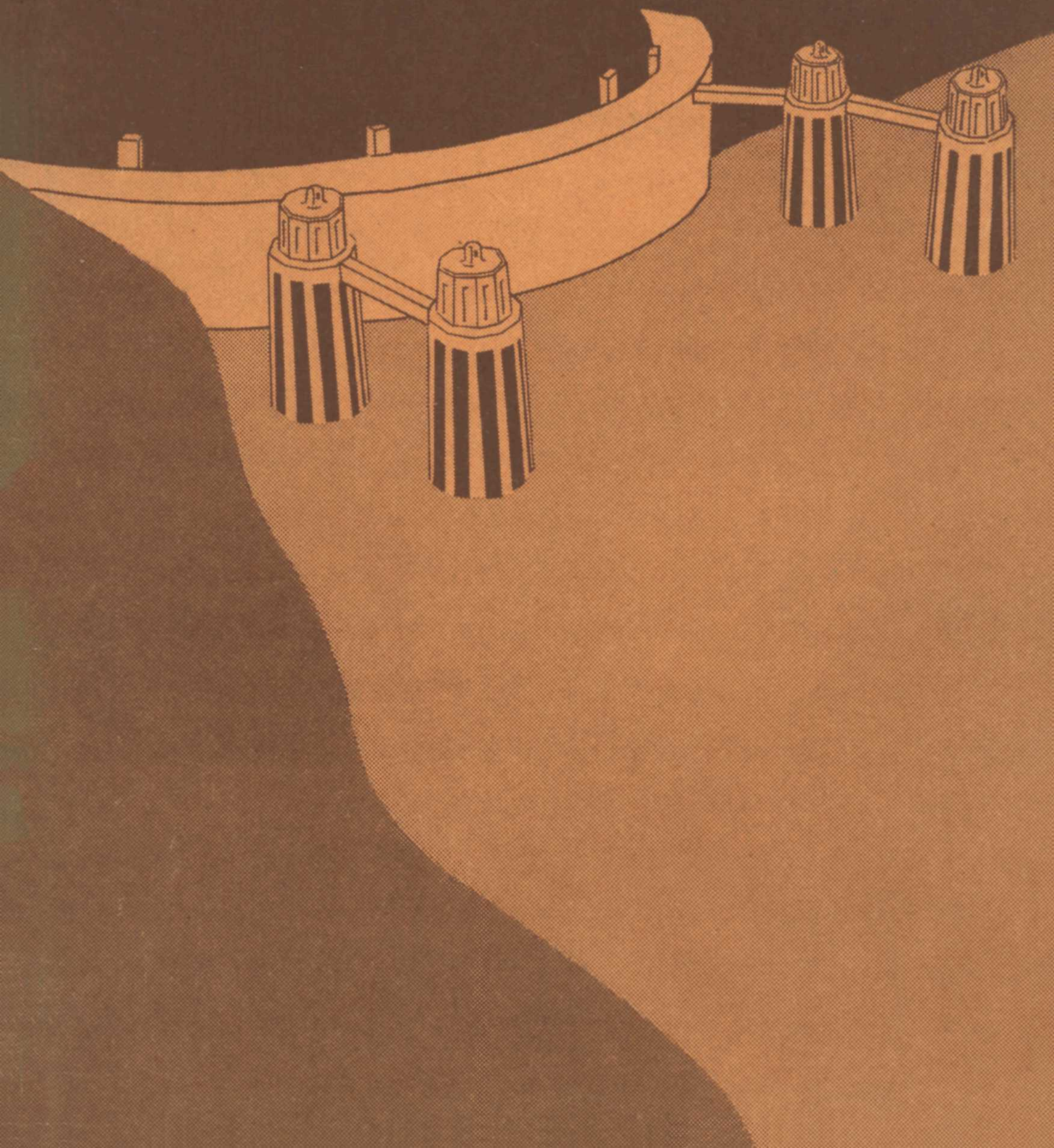
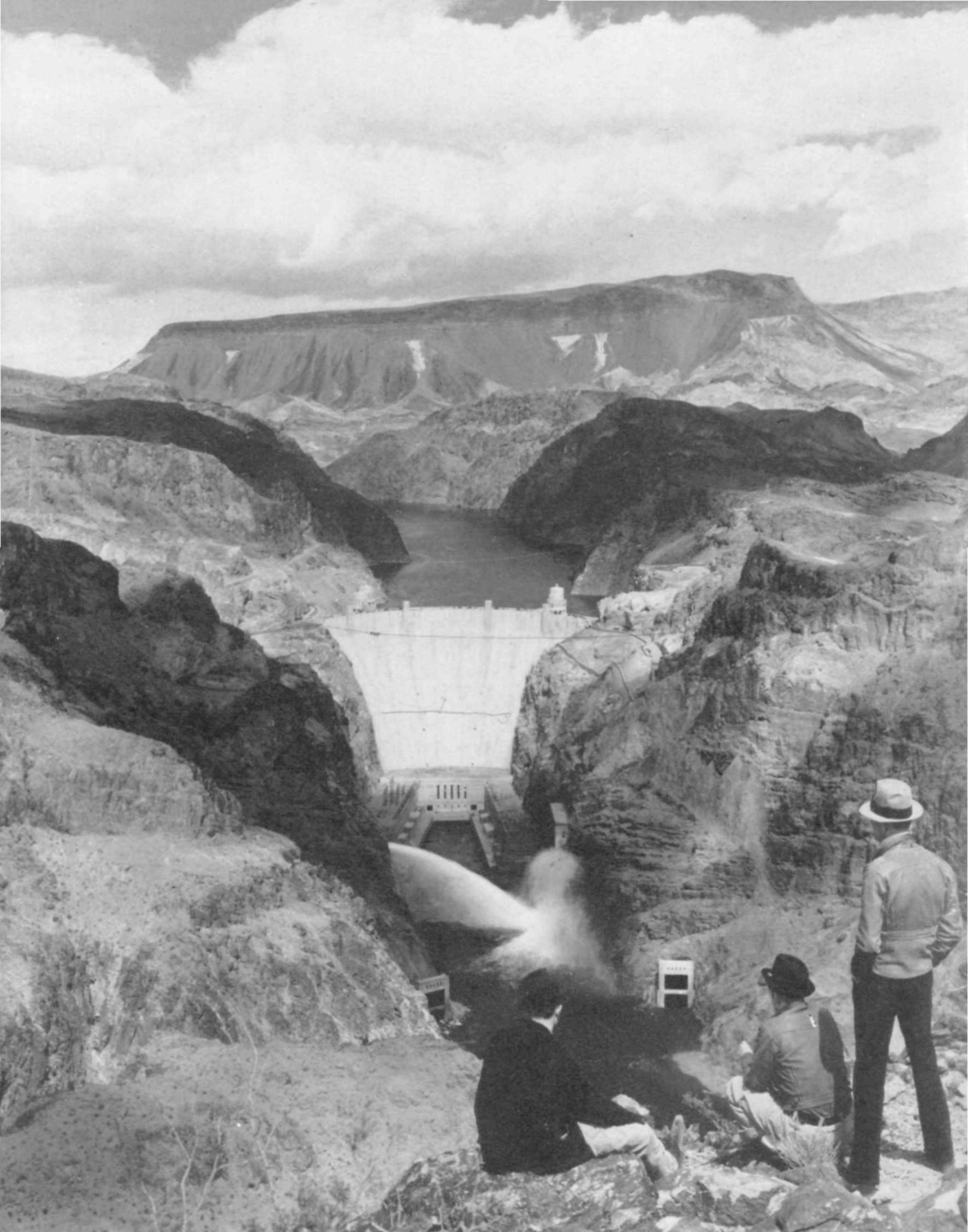
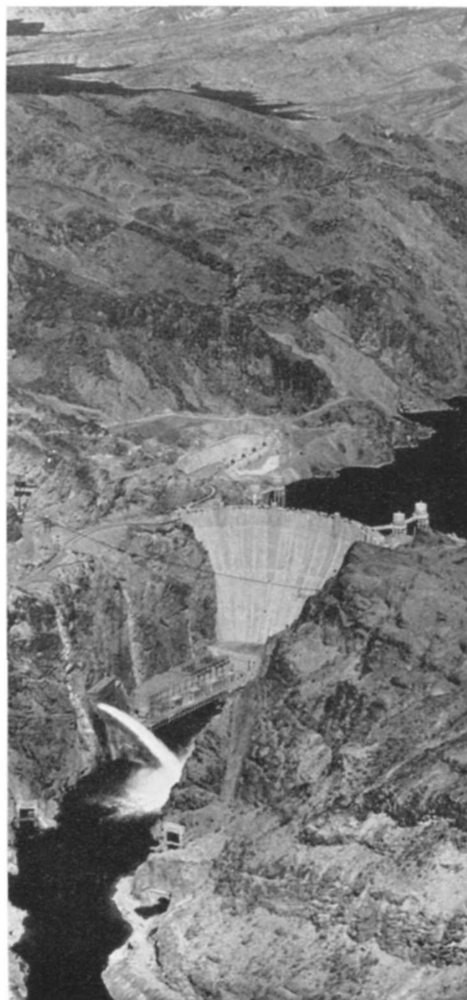
The Story of
Boulder Dam





The greatest engineering achievement of all time. Boulder Dam, built by the Bureau of Reclamation, majestic in its clean graceful lines, stands with one shoulder against the Nevada wall and the other against the Arizona wall of Black Canyon, forever to control the wild Colorado River

THE STORY OF
Boulder Dam



CONSERVATION BULLETIN NO. 9

UNITED STATES DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES
SECRETARY

BUREAU OF RECLAMATION
JOHN C. PAGE
COMMISSIONER

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THE STORY OF BOULDER DAM

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Explanation

ROLLING SWIFTLY *on its tortuous course through the hot, arid southwestern United States, battering its way through deep canyons, the Colorado was considered America's most dangerous river.*

Man's desperate need of water caused him early to turn speculating eyes on the Colorado, but whenever he tampered with the river he brought disaster upon himself.

Farmers, tempted by fertile desert soil, tapped the Colorado for water to irrigate and create rich gardens—and annually the river rose to destructive floods and annually, by fading away, it reduced the water supply upon which their lives and crops depended.

A great cry finally arose for the control and conservation of the waters of the Colorado, the most valuable natural resource of a desert empire.

The cry was answered: Reclamation engineers successfully mastered the Colorado with the most magnificent dam the world has ever seen—Boulder Dam.

The dramatic engineering achievement of building Boulder Dam has aroused great public interest. This booklet tries to satisfy that desire for information.

Chronology of Colorado River

1540 Alarcon discovers and explores the lower Colorado River.

1542 Cardenas discovers the Grand Canyon.

1776 Escalante explores the upper Colorado River and its tributaries.

1857 Lt. J. C. Ives navigates the river from its mouth to Vegas Wash.

1869 Maj. John Wesley Powell makes the first trip through the Grand Canyon.

1902 President Theodore Roosevelt signs the Reclamation Act.

1902–1918 Reclamation engineers make investigations and reports on control and utilization of the Colorado.

1918 Arthur P. Davis, Reclamation Director and Chief Engineer, conceives control of the Colorado by a dam of unprecedented height in Boulder Canyon.

1922 The seven Southwestern States initial the Colorado River Compact, Santa Fe, N. Mex., November 24.

1924 Bureau of Reclamation recommends construction of the Boulder Canyon project in its report on Colorado River.

1928 The Colorado River Board reports favorably on the feasibility of the project.

The Boulder Canyon Project Act, introduced by Senator Johnson and Representative Swing, passes the Senate on December 14, the House December 18, and is signed by the President on December 21.

1929 The Boulder Canyon Project Act declared effective June 25.

1930 Contracts completed for sale of all electric energy from the project.

Breaking ground on Government railroad September 17 inaugurates construction of the Boulder Canyon project.

1931 Bureau of Reclamation opens bids for construction of Boulder Dam and powerhouse March 4 and awards contract to Six Companies, Inc., which starts work March 11.

1932 The engineers divert the river, November 14.

1933 First concrete placed in dam June 6.

1935 Boulder Dam starts to impound water in Lake Mead February 1.

Last concrete placed in dam May 29.

President Franklin D. Roosevelt dedicates the dam September 30.

1936 First generator goes into full operation October 22.

Second generator goes into operation November 14.

Third generator goes into operation December 28.

1937 Two more generators go into operation March 18 and August 16.

1938 Storage reaches 24,000,000 acre-feet, and Lake Mead stretches 115 miles upstream.

Two more generators go into operation, June 26 and August 31; total, 7.

1939 Storage reaches 25,000,000 acre-feet, more than 8,000 billion gallons.

Two more generators, June 19 and September 12; total, 9. Installed capacity reaches 700,000 kilowatts, making Boulder's hydro-electric power plant the largest in the world.

1940 Three more generators ordered.

All-American Canal placed in operation.

Metropolitan Water District's Colorado River aqueduct successfully tested.

THE STORY OF BOULDER DAM

THE STORY OF BOULDER DAM

CHAPTER 1—THE RIVER

THE setting of this story is in the southwestern United States, a picturesque land of high mountains, deep canyons, and scorching deserts, of Joshua trees and giant cacti, of bighorn sheep and Gila monsters. The chief character is the treacherous, destructive Colorado River.

Third longest river in the Union, the Colorado rises high in the snow-capped mountains of Wyoming and Colorado, zigzags southwest for 1,700 miles, and finally pours into Mexico's Gulf of California far to the south.

The Colorado's drainage basin is vast. It covers 244,000 square miles, one-twelfth the land area of the United States. Tributaries extend their tentacles through seven of the large Western States.

The Colorado is mighty. It slashes through all in its path. It has gouged the rock of the mesas into gorges and chasms. One of the gorges, the Grand Canyon, is world famous, a titanic cleft over 200 miles long, a dozen miles in breadth and a mile deep.

South of the canyons the Colorado makes its way through the hottest and driest region in the United States. The temperature reaches more than 120 in the shade. Rain is almost unknown all summer long. There, dry as bone and shimmering in the heat, is an American Sahara.

The Exploring Spaniards Come

Exploring north from Mexico the Spanish conquistadors were the first white men to penetrate this forbidding land of aridity. They were surprised to find it peopled with Indians. They found that the Indians had attained a high civilization. The evidence was in imposing ruins of communal architecture unexcelled in the Old World. There were well-constructed four-storied apartment houses containing as many as 800 rooms.

How did the Indians manage to exist in this desert? The mystery was soon solved. The exploring Spaniards encountered canals and ditches which guided life-giving water from the stream into fields of corn, beans, and squash.

The art of irrigation had made it possible to establish the earliest civilization in the United States.

One of the first of the exploring Spaniards was Conquistador Alarcon. He was the first white man to view the Colorado. He ventured up the reddish-brown stream 150 miles. He was followed 2 years later by Cardenas, who discovered the Colorado's Grand Canyon.

It was a difficult terrain to explore, or to obtain food or supplies. Cardenas never succeeded in descending the sheer walls of the precipitous Grand Canyon, and the other explorers and missionary priests who followed him were also discouraged by the seeming inaccessibility of the river in the canyon section. To explore the deep gorges seemed almost hopeless. It was two centuries before a crossing was discovered.

So well did the river keep its origin from prying eyes that in early times none knew for a fact whether it was a river or a narrow swift-running strait separating California from the mainland. It was also said in the old days that the Colorado was subterranean for hundreds of miles. To venture downstream by boat in the Colorado's higher reaches was reputed to mean sure death.

A Dangerous Obstacle

To most who had found the river blocking their path the Colorado had been a dangerous obstacle, to be passed over or circumtoured as quickly as possible. To the curious few who had visions of tracing the stream's course, the Colorado quickly revealed that the dream was not the deed.

In 1846 war with Mexico gave New Mexico, Arizona, and California to the United States. In 1849 the discovery of gold at Sutter's mill in California brought adventurers pressing against the east bank of the Colorado. They poured across the river at two widely distanced points. One crossing was near Yuma, not far from the Mexican border, about 100 miles from the river's mouth. The other was "The Needles," 200 miles farther north.

Looking down the Colorado River toward Marble and Grand Canyons from the bluff at Lees Ferry, Arizona

When the land drained by the river became a part of the United States, the feeling grew that it had to be explored. In 1857 the War Department dispatched Lt. J. C. Ives to the task, instructing him to proceed up the river by boat as far as navigation was practicable. He succeeded in ascending in his boat *Explorer* only as far as the head of Black Canyon, a few miles below the confluence with the Virgin River. This was about 400 miles from the mouth of the Colorado.

In his report to the War Department, Lieutenant Ives said:

"The region last explored is, of course, altogether valueless. It can be approached only from the south, and after entering it there is nothing to do but leave. Ours was the first, and doubtless will be the last, party of whites to visit this profitless locality. It seems intended by Nature that the Colorado River along the greater portion of its lone and majestic way shall be forever unvisited and unmolested."

In 1869 Maj. J. W. Powell of the Geological Survey achieved the hitherto impossible. He succeeded in leading a river expedition down through the canyons of the Colorado. His expedition traveled from the Green River in Utah down to the Virgin River in Nevada, a few miles above where Lieutenant Ives had been stopped. He covered a thousand miles of unknown rapids and labyrinthian canyons. He became the first white man to gaze up at the sheer walls of the Grand Canyon and live to tell of it.

The Colorado explored, active investigation of the river took the next natural step—the attempt to make it useful. In 1875 Lieutenant Borklane mapped out a route for a canal to irrigate southern California's rich but arid land. Construction on the canal began about 20 years later and in 1901 the first water from the Colorado River poured from Imperial Canal, looping through Mexico, into southern California's Imperial Valley. A desert was metamorphosed into a garden with an all-year-round growing season.

Flood . . . and Drought

Like all other western desert streams, however, the Colorado ran hog-wild each spring. Fed by rapidly melting mountain snows, it swelled to a torrent which swept over its banks and inundated the country for miles around.

The rich, fertile Imperial Valley is a deep saucer, 250 feet below sea level at the lowest point. Lapping along the rim of this low-lying valley was the Colorado, ever menacing. In 1905, only 4 years after the river had been tapped for its life-giving waters, the disaster came. The Colorado burst its banks.

For nearly 2 years the swirling coffee-colored flood ran amuck, slashing through the Valley's sunny fields and flourishing communities. Time finally laid bare the mud-caked havoc wrought by the angry Colorado—ruined farm land, destroyed homes—highways washed away, railroads wrecked. A permanent memento was left in the form of a huge lake nearly 300 square miles in area which today is labeled on the map as Salton Sea.

The Reclamation Service had recently (June 17, 1902) been established by the Congress to develop the arid West by regulating and conserving its most valuable natural resource, water. Here was a Gordian knot to untie.

Protection of the lands lying below the elevation of the Colorado had required the building of levees. Each year the river with its silt-laden floods tore at these. The levees were built higher and stronger. To prevent another disaster such as that of 1905, about $1,000,000 was spent on the Ockerson Levee. It was barely completed in 1909 before the Colorado crashed through. Failing to find an opening into the Imperial Valley, the Colorado swirled westward into what is known as Bee River to Volcano Lake. On this new course the river flowed for 10 years, kept there by another expensive levee system.

Failing to smash this new levee the Colorado deposited millions of tons of silt in its channel, lifting itself still higher. The fight went on year after year.

The defensive measures became more and more oppressive. The cost of maintaining the levees rose to approximately $500,000 a year. Even this large expenditure did not eliminate the menace. About 100,000 people lived in fear that the river might overwhelm them.

On the other hand, there were occasions when the river ran dry. Men walked out on the riverbed and conferred about the emergency. Their crops were withering and dying for lack of moisture. Their livestock must be slaughtered to save drinking water for their families, if this drought should be extended. They were hauling precious water from 100 miles or more away

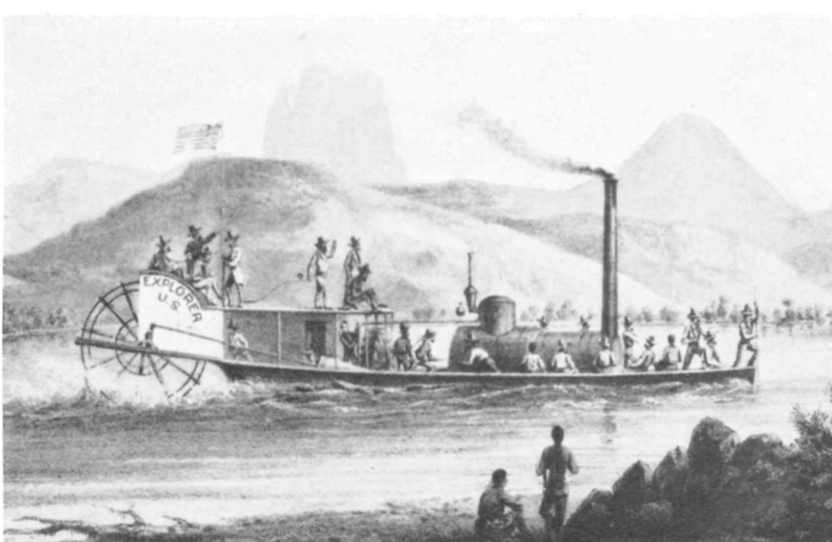
It was a vicious cycle of flood and drought. Both extremes threatened the lives and homes of the people of the Southwest who depended on the whims of the unmanageable Colorado.

The Bold Decision

This was the problem pondered by Reclamation engineers. Their study brought a strong and bold decision. There was only one solution: Put the wild Colorado in complete harness. Control it . . . once and for all time.

Could it be done?

Boat in which Lieutenant Ives traveled up the Colorado River from its mouth to the head of Black Canyon. Copy of an illustration in the Ives report



Dammed and under control the Colorado would have vast value. Uncontrolled and unregulated it had very little. The quick run-off and the absence of summer rains made any large irrigation or power development uncertain and unprofitable unless the river could be controlled. Nor could the river be depended upon as a source of water supply for cities. Also, further development by mere irrigation was infeasible—already more land had been canalized than could be irrigated by the natural flow of the river during periods of low discharge.

The area tributary to the Colorado River is composed roughly of an upper basin and a lower basin. The dividing line falls at Lee's Ferry, Ariz., a few miles south of where the river enters Arizona from Utah. The upper basin covers the drainage area in Wyoming, Utah, Colorado, and New Mexico; the lower basin covers the area in Nevada, Arizona, and California.

The two basins are about equal in area and are separated by what is known as "the canyon region." The canyon region is a 400-mile bottleneck through which the Colorado has battered since the mists of time. The gorges begin below Lee's Ferry and end with Black Canyon, just below the confluence with the Virgin River.

A comprehensive plan of development required detailed data from both upper and lower basins. Bureau of Reclamation engineers examined a total of 70 possible reservoir sites in the two basins.

The most suitable sites in the upper basin were found to be the Flaming Gorge site on the Green River in northern Utah with a probable storage capacity of 4,000,000 acre-feet; the Juniper site on the Yampa River in Colorado, with 1,500,000 acre-feet; and the Dewey site on the Colorado in eastern Utah with 2,270,000 acre-feet.

The chief defect of the proposed reservoir sites in the upper basin was their smallness. None was large enough to regulate the river. Another disadvantage was the distance from where regulation was most needed. They were hundreds of miles away from the irrigable fields of Arizona and California. Again, there were too many tributaries below them which might cause destructive floods.

The lower basin had two good sites. They were Boulder Canyon and Black Canyon. Each had the huge capacity of over 30,000,000 acre-feet, but the engineering problems were equally tremendous

The Black Canyon Site

The engineers favored the sites in the lower basin. The Bureau of Reclamation intensified investigations there. Engineers made geologic and topographic surveys, starting in 1919. Investigations showed that certain conditions favored Black Canyon over Boulder Canyon. The depth to bedrock was less, the geologic structure was better, and a dam of smaller dimensions would give the same reservoir capacity. From

Sketch of Black Canyon, made by Lieutenant Ives in 1857

1920 to 1923 the engineers actually lived in Black Canyon, diamond drilling and testing the rock.

The rock had to offer an unquestionably sound foundation. It was to support the highest dam the world had ever seen.

In Black Canyon these Reclamation engineers hoped to build a dam so high it would create a reservoir large enough to store the entire flow of the Colorado River—including all its savage floods—for 2 whole years.

The proposed dam would be located below the large tributaries, and be able to control them. It would create a power head within transmission reach of the great power markets of southern California. It would be in the midst of a heavily mineralized region in Nevada and Arizona where low-cost power could produce strategic metals.

The surveying engineers faced the most trying working conditions. Waves of heat reflected from the canyon walls sometimes raised the temperature to 130 in the shade. Cloudbursts washed away roads leading to the camps. High winds leveled the tents. Sudden floods wrecked drill barges.

In 1924 the Bureau of Reclamation submitted eight volumes of painstakingly accumulated field data to the Secretary of the Interior. The report emphasized the possibility of a high dam at Boulder or Black Canyon (also called Lower Boulder Canyon) in the lower basin. There, it was shown, in either of these deep canyons on the Colorado about 400 miles from its mouth, a large storage dam could master the river.

A report of the Senate Committee on Irrigation and Reclamation in March 1928 agreed that "The overwhelming weight of opinion favors the Boulder or Black Canyon site . . . Natural conditions at this point are extremely favorable for the construction of a great dam at a minimum of cost."

A board of consulting engineers also reviewed the attributes of the two sites. It agreed with Reclamation engineers that Black Canyon was the better site.

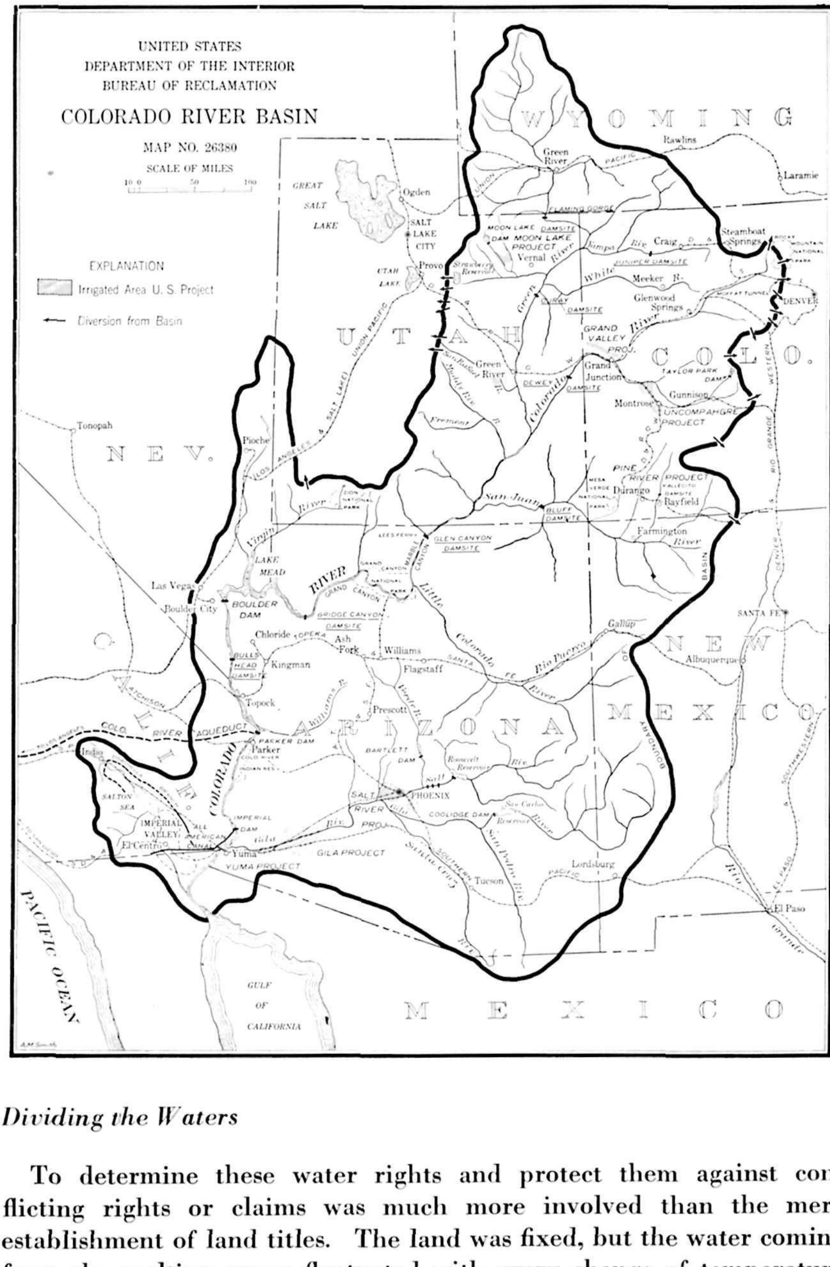
The locale for the greatest piece of engineering work in the world was settled.

Engineers and the general public had been referring to the future structure as Boulder Dam. The name clung, despite the decision to build the great dam in Black Canyon, and became fixed by usage.

In mastering the Colorado, the engineering was but one phase of the problem. Another—the legislative phase—had also to be solved.

The most difficult legislative aspect was the equitable division of the water.

The people who lived in the Colorado River Basin were dependent on the river. Wherever they lived, their right to use Colorado River water for irrigation was far more valuable than their title to the land.



Dividing the Waters

To determine these water rights and protect them against conflicting rights or claims was much more involved than the mere establishment of land titles. The land was fixed, but the water coming from the melting snows fluctuated with every change of temperature and in every month of the irrigation season.

The rights to the water which flowed down the sides of Fremont's Peak into upper Green River were determined by Wyoming laws which governed diversions from the river as long as it was within the boundaries of that State. When the river passed into Utah it became subject to the laws of Utah, and in succession to those of Nevada, Arizona, and California. The laws of New Mexico applied to the San Juan tributary. Beyond the international boundary, Mexico made claims.

The laws of six of the States were in harmony in that they recognized the right to appropriate the water, take it out and apply it to beneficial use. They were also in general agreement on the methods of determining how much water could be beneficially used, and the means employed to regulate diversion.

California's laws were different. California had enacted and put into operation a code of laws recognizing appropriation by beneficial use but also sought to retain its modified common-law doctrine of riparian rights, the right of a landowner to the water contiguous to his property whether or not he uses it. California's doctrine of riparian rights conflicted with the laws of the other six States.

It was thought also that the normal flow of the Colorado might be insufficient to supply all the uses projected by both basins, and when the idea of a great storage dam in the lower basin began to take shape the upper basin States became alarmed. They felt that the dam would enable water users in the lower basin to assert a right to all the unappropriated water above. Not as against existing uses, they said, but as a menace to future development, especially if power were combined with other uses. All the water might not be used for irrigation, but all could certainly be used to generate power.

In the meantime Arizona was formulating projects of her own, such as the irrigation of a large area of the lower Gila River basin and some land in the vicinity of Parker on the Colorado.

Crystallization of issues was a slow process. The States had approached the problem individually. The conception of a division of the water between basins instead of among individual States was a gradual development.

In 1920, at a meeting of representatives of the Governors of the Western States, a proposal for an interstate compact was endorsed. Each of the seven States of the Colorado Basin authorized the appointment of commissioners.

The Commission was presided over by Secretary of Commerce Herbert Hoover on behalf of the United States. After a series of meetings in Washington, D. C., and at various places in the Colorado River watershed, the Colorado River Compact was initialed by representatives of the seven States on November 24, 1922.

The compact adopted Lee's Ferry as the point of division between the upper and lower basins and effected an allocation of water between the two basins, leaving to future adjustments the division of water within each basin.

The Boulder Canyon Project Act

On December 21, 1928, the Boulder Canyon Project Act, presented to Congress in the Swing-Johnson bill, became law.

As finally passed, the Boulder Canyon Project Act: Approved the Colorado River Compact and made provision that in the event only six States should ratify, the compact should become effective as a six-State compact, provided California was one of the adhering parties, and provided also that California should agree to limit her use of water to the benefit of the other six States; authorized the construction of a dam at Black Canyon or Boulder Canyon; authorized construction of an All-American Canal connecting the Imperial and Coachella Valleys with the Colorado River; and authorized the expenditure of $165,000,000 for construction.

Six of the States ratified the compact. Arizona declined.

According to Charles B. Ward, chairman of the Arizona-Colorado River Commission, "The reasons for Arizona's refusal to ratify the seven States' compact were (1) Arizona objected to the inclusion of the Gila; and (2) while the prior appropriations doctrine would thereby be destroyed between the two basins by the allocation of waters to each of them, yet it would remain in full force and effect as between California and Arizona, and that while the upper basin States had escaped the danger which they had feared by California appropriating a great amount of water through the All-American Canal that it intended to build, yet the same danger would still confront Arizona."

Black Canyon—site of Boulder Dam

Drill barge exploring Hole 1-4, testing thickness of lava in the Colorado River bed

The authorization for the great dam listed the following purposes: (1) river navigation and flood control; (2) irrigation and domestic water supply and the satisfaction of present perfected rights; and (3) power.

The act established a unique method of financing construction. It established a special fund designated as the Colorado River Dam Fund. This fund was to bear somewhat the same relation to the Treasury as a subsidiary might have to a parent corporation. To this fund the act authorized the transfer from the Treasury of $165,000,000.

A condition precedent to the construction was that the Secretary of the Interior should provide for revenues adequate to insure operation, maintenance, and amortization. These revenues were to repay, within 50 years, all advances for the construction of Boulder Dam reimbursable under the act, with interest. They were to come mainly from the sale of power to be generated at the dam.

The necessary contracts for the sale of power for payment for the great dam were speedily arranged and concluded.

The stage for the drama was now set. The engineers could go to work.

The Bureau of Reclamation had a job, which would draw to the uttermost on its quarter of a century of experience and skill.

THE STORY OF BOULDER DAM

CHAPTER 2—THE DAM

THE canyon scene was an active one. Men and equipment were ferrying back and forth across the river. Batteries of vibrating drills sang out their machine-gun tune. Earth shovels roared, bucked, and swung about. Motor trucks charged up to receive their loads and swayed off. Orders were bawled, with yells of acknowledgment.

On top the canyon, high above the busy scene below, the picture assumed another perspective. The noise and activity became muffled and distant. Men became ants, and the earth shovels and trucks crept here and there on the canyon floor like slow-motion toys. Dominant over all was the great canyon and the river.

Men and machines declined to the diminutive, and the mighty Colorado seemed to surge with laughter at their puny efforts. But at intervals blasts shook the earth, and the surging waves of the Colorado changed to tremors. These Lilliputians seemed so determined . . .

★ ★ ★

The Fundamental Problem

To harness the Colorado River and bring it under beneficial control Reclamation engineers faced the fundamental problem of erecting a great dam that would do three things: Stop floods, hold the spring run-off for year-round use, and create a reservoir deep enough to trap the million tons of silt swept down the river daily without impairing the efficiency of the reservoir or interfering with the generation of power.

Blasting out the construction road to the dam site

The power plant in turn had to be large enough to make full economical use of the water, and also the long drop created by a high dam, for the sale of electrical energy was counted on to repay much of the cost.

It was determined that these requirements could be met by building a dam capable of impounding 10,500 billion gallons of water in a reservoir 589 feet deep, and by constructing a power plant capable of producing 6 billion kilowatt-hours annually.

The dam would be higher—726.4 feet from bedrock to roadway crest—than any ever constructed, and the power plant larger than any ever planned to that time. The 10,500 billion gallon reservoir would be the largest artificial lake ever created by man.

In the waters of the reservoir, just upstream from the dam, would stand four tall steel and concrete towers 33 stories high. Huge 170-ton steel gates in the towers would control the release of water from the reservoir. They would have the largest valves ever designed.

The huge gates when opened would permit the water to flow through penstocks—mammoth steel pipes big enough to drive a locomotive through with plenty of room to spare—and the penstocks would guide the water into the powerhouse or past the powerhouse into the river below the dam.

Two great troughlike spillways large enough to float a battleship, one on each side of the river just above the dam, would protect the dam and powerhouse from floods. All overflow would pour into the spillways, rush around the dam through huge tunnels 50 feet in diameter and emerge below.

The gigantic dimensions of the various structures and parts of Boulder Dam made the project appear almost presumptuous. Even engineers took pause. Some said: "It can't be done." A dam of such great magnitude presented insoluble problems, they maintained. Geologic conditions would not permit its erection. It would be impossible to control the river while the dam was being built. Even if the geologic conditions permitted, and the river were brought under control, the millions of tons of silt swept down by the river would fill the reservoir in a short time. Or if the silt were allowed to pass through it would destroy the gates, valves, and turbines.

They pointed out still other reasons for failure. No contractor would risk bidding on so large a job with such difficult construction conditions. The building site was in the lonely desert where no man could work in the summer because of the extreme heat. How could the millions of tons of construction material be transported across this blistering trackless desert and down the sheer 800-foot drop of the canyon?

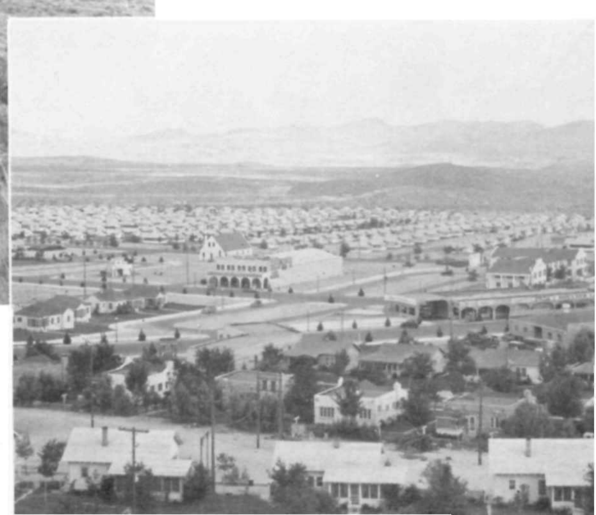
But exploration and preliminary work by the Bureau of Reclamation went steadily forward. Geologic examinations had shown that the task was not impossible. The job could and would be done, as assigned.

Specifications and drawings for the dam and appurtenant structures were being prepared in the main field office of the Bureau of Reclamation in Denver, Colo. Washington flashed word to rush the blueprint work. Actual construction should start as soon as possible in order to create employment, for the trying year of 1930 was upon the land. Drafting forces were increased and designers worked night and day. The specifications were rushed to completion.

On March 11, 1931, six months ahead of schedule, the Secretary of the Interior awarded the labor contract for construction of Boulder

The site of Boulder City

Boulder City, the model Government town



Dam to Six Companies, Inc., of San Francisco, Calif., the lowest bidder.

The bid was $48,890,995.50, the largest labor contract ever let by the United States Government at that time.

The Struggle Begins

The battle with nature was on. Arrayed on the Colorado's side were cloudbursts and sudden floods, the almost unbearable desert heat, the three-dimensional difficulty of transportation over burning desert and down over the brink of the canyon rim 800 feet to the canyon floor, and the hazards of working on the sheer canyon walls.

Allied with Reclamation engineers were the experiences gained from winning many similar though smaller battles, an ideal site for the great dam, and modern construction machinery.

It was necessary to build highways and railroads; erect machine shops, air compressor plants, garages, and warehouses; to span the canyon first by bridges and then later by heavy-duty steel wire cables half a mile long and as thick as a man's wrist; to construct a great gravel screening plant and two huge concrete mixing plants; to acquire

High scalers working 500 feet above the river

Drillers aloft

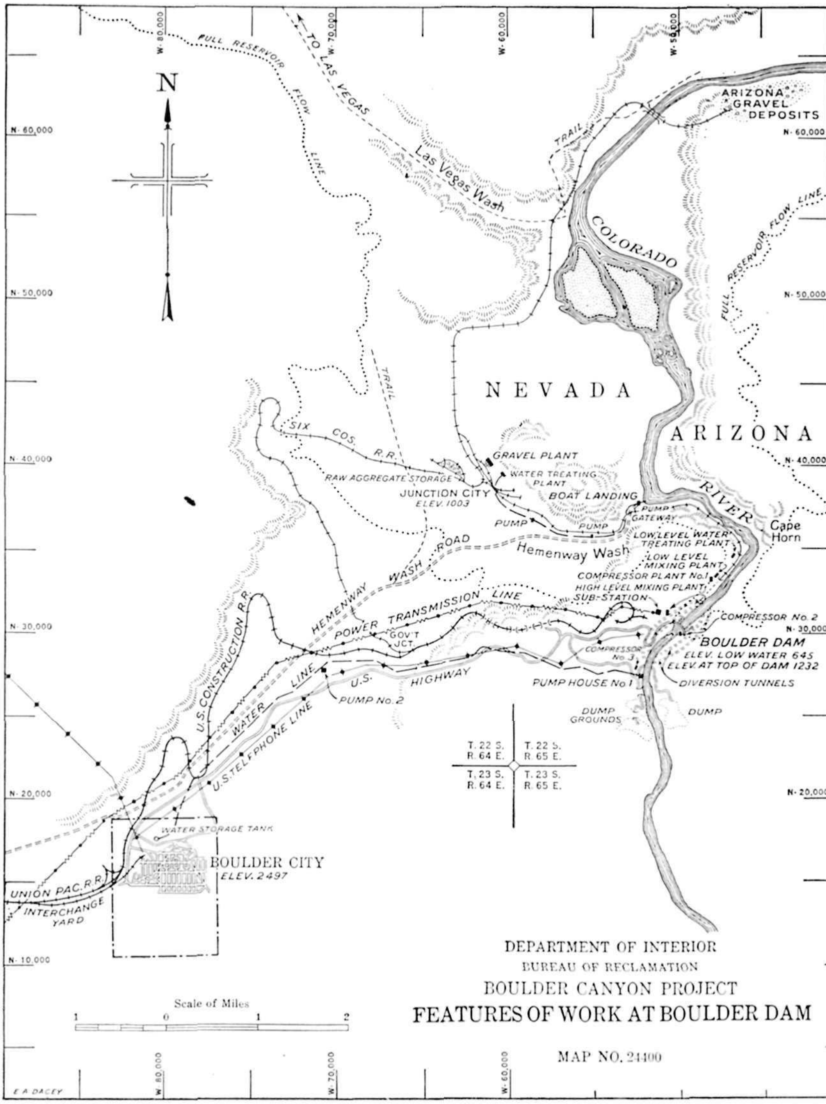
power draglines and power shovels, trucks, cars, derricks, and cranes in great numbers. It was necessary to bring power 222 miles across the desert from San Bernardino, Calif.

Care of the workmen required earnest thought. The temperature in Black Canyon rises to 130 in the shade and the daily mean for weeks stays above 100. All summer long the walls of the canyon throw off furnacelike waves of heat. Metal left in the glare of the sun burns to the touch.

After studying climatic soil conditions, a location for the construction town was chosen on a ridge 7 miles from the dam site. Here the Government's engineers plotted out paved streets, comfortable modern homes with green lawns and shrubbery, and dormitories and offices.

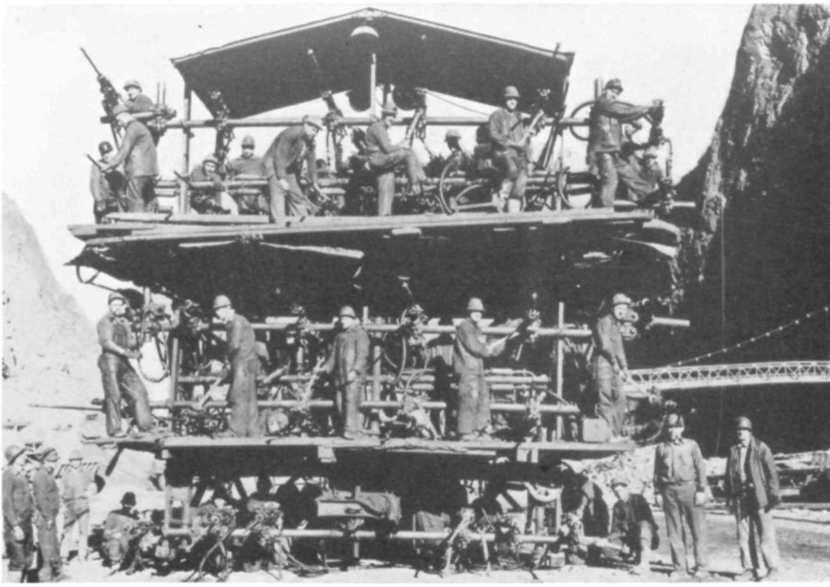
In the fall of 1931 the site of Boulder City was raw desert waste. A year later nearly 1,000 dwellings with all modern facilities sheltered the town's 5,000 inhabitants—the project officials, workmen, service employees, and their families. Built and under construction were stores, restaurants, churches, a school, a theater, hotel, and hospital—a complete modern little city.

Materials for the dam itself were required in quantities never before shipped to a single construction job in such a short time—5 million barrels of cement; 8 million tons of sand, gravel, and cobbles; 45 million pounds of reinforcement steel; 18 million pounds of structural steel; 21 million pounds of gates and valves; 840 miles of pipe. All were hauled over the railroads in the first 4 years of construction.



Often 60 carloads of materials a day arrived on the scene. The carloads of materials totaled more than 30,000 (not counting the 145,000 carloads of sand, gravel, and cobbles used for the concrete).

The Government and contractors employed as many as 5,250 men at one time with a gross monthly pay roll of more than $750,000. About 40 percent of the men were unmarried and lived in air-cooled dormitories. The workmen ate in a mess hall with a seating capacity of 1,300. Single men were charged $1.60 a day for meals, room, and trans-



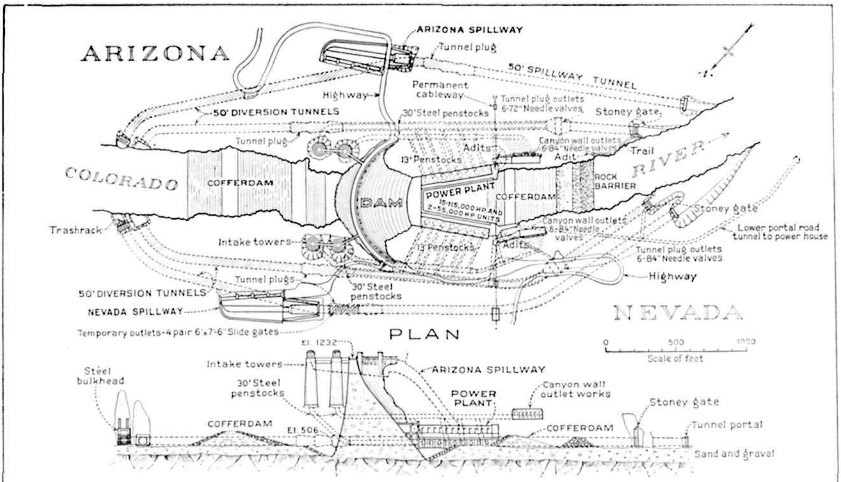
The jumbo drill—a battery of 30 drills ready for simultaneous action

portation to and from the canyon. Married men rented modern new homes from the contractor at $15 to $50 a month unfurnished.

Greatest Machinery Ever Seen

Even as the structures at Black Canyon were required to be the greatest of their kind ever built, so were many of the plants and much

A big hole for the river to flow through—one of the diversion tunnels



LONGITUDINAL SECTION
BOULDER DAM AND APPURTENANT WORKS

of the equipment. It was the greatest massing of specialized equipment ever witnessed on any construction project.

There were huge trucks for hauling materials, some of 16-cubic yard capacity, others of 50-ton capacity, and still others which were operated as 100- and 150-man transports.

Air compressor plants of 14,500 cubic feet per minute capacity were built near the river's edge.

The sand and gravel screening and washing plant to provide the aggregate (the sand, gravel, and cobbles to be mixed with the cement and water for the concrete) was the largest of its type. It could screen, wash, and place aggregate in readiness for mixture with cement and water at the rate of more than 16½ tons a minute

Plan of Attack

The general plan of attack in building Boulder Dam was to drill tunnels through the canyon walls around the site, to divert the Colorado through the tunnels, build cofferdams to block off the river from the dam site, excavate the site, and build the dam and power plant.

The narrowness of the canyon, the spread of activity up and down the river and the possible large fluctuation of the river's flow made the job of diverting the Colorado a ticklish one.

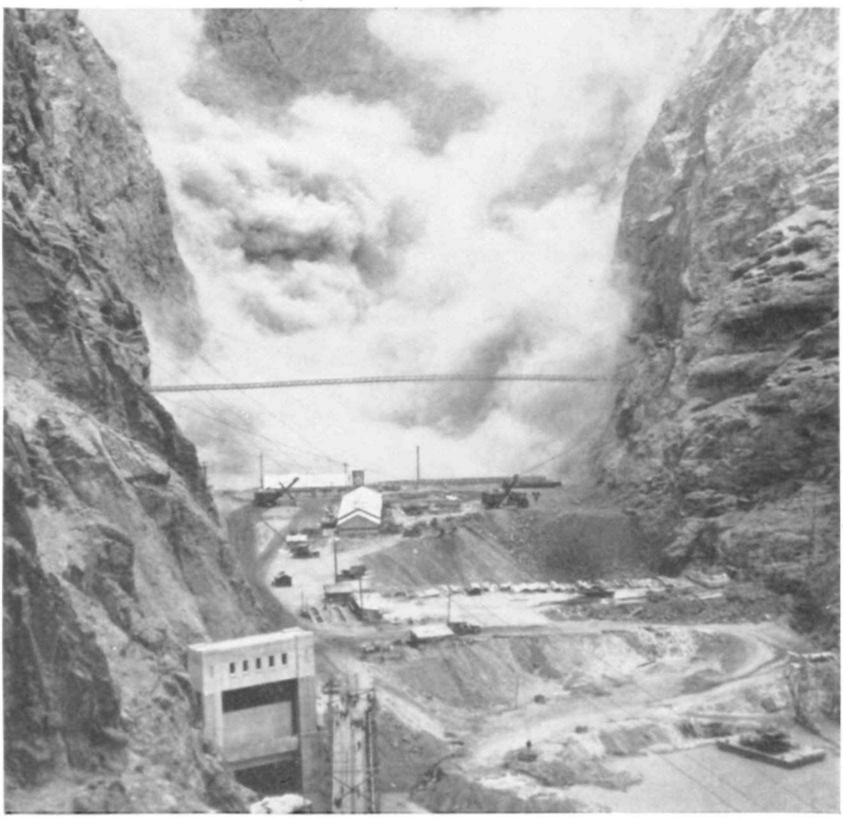
It had been decided to drive four diversion tunnels (two on each side of the river) around the dam site through the solid rock of the canyon walls. Two temporary cofferdams would then be built—one would be upstream, above the site but just below the tunnel inlets; the other would be downstream, below the site but just above the tunnel outlets. These cofferdams would block off the river so that the site could be pumped dry and excavated to foundation bedrock.

The four tunnels would have another important use besides diversion of the river. After completion of the dam, they would serve to house the outlet works used in the regulation of the reservoir. The two outer tunnels would become outlets for the huge spillways. The two inner tunnels would guide the stored water from the intake towers in the reservoir to the power plant or past it to the outlet valves below the dam.

The dispatch with which the diversion tunnels were driven forecast the efficiency and speed with which the entire job would be handled.

The canyon walls were attacked first by batteries of compressed-air drills. An especially designed drilling jumbo equipped with 30 drills lumbered into action. When the drills had bitten 10 and 20 feet into solid rock a ton of dynamite was loaded into the holes. The electrically

Blasting away the sides of the canyon



At work in the river bed

fired blast shook the walls. Power shovels moved to the tunnel face, and the broken rock was loaded into trucks. The trucks then roared up the grade to dump their loads in side canyons. Soon all was in readiness to repeat the performance.

An average blasting round broke 1,000 cubic yards of rock and advanced the heading 17 feet. Work progressed at times from 8 headings. A total length of 256 feet of tunnel was driven in 24 hours, and 6,848 feet in 1 month. Removal of the million and a half yards of rock in the 4 tunnels required 3,561,000 pounds of dynamite, or 2.38 pounds per cubic yard.

Each of the 4 diversion tunnels was holed out to 56-foot diameter—as high as a 4-story building—and lined with a 3-foot thickness of concrete. The total length of the tunnels was approximately 3 miles.

The Engineers Turn the River

As soon as the two tunnels on the Arizona side of the river were lined, a pile trestle bridge was built across the river downstream from the tunnel inlets and the temporary barriers in front of the tunnel portals were blasted away. Trucks ran out on the trestle bridge and dumped their loads of large rocks, then smaller ones, and finally sand, into the channel. Within 24 hours a temporary dike was formed, blocking the river and forcing it out of its age-old channel and into the tunnels.

Meanwhile, downstream below the dam site, a dike of tunnel muck was pushed across the river channel just above the tunnel outlets. This prevented the river from backing into the area.

The Colorado River had been diverted. With the temporary dikes in place, and the water pumps sucking the dam site clear of water, excavation proceeded swiftly for the main structure of the dam itself and the powerhouse. Safe and dry, the huge power shovels, draglines, and powerful trucks labored 24 hours a day digging down to the solid rock 135 feet below the river bed. They removed more than half a million cubic yards of muck, sand, and gravel.

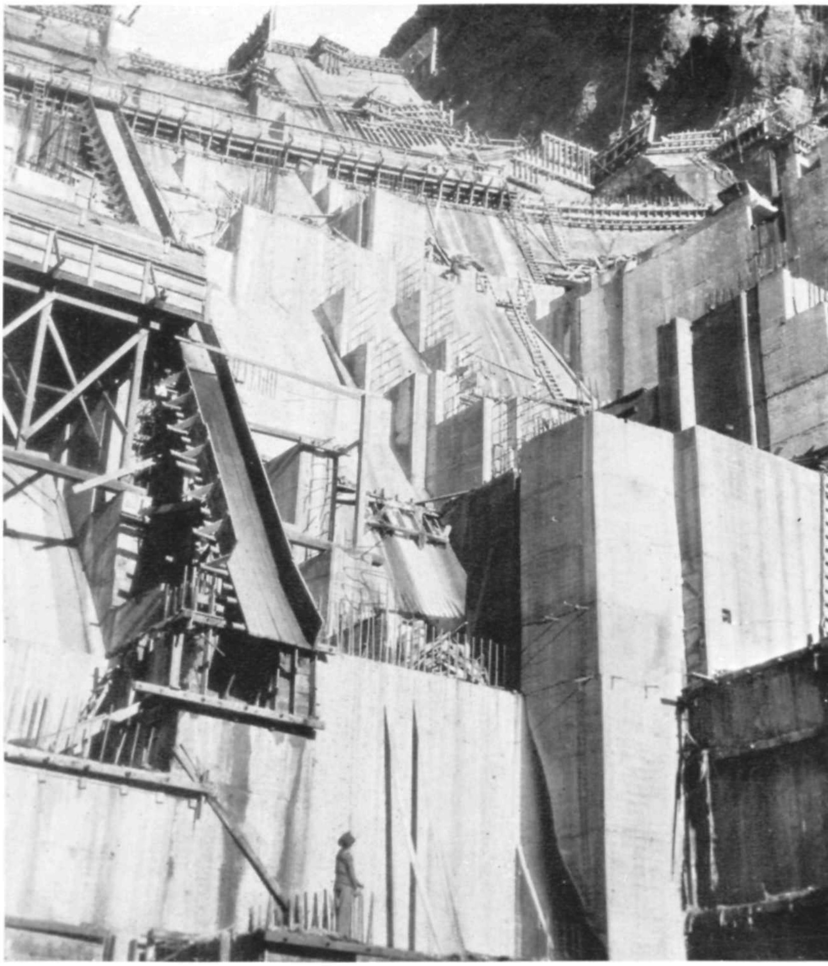
Work also went ahead on the removal of loose and projecting rock from the canyon walls. To get at the desired spots the "high scalers" either climbed up ropes or were suspended from anchors sunk in the canyon rim. They swung in safety belts or bosun chairs pendulum fashion hundreds of feet above the river and gouged at weak spots or drilled blasting holes. Nine hundred and thirty thousand cubic yards of rock were dislodged from the walls.

An Impasse Confronts

An impasse confronted the engineers in obtaining the steel pipe to form the penstocks inside the huge diversion tunnels. The penstocks required 2¾ miles of plate steel pipe nearly 3 inches thick whose gross weight exceeded 44,000 tons. The penstock header lines were to be 30 feet and 25 feet in diameter, the penstocks 13 feet (except 108 feet of 9-foot diameter), and the outlet conduits 86 inches and 102 inches in diameter.

Standard railroad cars were too small to transport the larger pipe sections, which would not pass through a normal railroad tunnel. They could not be shipped, therefore, from existing rolling mills. The engineers conferred. They hit upon the solution. They would construct a plant right at the dam site and manufacture the great pipes on the spot.

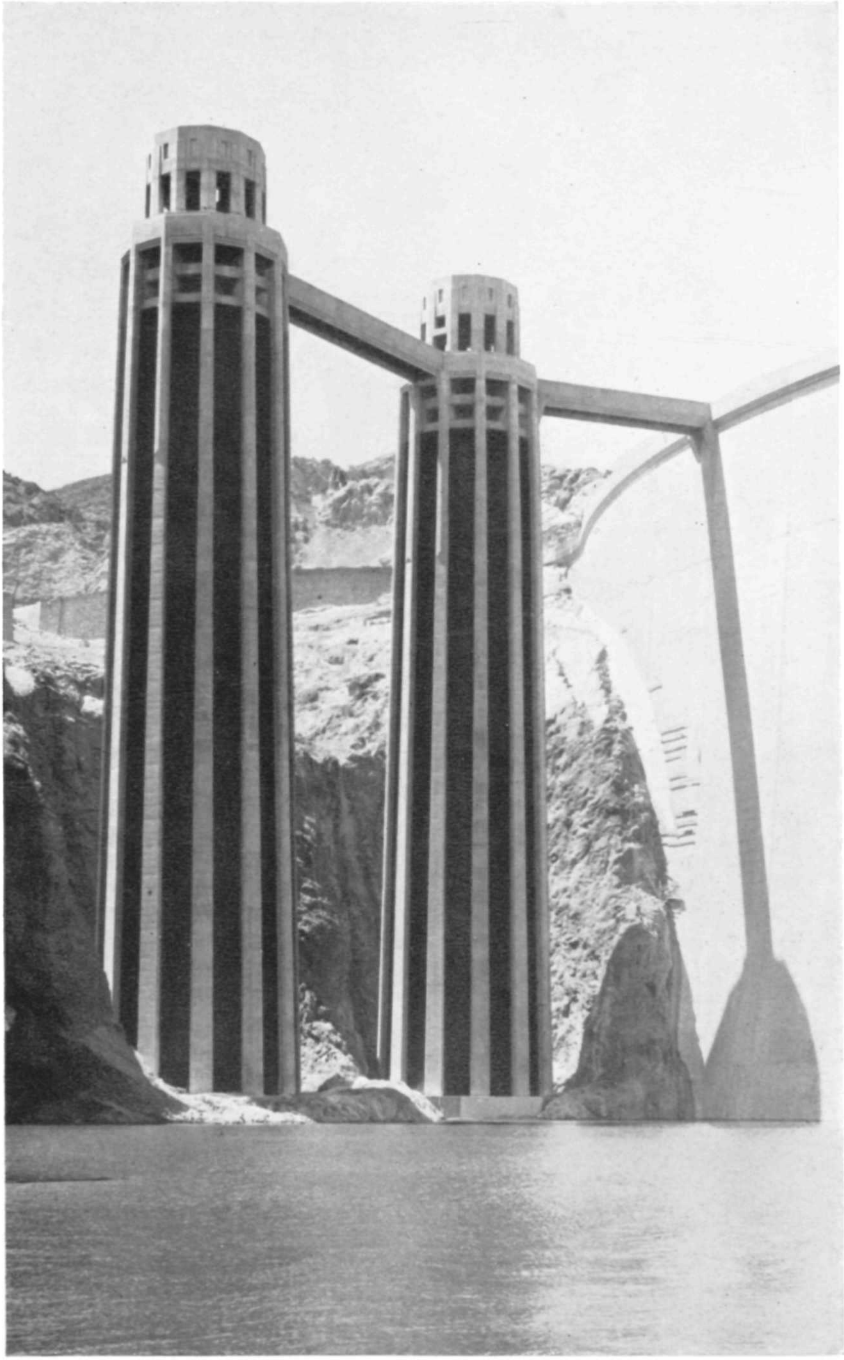
Dumping a bucket of 16 tons of concrete



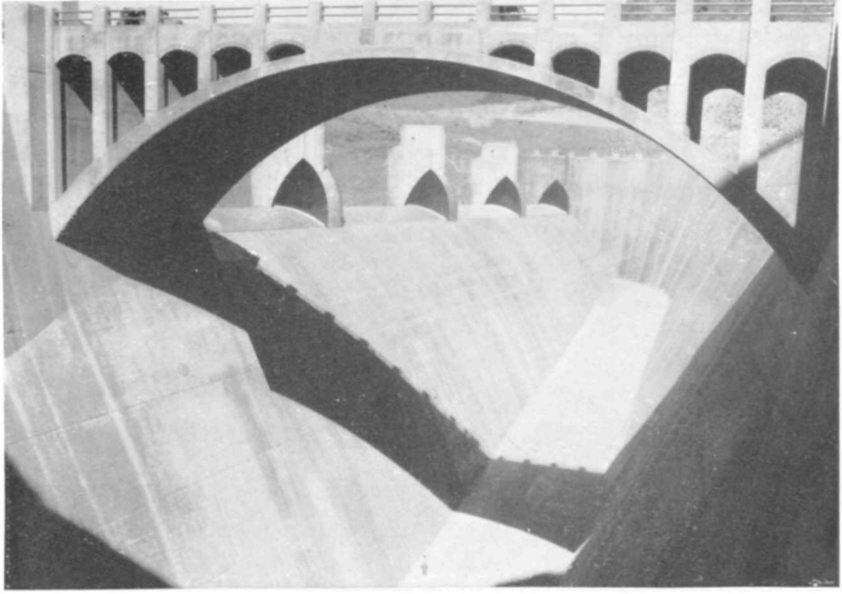
The dam rises, step by step, in solid blocks of concrete

The fabrication plant was erected along the construction railroad a mile and a half from the top of the Nevada dam abutment. The flat steel plates were shipped in by rail and the pipe sections were fabricated in the plant. A section of the largest pipe when completed was over 23 feet long and weighed 175 tons.

Fabrication of a 30-foot section consisted of marking six 10-foot 6-inch by 31-foot 5-inch flat plates, cutting them to size with an acetylene torch, planing welding grooves on three sides, preparing the plates for rolling by bending the ends in a 3,000-ton press, rolling the plates in 12-foot vertical rolls, assembling and electrically welding the plates together and adding butt straps and stiffeners. All welds between the



The graceful intake towers whose gates control the release of the reservoir water



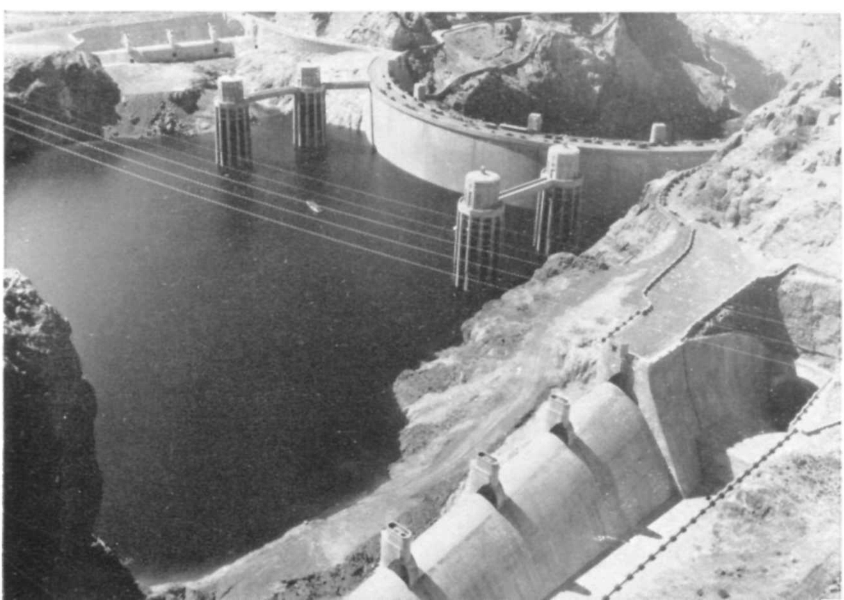
The Arizona spillway—big enough to float a battleship

rolled plates were then X-rayed by a 300,000-volt portable machine, the film examined, all flaws chipped out and replaced with new metal, and the weld X-rayed again.

The pipe was then taken by 75-ton traveling cranes to the normalizing furnace where it was heated to a temperature of 1,150° F. It was held at this temperature for several hours, and slowly cooled to relieve the stresses set up by rolling and welding. Fabrication of the pipes required approximately 76 miles of welding and 29 miles of X-ray film.

A 200-ton trailer pulled and controlled by two 60-horsepower caterpillar tractors transported the heavier pipe sections from plant to canyon rim. The 200-ton cableway transferred the pipe from canyon rim to a "car-on-a-car" at the portals of one of the construction adits whence it traveled on the double carriage through the adit to a penstock

Looking down on the lake, the spillways, the dam



header tunnel. Finally it was pulled to its position by winches and hoists.

All pipe sections were joined with steel pins, the largest of which were 3 inches in diameter, except the $8\frac{1}{2}$-foot outlet conduits, which were hot-riveted, and a few miscellaneous sections that were welded. In welding, the weld and pipe near it were stress-relieved by heating with gas rings.

Meanwhile, while the engineers were surmounting the difficulty of making and installing the great penstock pipes, the main job of concrete placement for the huge structure of the dam was being carried out swiftly. On June 6, 1933, the first bucket of concrete was placed. Six months later a million yards were in place. Another million was poured in the following half year, and the third million by December 6, 1934, only 18 months after starting placement.

As soon as construction of the dam, intake towers and outlet works was sufficiently advanced, and the upstream portions of the two inner diversion tunnels plugged with concrete, a steel bulkhead gate was lowered at the inlet of the outer diversion tunnel on the Arizona side of the river.

The River Harnessed at Last

This was February 1, 1935. Back of the unfinished dam, water started to rise. The Colorado had been blocked and thrown back on its haunches. By midsummer the new reservoir held more than one

Aerial view of Boulder Dam and Lake Mead

trillion gallons of water. And the formerly muddy brown waters of the river dropped their silt and became a beautiful deep blue.

When the newly formed Lake Mead had risen to the base of the intake towers, 260 feet above the river bed, the one remaining opening—the slide gates in the Nevada outer diversion tunnel plug—was closed to the Colorado. From that time on the river had to respond to rein. The broncho of the West was fully harnessed.

Concrete pouring continued and the crest height of the dam was reached March 23, 1935. By the following summer all the concrete—3,250,335 cubic yards, 6,900,000 tons of it—was in place, with the exception of the filling of temporary galleries.

In 21 months 1,200 men with modern equipment had built a structure whose volume was greater than the largest pyramid in Egypt, which, according to Herodotus, required 100,000 men and 20 years to build.

The dam towered to a height of 726.4 feet—more than half that of the Empire State Building in New York City; it had a base thickness of 660 feet—more than the length of two ordinary residence blocks; a crest thickness of 45 feet—room enough for 4 lanes of highway; and it was 1,244 feet long—nearly a quarter of a mile.

The Government's contract had allowed Six Companies, Inc., 7 years to complete the work, but with the aid of an efficient personnel, and the assistance of the most modern equipment, the contract was completed 2 years ahead of schedule.

The speedy and successful completion of the Boulder Dam contract was the finest achievement of the ability and lengthy experience of a combination of grand old construction men.

One of the master strokes in the construction of Boulder Dam was the cooling of the concrete. Left to itself, the vast bulk of the dam would have taken more than a century to cool off from the heat created by the setting of the cement, shrinking as it cooled, and cracking as it shrank. The ingenious solution was to build the dam in pierlike blocks and to cool the placed concrete by running ice-cold water through pipes imbedded in the blocks. As each block contracted and left gaps between itself and adjacent blocks, engineers pumped the gaps full of special grout concrete, making the structure monolithic, of one piece.

Boulder Dam was done. A permanent asset had been added to the Nation's productive economy. The years of study and the plans and the blueprints had materialized into lasting structural achievement. And within a few short years, more quickly than expected even by its creators, Boulder Dam amply demonstrated its economic and social value to the Southwest and the country as a whole. Its benefits were great and many. Soundly conceived, soundly constructed, Boulder Dam brought almost immediate returns.

THE STORY OF BOULDER DAM

CHAPTER 3—THE BENEFITS

A Significant Prophecy

WHEN the Committee on Irrigation and Reclamation of the United States Senate in March 1928 endorsed the construction of multi-benefit Boulder Dam it made this significant prophecy:

"A mighty river, now a source of destruction, is to be curbed and put to work in the interest of society."

Boulder Dam was built to bring the following major benefits:

First, flood control. Protection for the lives and property of 100,000 people who lived at the mercy of an unbridled river.

Second, water for the irrigation of nearly 2,000,000 acres of rich land, a third of which was already under intensive cultivation and completely dependent on the water supply.

Third, water for domestic, industrial, and municipal use by the rapidly expanding population of the southern California coastal region.

Fourth, elimination of damaging, clogging silt deposits, whose removal was costing more than $1,000,000 annually.

Fifth, improvement of navigation.

Sixth, a national playground and recreational area.

Seventh, a new wildlife and bird refuge.

Eighth (on a last-but-not-least basis), the generation of low-cost power.

On Lake Mead

On September 30, 1935, less than 5 years after the construction appropriation, in dedicating Boulder Dam, President Franklin D. Roosevelt said:

"This is an engineering victory of the first order—another great achievement of American resourcefulness, skill and determination. This is why I congratulate you who have created Boulder Dam and on behalf of the Nation say to you 'Well done.'"

Volumes have been written of the engineering and physical features of an undertaking that conquered America's most dangerous stream and conserved its vast resources for the good of mankind. The conservation of these resources, the actual work of the dam, is a story in itself.

Flood control is an important chapter of that story. In less than 5 years from the first construction appropriation, Boulder Dam took control over the floods of the Colorado River.

Lake Mead Swallows the Floods

Set in the midst of the brown, red and purple mountains and mesas of the Southwest, shining in the bright western sun, a great clear blue lake has been formed behind Boulder Dam. It is Lake Mead,[1] Boulder Dam's reservoir, the largest artificial lake in the world.

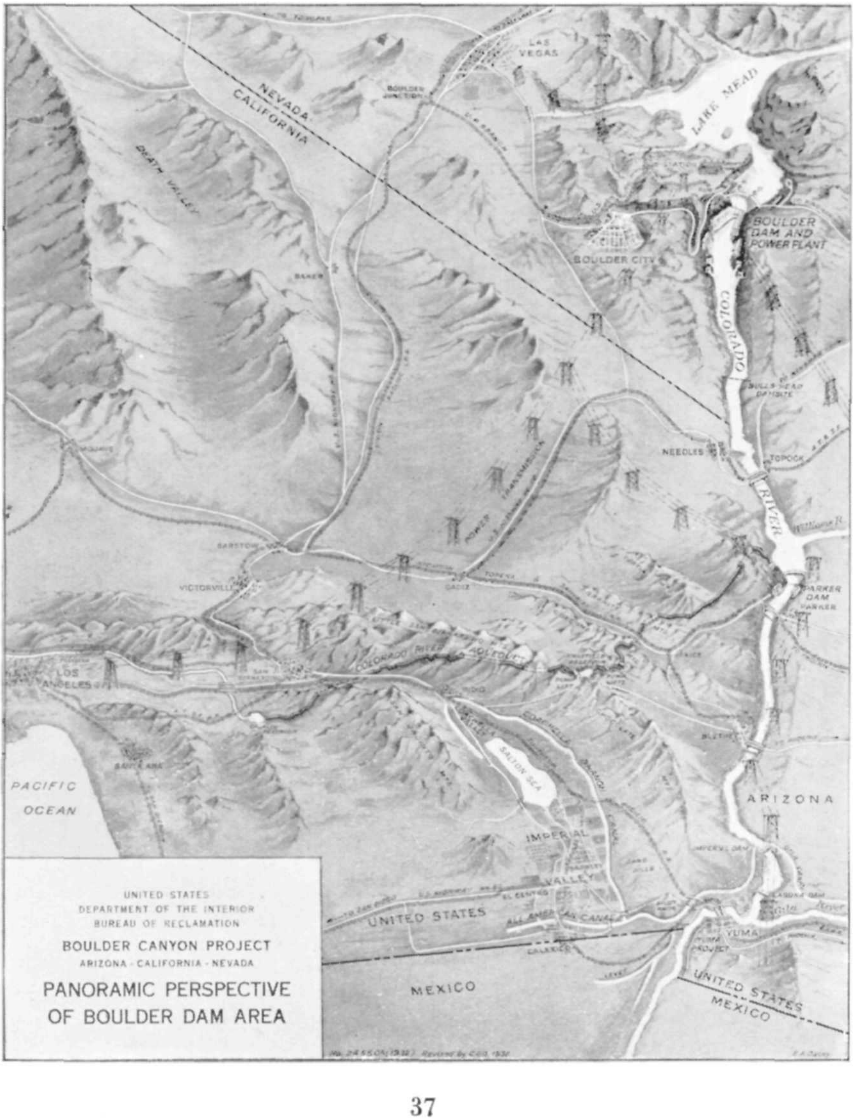
This useful and beautiful lake now gathers to itself the wild, muddy floods of the Colorado, so destructive and expensive in the years before the building of Boulder Dam. The lake has a storage capacity of 32,359,274 acre-feet—enough to store more than 2 years of the Colorado's average flow—enough to supply every man, woman and child in the United States with 80,000 gallons of water each.

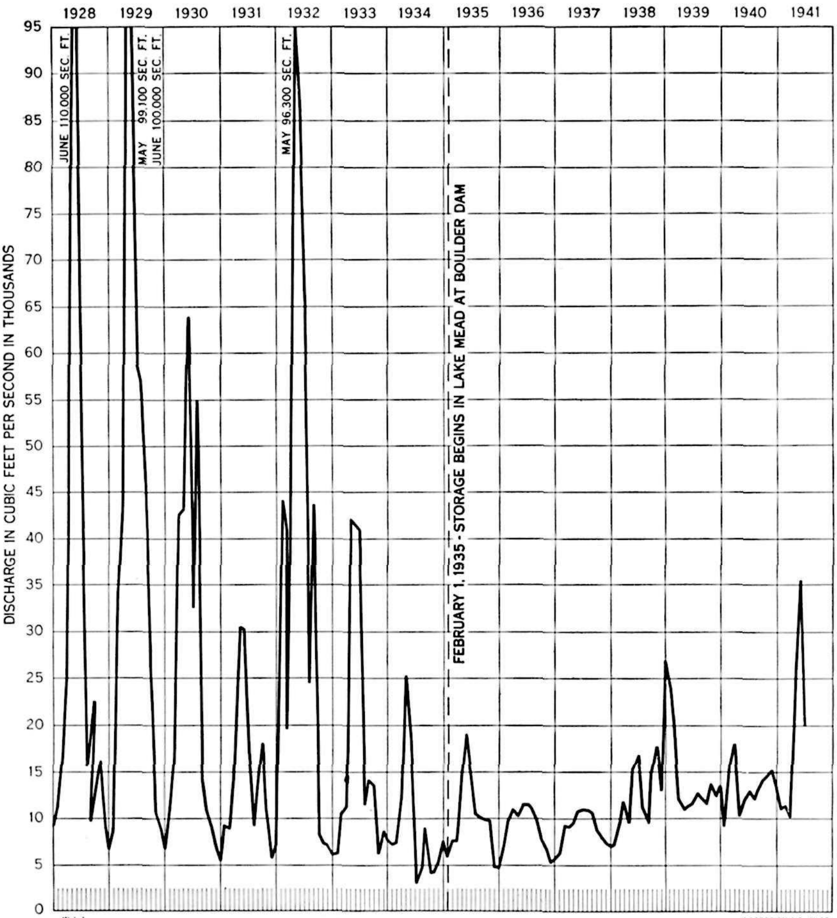
[1] Named for Dr. Elwood Mead, Commissioner, Bureau of Reclamation, 1924–36.

When full, Lake Mead has a depth of 589 feet, a shoreline of 550 miles, and a water surface area of 227 square miles. It extends upstream 115 miles above the dam.

With its great reservoir the dam controls not only the flashy, lesser floods which may occur during any month of the year, but also the great flood-tide run-off occurring in the spring and summer months.

The upper 72 feet of Boulder Dam's reservoir capacity—9,500,000 acre-feet—is reserved for its flood control work. This capacity is not encroached upon for the storage of water except to control the discharge





MAXIMUM DISCHARGE OF COLORADO RIVER AT BOULDER DAM

below the dam to the amount that can be carried safely through the lower valleys without the expenditure of excessive amounts of money for protective levee work.

No longer at the mercy of the Colorado are the homes and highly productive land in the Imperial, Coachella, Yuma, and Palo Verde valleys which pioneers had carved from the desert, representing property values of a quarter of a billion dollars.

With Lake Mead functioning, the large floods passing the dam site are reduced from 200,000 cubic feet per second to 45,000, and the extreme floods from 300,000 cubic feet per second to about 75,000. With this control established, 100,000 residents of the valleys below need no longer fear the Colorado, provided the channels and levees carrying away even the greatly reduced discharges are maintained.

No More Drought

The second great benefit from Boulder is the provision of an adequate, reliable supply of water for irrigation.

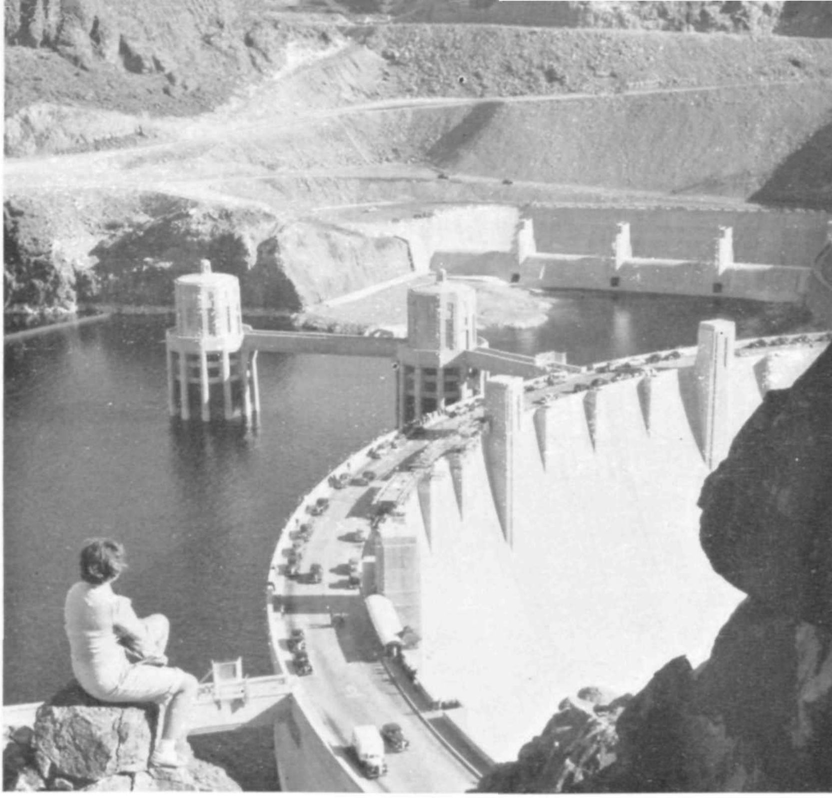
No more does this giant of a western desert stream fluctuate each year through a cycle of a roaring, flood-swollen spring torrent fed by melting northern snows to a sandy-bottomed sluggish creek during long dry summer and autumn months.

No more is the Colorado's water—as precious as the gold that drew the Forty-niners westward nearly a century ago—wasted unused into the sea during flood season. Instead, the Colorado's water is put to use.

The irrigated Southwest is the all-year vegetable and fruit basket of the United States. With an adequate supply of water for artificial application, the rich soil and warm climate make the Imperial and other valleys veritable Gardens of Eden. From farms under irrigation in the Southwest come in the dead of winter quantities of healthful green vegetables, citrus fruits essential to the varied American diet, figs and dates, grapes and raisins, olives, avocados, walnuts, almonds, and other exotic fruits and nuts once entirely imported from tropical lands.

It is estimated that about 1,900,000 acres of irrigable lands are located below Boulder Dam, in the United States. At present there are about 660,000 acres under cultivation, of which 450,000 lie in the Imperial and Coachella Valleys.

Imperial Valley winter lettuce, row on row



One of the 600,000 visitors during 1940 gazing at the dam

Without Boulder Dam the extension of irrigation in these lands was out of the question. The natural flow of the river was already overtaxed during the peak of the irrigation season. During a year such as 1934, when the Colorado River discharge was a little over 4,000,000 acre-feet, about one-quarter of the expected normal, there was serious shortage. Crops valued at $10,000,000 were lost. Entire communities were jeopardized.

Today the supply of irrigation water stored by Boulder Dam is adequate for all irrigation use. Lake Mead impounds more than five years' full irrigation supply for the irrigated farm lands below. Southwestern irrigation farmers need no longer dread the specter of drought, of a river running dry.

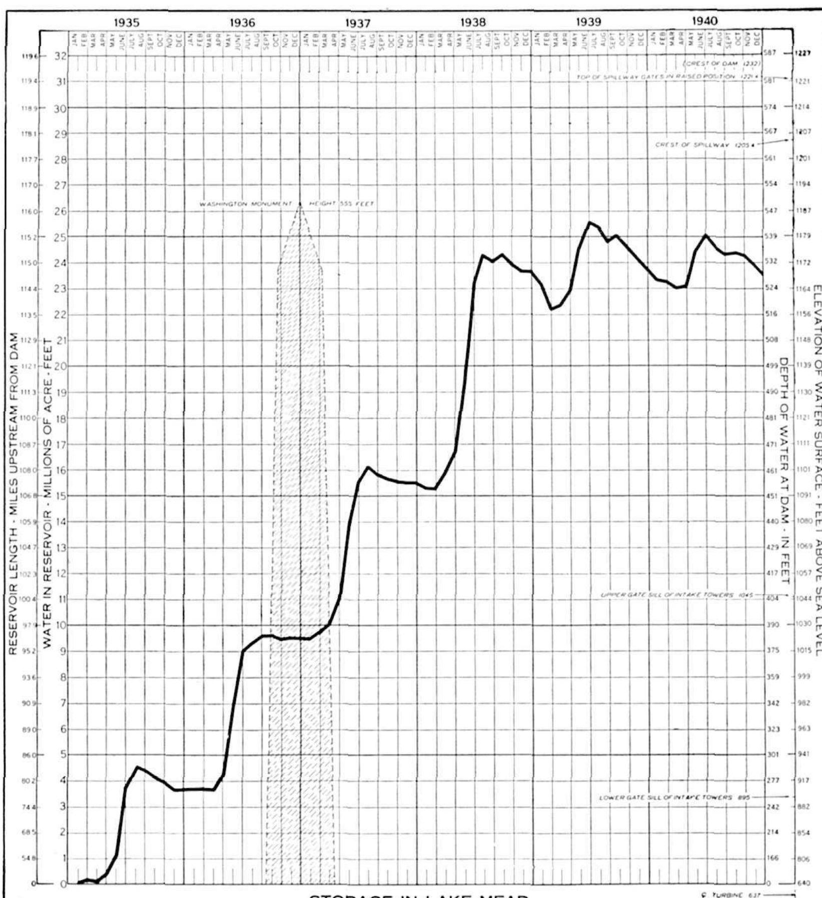
A Vital Metropolitan Water Supply

At the same time, opportunity for a new home and decent livelihood can be opened to 20,000 or more families on irrigated farms claimed from the desert. Communities and towns will also arise among these farms and offer a means of living to thousands of other families.

A third important benefit derived from Boulder Dam's construction is the provision of a metropolitan water supply vital to the economic welfare and growth of southern California and 13 of its coastal cities—Anaheim, Beverly Hills, Burbank, Compton, Fullerton, Glendale, Long Beach, Los Angeles, Pasadena, San Marino, Santa Ana Santa Monica, and Torrance.

Southern California is a semiarid region. Average rainfall near the coast is 15 inches annually, far less than that required for dependable agricultural development, to say nothing of the needs of modern industrial cities. In other areas the average annual rainfall shades down to 3 inches.

For many years the people of the southern California coastal plain had been pumping out of underground reserves 200,000,000 gallons a day more than Nature or man replaced. The result was a dangerous depletion of local water resources.



STORAGE IN LAKE MEAD
BEGINNING OF OPERATIONS FEBRUARY 1935, TO DATE

Motorboating up through the canyons, Lake Mead

A large supply of additional water was urgently required to sustain the 13 cities and their growing industries. In these cities and their suburban and rural sections resided nearly 3,000,000 people. Property values were assessed at $2,800,000,000.

The destiny of all this area depended on an additional supply of water.

The only available source of supply large enough was the Colorado River. Without regulation the Colorado was useless.

By regulating the Colorado River, Boulder Dam assured this supply and opened the river to this vital use.

With Boulder Dam in control of the Colorado it was possible to construct Parker Dam 155 miles below to form a forebay from which an aqueduct could draw off the water needed.

The 13 cities combined to incorporate the Metropolitan Water District of southern California which floated a $220,000,000 bond issue to pay for the dam and aqueduct. The Bureau of Reclamation built the dam with funds advanced by the District and the District built the aqueduct.

Today the Colorado River Aqueduct carries Colorado River water over mountain and desert for 242 miles, through tunnels, conduits, canals, and siphons, to distribute it to the homes and industries of southern California.

It is the largest single domestic water supply system in the world. It has a capacity of 1,500 cubic feet per second or approximately a billion gallons daily.

The Metropolitan Water District has a contract with the Government permitting it to draw 1,050,000 acre-feet of water annually from the Colorado River, water released at Boulder Dam. The charge for Lake Mead's water is nominal, 25 cents per acre-foot of 325,851 gallons.

According to the chief engineer and general manager of the Metropolitan Water District, Boulder and the aqueduct provide a supply of water "sufficient to meet the requirements of a population in excess of 7 millions"—more than twice the present population.

The soil of southern California is rich and fruitful, and the people energetic. It has been outstanding in the production of tangible wealth for the State and the Nation. The value of crops produced in Los Angeles County in 1930 exceeded that of any other county in the United States.

The new supply of water from Lake Mead has released for agricultural purposes much of the remaining underground reserves of the southern California coastal area. Boulder has made it possible for the entire region to grow and develop, industrially as well as agriculturally, and to continue to pour its contribution into the lifestream of the Nation.

Four happy fishermen and their Lake Mead catch

The Silt Menace Subdued

A fourth benefit of Boulder Dam is the elimination of hundreds of millions of tons of silt from the waters released at Boulder Dam.

The Colorado gets its name from its reddish-brown color, and the reddish-brown color comes from the silt carried in its turbulent waters. Engineers have estimated that the average flow of the river carries 330 tons of silt and sand past a given point every single minute of the day and night.

This silt not only obstructs the diversion works, canals, and ditches of those who wish to use the water, but its deposition is dangerous. Silt deposits result in the gradual building up of the ground elevation. A committee of the United States Senate in 1928 reported as follows:

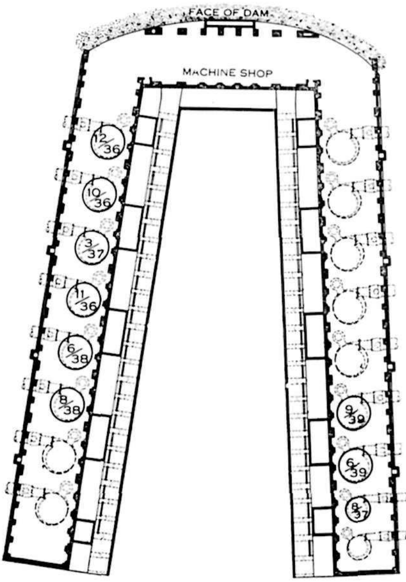
"The river has an annual discharge at Yuma of more than 100,000 acre-feet of silt. This silt greatly aggravates the flood menace. No temporary works can be built to hold it. It was the silt deposit that built the deltaic ridge on which the river now flows. It was the silt deposit that filled the Bee River and Volcano Lake, so that the river could no longer be held at that point, and the same silt deposit will quickly fill the depression where the river now flows.

"The gradient to the north into Imperial Valley is much greater than that to the south into the Gulf, and when the depression is filled there is no means known which, at any cost within reason, can prevent the river from again flowing into the Imperial Valley.

"The dam proposed in this bill will catch and hold the silt. Most

The most powerful powerhouse in the world

of the silt finding its way onto the delta is from and above the canyon section. If no other dams were provided on the river, the one proposed in this bill would retain all of the silt finding its way into the reservoir for a period of 300 years, and for more than 100 years before its storage capacity and usefulness would be seriously interfered with. As other dams are constructed on the river they will catch and retain the silt, thereby further extending the usefulness of the Boulder Canyon Reservoir."



PLAN OF POWER HOUSE
SHOWING DATES OF FIRST REGULAR OPERATION

Reclamation engineers set aside 5 to 8 million acre-feet of Boulder Dam's reservoir capacity for the job of settling out the silt. The deep reservoir forms a natural trap for the silt swept down the river. The flow slackens as it enters the lake and the silt, heavier than the water, sinks to the bottom of the reservoir, leaving the water above clear. As the silt drops down into the deep and capacious bottom of Boulder Dam's reservoir, blue Lake Mead bears witness that the task is well performed.

Navigation on the Colorado

A fifth benefit from Boulder Dam's construction is the improvement of navigation on Lake Mead and on the river between Boulder Dam and Imperial Dam, the point of diversion for the new All-American Canal which leads Colorado River water to the Imperial Valley.

Technically, before the construction of Boulder Dam, the Colorado was considered a navigable stream, but under conditions of unregulated flow navigation was impracticable. The flow of the river at Black Canyon ordinarily varied from 3,000 cubic feet per second to 150,000. Sometimes the variation in flow was still more severe. In August 1934 the river dropped to 1,780 cubic feet per second, and in 1884 the flood is estimated to have been between 300,000 and 350,000 cubic feet per second. At low flow, the river channel shifted daily and made navigation out of the question except for very small boats. At flood stage, on the other hand, the river was unnavigable because of its high velocity.

With the river regulated by Boulder Dam the steady flow ranges from 12,000 to 20,000 cubic feet per second. The maximum flow to be expected is about 45,000 cubic feet per second, to control the usual seasonal floods. This may reach 75,000 cubic feet per second once in about 100 years. The Colorado can now actually be navigated.

A Nation's New Playground

A sixth and truly symbolical benefit resulting from Boulder Dam—a national instrument for the use and enjoyment of the people—is the creation of a new national playground.

Visitors to the lake come from all parts of the United States by every mode of transportation—train, plane, auto, bus, bicycle, and even boat.

The tourists numbered 600,000 during 1940. They used nearly 200,000 automobiles and more than 2,000 large sightseeing buses and nearly 1,500 airplanes, mostly large transports.

Lake Mead is considered worth traveling hundreds of miles to see. The 115-mile lake stretches past Fortification Hill, through narrow Boulder Canyon, through Virgin Canyon, Iceberg Canyon, past the white Grand Wash cliffs, and far into the Lower Granite Gorge amid high coloring and spectacular geological formations. The lake reaches up into the lower end of the Grand Canyon itself, opening up hitherto unseen scenic beauty. Previously these vistas were utterly inaccessible.

The lake has 550 miles of shoreline for camping, bathing, boating, and fishing. Although hot during the summer months the climate during the remainder of the year is ideal for outdoor enjoyment. The winter is especially delightful.

The recreational area created by Boulder Dam is a day's drive by automobile from Salt Lake City, Phoenix, Los Angeles, and other cities in the Southwest.

Precautions have been taken by the Bureau of Reclamation for the comfort and enjoyment of visitors. Roadways to the dam itself have been widened, protective safety walls built, and special guides provided for a tour of the dam and powerhouse. Motor boats are available for lake trips. A special visitors' building contains a large, elaborate model of the dam area, complete in every detail.

Fishing is one of the prime attractions. Lake Mead abounds in black bass, bluegill perch, crappies, and catfish. Fishermen are not confined in their sport to certain weeks or months of the year; the lake has an open season all year round.

Below Boulder Dam the Colorado River has been planted with thousands of rainbow trout. It should soon become the finest trout stream in the Southwest. The clear cold water pouring down out of the deep recesses of Lake Mead creates a perfect habitat for the beauties. For 45 miles downstream, with deep inviting pools along the way, the river water is as fresh and invigorating as a mountain rill.

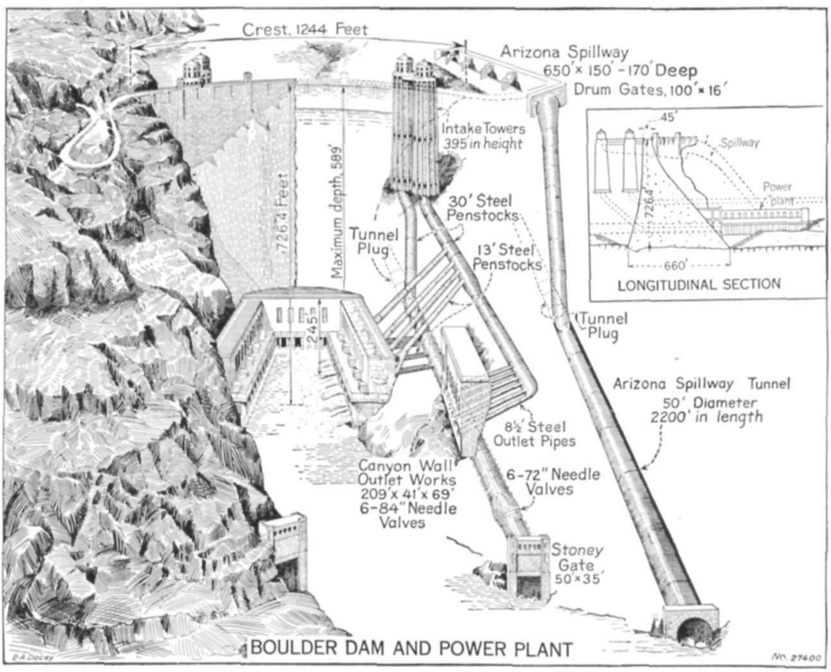
Haven for Wildlife

Other wildlife flourishes in the Boulder Dam area also. This—the formation of a wildlife and waterfowl refuge—is a seventh beneficial result of building Boulder Dam.

The area has been officially designated as a wildlife refuge, with hunting forbidden. Nearly 650,000 acres of mountain and mesa surrounding Lake Mead offer haven to animals and birds. They are fostered and protected. Mountain sheep and Gambel quail thrive in the uplands.

Lake Mead and Lake Havasu (the Metropolitan Water District reservoir formed by Parker Dam 155 miles below Boulder) offer sanctuaries of considerable value in waterfowl conservation. The pintail and the mallard, the Canadian goose, the snowy egret, the sandpiper and other birds frequent the refuges.

Lake Havasu, located on the main flyway, is ideal. Ducks, geese, and other birds on their long annual migrations south and back find Lake Havasu's shallow waters a harbor of rest.



BOULDER DAM AND POWER PLANT

Power and the Strength of the West

The eighth and one of the major benefits to the Southwest from the construction of Boulder Dam is the generation of low cost electric power.

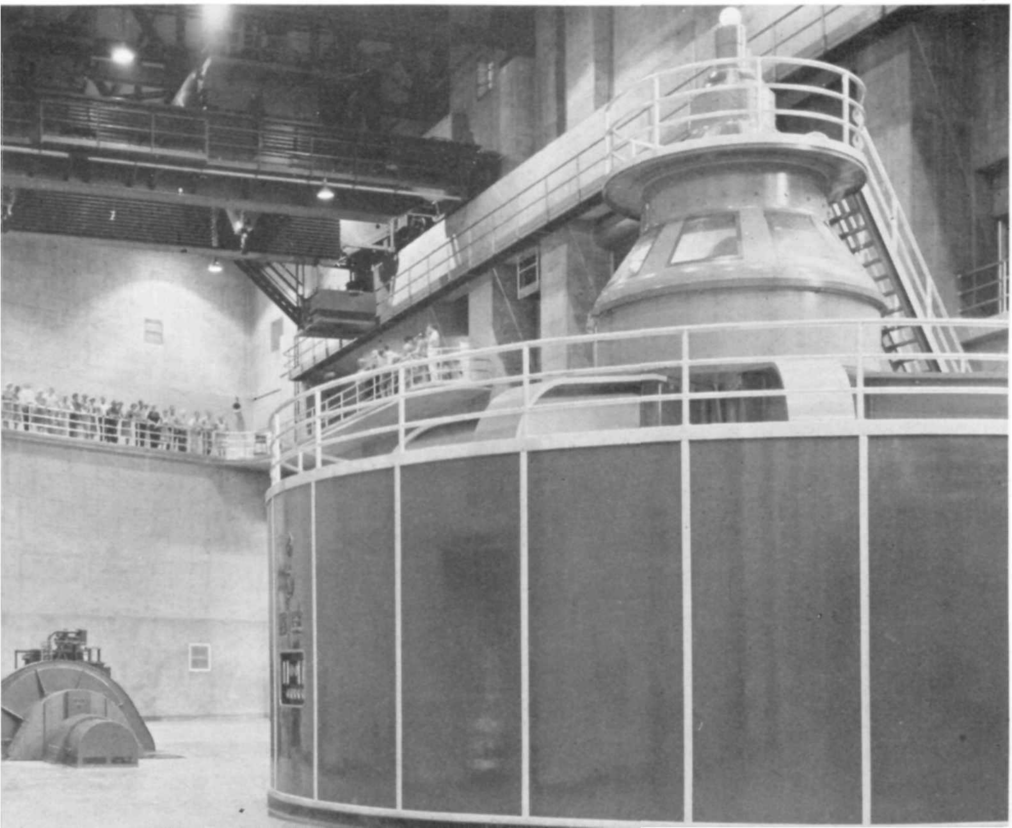
The West has ever been the elbow room of our expanding Nation. Population increase has been faster, development has been surer. The population of Los Angeles increased from 50,000 in 1900 to more than 500,000 by 1920, to more than 1,200,000 by 1930, becoming the fifth largest city in the United States. Other cities in southern California were expanding proportionately.

This progress could continue only so long as water and power for expansion could be obtained.

The intensive agriculture in the southern California metropolitan area was developed by irrigation with underground water. This underground water was also drawn upon for domestic and manufacturing use by the growing cities and towns. The supply was endangered by continual overdrafts.

Power was needed, also, as well as water. During the decade and a half preceding passage of the Boulder Canyon Project Act, use of electric energy in southern California increased three times as rapidly as in the rest of the United States.

A huge generator—capable of supplying an entire city with electric light

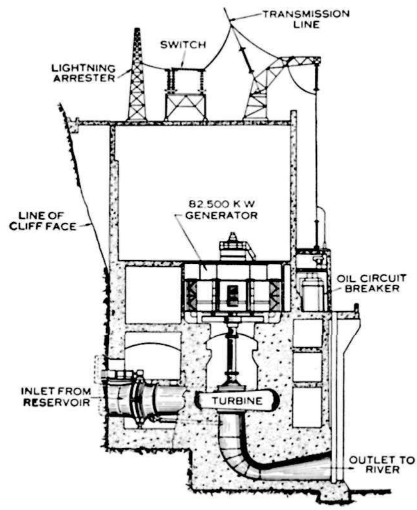


Both water and power were within reach and obtainable, being wasted in the roaring floods of the Colorado River. Instead of dealing death and destruction these floods could be transformed to an inexhaustible source of comfort and convenience for mankind.

The disastrous consequences of neglecting the conservation of a great natural resource like the waters of the Colorado River had been recognized for a quarter of a century. But the question was: How could this conservation be achieved? It would cost a hundred million dollars and more. Who would pay for it?

When plans for Boulder Dam were under consideration, the volume of power it could produce and the revenue it could return to the Treasury were adjudged large enough to make the construction pay for itself.

Power, then, made it possible to build Boulder Dam.



GENERATING UNIT - CROSS SECTION

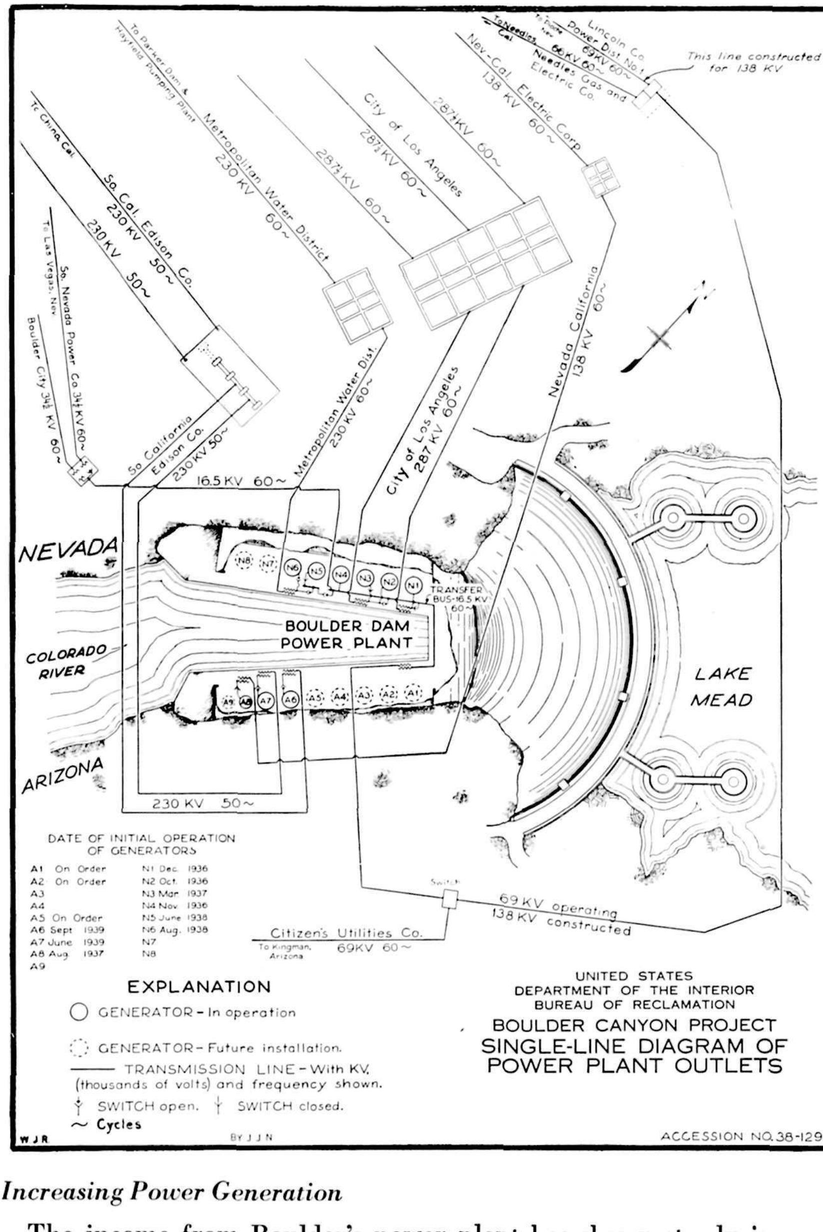
The Endless Tune of Untold Wealth

Boulder's gigantic hydroelectric plant is the largest now operating in the world. It is capable of supplying whole cities with light and power. High tension transmission lines radiate from Boulder Dam carrying electric energy for homes and farms, stores and factories, pumping plants, and mines and smelters. Nine giant generators today hum an endless tune of untold wealth—the myriad, creative wealth of hydroelectric power. More are being added yearly.

Boulder's installed capacity in 1940 was larger than that of the Russian Dniepostroy development, larger even than that of Niagara Falls and Muscle Shoals combined. It totaled 704,800 kilowatts.

When all its 17 generators are installed, Boulder will have an installed capacity of 1,322,300 kilowatts and be able to generate nearly 6 billion kilowatt-hours of electricity annually.

With only 9 of its 17 generators installed and operating, Boulder Dam in 1940 generated 3 billion kilowatt-hours, about half the total power consumption of southern California, Arizona, and Nevada within transmission distance of Boulder.



Increasing Power Generation

The income from Boulder's power plant has shown steady increase as the nine giant generators have been installed one after the other to meet the demand for electric energy. During 1936–37 Boulder income under temporary interim contracts (which disposed of power at secondary rates) totaled a quarter of a million dollars. The following fiscal year, 1937–38—the first under regular 50-year contracts for firm power—the gross income rose to nearly 3 million dollars. In 1938–39 it rose to nearly 4 million; in 1939–40, to 4½ million.

The first big customer for Boulder power was the city of Los Angeles, to which energy was transmitted October 9, 1936. The city celebrated the event with a "Pageant of Light." Huge arc lights on the city hall blazed with electricity sent from Boulder 266 miles away. Regular service to Los Angeles started 2 weeks later on October 22, and as soon as possible three more generators for the city were installed.

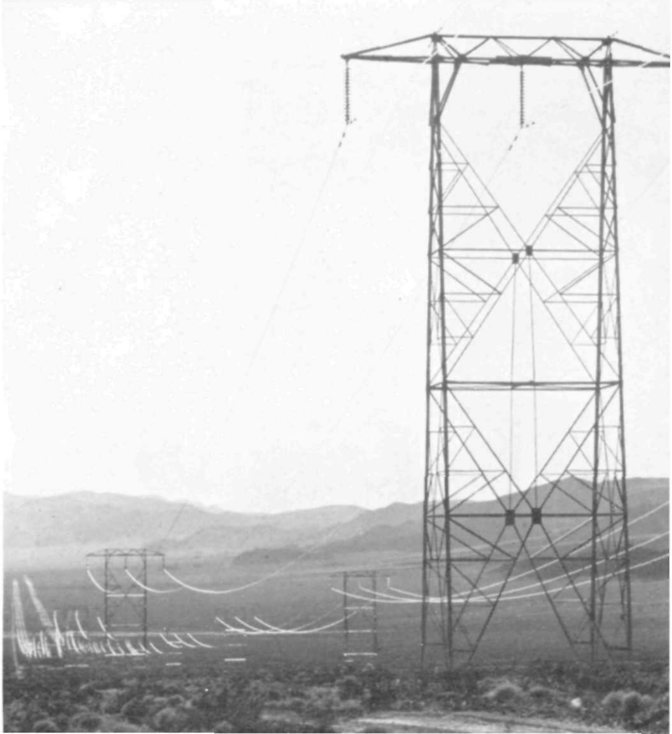
The four generators created power for other municipalities in southern California as well. The city of Los Angeles operated them for Los Angeles, Pasadena, Burbank, and Glendale; Las Vegas and Boulder City, Nev., also obtained energy.

The following year, 1937, a generator went into operation for the Nevada-California Electric Corporation, a private utility supplying customers in southernmost California.

Two more generators went into operation in 1938, bringing the total to seven. They were destined for use by the Metropolitan Water District of southern California to pump Colorado River water to the 13 coastal cities. The construction of the Colorado River Aqueduct had not kept pace with Boulder Dam which was completed 2 years before schedule, however, so part of the power generated by the Metropolitan Water District units was sold to the Needles Gas & Electric Co. of Needles, Calif., and the Citizens' Utility Co. of Kingman, Ariz.

The Southern California Edison Co., which serves consumers in seven counties of southern California, had a contract with the Government to take power beginning June 1, 1940, but at the company's request the

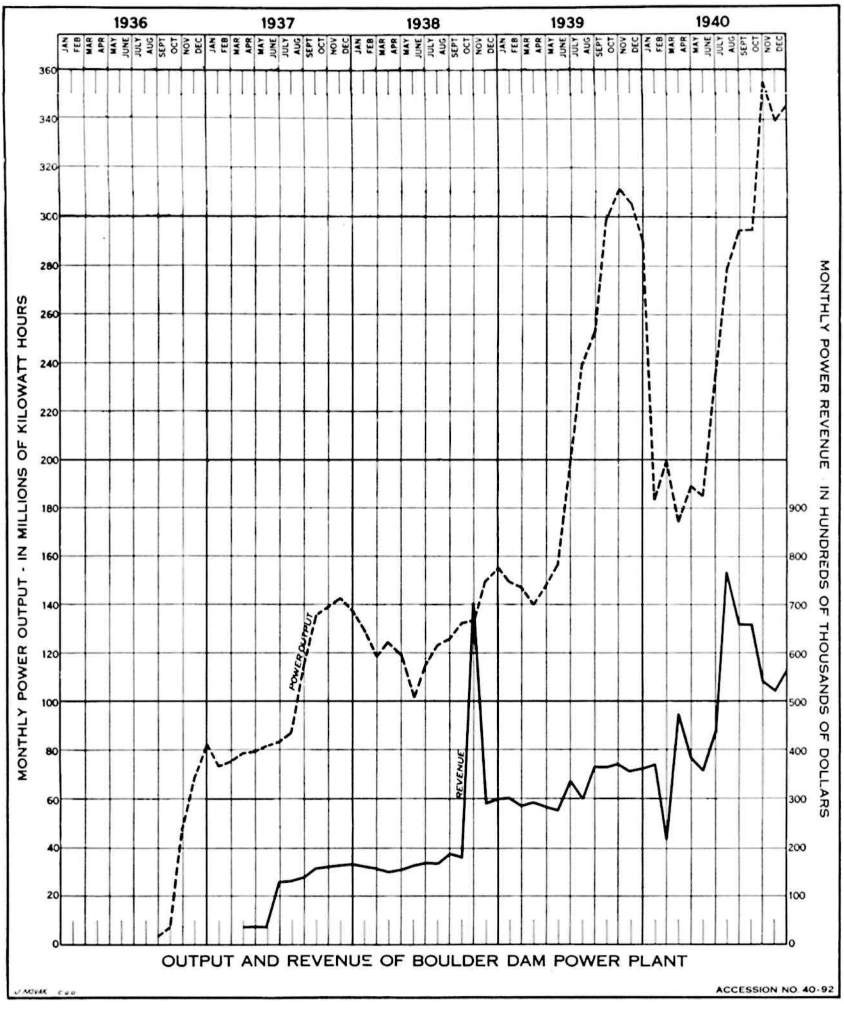
Power—
over the hills and far away



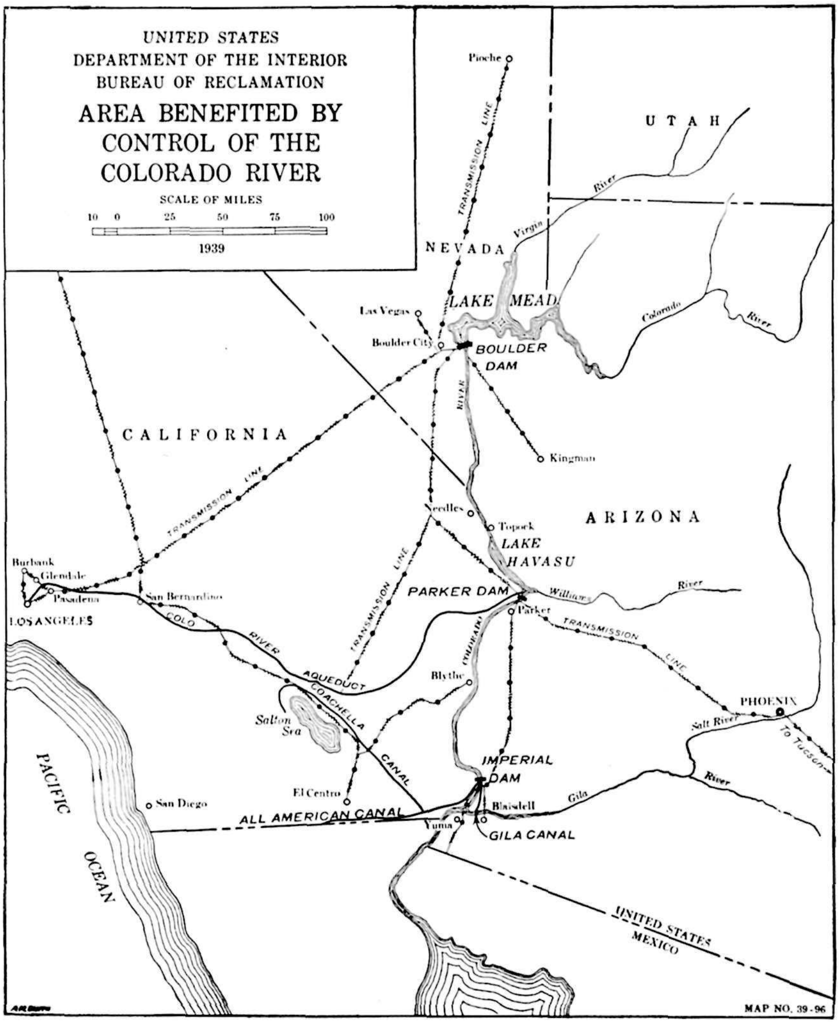
Bureau's forces speeded up installation. Two generators for the company went into operation at Boulder months before schedule, in the summer and fall of 1939. They were hurried into service under a full load 24 hours a day as soon as they had been tested. A power shortage made it necessary. They brought the total number of generators in operation at Boulder to nine.

As new generators have been added, the generation of power at Boulder has increased year by year: In 1936 the plant generated 124 million kilowatt-hours; in 1937, 1,180 million kilowatt-hours; in 1938, 1,523 million kilowatt-hours; in 1939, 2,508 million kilowatt-hours; and in 1940, more than 3,000 million kilowatt-hours.

Boulder has 11 high-tension transmission lines extending from its



OUTPUT AND REVENUE OF BOULDER DAM POWER PLANT



power plant to customers hundreds of miles away. Three lines extend to Los Angeles 266 miles away. Another line extends 233 miles to Chino, Calif. A fifth line goes to San Bernardino, Calif., 222 miles distant. Other lines go to Hayfield, Calif.; Parker, Ariz.; Kingman, Ariz.; Needles, Calif.; Pioche, Nev.; Las Vegas, Nev.; and Boulder City, Nev.

Parker Dam, on the Colorado River 155 miles below Boulder, will aid in generating power for the Southwest. A capacity of 120,000 kilowatts will help supply the needs of Arizona. High-tension transmission lines already have been built from Parker Dam to Phoenix, Ariz., and to Blaisdell, Ariz.

Rotary International is welcomed by the Boulder City school band

Pending the installation of generating equipment at Parker, Boulder is filling the deficiency through the transmission line built to Parker Dam for construction power. Boulder energy is being relayed at Parker Dam deep into central Arizona where a power shortage had threatened the intensive agricultural development of the Salt River Valley.

The Ramified Benefits

This distribution of low cost power from Boulder Dam throughout the Southwest is already showing material effect. In the midst of its ramified benefits, bound to multiply and become even more widespread through the years, certain significant facts already appear.

The introduction of Boulder power in 1936–37 was followed by a general lowering of rates. As of August 1, 1937, it was estimated that consumers in the city of Los Angeles were being saved $1,320,000 annually. Subsequent expansion of the city's municipal operations increased these savings still further.

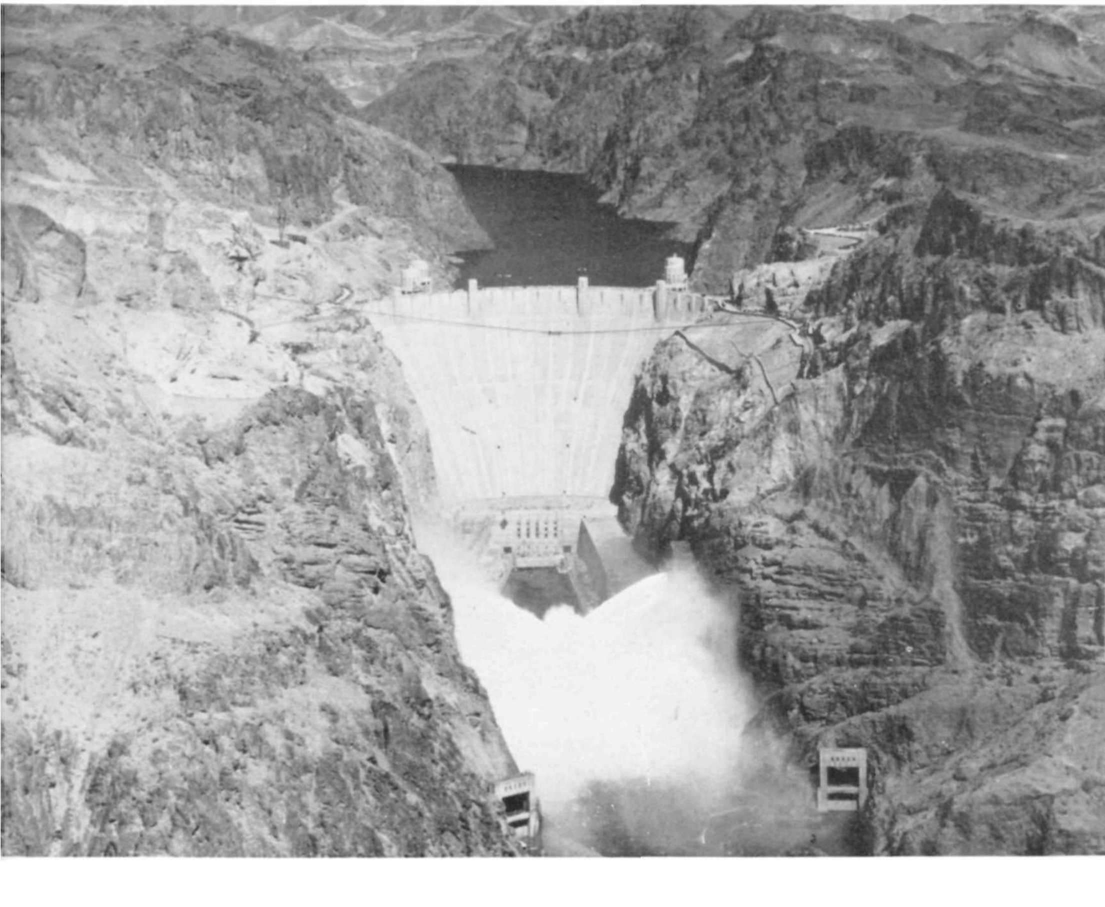
Rates in Las Vegas, Nev., have been reduced from a maximum of 8 cents a kilowatt-hour to 3 cents. Schedules for commercial and industrial uses in Nevada have also been reduced. The Lincoln County Power District No. 1 delivers Boulder power in its area, 156 miles from the dam, at 8.5 mills.

The number of electric customers of the three major contractors for Boulder power—the city of Los Angeles, the Southern California Edison Co., and the Nevada-California Electric Corporation—increased nearly 30 percent from 1935 to 1940. In the 10 years ending 1945, the number is expected to double with approximately 1,300,000 residential, industrial and commercial consumers dependent on Boulder for 75 percent of their supply.

The population of the metropolitan area of southern California increased 27 percent from 1930 to 1940, while the estimated growth for the country at large in the same period was only 7 percent. By 1950 a population of 5¼ million is expected to reside in the region served with water and power by Boulder Dam, as compared with 3,800,000 in 1940.

Low-cost power is already directly contributing new opportunities for livelihood for the rapidly increasing population of the region. It is

Boulder Dam's canyon wall outlets discharging a Niagara of water



bringing about a revival of mining operations in Nevada, for example, with the probability that many new developments will be undertaken both in that State and Arizona. (Thirty-six percent of Boulder's power is reserved for the use of these two States.)

Five mining districts in Nevada were without electric service before Boulder power became available. Hundreds of men have been put to work in reopened mines and negotiations are in progress looking to the opening of other workings. The Colorado River Commission of Nevada anticipates that by 1950, mineral and commercial developments in the area will require 60,000 kilowatts or more than five times the present consumption.

At the Boulder City pilot plant of the United States Bureau of Mines, extensive experiments have been made on the use of low-cost power in the reduction of minerals. Manganese deposits in the vicinity of Boulder have been studied with a view to the development of this important strategic mineral held essential to the national defense. Other minerals produced in the district include silver, copper, lead and zinc, platinum, molybdenum, and vanadium. Copper-nickel deposits in the Copper King District are also under investigation.

Harnessing of the Colorado for production of power also is conserving annually in California fields about 10,000,000 barrels of oil, which otherwise would have to be used in electric generation.

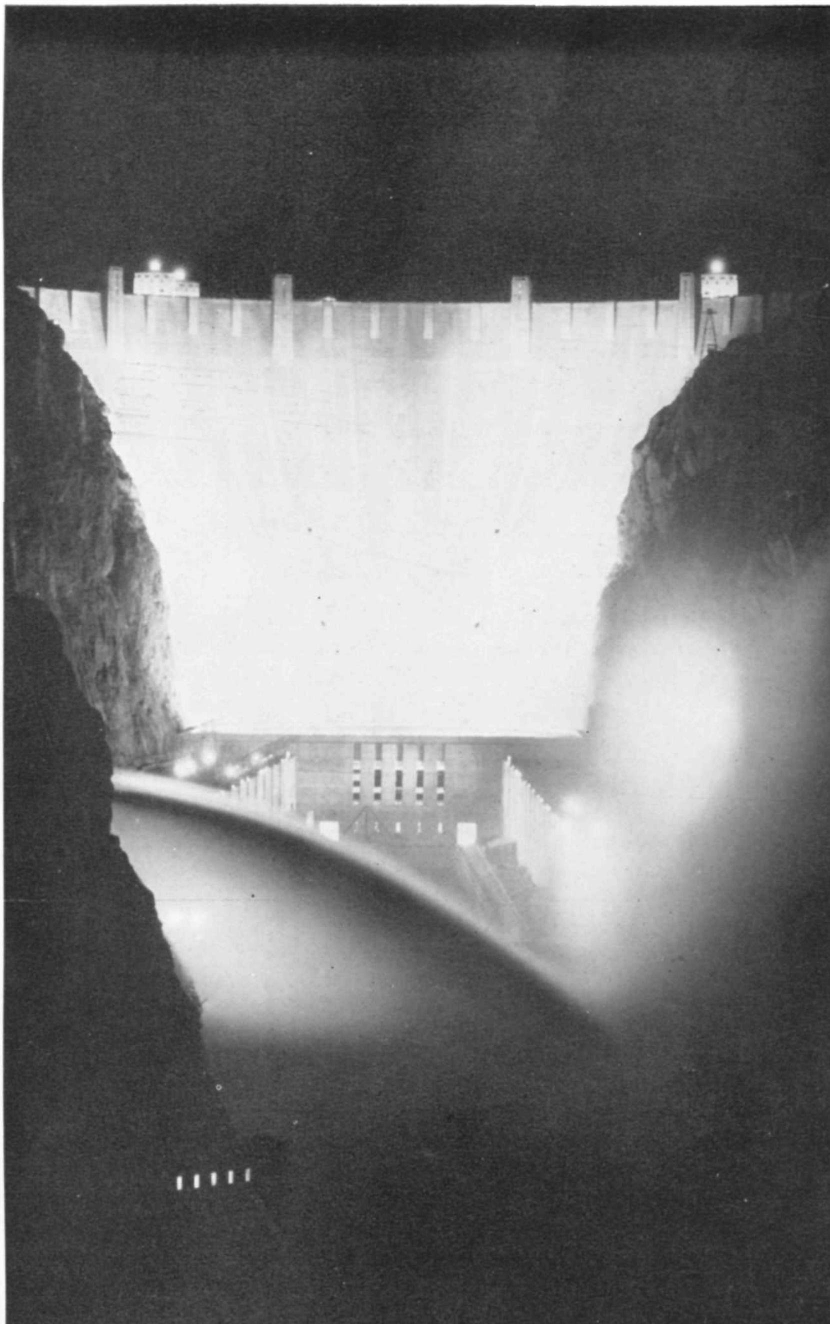
These examples of the effect of the introduction and distribution of low-cost hydroelectric power generated at Boulder Dam illustrate the importance of this great dam to the Southwest.

The Benefits Multiplied

In the future remain the incalculable gains to be obtained from the further development of the Colorado River Basin—more water conservation, and more power. Boulder Dam's power revenues are expected to make available under a new law $500,000 annually for the investigation and construction of such projects. The profits to the Southwest and the Nation brought by Boulder Dam will be multiplied, and the horizon of usefulness of Boulder Dam widened still further.

The elimination of destructive floods, the provision of an abundant water supply for irrigation and domestic use, the reduction of damaging silt deposits, the improvement of navigation, the creation of a national playground and a valuable wildlife refuge, the generation of electric energy, the further development of unused resources in the Colorado River Valley—all tell the story of Boulder Dam.

Countless American families know that story first-hand. They have a personal acquaintance with its meaning, and in 1940 they silently joined in the celebration as their radios, powered with Boulder current,



Boulder Dam, night

brought them the news of Boulder's fourth birthday party. The Columbia Broadcasting System's announcer introduced the ceremony with these words:

"Here's the first stop on our birthday visit to Boulder Dam. We're speaking to you from the visitors' gallery on the Nevada side. Within these walls the spirit and the power of Boulder Dam are almost a living force. Standing here in this room, as long as two city blocks and as high as a 5-story building, we can realize the workings of this project as never before. Behind my back are the waters of Lake Mead . . . 115 miles long and 590 feet deep . . . the largest man-made lake in the world. That tremendous body of water has been tamed . . . turned from its age-old destructive force by those 6½ million tons of concrete that rise above us from our location on the floor of Black Canyon. That water lies smoothly in its man-made bed . . . waiting its chance to take part in the magic of this powerhouse in which we stand, and at the same time serving as a great new recreational paradise which features boating, fishing, swimming, and thousands of square miles of scenic wilderness. . . .

"Perpetual motion may be as impossible as the scientists insist, but here in this generator room, we're watching something which for sheer efficiency and scientific achievement is probably as close to eternal power as anything we'll ever see. Even thousands of words couldn't begin to complete the picture of the vital part which Boulder Dam power, and the water which creates it, play in the life of Southwestern America . . . but here is an impression in sound of one of man's greatest and most complex achievements . . . the sound of the generators of Boulder Dam!"

FACTS AND FIGURES

In Question and Answer Form

The Dam

Where is Boulder Dam located?

In Black Canyon on the Colorado River where it forms the Arizona-Nevada state boundary, about 25 miles airline southeast of Las Vegas, Nev.

What does the Boulder Canyon project include?

Construction of a dam and power plant in Black Canyon and of the All-American Canal in southern California.

What will the project cost?

The Boulder Canyon Project Act authorized appropriations not to exceed $165,-000,000, divided as follows: Dam and reservoir, $70,600,000; power development, $38,200,000; All-American Canal, $38,500,000; interest during construction, $17,-700,000. Subsequent authorizations have increased the estimated over-all cost of the project to $205,000,000, of which $140,000,000 is allotted to the dam and $65,000,000 to the All-American Canal, including the construction of distribution and drainage systems which were not contemplated in the original act.

How much has been expended?

To June 30, 1940, $126,300,000 for Boulder, $31,900,000 for All-American Canal.

How high is Boulder Dam?

The maximum difference in elevation between the foundation rock and the roadway on the crest of the dam is 726.4 feet. The towers and ornaments on the parapet extend 40 feet higher above the crest.

How does this height compare with other dams?

Boulder is by far the highest dam in the world. Second is Grand Coulee Dam in Washington, 550 feet in height, until the completion of Shasta Dam in California, which will be 560 feet high. All three dams are constructed by the Bureau of Reclamation.

What type is Boulder Dam?

The concrete arch-gravity type, in which the water load is carried by both gravity action and horizontal arch action.

What is the maximum water pressure at the base of the dam?

Forty-five thousand pounds per square foot.

What is the volume of concrete masonry?

Three million two hundred and fifty thousand three hundred and thirty-five cubic yards in the dam alone, or 4,400,000 cubic yards in the dam, power plant, and appurtenant works. This amount of concrete would build a monument 100 feet square 2¼ miles high or, if placed on the ordinary city block, would rise to a height greater than that of the Empire State Building in New York City (1,248 feet). It would build a standard paved highway 16 feet wide from Miami, Fla., to Seattle, Wash. Mass concrete was placed in the dam at the rate of approximately 160,000 cubic yards per month, with a peak placement of 10,462 cubic yards a day (which includes some concrete placed in intake towers and powerhouse) and slightly over 225,000 cubic yards a month. The first concrete was placed on June 6, 1933, and the last concrete was placed in the dam on May 29, 1935.

What is the weight of the 3,250,335 cubic yards of concrete in the dam?
More than 6,900 tons.

How much cement was required?

More than 5,000,000 barrels. The daily demand during construction of the dam was from 25 to 36 cars (7,500 to 10,800 barrels). The Bureau of Reclamation used 5,862,000 barrels in the 27 years of construction activities preceding June 30, 1932.

How was chemical heat, due to setting of the cement in the mass concrete, dissipated?

By embedding in the concrete a system of pipes containing over 3,000,000 feet, or 582 miles, of 1-inch steel tubing, through which cooling water circulated from a cooling and refrigeration plant. The plant had sufficient capacity to produce 1,000 tons of ice from water at 32° F. in 24 hours. Cooling was completed in March 1935.

What was an unusual feature of Boulder's construction?

The dam was built in numerous blocks or vertical columns varying in s.ze from sections approximately 60 feet square at the upstream face of the dam to sections 25 feet square at the downstream face. Adjacent columns were locked together by a system of vertical keys on the radial joints and horizontal keys on the circumferential joints. Specifications restricted the rate of placement in any one block to a maximum height of 5 feet in 72 hours. After the concrete was cooled, grout (cement and water) under pressure was forced into the spaces opened up between the columns by the contraction of the cooled concrete, to form a monolithic structure.

What were the principal items of work?

Excavation, all classes, diversion tunnels, 1,500,000 cubic yards; excavation, common, for foundation of dam, power plant, and cofferdam, 1,330,000 cubic yards; rock excavation for dam foundation, 430,000 cubic yards; excavation, all classes, for spillways and inclined tunnels, 750,000 cubic yards; earth and rock-fill for cofferdams, 1,000,000 cubic yards; excavation, all classes, valve houses and intake towers, 410,000 cubic yards; concrete, 4,400,000 cubic yards; drilling grout and drainage holes, 410,000 linear feet; pressure grouting 422,000 cubic feet; all excavation, more than 5,500,000 cubic yards; total earth and rock-fill, more than 1,000,000 cubic yards.

How much reinforcement steel was used?

About 45,000,000 pounds.

What were the quantities of other principal materials?

Gates and valves, 21,670,000 pounds; plate steel outlet pipes, 88,000,000 pounds; pipe and fittings, 6,700,000 pounds, or 840 miles; structural steel, 18,000,000 pounds; miscellaneous metal work, 5,300,000 pounds; cement, 5,000,000 barrels.

Did the Government buy these materials?

Yes. The purchasing was handled by the Bureau of Reclamation, United States Customhouse, Denver, Colo.

What are the geologic conditions at the dam site?

The foundation and abutments are rock of volcanic origin, geologically termed "andesite breccia," hard and very durable.

What is the depth below low-water surface of the river to foundation rock?

From 110 feet to 130 feet. The lowest point of excavation in the upstream cut-off trench was at elevation 506, or 139 feet below low-water surface (elevation 645).

What are the canyon widths at the dam site?

From 290 to 370 feet at low-water level, and from 850 to 970 feet at elevation 1,232, the crest of the dam.

What was the time required to build the dam, power plant, and appurtenant works?

The contractors were allowed 7 years from April 20, 1931, under their contract. Placing of concrete in the dam was completed May 29, 1935.

How many men were employed by the Government and labor contractors during construction of the dam?

An average of 3,500 and a maximum of 5,218, occurring in June 1934. The average monthly pay roll was approximately $500,000.

What construction work was necessary before operations were started at the dam site?

(1) Construction of Boulder City to house both Government and contractors' employees. (2) Seven miles of 22-foot, oil-surfaced highway from Boulder City to dam site. (3) Building 22.7 miles of standard-gage railroad from the Union Pacific main line to Boulder City, and 10 miles from Boulder City to the dam site. (4) A power transmission line 222 miles long, from San Bernardino, Calif., to the dam site to furnish power for construction purposes.

The Reservoir (Lake Mead)

How much water will the reservoir hold?

When full, 32,359,274 acre-feet. An acre-foot is the amount of water that will cover 1 acre 1 foot deep. The water in the reservoir would cover the State of New York to a depth of 1 foot. The reservoir will store the entire average flow of the river for 2 years.

What is the area of the reservoir?

One hundred forty-six thousand five hundred acres, or 229 square miles. For comparison, Lake Tahoe in California-Nevada has an area of 193 square miles.

What is the length and width of the reservoir?

It is about 115 miles by river from Black Canyon to Bridge Canyon, the limit of the backwater. The reservoir extends up the Virgin River about 35 miles. The width varies from several hundred feet in the canyons to a maximum of 8 miles.

What is the elevation of the high-water line?

One thousand two hundred and twenty-nine feet above sea level. All lands below elevation 1,250 have been retained for reservoir purposes.

How will the reservoir capacity be utilized?

Nine million five hundred thousand acre-feet for flood control, 5,000,000 to 8,000,000 acre-feet silt pocket; 12,000,000 to 15,000,000 acre-feet active or regulation storage.

Who operates the dam and reservoir?

The Bureau of Reclamation operates and maintains the dam, reservoir, pressure tunnels, outlet works, and penstocks to but not including shut-off valves at the inlets to turbine casings. The National Park Service administers the Boulder Dam National Recreational Area.

How much silt will be deposited in the reservoir?

The estimated average volume of silt carried by the river into Black Canyon is about 137,000 acre-feet annually under present conditions, and this amount will decrease with upstream development. It is estimated that the total silt deposits in the reservoir will not exceed 3,000,000 acre-feet at the end of 50 years.

What is the length of the shore line?

About 550 miles.

What is the estimated annual evaporation on the reservoir?

Six hundred thousand acre-feet.

Diversion Works, Spillways, and Outlet Works

How was the river diverted during dam construction?

By a temporary earth and rock-fill cofferdam, through four 50-foot diameter tunnels, excavated to 56 feet and lined with 3 feet of concrete (300,000 cubic yards), and driven through the rock of the canyon walls, two on each side of the river. These tunnels could carry over 200,000 second-feet of water. The river was diverted through the two Arizona tunnels on November 13, 1932.

What was the length of these tunnels?

The four tunnels had a total length of 15,946 feet, or 3 miles.

After their use for river diversion, how were the tunnels used?

They were plugged with concrete at locations approximately one-third their length below the inlet ends of the inner tunnels and about midway in the outer tunnels. The two inner tunnels contain 30-foot diameter steel pipes connecting the intake towers in the reservoir with the penstocks to the power plant and the canyon wall outlet works. The lower portions of the two outer tunnels are used for spillway outlets.

What is the gate installation in the tunnels?

When river diversion through the tunnels was discontinued, the inlet ends of the two outer tunnels were permanently closed with 50-by-50-foot bulkhead gates. Each gate with steel frame weighs about 3,000,000 pounds and required 42 railroad cars for shipment. At the outlet ends of the two inner tunnels, 50-by-35-foot Stoney gates are installed, which may be closed when it is desired to unwater the tunnels for inspection or repairs.

What are the intake towers?

There are four reinforced-concrete towers located above the dam, two on each side of the river and about 165 feet apart in a direction parallel with the river. These towers are 75 feet in average diameter (82 feet at the base, 63 feet 3 inches at hoist house floor, and 29 feet 8 inches inside), 375 feet in height (338 feet tower, 37 feet hoist house), and each tower controls one-quarter of the supply of water for the power-plant turbines. The towers contain 93,674 cubic yards of concrete and 15,299,604 pounds of steel.

How are these towers connected to the power plant and outlet valves?

By 30-foot diameter plate-steel pipes installed in 37- and 50-foot diameter concrete-lined tunnels. Thirty-seven-foot inclined tunnels connect the upstream intake towers to the 50-foot diameter inner diversion tunnels, and 37-foot diameter tunnels lead from the downstream towers to the penstocks and outlet works at elevation 820, 180 feet above the diversion tunnels.

What method of control is used in the intake towers?

Two cylindrical gates, each 32 feet in diameter, and 11 feet high, one near the bottom (elevation 895) and the other near mid-height (elevation 1,045) of each tower, protected by trashracks located in front of the entrances to the tower. Total weight of the eight gates is 5,892,000 pounds, and of the trashracks, 7,024,000 pounds.

What pipes are installed in the tunnels for reservoir outlets?

Four thousand seven hundred feet of 30-foot diameter main headers, 1,900 feet of 25-foot diameter pipes below the branch penstock tunnels to the power plant, and 2,000 of 8½-foot diameter pipes in 11-foot diameter tunnels leading to the needle valve outlets. The maximum thickness of the largest pipe is almost 3 inches.

How are the 30-foot-diameter pipes connected to the power plant turbines?

By sixteen 13-foot diameter plate-steel penstock pipes totaling 5,800 feet in length installed in 18-foot diameter concrete-lined tunnels.

What were the principal items in the contract for fabrication and installation of the steel penstock and outlet pipes?

Forty-four thousand tons of steel were formed and welded into 14,000 feet of pipe varying from 8½ feet to 30 feet in diameter. One length of the largest pipe, 12 feet long, 30 feet in diameter, and 2¾ inches thick, was made from three steel plates, of such weight that only two plates could be shipped from the steel mill to the fabrication plant on one railroad car. Two such lengths of pipe welded together comprised *one erection section weighing approximately 135 tons and at intersections with the* penstocks as much as 186 tons. For comparison, the weight on the drivers of the Consolidation type of steam locomotive on the project was 99 tons.

What outlets are used?

Six 72-inch needle valves in each inner diversion tunnel plug outlet, and six 84-inch needle valves in each canyon-wall valve house, there being one house on each side of the river at elevation 820, which is about 180 feet above river level. The valve outlets are pointed downstream at an angle of 60°. Canyon wall valves are not used except under emergency or flood conditions. Each 72-inch valve is capable of discharging a maximum of 3,670 cubic feet per second at a velocity of about 175 feet per second.

What is the total maximum capacity of these works?

One hundred and twenty-five thousand cubic feet per second, of which 25,000 cubic feet per second is for power generation and 100,000 cubic feet per second is valve discharge.

What are the Arizona and Nevada spillways?

Each consists of a concrete-lined open channel, about 650 feet long, 150 feet wide and 170 feet deep, with the side next to the river formed into an ogee-shaped crest. The two spillways required 601,419 cubic yards of rock excavation. There were 127,500 cubic yards of concrete placed, the walls being lined with 18 inches of concrete, and the floors 24 inches.

How is water discharged from the spillways?

Through inclined shafts, 50 feet in diameter and 600 feet long, into the outer diversion tunnels.

What will be the maximum water velocity in the spillway tunnels?

About 175 feet per second (120 miles per hour).

What gate installation was made at the spillways?

Four 100-foot by 16-foot drum gates on each spillway crest controlled either automatically or manually. Each gate weighs 500,000 pounds.

What is the maximum capacity of the spillways, valves, and power plants?

Five hundred and twenty-five thousand cubic feet per second. Each spillway has a maximum discharge capacity of 200,000 cubic feet per second. Should a flood occur of sufficient volume to require the full capacity of the spillways, the energy of the falling water would be about 25,000,000 horsepower, the flow over each spillway would be about the same as the flow over Niagara Falls, and the total drop would be more than three times as great.

The Power Development

What was the installed capacity of the power plant at Boulder Dam on January 1, 1941?

Nine hundred and seventy-five thousand horsepower (ultimate 1,835,000 horsepower). For comparison, Niagara is 452,500 horsepower; Conowingo 378,000 (ultimate 594,000); and Wilson 250,000 (ultimate 600,000); Dnieprostroy (U. S. S. R.) 750,000. The installed capacity of Boulder's power plant on January 1, 1941, in kilowatts was 704,800, including 2 station service generators of 2,400 kilowatts each, with 247,500 kilowatts being installed. The ultimate capacity is 1,322,300 kilowatts.

What is a horsepower in terms of falling water?

One second-foot of water falling 8.81 feet equals 1 horsepower at 100 percent efficiency. A second-foot of water is 1 cubic foot, or nearly 7½ gallons, passing a given point in 1 second of time.

What is the ultimate continuous firm power output?

About 663,000 *horsepower, based on 83 percent plant efficiency, and 10 percent* maximum shortage.

How much electrical energy is ultimately available yearly?

Approximately 4,330,000,000 kilowatt-hours of firm and 1,550,000,000 kilowatt-hours of secondary energy on completion of the power plant, decreasing each year an estimated 8,760,000 kilowatt-hours as a result of upstream development, and a consequent reduction in stream flow.

What is a kilowatt-hour?

The energy resulting from an activity of 1 kilowatt for 1 hour. A kilowatt is 1,000 watts. One horsepower equals 0.746 kilowatt. 663,000 (horsepower) $\times$0.746$\times$24 (hours) $\times$365 (days) =4,330,000,000 kilowatt-hours.

How is the income from the sale of power used?

To pay all expenses of operation and maintenance of works incurred by the United States and to repay the major part of the cost of construction of the dam and power plant, with interest not exceeding 3 percent, within a 50-year period. Repayment of $25,000,000 of the cost allocated to flood control is deferred beyond the 50-year period, when further action will be subject to congressional direction. Arizona and Nevada each are to receive $300,000 annually in lieu of taxes which may have been collected by the two States, and $500,000 annually is set aside from revenues for the further irrigation and power development of the Colorado River Basin.

Where is the power plant located?

Just below the dam, one-half on the Nevada side of the river and one-half on the Arizona side, forming a U-shaped structure 1,650 feet long built of steel and reinforced concrete. Each wing is 650 feet long, 150 feet high above normal tailrace water surface, and 229 feet (nearly 20 stories) above the lowest concrete in the powerhouse footings. There are 10 acres of floors.

How does the water reach the turbines?

Through four pressure tunnels, two on each side of the river, each provided with shut-off gates and trashracks.

What are the power installations?

Fifteen 115,000-horsepower and two 55,000-horsepower vertical hydraulic turbines; eleven 60-cycle and four 50-cycle main generating units of 82,500 kilovolt-ampere capacity each, and two 60-cycle main generating units of 40,000 kilovolt-ampere capacity each. The larger units were the largest in the world.

What facilities were provided for transporting power-plant machinery from the canyon rim to the power plant?

A permanent cableway of 150 tons normal capacity, electrically operated, with a span of 1,200 feet across the canyon, is used to lower not only power-plant machinery, but also handled the outlet pipes and other machinery, materials, and equipment.

Under what heads do the turbines operate?

Maximum head 590 feet, minimum 420 feet, average 530 feet.

How is the firm power generated at Boulder Dam allocated?

Metropolitan Water District of southern California 36 percent, States of Arizona and Nevada 18 percent each, Southern California Edison and other private utilities 9 percent, city of Los Angeles 13 percent, other cities 6 percent.

Who operates and maintains the power plant?

The City of Los Angeles and the Southern California Edison Co., under the general supervision of a director of power appointed by the Secretary of the Interior. The city generates power for the States, municipalities and the Metropolitan Water District. The Southern California Edison Co. generates power for itself and other private utilities.

Who are the principal contractors?

The Bureau of Power and Light of the City of Los Angeles, the Southern California Edison Co., the Nevada-California Electric Corporation, the Metropolitan Water District of Southern California, the municipalities of Burbank, Glendale, and Pasadena, and the State of Nevada.

How is power transmitted to market?

The contractors for power build transmission lines at their own expense.

Who pays the cost of transmission of power?

The contractors who buy the power.

Colorado River Water Allocation

What is meant by an allocation of water?

Authority to use and reuse water until stream flow is decreased by the amount of the allocation.

What is the allocation of water under the Colorado River compact?

Based on a mean annual run-off of 16,000,000 acre-feet, the compact allocated 7,500,000 acre-feet to the upper basin States and 7,500,000 acre-feet to the lower basin States, with the right of the latter in any one year to increase their beneficial consumptive use of such water by 1,000,000 acre-feet.

How much of the water allocated to the lower basin States does California get?

California has agreed that the aggregate annual consumptive use of the river water shall not exceed 4,400,000 acre-feet of the 7,500,000 allocated to the lower basin by article III (a) of the compact. In addition, California can use one-half of the surplus waters available above the 7,500,000 acre-feet allocated.

How much water is allocated to Nevada and Arizona?

The Boulder Canyon Project Act authorizes Arizona, California, and Nevada to enter into an agreement which shall provide that Nevada gets 300,000 acre-feet and Arizona 2,800,000 acre-feet for exclusive beneficial consumptive use; also, that Arizona may annually use one-half of the surplus water unapportioned by the compact, and, in addition, shall have the exclusive beneficial consumptive use of the Gila River and its tributaries within the State. Such an agreement has not yet been made.

What agreement as to division of water has been made by the various California interests?

(1) Three million eight hundred and fifty thousand acre-feet of water per annum for beneficial consumptive use for irrigation, as follows: First, to Palo Verde Irrigation District, 104,500 acres; second, to Yuma Reclamation project, 25,000 acres in California; remainder to lands in the Imperial and Coachella Valleys served from the All-American Canal and to 16,000 acres on the Lower Palo Verde Mesa; (2) the next 550,000 acre-feet to the Metropolitan Water District for domestic water supply; (3) the next 662,000 acre-feet to the Metropolitan Water District (550,000) and the City of San Diego (112,000) for domestic water supply; (4) the next 300,000 acre-feet to the Imperial and Coachella Valleys and to 16,000 acres on the Lower Palo Verde Mesa; (5) remainder for irrigation use in the Colorado River basin in California.

Boulder City

Where is Boulder City located?

The location is about 7 miles west of the dam site, at the summit and near the terminus of the Union Pacific section of the branch railroad.

How large is Boulder City?

Population now (1941) about 3,000.

What is the source of the domestic water supply?

Water is pumped from the Colorado River to the town, a distance of nearly 7 miles, with a total lift of about 2,000 feet. The intake is about 3,500 feet downstream from the dam site on the Nevada side. The water first goes to a presedimentation basin 100 feet above river level, then to a 100,000-gallon receiving tank at Boulder City, from there to a filtration and purification plant, and finally to a 2,000,000-gallon storage tank.

What other improvements were necessary?

Sewage and lighting systems were installed; sidewalks and curbs have been provided and streets surfaced and paved.

Did employees of the contractors on the dam and power plant live in the town?

Yes. A portion of the town was set aside for the contractors' use. The contractors arranged for the housing of their workmen, with construction subject to Government approval. They built mess halls, dormitories, hospital, clubhouse, commissary, machine shop, storehouses, garage, laundry, and 700 employees' cottages. The 12 great dormitories were heated in winter and artificially cooled in *summer and were equipped with electric lights, running water, and shower baths.*

Who owns the lands in the town site?

The Government owns the land, all of which is under first form of withdrawal.

How is a town lot obtained for business purposes?

The land is leased to those awarded business permits. The Government retains ownership and supervisory control. Continuation of the leases is contingent upon compliance with the terms of the contract.

How much money has been expended at Boulder City?

It cost the Government about $1,700,000 to build the town.

What provisions were made for erecting buildings suited to the climatic conditions in that section?

A city planner, well acquainted with the type of building construction required, was employed. Government buildings are largely of the Spanish type of architecture, and the main buildings are air-conditioned. The Bureau of Reclamation encountered somewhat similar climatic conditions during construction of the Yuma and Salt River projects in Arizona.

What is the form of town government?

The city-manager plan is followed. The city manager is responsible to the Director of Power for Boulder Dam, who is appointed by the Secretary of the Interior and directly responsible to the Commissioner, Bureau of Reclamation.

What is the range of temperature in that locality?

From 20° to 120° F.

How near is Boulder City to Las Vegas, Nev.?

About 21 miles southeast in an air line, 24 miles by highway, and 32 miles by railroad.

What is the elevation of the town?

About 2,500 feet above sea level.

Irrigable Areas

How much irrigable land is there below the Boulder Canyon Reservoir, in the United States?

About 1,900,000 acres, according to present estimate.

How is the area divided between the States?

Arizona 700,000 acres; California 1,175,000 acres; Nevada 25,000 acres. These areas may be changed materially when more complete surveys are made.

What is the present area under irrigation from the Colorado River below the dam site?

About 660,000 acres, divided as follows: California 600,000, Arizona 60,000.

What are some of the existing and potential projects in Arizona?

The Gila River Valley with a gross area of about 600,000 acres in the southwestern part of the State, the Colorado River Indian project of about 110,000 acres near Parker, and the Mohave Valley with an irrigable area of 33,000 acres near Needles, Calif. The Yuma Reclamation project, Arizona-California, adjacent to the city of Yuma, is an active Federal project, with about 53,000 acres irrigated at the present time, and a total ultimate irrigable area of 112,000 acres, including about 45,000 acres of undeveloped mesa lands. The first unit of the Gila project, consisting of 139,000 acres of new land and providing a supplementary water supply for 11,000 acres, is under construction by the Bureau of Reclamation. The Colorado River Indian project is under construction also, by the Office of Indian Affairs.

All-American Canal

Is the All-American Canal a part of the Boulder Canyon project?

Yes. The Boulder Canyon Project Act of December 21, 1928, authorized the building of a main canal from the Colorado River to the Imperial and Coachella Valleys.

Why the name, "All-American"?

Because the canal is built entirely in the United States. The Imperial main canal, which the All-American Canal replaces, is largely in Mexico.

What is the estimated cost of the All-American Canal?

Sixty-five million dollars, including drainage and distribution systems.

Is this expenditure reimbursable?

Yes. Under repayment contracts between the Imperial Irrigation District and the Coachella Valley County Water District, California, with the United States, the cost will be returned to the Government under the terms of Reclamation law.

Will the District have to pay for water?

There will be no charge for the use, storage, or delivery of water for irrigation or water for potable purposes.

Where is the intake?

At the Imperial diversion dam, about 15 miles northeast of Yuma, Ariz., and 5 miles north of Laguna Dam, which is the diversion point for the main canal of the Yuma Reclamation project.

What type of structure is the Imperial Dam?

The Imperial Dam is a hollow reinforced concrete structure raising the water surface about 22 feet. At its west abutment is located the headworks structure for the All-American Canal and at its east abutment the headworks structure for the Gila Canal in Arizona. Below the headworks on the California side is located the All-American Canal desilting works consisting of six large desilting basins designed to remove the silt picked up by the river on its 300-mile journey from Boulder.

How much water will the canal carry?

A maximum diversion of 15,155 cubic feet per second, which includes 2,000 cubic feet per second to be diverted at Siphon Drop for the Yuma project and 3,000 cubic feet per second returned to the river at Pilot Knob for power development.

What are the dimensions of the canal?

The maximum section is about 232 feet in width at the water surface, 160 feet in width at the bottom, and 20.6 feet in depth. There are only two larger canals in the United States, both ship canals.

What is the length?

The All-American Canal to Imperial Valley, 80 miles long, is completed. The branch canal to the Coachella Valley, under construction, is 130 miles long.

Are sand hills crossed by the canal?

Yes. The canal for 10 miles passes through a ridge of shifting sands. The deepest cutting is over 100 feet.

What structures were needed?

Siphons or culverts were used to carry the canal under many washes and at other washes the discharge from the wash was carried over the canal in concrete overchute type structures. The All-American Canal was also carried across the Alamo and New Rivers. Several highway and railroad bridges were also required.

Is additional water supply for the city of San Diego tied in to All-American Canal plans?

A repayment contract was negotiated between the city of San Diego and the Secretary of the Interior for providing capacity in the All-American Canal for carrying water to some point near the end of the canal from which point it would be taken by an aqueduct to San Diego.

Will San Diego pay for this water?

The contract calls for a payment of about $400,000 of the cost of the All-American Canal.

Is there opportunity for power development?

Yes. An estimated total capacity of 87,400 kilowatts may be developed in five plants. The largest will be at Pilot Knob, 7 miles west of Yuma, Ariz., where surplus water is returned to the Colorado River. It will have a capacity of 41,400 kilowatts. Of four other potential plants at drops on the All-American Canal and the Coachella branch, installations of 30,000 kilowatts have been made at two. The total capacity of the four plants is 46,000 kilowatts. The Bureau of Reclamation will develop Pilot Knob, and the Imperial Irrigation District will develop the four other drops.

What are the principal California projects which may be benefited by the All-American Canal?

The Imperial Valley has a present irrigable area of 522,000 acres, and about 357,000 acres of valley and adjacent mesa lands which can be irrigated under the All-American Canal. The Coachella Valley in Riverside County near Indio has an irrigable area of 160,000 acres, which will be served by a branch of the All-American Canal.

Where is the irrigable acreage in Nevada?

Areas aggregating about 25,000 acres may be irrigated by pumping along the Colorado River near Searchlight and from the Boulder Canyon Reservoir near Las Vegas.

What is the approximate classification of the total irrigable lands?

Public, 44 percent; private, 40 percent; State, 1 percent; railroad, 2 percent; Indian, 8 percent; and public land entered, 5 percent.

Imperial and Coachella Valleys

What is the irrigable area of the Imperial Irrigation District?

Five hundred and twenty-two thousand acres, requiring 1,700 miles of canals and laterals.

How much land is now irrigated?

From 400,000 to 450,000 acres.

What is the present irrigated area in Mexico (Lower California) from the Imperial Main Canal?

About 200,000 acres.

What are the principal crops in the Imperial Valley?

Alfalfa, cantaloups, lettuce, barley, corn, milo maize, and small fruits. About 30,000 carloads of cantaloups and lettuce are shipped out of the Imperial Valley each season.

What are the crop yields?

Alfalfa, as much as 7 to 10 tons per acre, a ton to a cutting; cantaloups, 96 crates per acre.

What is the growing season?

Three hundred and sixty-five days.

What is the elevation of the valley?

From 250 feet below sea level at the Salton Sea to 50 feet above sea level. The adjoining mesas or high lands vary in elevation from 50 to 250 feet.

What is the Salton Sea?

An inland sea in a depression in the northern part of Imperial Valley. Immediately prior to 1905, it was only a small lake, but the Colorado River break of 1905–7 increased the water surface area of the sea to 515 square miles, a length of 42 miles and maximum depth of 80 feet. The present area is 287 square miles and the elevation of the water surface is about stable at 244 feet below sea level. The Salton Sea is salty, because of its saline bed.

What is the rainfall in this section?

About 3 inches a year.

How large is the Coachella Valley?

The gross acreage is 187,000 acres. The estimated irrigable area under the proposed canal system is 162,000 acres. There are now about 15,000 acres under cultivation.

What is the total irrigable area in the Imperial and Coachella Valleys and adjacent East Mesa, West Mesa, Pilot Knob Mesa, and Dos Palmas unit, which may be served by the All-American Canal and its branches?

The estimated area is about 1,000,000 acres.

What is the status of these lands as to ownership?

Approximately 30 percent public, 65 percent private, and 5 percent State, railroad, and Indian.

Gila Valley

What is the Gila Valley?

River bottom and adjacent mesa lands along the Gila River from Yuma to Aztec, with a net irrigable area below elevation 600 of about 500,000 acres.

How may these lands be irrigated?

Water can be diverted from the Colorado River at the Imperial Dam and pumped by successive stages to canals serving the lands. The pumping lift to the highest lands will be nearly 500 feet. Present plans provide for the irrigation of 150,000 acres, including 11,000 acres with supplemental water, as the first unit, now under construction by the Bureau of Reclamation.

The Colorado River Aqueduct

Is the aqueduct a part of the Boulder Canyon Project?

No, but one of the purposes of the project is to provide a supplemental domestic water supply for Los Angeles and 12 other cities in southern California. The aqueduct transports water which is stored in the reservoir behind the Boulder Dam.

What is the Metropolitan Water District?

A municipal corporation comprising 13 cities, including Los Angeles, in southern California that will use this water supply.

What portion of the Colorado River water will the district receive?

The district has contracted with the Secretary of the Interior for delivery each year from the reservoir up to but not exceeding 1,050,000 acre-feet. This corresponds to a flow of about 1,500 cubic feet per second, or about a billion gallons daily from the river. The district will pay to the United States 25 cents per acre-foot for the actual amount used, or an average annual payment of about $250,000.

Will the district obtain power from the plant at Boulder Dam?

Yes. Its allocation is 36 percent of the firm power produced, with a preferential right to the use of dump or secondary power, which will be transmitted over lines built by the district.

Where on the Colorado River is the intake for the aqueduct located?

At Parker Dam in Upper Parker Canyon, about 155 miles below Boulder Dam, and 12 miles above Parker, Ariz. Parker Dam was constructed by the Bureau of Reclamation with funds advanced by the Metropolitan Water District.

How is the diversion effected?

By pumping from the reservoir back of the Parker Dam. This dam is 320 feet high, but only 85 feet of the structure protrudes above the river bed. It is of the concrete arch type superimposed by five 50-by-50-foot Stoney gates for river control.

What is the pumping lift to cross the mountains?

One thousand six hundred and seventeen feet. Five pumping stations are required.

What is the total length of the aqueduct?

About 242 miles of main aqueduct and 150 miles of feeder lines.

What power is developed at Parker Dam?

Ultimate installation is 120,000 kilowatts, half of which is reserved to the United States, the other half belonging to the Metropolitan Water District. Three units of a combined capacity of 90,000 kilowatts were being installed at the beginning of 1941, and the fourth was on order.

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