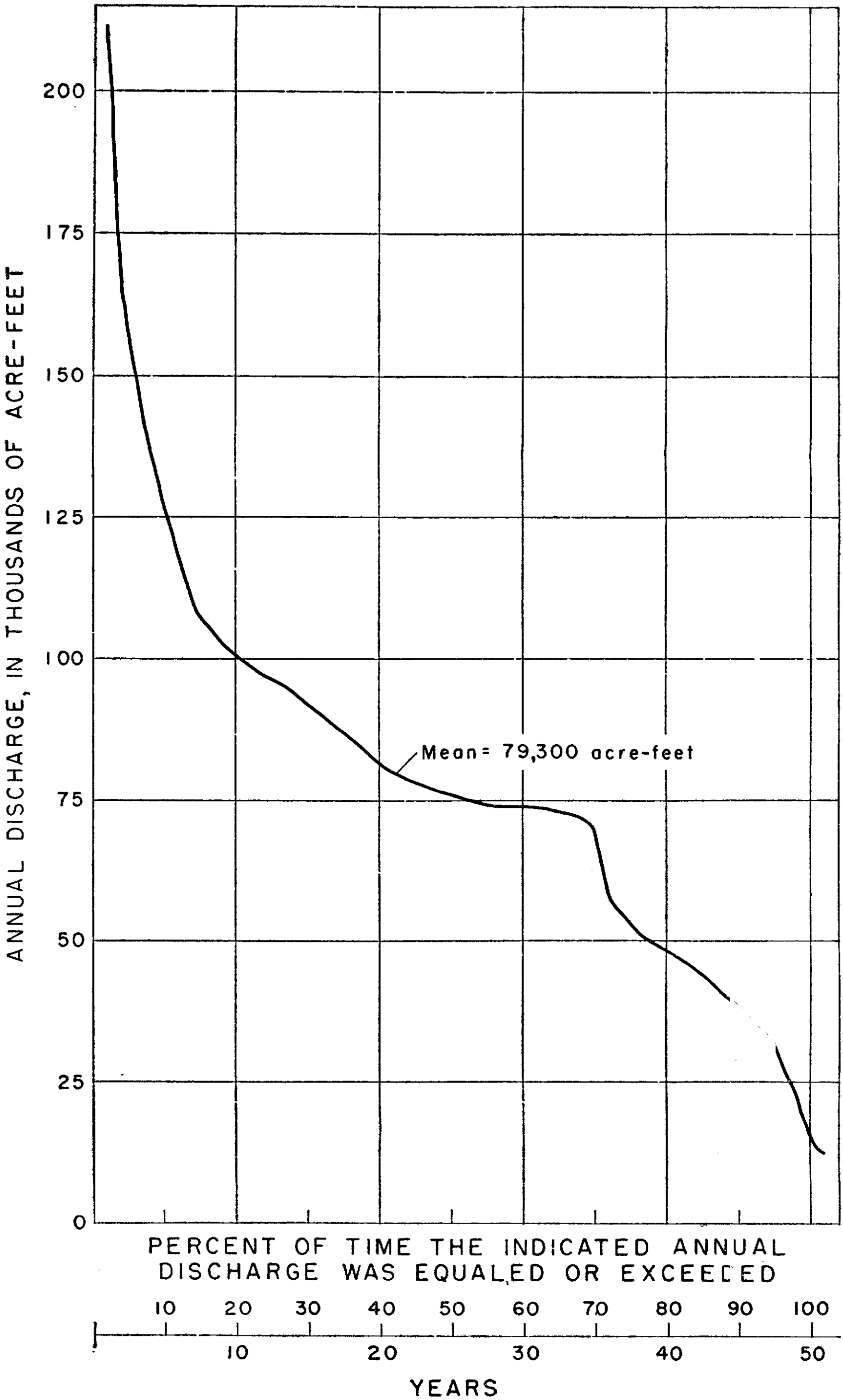

FIGURE 1.—Duration curve of annual discharge, West Fork Carson River at Woodfords, Calif., 1891 and 1902–50.

were estimated by extension of the capacity curve and may be somewhat in error.

Area and capacity of Hope Valley reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
7,000	-----	--------	7,100	570	12, 600
7,020	2	20	7,120	1, 180	30, 100
7,040	6	100	7,150	-----	[1] 85, 000
7,060	57	730	7,200	-----	[1] 150, 000
7,080	282	4, 120			

[1] Estimated from extension of the capacity curve.

Lands which would be affected by a reservoir at the Hope Valley site are withdrawn in Hope Valley Reservoir Site 41. Certain parts of the area as indicated on plate 1 are also withdrawn in Federal Power Project 127.

A dam 125 feet high would develop a storage capacity of 40,000 acre-feet. This is the amount which would be required to control the average annual discharge of 70,000 acre-feet at the Hope Valley site on a year-to-year basis. This is illustrated in the schedule of operation shown in table 2. It is based on the discharge at the gaging station "West Fork Carson River above Woodfords" in the water year 1950, which was 97 percent of the average of the 50-year period considered herein. Runoff at this station is assumed to be the same as the runoff at the Hope Valley dam site. A uniform release of 88 cfs could have been maintained 100 percent of the time with storage capacity of 37,000 acre-feet. The reservoir content was assumed to be 26,000 acre-feet on Sept. 30, 1949. Only the loss due to evaporation was considered and this was applied roughly in accordance with the magnitude and distribution of evaporation at Lake Tahoe, elevation 6,223 feet. It was estimated that the annual evaporation would have been about 41 inches or about 3,200 acre-feet from the hypothetical reservoir at Hope Valley.

TABLE 2.—*Illustrative schedule of operation, in acre-feet, Hope Valley reservoir, year ending Sept. 30, 1950*

Month	Inflow	Release	Loss [1]	Release plus loss	Gain or loss	Contents end of month
September	-------	-------	------	-------	-------	26, 000
October	652	5, 442	286	5, 728	−5, 076	20, 924
November	802	5, 266	158	5, 424	−4, 622	16, 302
December	712	5, 442	72	5, 514	−4, 802	11, 500
January	1, 240	5, 442	59	5, 501	−4, 261	7, 239
February	1, 380	4, 915	33	4, 948	−3, 568	3, 671
March	2, 470	5, 442	29	5, 471	−3, 001	670
April	14, 000	5, 266	74	5, 340	+8, 660	9, 330
May	24, 170	5, 442	275	5, 717	+18, 453	27, 783
June	14, 950	5, 266	495	5, 761	+9, 189	36, 972
July	4, 040	5, 442	620	6, 062	−2, 022	34, 950
August	2, 220	5, 442	610	6, 052	−3, 832	31, 118
September	1, 190	5, 266	473	5, 739	−4, 549	26, 56

[1] Estimated evaporation loss.

Examination of the duration curve (fig. 1) indicates that a similar schedule, based on an annular runoff of 70,000 acre-feet, could have been maintained without deficiency for 21 of the 50 years of record used herein. Uniform flows which could have been maintained on a yearly basis for the total period after deducting estimated losses due to evaporation are listed below.

Flow (cfs)	Time available [1] Years	Percent	Flow (cfs)	Time available [1] Years	Percent
91	21	[2] 42	40	45	90
87	25	[3] 50	28	48	96
81	35	70	12	50	100

[1] During 50-year period of record.
[2] Average.
[3] Median.

The Hope Valley capacity table (p. 13) indicates that storage of 150,000 acre-feet (about twice the average annual runoff) could be developed by a dam 200 feet high at the Hope Valley site. With storage capacity of that amount it is estimated that a uniform flow equal to the average annual discharge, or 95 cfs, could have been maintained without deficiency during the first 23 years of the period. Loss due to evaporation would have been more than equaled by excess runoff. During the last 27 years of the period an estimated uniform flow of 69 cfs could have been maintained after making allowance for evaporation losses. By the end of the extreme low-flow period of 1928–34 the reservoir would have been nearly emptied but would have filled again by the end of 1943. During the last 7 years of the period inflow would have very slightly exceeded release of 69 cfs plus loss.

The use of water stored at the Hope Valley site for power development would require re-regulation of power releases or importation of water from an out-of-basin source to satisfy prior rights for irrigation. Water could be transferred from East Fork Carson River to supplement regulated flow from the Hope Valley site for irrigation in the part of the Carson Valley which is now supplied by diversion from the West Fork.

There is a site at the lower end of the valley below Woodfords where construction of a 100-foot dam would provide capacity of about 5,000 acre-feet, which could be used for re-regulation of the discharge from a powerhouse. A dam at this site would require relocation of half a mile of State Highway 88. The cost of storage probably would be high in relation to the small amount of regulation afforded.

Examination of the topographic map of the Markleeville quadrangle indicates that some storage might be developed by a dam at the lower end of Diamond Valley in sec. 29, T. 11 N., R. 20 E. The topography as shown is too generalized to permit detailed analysis of the storage possibilities but it is estimated that capacity of about 15,000 acre-feet might be provided by a dam 100 feet high. Water could be diverted from West Fork Carson River, near Woodfords, by means of 1½ miles of tunnel or a somewhat longer canal, and when needed would be returned to the river through natural water courses by the installation of two short canals to maintain elevation through saddles.

PLAN OF DEVELOPMENT AND ESTIMATE OF POWER

West Fork Carson River falls 1,900 feet in 9½ miles below the Hope Valley dam site. Of the total head 1,400 feet is in the 6 miles between the dam site and a point near Woodfords where diversion could be made to Diamond Valley. The total head is susceptible of development but maximum utilization will depend on the transfer of water from the East Fork to supplement regulated flows from the Hope Valley site during the season of peak irrigation demand. If such a transfer of water is feasible the total gross head of 1,900 feet could be developed. Development of the total head through a single powerhouse would require about 5 miles of tunnel and 2½ miles of penstock, or alternatively about 9 miles of conduit and 2½ miles of penstock. The powerhouse would be located on the West Fork near the north line of sec. 19, T. 11 N., R. 20 E., near Paynesville.

Development of the head between Hope Valley and the available points of diversion for regulation of releases from Hope Valley reservoir would require a powerhouse near Woodfords at stream elevation about 5,600 feet. Fourteen hundred feet of gross head could be developed there by means of 4 miles of tunnel or 5 miles of conduit with about 2,500 feet of penstock required in either case.

The profile of the West Fork and the two plans for power development that have been discussed are shown diagrammatically on plate 2.

The potential power on West Fork Carson River under two general conditions of development is shown in table 3. Under the first condi-

TABLE 3.—*Potential power in kilowatts, West Fork Carson River*

Flow (cfs)	Power, in kilowatts		Time available [1]	
	Paynesville power site, head 1,900 feet	Woodfords power site, head 1,400 feet	Years	Percent
With 40,000 acre-feet of storage				
91	11,800	8,700	21	40
87	11,200	8,300	25	50
81	10,400	7,700	35	70
40	5,200	3,800	45	90
28	3,600	2,700	48	96
12	1,600	1,100	50	100
With 150,000 acre-feet of storage				
95	12,300	9,000	23	46
69	8,900	6,600	50	100

[1] During 50-year period of record.

tion 40,000 acre-feet of storage would be developed at the Hope Valley reservoir and the reservoir operated on a year-to-year basis. Under the second condition 150,000 acre-feet of storage would be developed so that carry-over storage for several years would be available during years of low flow.

EAST FORK CARSON RIVER

WATER-SUPPLY CHARACTERISTICS

Gaging stations have been maintained on East Fork Carson River and its tributaries as indicated in table 1. The longest available record is that for the station "East Fork Carson River, near Gardnerville, Nev." This station has been operated intermittently at or near its present location since 1891. The average annual runoff during the 50-year period 1891 and 1902–50 is estimated to have been 272,000 acre-feet. (Missing records were estimated from the extended record for the corresponding period at the station on West Fork Carson River near Woodfords.) The maximum discharge of record was 12,100 cfs, Nov. 21, 1950. The minimum was 8 cfs, Dec. 4–10, 19–23, 1904. The average annual discharge for the low-flow period 1928–34 is estimated to have been about 140,000 acre-feet. The duration characteristics of annual discharge for the gaging station "East Fork Carson River near Gardnerville, Nev." are shown in figure 2 and are summarized below.

Annual discharge	*Time available* [1] *Years*	*Percent*	*Annual discharge*	*Time available* [1] *Years*	*Percent*
272,000	21	[2] 42	129,000	45	90
253,700	25	50	49,000	50	100
228,000	35	70			

[1] During 50-year period of record.
[2] Average.

Fragmentary records were obtained at various times on East Fork Carson River at a location near Markleeville and also on several of the major tributaries; however, these are too incomplete to reflect a true measure of the discharge which occurred during the years when the records were collected.

Additional gaging stations were established on East Fork Carson River and the larger tributaries in 1946 (see table 1) in connection with a study of the Carson River basin by the Bureau of Reclamation. Discharge records for these stations for the 4 water years ending Sept. 30, 1950, were used to estimate the average discharge for the 50-year period 1891 and 1902–50 at several storage sites discussed in the section on Undeveloped Reservoir Sites. Examination of the record for the station "East Fork Carson River near Gardnerville, Nev.," indicates that the average annual discharge for this 4-year period was 75 percent of the average for the 50-year period.

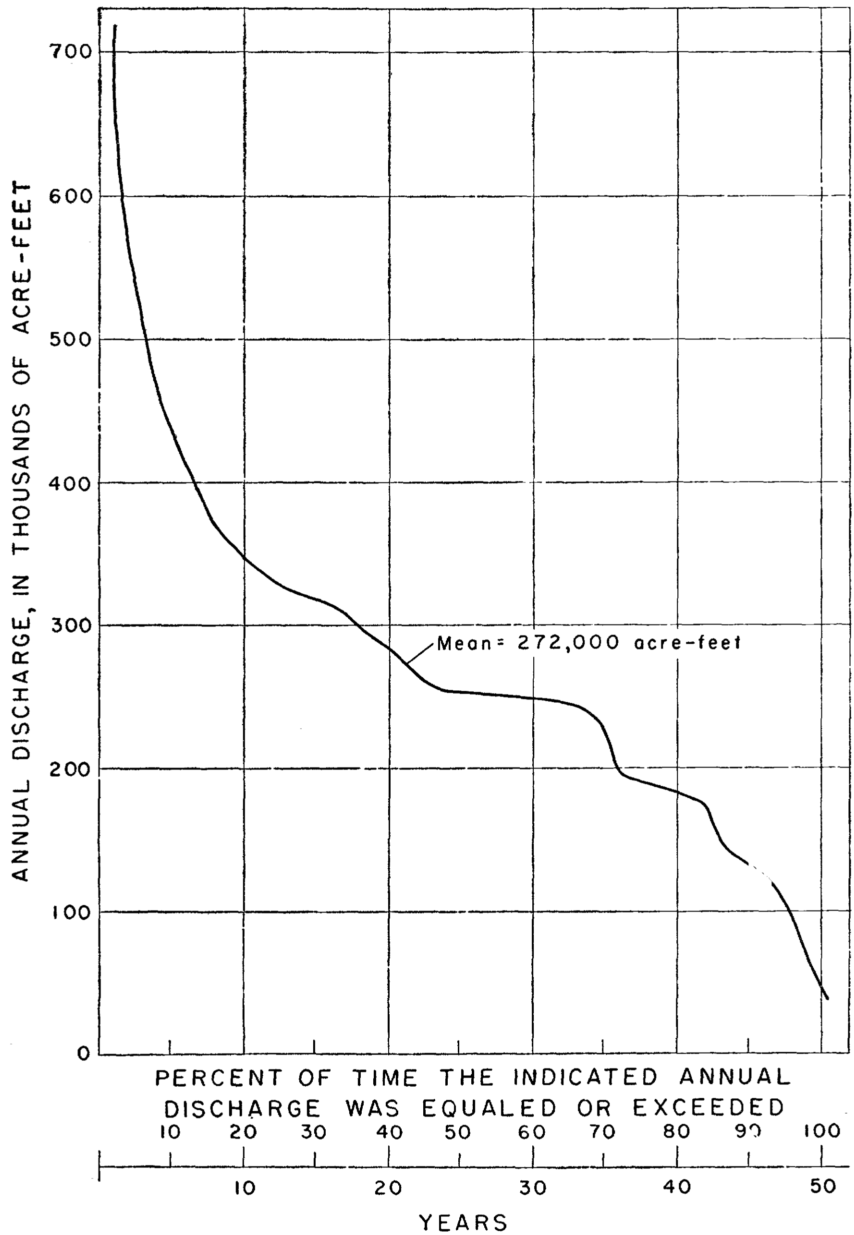

FIGURE 2.—Duration curve of annual discharge, East Fork Carson River near Gardnerville, Nev., 1891 and 1902–50.

Unequal distribution of precipitation on the upper Carson River basin, discussed under climate (see p. 8), makes it impracticable to use drainage area ratios to estimate discharge at sites far removed from a gaging station. Lacking a more accurate method the following device was used to estimate the discharge at several sites discussed later. A chart was prepared, using a portion of the topographic map of the Markleeville quadrangle as a base, showing estimated isograms of discharge expressed in inches of runoff from the drainage area. The average annual discharge at gaging stations in the basin for the 4 water years ending September 1950 was used to control the lines on the chart with allowance being made for probable effects of topography. The lines were drawn at intervals representing each change of 5 inches in estimated runoff through the range from a total areal runoff of 10 inches to a total of 30 inches. Discharge at a desired location was then determined by interpolation between 5-inch isograms and converted from inches runoff on the drainage area to the unit desired.

DEVELOPED STORAGE

Storage, estimated by the Geological Survey to amount to 5,000 acre-feet has been developed in the upper basin of East Fork Carson River (WSP 1180, p. 171). This has been provided by increasing the capacity of several small mountain lakes by damming their outlets. Tamarack Lake, Upper and Lower Sunset Lakes, and Wet Meadows Lake, with combined capacity of about 850 acre-feet, are located at the headwaters of Pleasant Valley Creek. Upper and Lower Kinney Lakes and Kinney reservoir, total capacity about 1,700 acre-feet, are located in the upper drainage basin of Silver Creek. Heenan Lake, capacity about 2,500 acre-feet, is located on Monitor Creek, tributary to East Fork Carson River a short distance upstream from Markleeville. These reservoirs presumably were constructed to provide additional irrigation water during periods of low flow.

UNDEVELOPED RESERVOIR SITES

There are several sites on East Fork Carson River and its major tributaries which appear favorable for the development of storage. The potential possibilities of most of these has long been recognized as evidenced by the fact that the lands involved were among the first to be withdrawn for the purpose of water resources development. The unpatented lands in most of these sites were withdrawn under the Act of 1888 and have remained in withdrawn status since. Some additional lands along the river from the vicinity of Markleeville downstream were later withdrawn in Power Site Reserve 149.

In the following discussion of individual sites the storage capacity necessary for complete regulation in a year of average runoff has been estimated from the monthly distribution of runoff during the water year ending Sept. 30, 1950, as reflected by records for the various stations which were operated in the basin during that year. Runoff at the gaging station "East Fork Carson River near Gardnerville, Nev.," in that year was 92 percent of the average annual runoff of the 50-year period 1891 and 1902–50. In the discussion of the location of various sites reference is made to stream mileage and elevation. Source for this information is the Geological Survey river-survey map "Carson River and East Fork from Dayton, Nev., to mile 80, and West Fork to mile 30, Calif.-Nev."

HORSESHOE BEND

The Horseshoe Bend dam site is in the SE¼ sec. 35, T. 12 N., R. 20 E., at mile 40.5. Topography at this site was mapped to an elevation of 5,200 feet; the stream at the dam site lies at 4,960 feet. The map indicates a saddle with elevation of about 5,150 feet on the left bank in the SW¼, sec. 2, T. 11 N., R. 20 E. An auxiliary dam would be required in this saddle if a reservoir were constructed with a maximum water surface above that elevation. An unsurfaced road which follows the stream through part of the reservoir area would have to be relocated. The area and capacity data for this reservoir site are shown below.

Area and capacity of Horseshoe Bend reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
4,960	0	0	5,100	497	24,000
4,980	18	180	5,120	601	35,000
5,000	37	730	5,140	698	48,000
5,020	118	2,280	5,160	828	63,200
5,040	171	5,170	5,180	985	81,400
5,060	244	9,320	5,200	1,190	103,000
5,080	363	15,400			

Development of large storage capacity at the Horseshoe Bend site is not considered practicable because of the required auxiliary dam already mentioned; however, a diversion dam at this site or at an upstream location near the center of sec. 2 may be desirable in event of coordinated development of East and West Forks Carson River. By construction of a tunnel about 2 miles in length, or a canal somewhat longer, water could be diverted to the West Fork to supplement controlled flows from Hope Valley reservoir. This would eliminate the need for a large amount of re-regulatory storage on the West Fork below the Woodfords power site.

No lands now in reserve would be affected by development at the Horseshoe Bend site unless a dam were constructed with a crest above elevation 5,200 feet.

WATASHEAMU

The Watasheamu dam site is in the SE¼ sec. 2 and NE¼ sec. 11, T. 11 N., R. 20 E., at mile 43.5, stream elevation 5,020 feet. The site has received considerable attention as the possible location of a large storage dam on East Fork Carson River. Construction of a dam at this site above elevation 5,220 feet would flood the valley bottom in sec. 1 and part of sec. 2, T. 10 N., R. 20 E. These lands are in Power Site Reserve 149. An unsurfaced road which crosses the reservoir area would have to be relocated. Area and capacity data for this site are shown below.

Area and capacity of Watasheamu reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
5,020	0	0	5,180	595	37, 600
5,040	10	100	5,200	771	51, 200
5,060	57	770	5,220	938	68, 300
5,080	140	2, 740	5,240	1, 130	89, 000
5,100	229	6, 430	5,260	1, 310	113, 000
5,120	298	11, 700	5,280	1, 540	142, 000
5,140	372	18, 400	5,300	1, 780	175, 000
5,160	475	26, 900			

PINYON

The dam site is located in the SW¼ sec. 13, and the SE¼ sec. 14, T. 11 N., R. 20 E., at mile 45.7. Topography of the reservoir site is shown to an elevation of 5,400 feet except for a small area in the vicinity of Bryant Creek where the contours were not completed. Stream elevation at the dam site is 5,080 feet. In preparing the table of reservoir areas and capacities shown below incomplete areas in the topography were filled-in by assuming that the slopes of the valley wall and tributary streams were the same as at upper limits shown.

Area and capacity of Pinyon reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
5,080	0	0	5,220	579	28, 600
5,100	28	280	5,240	751	41, 900
5,120	69	1, 250	5,260	889	58, 300
5,140	118	3, 120	5,280	1, 080	78, 100
5,160	191	6, 210	5,300	1, 300	102, 000
5,180	294	11, 100	5,400	[1] 2, 340	284, 000
5,200	440	18, 400			

[1] Estimated in incomplete area of map.

Construction of a reservoir at this site would flood lands in Power Site Reserve 149, in amounts dependent on the height of dam. An unsurfaced road traverses a portion of the stream valley through the reservoir area and would have to be relocated.

It appears, from a comparison of the capacity tables for the three sites discussed above, that the Pinyon reservoir site offers the best opportunity of any of these for the development of large amounts of hold-over storage.

Runoff at the Horseshoe Bend, Watasheamu, and Pinyon reservoir sites is assumed to be equivalent to the runoff at the gaging station "East Fork Carson River near Gardnerville, Nev." It was estimated earlier that the average annual runoff at that station for the 50-year period 1891 and 1902–50 was about 272,000 acre-feet. On the basis of the monthly distribution of runoff in the water year ending Sept. 30, 1950, storage capacity of 130,000 acre-feet would be required for complete regulation in a year of average runoff at these sites. Development of storage capacity of this amount at the Horseshoe Bend site seems unlikely in view of the more favorable locations a short distance upstream. Development of this capacity would require a dam about 255 feet high at the Watasheamu site, or about 240 feet high at the Pinyon site.

MARKLEEVILLE

This site could be developed by construction of a dam in the SW¼ sec. 11, T. 10 N., R. 20 E., 1½ miles downstream from the mouth of Markleeville Creek. Storage capacity of 97,000 acre-feet could be made available with a 230-foot dam, or 244,000 acre-feet could be provided with a 330-foot dam.

Runoff at the site, assuming the same unit runoff as for the gaging station "East Fork Carson River near Gardnerville, Nev.," would be 80 percent of the runoff at that station; but available precipitation records indicate that the area between Markleeville and the gage are much less productive than the headwaters areas. It is estimated that runoff at the Markleeville dam site may be as much as 95 percent of the runoff at the gaging station and that as much storage capacity would be required for regulation in a year of average runoff as at the Pinyon or Watasheamu sites.

Construction of a reservoir at the Markleeville site would flood the town of Markleeville, county seat of Alpine County, and several miles of State Highway 24. Consequently, the possibility of substantial storage development at that site is very remote since sites of equal merit are available downstream at locations where such conflict would not occur.

SILVER KING

A dam constructed in the canyon a mile below the mouth of Silver King Creek would provide storage capacity as indicated below.

Area and capacity of Silver King reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
6,370	0	0	6,440	347	11, 100
6,380	10	50	6,460	475	19, 300
6,400	136	1, 510	6,480	617	30, 200
6,420	238	5, 250	6,500	777	44, 200

The dam site is in the N½ sec. 2, T. 8 N., R. 21 E., at mile 71.9, stream elevation 6,370 feet. Development of storage above elevation 6,438 feet would require construction of an auxiliary dam in the NW¼ sec. 35, T. 9 N., R. 21 E., in the saddle between Silver King and Bagleys Valleys.

The estimated average annual runoff at the site for the 4 water years ending September 1950 was 80,000 acre-feet, or 106,000 acre-feet for the 50-year period 1891 and 1902–50. (See p. 18.) The seasonal distribution of runoff at the Gardenville station for the year ending Sept. 30, 1950, indicates that 49,000 acre-feet of storage capacity would be required to regulate the runoff at the Silver King site in a year of average discharge. This would require a dam about 140 feet high on East Fork Carson River and an auxiliary dam about 72 feet high in the saddle discussed above. In event of development to this extent most of the lands in Silver King Reservoir Site 19, would be subject to flowage.

DUMONTS MEADOW

Construction of a dam at the Soda Springs dam site near the north line of sec. 22, T. 8 N., R. 21 E., at mile 77.2, stream elevation 6,670 feet, would provide the reservoir areas and capacities indicated below.

Area and capacity of Dumonts Meadow reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
6,670	0	0	6,740	305	8, 590
6,680	12	60	6,760	404	15, 700
6,700	89	1, 070	6,780	487	24, 600
6,720	179	3, 750	6,800	552	35, 000

Development of storage of more than 3,750 acre-feet at this site would require an auxiliary dam in the saddle on the right abutment. Above elevation 6,790 feet the auxiliary dam would be part of the main structure.

A gaging station was installed on East Fork Carson River about 2 miles southwest of Soda Springs ranger station in September 1946. The station is about 3 miles upstream from the Soda Springs dam site. The average annual runoff in the period October 1946–September 1950 was 39,200 acre-feet. The runoff for the same period at the dam site was estimated by the method described on page 18, to be 45,800 acre-feet; or 61,000 acre-feet for the 50-year period used herein. It was estimated, from the seasonal distribution of runoff at the gaging station in the water year ending Sept. 30, 1950, that 35,500 acre-feet of storage capacity would be required to regulate runoff in a year of average discharge. Examination of the table of capacities indicates that storage of this amount would require a dam about 130 feet high on the stream and an auxiliary dam in the saddle to the east of the dam site about 78 feet high.

Except for a small fringe area on the right bank and another small area at the upstream end, a reservoir of this size would be confined to lands withdrawn in Dumonts Meadow Reservoir Site 21.

PLEASANT VALLEY

This site is located on Pleasant Valley Creek about 3½ miles southwest of Markleeville. The dam site is near the center of sec. 32, T. 10 N., R. 20 E., at mile 2 and at stream elevation 5,790 feet. The table below indicates areas and capacities available at various elevations.

Area and capacity of Pleasant Valley reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
5,790	0	0	5,900	215	6, 610
5,800	4	20	5,920	321	12, 000
5,820	12	180	5,940	495	20, 100
5,840	43	730	5,960	629	31, 400
5,860	59	1, 750	5,980	719	44, 800
5,880	106	3, 400	6,000	790	59, 900

The average annual runoff at the site for the period October 1946–September 1950 was estimated to be about 28,200 acre-feet, or 38,000 acre-feet for the period 1891 and 1902–50. A study of the seasonal distribution of runoff at the gaging station "Pleasant Valley Creek, above Raymond Canyon" in the water-year ending Sept. 30, 1950, indicates that 24,000 acre-feet of storage capacity would be required to regulate runoff at the dam site in a year of average discharge. This would require a dam 160 feet high.

Lands of the United States which would be affected by a reservoir of that size are withdrawn in Pleasant Valley Reservoir Site 15.

WOLF CREEK

This site could be developed by construction of a dam on Wolf Creek in the NE¼ sec. 29, T. 9 N., R. 21 E., near mile 1. The table below indicates the storage capacity which would be available with different heights of dam.

Area and capacity of Wolf Creek reservoir site

Elevation (feet)	Area (acres)	Capacity (acre-feet)	Elevation (feet)	Area (acres)	Capacity (acre-feet)
6,360	0	0	6,440	227	6,490
6,380	6	60	6,460	307	11,800
6,400	57	690	6,480	361	18,500
6,420	148	2,740	6,500	394	26,100

The average annual runoff for the 4 water years ending Sept. 30, 1950, was estimated by the method described on page 18 to be 29,800 acre-feet; or 40,000 acre-feet for the 50-year period. On the basis of the seasonal distribution of runoff at the gaging station "Wolf Creek near Markleeville" in the water year ending Sept. 30, 1950, it was estimated that 21,000 acre-feet of storage capacity would be required for regulation of runoff at the Wolf Creek site in a year of average discharge. This would require a dam about 130 feet high.

Lands withdrawn in Wolf Creek Reservoir Site 20 would be affected by development to the extent discussed above.

PLAN OF DEVELOPMENT AND ESTIMATE OF POWER

Power development in the East Fork Carson River basin would require substantial storage regulation on upper East Fork Carson River and the principal tributaries because of the wide seasonal variation of flow. It will also require an extensive system of waterways because of the lack of concentrated fall below the available storage sites. A general consideration of these characteristics seems to indicate that extensive development would not be feasible; however, the following illustrative plan of development is offered as an index of the power which could be developed on East Fork Carson River. It is assumed for the purpose of the illustration that development would be designed to utilize flows available in a year of average discharge. The plan of development outlined in the following paragraphs and the profile of the East Fork are shown diagrammatically on plate 2.

Development would be made in five stages with storage regulation at the Silver King and Watasheamu sites on the East Fork and at Wolf Creek and Pleasant Valley Creek sites. No storage is proposed on Silver Creek because of conflict with State Highway 24 and the absence of a satisfactory reservoir site. A small amount of power could also be made available on Markleeville Creek but this would require independent development which evidently would not be feasible and is therefore not considered herein.

It was estimated earlier that 49,000 acre-feet of storage capacity would be required to regulate the runoff of East Fork Carson River and Silver King Creek at the Silver King site. This would permit a uniform release of 146 cfs of which as much as 20 cfs might be bypassed for fishery purposes. The balance of 126 cfs available for power development would be diverted below the dam at stream elevation about

6,360 feet. Water thus diverted would be conducted through 3 miles of tunnel and 800 feet of penstock to a powerhouse near the mouth of Wolf Creek, at stream elevation 6,110, mile 67.8. The gross head thus developed would be 250 feet. The powerhouse would be designed to accommodate an additional 55 cfs of regulated flow from the Wolf Creek reservoir which could be utilized under an average gross head of 315 feet by means of 2,000 feet of pressure tunnel or penstock.

The discharge from the Wolf Creek powerplant would be diverted at elevation 6,075 feet through 3½ miles of tunnel and 800 feet of penstock to a powerhouse near the mouth of Monitor Creek at stream elevation about 5,690 feet, mile 62.2. The gross head would be 385 feet.

The discharge from the Monitor Creek powerhouse would be diverted at the old Mt. Bullion dam site, at stream elevation 5,655 feet, mile 61.8, through 2½ miles of tunnel and about 1,000 feet of penstock to a powerhouse near the mouth of Indian Creek, stream elevation 5,470 feet, mile 58.3. The gross head would be 185 feet.

The uncontrolled flow of Silver Creek could be diverted at the Mt. Bullion diversion dam for development of seasonal power at the Indian Creek powerhouse. It is estimated that this would require additional tunnel capacity of 250 cfs and corresponding additional plant capacity to accommodate the flow during the period of highest runoff. A large part of such seasonal power would be available in the 3-month period April through June.

The Indian Creek powerhouse would be designed to utilize an additional 52 cfs of regulated flow from Pleasant Valley reservoir. This would be diverted at elevation 5,775 feet near the base of Pleasant Valley dam through 2.3 miles of tunnel and 1,000 feet of penstock. Gross head developed would be 300 feet.

The discharge from the Indian Creek powerhouse would be diverted at the Markleeville dam site, mile 55.4, stream elevation 5,390 feet, through 2.1 miles of tunnel, or a somewhat longer canal, and about 1,000 feet of penstock to a powerhouse on the proposed Watasheamu reservoir. It is assumed for the purpose of this report that this reservoir will be constructed with a maximum water-surface elevation of about 5,280 feet. The gross head on this plant then would be 110 feet. It is estimated that a flow of 265 cfs would be available 100 percent of the time at the Markleeville diversion dam. Utilization of peak flow from uncontrolled tributaries for the production of seasonal power would require about 600 cfs of additional conduit capacity and corresponding additional plant capacity. Seasonal power would be largely produced in the 3-month period April through June.

The final stage would be the development of power in connection with the proposed Watasheamu reservoir. It is assumed for the purpose of this report that a reservoir of 130,000 acre-feet of active capacity would be provided at the Watasheamu site. This amount was estimated to be necessary for regulation at the site in a year of average discharge. (See p. 21.) It is also assumed that the lower 100 feet of the reservoir would be used to create head. Development of 130,000 feet of active storage in addition to the reserve would require a dam 260 feet high. The maximum reservoir surface would be at elevation 5,280 feet.

A powerhouse would be located in the NW¼ sec. 1, T. 11 N., R. 20 E., near mile 41, stream elevation 4,965 feet, near the Horseshoe Bend site. The plant would receive water from the reservoir through 3,500 feet of pressure tunnel and 700 feet of penstock and would operate under a mean head of 230 feet. Average annual discharge at the site was estimated to be 272,000 acre-feet. (See p. 21.) This represents a flow equivalent of 375 cfs. If allowance were made for an estimated annual evaporation of 3,000 acre-feet from the reservoir and maintenance of 25 cfs in the river channel (this is approximately the minimum flow to be expected in a year of average discharge), the flow available for power production would be 345 cfs. The maximum energy output at the site in a year of average discharge under the conditions specified above would be about 46,253,000 kwhr. This would represent optimum utilization with operation of the reservoir on a power schedule. If, however, a reservoir is provided at the site it would undoubtedly be operated primarily for irrigation and flood control with power a secondary feature. The ultimate project would probably be designed to produce less energy than is shown to be available in the above estimates. A large proportion of energy produced from releases on an irrigation schedule would be of a seasonal nature. Table 4 summarizes the potential energy available from utilization of the East Fork Carson as outlined here.

TABLE 4.—*Potential power and energy at undeveloped sites in a year of average runoff, East Fork Carson River*

Power site	Source of water	Gross head (feet)	Flow in cfs		Potential power kw 80 percent efficiency	Potential annual generation kwhr [1]
			Regulated	Unregulated		
Wolf Creek	Silver King reservoir	250	126		2140	18,764,000
	Wolf Creek reservoir	315	55		1180	10,319,000
Monitor Creek	Discharge from Wolf Creek powerhouse.	385	181		4740	41,514,000
Indian Creek	Discharge from Monitor Creek powerhouse.	185	181		2280	19,960,000
	Pleasant Valley reservoir	300	52		1060	9,294,000
	Silver Creek	185		[2] 50		[3] 5,510,000
Watasheamu	Discharge from Indian Creek powerhouse.	110	[4] 265		1980	17,362,000
	Natural flow of Markleeville Creek and other tributaries.	110		[2] 57		[3] 3,732,000
Horseshoe Bend	Release from Watasheamu reservoir.	230	345		5400	47,267,000

[1] Totals rounded.
[2] Average.
[3] Seasonal (or dump) energy largely produced during the 3-month period April–June.
[4] Partly estimated.

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