The Story of the Colorado-Big Thompson Project

Olympus Dam and Lake Estes.

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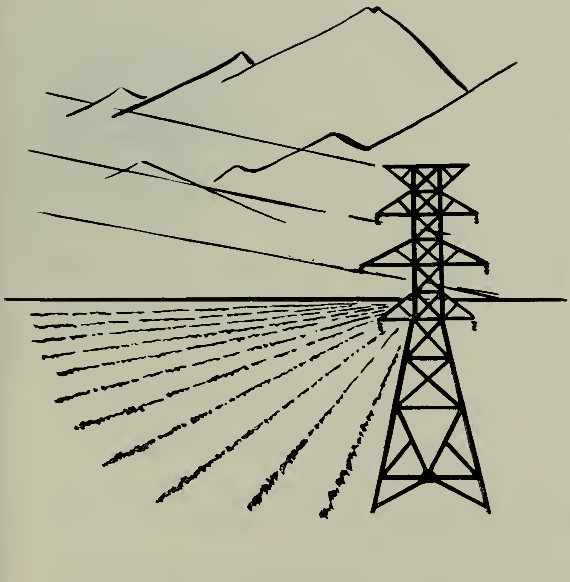

UNITED STATES DEPARTMENT OF THE INTERIOR

Stewart L. Udall, *Secretary*

BUREAU OF RECLAMATION

Floyd E. Dominy, *Commissioner*

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Foreword

Man's quest for economic self-support and sustenance for himself and others has been a driving force in reaching some of his greatest achievements. An expression of this quest, the story of the Colorado-Big Thompson Project, tells about one of the most exciting water-development enterprises in American history.

Contents

Chronology

1803 Eastern Colorado included in Louisiana Purchase.

1850 Western Colorado included in original Utah Territory.

1854 Eastern Colorado included in original Territories of Nebraska and Kansas.

1861 Colorado Territory regularly organized. First Territorial Legislature passed statute permitting use of water for irrigation, but requiring no record of appropriation.

1866 Congress approved act providing "That whenever by priority of possession rights to the use of water for mining, agriculture, manufacturing, or other purposes has vested and accrued, and the same are recognized and acknowledged by the local customs, laws, and the decisions of the courts, the possessors and owners of such vested rights shall be maintained and protected in the same; and the right-of-way for the construction of ditches and canals for the purpose of aforesaid is hereby acknowledged and confirmed."

1870 First major irrigation enterprise in northern Colorado—by the Union Colony near Greeley. This colony, founded by Horace Greeley, Editor of the New York Tribune, irrigated about 12,000 acres along Cache la Poudre River. Other irrigation enterprises followed at Fort Collins, Longmont, and Loveland. In this era of canal construction, conflicts for water precipitated general consideration of the irrigation situation.

1876 Colorado admitted as State. State Constitution declared public ownership of all unappropriated water and doctrine of priority of appropriation for beneficial use.

1879 Colorado State Legislature passed act of 1879, supplemented 2 years later by act of 1881. The two acts provided: (1) For acquisition of titles to rights and (2) for administration of water so that each appropriation might receive its authorized amount. These two laws were historic in irrigation legislation as the first to provide for public administration of water used for agricultural purposes. Formation of water districts, the vehicle for administration, began.

1881 Water divisions and office of State engineer created, supervising control over the public waters and their diversion for purposes of irrigation. Water districts grouped into divisions, with a superintendent over the district commissioners and the State engineer over the superintendents. State engineer, division superintendents, and district commissioners all appointed by the Governor. This system remains today substantially the same as originally adopted.

1889 Survey made by K. P. Maxwell, State engineer, involving tunnel from Monarch Lake to St. Vrain Creek and canal from Monarch Lake to Grand Lake. State legislature appropriated $20,000 for this survey, and $3,000 for a survey of the possibilities of diverting water from North Platte, Laramie, and Grand (Colorado) Rivers to the South Platte River. No conclusions resulted.

1893 Colorado State Legislature enacted law which provided that conveyance of water rights, except when in the form of ditch stock, should be attended with the same formalities as real estate.

1895 Legislature enacted law making it duty of district commissioners to shut off water being "wastefully, extravagantly, or wrongfully used".

1899 State law enacted providing that persons desiring to change points of diversion of their ditch from a stream should observe same formalities in district court as if obtaining an original decree, and permitting such changes if the court shall first find that it "will not injuriously affect the rights of others".

1904 Order issued withdrawing lands in T. 3 N., R. 75 W., for Grand River-Big Thompson Project. Grand River later renamed Colorado River.

1905 Report by Reclamation Service contemplated raising elevation of Grand Lake 20 feet by building dam at its outlet and creating reservoir of 140,000 acre-feet. This plan included a tunnel, about 12 miles long, from Grand Lake to Big Thompson River or St. Vrain Creek.

1915 Congress passed bill creating Rocky Mountain National Park, including reservation preserving rights for future water development.

1922 Colorado River Compact signed November 22, apportioning water between upper and lower basin States.

1933 Group of northern Colorado citizens engaged consulting engineer to report on feasibility of large-scale transmountain diversion.

1935 Public Works Administration allotment of $150,000 provided for survey by Bureau of Reclamation of Grand Lake-Big Thompson Project.

1935 On January 21, Northern Colorado Water Users' Association organized. In April, Director of Geological Survey delivered memorandum report on project to Secretary of the Interior. In May, automatic stream gages installed to determine replacement storage and diversion needs. In July, surveys began, following plan of agreement between National Park Service and Bureau of Reclamation.

On July 19, Office of the Solicitor at Washington ruled that Bureau of Reclamation could enter upon and utilize for flowage any area within Rocky Mountain National Park. Agreement reached between Park Service and Bureau on July 25.

On October 7, U.S. Attorney General ruled that proposed Grand Lake-Big Thompson Transmountain Diversion Project was a "Government reclamation project", and that Bureau of Reclamation was authorized to enter upon and utilize any area within the Rocky Mountain National Park which might be necessary for the development and maintenance of such a project.

1936 Bureau of Reclamation report and preliminary estimate of Grand Lake-Big Thompson Transmountain Project issued February 8.

In April, Office of the Solicitor ruled that Colorado River Compact permits transmountain diversion of waters of Colorado River from their natural watershed into other watersheds, providing it is beneficially used within a Colorado River Basin State.

1937 Report of feasibility on proposed Colorado-Big Thompson Project was made to Secretary of the Interior in April, and printed by the Congress as S. Doc. No. 80, 75th Cong. A Colorado State Legislature law providing for organization of State water conservancy districts enacted in May.

In July, Congress granted appropriation of $900,000 to begin construction. Public hearing conducted in November by Secretary of the Interior.

President approved findings regarding feasibility December 21.

1938 Secretary approved agreement between National Park Service and Bureau relating to water and power uses and to use and restoration of land surface within boundaries of Rocky Mountain Park.

In July, contract executed with newly formed Northern Colorado Water Conservancy District for repayment of portion of project cost.

1938 Work started on construction of Green Mountain Government camp, on transmission line from Public Service Co. in Dillon to damsite and on Green Mountain Dam and Powerplant.

1940 In June, drilling of Alva B. Adams Tunnel began.

1942 By order of War Production Board, construction stopped at year's end on all project features, except Green Mountain Dam and Powerplant, which was nearly completed and would soon produce power for war effort. Features underway included Granby Dam diversion outlet tunnel and Granby Dikes 1, 2, and 4, and the Alva B. Adams Tunnel.

1943 Commercial operation of generating unit No. 1 at Green Mountain started at 3 p.m., May 18, 1943. Unit No. 2 placed in operation and power delivery to Public Service Co. of Colorado began at 6:31 p.m., May 24, 1943. Work resumed on Adams Tunnel in August.

1944 Adams Tunnel holed through on June 10, 1944, at 12:24 p.m.

1946 Cessation of World War II released construction materials and manpower for civil purposes, and project construction experienced rapid expansion. Work resumed on Granby Dikes 1, 2, and 4. Contracts awarded for Granby Dam and for Horsetooth Reservoir dams.

1947 On June 23, first water passed through Alva B. Adams Tunnel for irrigation in valley of Big Thompson River. (First major transmountain deliveries came in 1953, however, after initial Eastern Slope distribution facilities had been constructed.)

1949 Filling of Granby Reservoir commenced.

1950 In September, Estes Powerplant produced first Eastern Slope power.

1951 In January filling of Horsetooth Reservoir began. Also in January, first water pumped into the Granby Pump Canal by Granby Pumping Plant.

Adams Tunnel 69-kilovolt cable energized February 28, 1951.

In April, Marys Lake Powerplant connected to transmission system.

In July, Poudre Supply Canal completed, enabling water service to irrigation companies along Cache la Poudre River.

1952 In November, Carter Lake Reservoir completed.

1953 In May, North Poudre Supply Canal completed.

In December, Willow Creek Pumping Plant began lifting water to Lake Granby.

1954 In January, Pole Hill and Flatiron Powerplants began operation.

In February, reversible pump turbine at Flatiron began pumping to Carter Lake; it was first used as a turbine in June.

In May, first water delivered to Little Thompson and St. Vrain Valleys.

In August, water service began to Boulder Creek Valley.

1956 South Platte Supply Canal, last major water distribution feature, scheduled for completion in spring.

1959 In April, Big Thompson Powerplant placed in service.

Introduction

Snowcapped peaks on the eastern side of the Rocky Mountains in northern Colorado drop off rapidly into foothills and the valley of the South Platte River. Plains then stretch to the borders of Nebraska and Kansas—170 miles of arable land richly endowed by nature.

The pioneers entering this country in the 1860's—farmers by background and inclination—saw bright opportunity. The tall prairie grasses told of rich soil and forecast lush crops. There were neither rocks to clear as in New England nor forests to remove as in the midlands. Streams cool and clear tumbled out of the canyons, flattened, and joined the South Platte.

The land-hungry emigrants who eagerly broke the soil and planted seeds could not know they were founding one of the richest agricultural areas of the United States. The hundreds of first arrivals swelled later to thousands.

Even the early cultivators recognized that there was one condition different from what they had known in the eastern parts of the Nation—the amount and timing of summer rainfall. The 30 or 40 inches of precipitation a year they had known in Missouri or Pennsylvania dropped off here to less than half that amount. Irrigation was an obvious requirement.

The first canals built by the settlers diverted water directly from the river or its tributaries onto the low-lying lands. Then canals were built to the nearby upper benches. Finally, plains reservoirs—to contain the springtime excess flows and hold them for release during the hotter, late times when they were needed to continue crops—completed the development of waters within the river basin.

Reservoir storage became important not only for a single season but also for holdover purposes from years of plenty to years of drouth. Nature in its vagaries, produced weather cycles, proving that this farm paradise had a major imperfection. Years of average or above-average precipitation would yield bounteous returns in crops and prosperity. Then would come below-average years when sun and wind dried out earth and sprouting plants, and hardship would follow.

The farmers learned the lessons this climate taught—land cultivation will yield good returns only when precipitation happens to be ample and favorably distributed, and then only if good farming practices are followed. Too often, the springtime freshets carried the large proportion of the annual moisture supply.

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Yes, irrigation and storage here were desirable. But there was yet another lesson to be learned. As is so often the case in the semiarid West, there was more good land than water to put on it. The farmers, spreading their agricultural enterprise over more and more acres, even before 1890 were looking beyond their own side of the Continental Divide, wanting and needing the surplus waters on the west side.

The importation of large quantities of water from the Colorado River was a task beyond the financial and engineering abilities of the time. Seven hundred thousand acres, however, representing one of the largest privately developed irrigated areas in the United States, would not permanently be denied the supplemental resources of water they required.

This dream of plenty was the genesis of the Colorado-Big Thompson Project. Its construction finally transpired between 1937 and 1958.

I. The Long Road

(1870-1935)

Migration's Impact

The story of the Colorado-Big Thompson Project starts with the Louisiana Purchase of 1803. Development of this area was slow. Unexplored, unmapped, and unknown, and inhabited as it was by the American Indian, the area was full of hardship and peril to the pioneer in search of a home.

Official exploration began with the expeditions of Lewis and Clark in 1804, Pike in 1806, and Long in 1820. Under a Government commission in 1843, Fremont found Indian trails along the streams and over the mountain passes to be well known to white hunters, trappers, and fur traders—those daring Davy Crocketts of our western lands.

At favorable spots—where streams or wilderness trails joined—camps and settlements developed. Here farming and stock raising became established parts of the business of supplying the adventurer.

Some early outposts were in today's Colorado near the mouth of Bijou Creek, and along the Cache la Poudre and Thompson Rivers and St. Vrain Creek. Fort St. Vrain and Fort Lupton were two of the stronger settlements. In 1843, John C. Fremont found Lancaster Lupton's trading post on the South Platte River to be complete with a garden, livestock, and poultry.

But high mountains diverted the stream of emigrants traveling toward California's gold, the Oregon country, and the promised land of the Utah Territory in the 1840's and 1850's. These travelers bypassed northeastern Colorado in favor of the easier way of the Oregon Trail through Nebraska and Wyoming, or the Santa Fe Trail from the Arkansas River Valley across the lower ranges in New Mexico.

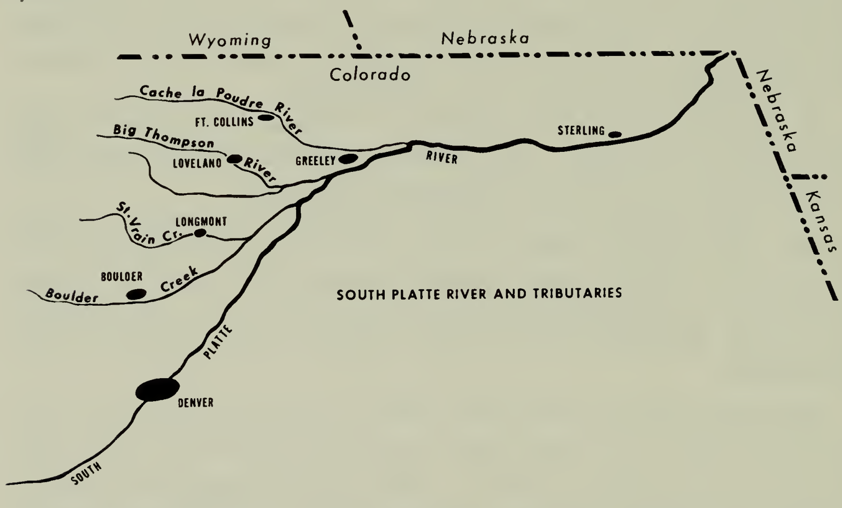
Interest in the fertile South Platte River Valley would have been slower by decades if gold had not been discovered in 1858, first at the confluence of Cherry Creek and the South Platte River at the site of Denver, and then at Russell Gulch and along Chicago Creek to the west near the present Idaho Springs.

While nomadic and sometimes belligerent Indians watched the behavior of the white man with amazement, the South Platte Valley became a primary route into the fabulous "Pike's Peak Country".

The mining bonanza created communities no less hungry for food than for gold. The entire area was stimulated and expanded by the need for agricultural products.

The long haul of supplies made shortages inevitable and induced fabulous prices for foodstuffs. Local demand encouraged local supply. First, an enterprising settler applied water to a few acres of garden along Boulder Creek near Denver in 1859. Other irrigation followed. Some travelers, rather than push along to the gold camps, stopped and planned farms and homes. Undoubtedly most of the first settlers were disappointed prospectors. Although the organization of counties began in 1861, settlement was sparse.

Then Horace Greeley admonished young hopefuls to "Go West, young man," and colonization speeded up. Nathaniel Meeker established the Union Colony on the South Platte at the mouth of the Cache la Poudre, in April 1870, under Greeley's aegis. This was a cooperative venture of about 600 members to establish a settlement to be supported by irrigated agriculture. Greeley, Colo., was a community of nearly 2,000 people by 1871.



In quick order the St. Louis Western Colony was established 5 miles south of the Union Colony, and the Tennessee Colony developed 27 miles down the South Platte River near the present town of Orchard. The Chicago Colony, which is now the prosperous agricultural community of Longmont, and the Fort Collins Colony were founded during the summer of 1871.

In 1870 the Denver Pacific Railroad from Cheyenne to Denver and the Kansas Pacific Railroad to Denver from the East were completed. Although these facilities could move in more staples, the booming mining areas still spurred the South Platte Valley to produce more of nature's green gold.

In 1871 the Union Colony built the first systematic irrigation system. Greeley Canal No. 1, 27 miles long, first served 12,000 acres and had a capacity for 25,000 acres. Then Greeley Canal No. 2 was built to serve the uplands away from the river.

By 1882, just 6 years after Colorado became a State, the whole Cache la Poudre Valley west of Greeley was "one vast network of canals", say the historians. One of the largest, the Larimer and Weld Canal, with three easily constructed reservoirs, irrigated 60,000 acres between Fort Collins and Greeley.

The "Water Barrel" Runs Dry

Leaders of wagon trains crossing the prairie carefully calculated stops at springs or rivers to rebrim their water barrels and water their stock. There was suspense in the open crossings. If the weather had been persistently hot and dry, the waterholes might be only cracked mud. Ever optimistic, the adventurers would thrust on, expecting that replenishing supplies would be not far ahead.

Irrigators in the South Platte Valley were much like the wagon train bosses. Usually there was plenty of water and they could be generous with its use. But availability was a gamble, and sometimes they lost. Then they could just hope to win new supplies ahead.

By 1900 nearly all direct-flow water had been appropriated and most of the choice land had been taken. The population of Weld, Larimer, and Boulder Counties had grown from 4,400 in 1870 to 50,600 at the century's end. (In 1960 the population of these counties was 199,941.)

An era opened with the establishment of a beet sugar factory at Loveland in 1890. Four factories soon were added in Fort Collins, Greeley, Eaton, and Windsor, and others were built later at Fort Lupton and Johnstown.

Reservoir building, the answer to seasonal shortages and to the absence of dependable new direct-flow rights needed for expansion of agriculture, put the high spring runoff into the "barrel" for later use.

Colonization had proceeded under the sponsorship of land-development companies and the railroads. To furnish supplemental water to ditches having direct-flow rights and to develop new lands, mutual reservoir companies were then formed to develop offstream reservoirs. By 1910 reservoir storage capacity had been built for nearly 600,000 acre-feet and all of the good storage sites were used.

Meanwhile, there had been a parallel growth in cattle-raising on the short grass plains to the east of the irrigated area. Cattle, trailed from Texas, were pastured on the plains and then were shipped from such centers as Greeley and Sterling to the meat-hungry markets of the East.

The large cattle ranches in the lower valley discouraged development of small agricultural tracts, and uses upstream tended to dry up the lower reaches during what would be the irrigation season. The demands of World War I changed this pattern and brought about the formation of irrigation districts in the lower valley, representing the last major surface irrigation expansion in the South Platte River Valley.

The Union Colony had pioneered in separating water rights from the land and in establishing the principle of water exchange which allowed downstream water rights to be used on the land upstream. It also popularized alfalfa as a crop, established the potato as a commercial crop, and initiated the first farmers' clubs.

Colonies and cooperatives and mutual companies and irrigation districts—during half a century each of these was an attempt to improve the use of land and water. Still, there were too many times when the "water barrel" would be dry. But another two decades would elapse before arrival of the next technique to put more water in the barrel—today's conservancy district.

Looking to the West

The Northern Colorado Water Conservancy District is the legal agency of property owners who benefit from the Colorado-Big Thompson Project. Within the present district are about 120 separate ditch systems and 60 principal storage reservoirs. The district had to be created as an entity to have the right to tax property throughout its area and to contract with the U.S. Government to repay the irrigation cost of the proposed new project.

A brief review of western water law and experience is requisite to an understanding of how this new organization fitted into the development of the area.

The pioneer coming into the new land had an advantage because the western "appropriation law" is a rule of "first in time, first in right". First-comers who applied streamflow to full beneficial use acquired rights to the streamflow. (This doctrine is different from that in the Eastern States where riparian rights are recognized: If water flows past your land you may use it.) The hopefuls arriving later established their own rights through use. When surplus waters were available, they were entitled to use them; in time of shortage they did without.

In due course, court decrees legalized rights according to seniority of use, and the date of its water decree often determined the value of land for use or sale. Many a savage battle over water rights ended in bloodshed, and to the victor went survival. Perennial shortages plagued those ditches having late priority water rights, and water rights dated even in the 1880's could be poor rights during drouth.

It's not surprising, therefore, that the first court decree for a transmoun-

tain diversion to bring in new resources was granted as early as 1882. Under this decree a canal was built to bring a small amount of water from Michigan Creek, a tributary of the North Platte River, to the Cache la Poudre River.

Of nine similar privately financed transmountain diversions constructed prior to the Colorado-Big Thompson Project, the largest is the Grand River Ditch, located high on the Continental Divide. It collects water from the mountain slopes that feed the North Fork of the Colorado River and delivers about 20,000 acre-feet a year into the Cache la Poudre River.

There still was much more water available to the farmers looking to the west side of the mountains, but they were thwarted by the tremendous cost and difficulty of getting it.

Hiram Prince of Boulder County addressed these words to the Colorado State Legislature in 1889: "Gentlemen, Colorado's surplus waters are on the Western Slope of the Continental Divide; the lands available for their use are on the Eastern Slope. I want an appropriation of $25,000 to find a route for bringing these waters across the mountains where they can be used."

Mr. Prince's plea was persuasive. The legislature appropriated $20,000 for a survey by State Engineer K. P. Maxwell of a plan to tunnel from Monarch Lake on the Western Slope to St. Vrain Creek and to construct a canal from Grand Lake to Monarch Lake.

The next step in the historic search of a dream of plentiful water was the withdrawal from entry of possible project sites on Government land on the Western Slope in 1905 intended to reduce right-of-way costs when the time would come for the Nation to develop these choice storage sites. In this same year the federal Reclamation Service, predecessor to the Bureau of Reclamation, suggested that the elevation of Grand Lake be raised and a tunnel driven from Grand Lake to the Big Thompson River or to St. Vrain Creek. But the costs were too high and the engineering too difficult for the time.

In 1933, under the pressure of new drouth, northern Colorado irrigators and community leaders organized the Northern Colorado Water Users Association to make a private study of the feasibility of a transmountain diversion, approximating in its scope the present project. The report of Royce J. Tipton, Denver consulting engineer, was favorable. In 1935, the Public Works Administration granted $150,000 for a survey by the Bureau of Reclamation of what was called the Grand Lake-Big Thompson Project.

The needs were no less than three decades before, the benefits were greater, and economic conditions in the area had advanced along with engineering techniques. What had been infeasible a generation earlier was now feasible. The Bureau of Reclamation report endorsed the project, and presented its conclusions to the Congress.

Senate Document 80—the Colorado-Big Thompson Project Report—in 1937 became the form of congressional authorization for the project. It contained endorsements of the proposal by the Western Slope Protective Association, representing Colorado River Basin interests, and by the Northern Colorado Water Users Association.

However, Western Slope residents were not eager to give up water resources that were surplus, but which some day might be useful for industrial or irrigation expansion on their own side of the mountains.

The negotiations called for master diplomacy on both sides, and the welfare of the State of Colorado as a whole prevailed. As compensation, the Northern Colorado Water Users Association agreed to provide, at its expense, spring runoff storage on the west side to replace diverted waters and to assure river flows for irrigation. This storage, Green Mountain Dam and Reservoir, was the first project feature placed under construction when work began.

The Water Users Association obtained passage by the Colorado State Legislature of the Water Conservancy District Act. Association leaders then obtained the approval of owners of property within the boundaries of the proposed district.

With district court sanction, the Northern Colorado Water Conservancy District was established by overwhelming public vote. The same community leaders—private citizens dedicated to a cause—who had directed the Water Users Association became the district's first officers and directors.

A contract for the district to repay the Government for part of the project cost was signed in 1938. At long last, the way was clear to bring the water through the mountains, to find a route as Hiram Prince had asked in 1889.

Northern Colorado Water Conservancy District directors and officers signing repayment contract with the United States for construction of the project, July 5, 1938.

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II. A Dream Unfolds

(1935-58)

Seeing a Way

This booklet outlines in broad terms the features of the project and their interrelationships which form the unique Colorado-Big Thompson Project. It does not attempt to present the engineering techniques required to transform the dreams into reality, or the construction procedures for each of the more than 100 engineering features. Summary statistical data on project works appear on pages 50–54 of this book.

Those wishing to learn the engineering considerations involved may consult the 4-volume Technical Record of Design and Construction of the Colorado-Big Thompson Project, available from the Government Printing Office or libraries.

After legislation giving the go-ahead to the Colorado-Big Thompson Project had been passed, the problem of accomplishing the transmission of water from one side of the Continental Divide to the other was placed squarely before the Reclamation engineers.

The water was on the west, the lands on the east. The means of bringing them together would require a vast, interrelated series of engineering works.

The areas and distances involved were large. Hundreds of miles separated the extremes of the project. Interspersed between these points was some of the most rugged terrain in the United States, ranging from less than a mile to more than 14,000 feet above sea level.

To overcome the obstacles of mountain terrain and to fit this gigantic jigsaw puzzle together, an elaborate triangulation network was established. Engineers, perched with their instruments atop the high peaks, could see and tie together important points on both sides.

From these vantages the four main parts of the project—Western Slope storage, transmountain diversion, foothills aqueduct, and Eastern Slope storage and distribution systems—were located for construction.

Perhaps the most valuable contribution from this network was the precise location of the 13.1-mile Alva B. Adams Tunnel for the transmountain diversion. This tunnel pierced the Continental Divide approximately a mile vertically below its highest point of land surface.

Vertical control, or accurate elevation, was also required, in addition to the exact locations of the various features, if full advantage were to be taken of the falling water. Heights above mean sea-level datum for both sides of the divide were carefully correlated by precise instruments and by efforts of the surveyors.

With field data accurately and carefully recorded, designing to make best use of nature's topography was done by the engineers in the office of the Assistant Commissioner and Chief Engineer at Denver, Colo.

New kinds of decisions now had to be made. How to fit all of the pieces together? What features to construct first? When should the generator for a powerplant be ordered? When should a canal be ready for service? How could parts of the project be utilized in the interim before project completion? These questions and many others required careful scheduling and programing of construction.

Green Mountain Reservoir, constructed on the Blue River, eliminates the Colorado-Big Thompson Project's interference with irrigation and power generation under prior rights on the Colorado River. Spring runoff is stored and later released to meet the requirements on the Colorado River, thus allowing diversion of more water by the project throughout the year. Green Mountain Powerplant produces power revenues to assist in repayment of project costs.

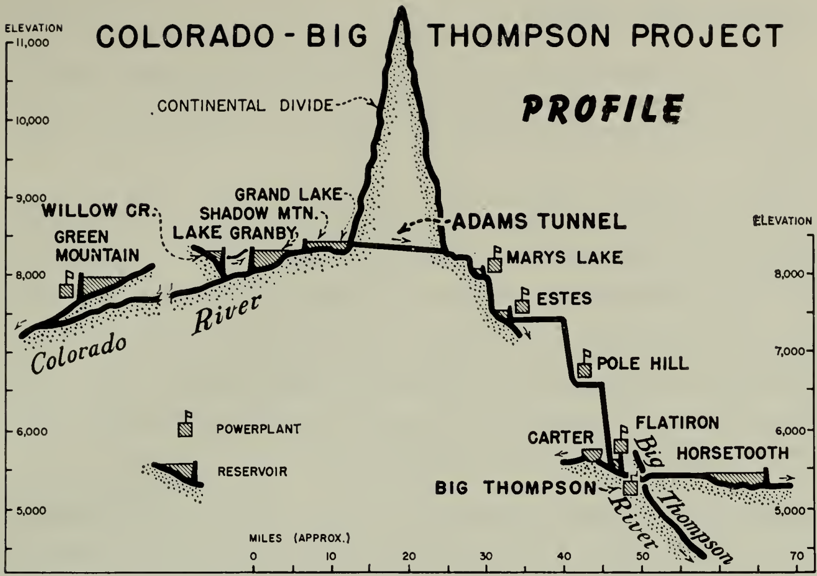
The structure of the project considered the most vital and requiring the longest time to construct was the Continental Divide tunnel, named in 1944 for the late Senator Alva B. Adams of Colorado, who did much to make the project possible. This feature was started in 1940, preceded only by Green Mountain Dam and Powerplant and a few minor features.

Among the problems were the financial studies and analyses required to justify the tremendous undertaking represented by the project as built. The delays caused by shortages of manpower and materials during World War II were beneficial from a planning standpoint because a larger and more efficient project grew out of the initial concept, so briefly studied. The war years, and the tremendous growth of the area since the war, have more than justified the development of every kilowatt of electrical energy within the larger purpose of providing a water supply.

Fulfilling the Dream

Lake Granby is the principal reservoir in which surplus water originating on the headwaters of the Colorado River is stored prior to diversion. Water from Willow Creek is regulated, stored, and delivered to Granby Reservoir through Willow Creek Reservoir, Pumping Plant, and Pump Canal.

From Lake Granby, the water is lifted a maximum of 186 feet by the



Granby Pumping Plant into the Granby Pump Canal and thence into Shadow Mountain Lake and on to Grand Lake, a famous natural feature. The water flows by gravity from Grand Lake through the Alva B. Adams Tunnel under the Continental Divide to the Eastern Slope, whence it passes through a series of conduits, tunnels, penstocks, and powerplants and is stored in Carter Lake and Horsetooth Reservoir.

During the irrigation season, water is released from these reservoirs through the Charles Hansen, North Poudre Supply, St. Vrain Supply, Boulder Creek Supply, and South Platte Supply Canals to the Cache la Poudre, Big Thompson, Little Thompson, and South Platte Rivers and to St. Vrain and Boulder Creeks. From these natural water courses, the water is diverted into existing irrigation canal systems or private reservoirs for delivery to the farmlands.

The project plan also provided for installation of hydrogenerating equipment having a total capacity of 183,950 kilowatts and appurtenant switchyards, transmission lines, and substations to deliver the generated energy to the power market area.

There are 13 reservoirs and regulating basins, 25 earth and rockfill dams and dikes, 6 powerplants, 3 major pumping plants, 24 tunnels, 11 canals, 16 major siphons, 8 penstocks, 785 circuit miles of transmission lines, and 43 substations and switchyards.

Construction of the project is complete. Its total estimated cost is $160,432,000, with allocations of $100,665,000 to irrigation and $59,767,000 to power. The allocation of almost $59,800,000 to power included $1,370,000, reimbursable by other projects. The reimbursable costs will be repaid through power revenues and assessments of water users.

Gathering and Saving

The water-producing area of the Colorado-Big Thompson Project is on the headwaters of the Colorado River near the top of the Continental Divide. From here the Colorado River starts its long course to the Pacific Ocean.

Today's engineers envisioned the great bowl that is Lake Granby as the one spot where sufficient storage could be trapped and retained for controlled diversion to the Eastern Slope. Where the river flowed out of this bowl, surrounded by mountains, Granby Dam, an earth and rockfill dam, 298 feet high, and four dikes were placed to hold back the mountain waters in their gathering rush down the Colorado. (The water spread 1-foot deep would cover nearly 1,000 square miles of land.) The 539,758 acre-foot storage capacity is a little more than twice the average annual amount supplied to the district by the project.

By a controlled opening in the dam, sufficient water is released at all times to maintain a live fishing stream below the dam. More than 4 million cubic yards of earth and rock were used to build the dam, and the greater part of 4 years was required for the construction due to the high elevation and the uncertain mountain weather. A scenic highway across the dam and along the reservoir rim for approximately 15 miles replaces a road that was inundated by the reservoir.

The waters of Willow Creek, a westerly tributary entering the river below Granby Dam, are caught by Willow Creek Dam. A canal, pumping plant, and pipeline lift these excess waters 175 feet so that they are added to the project's water supply in Lake Granby. Downstream irrigation uses are satisfied by releases through the dam.

Nearby, on the Blue River, surplus water is stored in Green Mountain Reservoir for release to prevent transmountain diversions from interfering with existing water rights on the Colorado River. The reservoir assures maintenance of specified flows at downstream irrigation points. Of the total reservoir capacity of 154,600 acre-feet, 52,000 are reserved exclusively for the replacement function.

From Pacific to Atlantic

The engineers' plan for Colorado River storage and replacement was relatively simple. A reserve of divertible water had been found and was acceptable under compact provisions for the Colorado River, but an elevation on the east side of the mountains comparable to Lake Granby was too far removed for economical tunnel construction.

A direct tunnel diversion was out of the question. As a substitute, a pumping plant was devised which would lift the water to the normal level of Grand Lake and from that height to flow by gravity through a tunnel to deliver the water to the lands east of the mountains. The tunnel, even though 13.1 miles long, was economically feasible.

Granby Pumping Plant at the northeast corner of Lake Granby became Paul Bunyan's "Big Blue Ox," to lift the lake storage nearly 200 feet.

The plant, an almost boat-shaped concrete structure, was built on the shore of the reservoir with its intake pipes extending into the reservoir. A portion of the pumping plant, equivalent in height to a modern 12-story building, is submerged in the bank of the reservoir. The buried part of the building was built with massive reinforced concrete walls 3 to 8 feet thick to withstand the pressures of the water in the reservoir and the saturated fill around it.

The water pumped from Lake Granby flows northeasterly from the 2-mile length of the Granby Pump Canal and then through interconnected Shadow Mountain and Grand Lakes to the submerged mouth of Alva B. Adams Tunnel and emerges on the Eastern Slope into the Gulf of Mexico drainage of the Atlantic.

Shadow Mountain Lake was constructed below Grand Lake to provide a passage for the pumped water, and to regulate its flow. The lake was formed by a low dam across the North Fork of the Colorado River about 600 feet downstream of its junction with Grand Lake outlet, the natural stream draining Grand Lake.

The water surface elevation of Shadow Mountain Lake is the same as that of Grand Lake, a natural lake of 504 acres. A check structure was constructed between the two lakes so that Shadow Mountain Lake could be lowered without affecting the natural beauty of Grand Lake, along whose shoreline are many summer homes and tourist resorts. Grand Lake is the anchorage of "the world's highest yacht club".

The 550-cubic-feet-per-second diversion through the tunnel may be obtained during the spring runoff without pumping from Lake Granby. Inflow greater than diversion needs passes through the large gated spillway of Shadow Mountain Dam into the Colorado River channel to be stored in Lake Granby, later to be pumped back uphill when natural inflow drops below the transmountain diversion requirements.

For a while in 1937 it looked as though there would be no project. Many sincere supporters of the national park system conceived that construction would violate Rocky Mountain National Park by tunneling under the park. It was not enough—as was true—that both portals would be outside the park boundaries—Grand Lake would be "ruined" by fluctuation.

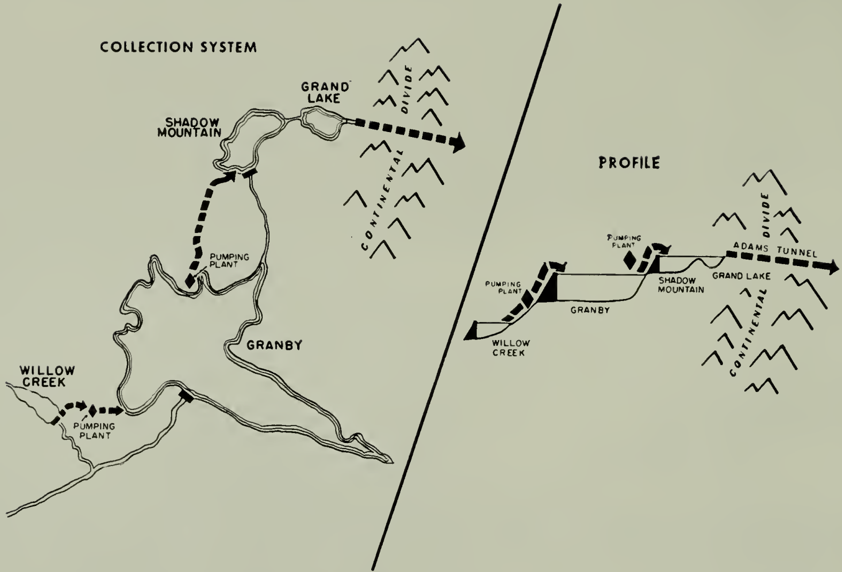
Notwithstanding the Bureau of Reclamation's mature voiced appreciation of the unscarred beauty of the park, public opinion and congressional appropriations were won only after plaster models of the area and the proposed works were exhibited all over the United States. They illustrated that the project would enhance—not detract from—natural grandeur. Subsequent construction validated the Bureau's position.

Green Mountain Dam and Reservoir.

Willow Creek Dam and Reservoir.

Granby Dam and Lake.

Shadow Mountain Dam and Lake.



The Grand Lake water surface was to be maintained within 1 foot of the normal elevation as required by S. Doc. No. 80, the authorizing document. (Historically, the lake suffered much greater extremes of surface elevation due to variations in natural runoff.)

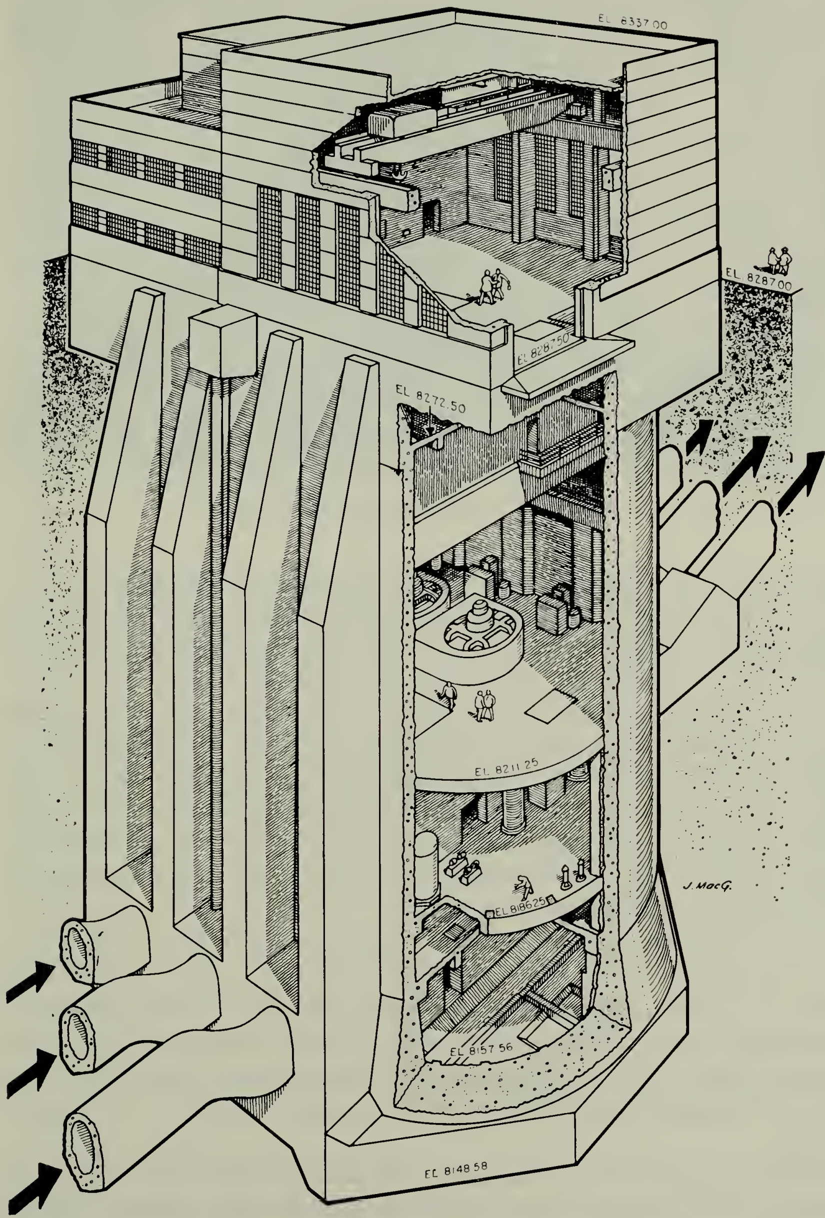
The towering mountain range was formidable. There was no way over and no way around. The only way was "through," and this appeared to be next to impossible to many economists, engineers, and contractors.

Never before had such a water-bearing tunnel of this length been constructed. What would be encountered in the hole under the mountain? What could be expected in the way of geologic faults, fissures, bad ground, subterranean pressures, and other construction hazards?

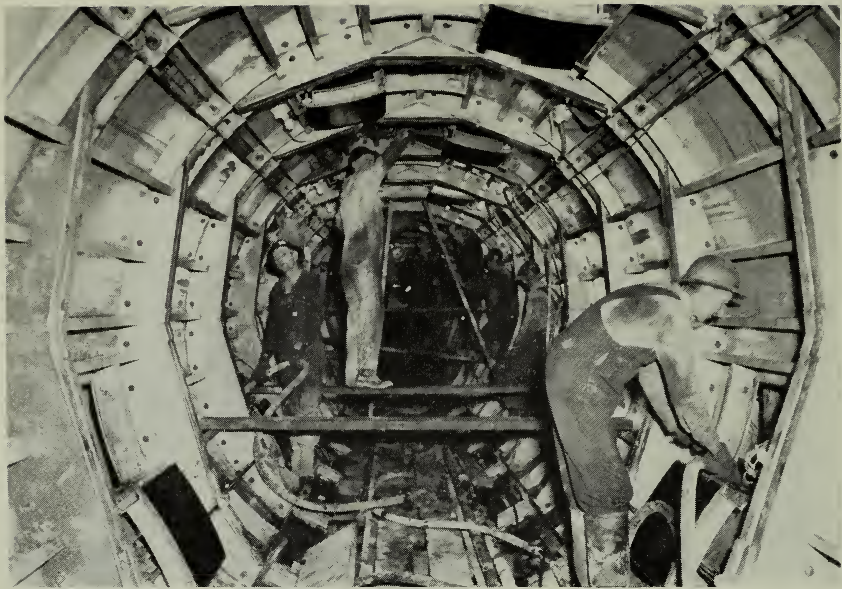
The National Park Service agreed to necessary surveys and seismographic explorations in the park. The line of the tunnel was traced over the top of the divide—a tremendous task of scaling peaks and cliffs, lugging equipment in an altitude where every breath was torture. These surveyors examined the surface of the ground, but what would be the conditions down in the earth 4,000 feet below where the tunnel was to be?

The tunnel was excavated successfully from a point one-fourth of a mile outside the park's western boundary. The eastern end of the bore entered the mountain some 300 feet outside the eastern boundary of the park. The way through the Continental Divide proved to be almost all granites, gneisses, and schists.

After thorough analysis of data and design by Bureau of Reclamation engineers, excavation of the Adams Tunnel from both ends was started in the summer of 1940 under a contract awarded by the Bureau. The first shot was fired by the construction company for the excavation from the east



Cross-section, Granby Pumping Plant.



Excavation of Alva B. Adams Tunnel.

end on June 15. On March 31, 1944, shots from the east working face were heard by the western crews when the distance between working faces was still 4,245 feet apart. Work on the west side was stopped June 7, 1944, for the sake of safety, and the eastern crew holed through 3 days later.

At last, 55 years after the first survey of the plan for transmountain diversion, a path was cleared so that runoff from the Pacific watershed could flow toward the Atlantic. The centerlines, as surveyed from each end of the tunnel, were completely accurate. When the lines met in the middle of the tunnel, the height of a penny would cover the differences of both line and elevation. No greater satisfaction could come to the Bureau engineers who performed the precise work.

After excavation, the unreinforced tunnel was lined with a concrete ring averaging 1 foot in thickness, giving a smooth, straight, circular bore 9 feet, 9 inches in diameter for the water passage. The only problem in connection with the construction of the tunnel, beyond those normally encountered in this type of work, was the handling of relatively short sections of bad "squeezing ground" near the West Portal. These were effectively sealed.

Much might be added about the construction of this feature, such as the placing of 124,375 cubic yards of concrete in the tunnel lining, the excavation of 308,477 cubic yards of rock, and utilization of 5,351,224 pounds of steel reinforcement and structural shapes. But the greater story would be of the men who built it.

Long hours in the dark underground . . . men inching their way forward, wondering what the next shot would bring . . . living and breathing questions as to whether a subterranean cave-in would engulf all, or an underground stream would drown them. Daylight and air were miles away every working hour . . . a power cable could blow up and throw everything in complete darkness, while concrete continued to flow. These things could have happened and, although they didn't, the pathway from Pacific to Atlantic was indeed more than just a hole in the ground.

First water was run through the tunnel June 23, 1947, a memorial to the men who dreamed of it and the men who made it possible.

The Way down the Hill

The ancient Chinese said that "dropping of water will wear away great stones". The torrent of water imported through the Adams Tunnel would indeed wear away the mountains between East Portal and the foothills if allowed to run unchecked down the mountains.

The amount of diverted water may be pictured. A trough 10 feet deep and 55 feet wide, flowing full of water moving 1 foot each second, would carry as much water as the Adams Tunnel at its 550-cubic-feet-per-second capacity.

The engineering and economic problem was to fulfill all of the power potential in the imported water before releasing it at the elevation of the irrigated area. In an average year the project has 400 million tons of water dropping 2,800 feet in elevation on its way to the irrigation distribution area.

Like horsepower and the waterwheel of the old New England mills, the value of the water as a symbol of strength is not realized until it is made to turn hydraulic turbines which revolve generators and produce electricity.

Controlled use of the project's falling water produces electrical energy which is in demand and therefore easily converted into dollars. The project, with six powerplants, is producing approximately 700 million kilowatt-hours annually and each year is collecting about $4 million in revenues from electric sales.

Initial plans following the dream of a stable irrigation supply for more than 700,000 acres of irrigated land in the Northern Colorado Water Conservancy District were tentative and incomplete. They were based on meager data and rough estimates, and were limited by the planning funds available at the time.

As the project unfolded, and time, manpower, and funds were used, the engineers searched the 18 airline miles of rugged mountains and canyons on the Eastern Slope, and found first, a route to make the water develop its maximum energy as it ran downhill, and second, the locations where the water could fall rapidly under the skilled control of powerplant operators.

The natural paths for the water to run downhill would not prevent the destructive and wild dissipation of the power in the water. The engineer had to utilize reinforced concrete siphons, steel pipe, tunnels, and canals to supplement the natural water courses. Nature's perfect waterfall sites were located. Here, during the Ice Age, melting snows ran torrents down the steep sides of the cliffs. At these spots the engineer planned giant steel penstocks and hydraulic turbines to convert the power in the water to electric energy that could be carried through transmission wires to farm homes, industry and the cities, and through sale at fair market prices, repay the cost of the works.

Between the Adams Tunnel and the Big Thompson River at Estes Park, the difference in elevation is 800 feet; the route down the Eastern Slope of the Continental Divide accounted for utilization of 687 feet of net effective power head. In this part of the system a base load plant at Marys Lake and a peaking plant at Estes account for practically all of the power available in the falling water. Between Estes and Flatiron a similar two-plant setup accounts for 1,870 feet of net effective power head in the 2,000 feet of fall.

The improved engineering plant increased the cost of the project, but less than half of that which was caused by wartime delays and mounting labor and material costs. With every improvement in plan came greater assurance of firm water supply, and from the water, greater quantities of electric energy.

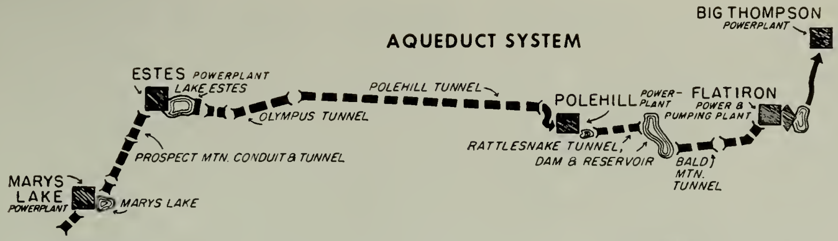
A small pond built at the mouth of Adams Tunnel at the eastern end aided in the regulation of the tunnel flows. Tunnel muck and spoil were used to build the 76-foot-high dam 245 feet long.

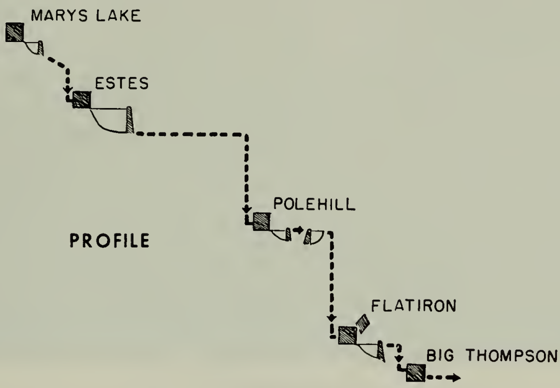
From East Portal, Aspen Creek Siphon conveys the imported water across country to Rams Horn Tunnel. The inverted concrete siphon is buried beneath the ground for its entire length. Both the siphon and the tunnel have a capacity of 550 cubic feet per second to match the capacity of the Adams Tunnel.

First water through the Adams Tunnel in 1947 was utilized before the Aspen Creek Siphon or Rams Horn Tunnel were built. Transmountain diversion flows were carried by a 1½-mile, 54-inch steel pipeline, erected by the conservancy district. This temporary route was down Wind River and into the Big Thompson River directly.

In the final construction at East Portal a 30-inch concrete pipe was installed to carry the Wind River under and past East Portal Reservoir to avoid commingling of flows and the resulting separation difficulties.

Rams Horn Tunnel ends at the penstock gatehouse of the Marys Lake Powerplant. Here the diverted water is guided down the 475 feet of





96-inch steel penstock to turn the hydraulic turbine and 8,100-kilowatt generator at Marys Lake. If necessary, it can be sent around the powerhouse in a bypass siphon spillway chute to the afterbay reservoir provided at the foot of Marys Lake Powerplant.

The Marys Lake afterbay reservoir is a natural basin enlarged by two dikes to provide just the right amount of pondage to permit the Estes Powerplant to be operated to meet peaks of electrical demand on the system. The main dike at the northeast end includes the control works for releases through Prospect Mountain Pressure Conduit and Tunnel carrying 1,300 cubic-feet per second to Estes Powerplant, about 2½ miles northeast of Marys Lake.

Each of the three Estes generators has a rated capacity of 15,000 kilowatts.

Lake Estes, the Estes powerplant afterbay reservoir, is formed by the 70-foot-high Olympus Dam across the Big Thompson River. It reregulates the imported water run through the powerplant, and also the flows of the Big Thomspon River. The dam has control gates for river releases, for releases into the Olympus Siphon, and for reservoir spills.

Olympus Siphon conveys Lake Estes releases to Olympus Tunnel. Olympus and Pole Hill Tunnels provide a dog-leg route instead of a single tunnel so that the two added portal headings could be used to facilitate excavation and lining. Olympus is nearly 2 miles and Pole Hill is 5 miles

East Portal, Alva B. Adams Tunnel.

Marys Lake Powerplant.

Estes Penstocks.

Estes Powerplant.

long. The tunnels were joined at the central headings by a covered concrete section.

From the Pole Hill Tunnel, one-half mile of concrete-lined open channel conveys the water to the Pole Hill penstock gate structure. Here gated controls and a spillway control the flow in the penstock. Water, if not used by the powerplant, can be spilled down the rocky slopes above Little Hell Creek into the small afterbay below the powerplant. The plant has a single generating unit of 33,250 kilowatts, controlled from Flatiron.

A siphon and then a tunnel discharge into Rattlesnake Reservoir, the forebay for Flatiron Powerplant. This reservoir, about 13 miles east of Estes Park, provides both regulating storage for daily peaking power needs at Flatiron and additional storage for Flatiron Powerplant operation during limited shutdowns of the system between Lake Estes and the Pole Hill Powerplant. The Bald Mountain Pressure Tunnel and penstocks convey Rattlesnake flows to Flatiron, where two generators are rated at 31,500 kilowatts each.

An afterbay serves as a tailrace channel for the powerplant and a forebay for the pumping unit. Flatiron Powerplant houses also a reversible pump-turbine unit which pumps to Carter Lake or may be used as a power unit with flow reversed in the Carter Lake Pressure Tunnel. Power generation helps meet peak load requirements.

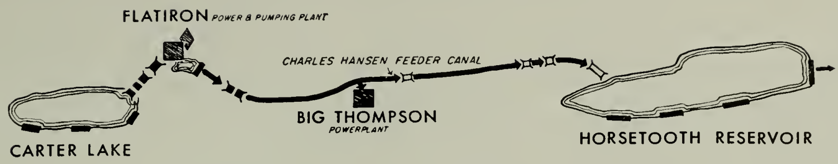
The Big Thompson Powerplant, for seasonal operation, provides additional revenue. Surplus flow of the Big Thompson River is routed through the Pole Hill and Flatiron Powerplants and returned to the river through this plant. The sixth powerplant is at Green Mountain Dam on the Western Slope.

Water to the Land

A total of 322,854 acre-feet was diverted through the Adams Tunnel for the year 1954. The maximum design capacity was planned for 398,100 acre-feet. The anticipated longtime average annual diversion is estimated as 257,000 acre-feet. In 1955 the diversion was 253,089 acre-feet. Although the project was not then complete, it was able to serve nearly two-thirds of the service area. Lake Granby, the "last waterhole", had a good supply of water in storage and the pumps were able to tip the bucket so that this water could run eastward to the parched land.

The way it was done is the way it was planned. The diversions are controlled and electric energy taken from them on their "way down the hill". Below the Flatiron Power and Pumping Plant a small dam ponds the water so that some of it may be pumped up to Carter Lake by the reversible pump-turbine, using project power when it is not needed elsewhere.

FOOTHILLS STORAGE SYSTEM



The Flatiron afterbay also provided gravity flow, which is directed northward 13.2 miles to Horsetooth Reservoir by way of the Charles Hansen Feeder Canal, a name that commemorates the late publisher of the *Greeley Tribune* and president of the Northern Colorado Water Conservancy District from its formation in 1937 until his death in 1953. The canal delivers supplemental irrigation water to the Big Thompson River and carries project water to the reservoir for subsequent use on the lands of the northern part of the district. Facilities are included for diverting Big Thompson River water into the canal, for turning water out and through the Big Thompson Powerplant into the river, and for delivery to Buckhorn Creek, farm turnouts, and the city of Loveland.

The canal crosses the highway and Big Thompson River in the Big Thompson Siphon. The siphon is a drop of 109 feet down the canyon wall in a concrete-lined tunnel, then a plate-steel pipe bridging the highway and river, and finally a concrete pipe ascending the north slope.

The Horsetooth Supply Conduit diverts water from the Big Thompson River about 1 mile above the river crossing of the Feeder Canal. The supply conduit consists of a diversion structure, a 1-mile tunnel and an outlet structure. Prior to completion of the aqueduct system, it was used to deliver project water sent down the Big Thompson River into storage in Horsetooth Reservoir.

The supply conduit adds to the flexibility of operations. It can carry Estes water into the northern canal system, using the Big Thompson River as a channel, in the event the aqueduct and power system could not be used. It normally can divert Big Thompson flows into the feeder canal to pass them through the Big Thompson Powerplant and back to the river. It can also divert surplus Big Thompson River waters into Horsetooth Reservoir through the canal.

Horsetooth Reservoir occupies a valley between two hogback ridges. Four dams and a dike provide the desired storage capacity. From south to north, the structures are Spring Canyon Dam, Dixon Canyon Dam, Soldier Canyon Dam, and at the north end Horsetooth Dam and Satanka Dike.

The Dixon Creek Feeder Canal is supplied from an outlet in Soldier Canyon Dam and carries water 3 miles to Dixon Reservoir on Dixon Creek.

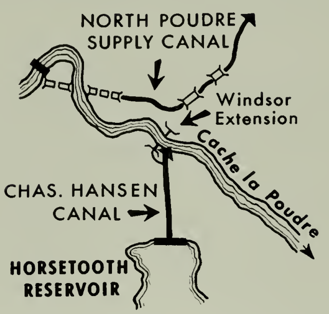
Flatiron Powerplant.

Carter Lake.

Big Thompson Siphon.

Horsetooth Reservoir.

NORTHERN DISTRIBUTION SYSTEM



The 5.1-mile Charles Hansen Canal carries Horsetooth Reservoir releases to the Poudre River. There, the major part of the flow is taken to the Poudre River down a chute and through a stilling basin. The remainder of the flow is carried through for the Windsor Extension Canal system which crosses the river.

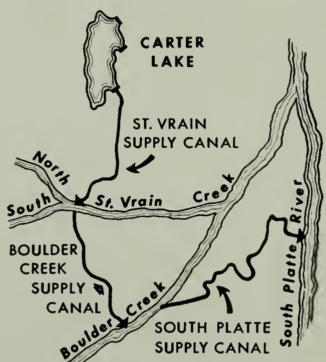
The chuted portion of the Charles Hansen Canal is an exchange for a supply diverted upriver into the North Poudre Supply Canal. The diversion dam diverts water via a measuring flume into Tunnel No. 1 through a ridge. The water is taken under the river in a siphon, and thence through tunnels, siphons, and canal sections for more than 12 miles to the North Poudre Ditch.

These works comprise the project storage and delivery system for the northern part of the Northern Colorado Water Conservancy District.

The system for the southern part starts with the Flatiron pump, the Carter Lake Pressure Tunnel, and Carter Lake. Carter Lake provides storage for supply canals leading southward for the Little Thompson, St. Vrain, Boulder, and lower South Platte Valley areas. The pressure tunnel provides a double function—water can be lifted through it 240 feet from Flatiron to Carter, or water can pass down it. In the latter use, Carter Lake stored water runs northward into the Horsetooth Supply Canal system.

When Carter Lake storage runs back into the Flatiron afterbay, the pump is designed to operate as a generator to provide peak demands for electric energy from the Flatiron plant. A 42-inch submerged tube valve at the Flatiron plant will bypass the pump-turbine unit in emergencies.

Carter Lake was formed in a natural basin by the addition of three dams in low saddles in the hogback ridge. Releases through an outlet tunnel through the main dam supply the St. Vrain Supply Canal leading southward nearly 10 miles. This canal joins the Boulder Creek Supply Canal leading to Boulder Creek, which is used to convey water to the South Platte Supply Canal.



The St. Vrain Supply Canal supplies the Little Thompson River, St. Vrain Creek, and the Boulder Creek Supply Canal. The Boulder Creek Supply Canal serves five turnouts, and near the end, runs through the city of Boulder's "Twin Lakes" Reservoir, which stores the water allotted the city. Boulder Creek Supply Canal obtains its water from a turnout in the St. Vrain Canal rather than from a diversion out of St. Vrain Creek, thus preventing debris and silt from entering the Boulder Canal.

The South Platte Supply Canal diverts from the diversion dam of the Lower Boulder Ditch about 2 miles down Boulder Creek from the end of the Boulder Creek Supply Canal. The route selected was somewhat longer than other routes studied, but by utilizing the one continuous existing Lower Boulder, Sullivan, and Coal Ridge ditches, construction savings were effected.

The project storage and canal delivery system is the backbone of the tremendous private irrigation development extending eastward to the Nebraska State line.

From Snow to Electric Light

When the sun glances off the ice crystals of Colorado's high mountain peaks with a prophetic flash of clear blinding light, one can hardly be called nearsighted or uninformed if one cannot believe that the project, using those same ice crystals, can make a lamp burn brightly miles away.

In the Colorado-Big Thompson Project, the energy in the flashing rivulet, running away from the melting ice and snow on the mountain top, is actually caught, guided under the ridge-pole of America, and tamed to controlled lighting as its weight is converted to electricity. Through the intricate network of the Colorado-Big Thompson Project power system . . . the North Platte River power system . . . the lines of Rural Electrification Associations . . . municipalities . . . the Public Service Co. of Colorado, Pacific Power & Light Co., and other local power companies, the energy stored by nature in the drop of water lights lamps and turns motors in eastern Colorado, western Nebraska and southeastern Wyoming.

The power features of the project alone stretch 250 miles across Colorado from Oak Creek on the west to Holyoke and Wray near the eastern State line.

Power for starting project construction was furnished to the Government by the Public Service Co. of Colorado, a private corporation. The initial points of service were Dillon for the Western Slope features and Loveland for the Eastern Slope features.

A segment of what was to be the permanent project power transmission network was built in 1940 between Greeley and Fort Morgan to serve the irrigated areas and municipalities in this area. Until Colorado-Big Thompson Project power was available, these loads were supplied by power produced at Seminoe Dam in Wyoming, a feature of the Kendrick Project of the Bureau of Reclamation, and transmitted via Cheyenne.

The largest wholesale user of federally produced power in this area was and still is the Morgan County REA, which distributes electricity to more than 2,600 farm homes and more than 1,400 irrigation wells. From about 5 million kilowatt-hours supplied in 1941 this one organization has developed sales of over 110 million kilowatt-hours in 1960.

In 1944 a 115,000-volt permanent line was built southward from the Greeley-Fort Morgan line to serve the Prospect Valley area. A dire need for irrigation pumping power during the dry 1944 irrigation season was met by completion of the line and substation.

Starting in May 1943, electric power from the Green Mountain Powerplant was fed back through Dillon to the Public Service Co. system serving Denver and vicinity. Green Mountain power was very important in helping meet wartime needs in Denver.

Production of power at Estes Powerplant on the Eastern Slope started in December 1950, and on February 28, 1951, the cable circuit through Alva B. Adams Tunnel was energized at 69 kilovolts. The generators at Green Mountain and Estes were synchronized and tuned to run together as a team.

The dream was one step further along the road to success as it now became possible to direct electrical energy eastward to supply Eastern Slope demands, or westward if the project pumping system needed energy to lift the water up the mountain. Through the war years, the project transmission net had been held to the three disconnected segments. The Flatiron-Greeley tie was made in March 1950, and the tie of Western and Eastern Slopes was completed in February 1951. Thereafter progress was uniform until at present the project system is complete with nearly 800 miles of 115,000- and 69,000-volt lines, and 43 substations. The project has two mobile substations for emergency use. A connection to the Missouri River Basin Project lines at Sterling was made in 1948. The Greeley tie is to the North Platte River systems, as well as to the Public Service Co. of Colorado. The development of the transmission system is shown by the following table:

	Miles
1938	27
1942	178
1946	211
1950	419
1954	786

Except for 2 miles of steel tower construction near Estes, 13 miles of submarine cable in the tunnel, and two steel towers at Flatiron Powerplant, the entire transmission system is of wood-pole construction.

After reconstruction of the Green Mountain Switchyard in 1952, all of the project's six powerplant switchyards are of steel construction. So also are the two Western Slope pumping plant switchyards. The majority of the project substations are of permanent steel-type construction.

The 69,000-volt cable circuit through Alva B. Adams Tunnel is one of the unusual features of the project. The tunnel route was chosen because of lower bids and less operational cost than a 39-mile overhead route which would have been located at elevations about 10,000 feet over the divide.

The Bureau had authority to construct a surface transmission line through Rocky Mountain National Park. Recognizing the disfiguration that would result, and at the same time striving to construct at lowest possible cost, it faced a dilemma that was solved by receiving lower bids for the tunnel route.

The three wires of the cable, pipe encased and suspended from the top of the tunnel, are insulated with inert nitrogen gas automatically maintained in the pipe at 200-pounds-per-square-inch pressure. An alarm system is designed to warn of any leakage developing. The cable provides also a carrier-current telephone channel and a telemeter channel to convey operational information from the Western Slope to the control center on the Eastern Slope. Initial years of transmission showed no faults.

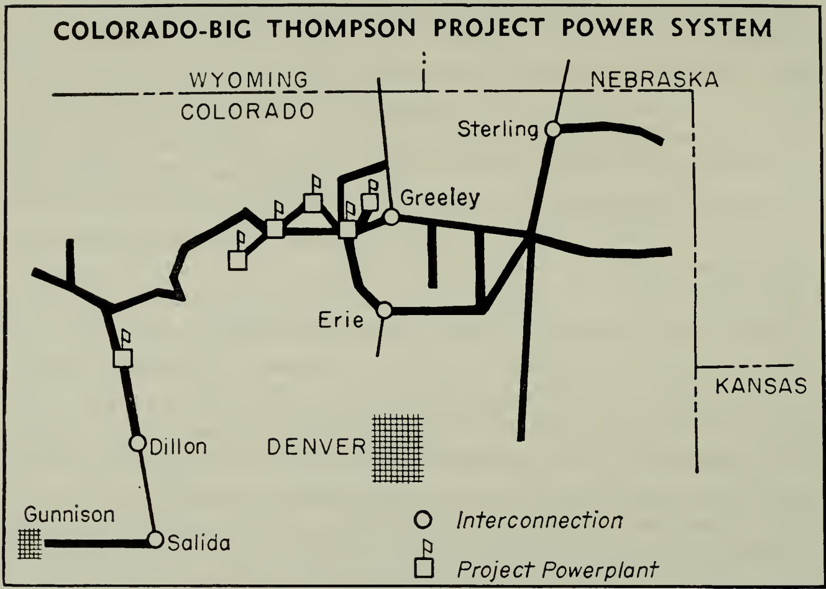
The Colorado-Big Thompson transmission system is connected to the Kendrick Project and North Platte Project systems at Greeley, and to the Missouri River Basin Project lines at Sterling. In addition to the ties with the Public Service Co. at Dillon, Greeley, Erie, and the Beaver Creek Substation near Brush, Colo., the company "wheels" power over its lines to Salida, Colo., where service is provided to customers in southwestern Colorado by means of the Salida-Gunnison line of the Fryingpan-Arkansas Project.

Existing multiple-purpose features of the Colorado-Big Thompson Project and other facilities in the Bureau's Region 7 include 9 storage reservoirs with a combined capacity of 3,570,000 acre-feet, 8 regulating reservoirs, 12 powerplants with an installed capacity of 365,150 kilowatts, and 3 pumping plants. These combined facilities harness the waters of the North and South Platte Rivers.

There are a few common ways to evaluate electric service. In the first place, we know when the frequency is irregular. If it were 25-cycle power, we would see our lights flicker. At 60 cycles, any variation would be noticed in accuracy of our electric clocks because if the frequency were less than 60, clocks would be slow; if more than 60, they would be fast. A time standard is maintained on the project which is checked consistently by radio with the Bureau of Standards.

The other way by which we measure our electric service is line voltage, normally brought to homes at 120 volts for domestic uses. Most electric appliances are designed for service to be steady at 120 volts. If there were no voltage control on our electric system, we would suffer "popping" lights—lights that burn out quickly due to overvoltage. A television image would fade with undervoltage.

Because of long transmission distances and variable loads as applied by



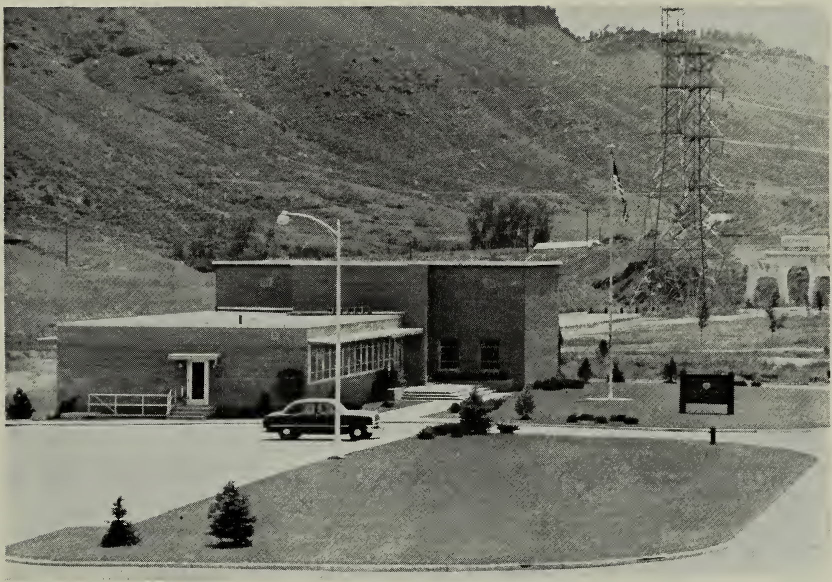
private and commercial users on the system, regulating equipment is necessary to help maintain uniform voltage.

On the C–BT project system a synchronous condenser station is located near Brush at the Beaver Creek Substation. Here, at a considerable distance from the generators of the project, and centrally located for services to the area, this giant condenser helps maintain uniform voltage on the lines. A similar unit installed at Gering, Nebr., on the North Platte system, performs a similar function in that area.

The central dispatching office at Flatiron schedules water and power releases to coordinate operation of the North and South Platte and the Wind River systems.

The project operates a microwave radio network with fixed stations at Akron, Colo., on the plains; atop Bald Mountain near Flatiron on Prospect Mountain near Estes, and on Blue Ridge near Green Mountain. Control equipment for the mountain stations is at the nearby powerplants. All line trucks and most other mobile equipment are equipped with mobile radios which can communicate with the fixed stations.

Project headquarters at Flatiron controls operation of the intricate project, directing movements of water from Western to Eastern Slopes, ordering pump service, and controlling power generation for maximum efficiency not only in Colorado but also in Wyoming plants. This management requires skillful study and application of snow runoffs, control of floodflows, equation of power generation according to demand, and provision of water supply for irrigation and municipal purposes—exacting requirements!



Project headquarters building.

III. A Reality Arrives

The emigrants crossing the plains had looked ahead to the time of filling their water barrels. The settlers diverted the plentiful supplies of the spring runoffs, and wished they had more. The developers built canals, and later storage reservoirs. Still there was not enough water.

At the time of crisis, when local enterprise with all its vigor was not enough, the urgency had become great enough to seek outside help.

Unemployment beset the land. Men desperately craved work to do. Drouth compounded the problems of manmade economics. Seeds drilled into the ground sprouted into puny plants, their thirst denying man the sustenance he sought. Not only farmers but their service communities suffered.

Man had made the situation. He had created the ditch systems. He had laid out the lands to be irrigated. It was up to man to fill the ditches and to wet the roots of the struggling crops.

Then came the solution—transbasin diversion.

The prospect of removing water, the West's most precious commodity, from the watershed of its origin is invariably a call to arms. Colorado's Western Slope rallied in opposition. The able leadership of the proponents made their logical case, however, and agreement was reached.

The plan staggered imagination. Dams, power and pumping plants, tunnels, canals, siphons, transmission lines, substations—this most complex scheme had to be accepted by the public at large, not really understood.

Charges of short-term investigation . . . no "authorization" . . . "robbing" a watershed . . . remarkable complexity—how did the Colorado-Big Thompson Project overcome such obstacles?

The twofold answer is clear: (1) Economic soundness, evident at the outset and sufficiently strong to withstand multiplication of more than three times of the original cost estimate, so that every cent of the Government's investment will be repaid by the beneficiaries, and (2) the need was beyond question, and was proved by the initial water deliveries.

To the Rescue

A playwright planning a dramatic stage entrance would have scripted for the imported water to arrive in just the manner it did.

Northwestern Colorado had been buffeted by drouth during the years when the C–BT was being studied and construction was started. Then came years when the water supply in the South Platte River Basin was more favorable, including some "good" years.

The first major water deliveries were made in 1953, nearly 16 years after the first earth was moved, although filling of Horsetooth Reservoir had begun in 1951. The water was gratefully received along the Big Thompson River and to the north and east. The southern system was not yet in service.

Looking upon the cold and pure melted snow tunneled through the mountains early in 1954, farmers felt no great excitement. They didn't know what lay ahead. They didn't know they were starting another drouth cycle.

As the season progressed and precipitation failed, the South Platte basin's stored supplies began to ebb and the Western Slope water took on the aspects of treasure.

The importations in 1954 literally averted disaster for thousands of farmers. Late in the play, the dramatist came to his climax—the within-basin water was used up. The project water carried the crops to maturity and moneymaking yields. This "finishing water" was the essential justification of the C–BT, and in 1954 it bowed to many curtain calls.

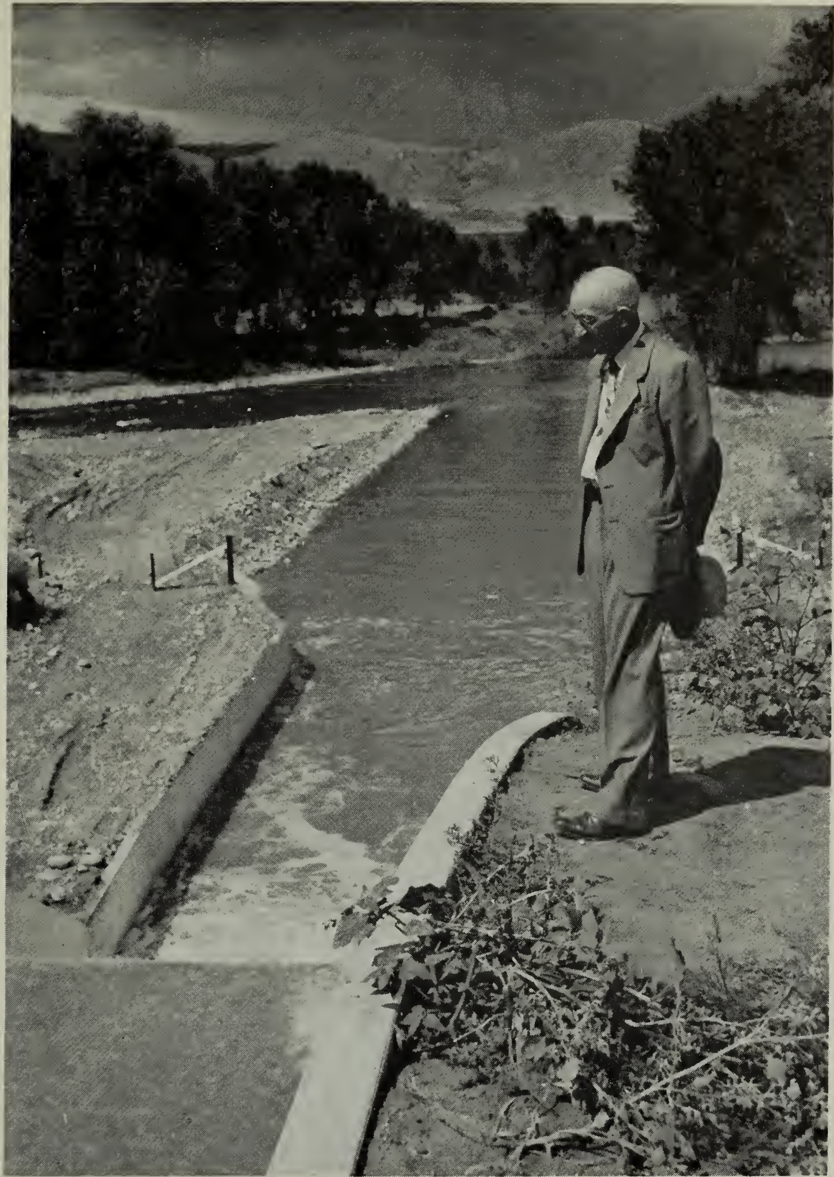
Drouth conditions in 1955 were only slightly less severe, and the value of project water was almost as great as in 1954. The first 2 big years, when project water was more than half of the total uses from storage, brought the project onstage in a way that told every member of its audience that it was there.

The initial major operating experience brought out an exceedingly important part of the project plan—holdover storage. The large capacity of Lake Granby affords opportunity to space out water uses over a period of years so that the "fat" years equalize the "lean." Such was the case in 1954 and 1955: Granby had large supplies in storage to compensate for successive drouths. Granby could provide a full supply for diversion if the impossible happened—if not one drop of precipitation fell on the Western Slope for a full year.

Irrigation Operation

The dramatic episodes are in the past. The daring concepts involved in the transbasin diversion scheme . . . the scale of the project works . . . a 13-mile tunnel bored through unknown geology . . . the excitement of pioneering.

The C–BT probably will never again be quite so showy as it was in 1954 and 1955. Management experience has taught the Northern Colorado Water Conservancy District, its participating ditch companies, and indi-



Parshall flume to the Poudre River—Ralph Parshall.

vidual farmers how to space out their water requirements—when and how to utilize their within-basin water rights, when to request their shares of project water, and how to conserve water.

In its maturity, the C–BT is taking in stride the performances expected of it. Typically, no beating of drums accompanied its accomplishments in 1960.

This was a "good" year in the project service area. Gross crop values totaled $89,860,000, or $124.80 an acre. In a large acreage that included much hayland and pasturage, this was a tremendous record, the highest in area history, and for which the C–BT deserved credit.

Winter precipitation was not far off from average. The rate of snowmelt was favorable, coming slowly and spaced out during the spring so that the riverflows could be fully diverted and drawing on stored supplies was deferred.

Warm summer and fall weather with scant precipitation placed heavy burdens on stored water, including project supplies. As a result, project water, although only 22 percent of the crop season's consumption, was responsible for 30 percent of the value of crop production, or $27 million. But this was what is now expected of the C–BT.

The long-term estimate is that imported water will be about one-fourth of the irrigation needs of the lands being served, and will approach one-half of the total uses that come from storage.

"Direct flow" water rights, based on diversions from the streams, were the first bases for irrigation and remain the most substantial consideration.

During the period 1957–60, project water was 40 percent of the water used on seasonal crops.

Management of Irrigation

The Northern Colorado Water Conservancy District operates the irrigation and municipal water delivery features of the project. A sort of holding company for the irrigation companies and other beneficiaries within the project area, the quasi-municipal conservancy district was established in 1937 under a Colorado law enacted to meet the special requirement.

This law set a national precedent. Under it, owners of all types of property within the district boundaries help to repay project costs through mill levies, on the principle that those who benefit from the construction and operation should contribute to the costs.

A one-half mill levy was made during the latter part of the construction period to finance conservancy district activities and initial operations, and to accumulate a reserve for operation, maintenance and contingencies.

The district allocates its annual supply of water to the several classes of users, and releases are made from project reservoirs according to time and need. It collects water rentals and receives tax revenues through the county assessors. As a rough approximation, each year more than $3 of conservancy district revenues come from property tax revenues for each $5 of revenues from water rentals.

The initial payments toward the irrigation construction cost were paid as water rental charges. An amendatory contract provided for fixed annual water payments for a period of 5 years through 1961. Beginning in 1962 the conservancy district payment will be $475,775 a year. The levy was increased to 1 mill in 1957.

As finally established, the district totals 1,481,600 acres in Boulder, Larimer, Weld, Morgan, Washington, Logan, and Sedgwick Counties. Weld and Larimer are among the top-ranking counties in agricultural production in the United States.

The city of Boulder initially declined the opportunity to be included in the conservancy district. Under the demands of population growth, the city was admitted later to the district, paying to catch up and become equal with the obligations of the initial area. Boulder enlarged twin reservoirs lying eastward of the city so as to be able to receive project water to provide for irrigation uses downstream on Boulder Creek. This permitted the city to utilize, by exchange, a greater share of the creek for municipal purposes than it heretofore had a right to use.

The original estimate was that annual diversions from the Western Slope would average 310,000 acre-feet. Water users signed up for the number of shares they equitably could use to supplement their within-basin water rights.

Final allotments were made in 1955, following a district study of applications and needs. The allotments to a number of irrigation districts and to hundreds of individual users under the various ditches were based on acre-feet.

The first years of experience indicated that the anticipated average of 310,000 acre-feet was greater than the diversion would be. Now, each year the Bureau and the district jointly estimate the supplies needed and the supplies available.

One share, originally 1/310,000 or 1 acre-foot, might in any given year now be a fraction of an acre-foot rather than the full amount—1/265,000, or 1/180,000, as examples.

From 1957 to 1960, early years of full operation, the water losses of the entire Eastern Slope system due to seepage, evaporation and other causes averaged less than 4 percent a year—an extremely low figure that is a testimonial to efficient operation both by the Bureau and the district.

Municipal supply has been an important aspect of distribution of the imported waters. Nine communities—Fort Collins, Greeley, Loveland, Longmont, Berthoud, Johnstown, Lyons, Mead, and Boulder—had original allotments totaling 44,950 acre-feet.

This is a transient figure, however. Year by year as urban population grows, irrigation allotments are transferred to domestic purposes. (One acre-foot will provide for the personal water needs of four persons for a year's time.)

Boulder, Fort Collins, Longmont, and Greeley alone experienced an increase of population between 1950 and 1960 of 40,320—57.5 percent—to a total of 110,480. Future gains will be even greater it is anticipated, and

District headquarters building.

Main Street—new prosperity.

Beet harvest time near Ft. Collins, Colo.

Produce for the Nation's tables.

domestic water supply needs necessarily will come from conversion of irrigation uses as orchards, beet fields, and hay lands become subdivisions.

Maintenance

The Northern Colorado Water Conservancy District operates and maintains at its own expense the supply canals which serve as trunk lines to take the water from foothills storage to the natural streams or ditches from which the cities and irrigation companies extract supplies.

The Bureau of Reclamation, as representative and administrator of the Government's investment, maintains the major project works including the feeder canals.

It similarly operates and maintains the power facilities. The Bureau delivers the bulk power at substations to public and private distributors in a fashion that parallels the district's water delivery to irrigation companies and other users.

For specified features serving both irrigation and power purposes, the Bureau and the district each pay half of the costs for operation and maintenance by the Government.

Power Increments

The total project cost was $160 million. Some $29 million of the construction cost will be repaid by the water users through the conservancy district. The full balance, three-fourths of the cost, will come from revenues from power sales.

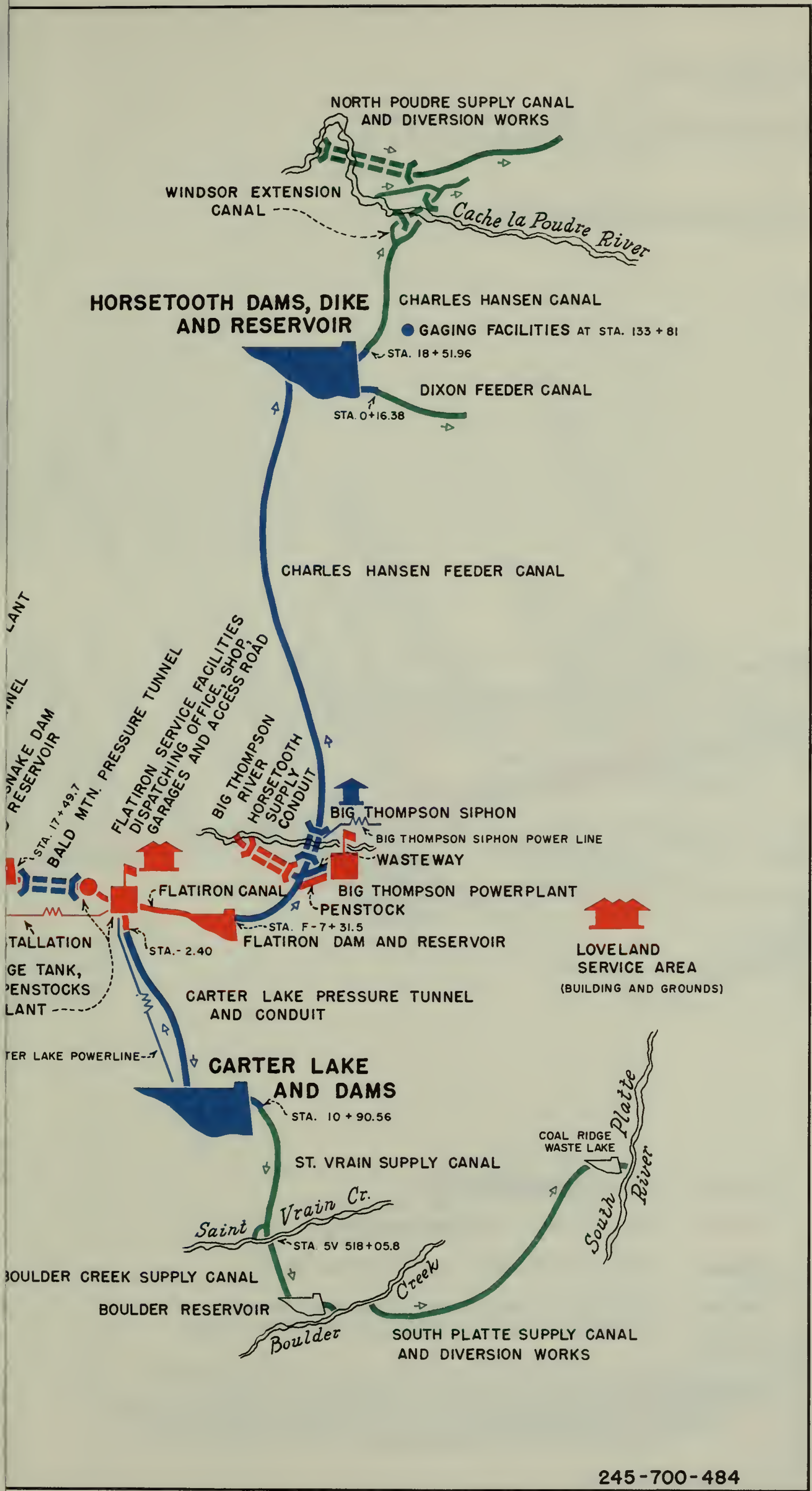
The water cascading for irrigation descends 2,800 feet from the east portal of the Adams Tunnel to the foothills. This was a planned opportunity that was fully exploited for power development.

The chain of power installations extracts the kilowatts, and a network of transmission lines sends them to the farm pump, to the household toaster, and to the city lights and industrial machines in eastern Colorado, southeastern Wyoming, and western Nebraska.

Like the irrigation water, the new power source arrived in an expanding and progressive area at staggered intervals at times when the additions were badly wanted to meet increasing consumption rates by farms and communities.

This enlargement of "load" was difficult to foresee, but it occurred and is occurring. What seemed to be an adequate supply in one year proved to be far short a few years hence.

Purchasers of Colorado-Big Thompson Project power relay it to 14 communities to serve 84,000 individuals. Longmont, Loveland, and Fort Morgan obtain substantially all of their power supplies from project plants.



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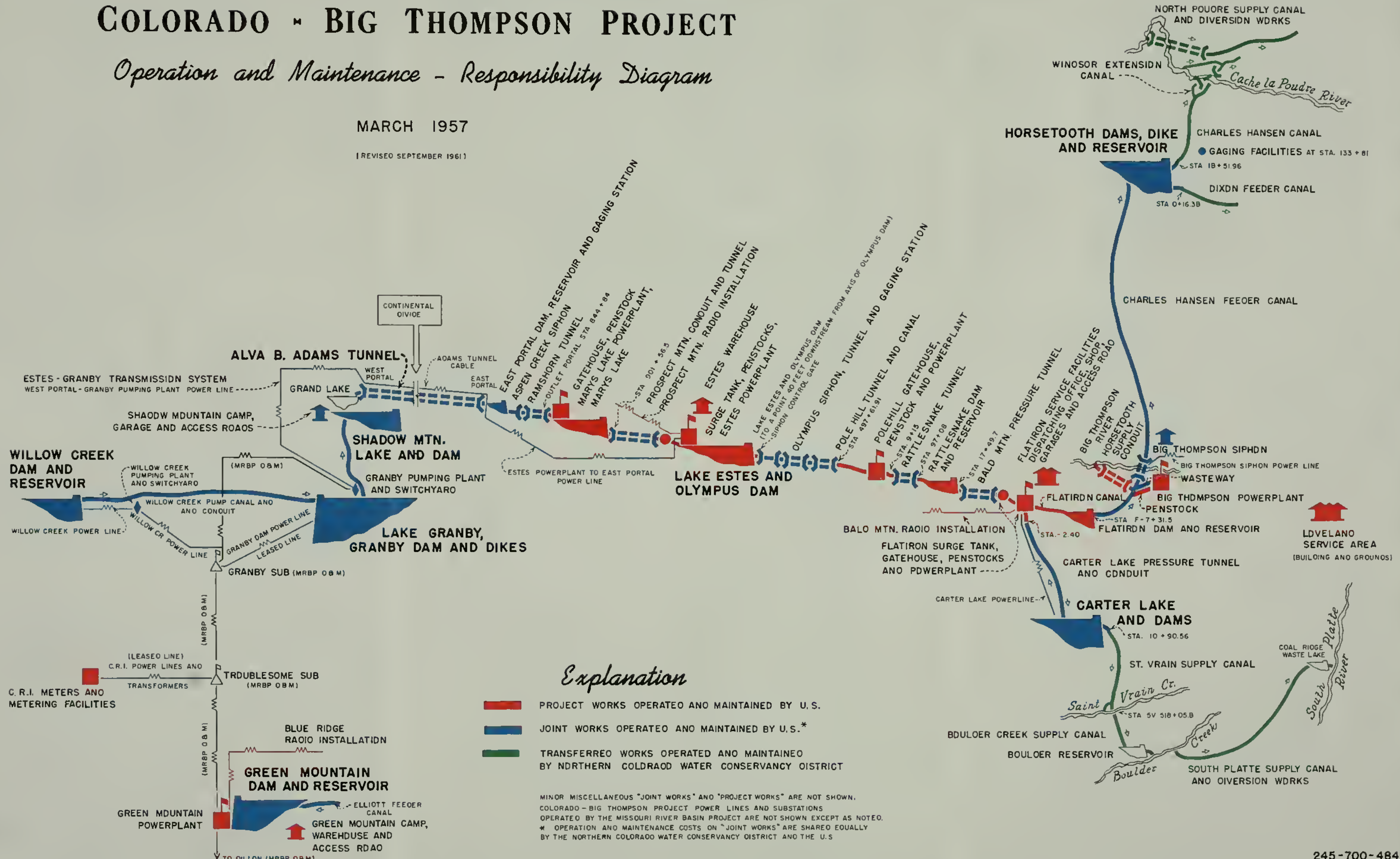
BUREAU OF RECLAMATION

COLORADO - BIG THOMPSON PROJECT

Operation and Maintenance - Responsibility Diagram

MARCH 1957

(REVISED SEPTEMBER 1961)



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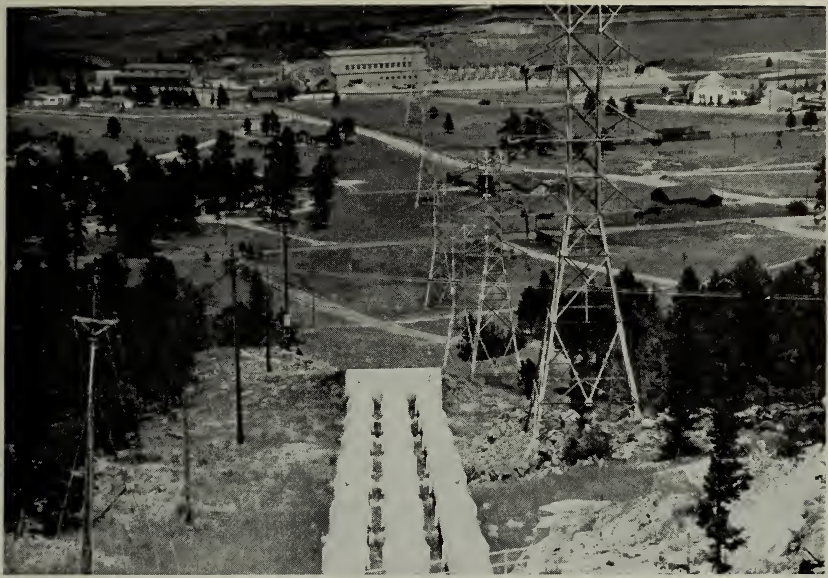

Steel towers at Estes.

Rural cooperatives serve over 250,000 people in Colorado with C–BT generation. A special and significant but unmeasurable gain is in the use of project power for irrigation pumping; another is for oil production and exploration.

The story of C–BT performance is told in statistics—how many communities, individuals, members of cooperatives. The statistics might be impressive from the standpoint of collective bulk and massiveness—but the importance lies in interpretation of meaning.

To the farmer who has read his weekly newspaper by gas lamp, the advent of the electric light is deliverance. To the farmer's wife who has swept floors with a broom, the vacuum cleaner powered by electricity is "like city folks". The urban dweller has little realization of life as it is lived by isolated rural dwellers.

One of the meanings of the C–BT is that it brought electric power to rural residents for whom it previously had been inaccessible or was too expensive to be enjoyed. The low rates for the Federal power brought it within reach of many who had no other way to get it.

This is the individual, the human evaluation of the meaning of project power. Another is the comprehensive aspect.

Without hydroelectric power, not even the Federal Government's assistance would have been enough to bring the Colorado-Big Thompson Project into reality.

Hydropower on the C–BT is essentially a bootstrap operation. Water from the Western Slope is lifted into the tunnel and delivered to the farmlands on the Eastern Slope. How? The pumping has to be done with electricity. The power originates from the project.

The two-way transmission through the Alva B. Adams Tunnel is vital to the project plan. Water lifted less than 200 feet into Shadow Mountain Reservoir and Grand Lake is dropped down the eastern mountain front through a chain of powerplants.

The fall of water on the eastern side is converted into kilowatts—which generate first of all the power needed to do the lifting, and then the salable power which pays so much of the total construction cost despite low rates.

Operation of the pumping plants that lift water out of Willow Creek Reservoir and out of Lake Granby consume the greater part of the project's internal power consumption. Station service, including residential camps, uses some of the generation.

A tiny part of the internal consumption reflects the justice of project planning. This power operates the pumps of the individual ranchers—12 in all—whose properties lie along the Colorado River between the transbasin diversion and Kremmling, and who had historical rights to divert the springtime river flows onto their irrigated pastures.

Capturing the flows in Lake Granby meant that the river would have lower levels along this stretch than in the historical past. At project expense, therefore, pumps were installed for these 12 ranchers. Pumping water to these few acres is unimportant except to the individual owners. But the C–BT anticipated the effects of the diversion and did something about it.

Nonreimbursable Benefits

As mentioned, revenues from irrigation and municipal water supply, from power, and from property taxes levied in the Conservancy District will repay the full project cost. These are due to "reimbursable benefits".

Other indirect benefits are "nonreimbursable". They were not taken into account in measuring the gains that would accrue from the transbasin construction. Although never fully analyzed or surveyed, they are real.

Principal among them are assistance to the livestock industry, recreation, creation of processing industries for agricultural and livestock production, stabilization of population, new economic opportunity, and incidental flood control.

Agricultural northeastern Colorado is an area dependent not only on cash crops, but also on the economy of livestock raising—cattle and sheep, sold either for market or for feeding. Nearly all the farmers in the area produce livestock feed for their own use or for sale to feedlots. Several of the Nation's largest livestock feeders are located in the area.

Sugar beets are an important crop, not only because of their cash crop value, but also because the tops and the pulp residue make excellent livestock feed. Feed corn, corn for ensilage, and various hays are other leading crops.

The irrigation water imported from the Western Slope assures greater reliability of crop production year in and year out; this production in turn assures livestock raisers of consistent local supply. Increased production of cattle and sheep results in income conservatively estimated at $7 million a year.

The byproduct of animal fertilizer, used to help maintain soil fertility, is an important consideration.

Recreation

No one could accurately forecast the recreation use that would occur as reservoirs were created. The experienced use transcended all expectation.

Lake Granby, the largest body of water in Colorado, is the State's most popular among boat fishermen. (John Martin flood control reservoir in the Arkansas River Valley has a greater capacity than Granby's but rarely contains as much water.)

The western shores of Lake Granby and Shadow Mountain Reservoir are lined with motels, marinas, and other business enterprises serving the recreationists. The National Park Service, to administer these for recreation, incorporated them into the Shadow Mountain National Recreation Area, one of the few such designated areas in the country.

Constant-level Lake Estes is an enhancement of the resort attractions of the village of Estes Park. The summer-long stream of visitors to Rocky Mountain National Park uses and enjoys these lakes. It's safe to say that few of the recreationists are aware that they exist for the mundane purpose of irrigation.

Carter Lake and Horsetooth Reservoir, the main Eastern Slope storages, have recreation uses a little different in character. Offstream and away from major highways, they are visited by people who go to them directly for their recreational values. They are managed for recreation by the Larimer County Board of Commissioners.

About 700,000 visitors use the various C–BT Eastern Slope bodies of water annually. The Western Slope reservoirs are used by about 800,000 each year.

Innumerable commercial facilities were needed to take care of the demands for fishing, boating, water skiing, and other uses, including cabin and resort development. All mean substantial business volume superimposed on the area's previous economy. The effects are not limited to the immediate vicinity, but overflow to Denver and many smaller communities.

Flood-control benefits are felt principally along the streams on both slopes which now have control structures. Spring torrents in the past could be

Camping on the shores of Lake Granby.

Boat fishermen enjoy a day's outing.

damaging floods, and mountain thunderstorms even though of short duration can generate large volumes of water. These are waters that formerly wasted in two ways—they were lost to beneficial purposes, and as they ran away they were destructive.

Flood, sediment, and pollution control are important to the economic feasibility of other projects, on which the "nonreimbursables" are major factors. On the C–BT, they exist but their value is not substracted from total project costs.

Extension of Effects

Effects of the Colorado-Big Thompson Project go beyond the district boundaries to the region and on to the Western States and the Nation. New business is created in far corners by the heightened and stable prosperity within the district.

The continuing effects will be many times the short-term (20-year) consequences that the construction period meant to the building industry, to suppliers of materials and machines, and to labor—large though those consequences were.

The Colorado-Big Thompson Project is a notable example of the National Government's working hand-in-hand with groups and individuals to bring about a great improvement in the use of water resources.

Without local enterprise, understanding, and support, the project could not have been constructed. Without the assistance of the Federal Government, under authority granted in 1902 by the Congress to assist in western irrigation development, all the enthusiasm of private enterprise could not have made the dreams of northeastern Colorado civic leaders become a reality.

When the desire and need reached a peak, the Bureau of Reclamation was available with the authority, the experience, and the organized technical skill to bring fruition into being.

Viewed objectively, taking into account the unmeasurable as well as the measurable benefits, the Colorado-Big Thompson Project is one of the biggest bargains in the Nation's history.

The cost and the effort of construction—so large and difficult while being completed—the travail of the sponsors, the dilemmas of the planners, the postponements and added expense due to war, the surmounted problems of the designers and builders—these pale into relative unimportance when results are tallied.

The Colorado-Big Thompson Project is delivering results beyond the highest hopes of those who foresaw that the filling of the "water barrel" lay on the western side of the mountains.

Facts and Figures

What does the transmountain diversion propose to take across the Divide through the Adams Tunnel?

The estimated average annual diversion with a tunnel capacity of 550 cubic feet each second is 265,000 acre-feet, enough water to supply a city the size of Denver, Colo., for approximately 3 years.

What is the Alva B. Adams Tunnel?

It is the longest irrigation water tunnel in the United States, 13.1 miles. At the top of the Continental Divide, it is 3,780 feet under the surface. It is a 9-foot, 9-inch, circular concrete-lined tunnel.

Has the tunnel more than one function?

Yes. The 69,000-volt power transmission circuit, installed in a nitrogen gas-filled pipe 5 inches in diameter, is suspended from the roof of the tunnel. This electric line connects Western Slope power and pumping plants with the power system on the Eastern Slope.

Where did the power come from for the project?

A private power company, the Public Service Co. of Colorado, supplied the initial power for construction. When the first project powerplant was completed and producing electric power, this power was used for contractors engaged on the work, for municipalities along the transmission lines, and for distribution by P.S.C. in the Denver area to meet wartime demands.

What does the project use to make power?

The falling water as it is moved from west to east—from one side of the Continental Divide to the other—from the high elevation of the mountain collection area to the low elevation of the plains utilization area.

Is hydropower important to the project?

Yes. It provides rural areas, municipalities and private power agencies with energy to meet the growing demands of the electric age. The revenues from the sale of power are returned to the Treasury to repay the Nation for the investment in this giant multipurpose project.

Is all the electric energy produced sold?

No. A part of the power runs the project pumps, which lift water so it may perform its project work. The electric energy which is used to run private irrigation pumps is, of course, sold to the users through the electric distribution systems and their operators.

Summary Sheets

Dams and Dikes

(Nearly all of earth and rockfill construction)

Name	Location	Height, feet		Crest		Total volume, cubic yards	Spillway capacity, second-feet	Outlet capacity, second-feet
		Structural	Hydraulic	Length, feet	Elevation, feet			
Green Mountain	On Blue River, 13 miles southeast of Kremmling	309	264	1,150	7,960	4,360,211	25,000	[1] 2,000
Granby	On Colorado River, 5½ miles northeast of Granby	298	223	861	8,290	2,974,057	11,500	435
Granby Dikes Nos. 1, 2, and 4	Low areas on southwest shoreline of Granby Reservoir, west of Granby Dam.	20–98	(2)	4,430	8,290	994,482	None	None
Granby Dike No. 3	Saddle on south shoreline of Granby Reservoir, southeast of Granby Dam.	60	(2)	1,994	8,292	743,719	None	None
Willow Creek	On Willow Creek, 4 miles north of Granby	127	95	1,100	8,140	392,368	3,200	2,050 [3] 400
Willow Creek Forebay	On Willow Creek Feeder Canal, 1 mile west of Granby Reservoir.	24	11	580	8,120	15,000	450	(4)
Shadow Mountain Dam and Dikes.	On Colorado River, 1 mile upstream from Granby Reservoir, 3 miles southwest of Grand Lake.	63	37	3,077	8,375	167,428	10,000	(5)
East Portal	On Wind River at East Portal of Adams Tunnel, 4½ miles southwest of Estes Park,	76	10	245	8,265	(6)	550	(3)
Marys Lake Dike No. 1	Northeast shoreline of Marys Lake Reservoir, 2¼ miles southwest of Estes Park.	29	20	820	8,050	90,252 (Nos. 1 and 2)	None	[3] 1,300
Marys Lake Dike No. 2	South shoreline of Marys Lake Reservoir, 2½ miles southwest of Estes Park.	35	25	950	8,050		None	None
Olympus	On Big Thompson River, 1½ miles east of Estes Park	70	45	1,951	7,481	311,613	21,200	[3] 550
Pole Hill Afterbay	On Little Hell Creek, below Pole Hill Powerplant, 10½ miles east of Estes Park.	32	21	220	6,597	6,000	550	[3] 550
Little Hell Creek Diversion	On Little Hell Creek above Pole Hill Afterbay, 10½ miles east of Estes Park.	43	33	220	6,640	±10,000	None	(7)
Rattlesnake	On Rattlesnake Creek, in Rattlesnake Park, 12 miles east of Estes Park.	130	100	1,100	6,595	432,130	10,400	23
Flatiron	On Chimney Hollow Creek, north of Flatiron Powerplant, 8 miles southwest of Loveland.	86	55	1,725	5,486	381,544	23,600	930
Carter Lake No. 1	Natural outlet from Carter Lake Basin, 7 miles northwest of Berthoud.	214	201	1,235	5,769	2,547,388	None	1,260
Carter Lake No. 2	Saddle on east shoreline of Carter Lake Reservoir, 7¼ miles northwest of Berthoud.	75	(2)	1,150	5,769	321,174	None	None

Carter Lake No. 3	Saddle on northeast shoreline of Carter Lake Reservoir, 7½ miles northwest of Berthoud.	55	(2)	1,425	5,769	211,852	None	None
Horsetooth	North end of Horsetooth Reservoir, 4 miles northwest of Fort Collins.	155	(2)	1,840	5,440	1,871,363	None	2,500
Soldier Canyon	East shore of Horsetooth Reservoir, 3½ miles west of Fort Collins.	226	203	1,438	5,440	3,211,621	None	90
Dixon Canyon	East shore of Horsetooth Reservoir, 3 miles southwest of Fort Collins.	240	215	1,265	5,440	2,961,350	None	None
Spring Canyon	East shore of Horsetooth Reservoir, 4½ miles southwest of Fort Collins.	220	198	1,120	5,440	2,095,240	None	None
Satanka Dike	Saddle on north shoreline, about 800 feet northwest of Horsetooth Dam.	20	(2)	348	5,440	(8)	None	None
Big Thompson Diversion	On Big Thompson River, 8½ miles northwest of Loveland	35	8	50	5,486.5	1,296	(9)	[3] 600
North Poudre Diversion	On Cache la Poudre River, about 1 mile upstream from its confluence with North Fork of Cache la Poudre River.	24	6	130	5,439	1,262	(9)	[3] 250

[1] Including powerplant and bypass outlets. [2] Offstream. [3] Diversion outlet. [4] 2- by 3-foot sluicing outlet. [5] 30-inch sluicing outlet. [6] Utilized tunnel waste. [7] Bypass channel. [8] Included in Horsetooth Dam. [9] Overflow.

Storage System (Dams and Reservoirs)[1]

Reservoir	Location	Total capacity, acre-feet	Surface area, acres	Maximum range in storage			Normal range in storage[2]			Dead storage, acre-feet
				Capacity, acre-feet	Water surface elevation, feet		Capacity, acre-feet	Water surface elevation, feet		
					High	Low		High	Low	
Green Mountain	On Blue River, 13 miles southeast of Kremmling	154, 645	2, 125	[3] 146, 888	7, 950	7, 800	106, 021	7, 950	7, 878. 0	7, 757
Lake Granby	On Colorado River, 4½ miles northeast of Granby	539, 758	7, 256	465, 568	8, 280	8, 186	465, 568	8, 280	8, 186. 0	74, 190
Willow Creek	On Willow Creek, 4 miles northwest of Granby	10, 553	303	9, 067	8, 130	8, 077	3, 878	8, 130	8, 114. 3	1, 486
Shadow Mountain and Grand Lakes.	On Colorado River, 1 to 5 miles upstream from Granby Reservoir.	18, 369	1, 852	17, 863	8, 367	8, 347	1, 839	8, 367	8, 366	[4] 506
Marys Lake	Offstream, below Marys Lake Powerplant, 2 miles southwest of Estes Park.	927	42	885	8, 040	8, 007. 5	547	8, 040	8, 025	42
Lake Estes	On Big Thompson River, below Estes Powerplant, ½ mile east of Estes Park.	3, 068	185	2, 659	7, 475	7, 450. 2	2, 328	7, 475	7, 456	409
Rattlesnake	In Rattlesnake Park, at East Portal of Rattlesnake Tunnel, 12 miles east of Estes Park.	2, 181	97	1, 765	6, 580	6, 550	1, 568	6, 580	6, 556	416
Flatiron	In Chimney Hollow, north of Flatiron Powerplant, 14 miles east of Estes Park, 8 miles southwest of Loveland.	760	47	635	5, 472. 8	5, 454. 75	436	5, 472. 8	5, 462	125
Carter Lake	Offstream, 7 miles northwest of Berthoud	112, 230	1, 144	108, 924	5, 759	5, 618	108, 924	5, 759	5, 618	3, 306
Horsetooth	Offstream, 3½ miles west of Fort Collins	151, 752	1, 899	143, 486	5, 430	5, 270	141, 773	5, 430	5, 293	8, 266
Totals		994, 243		897, 740			832, 882			96, 503

NOTE: Distances are map miles.

[1] Does not include Willow Creek Forebay, capacity 28 acre-feet; East Portal Reservoir, capacity 20 acre-feet; and Pole Hill Afterbay, capacity 13 acre-feet.

[2] Normal range in storage is the storage normally used to fulfill project obligations and to operate the facilities in accordance with established criteria. It does not include an incremental capacity above dead storage required to provide sufficient head for delivery of water in accordance with commitments and operating criteria.

[3] 52,000 acre-feet of storage allocated for strict replacement purposes as set forth in S. Doc. No. 80.

[4] Shadow Mountain Lake.

Powerplants

Plant	Location	Number of generating units	Installed capacity, kilowatts	Average net head, feet	Hydraulic capacity, second-feet	Penstock length (each), feet	Peaking plant
Green Mountain	Below Green Mountain Dam, 13 miles southeast of Kremmling.	2	21, 600	203	1, 660	870	Yes.
Marys Lake	On western shore of Marys Lake, 2½ miles southwest of Estes Park.	1	8, 100	205	550	475	No.
Estes	On western shore of Lake Estes, ½ mile east of Estes Park.	3	45, 000	482	1, 300	3, 969–4, 085	Yes.
Pole Hill	In Little Hell Creek Canyon, about 10½ miles east of Estes Park.	1	33, 250	815	550	2, 040	No.
Flatiron units:							
1 and 2	Near southern shore of Flatiron Reservoir, 15 miles east of Estes Park.	2	63, 000	1, 055	960	5, 790	Yes.
3	Same	1	8, 500	250			
Big Thompson	Near mouth of Big Thompson Canyon, 7 miles west of Loveland.	1	4, 500	178	370	295	No.

Pumping Plants

Plant	Location	Number of units	Pumping plant rating [1]		
			Capacity, second-feet	Lift, feet	Installed horsepower
Granby	On north shore of Granby Reservoir, 7 miles northeast of Granby.	3	600	186	18, 000
Willow Creek	On Willow Creek Feeder Canal, 1 mile west of Granby Reservoir.	2	400	175	10, 000
Colorado River improvements [2]	Along Colorado River in vicinity of Kremmling.	[2] 12	2–12	7½–17	7. 5–20
Flatiron	At Flatiron Powerplant, 15 miles east of Estes Park.	[3] 1	370	240	13, 000

[1] Rating based on horsepower output for specified vertical lift.
[2] Packaged units, installed for replacement purposes.
[3] Pumping unit may be operated in reverse as generating unit to utilize water released back to Flatiron Reservoir.

Canals and Conduits

Feature	Location	Total length, miles	Design capacity, second-feet
Elliott Creek Feeder Canal [1]	Elliott Creek to Green Mountain Reservoir	1. 1	90
Willow Creek FeederCanal	Willow Creek Reservoir to Granby Reservoir	3. 4	400
Granby Pump Canal	Granby Pumping Plant to Shadow Mountain Lake	1. 8	1, 100
Alva B. Adams Tunnel	Grand Lake to Wind River	13. 1	550
Aspen Creek Siphon	East Portal Reservoir to Rams Horn Tunnel	1. 3	550
Rams Horn Tunnel	Aspen Creek Siphon to Marys Lake penstock	1. 3	550
Prospect Mountain Conduit	Marys Lake to Prospect Mountain Tunnel	. 6	1, 300
Prospect Mountain Tunnel	Prospect Mountain Conduit to Estes penstocks	1. 1	1. 300
Olympus Siphon	Lake Estes to Olympus Tunnel	. 8	550
Olympus Tunnel	Olympus Siphon to Pole Hill Tunnel	1. 8	550
Pole Hill Tunnel	Olympus Tunnel to Pole Hill Canal	5. 4	550
Pole Hill Canal	Pole Hill Tunnel to Pole Hill penstock	. 5	550
Rattlesnake Siphon and Tunnel.	Pole Hill Afterbay to Rattlesnake Reservoir	1. 7	550
Bald Mountain Tunnel	Rattlesnake Reservoir to Flatiron penstocks	1. 3	960
Flatiron Canal	Flatiron Powerplant to Flatiron Reservoir	. 3	960
Carter Lake Pressure Tunnel and Pressure Conduit.	Flatiron Pumping Plant to Carter Lake Reservoir	1. 4	550
St. Vrain Supply Canal	Carter Lake Reservoir to St. Vrain Creek	9. 8	625
Boulder Creek Supply Canal	St. Vrain Creek to Boulder Creek	15. 7	200
South Platte Supply Canal	Boulder Creek to South Platte River	32. 2	230
Charles Hansen Feeder Canal:			
Flatiron Section	Flatiron Reservoir to Big Thompson turnout	3. 8	930
Horsetooth Section	Big Thompson turnout to Horsetooth Reservoir	9. 4	550
Horsetooth Supply Section.	Big Thompson River to Flatiron Section	1. 0	[2] 375
Dixon Feeder Canal [3]	Horsetooth Reservoir to Dixon Reservoir	3. 0	8
Charles Hansen Canal	Horsetooth Reservoir to Cache la Poudre River	5. 1	1, 500
Windsor Extension	Poudre Supply Canal bifurcation to Windsor Canal	. 5	250
North Poudre Supply Canal.	North Poudre Diversion Dam to North Poudre Ditch	12. 5	250

[1] Constructed as part of Green Mountain Reservoir.
[2] Approximate capacity in present condition; will carry 600 second-feet when tunnel is completely concrete lined.
[3] Constructed as part of Horsetooth Reservoir.

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