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Wyoming Water Planning Program
Report No. 3

WATER & RELATED LAND RESOURCES

OF THE

GREEN RIVER BASIN, WYOMING

September, 1970



A Report from the

WYOMING WATER PLANNING PROGRAM

State Engineer's Office

Cheyenne, Wyoming



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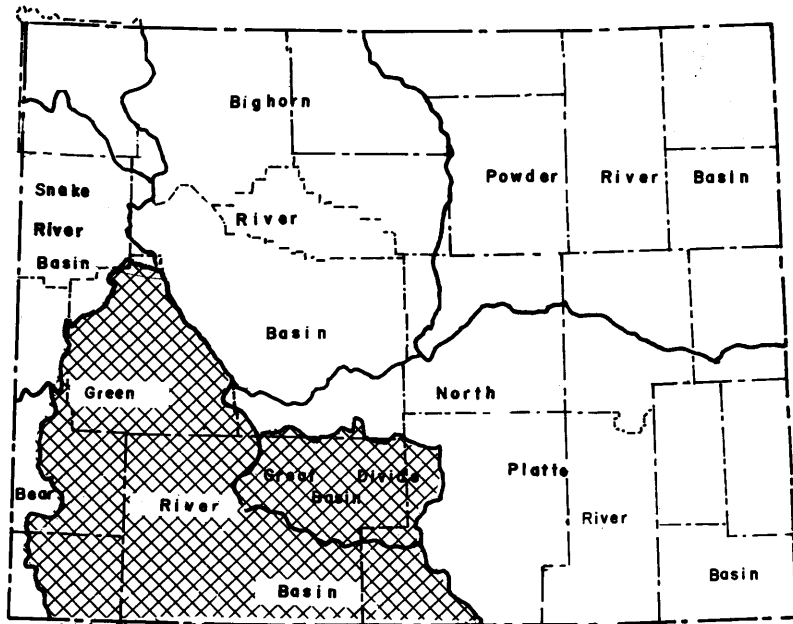
Wyoming Water Planning Program
Report No. 3

WATER & RELATED LAND RESOURCES

OF THE

GREEN RIVER BASIN, WYOMING

September, 1970



WYOMING

STUDY AREA

WATER & RELATED LAND RESOURCES
OF THE
GREEN RIVER BASIN, WYOMING

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PREFACE

This report on the Green River Basin has been prepared for the people of Wyoming as part of a "State Water Plan." The work upon which this report is based was supported by funds provided by the Wyoming Legislature, and by the Water Resources Council under Title III of the Water Resources Planning Act of 1965 (Public Law 89-80). The report is presented as part of the planning effort authorized by the 39th Legislature of the State of Wyoming, which directed that, "The State Engineer is responsible for the coordination of Wyoming's water and related land resources planning and is authorized to enter into contracts and agreements with the United States of America or its duly authorized representative agency for planning pertaining to the development of Wyoming's water and related land resources." As a result of this legislation, the Water Planning Program was established as a division of the State Engineer's Office, under the general supervision and direction of the State Engineer.

The report discusses water and related land resources in the Green River Basin and provides a means of evaluating the water needs and resources of the Basin relative to the overall water needs and resources of Wyoming. The complete "State Water Plan" will incorporate this analysis of the Green River Basin in the formulation of a statewide plan, with alternatives, to develop the water and related land resources of Wyoming.

In this report, the present water uses in the Green River Basin are inventoried and future water needs are determined. Several plans are presented in which alternative water development facilities are proposed. The sizes of reservoirs and conveyance systems used in the plans were based upon available information. Costs were estimated to facilitate comparison of alternative plans. This report does not attempt to prescribe a course of action. Rather, it attempts to provide information so that practical decisions can be made by the citizens of Wyoming concerning future water and related land resource development in the State.

The Governor's Interdepartmental Water Conference provides a coordinating forum for the water planning effort. State agencies with water resource responsibilities contribute useful data to the Water Planning Program and through regularly held meetings keep informed of policy, planning, and legislative considerations. Contributions to this report were made by several agencies. The member agencies of the Governor's Interdepartmental Water Conference are:

Governor Stanley K. Hathaway

State Engineer's Office

Attorney General's Office

State Department of Agriculture

Department of Economic Planning and Development

Department of Health and Social Service

Game and Fish Commission

The Geological Survey of Wyoming

Wyoming Highway Department

Wyoming Recreation Commission

University of Wyoming

Agriculture Extension Service

College of Law

Water Resources Research Institute

Data were also obtained from reports by the Bureau of Reclamation, the U. S. Geological Survey, and the Soil Conservation Service.

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CHAPTER I

DESCRIPTION OF THE BASIN

DESCRIPTION OF THE BASIN

LOCATION AND SIZE

The Green River Basin as defined in this report includes an area of approximately 21,020 square miles in southwestern Wyoming, bordering on the states of Utah and Colorado. The Basin extends northward from the state line, latitude 41°00' North, to latitude 43°37' North, a distance of approximately 168 miles. It is located between west longitudes 106°51' and 110°55', with an east-west span of approximately 213 miles.

The report area is further defined as that part of southwestern Wyoming that is drained by the Green River and its tributaries, including the Little Snake River and other tributaries that join the Green River downstream from the state line, and the Great Divide (Red Desert) Basin. The Great Divide Basin is a closed topographic basin some 3,916 square miles in area, situated east of and adjacent to the Green River drainage area. The Green River drainage area covers 17,104 square miles (see Figure I-1). Practically all of Sweetwater County, much of Sublette County, and parts of Carbon, Lincoln, Uinta, Fremont, and Teton Counties are within the report area.

HISTORY

When the early trappers first came to the Green River Valley, they were told by the Indians that the Spaniards had previously lived along the stream. Although the Indians called the River Seeds-ka-dee (Prairie Hen), the trappers called it the Spanish River (15)¹. There is, however, no documented record that the Conquistadores ever reached Wyoming. The State and the Green River first became a part of recorded history in the early 1800's when a central land route was pioneered from the Missouri River to Oregon. That route traversed the Green River Basin (1).

Fur-Trapping Era

The fur trade became a lucrative industry in the Northwest soon after the Louisiana Purchase (1803). In an effort to find a land route to Oregon, a group of Astorian fur traders under the leadership of Wilson P. Hunt eventually crossed the Continental Divide of the Wind River Range in 1811. Before leaving Wyoming, they followed the Spanish (Green) River for 15 miles; they then crossed the watershed divide between the Green and a branch of the Snake River in the vicinity of the present town of Bondurant, in the northwest corner of Sublette County.

The fur-trapping era lasted until about 1840. Trappers and frontiersmen of this era included General William Ashley, Jim Baker, John Fremont,

¹ Number in parentheses refers to a specific reference listed in the Bibliography of Selected References at the end of the report.

Jim Bridger, John Colter, Kit Carson, Father DeSmet, Milton Sublette, and Captain B. L. E. Bonneville. In 1832, Captain Bonneville built Wyoming's first trading post six miles west of the town of Daniel in Sublette County. The post was constructed near the southwest bank of the Green River, where for the previous ten years fur trappers had gathered for the annual rendezvous (1).

Mining Era

The wave of immigrants which started westward with the 1849 California gold rush crossed southern Wyoming via the Overland-California-Oregon Trail. About this same time the Mormons were crossing the Basin en route to the Salt Lake Valley.

In the 1860's, mining became an important contributor to the economy of the Basin and adjoining areas. The mining stampede brought most of the early settlers, especially to Sweetwater County. Out of necessity and opportunity mining broadened into other enterprises, such as stock raising, agriculture, and business.

About the middle of the 19th century there was a population surge to the West. Simultaneously the Federal Government, by its land grant program, enticed railroaders into building railroads across the western United States.

Railroading Era

The Union Pacific Railroad reached the Basin from the east in 1868. During the summer of that year, a group of individuals founded the town of Green River, to benefit from "spin-offs" of railroad construction (1). The railroad made the area much more accessible and facilitated commerce. With its coal-burning locomotives, the railroad also brought about development of the Basin's coal resources.

Beginning of the Stockgrowing Era

Within a few years after the railroad was established, it became recognized that Wyoming was the center of "the greatest open range country known to man" (1). Texas was overrun with cattle, and large herds were trailed into eastern Wyoming. While Texas Longhorns were being driven to Wyoming, another drive started in Oregon. Oregon cattle were driven into the Star Valley region (northern Lincoln County), and from there into southwestern Wyoming. These cattle provided the foundations for Wyoming's Short-horn and Hereford herds (22).

The benefits of irrigation were recognized in the early mining towns. A few water rights for irrigation were established in the Blacks Fork and Smiths Fork Valleys in 1862 and 1864 respectively. Following the installation of the railroad in the Basin, irrigation works were slowly but steadily constructed. Beginning in 1886, the establishment of water rights and irrigation works were accelerated to provide the means of growing winter feed for large cattle herds.

WYOMING'S GREEN RIVER BASIN

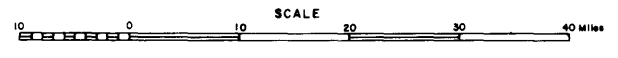
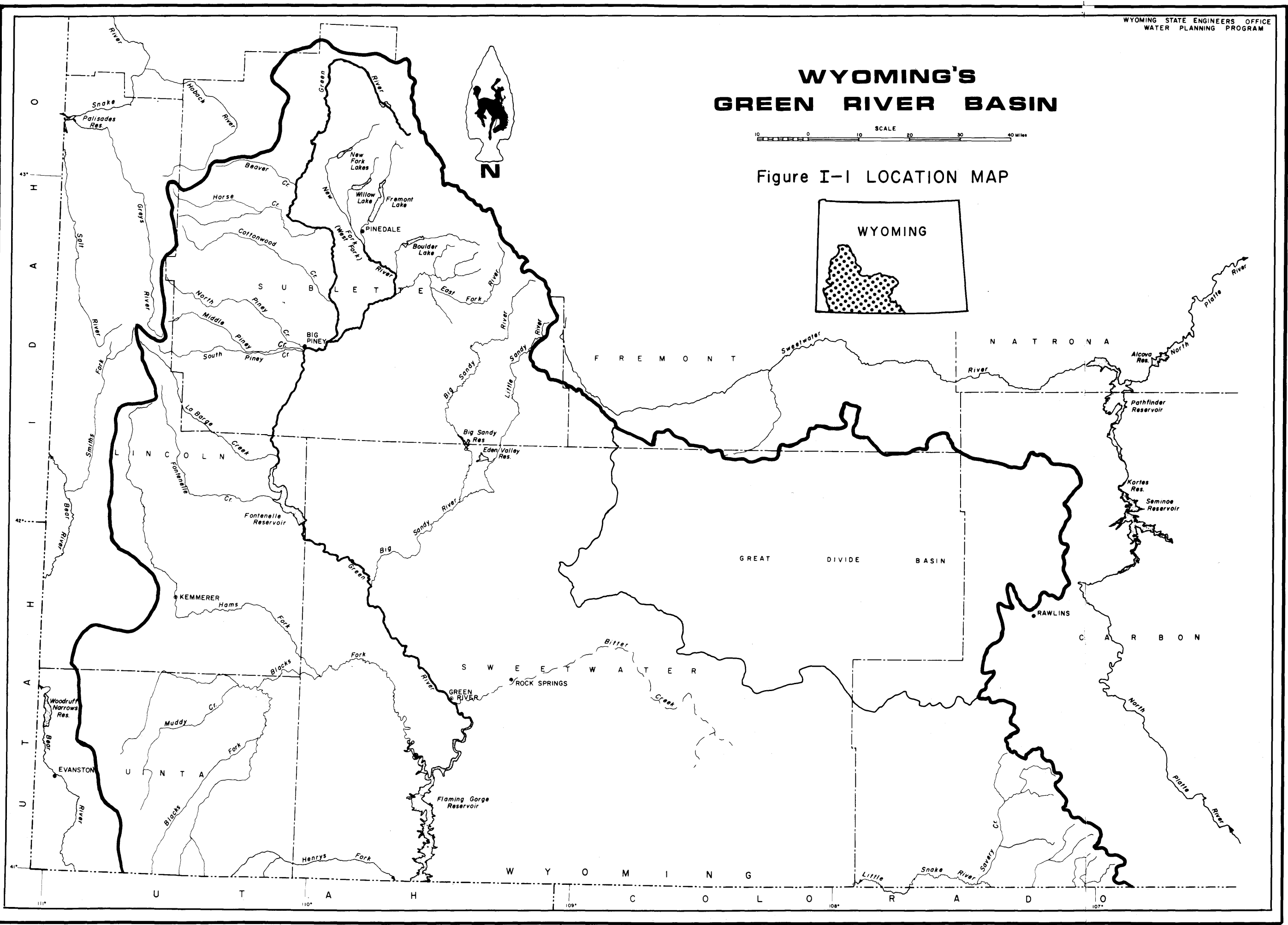
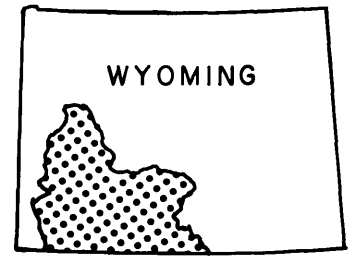


Figure I-1 LOCATION MAP



The expansive grazing areas also attracted sheepmen. Uinta County tax rolls recorded a flock in the vicinity of Fort Bridger as early as 1869 (14). In the early 1880's, large bands of sheep were trailed cross-country from Oregon and California into southwestern Wyoming. Cattlemen claimed a priority over sheepmen in the Green River territory, and there was considerable agitation along tributaries of the Green River in 1895. As a result of the confrontation, thousands of sheep were killed by cattlemen (66). Sheepmen held priority only in the Red Desert, where they had leased the alternate sections of railroad land prior to 1900. Sheep could thrive in the Red Desert in winter, and on the high mountain slopes in summer.

The stockgrowing industry reached an economic plateau during the time of open-range grazing. Ranchers began to realize that some fences were necessary to protect the individuals' rights and to conserve the rangeland. The Federal Government also became concerned with the use of the open range and acted to conserve the resources and stabilize the livestock industry with the Taylor Grazing Act of 1934. The U. S. Interior Department in 1936 established several statutory grazing districts, two wholly within the Basin and one partially within the Basin. The Rock Springs District and the Pinedale District are wholly within the Basin; the Rawlins District includes the eastern two-thirds of the Great Divide Basin and a small part of the Green River drainage area. Not all of the Basin area is within statutory grazing districts.

Industrial Mineral Development Era

Industrial mineral development has added to the agricultural base economy and is still contributing to the Basin's development. The importance of coal declined in the 1950's due to the phasing out of coal-burning railroad locomotives; however, recent estimates of the potential for coal-fueled electric power generation and the hydrogenation of coal offer promise for the revival of coal mining on an even greater scale.

The production of oil and gas in the Basin is significant. As early as 1867, the small unrefined production from an oil well near Fort Bridger sold for \$25.00 a barrel (14). Oil and gas operations are extensive in the western part of the Basin and in the Rock Springs area.

The exploration for petroleum led to the discovery of trona, or "soda ash," in 1938. Commercial production began in 1952, and there are now four companies operating in the Basin.

Large reserves of oil shale exist and offer a potential for future development, should a need for these resources arise. Exploration for uranium is being conducted in parts of the Basin. A small area of intermittent uranium production is located west of Baggs, on the Wyoming-Colorado state line (32).

Modern Water Development Era

The modern water development era began with the construction of major storage facilities. One of the earliest of these was the Eden Irrigation and Land Company Number 1 Reservoir, constructed off-channel of the Big

Sandy River (T.26 N., R.105 W.) in 1924. The reservoir has a total adjudicated capacity of 18,489.93 acre-feet of water, stored for irrigation and domestic uses.

Since then, other projects have been constructed, primarily for irrigation but also for municipal and industrial uses. Flaming Gorge Reservoir on the Green River, completed in 1962, was constructed to help meet downstream water obligations, and also opened up new areas for outdoor recreation and tourism. The most recently completed facility is the Fontenelle Dam and Reservoir on the Green River, which will provide stored water for irrigating lands of the Seedskafee Project, for municipal and industrial uses, and for recreation in the Basin.

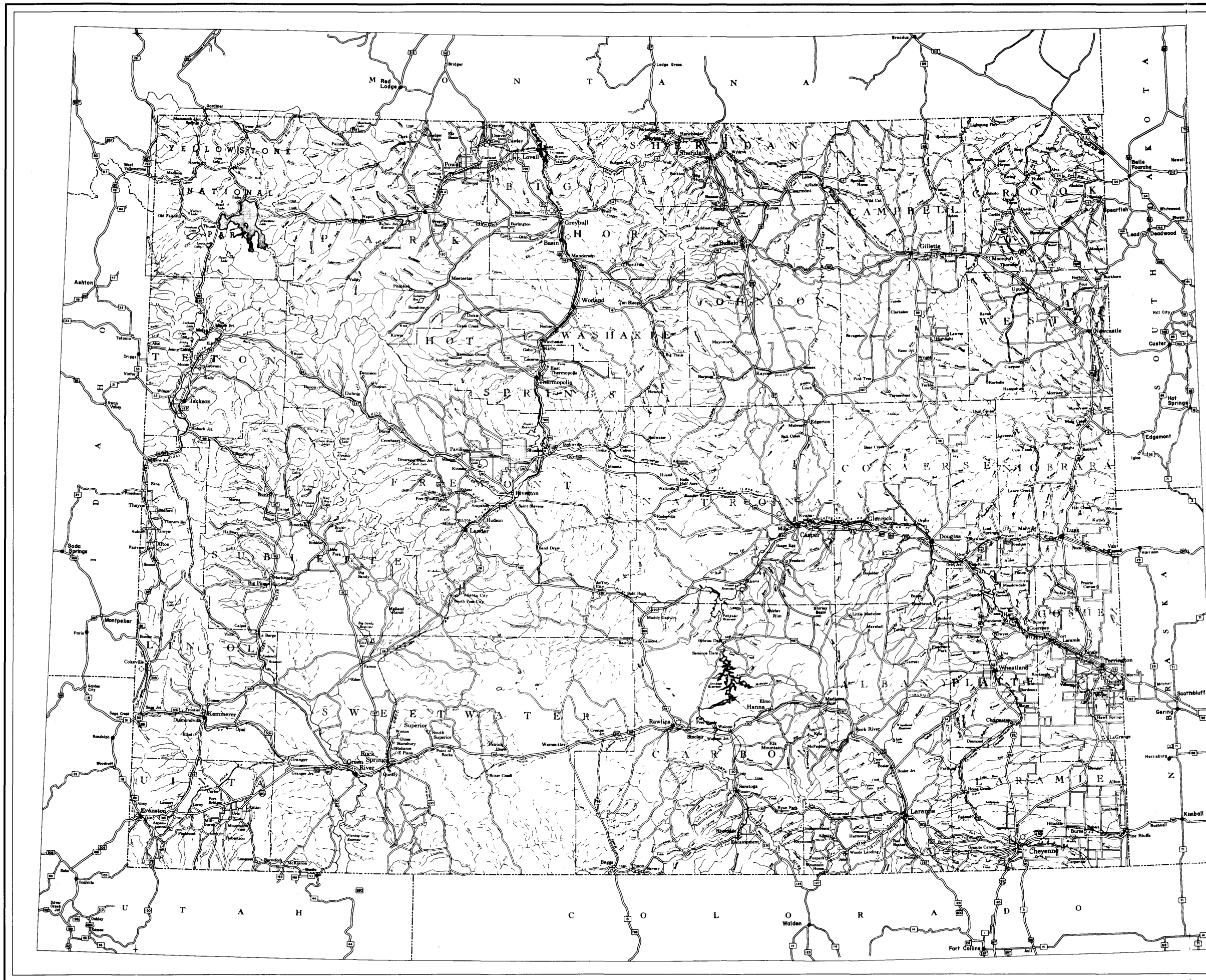
TRANSPORTATION

Emigrants from the east usually followed two parallel routes to the mountain front. After reaching the Continental Divide, the trail pattern became more complex. South Pass became the "jump-off" point for several trails across the northern Green River Basin: The Lander Road crossed the Green River, then turned north; the Oregon-California-Utah Trails went southwestward. The Overland Trail continued westward through Bridger Pass and crossed the Green River near the site of the town of Green River, south to Fort Bridger, then westward again.

The Pony Express route, the Western Union's telegraph line, and the stage coach generally followed the Overland Trail across the Basin (14). The Union Pacific Railroad and Interstate Highway I-80 follow the same general route.

Roads

The old trails evolved into "territorial roads." Until about 1910 roads in Wyoming were under county jurisdiction. In 1911 the Wyoming Legislature enacted a bill to provide the first highway system in the State and designated 12 routes, three of which were to serve the Green River Basin. The latter were an east-west highway from eastern Wyoming through Rock Springs and Green River, eventually going north to Yellowstone Park; a north-south highway from Yellowstone Park to Jackson, Daniel, Marbleton, and Kemmerer; and a third highway beginning at Granger (in Sweetwater County) and going southwestward through Lyman and Bridger to Evans-ton (1). Because of lack of funds these roads were not built until Federal funds became available in the 1920's and 1930's. The Interstate and U. S. Highway systems of primary and secondary roads, augmented by the State and county road systems, permit traffic to move through the area and tie the Basin to other parts of Wyoming, and to Colorado and Utah. The roads are kept open to traffic all year even through mountain passes. The primary highway program for the next several years includes local surfacing and grading, road widening, road alignment, and the construction of rest areas at the Lyman Interchange and the Flaming Gorge Interchange (70). The highway system is shown on Figure I-2.



GENERAL LEGEND

<p>ROADS AND ROADWAY FEATURES</p> <ul style="list-style-type: none"> INTERSTATE HIGHWAY NUMBERED HIGHWAY UNNUMBERED HIGHWAY COUNTY HIGHWAY PRIMARY HIGHWAY <p>CITY AND TOWN CENTERS</p> <ul style="list-style-type: none"> STATE CAPITAL COUNTY SEAT CITIES AND TOWNS JANET PLACES <p>ALWAYS AND RAILROADS</p> <ul style="list-style-type: none"> RAILROAD RAILROAD CROSSING RAILROAD FACILITY RAILROAD 	<p>BOUNDARIES</p> <ul style="list-style-type: none"> STATE COUNTY TOWNSHIP NATIONAL FOREST NATIONAL PARK, RESERVATION AND MONUMENT <p>DRAINAGE</p> <ul style="list-style-type: none"> ALTERNATE STREAM NATURAL STREAM LAKE STREAM LAKE OR RESERVOIR INTERNATIONAL LAKE OR RESERVOIR
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Figure I-2
TRANSPORTATION SYSTEMS
MAP

STATE OF
WYOMING

PREPARED BY THE
WYOMING HIGHWAY DEPARTMENT
PLANNING AND RESEARCH DIVISION
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

SCALE
0 10 20 30 40 MILES

1957
Revised to January 1, 1970

APPROVED JANUARY 9, 1957

Secondary highways are presently being planned and constructed mainly to serve recreation demands. In the past, most secondary highways were built to serve ranchers and mineral development, and this service will be continued as needs become apparent and requests are made by the counties involved. There probably will be a need in the near future to complete a secondary highway from the vicinity of Green River to the Fontenelle Reservoir recreation area. A county road between La Barge and Farson may need to be replaced with a secondary highway. The county road serves a large ranching community and reportedly is inadequate for spring and winter travel (70).

Railroads

The Union Pacific Railroad provides another means of transportation in the Basin. The main line runs east-west approximately through the middle of Sweetwater County and branches near the western edge of the county. The northern branch serves the Pacific Northwest, and the southern branch serves Utah, Nevada, and California.

Air Transportation

Commercial air transportation is provided by Frontier Airlines routing to and from Rock Springs. Two flights daily provide passenger and air freight service. Airstrips are also located at Big Piney, Pinedale, Green River, Kemmerer, and Fort Bridger.

POPULATION

The Green River Basin is typical of much of Wyoming and the arid west in that it has a fairly dense population in and near the larger towns and is virtually uninhabited in other areas. In most cases these towns were colonized originally because water was available.

The preliminary 1970 census figures show a total population, in the counties wholly or partially within the Basin, of approximately 83,000 persons. Adjusting this figure to include only persons within the Basin boundaries results in an estimate of approximately 29,000 persons within the report area.

Approximately sixty-three percent of the Basin population, or 18,145 persons, reside in Rock Springs, Green River, and Kemmerer. Rock Springs, with a population of 11,657, is the only city with more than 10,000 persons.

In the past, the Basin population had a trait of mobility. The future development of a relatively untapped store of mineral resources with attendant industries will curtail the tendency to move and will attract people from other areas. Development of the natural resources and recreation and tourism will help establish a growing population trend.

TABLE I-1 -- Population Projection for Entire Counties Wholly
or Partially Within the Green River Basin
(Includes Great Divide Basin)¹

<u>County</u>	<u>1972</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>
Carbon	13,700	15,000	16,400	18,800	13,600
Lincoln	8,100	6,800	7,200	10,700	13,100
Sublette	4,000	4,700	5,500	6,400	8,700
Sweetwater	21,600	27,700	31,100	34,600	42,000
Uinta	7,000	6,700	5,700	5,600	5,500
Fremont	32,900	42,700	54,800	71,600	95,500
Teton	4,700	5,100	5,500	6,400	8,200

¹ Projections through the year 1990 were prepared by the Wyoming Department of Economic Planning & Development and were rounded to the nearest hundred. Projections for years 2000 and 2020 were prepared by the Wyoming Water Planning Program.

TABLE I-2 -- Population Projection for That Portion of the
Counties Within the Green River Basin
(Includes Great Divide Basin)¹

<u>County</u> ²	<u>1972</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2020</u>
Carbon	600	600	600	600	600
Lincoln	3,800	3,200	3,900	5,700	8,000
Sublette	3,900	4,300	5,400	6,500	8,600
Sweetwater	21,600	27,700	31,100	34,600	42,000
Uinta	<u>2,100</u>	<u>1,800</u>	<u>800</u>	<u>700</u>	<u>600</u>
Total	32,000	37,600	41,800	48,100	59,800

¹ Figures given are only estimates interpolated from studies by the University of Wyoming (Demographic Study of Wyoming--Population in Transition, December 1969), and a report by Cameron Engineers (Wyoming Mineral Industries, 1969) and are rounded to the nearest hundred. The estimates assume an increase in population of 3.59 persons for each employee added to the labor force.

² Fremont and Teton are not tabulated because populations of the included mountainous areas are considered nonresident or nonexistent.

LAND OWNERSHIP

Figure I-3 is a land status map illustrating land ownership within the Basin. The Federal Government owns approximately two-thirds of the land within the Basin, most of which is administered by the Bureau of Land Management (see Table I-3). The U. S. Forest Service also administers a significant amount of acreage in segments of the Medicine Bow, Bridger, and Wasatch National Forests that are within the Basin.

WYOMING'S GREEN RIVER BASIN

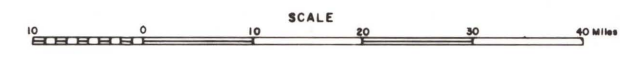


Figure I-3 LAND STATUS MAP
(Source: U.S.B.L.M. Land Status Map, 1967)

Legend

- PRIVATE LANDS
- NATIONAL RECREATION AREA
- NATIONAL FOREST
- PUBLIC LANDS
- AREA OF UNION PACIFIC R. R. ALTERNATE SECTION OWNERSHIP

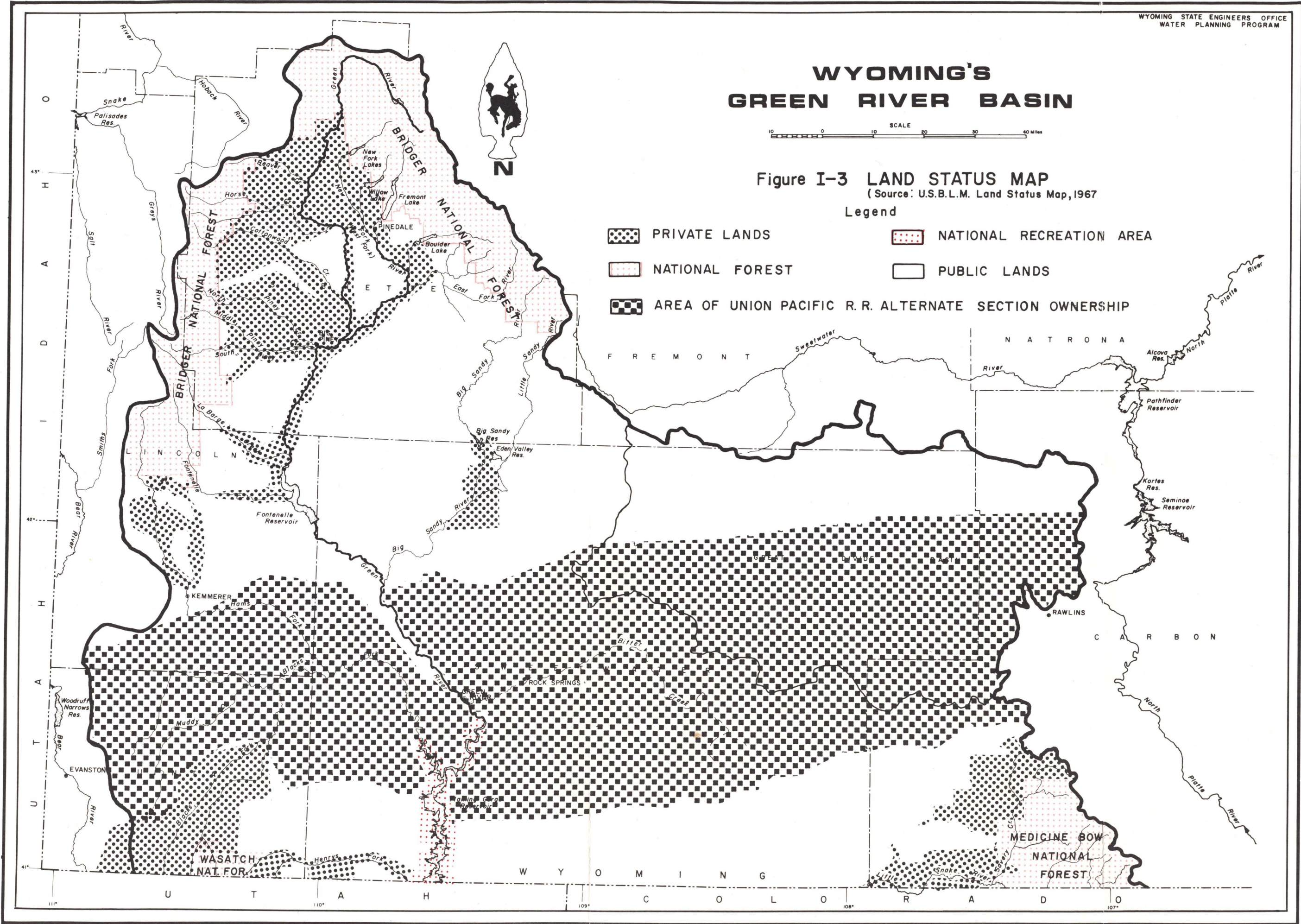


TABLE I-3 -- Land Ownership and Administration in the
Green River Basin
(Includes the Great Divide Basin)

	<u>Area in Acres</u>	<u>Percent</u>
<u>Federal Lands</u>		
Department of Agriculture		
Forest Service	1,130,000	
Department of the Interior		
Bureau of Land Management	7,861,000	
Fish and Wildlife Service	12,000	
Bureau of Reclamation	45,000	
Total Federal Lands	9,048,000	68
<u>State Lands</u>	951,000	7
<u>Private, County, and Municipal Lands</u>	3,366,000	<u>25</u>
Total Land in the Basin	13,365,000	100

Source: Upper Colorado Region Comprehensive Framework Study (1969).

The remaining one-third of the Basin land is under State, county, municipal, and private ownership. The Union Pacific Railroad owns a "checker-board" of every other section of land in a strip 20 miles wide on either side of the railroad.

Land ownership can be compared with land areas in the Basin by referring to Tables I-3 and I-4.

Lands are used principally for livestock grazing and feed, forests, recreation and mining.

TABLE I-4 -- Total Area by County, Green River Basin
(Includes Great Divide Basin)

<u>County</u>	<u>Water Area</u>		<u>Land Area</u>		<u>Total Area</u>	
	<u>Sq. Miles</u>	<u>Acres</u>	<u>Sq. Miles</u>	<u>Acres</u>	<u>Sq. Miles</u>	<u>Acres</u>
Carbon	6.4	4,100	2,347.6	1,502,700	2,354.0	1,506,800
Fremont			205.0	131,200	205.0	131,200
Lincoln	16.1	10,300	1,942.3	1,243,100	1,958.4	1,253,400
Sublette	64.7	41,400	4,371.3	2,797,600	4,436.0	2,839,000
Sweetwater	50.6	32,400	10,428.4	6,674,200	10,479.0	6,706,600
Teton			10.0	6,400	10.0	6,400
Uinta			<u>1,577.8</u>	<u>1,009,800</u>	<u>1,577.8</u>	<u>1,009,800</u>
Basin Total	<u>138</u>	<u>88,000</u>	<u>20,882</u>	<u>13,365,000</u>	<u>21,020</u>	<u>13,453,200</u>

Source: Upper Colorado Region Comprehensive Framework Study (1969).

PHYSIOGRAPHY

The Green River Basin is a high arid plateau flanked and intersected by higher mountain ranges. The Rock Springs Uplift is an interior land form of the Basin.

Topography

Topographic elevations range from 6,050 feet in the Green River drainage near the state line to 13,785 feet above sea level at Gannett Peak on the Continental Divide. The rough mountain topography along the Basin rims passes into wooded upland slopes flanked with grass-covered mountain meadows; then to an interior floor typified by treeless high arid plains, badlands, mesas and bluffs, and deep canyons.

Glaciers are still active along the Continental Divide. Glacier melt-water collects in numerous small lakes at high elevations, and these lakes head the Green River and its higher tributaries. In contrast, large areas of desert plateau contribute practically no water to the Green River.

The Great Divide Basin contributes no surface runoff to the Green River, nor does it exhibit any exterior surface drainage. The interior of this basin is a desert with active sand and silt dunes, some rising 100 feet above the desert floor. The Continental Divide appears to bifurcate and enclose the Great Divide Basin with an east rim and a west rim.

Drainage System

The Green River and its major tributaries are perennial streams. Numerous smaller tributaries flow intermittently, only in response to direct precipitation. The major tributaries of the Green River are:

West Side of Basin

Henrys Fork (heads in Utah)
Blacks Fork River (heads in Utah)
Fontenelle Creek
La Barge Creek
South)
Middle) Piney Creek
North)
Cottonwood Creek
Horse Creek
Beaver Creek

East Side of Basin

New Fork River
Big Sandy River
Bitter Creek
Little Snake River (heads in Wyoming and Colorado, flows through Wyoming and Colorado to the Yampa River which is a tributary of the Green River)

The headwaters of the Green River drainage system are in the Wind River and Gros Ventre Ranges, the Wyoming Range and Uinta Mountains, and the Sierra Madre Mountains. In plan view the mountains form a distorted horseshoe open to the south, from which the Green flows towards its juncture with the Colorado River in Utah.

GEOLOGY

Mineral wealth has figured prominently in the Basin's development from its early history. Early prospectors looked for obvious signs at the surface or in shallow pits in their search for gold. After the more apparent mineral deposits were found, prospectors had to decipher the geologic record in order to make new discoveries.

Basin Evolution

Prospectors learned that the Green River Basin evolved geologically through many milleniums by a sequence of events:

1. Deposition of rock-forming sediments, layer upon layer, thousands of feet thick, in marine and coastal environments. These are the older rocks in the Basin and host accumulations of petroleum and coal.
2. Uplift of older sedimentary deposits, and mountain-building; deposition of younger sediments in a predominantly continental environment. The younger rocks are hosts for petroleum and uranium minerals.
3. Intense regional deformation and mountain-building.
4. Gentle folding of rock strata, and the accumulation of sediments in large lakes at the foot of the mountains. Coal, oil shale, and sodium salts (trona) are present in the lake-bed sediments.
5. Continued continental deposition, volcanism, large-scale faulting and structural collapse; origin of the Continental Divide in Wyoming. Uranium minerals are found disseminated in sandstones and conglomerates of this continental sedimentary accumulation.
6. Development of an incipient modern drainage system.
7. Glaciation along the Continental Divide.
8. Weathering, erosion, stream and wind deposition, continuing to the present.

Green River Evolution

In deciphering the record, some geologists have postulated that the present drainage system of the Green River is of relatively young geologic age, and that the ancestral Green River drainage was two distinct river systems before the present Continental Divide in Wyoming came into being. An Upper Green in Wyoming, and a Lower Green in Colorado and Utah, were separated by an earlier Continental Divide through the crest of the Uinta Mountains. The Upper Green flowed east through the present Great Divide Basin towards the North Platte River, and the Lower Green flowed south. Earth movements brought about the collapse of the eastern end of the Uinta Mountains and the rise of the present Continental Divide across central Wyoming. Drainage to the east was obstructed by the rising Continental

Divide. The low areas began filling with sediment from eroding uplands and outfallings of volcanic ash. The Upper Green River spilled across the lowered Uinta Mountain crest and was captured near Flaming Gorge by the drainage system of the Lower Green (25). This was the inception of the Green River drainage system as it is now known.

SOILS²

The differences in soils of the Green River Basin are due basically to the kind and origin of the parent material, and to variations in climatic conditions.

Mountain Soils

The soils of the more humid mountains and foothill slopes, on the northern fringe of the Basin, are very shallow to deep, well drained, moderately permeable, dark colored, loamy and stony. In the mountains on the west, soils are forming in weathered limestone, shale, and sandstone. In the east, they are developing in weathered igneous rock. The foothills are mostly glacial moraines and the soils are very cobbly. Rock outcrops are common throughout the mountainous and most of the foothills areas. The mountainous area that is forested is used for summer grazing. The higher elevations above timberline support Alpine-type vegetation.

In the mountain valleys there are deep and moderately deep, well-drained, dark colored loamy soils underlain by sand, gravel, and cobble. Locally, valley surfaces are very gravelly or very cobbly. Soils in these valleys are moderately permeable and have moderate to high available water-holding capacities. The valleys are used primarily for grazing and also for the production of native hay.

Upland Soils

The major portion of the Basin consists of nearly level to rolling uplands, dissected by the nearly level to slightly undulating floodplains of the Green River and its tributaries. Most of the upland soils are moderately deep to shallow, well drained, and loamy to clayey in texture. They are developing in weathered shales and sandstones which contain variable amounts of soluble salts and/or alkali. The soils are mostly light colored, but in the western part of the Basin where the annual precipitation is about 12 to 14 inches, the soils are dark colored. Upland soils have moderate to low permeability and moderate to low available water-holding capacities. They are used mostly for grazing. Locally they may be irrigable, but care must be used in developing the irrigation system so as to avoid the possibility of serious salinity and/or alkalinity problems.

Floodplain Soils

In the central and southern parts of the Basin, soils on the floodplains are developing in a mixture of materials derived from weathered shales and

² Contributed by USDA Soil Conservation Service

sandstones that contain varying amounts of soluble salts and/or alkali. The soils are deep to moderately deep and are generally underlain with gravel and cobble. They are loamy to clayey in texture and tend to be poorly drained. Soil-color is usually light but may be darker by influence of parent materials. Nearly everywhere in the Basin these soils contain some soluble salts and/or alkali. They are moderately to slowly permeable and have moderate available water-holding capacity.

Floodplain soils in the western part of the Basin are dark colored. A major problem here is wetness and salinity and/or alkalinity. There are, however, some areas free from that problem. Floodplain soils in this part of the Basin are mostly irrigated and used for the production of native hay and alfalfa.

Fan and Terrace Soils

Broad, nearly level to sloping outwash fans and terraces are found northwest of Big Piney and in the Pinedale-Boulder area. Soils of these fans and terraces are deep to moderately deep, well drained, dark colored and loamy, and underlain with gravels and cobbles. Locally the soil is very gravelly or very cobbly, especially along the steeper terrace breaks. Soils of this type (fan and terrace) are moderately permeable and have moderate to high available water-holding capacities. Wherever these soils are irrigated they can produce native hay and alfalfa. Areas where this type of soil is present and not irrigated probably have the greatest potential for future agricultural development of any land in the Green River Basin.

Badland Soils

Badlands are characterized by shallow and very shallow clayey soils forming in weathered shale, in areas of steeply dissected uplands. There are several tracts of badlands and associated dissected topography in the Basin, and one of the largest of these is south of Interstate 80 and west of the Green River. Badlands may support very limited grazing, but are not widely utilized for agricultural uses.

Sand Dune Soils

Low hummocky sand dunes consisting of deep loose sands are common in parts of the Basin. One of the most extensive dune areas is east of Eden, known as Sweetwater Dunes. Dune soils are rapidly permeable and have low available water-holding capacities. They are unsuited for farming and have only a limited use for livestock grazing.

CLIMATE³

The climate of the Basin is a product of its location, elevation, and topography. The floor of the Basin is semiarid as a result of its distance and isolation from moisture sources. The many mountain ranges between

³ Contributed by John Alyea, Wyoming State Climatologist, Environmental Science and Services Administration.

moisture sources and the Basin receive most of the incoming moisture, leaving little to be precipitated on the Basin floor. The mountains surrounding the Basin annually receive up to 40 inches of precipitation, while the interior plateau receives as little as six inches. The high elevation of the Basin, as well as its northerly latitude, is responsible for comparatively low average temperatures and short growing seasons.

The predominant source of weather for the area is maritime air masses from the Pacific. Occasionally, in the fall and winter, Canadian arctic air masses invade the area, but they are usually blocked by the mountains to the northeast. Rarely, continental tropical air from Mexico invades the area in the summer.

Precipitation

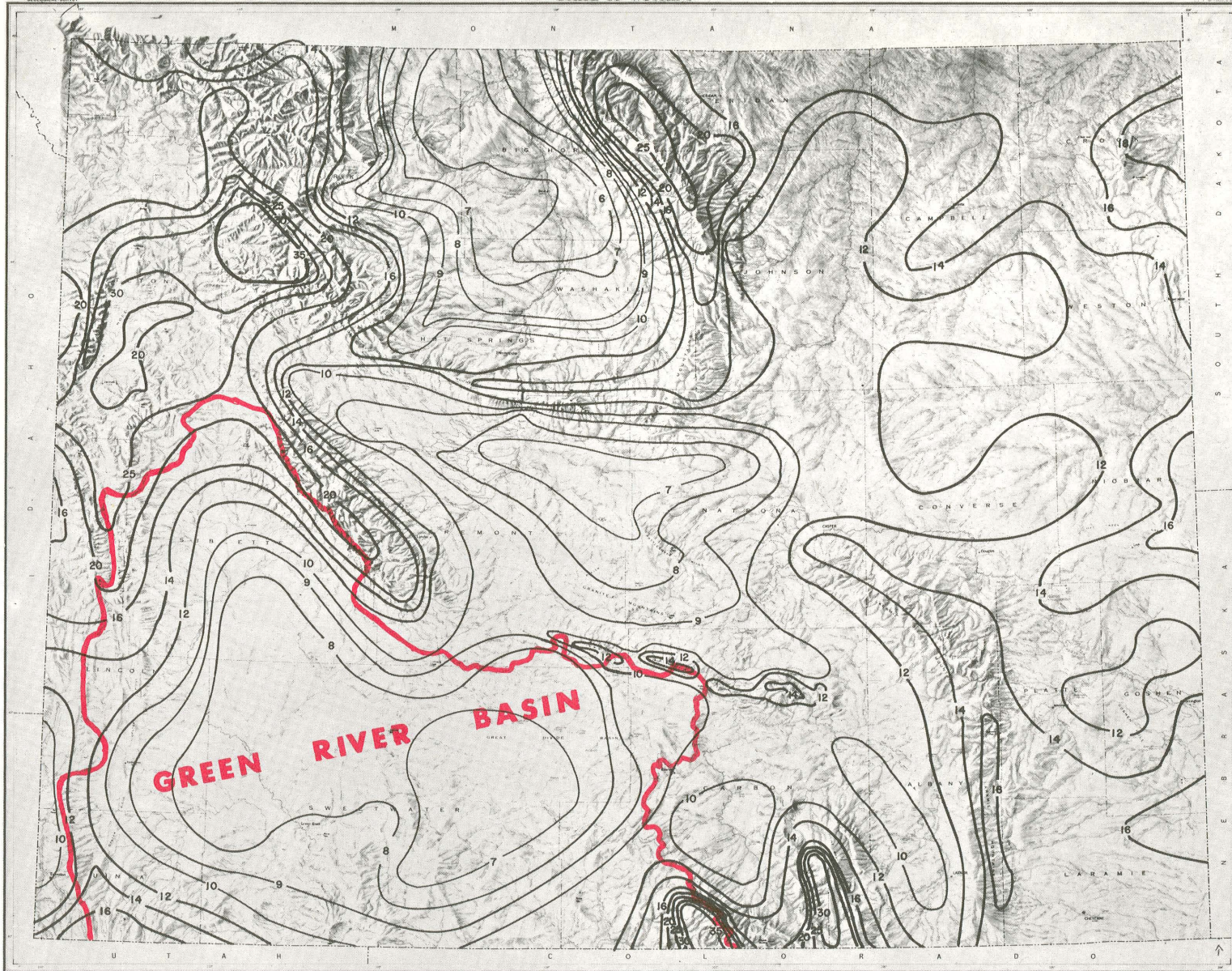
The Precipitation Map, Figure I-4, shows the variation of precipitation over the State and the Basin. The variation of precipitation throughout the year is illustrated in Figure I-5, which shows the averages for representative weather stations in the Basin. Summertime precipitation is usually in the form of showers with occasional cloudbursts. Fall and winter snows are normally light, while springtime brings wet snows and rains. Snowfall averages 40 to 50 inches over the northern half and 20 to 30 inches over the southern half of the Basin. Normally, sunshine and wind keep great snow thicknesses from accumulating on the plateau, while in the mountains accumulations of several feet occur.

Water supplies of the area bear a direct relationship to the precipitation. The streams with a dependable flow rise in the mountains and derive most of their annual runoff from the spring and early summer snowmelt.

Temperature

Basin temperature variations are also shown in Figure I-5. The relatively high elevation of the Basin combined with the varying cold and warm air masses that invade the area results in large annual and daily temperature ranges. The highest summer temperature of 107° F (Fahrenheit) was recorded at Green River Aviation station (elevation approximately 6,100 feet), but even the Kendall weather station in the mountains at the northern end of the area (elevation 7,647 feet) has recorded 103° F. The coldest winter temperature of 55° F below zero was recorded at Farson.

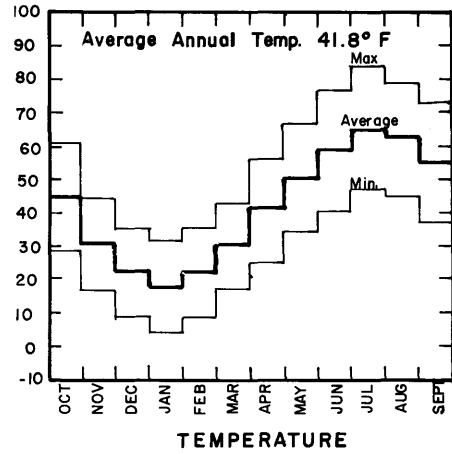
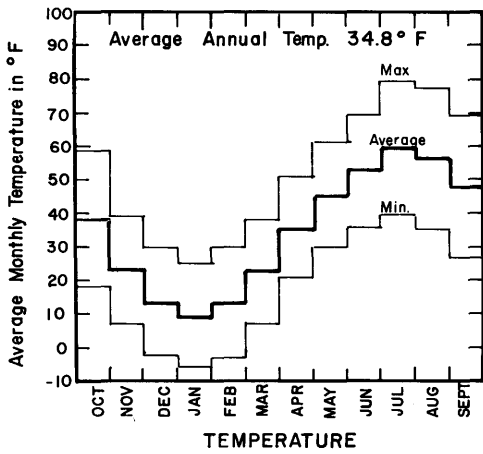
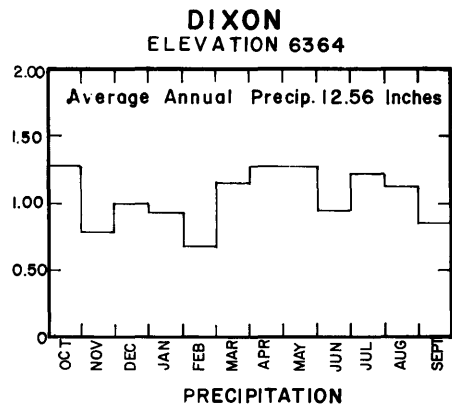
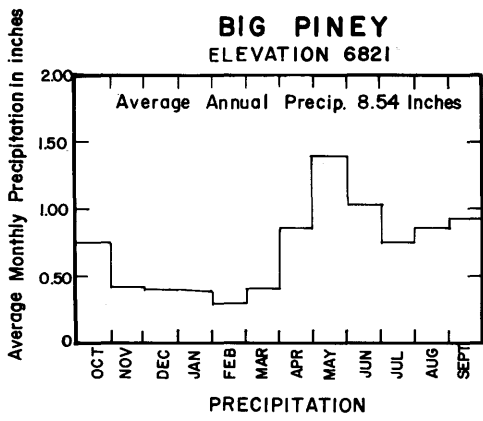
The growing season in the Basin is shortest near the mountains at the northern end of the area and increases to the south. The growing season for the predominant crops of the area, grass and alfalfa, is between the last killing frost in the spring and the first killing frost in the fall. A killing frost for these crops is normally judged to occur when the day's minimum temperature dips to 28° F or lower. The Average Growing Season Map, Figure I-6, shows that the growing season varies from about 70 days at Big Piney and Pinedale to 130 days near Green River. The growing season, average temperatures, radiation, and other climatological factors affect the evapotranspiration rate, or water use, of plants. The consumptive use of irrigation water increases from the higher, cooler portions of the area to the lower, warmer basin floor.



Prepared by the Wyoming Water Planning Program in cooperation with E.S.S.A. Weather Bureau State Climatologist Wyoming

**MEAN ANNUAL PRECIPITATION
AS OF 1965
(IN INCHES)**
Figure I-4

Important Note: Caution should be used in interpolating on this map. Mountainous areas receive higher amounts than indicated. Wide fluctuations from average can be expected in local areas from year to year.



SOURCE: U.S.W.B. Records

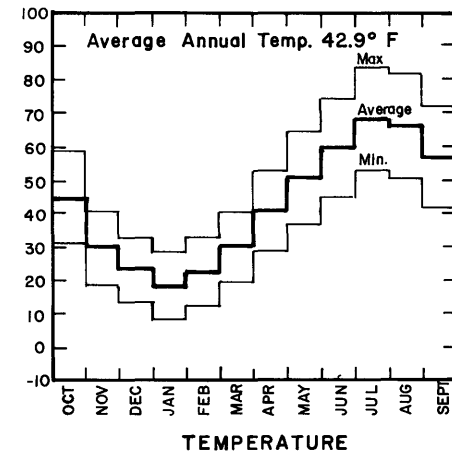
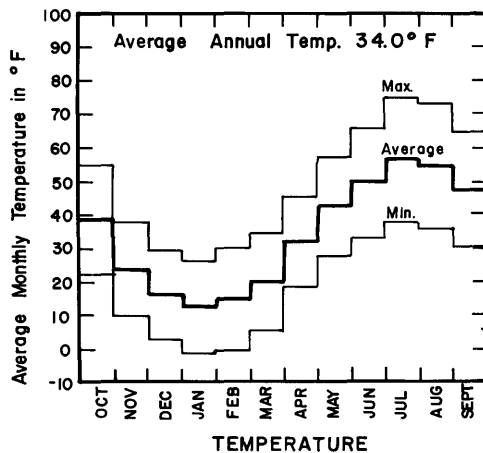
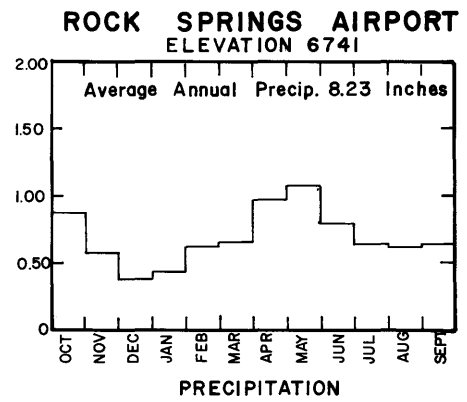
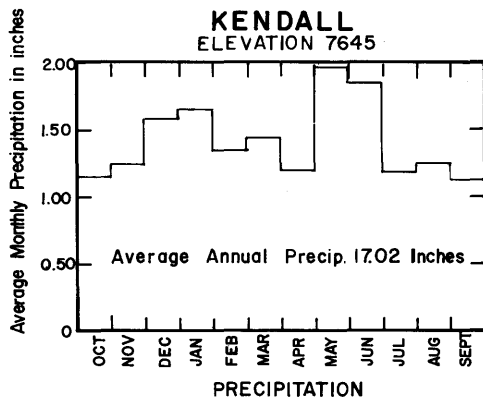
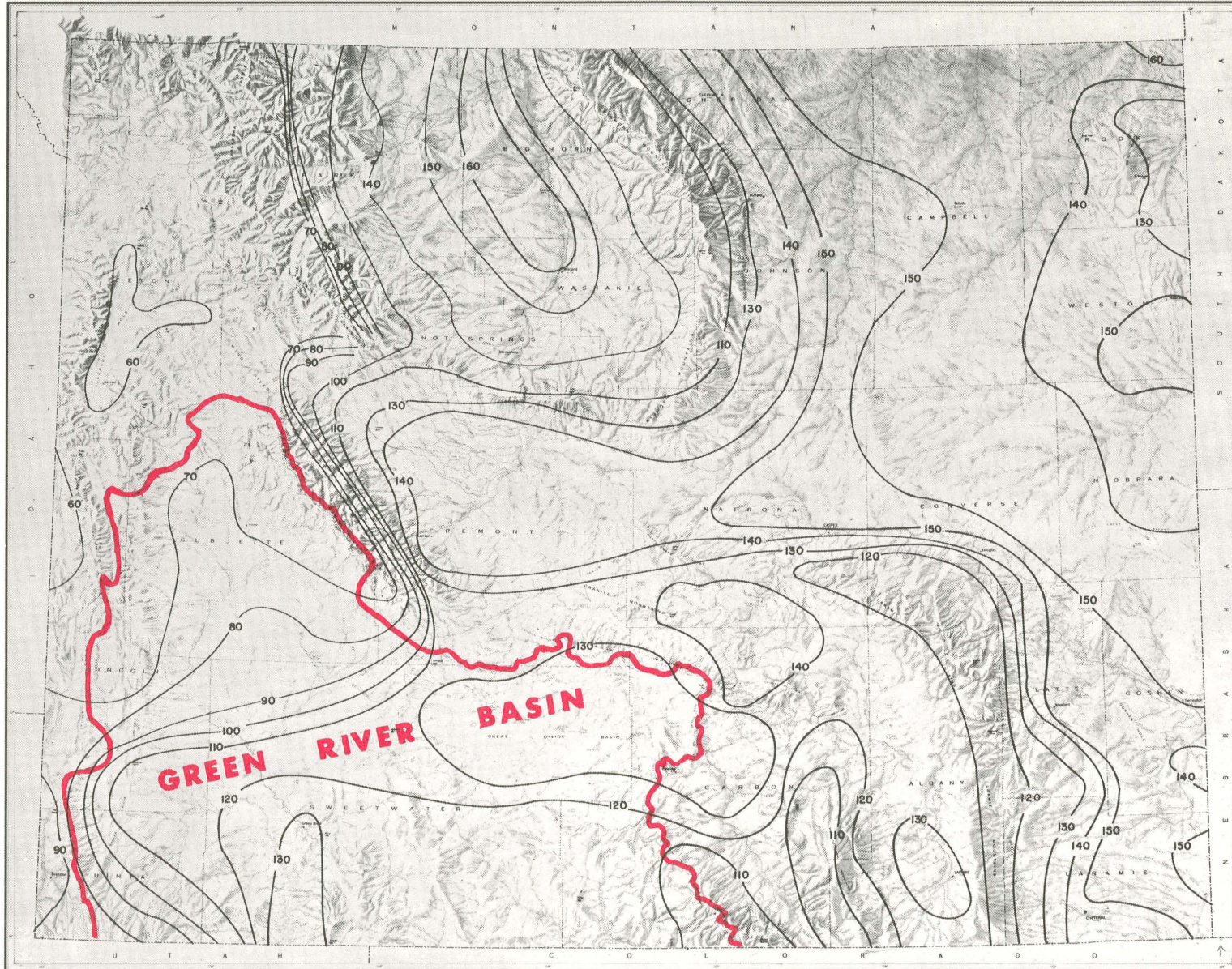


Figure I-5 Average Monthly Precipitation & Temperature At Selected Stations Of The Green River Basin



Prepared by the Wyoming Water Planning Program in cooperation with E.S.S.A. Weather Bureau State Climatologist Wyoming.

AVERAGE GROWING SEASON FOR
FORAGE CROPS
(IN DAYS)
Figure I-6

Important Note:

Caution should be used in interpolating on this map. Wide fluctuation from average can be expected in local areas from year to year. Isolines show average number of days between last spring occurrence and first fall occurrence of 28° F.

WYOMING

Sunshine, Relative Humidity, and Winds

Sunshine is estimated to average about 65 to 70 percent of the possible daytime hours on an annual basis, ranging from about 55 to 60 percent during the winter and spring to about 75 to 80 percent during the summer and fall.

Relative humidity over most of the area is estimated to average about 55 percent annually, ranging from 35 to 40 percent for July and August to 70 to 75 percent during December. Considerable variation in relative humidity is recorded both daily and annually.

Winds are relatively strong over the area and, as is typical of a semi-arid country, the strongest winds are during daylight hours. Winds average around 12 mph (miles per hour) annually, with 15 mph winds in winter and spring and 7 to 10 mph in the summertime. Strong winds of 30 to 40 mph with higher gusts will prevail for a few days, but occasional periods occur with very light winds.

Climate and Economy

Climate is an important factor in the economy of the Green River Basin. The sparse rainfall makes most of the Basin agriculturally suitable only for livestock grazing. Irrigation is required for successful crop production. The short growing season and cool summers combine to limit crops to forage and small grains. However, the climate of the Basin provides no exceptional obstacles to the industrial development of the vast mineral wealth of the area. The climate enhances opportunities for hunting, fishing, camping, winter sports, and similar recreation in the Basin.

CHAPTER II

WATER RESOURCES

W A T E R R E S O U R C E S

The water resources of any region are its lakes, streams, groundwater, and the precipitation that creates the water supplies. Most of the streams of the Green River Basin originate in the mountainous areas where the greatest precipitation occurs. Intermittent streams originating at lower elevations in the Green River Basin and those in the Red Desert flow in response to rainstorms and the snowmelt that may be available. There are no surface streams flowing out of the Red Desert (Great Divide Basin); therefore it does not contribute surface water to the surface drainage system.

Groundwater provides a source of domestic and stock water and the water supplies for many small towns in the area. Although groundwater is available for higher-cost future uses, its present use is very minor.

SURFACE WATER

Water Supplies and Streamflow Characteristics

All Green River Basin streams that are important as water supply sources contribute the major part of their annual runoff in the spring and early summer. Late summer, fall, and winter flows are derived from groundwater effluent, mostly from the alluvial aquifers associated with the streams. These aquifers are recharged by spring runoff and irrigation.

Surface water flows are measured by stream gages maintained through cooperative agreements between the Wyoming State Engineer, the U. S. Geological Survey, and others. Prior to 1930 very few gages were operated in the Basin. From 1938 through 1945 approximately twenty stream gages were installed. Another twenty gages have been installed since 1945. Figure II-1 shows the locations of the more important stream gages in the Basin. It has been necessary to supplement available flow records with estimates in order to provide sufficient data for area water supply studies.

The water year of 1932 (ending September 30) has been used as the beginning of the base period for the water supply studies in this report. The study period 1932-1967 was selected because it is current and because the records show a period of recurring drought conditions in the area. There are four stream gages presently in operation that were in operation in 1932; a fifth gage has a continuous record from 1932 through 1954.

Estimates of the amount of water leaving the State from the Green River Basin were based upon records from stream gages on the Green River and Henrys Fork near the Wyoming-Utah state line and the Little Snake River near the Wyoming-Colorado state line. The average state line discharge of the Green River and Henrys Fork is 1,495,800 acre-feet per year.¹ The average state line discharge of the Little Snake River is 371,800 acre-feet per year. The

¹ Annual discharge figures are based on U. S. Geological Survey gage records and are average flows for the period 1932 through 1967.

total average outflow from the Green River Basin in Wyoming is 1,867,600 acre-feet per year.

Yearly streamflows are quite variable. Most of the annual runoff occurs during the snowmelt. High runoff occurs in May and June and subsides to the base flow by late July. Figure II-2 shows the average annual runoff of selected streams in the Basin. The monthly hydrographs (Figure II-3) illustrate why most irrigated areas have some late summer irrigation shortages and demonstrate that reservoirs could effectively capture spring runoff for later release to stabilize supplies in water-short years.

Streamflows may be artificially augmented in the future. Sources of increased water supplies for uses both in Wyoming and downstream states are watershed management, importation of water from other river basins, and augmentation of precipitation (weather modification). The U. S. Bureau of Reclamation is conducting extensive research on artificially augmenting precipitation. As part of this research, the Natural Resources Research Institute at the University of Wyoming has found that precipitation can be induced from "cap clouds" over mountains that would ordinarily not produce snowfall. The NRRRI is currently under contract with the State of Wyoming to develop procedures to augment the snowpack on parts of the Wind River Mountains and thereby increase streamflow (2).

Floods

Most flooding results from high spring runoff. Although annual flooding does occur, there is no major flood damage problem because of the short duration of peak flows and the low population density of the Basin. Storing spring floodwaters will help eliminate flood damages and supply late-season irrigation water to lands now experiencing a short-season water supply.

Water Quality²

Quality of water refers to its physical and chemical characteristics and biological and radiological content. The goal of water quality management is to maintain water of adequate quality for multiple uses, both for present and future needs. Two water quality factors should be considered in every water development project. First, the water must be of adequate quality for the use for which it is intended. Second, if the water is not 100 percent consumptively used, the return flow quality must be considered.

Water Quality Standards

The Federal Water Quality Act of 1965 required that all states adopt water quality standards for all interstate waters. The water quality standards approved by the Wyoming State Board of Health were accepted and approved by the Federal Water Pollution Control Administration (now Federal Water Quality Administration) of the Department of the Interior in November 1968. The primary particulars of these standards are presented below.

In the Green River drainage, the following streams are designated as interstate waters for which water quality standards have been established:

² Contributed by the Sanitary Engineering Division of the State Department of Health and Social Services.

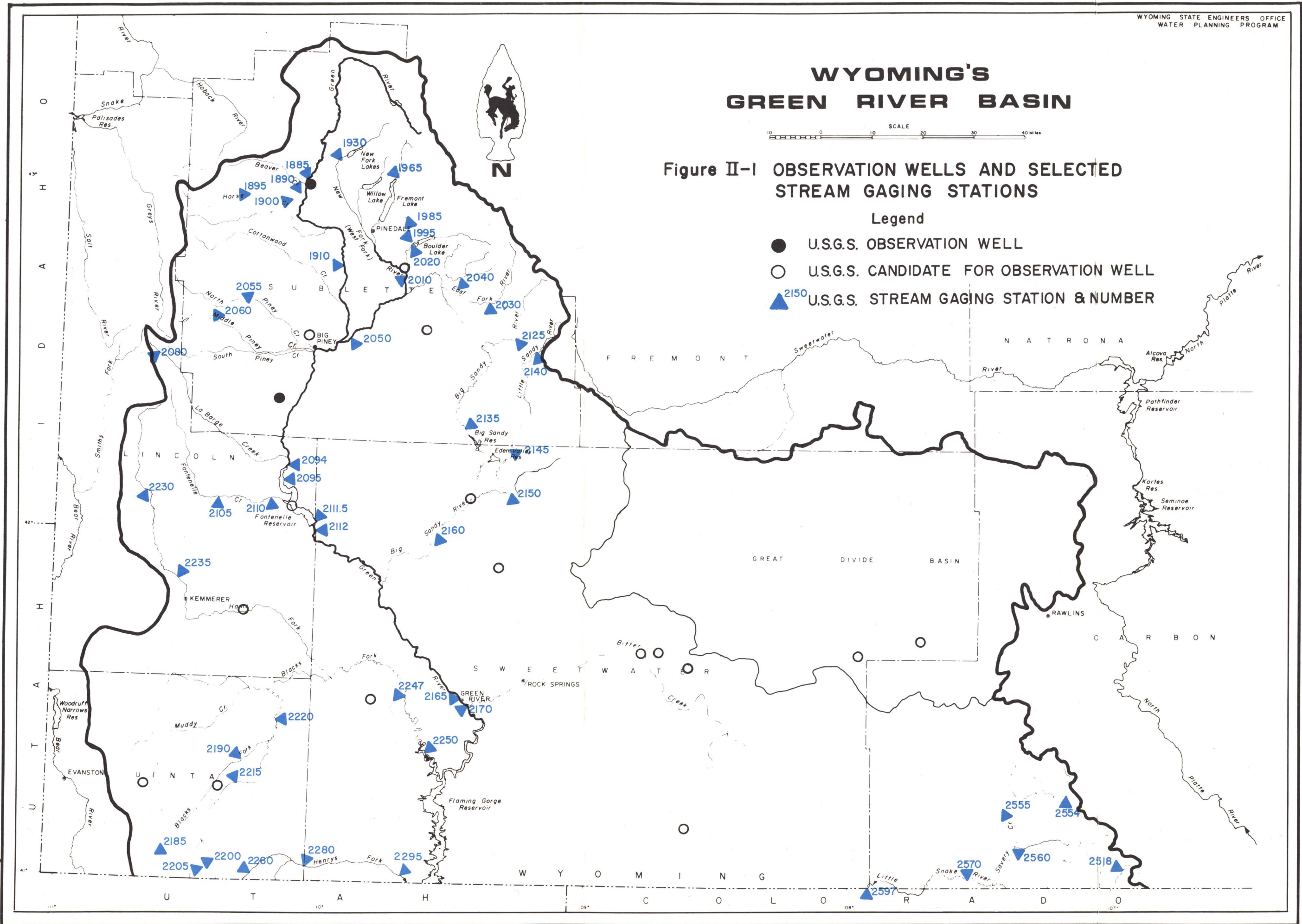
WYOMING'S GREEN RIVER BASIN

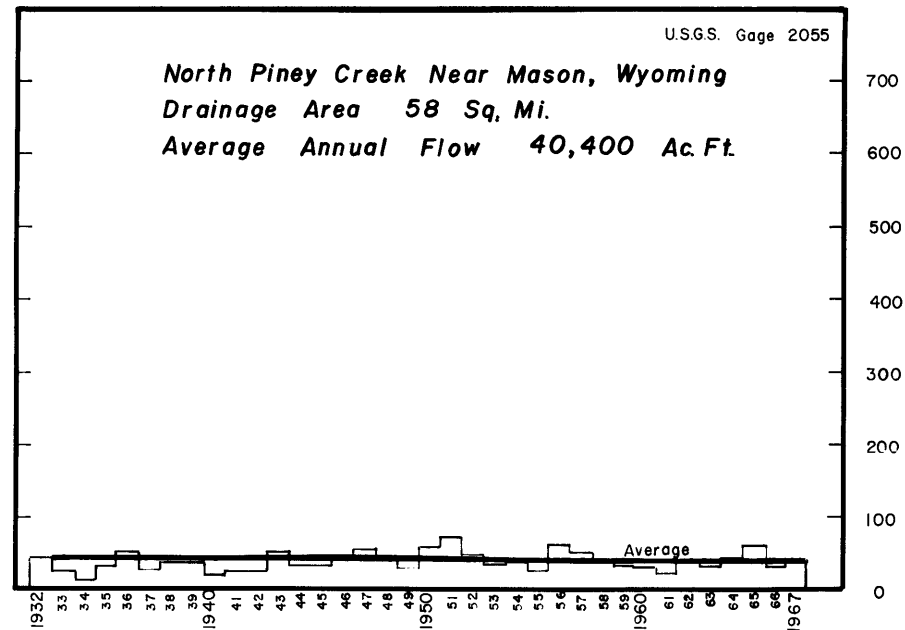
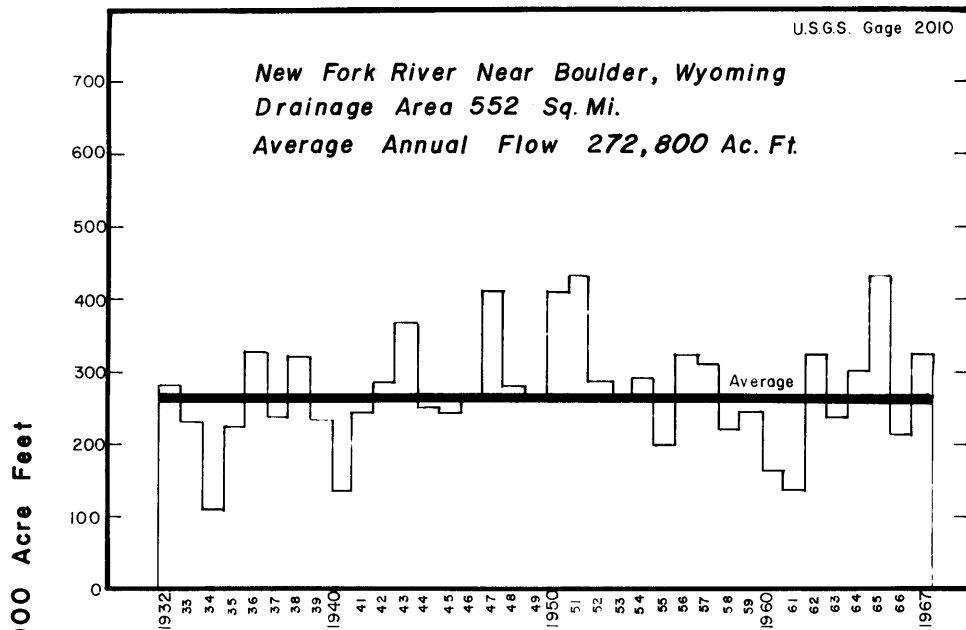


Figure II-1 OBSERVATION WELLS AND SELECTED
STREAM GAGING STATIONS

Legend

- U.S.G.S. OBSERVATION WELL
- U.S.G.S. CANDIDATE FOR OBSERVATION WELL
- ▲ 2150 U.S.G.S. STREAM GAGING STATION & NUMBER





SOURCE: U.S.G.S. Records

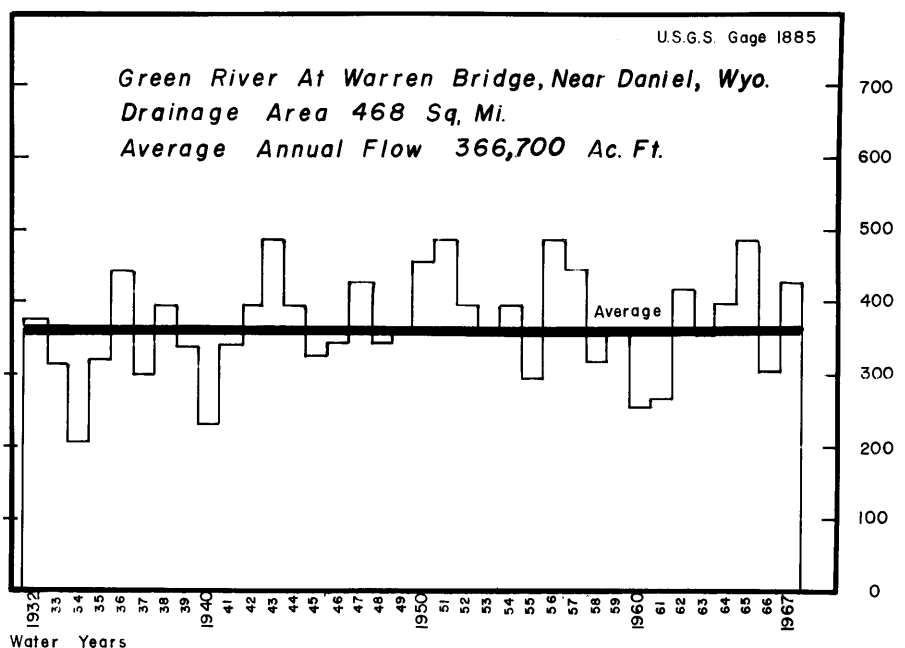
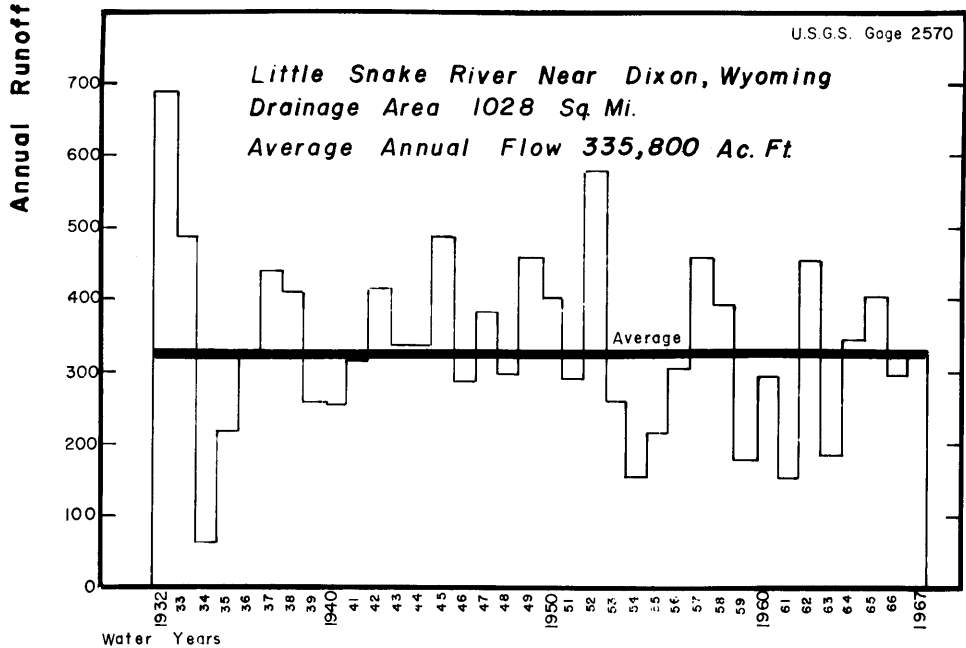


Figure II-2 Annual Runoff Of Selected Streams In The Green River Basin

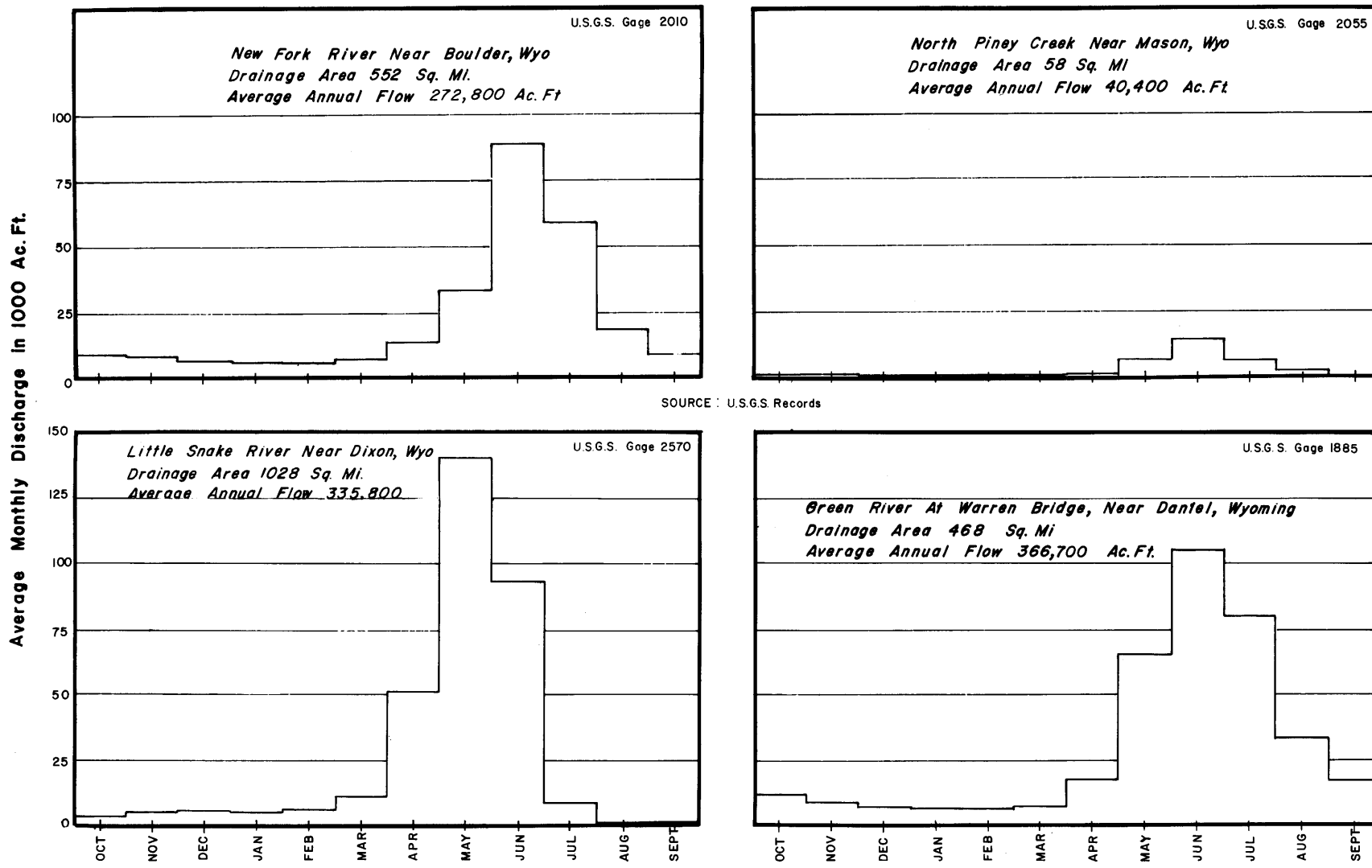


Figure II-3 Average Monthly Runoff Of Selected Streams In The Green River Basin

Green River, Blacks Fork, Smiths Fork, Henrys Fork, Vermillion Creek, Red Canyon Creek, and the Little Snake River. Water-quality samples are routinely collected from the Green River at Green River, Wyoming, Flaming Gorge Reservoir at Buckskin Crossing, and Fontenelle Reservoir.

The water quality standards established for interstate streams are based on physical and chemical characteristics, biological content, and radiological content. Water quality standards for intrastate streams have not been established.

Generally, the quality of interstate waters in the Green River Basin is within the limits of established standards.

Based on water use, ten basic standards and five variable standards for geographical areas have evolved. The following list of standards is summarized from "Water Quality Standards for Interstate Waters in Wyoming," published by the Wyoming Department of Public Health (now the Department of Health and Social Services):

A. Basic Water Quality Standards

1. Physical: Water should be essentially free of obvious and/or offensive pollutants such as particulates, taste, odor, and color, and the temperature should permit natural aquatic life.
2. Chemical: Water should be free of toxic materials, and the dissolved oxygen and pH (measure of acidity or alkalinity) should permit natural aquatic life.
3. Bacteriological: The concentration of bacteria in water should be within the most probable number (MPN) limit set for the particular stream.
4. Radiological: Water should have a level of radioactivity below the limit set in the U. S. Public Health Service Drinking Water Standards of 1962.

B. Water Quality Standards for Interstate Waters of the Green River System

1. Wastes or substances of other than natural origin shall not be discharged into these waters in amounts which will cause organisms of the fecal coliform group to nominally exceed 240 per milliliter (MPN), with single sample exceptions in isolated instances.
2. Wastes or substances of other than natural origin shall not be discharged into these waters in amounts which will result in a pH of these waters of less than 6.5 or greater than 8.5.
3. Where salinity (total dissolved solids) increase can be attributed to specific discharges capable of control, specific control measures shall be instituted and a specific numerical standard may be adopted.

Salinity in water is becoming a controversial issue due to unknowns and variables affecting its degree of concentration. Where salinity increase is due to widespread irrigation or through natural accumulation of salts, the control is beyond present technology and a numerical standard has no meaning. Where control remains beyond present technology, an interim approach with the following provisions is recommended:

1. A routine monitoring program should be implemented to determine any unreasonable increases that might be attributable to new specific sources capable of control.
2. An educational program should be established through the Agricultural Extension Service and the Soil and Water Conservation Districts as to the proper control and use of water and implementation of improved control methods as they are developed.
3. As the State has initiated a "State Water Plan" that must consider quality as well as quantity and uses, and as completion of the basic plan is projected for 1972, sufficient data should be available by that time to consider specific numerical standards for salinity.

The intent of the Interstate Water Quality Standards is to insure that all multiple use demands are met. This means that recreation, fish and wildlife propagation and overall aesthetic values are met, while at the same time municipal, industrial, and agricultural demands are met. These latter demands call for both a source of usable water and for an assimilative receptacle for the discharge or return flow of wastewaters. A further criteria for quality levels in streams is to hold quality at such levels that relatively straightforward conventional treatment techniques, such as sedimentation, filtration, and chlorination, would be the minimum treatment necessary to enhance the quality to potable conditions.

Green River Basin Historical Water Quality Data

Physical and chemical quality monitoring is done continuously through a joint program of the U. S. Geological Survey, the Wyoming Department of Agriculture, and the Wyoming State Engineer's Office. Twelve sampling stations (ten for chemical, two for sediment) are located within the Basin.

Due to the adoption of water quality standards, the Wyoming Department of Public Health has initiated a monitoring program at selected sites to detect serious bacteriological contamination in Green River Basin streams from May to September. Bacteriological contamination is an important indicator, and, if excessive, the indicated pollution is relatively easy to correct through conventional water treatment such as chlorination.

The Wyoming Department of Public Health has established radiological monitoring stations on the Green River at Daniel, Green River, the Fremont Lake outlet, and also on the New Fork River near Pinedale and Big Piney. The monitoring program is to collect background data for an historical base reference period.

Existing and Potential Water Quality Problems

The available data generally indicate that the waters of the Green River Basin are of excellent bacteriological, radiological, chemical, and physical quality, although salinity from natural sources and return flows increases in the lower reaches of some streams. Salinity is the most difficult water quality problem to trace and is the most costly to treat.

There are two basic causes of salinity increases in a stream, and they need to be distinguished. These are the "salt loading" and "salt concentrating" effects. Salt loading is produced by the discharge of additional minerals from municipal, industrial, agricultural, or natural sources into a stream. The salt concentrating effect occurs as a result of the diversion and consumptive use of water. In this case, the salt load diverted and returned to the stream is the same, but there has been a consumption of pure water and a loss of this water from the system which increases the concentration.

Few irrigation return flows are monitored in the Basin, and therefore it is difficult to quantify the salinity contribution. Observations since 1955 by the U. S. Bureau of Reclamation at the Eden Project in Sweetwater County show salt yields ranging from two to six tons per irrigated acre per year.

A major portion of salinity pollution comes from natural or geologic sources. Geologic sources of salinity may either be diffuse (widespread) or point (discrete) sources. Surface runoff is a common diffuse source of salinity pollution. Point sources include springs which issue as a single flowing stream or series of streams within a small area.

Major identified point sources of salinity in Wyoming's Green River Basin are Warm Kendall Spring and Cold Kendall Spring, north of Pinedale, which produce 9,800 tons of salt per year. A major identified diffuse source of salinity is the area from Pinedale north to the Snake River-Green River divide. This area produces over 100 tons of salt per square mile per year. The area around Fontenelle Reservoir produces 50 to 100 tons per square mile per year (45).

At present, most area industries use 100 percent of their diversions. Except for the fact that this reduces the capability of the stream to dilute other salinity sources, this has no effect on salinity.

Low population density and waste water treatment limit M & I salinity contributions in the Basin to a small amount. In the entire Upper Basin, the M & I uses are estimated to contribute only one percent of the salinity measured at Hoover Dam. As the population and industrial activities of the Basin continue to increase, an attendant increase of municipal sewage effluents and industrial waste water discharges will occur. Continued effort will be applied, including prior review and approval of new plans for waste water treatment, to insure continuing compliance with Wyoming's water quality standards.

With continued growth of recreation in the Basin, proper facilities will also be required at campgrounds, picnic areas, and other such places in order to prevent localized pollution problems.

The effects of the various potential developments in the Basin on water quality are discussed in Chapter IV.

Water Rights

The Wyoming Constitution declares that the waters of all natural streams, springs, lakes, or other collections of still water, within the boundaries of the State, are the property of the State. Constitutional provisions allow the appropriation of water for beneficial uses and establish the Office of State Engineer and the Board of Control to supervise such appropriations. The State Engineer is President of the Board of Control and has general supervision of the distribution of water and of the officers connected with water distribution. The Board of Control consists of the State Engineer and the Superintendents of each of the four administrative water divisions of the State.

State Statutes establish the procedures for the appropriation of water for beneficial use. First, a permit to use water and construct works must be obtained from the State Engineer. After the diversion is completed and proof of beneficial use of water is made to the Board of Control, the Board will adjudicate the water right.

Priority of appropriation is based upon the relative dates on which applications for permits were accepted in the State Engineer's Office. "First in time is first in right," is the basis of Wyoming water law.

The "Water Resources Inventory for Water Division Number 4," published in 1965 by the State Engineer, presents tabulations of water rights in the Basin. Table II-1 is a summary of data in that report.

TABLE II-1 -- Summary of Adjudicated and Unadjudicated Irrigation Water Rights in the Green River Basin, Through 1963

Units	Adjudicated Rights		Unadjudicated Rights Completed Status		Total Water Rights Acres
	Reservoir Storage Acre-Feet	Total Adjudicated Acres	Reservoir Storage Acre-Feet	Total Permit Acres	
Henrys Fork	4,106	19,819	277	1,334	21,153
Lyman	6,397	86,829	49,408	9,771	96,600
Big Muddy Creek	1,408	14,352	413	1,621	15,973
Hans Fork	1,901	17,713	28,179	5,297	23,010
Fontenelle Creek		10,209	218	1,525	11,734
La Barge Creek		14,195		1,664	15,859
Piney Creek	7,337	56,198		2,865	59,063
Cottonwood Creek		28,559		2,859	31,418
Horse Creek		18,665		489	19,154
Beaver Creek		11,878		644	12,522
Upper Green River		33,594	21	20,263	53,857
New Fork River	63,440	96,978	4,841	3,852	100,830
Big Sandy River	10,727	23,946	40,298	1,158	25,104
Middle Green River	184	9,976	285,397	1,872	11,848
Bitter Creek	141	3,577	158	563	4,140
Lower Green River	671	3,232	307	1,757	4,989
Little Snake River	2,012	25,513	180	4,086	29,599
Total	98,324	475,233	409,697	61,620	536,853

Total irrigated acreage in the Green River Basin of Wyoming was determined by the Wyoming Water Planning Program during the summer of 1968. The irrigated lands were mapped on aerial photographs in the field. Irrigated lands totaled 332,258 acres, some 200,000 acres less than existing water rights. No attempt was made in this inventory phase of work to compare irrigated lands with water rights. The existence of more water rights than irrigated land is not unique to the Green River Basin. A similar situation exists throughout the State.

Interstate Compacts

Interstate compacts are agreements negotiated between states. The Colorado River Compact of 1922 divided the beneficial uses of water in the Colorado River between the Upper Basin (those parts of the States of Wyoming, Arizona, Colorado, New Mexico, and Utah which drain into the Colorado River system above Lee Ferry, Arizona) and the Lower Basin (those parts of the States of Arizona, California, Nevada, New Mexico, and Utah which drain into the Colorado River system below Lee Ferry). Each of the Basins was allocated the beneficial consumptive use of 7.5 million acre-feet of water annually.

One Colorado River Compact provision has particular significance to the Upper Basin: The Upper Basin will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 million acre-feet for any period of 10 consecutive years. The Colorado River Storage Project was authorized by Congress in 1956 to provide Upper Basin reservoirs to regulate the river and make the required water deliveries at Lee Ferry. Thirty-two million acre-feet of reservoir storage space has been constructed in four units of the Project--Flaming Gorge, Curecanti, Navajo, and Glen Canyon.

A treaty committing the United States to deliver not less than 1.5 million acre-feet of water annually to Mexico was made effective in 1945. A provision for the delivery of water to Mexico is included in the Colorado River Compact. The delivery is to be provided from water surplus to the specified Upper and Lower Basin consumptive uses. In the event surpluses are insufficient to make the delivery, the compact states (Article III, paragraph c), "...such deficiency shall be equally borne by the Upper Basin and the Lower Basin, and whenever necessary the States of the Upper Division shall deliver at Lee Ferry water to supply one-half of the deficiency so recognized in addition [to the 10-year, 75 million acre-feet delivery.]"

The Upper Colorado River Basin Compact was ratified in 1948 by all the Upper Basin States, followed by Federal approval in 1949. Since Arizona has a small area in the Upper Basin, it was included with the other Upper Basin States in the negotiations. The Upper Colorado River Compact apportions the consumptive use of water as follows: 50,000 acre-feet per year to Arizona; of the remainder, 51 3/4 percent to Colorado, 11 1/4 percent to New Mexico, 23 percent to Utah, and 14 percent to Wyoming. The compact also divided the waters of Henrys Fork between Wyoming and Utah on a priority of appropriation basis. The waters of the Little Snake River below its confluence with Savery Creek were divided between Wyoming and Colorado on a priority of appropriation basis for existing development; the unused waters were divided equally.

Water Supplies Available Under Compacts

The compact requirement for the Upper Basin to deliver an average of 7.5 million acre-feet of water annually at Lee Ferry presents a serious problem to the Upper Basin. This is because of the extreme variations of annual streamflow and the long-term droughts that occur in the Colorado River drainage. Water stored in the reservoirs of the Colorado River Storage Project during years of high runoff is to be released during low-flow years so that Upper Basin uses will not be curtailed for the Lee Ferry delivery.

The division of the Colorado River was based on the water supplies estimated to be available in 1921. In 1965 Tipton and Kalmbach, consulting engineers, estimated that approximately 6.3 million acre-feet of water would be available annually in the Upper Basin after the 75 million acre-feet, 10-year delivery to the Lower Basin. Because of channel losses and the Mexican Treaty water obligations, the consumptive uses available from the main stem of the Colorado River in the Lower Basin must also be less than 7.5 million acre-feet of water annually. It is imperative that the Colorado River water supply be augmented so that consumptive uses equaling the compacted amounts can be developed.

Tipton's estimate of water available to the Upper Basin assumes that 29 million acre-feet of the storage capacity in Colorado River Storage Project reservoirs would be used for the Lower Basin delivery. If all of the 32 million acre-feet capacity is used, the Upper Basin could utilize only slightly more than the 6.3 million acre-feet of water estimated by Tipton because evaporation losses reduce the effectiveness of the long-term carry-over storage. The evaporation losses from the project reservoirs are generally considered to be chargeable to the Upper Basin States on the same basis as that on which the water supplies are divided.

The provisions of the Upper Colorado River Compact entitle Wyoming to 1,043,000 acre-feet of beneficial consumptive uses of water annually, assuming an average of 7.5 million acre-feet per year for the Upper Basin can be made available. If the Upper Basin is limited to 6.3 million acre-feet, Wyoming's entitlement would be about 875,000 acre-feet per year. All present uses are chargeable against this amount. The Lower Basin contends that the Upper Basin has an obligation to deliver water under the Mexican Treaty. If this contention is valid, Wyoming's share could be reduced to the consumptive use of about 805,000 acre-feet of water per year.

The Upper Colorado River Basin Compact Commission estimated the amounts of channel losses that result from water flowing from each compact state to Lee Ferry. The Commission's Engineering Advisory Committee found that when streamflows were reduced, channel losses were less. The engineers estimated that consumptive uses of water would reduce streamflows resulting in a salvage of water. The U. S. Bureau of Reclamation has reported the salvage resulting from future Wyoming consumptive uses at between four and five percent. The estimation of salvage is difficult, however, and there is no apparent uniformity among the compact states in using salvage as a part of their available water supply. The method of handling salvaged water will probably become better defined as the consumptive uses in the Upper Basin increase. If salvage can be taken into account at five percent, then Wyoming

may be entitled to the consumptive use of as much as 1,095,000 acre-feet of water per year.

For purposes of this report, neither the Mexican Treaty nor salvage has been considered (see Chapter IV).

GROUNDWATER OCCURRENCE AND USE

Occurrence

Precipitation and infiltration of surface water are the primary sources of groundwater. The past geologic environment has determined the amount of underground storage space, the depth to the water table or piezometric surface, the hydraulic gradient, and the ability of the reservoir rock or sediment to transmit water.

Underground water, rather than collecting in large pools, usually occurs as drops of water filling very small spaces in the sediment or rock. If enough of these small spaces are interconnected, the saturated portion of the rock is an aquifer. Aquifers are found in unconsolidated sands and gravels, in sandstone and conglomerate, and other rock types. The effectiveness of an aquifer can be increased by secondary porosity and permeability. For example, in limestone, solution cavities of tremendous volumes can develop below the water table and can contain large enclosed pools of groundwater. Fractures can even create an aquifer in rock which otherwise would not effectively transmit water. It has been estimated that groundwater down to a depth of approximately 300 feet in the Basin generally is unconfined. Water in a well to this depth will not rise unless pumped, as there are no impermeable layers causing artesian pressure. Deeper groundwater usually is under artesian pressure due to impermeable layers above and below the aquifer, and will rise above the top of the aquifer when a well is drilled through the upper confining layer.

The maximum thickness of sedimentary rocks reaches an estimated 30,000 feet in a deep syncline (downfold) that trends northwest through the center of the Upper Green River Basin in Wyoming, parallel to the Wind River Mountains (64). The Quaternary interval has a reported maximum thickness of 200 feet. Tertiary strata have a reported maximum thickness of 10,000 feet and Cretaceous strata, 11,000 feet. Figure II-4 is a map showing the general surface distribution of Quaternary, Tertiary, and pre-Tertiary formations.

There are numerous aquifers in the Basin. The groundwater potential of the geological section is described in Table II-2. Groundwater is present in Quaternary sediments. Tertiary rocks host coal, oil shale, and trona deposits as well as groundwater. Cretaceous rocks may produce groundwater in local areas near surface exposures, and coal, oil, and natural gas. Sedimentary rocks older than Cretaceous are exposed along the Basin rim and are present in the subsurface. They have not as yet proven to be of economic importance and do not contribute significantly to the available groundwater supply due to their great depth.

Estimate of Water Availability

Groundwater is present throughout the Basin. The depth of shallow groundwater varies from near-surface (less than ten feet) to about 300 feet. Within this depth interval are the unconsolidated aquifers, such as flood-plain and fan alluvium, terrace gravel, lake deposits, glacial deposits, and shallow consolidated sandstones.

Wells in shallow aquifers generally yield less than 20 gallons per minute (gpm) of poor- to good-quality water. The concentration of total dissolved solids (TDS) ranges from 250 to 2,800 parts per million (ppm). Exceptional yields as high as 4,500 gpm are reported from alluvial sands and gravels. Terrace gravels reportedly yield 2,000 gpm. Yields from shallow consolidated sandstones and conglomerates vary from less than ten gpm to more than 200 gpm.

Deeper wells produce moderate to large yields; however, the potential yield at any specific well site is unpredictable with the information presently available. The main body of the Wasatch formation is considered to be a good source of water, especially if a great thickness of the formation is penetrated by a well. Such a well might produce a yield of 700 gpm.

The Battle Spring formation of the Great Divide Basin, which is equivalent to all of the Wasatch-Green River interval below the Laney shale (refer to Table II-2), may produce maximum yields in excess of 1,000 gpm of fair- to good-quality water, if the entire formation thickness is penetrated.

Generally, the deeper aquifers yield water of inferior quality. Large yields (800 gpm) from the Rock Springs formation (in the Mesaverde group) are possible, but high concentrations of total dissolved solids (6,000 ppm) are common. At even greater depth, the Madison limestone, however, may be capable of sustaining large yields (greater than 500 gpm) of fair-quality (500 to 1,000 ppm) water.

Use of Groundwater

Groundwater is very important to the stockgrower, and the principal uses of groundwater in the Basin are for stock and domestic purposes. Most wells are several hundreds of feet deep and deeper towards the center of the Basin.


The source of municipal water for the towns of Bairoil, Baggs, Big Piney, Granger, Little America, Lyman, South Superior, and Wamsutter is groundwater. Residents of Daniel, Eden, Farson, Fort Bridger, Lamont, La Barge, Mountain View, Opal, and other small communities get their water from private wells.



Industrial uses of groundwater include oil well drilling, the secondary recovery of oil, coal mining operations, sodium carbonate processing, and highway construction. It is estimated that approximately 4,400 acre-feet of groundwater are withdrawn annually for these purposes.



According to reports, the amount of agricultural land irrigated by groundwater as a principal supply source amounts to only about 1,300 acres. There are probably additional lands where groundwater provides a supplemental supply.




Figure II-4 SURFACE GEOLOGY MAP ILLUSTRATING GROUND WATER POTENTIAL
(Generalized From The Geologic Map Of Wyoming, 1955)

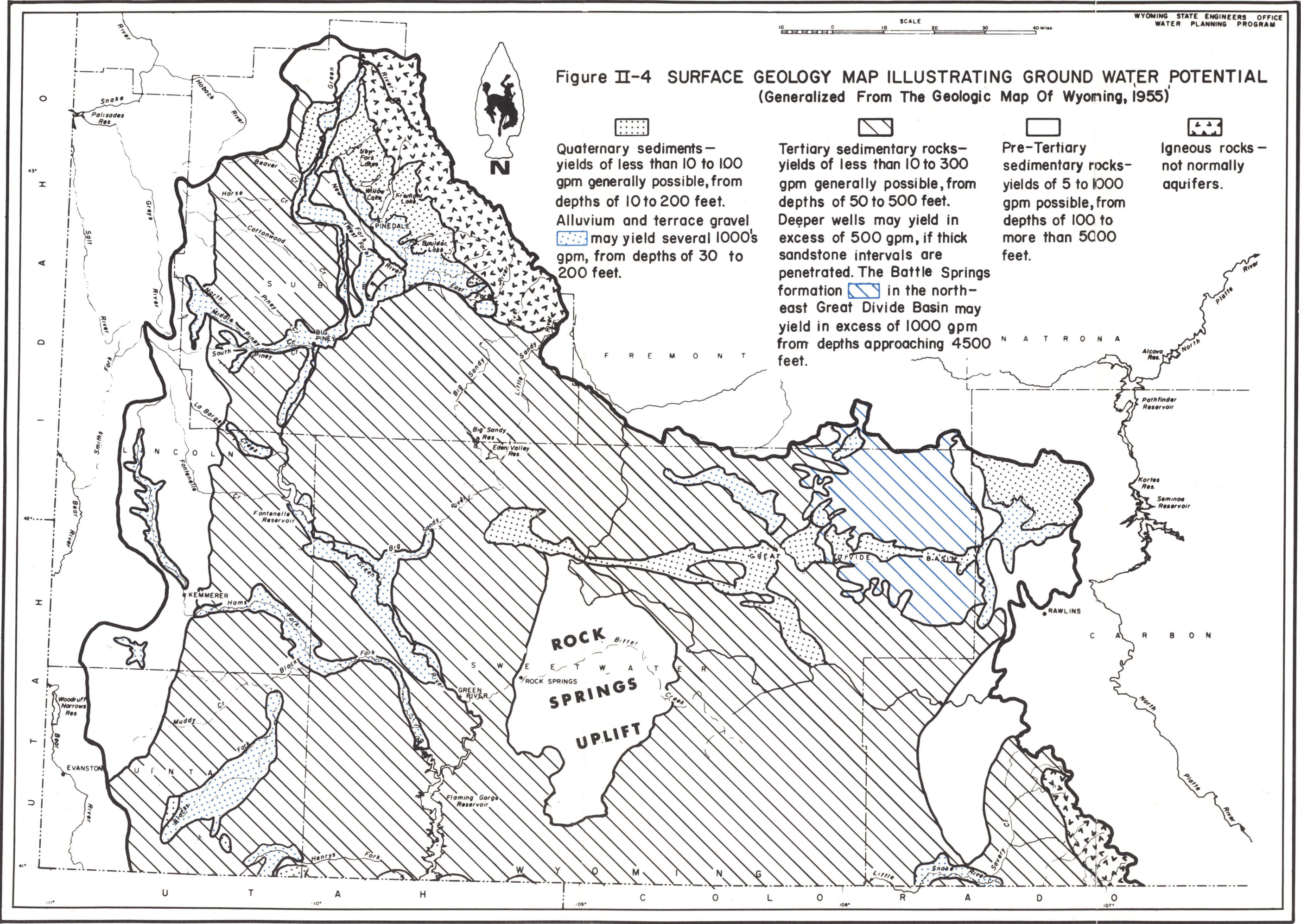
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Quaternary sediments— yields of less than 10 to 100 gpm generally possible, from depths of 10 to 200 feet. Alluvium and terrace gravel  may yield several 1000's gpm, from depths of 30 to 200 feet.
- 

Tertiary sedimentary rocks— yields of less than 10 to 300 gpm generally possible, from depths of 50 to 500 feet. Deeper wells may yield in excess of 500 gpm, if thick sandstone intervals are penetrated. The Battle Springs formation  in the north-east Great Divide Basin may yield in excess of 1000 gpm from depths approaching 4500 feet.
- 

Pre-Tertiary sedimentary rocks— yields of 5 to 1000 gpm possible, from depths of 100 to more than 5000 feet.
- 

Igneous rocks— not normally aquifers.



**WYOMING'S
GREEN RIVER BASIN**

TABLE II-2 -- Generalized Geologic Section, With the Groundwater Potential of Formations or Units in Chronological Order of Youngest to Oldest (10) (11) (12)

Geologic Age Formation or Unit (thickness in feet, ±)	Lithology and Distribution	Groundwater Potential
Quaternary (Present to 1,000,000 years ago)		
Alluvium (0-200)	Unconsolidated or only weakly cemented deposits of sand, gravel, silt, clay, of floodplains and alluvial fans.	Good source of groundwater; yields less than 10 gpm (gallons per minute) to wells, with exceptions as high as 4,500 gpm; quality varies from good to poor, with a range of 250 to 2,800 ppm (parts per million) TDS (Total Dissolved Solids).
Sand dunes (0-100)	Unconsolidated deposits of wind-blown sand.	Not a good source, but recharges underlying formations or units.
Lake deposits (0-25)	Clay, silt, and sand, similar to finer fractions of alluvium; extensive in the Great Divide Basin.	Probably poor potential; water in small lakes in the Great Divide Basin has about 400 ppm TDS.
Glacial deposits (thickness unreported)	Poorly sorted mixture of sand, silt, gravel, and boulders, mainly found on the southwest flank of the Wind River Range.	Unknown potential, but stratified intervals of sand or gravel could be water-bearing, particularly in the vicinity of mountain lakes. A greater potential may exist for recharging underlying or adjoining alluvium and bedrock, as glacial deposits normally occupy a higher topographic position and are of limited areal extent.
Gravel (Terrace) deposits (0-70)	Sand and gravel, similar to alluvium but at elevations above present stream levels.	Good potential locally, but may drain easily; yields generally less than 20 gpm, but greater yields (up to 2,000 gpm flowing) are known. Recharged by irrigation water in certain areas.
Tertiary (1,000,000 to 63,000,000 years ago)		
Igneous rocks (100)	Of local extent; both intrusive and extrusive.	Unknown potential.
North Park formation (0-800)	Sandstone, limestone, and a basal conglomerate. Present in southeastern part of Basin (Sierra Madre Uplift).	Reportedly has good potential; yields excellent quality spring water; maximum yield of several hundred gpm may be possible.
South Pass formation (0-200)	Pebbles and boulders in a fine-grained ashy sandstone matrix. Present in northeastern part of Basin.	Potential unknown.
Browns Park formation (0-1,200)	Sandstone and conglomerate. Present in southeastern part of Basin.	Potential unknown, but probably fair to good; yields of several hundred gpm of fair-quality water (TDS up to 1,000 ppm) may be possible locally.
Bishop conglomerate (0-200)	Conglomerate and sandstone, poorly sorted. Present in southern Rock Springs Uplift.	One well known to yield 42 gpm, with a TDS content of about 600 ppm; a spring has 350 ppm.
Bridger formation (500-2,300)	Mudstone, sandstone, and thin-bedded limestone and marlstone, with large amounts volcanic ash incorporated. Upper 250 feet may be same as Uinta formation in southeastern part of the Basin.	Poor potential excepting very locally; yields of less than 50 gpm of highly mineralized water can be expected. The potential is better where the sandstones of the formation are overlain by alluvium or terrace gravel.
Pass Peak conglomerate (1,000-5,000)	Conglomerate, sandstone, and shale. Present in northwestern part of the Basin.	Good potential; maximum yield probably will exceed 200 gpm; in four wells, TDS range is 200 to 300 ppm.
Green River-Wasatch interval	(The Green River-Wasatch interval may have a maximum thickness of 10,000-11,000 feet)	
Laney shale member of the Green River formation (0-1,900)	Marlstone, oil shale, tuff, siltstone, sandstone. Equivalent to the upper tongue of the Green River formation in the western part of the Basin. May be as much as 3,000 feet thick in southeastern part of Basin.	Poor to good potential; large variation in yields, from one to 300 gpm; range of TDS is from 500 to more than 4,000 ppm.
Cathedral Bluffs tongue of the Wasatch formation intertonguing with the Wilkins Peak member of the Green River formation (0-2,500)	The Green River and Wasatch formations intertongue and are difficult to differentiate. Lithology is marlstone, claystone, oil shale, and arkosic sandstone. In the eastern part of the Great Divide Basin, the age equivalent is the Battle Spring formation, an arkosic sandstone about 4,000 feet thick.	The Cathedral Bluff tongue yields very small amounts of mineralized water and has a poor potential. The Wilkins Peak member has a poor potential (might yield up to 30 gpm of brine locally).
(The Battle Spring formation is equivalent to all of the Green River and Wasatch below the Laney shale)		The potential of the Battle Spring formation is very good in the northeastern part of the Great Divide Basin. Maximum yields of wells penetrating the entire formation might exceed 1,000 gpm. The range of TDS probably would be from less than 200 to about 1,000 ppm.
New Fork tongue of the Wasatch formation intertonguing with the Fontenelle tongue of the Green River formation; and the equivalent of both, the Tipton tongue and shale of the Green River formation (0-500)	Mudstone, sandstone, oil shale, limestone.	The New Fork tongue has fair potential; yields of two to 40 gpm are reported with one well having 1,730 ppm TDS. The Tipton tongue has good potential in the central part of the Basin, but poor elsewhere. In the central part of the Basin, yields of 10 to 170 gpm and 500 to 3,000 ppm TDS are reported. The Fontenelle tongue probably has poor potential.
Main body of the Wasatch formation (0-4,000)	Claystone, siltstone, sandstone, oil shale, and coal.	Good potential from several aquifers. Yields range from one to 700 gpm, some flowing. The aggregate thickness of the water-bearing sandstone probably is from 1/3 to 2/3 of the total formation thickness.
Fort Union formation (0-2,700)	Sandstone, siltstone, and coal.	Probably good potential, although unknown in much of the Basin; a good source of water in the Great Divide Basin. Yields of three to 300 gpm are reported, and the maximum may be greater; the TDS range is from 800 to 3,320 ppm.

TABLE II-2 -- continued

Geologic Age Formation or Unit (thickness in feet, ±)	Lithology and Distribution	Groundwater Potential
Cretaceous ¹ (63,000,000 to 135,000,000 years ago)		
Lance formation (0-4,500)	Sandstone, shale, coal.	Yields of five to 30 gpm reported in the Great Divide Basin; large yields may be possible but the Basin potential is unknown.
Lewis shale (0-2,700)	Shale, locally with numerous sandstone beds.	Poor potential, but sandstones may yield water.
Mesaverde group Almond formation (0-1,000)	Sandstone, siltstone, shale, coal.	Potential unknown, but probably fair. Yields of 20 to 100 gpm and 500 to 1,500 ppm TDS can be expected.
Erickson formation (400-700)	Sandstone, siltstone, shale.	Good potential; yields of 10 to 200 gpm and 300 to 1,200 ppm TDS are reported.
Rock Springs formation (900-1,700)	Sandstone, shale, coal.	Good potential; probable range of yields is about 20 to 800 gpm, and 600 to 6,000 ppm TDS.
Blair formation (900-1,800)	Sandy shale and siltstone.	Yields of less than 60 gpm of highly mineralized water can be expected.
Baxter shale (2,000-5,000)	Dark gray shale, with minor amounts interbedded sandstone, siltstone, and limestone. (Equivalent units are the Cody shale, the Steele shale, the Niobrara formation).	Potential unknown, but probably poor.
Frontier formation (190-900)	Sandstone and dark gray shale, with a few beds of bentonite.	Potential unknown. One water well yields 50 gpm, 720 ppm TDS. Oil-field waters have 1,300 to 57,000 ppm TDS.
Mowry shale (150-525)	Dark gray shale, with siltstone and bentonite; fish scales are common.	Probably poor potential.
Thermopolis shale (40-235)	Dark gray to black fissile shale, with thin beds of sandstone, siltstone, and bentonite. The Muddy sandstone in the upper part is 20-155 feet thick.	Probably poor potential. Oil-field waters from the Muddy sandstone have 3,500 to 10,000 ppm TDS.
Cloverly formation (45-240)	Sandstone, shale, conglomerate.	Yields of 25 to 85 gpm and 223 to 557 ppm TDS have been reported. Oil-field waters have 8,000 to 36,000 ppm TDS in the Rock Springs Uplift, and about 3,000 to 17,000 ppm elsewhere.
Jurassic (135,000,000 to 181,000,000 years ago)		
Morrison formation (170-450)	Variegated claystone, shale, lenticular sandstone.	Probably poor potential.
Sundance formation (130-450)	Sandstone, shale, siltstone and limestone.	One well yields 28 gpm, with 1,100 ppm TDS; the water is high in fluoride (6.0 ppm) and iron (4.2 ppm).
Nugget sandstone (or equivalent) (0-650)	Sandstone; correlation and age of this unit are questionable in the Basin.	Unknown potential; water with 7,800 to 50,000 ppm TDS in the Rock Springs Uplift may be from this unit.
Triassic (181,000,000 to 230,000,000 years ago)		
Chugwater formation (900-1,500)	Red shale, siltstone, sandstone, and the Alcova limestone member.	Probably poor potential.
Undifferentiated (170-460)	Similar to Chugwater above, but Triassic and <u>Permian</u> in age. The Goose Egg, Park City, and Dinwoody formations may each be partially equivalent to this unit.	Unknown, but probably poor potential.
Permian (230,000,000 to 280,000,000 years ago)		
Tensleep sandstone (0-840)	Sandstone and lesser amounts of thinly interbedded limestone and dolomite. The lower part is considered <u>Pennsylvanian</u> in age. The unit is not known to be present in the southeastern part of the Basin.	Potential unknown. One spring has a reported yield of 200 gpm and 339 ppm TDS. In basins to the north and east, the TDS range is from 200 to 5,000 ppm.
Pennsylvanian (280,000,000 to 310,000,000 years ago)		
Amsden formation (0-260)	Sandstone, shale, siltstone, predominantly red in color, with cherty limestone. The Darwin sandstone member, about 60 feet thick, is at the base. The Amsden is not known to be present in the southeastern part of the Basin.	Potential unknown.
Mississippian (310,000,000 to 345,000,000 years ago)		
Madison limestone (5-325)	Limestone and dolomite.	Potential unknown but may be good if caverns and solution cavities can be tapped. In other basins TDS varies from 300 to 4,000 ppm.
Devonian (345,000,000 to 405,000,000 years ago)		
Undifferentiated (0-2,300)	Sandstone, dolomite. Probably present in northwestern part of the Basin.	Unknown potential.
Siluro-Ordovician (405,000,000 to 500,000,000 years ago)		
Undifferentiated (0-2,200)	Dolomite, shale. Probably present in northwestern part of the Basin.	Unknown potential.
Cambrian (500,000,000 to 600,000,000 years ago)		
Undifferentiated (0-800)	Predominantly sandstone.	Yield of one well is 150 gpm and 663 ppm TDS; of one spring is 100 gpm and 214 ppm.
Precambrian (prior to 600,000,000 years ago)		
Igneous and metamorphic rocks	Granite, gneiss, and schist.	Potential unknown; probably will yield good-quality water where weathered or fractured, as in certain mountainous areas.

¹ Data for Cretaceous through Mississippian, and Cambrian, are more typical of the Great Divide Basin than of the entire Green River Basin.

Some groundwater is not suitable for irrigation. It is reported that, because of a high sodium content, water in the Green River-Wasatch interval in the southern two-thirds of the Basin is not suitable for irrigation. However, water produced from the alluvium and gravels of the northern and southwestern parts of the Basin, from the Wasatch formation of the northern part, and from the Tertiary (undivided) of the northern and northeastern parts of the Basin probably would be of suitable quality for irrigation (64).

The groundwater in the Basin generally becomes more mineralized with depth. There are, however, instances where wells are drilled through the alluvium and into deeper bedrock in order to avoid possible contamination by surface pollutants.

Groundwater reserves in the Basin are large, mainly because of the great area and thickness of consolidated formations that contain aquifers. Because the rate of recharge to these aquifers is relatively small, large withdrawals of water such as would be needed for large-scale irrigation and industrial uses would measurably lower water levels.

Data Needs

Both quantitative and qualitative data concerning groundwater in the Basin are lacking. The cooperative program by the State Engineer and the U. S. Geological Survey provides for periodic measurements of water levels in certain observation wells in the Basin (see Figure II-1). This is a relatively new phase of the cooperative program, and the record is of very short duration. Other information is provided by well records, mineral exploration, and field investigation reports by the U. S. Geological Survey and others.

Data are needed in order to more fully inventory and evaluate the groundwater resources of the Basin, and to permit an appraisal of the resource as part of a water and related land resources development plan for the Basin.

CHAPTER III

THE ECONOMY AND RELATED WATER USES

T H E E C O N O M Y A N D R E L A T E D W A T E R U S E S

AGRICULTURE

The description of the agricultural economy of the Green River Basin is based upon Agricultural Census data and State Board of Equalization figures on taxable valuation. Lincoln, Sublette, Sweetwater, and Uinta Counties reasonably represent conditions in the Basin.

Present Economy

The Agricultural Census shows the value of all farm products sold in 1964 to be about \$16,393,921 in Lincoln, Sublette, Sweetwater, and Uinta Counties. Livestock and livestock products contribute about 91.6 percent of the value (Table III-1). Beef cattle and sheep are the main sources of cash income.

TABLE III-1 -- Value and Distribution of Farm Products Sold,
1964 Census of Agriculture

Item	C O U N T Y				Total
	<u>Lincoln</u>	<u>Sublette</u>	<u>Sweetwater</u>	<u>Uinta</u>	
All Farm Products Sold, dollars	\$6,425,861	\$4,232,508	\$2,963,504	\$2,772,048	\$16,393,921
All Livestock and Livestock Products Sold, dollars	\$5,605,341	\$3,963,631	\$2,771,224	\$2,675,559	\$15,015,755
Livestock and Products as a Percent of All Products Sold	87.2%	93.6%	93.5%	96.5%	91.6%
All Crops Sold, dollars	\$ 785,630	\$ 178,576	\$ 167,256	\$ 96,459	\$ 1,227,921
All Crops as a Percent of All Products Sold	12.2%	4.2%	5.6%	3.5%	7.5%
Poultry and All Other Sales Percent of All Products	.6%	2.1%	.9%	---	.9%
Average Sales Per Farm, dollars	\$ 12,193	\$ 24,325	\$ 20,580	\$ 10,540	

The average gross sales of all farm products sold per farm varied from \$10,540 in Uinta County to \$24,325 in Sublette County (Table III-1). In 1964 about 43 percent of the farms in Sublette County and more than 60 percent of the farms in Lincoln, Sweetwater, and Uinta Counties each grossed less than \$10,000 (Table III-2).

TABLE III-2 -- Number of Farms¹ by Value of Farm Products Sold - 1964

Gross Value of Products Sold	C O U N T Y				Total No. Farms	Percent of Total Farms
	Lincoln	Sublette	Sweetwater	Uinta		
Under \$250	18	5	9	10	42	3.79
\$250-499	18	2	3	3	26	2.35
\$500-999	25	8	10	6	49	4.42
\$1,000-1,499	23	-	8	5	36	3.25
\$1,500-1,999	31	5	9	13	58	5.24
\$2,000-2,499	15	3	10	14	42	3.79
\$2,500-4,999	80	21	21	54	176	15.88
\$5,000-7,499	72	14	17	46	149	13.45
\$7,500-9,999	64	17	3	33	117	10.56
\$10,000-14,999	72	25	15	26	138	12.46
\$15,000-19,999	41	26	5	24	96	8.66
\$20,000-29,999	33	16	5	13	67	6.04
\$30,000-39,999	13	6	4	7	30	2.71
\$40,000-59,999	5	12	8	2	27	2.44
\$60,000 and over	<u>17</u>	<u>14</u>	<u>17</u>	<u>7</u>	<u>55</u>	<u>4.96</u>
Total	527	174	144	263	1,108	100.00

¹ These figures include about 400 farms in Lincoln and Uinta Counties that are outside the Green River Drainage Basin.

Source: 1964 Census of Agriculture

Operators of small farms and ranches and inexperienced operators have difficulty in establishing economic units. The inadequate scale of operation and accompanying low net income result in a low income group within agriculture that does not have the capital resources to employ the technology and efficiency necessary to establish an economic unit. A combined irrigated land and rangeland unit capable of supporting less than 150 animal units generally results in too low an income to meet production costs and afford an adequate living.

The well-managed larger ranches generally meet production costs and realize moderate profits. These operators have the financial capability to adjust to new technological developments and are slowly adjusting to these changes.

During the past decade there was no appreciable change in crop prices received. From 1959 to 1969 the index of livestock prices received increased from 256 to 323. Over one-half of this increase occurred in 1969. The Wyoming Cooperative Crop and Livestock Reporting Service reports that from 1959 to 1968 beef marketed in Wyoming increased from about 413 million pounds to about 610 million pounds, an increase of 48 percent. Cash receipts from farm marketing and realized gross farm income have increased substantially during the period, but the rise in production expense has offset these gains (41). Net farm income fluctuates from year to year. During the period 1959 to 1969, the parity ratio (ratio of the index of prices received to the index of prices paid) has declined from 81 to 74, or about 9.1 percent (Table III-3).

TABLE III-3 -- Index of Parity, Prices Received and Prices Paid, Selected Years 1950-1969. 1910-1914 = 100

Year	Parity ¹	All Prices Received			Prices Paid		
		All	Crop	Livestock	Production Items	Livestock	All prices, commodities and services, including interest, taxes, salaries and wages
1950	101	258	233	280	246	402	256
1954	89	246	242	249	255	302	278
1959	81	240	222	256	266	380	298
1964	76	237	239	236	270	312	313
1968	73	261	229	288	292	389	355
1969	74	275	220	323	304	436	373

¹ Parity -- Ratio of index of prices received to index of prices paid, including interest, taxes and wage rates.

Source -- Agricultural Prices, Statistical Reporting Service. PR 1-3 (1970).

Dry Cropland

There are about 3,000 acres of dry cropland in the Little Snake River drainage. About 1,000 acres of dry cropland are reported in the remainder of the Green River Basin.

Irrigated Land

The irrigated lands in the Green River and the Little Snake River drainage areas were mapped in 1968 in conjunction with necessary land and water use studies. This mapping program was carried out because of variations in the estimates of the amount of irrigated land in the Basin, and a lack of recent data concerning land and water use in the area. For the mapping program, irrigated land was defined as land watered for agricultural purposes by artificial means. These include subirrigated lands and seeped areas under ditches, as well as lands irrigated directly by ditches or sprinklers. Lands under ditches that had not been irrigated for a number of years were

excluded. However, some idle lands and lands not irrigated in an average water year were included, such as cropland acres from which a crop was not harvested during the crop year. Idle lands were estimated by field observations and photo interpretation, from information in the U. S. Bureau of Census report (1964 Agricultural Census), the U. S. Bureau of Reclamation Crop Report (1966-1967), and from data collected by the Water Resources Work Group assisting in the Comprehensive Framework Study of the Upper Colorado Region. Idle lands were deducted from the irrigated land total to determine the average annual irrigated acreage.

Table III-4 is a tabulation of the irrigated land in the Green River Basin. The tabulation has been rounded to the nearest 100 acres. A total of 332,300 acres of irrigated land was mapped of which 29,100 acres were idle. The average irrigated acreage, about 303,200 acres, was used to compute irrigation consumptive use chargeable to Wyoming under provisions of the Upper Colorado River Compact. Consumptive use rates computed by the Soil Conservation Service for the Upper Colorado River Region study were reviewed by the Water Planning Program staff and used to estimate depletions.

TABLE III-4 -- Tabulation of Irrigated Land in the
Green River Basin in Wyoming
(Acres)

<u>Study Area¹</u>	<u>Total Irrigated Acreage</u>	<u>Idle Acres</u>	<u>Average Acreage Irrigated Annually</u>
1. Upper Green River	202,300	14,100	188,200
2. Big Sandy River	19,300	2,500	16,800
3. Hams Fork	11,200	1,100	10,100
4. Lyman Area	64,900	9,000	55,900
5. Henrys Fork	17,600	1,400	16,200
6. Lower Green River	2,600	400	2,200
7. Little Snake River	<u>14,400</u>	<u>600</u>	<u>13,800</u>
	332,300	29,100	303,200

¹ See Figure III-2, page 69

Land use in the study area was determined from work plans of the Soil Conservation District. Crop distribution was determined from a 25-percent sample and the use of statistical data.

Economic Importance of Agriculture

Rangeland for grazing and irrigated lands to provide a winter feed base are interdependent components of the agricultural enterprise. Irrigation is

required for the successful production of crops to provide this feed base. The value of irrigated crops sold and crops marketed through livestock provides a significant portion of the total value of all farm products sold. Current normal crop distribution, yields, value of production, and net returns are summarized in Table III-5. The gross annual value of crop and pasture production on irrigated land in the Green River Basin is about \$7,794,460. The net return to irrigated land in the Basin amounts to about \$1,751,630, or about \$5.27 per acre. The University of Wyoming production-cost data developed for the Agricultural Sector Study (to be published in late 1970) were used for estimating production costs. These figures do not include interest on land investment but include all other costs of production, including interest on operating capital and labor costs. The above estimated value of crops harvested gives a reliable estimate of the direct value of water applied to irrigated lands.

TABLE III-5 -- GREEN RIVER BASIN--Summary of Current Normal Crop Distribution, Yields, Production, Price, Value of Production, Production Costs and Net Return to Land

Crop	Acres	Yield	Production ¹	Price ²	Value of Production (dollars)	Production Costs (dollars)	Net Return ³ To Land (dollars)
Alfalfa	20,335	2.0 ton	40,670	22.28	906,130	993,975	- 87,845
Improved Grass Hay	75,780	1.6 ton	121,250	22.28	2,701,450	2,189,285	512,165
Native Hay	99,360	1.1 ton	108,890	22.28	2,426,070	2,258,450	167,620
Barley	3,710	42.9 bu	159,060	.98	155,880	178,265	- 22,385
Oats	970	34.4 bu	33,370	.68	22,690	46,530	- 23,840
Pasture	101,985	2.0 AUM ⁴	204,405	4.00	817,620	376,325	441,295
Aftermath Grazing ⁵		AUM	191,155	4.00	764,620		764,620
Other	1,000						
Idle	29,120						
Total	332,260				7,794,460	6,042,830	1,751,630

¹ Due to disaggregation of data from the county and area production, these figures may not be precisely the product of yield times acres.

² Average prices 1964 to 1968.

³ Gross value of production less fixed costs of production, operating costs, and all other production costs except interest on land investment.

⁴ Animal unit month grazing.

⁵ Aftermath grazing yields are estimated at 1.0 AUM for native and improved hay, .5 AUM for alfalfa and 1.25 AUM for small grain.

Source--State Water Plan and University of Wyoming for production costs.

Secondary benefits stemming from or induced by irrigation are increased income to service industries in the community, local business establishments, and processors of agricultural products. Most of the income from irrigation is spent locally. Ranching is dependent upon imports for machinery, tools, and supplies. A major portion of crop production costs, estimated at about \$6,042,830, flows through local business channels. In many communities of the Green River Basin, irrigation and the associated livestock industry provide the major economic base for supporting all local business activity. In other areas, such as portions of Sweetwater County, agriculture provides a smaller portion of the money supporting the local economy.

The percent of local taxes generated by agriculture varies considerably between counties. The 1969 assessed valuation of the significant items used by agriculture is tabulated in Table III-6.

TABLE III-6 -- Assessed Valuation in Dollars, 1969 Land Improvements, Livestock and Machinery¹

Item	C O U N T Y				Green River Basin Counties
	Lincoln	Sublette	Sweetwater	Uinta	
Land					
Suburban	\$ 14,780	\$ 3,995	\$ 88,889	\$ 5,138	\$ 112,802
Irrigated Land, First Class	853,027	--	465,836	1,099,400	2,418,263
Irrigated Land, Second Class	639,543	1,597,320	--	438,340	2,675,203
Uncultivated With Water Rights	39,774	136,740	58,275	392,280	627,069
Irrigated Pasture Land	282,941	506,848	41,895	5,940	837,624
Dry Farm Land	297,136	--	--	2,920	300,056
Grazing Land	<u>1,111,772</u>	<u>793,115</u>	<u>2,398,976</u>	<u>1,163,934</u>	<u>5,467,797</u>
Subtotal	3,238,973	3,038,018	3,053,871	3,107,952	12,438,814
Improvements on Land	2,031,974	1,287,020	1,089,146	957,525	5,365,665
Livestock					
Cattle	1,291,843	2,817,020	411,329	1,131,734	5,651,926
Horses	68,125	106,105	35,065	41,350	250,645
Sheep	345,793	105,981	723,551	239,167	1,414,492
Other Livestock	1,910	316	92	480	2,798
Dogs, Bees, and Fur-Bearing	1,705	931	--	4,012	6,648
Poultry	<u>795</u>	<u>1,708</u>	<u>1,035</u>	<u>117</u>	<u>3,655</u>
Subtotal	1,710,171	3,032,061	1,171,072	1,416,860	7,330,164
Machinery and Equipment²					
Farm Machinery	115,825	54,998	49,125	33,009	252,957
Threshing Machines, Balers	93,345	50,175	32,400	43,426	219,346
Tractors	253,033	159,495	71,475	111,572	595,575
Engines--Gas and Steam	114,680	19,709	2,750	500	137,639
Saddles and Harness	<u>17,325</u>	<u>27,115</u>	<u>4,350</u>	<u>9,738</u>	<u>58,528</u>
Subtotal	594,208	311,492	160,100	198,245	1,264,045
Total--Agriculture	\$ 7,575,326	\$ 7,668,591	\$ 5,474,189	\$ 5,680,582	\$ 26,398,688
Total Assessed Valuation	\$ 41,057,126	\$ 34,184,085	\$104,749,200	\$ 23,468,683	\$203,459,094
Agriculture--Percent of Total Assessed Valuation	18.451	22.433	5.226	24.205	12.975

¹ Part of the assessed valuation is outside the Basin area.

² Does not include motor vehicles or miscellaneous tools and equipment.

Source--State Board of Equalization.

Projections of Future Conditions

In making Basin agricultural projections, projections of national and regional agricultural needs made by the Federal Office of Business Economics and the Federal Economic Research Service were considered. It was assumed that a major portion of farm products sold will continue to be exported to markets outside the Basin. Farms and ranches will continue to increase in size and efficiency. Operators will adopt technology at an increasing rate and continue the trend of substituting capital for labor. Agricultural employment will continue to decrease.

Projected changes in irrigated acres and new irrigated lands projected for development are tabulated in Table III-7. The locations of potential irrigation projects are shown in Figure III-1.

TABLE III-7 -- Status of Irrigated Lands and Projected Changes

	Current Normal <u>Acres</u>	1980 <u>Acres</u>	2000 <u>Acres</u>	2020 <u>Acres</u>
<u>Present Use¹</u>				
Irrigated	303,140	300,175	295,000	290,000
Idle	29,120	29,085	28,260	27,260
<u>Projected Developments</u>				
Seedskadee Project		16,000	57,000	57,000
Savery-Pot Hook Project		7,000	7,000	7,000
Eden Improvement Project		3,000	3,000	3,000
Private Developments		15,000	22,000	29,000
Total	332,260	370,260	412,260	413,260

¹ It is projected that the future abandonment of least suitable lands will decrease the amount of present irrigated and idle lands.

New irrigated land developments planned by the Bureau of Reclamation by 1980 include 16,000 acres of the Seedskadee Project, about 7,000 acres of the Savery-Pot Hook Project, and about 3,000 acres of the Eden Project. An additional 41,000 acres are projected for development in the Seedskadee Project by the year 2000 (Table III-7). Lands within these projects have been classified by the Bureau of Reclamation, and the soils are suitable for irrigation. When planned, the projects had the financial ability to repay allocated annual costs and provide a profitable irrigation enterprise.

Privately irrigated lands projected for future development are estimated to amount to 15,000 acres by 1980, an additional 7,000 acres by the year 2000, and another 7,000 acres by 2020, for a total of about 29,000 acres. The projected new private irrigation generally will be enlargements of existing developments.

Opportunities for new private irrigation include lands under the Highland Canal at Pinedale, the Paradise Canal near Boulder, and the Canyon Canal in the 40 Rod Flat area. The Green River Supply Canal near Big Piney could serve an additional 3,000 to 5,000 acres. Some new lands could be developed by utilizing the existing canal as part of the proposed project to provide a supplemental water supply for existing irrigated lands in the Big Piney area. A single purpose development of any substantial acreage of new lands would be of marginal feasibility.

A 1968 preliminary economic evaluation of existing irrigated lands under the proposed Green River Supply Project indicates that lands in the area receiving an adequate water supply would provide a net return to land and management of about \$8.25 per acre. Some financial and credit assistance would be necessary for this proposed development.

A Green River water right permit has been granted to the Uinta Development Company to irrigate about 58,000 acres lying west of the Green River

near Green River, Wyoming. This private irrigation project could be accomplished in conjunction with industrial development in the lower Green River Basin.

It is estimated that about 15,000 acres of presently irrigated lands will be abandoned by the year 2020. This is approximately one percent per year abandonment of lands classified by the Soil Conservation Service as having severe crop limitations. These soils have salinity or alkalinity problems and will tend to decline in production and become unprofitable for irrigated crop or pasture production.

Yield projections are based on data provided by the University of Wyoming, the Great Plains Agricultural Council, and the Economic Research Service. Current normal and projected yields were established for each land resource area and extended to the Basin for average yields. Current normal and projected yields are presented in Table III-8.

Changes in crop distribution for 1980 were determined by the University of Wyoming as a part of the Agricultural Sector Study. Historical trends were used to establish these changes in land use and crop distribution and were extended to the years 2000 and 2020 with minor adjustments (Table III-8). Projections will need to be adjusted periodically, but they do provide a means of estimating future agricultural production.

Water Resource Requirements

Present Water Uses and Needs

Most of the water presently used in the Basin is for irrigation. Water consumption varies with the kind of crop and with climatic factors such as temperature, humidity, and radiation. Irrigation must provide the major portion of the water necessary for dependable crop production because of limited precipitation in the Green River Basin.

The climatic factors which determine consumptive use of water are closely related to physical features such as latitude and elevation. In order to estimate irrigation water use, the Basin was subdivided into smaller study areas. The study areas are shown on Figure III-2.

Estimates of water consumed by grass hay for a full season vary from less than one acre-foot per acre in the Upper Green River area (Study Area 1) to about one and one-third acre-foot per acre in the lower, warmer areas of the Basin which have a longer growing season (Study Areas 5 and 6). Consumptive use rates determined for the Upper Colorado Region Framework Study were used to estimate the depletion of water in the Basin. The estimated present consumptive use of water by irrigation in the Basin is 241,600 acre-feet per year.

The estimated evaporation from irrigation reservoirs is 9,900 acre-feet per year, and the evaporation from stock ponds is presently about 2,400 acre-feet per year. The evaporation at Fontenelle Reservoir is estimated to be 14,000 acre-feet per year. The total evaporation loss is 26,300 acre-feet per year. The present annual streamflow depletion by agriculture (crop consumptive use and evaporation) totals 267,900 acre-feet per year.

TABLE III-8 -- Irrigated Lands-Yields, Distribution and Production

<u>Projected Yields</u>	<u>Unit</u>	<u>Current Normal Yield</u>	<u>1980 Yield</u>	<u>2000 Yield</u>	<u>2020 Yield</u>
<u>Crop</u>					
Alfalfa	Tons/acre	2.0	2.95	3.4	3.8
Improved Hay	Tons/acre	1.6	1.8	2.0	2.4
Native Hay	Tons/acre	1.1	1.2	1.3	1.4
Barley	Bu./acre	42.9	48.5	58.0	68.0
Oats	Bu./acre	34.4	34.4	46.0	57.0
Pasture	AUM/acre	2.0	2.0	2.2	2.4
<u>Aftermath Grazing</u>					
Alfalfa	AUM/acre	.5	.5	.5	.5
Improved Hay	AUM/acre	1.0	1.0	1.0	1.0
Native Hay	AUM/acre	1.0	1.0	1.0	1.0
Small Grain	AUM/acre	1.25	1.25	1.25	1.25
<u>Crop Distribution</u>					
		<u>Current Normal Acres</u>	<u>1980 Acres</u>	<u>2000 Acres</u>	<u>2020 Acres</u>
<u>Crop</u>					
Alfalfa		20,335	40,025	58,000	62,000
Improved Hay		75,780	105,250	132,000	138,000
Native Hay		99,360	94,160	84,000	74,000
Barley		3,710	5,420	14,000	16,000
Oats		970	---	---	---
Pasture		101,985	96,320	96,000	96,000
Other		1,000	---	---	---
Idle		29,120	29,085	28,260	27,260
Total		332,260	370,260	412,260	413,260
<u>Crop Production</u>					
	<u>Unit</u>	<u>Current Normal¹</u>	<u>1980¹</u>	<u>2000</u>	<u>2020</u>
<u>Crop</u>					
Alfalfa	Ton	40,670	118,075	197,200	235,600
Improved Hay	Ton	121,250	189,450	264,000	331,200
Native Hay	Ton	108,890	112,670	109,200	103,600
Barley	Bu.	159,060	262,730	812,000	1,088,000
Oats	Bu.	33,370	---	---	---
Pasture	AUM	204,405	193,135	211,200	230,400
Aftermath Grazing	AUM	191,155	226,195	226,500	263,000

¹ The current normal and 1980 production may not be precisely the product of yield times acres due to disaggregation of data to conform to the Green River Basin.

Source--University of Wyoming, The Great Plains Agricultural Council, Economic Research Service, and Wyoming Water Planning Program

Most irrigation is by direct diversion from streams, and flood irrigation is the principal method of application. Border dike irrigation is gaining popularity in some areas and is the principal means of irrigation in the Eden Project. Sprinkler irrigation is used to a very small extent. An automatic rotating sprinkler system is used successfully on the Seedskadee Development Farm.

Irrigation diversion requirements depend upon the crop and the losses incurred in getting water from the source into the root zone. Most losses accrue to groundwater and eventually appear as return flow. Although few specific studies of irrigation efficiencies in the Basin have been made, it is apparent that the commonly used flood irrigation methods are inefficient. This is because diversions are made with maximum ditch capacities during the peak runoff season when water is plentiful but crop consumption is low. Later in the season, when streamflows are lower, irrigation efficiencies increase because the use of the available water supply is maximized. Late-season water shortages occur in many areas of the Basin, and irrigation practices and crops have largely been adapted to this situation. For example, the production of native hay and pasture is accomplished by irrigating until water supplies run short in late July or August, at which time the hay is harvested. Some areas have water shortages by mid-July that restrict yields of the native grasses. Improved water supply distribution would enhance present operations, and, if water availability could be extended through August, more profitable crops could be grown.

Construction of reservoirs to store spring runoff for late-season use is an obvious solution to improving the water supply. This has been done on some tributaries where feasible damsites exist. The principal reservoirs are listed in Table III-9 and located on Figure III-3. Nearly all the reservoirs in the Basin are used at least partly for irrigation. More reservoir storage is needed to provide water for late-season irrigation. Even with storage some streams lack water to firm up irrigation water supplies. In these cases, water supplies from adjacent areas may be required to supplement the local supply.

Areas that need water supply improvements to provide ample water for existing development are as follows:

Study Area 1 -- Upper Green River: Approximately 49 percent of the irrigated lands in Area 1 receive a full-season water supply. Lands irrigated from the Green River and the New Fork River and its tributaries generally have a full-season water supply. Irrigation from the East Fork has annual water shortages in July. No feasible storage sites have been found on East Fork. Improvement of the water supply may be possible by utilizing water from Silver Creek or Boulder Creek, and studies by the Bureau of Reclamation include these possibilities. Pole and Fall Creeks could also be developed to improve local water supplies and provide water for new development. An additional water supply might be obtained from alluvial aquifers.

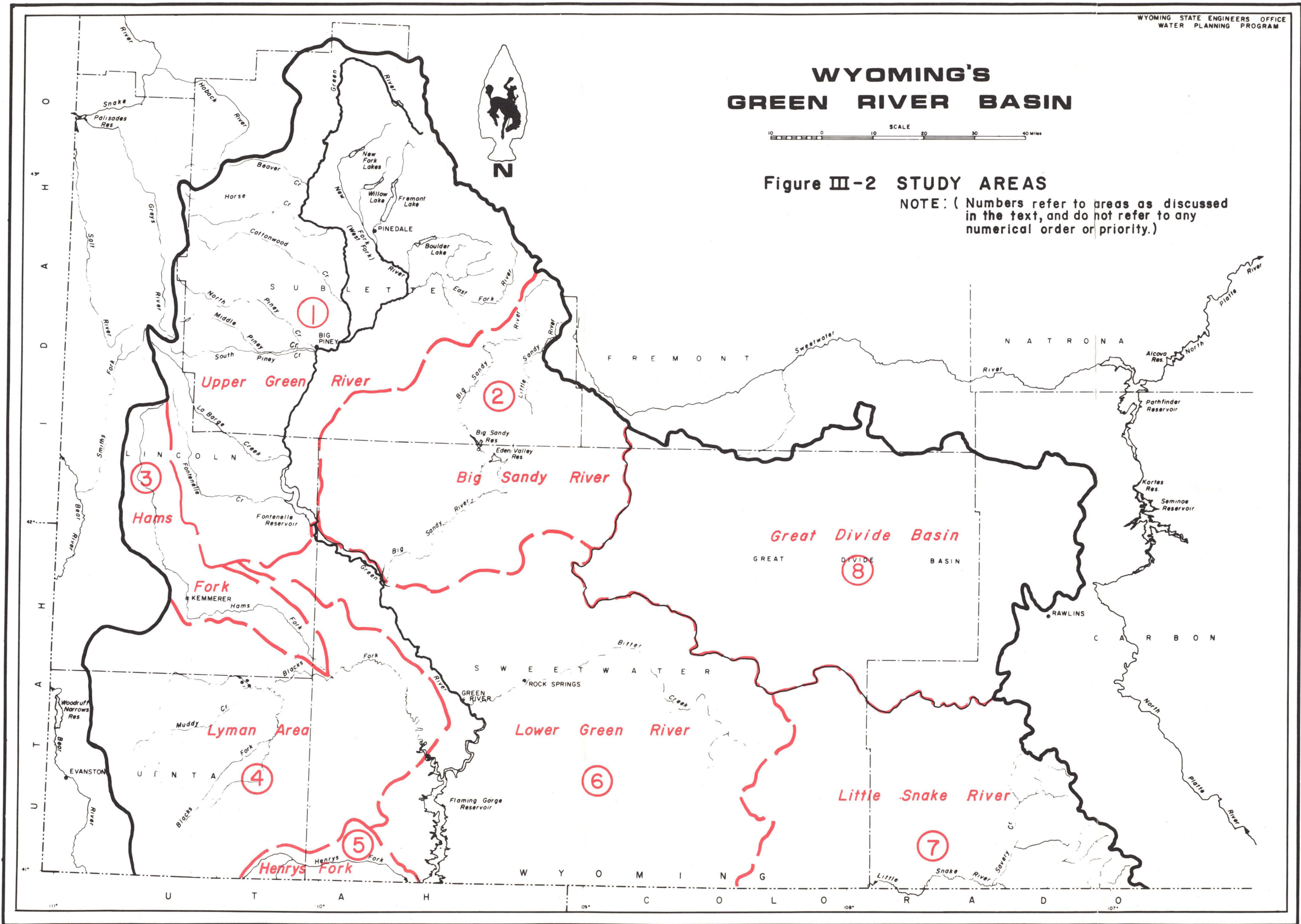
Nearly all of the lands irrigated from tributaries entering the Green River from the west have late-season water shortages. Few suitable reservoir sites have been found. The irrigated lands in the vicinity of Big Piney could receive supplemental water from the Green River through an extension of the Green River Supply Canal. Water supply studies show that

WYOMING'S GREEN RIVER BASIN



Figure III-2 STUDY AREAS

NOTE: (Numbers refer to areas as discussed in the text, and do not refer to any numerical order or priority.)



providing supplemental water in August of most years will require storage on the Green River.

Study Area 2 -- Big Sandy River: Approximately 75 percent of the irrigated lands in Area 2 receive a full-season water supply. The Bureau of Reclamation has determined that supplemental water is needed for the 17,000 acres presently irrigated in the Eden Project. Additional water is also needed to bring the remaining 3,100 acres of the Project into production. The source of water for these purposes would be the New Fork River and its tributaries.

Study Area 3 -- Hams Fork: Approximately 39 percent of the irrigated lands in Area 3 receive a full-season water supply. Industry may eventually use all of the remaining early-season water from Hams Fork. At the present time there are two proposed Soil Conservation Service projects under Public Law 566 on Hams Fork to develop irrigation, municipal, and industrial water.

Study Area 4 -- Lyman Area: Approximately 37 percent of the irrigated lands in Area 4 receive a full-season water supply. The authorized U. S. Bureau of Reclamation Lyman Project will provide storage for lands irrigated from Smiths Fork and Blacks Fork. Meeks Cabin Dam on Blacks Fork, with an active capacity of 33,000 acre-feet, is now under construction. China Meadows Dam on East Fork of Smiths Fork will provide 13,000 acre-feet of storage.

Study Area 5 -- Henrys Fork: Approximately 47 percent of the irrigated lands in Area 5 receive a full-season water supply. Three reservoirs in Utah serve lands in Wyoming irrigated from Henrys Fork. Although irrigation shortages do exist, no additional feasible storage reservoir sites have been found.

Study Area 6 -- Lower Green River: Lands irrigated from the main stem of the Green River have a full-season water supply. Lands irrigated from tributaries have severe water shortages. Approximately 20 percent of the irrigated lands in Area 6 receive a full-season water supply. The authorized Seedskaadee Project has a potential of 57,000 irrigated acres for which 90,000 acre-feet of Fontenelle Reservoir storage capacity have been allocated.

Study Area 7 -- Little Snake River: Approximately 33 percent of the irrigated lands in Area 7 receive a full-season water supply. The authorized U. S. Bureau of Reclamation Savery-Pot Hook Project will provide supplemental water to about 10,700 acres and will bring about 7,000 acres of new land into production in Wyoming. Savery Reservoir, with a capacity of 18,600 acre-feet, will be the Wyoming storage feature of this project.

Study Area 8 -- Great Divide Basin: There is an extremely small amount of irrigated land in the Great Divide Basin. Surface water supplies are very meager and unreliable. Groundwater supplies are available for most purposes.

Future Water Requirements

Table III-10 shows the estimated average annual streamflow depletions due to projected irrigation increases in the Basin through the year 2020. Annual depletions will increase from the present 267,900 acre-feet to 414,900 acre-feet by the year 2020. This includes authorized projects and other probable developments. It has historically been difficult to perfect

TABLE III-9 -- Principal Reservoirs in the Green River Basin
(Reservoirs of over 1,000 Acre-Foot Capacity)

Reservoir	Capacity Acre-Feet	Use ¹	Water Source
Big Sandy	39,700	I,F&WL,R	Big Sandy River
Black Joe Lake	1,102	I	Black Joe Creek
Boulder Lake	22,280	I,F&WL,D	Boulder Creek
Bush Creek	17,267	I,S,D	Bush Creek
Bush Lake	1,686	I&S	Bush Creek
Divide	1,027	I,S,D	Divide Creek
Eden	18,490	I,D	Big Sandy River and Little Sandy River
Elkhorn	1,450	I&S	Little Sandy River
Flaming Gorge	3,789,000	I,P,F&WL,R	Green River
Fontenelle	345,000	D,I,M&I,F&WL,P	Green River
Fremont Lake	10,763	I,S,D	Pine Creek
Hay Reservoir	8,327	I,S,D	Red Creek
Kemmerer #1	1,058	M&I	Hams Fork
McNinch #1	1,086	I,S,D	North Piney Creek
Meeks Cabin	33,090	I	Blacks Fork
Middle Piney	4,201	I,S,D	Middle Piney Creek
New Fork Lake	20,340	I	West Fork of New Fork River
Patterson Lake	1,237	I	Blacks Fork River
Silver Lake	933	I,S	Silver Creek
Sixty-Seven	5,211	I,S,D	North Piney Creek
Lake Eva Naughton	42,393	M&I,P,D	Hams Fork
Willow Lake	18,816	I,S,D	Lake Creek

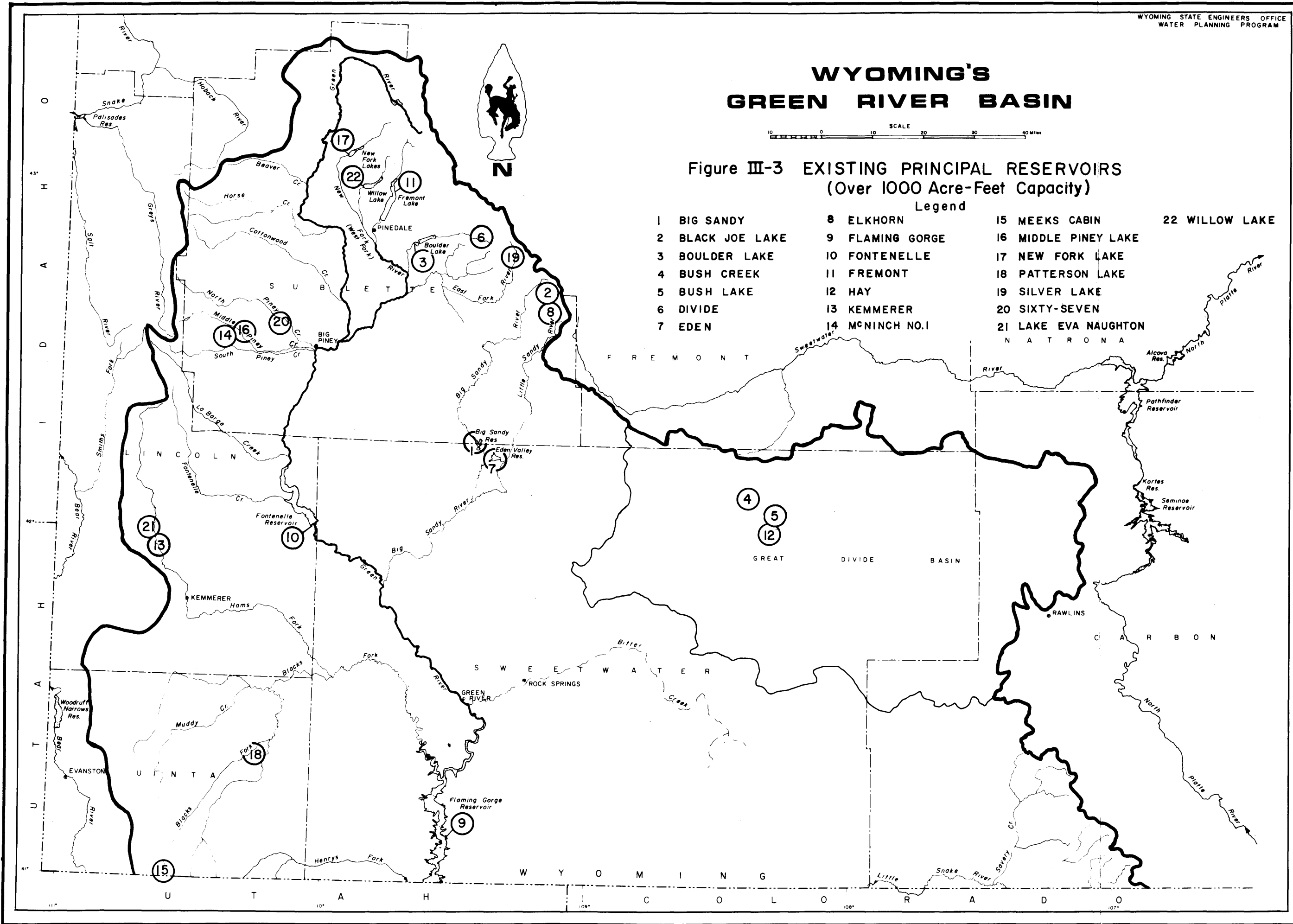
¹ I-Irrigation; M&I-Municipal and Industrial; P-Power; F&WL-Fish and Wildlife; R-Recreation; S-Stock; D-Domestic.

WYOMING'S GREEN RIVER BASIN



Figure III-3 EXISTING PRINCIPAL RESERVOIRS
(Over 1000 Acre-Feet Capacity)

- Legend
- | | | | |
|------------------|-----------------|----------------------|----------------|
| 1 BIG SANDY | 8 ELKHORN | 15 MEEKS CABIN | 22 WILLOW LAKE |
| 2 BLACK JOE LAKE | 9 FLAMING GORGE | 16 MIDDLE PINEY LAKE | |
| 3 BOULDER LAKE | 10 FONTENELLE | 17 NEW FORK LAKE | |
| 4 BUSH CREEK | 11 FREMONT | 18 PATTERSON LAKE | |
| 5 BUSH LAKE | 12 HAY | 19 SILVER LAKE | |
| 6 DIVIDE | 13 KEMMERER | 20 SIXTY-SEVEN | |
| 7 EDEN | 14 MCNINCH NO.1 | 21 LAKE EVA NAUGHTON | |



new irrigation in an area of short growing season. If the projected depletion, the West Side Project, the East Side Project, and the private development all occur, the depletions from irrigation will be about 579,000 acre-feet per year by the year 2020.

TABLE III-10 -- Projected Accumulated Increases in Irrigated Acreages and Streamflow Depletions in the Green River Basin, Wyoming

Description	Present		1980		2000		2020	
	Acres	Depletion Acre-Feet/year	Acres	Depl. A-F/yr	Acres	Depl. A-F/yr	Acres	Depl. A-F/yr
Present Irrigation	332,260	267,900 ¹	332,260	267,900	332,260	267,900	332,260	267,900
Reduction in Least Suitable Lands			(-3,000)		(-9,000)		(-15,000)	
Committed								
Seedskaadee			16,000	24,000	57,000	86,000	57,000	86,000
Lyman			Supplemental	10,000		10,000		10,000
Savery Pot Hook			7,000 + Supplemental	12,000	7,000	12,000	7,000	12,000
Private Irrigation			15,000	15,000	22,000	22,000	29,000	29,000
Eden Improvement			3,000	10,000	3,000	10,000	3,000	10,000
Total Identified	332,260	267,900	370,260	338,900	412,260	407,900	413,260	414,900

Alternates of irrigation not identified above:²

West Side Project--Supplemental supply for Big Piney area lands, plus development of up to 25,000 acres new land--depletion up to 50,000 acre-feet.

Big Piney area supplemental supply³--no new land--depletion 7,000 acre-feet.

East Side--22,000 acres new land--depletion 32,000 acre-feet.

Uinta Development Co. Project--Study Areas 4 and 6--58,000 acres new land--depletion 82,000 acre-feet.

¹ Includes depletions from irrigation and evaporation from existing reservoirs and stock ponds. Assumed not to change from reduction in amount of least suitable lands because supplemental supplies will use saved water.

² These projects not forecast as to time of construction.

³ Alternate to the West Side Project.

MINERAL RESOURCES AND INDUSTRIES

In 1967 Wyoming ranked 12th among the states in the value of mineral production, as reported by the U. S. Bureau of Mines. Wyoming's mineral production and rank in national mineral production are increasing, and the present economy of the State is greatly dependent upon the mineral industries.

Wyoming has very little manufacturing to serve as a market for mineral products; therefore, the mineral industry relies on the production of raw materials that can be shipped to distant markets and yet be competitive.

In September of 1968, Cameron Engineers of Denver, Colorado, was commissioned by the Wyoming Natural Resource Board and the State Engineer to study the existing mineral resources and industries of Wyoming, and project to the year 2020 mineral development, water and utility requirements, employment, and the probable economic benefits to the State. That report is the basis for the following discussion on the mineral industries in the Green River Basin.

Mineral resources of the Green River and Great Divide Basins include coal, petroleum, oil shale, uranium, and trona. Also included in the following discussion is a description of the Basin's timber industry.

Coal

Existing Conditions

Coal was first mined in Wyoming in 1868 by the Union Pacific Railroad at Carbon, Wyoming. Forty years later coal mining was Wyoming's leading industry, producing over six million tons in 1908, one-third of which came from the Rock Springs area.

The railroads were the largest consumers of coal in Wyoming until the conversion to diesel locomotives in 1953. Sweetwater, Carbon, and Sheridan Counties were most seriously affected by this conversion.

Though coal is now practically unused by railroads, coal production in Wyoming has increased since its low in 1958 because of the demand for power plant fuel. Today over 79 percent of all coal mined in Wyoming is used in electric power generation.

Reserves and Present Development

A map of the coal resources in the Basin is shown in Figure III-4. Table III-11 shows the coal reserves of counties wholly or mostly within the Basin.

TABLE III-11 -- Green River Basin Coal Reserves by County
(Millions of Tons)

County	Estimated Original Reserves	Estimated Production Prior to 1950	Production 1950 to 1968	Estimated Unrecover- able	Remaining Reserves 1968
Lincoln	2,825	36	11	12	2,766
Sublette	7				7
Sweetwater	14,909	194	19	348	14,348
Uinta	<u>2,049</u>				<u>2,049</u>
Green River Basin	19,790	230	30	360	19,170

In 1967 the only coal-burning power plant in operation in the Green River Basin was Utah Power and Light's Naughton Plant, with a generating capacity of 163 megawatts (a megawatt is 1,000 kilowatts). The plant consumed 534,000 tons of coal in 1967 while operating at an average of 69 percent capacity. Utah Power and Light has recently installed a second (220-megawatt) generating unit at its Naughton Plant and at the present time is constructing a third unit at the Naughton Plant. This unit will have a generating capacity of 330-megawatts and is expected to be completed in 1972. Pacific Power and Light Company is building a 1,500-megawatt plant near Superior, Wyoming.



WYOMING'S GREEN RIVER BASIN

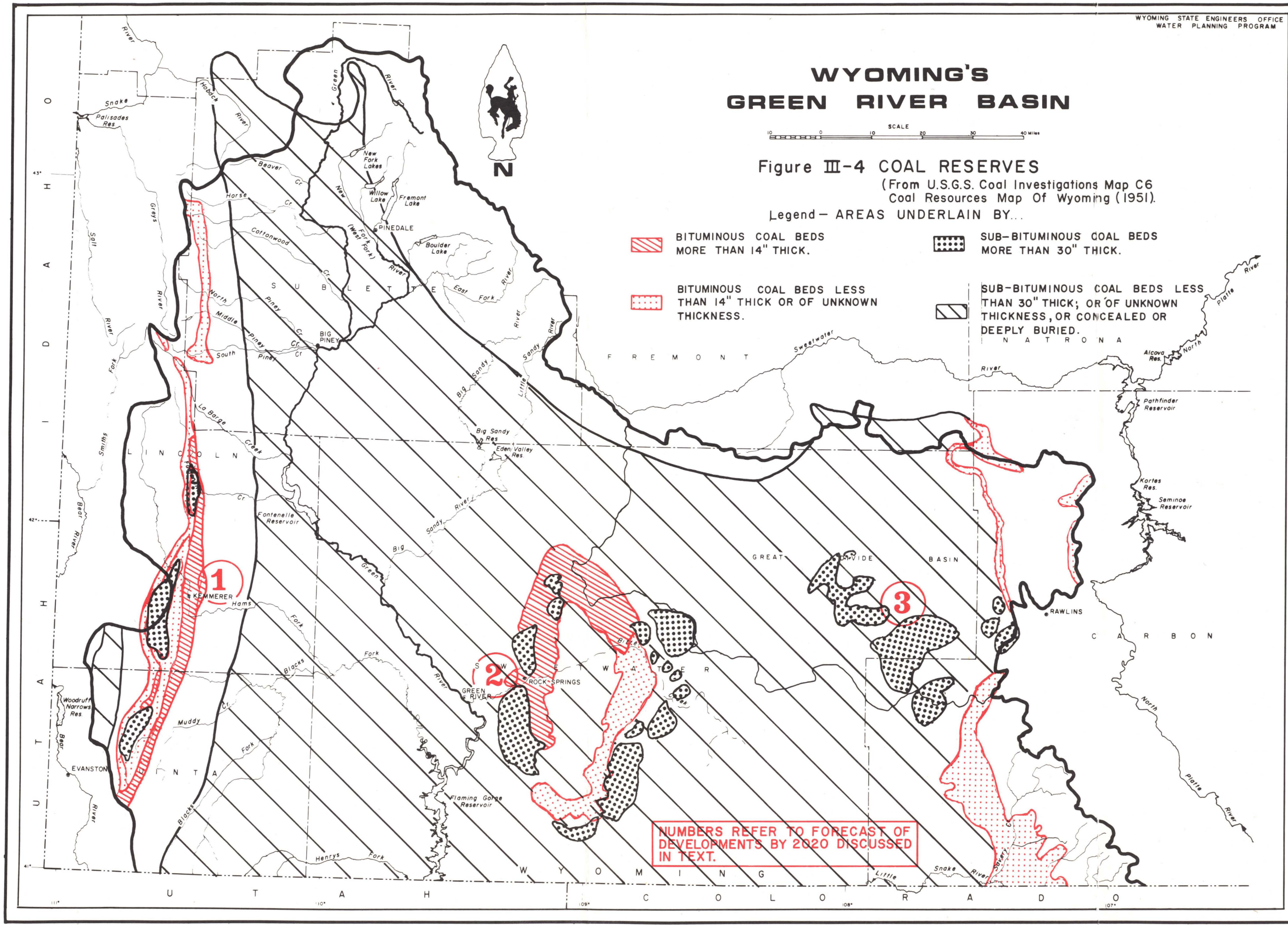
SCALE 0 10 20 30 40 MILES

Figure III-4 COAL RESERVES

(From U.S.G.S. Coal Investigations Map C6
Coal Resources Map Of Wyoming (1951).)

Legend - AREAS UNDERLAIN BY...

-  BITUMINOUS COAL BEDS MORE THAN 14" THICK.
-  SUB-BITUMINOUS COAL BEDS MORE THAN 30" THICK.
-  BITUMINOUS COAL BEDS LESS THAN 14" THICK OR OF UNKNOWN THICKNESS.
-  SUB-BITUMINOUS COAL BEDS LESS THAN 30" THICK; OR OF UNKNOWN THICKNESS, OR CONCEALED OR DEEPLY BURIED.



NUMBERS REFER TO FORECAST OF DEVELOPMENTS BY 2020 DISCUSSED IN TEXT.

Two small experimental coking plants operating in the Green River Basin are probably forerunners of large commercial plants. Both plants operate continuously and supply coke to the phosphorous industry. The Kemmerer Coal Company, through its subsidiary Gunn-Quealy Company, operates a carbonizer at Quealy six miles south of Rock Springs. In 1968 the carbonizer processed 30,000 tons of coal to produce an estimated 15,000 tons of coke. The FMC (Food Machinery Corporation) Coke Plant near Kemmerer processed more than 114,000 tons of coal to produce an estimated 60,000 tons of coke in 1968.

Economic Importance

In 1968 the coal industry in the Green River Basin paid approximately \$18,000 in property taxes and over \$77,500 in gross production taxes. A State severance tax was put into effect in 1969, but figures on income to the State from this tax are not yet available. In addition, the coal industry pays sales, service, and use taxes. From July 1, 1966, to June 30, 1967, this amounted to \$6,300 for sales and service taxes and \$2,660 for use taxes on a statewide basis. The State received an income from royalties and rentals of coal lands in Wyoming totaling \$322,350 in 1967.

Growth Factors

Wyoming coal is used to produce power which is consumed both within and outside the State. Coal is also shipped out of the State for power generation elsewhere.

It has been estimated that by 1972 the total requirement for Wyoming coal for power generation will have increased from 1968's 3.04 million tons a year to 5.75 million tons a year, due to completion of the plants now under construction.

Nuclear power will be slow to replace fossil-fuel power in Wyoming because of an adequate supply of low-cost fuels. Cameron estimates that starting in 1990 and continuing through 2020, nuclear power will provide about ten percent of the power production in the State.

Two factors are expected to increase the amount of coal used to make coke for the phosphorus industry. The first factor is the projected expansion of the phosphorus industry. The second is that the former sources of metallurgical coke in Illinois are becoming less dependable, or the coke less desirable, indicating that Wyoming coal may be the source of most of the future requirements of the industry.

The thickness and availability of Wyoming coal deposits at relatively low cost make them attractive for possible conversion to synthetic fuels. Whereas Wyoming coal has been unable to compete economically in the large markets like Chicago, liquid fuels derived from coal can be transported at relatively low cost and should supply a share of that market by 1980. Similarly, by the 1980's gas made from coal in Wyoming might reach large markets like those in Minneapolis by pipeline. Cameron assumes that technological developments will occur which will make synthetic fuels competitive in markets now satisfied by natural oil and gas.

The projected growth of the coal industry in the Basin is shown in Table III-12. The impact to the Basin is presented in terms of production,

employment, payroll, capital investments, water consumption requirements, and electric power requirements. It may be seen that the industry can have a pronounced effect on employment with a projected fourfold increase by the year 2000 and a twelvefold increase by 2020. Capital investments would increase about nine times by the year 2000 and 38 times by 2020. The location of developments by the coal industry in the Basin as projected by the Cameron Report through the year 2020 are shown in Figure III-4. Area number one (1) on the map will, according to the report, have eight coal mines, four steam-electric power plants, one synthetic liquid fuel plant, one gasification plant, and four coal carbonizers. Area number two (2) will have six coal mines, two steam-electric power plants, one synthetic liquid fuel plant, and three coal carbonizers. Area number three (3) will have four coal mines, two steam-electric power plants, and one gasification plant.

TABLE III-12 -- Projected Growth of the Coal Industry in the Green River Basin

	<u>1967</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>Steam Electric Plants</u>				
Number of Plants	1	2	2	8
Average Output, billion kwh	.981	12.04	12.04	64.60
Value of Power, million dollars	2.94	36.12	36.12	193.80
Number of Employees	47	152	152	412
Annual Payroll, million dollars	.376	1.216	1.216	3.296
Capital Investment, million dollars	57	232	232	1,012
Water Required, thousand A-F/year	5	22	22	112
<u>Synthetic Liquid Fuels Plants</u>				
Number of Plants			1	2
Amount Produced, million barrels			27.38	54.76
Value of Fuel, million dollars			82.14	164.28
Number of Employees			200	400
Annual Payroll, million dollars			1.6	3.2
Capital Investment, million dollars			300	600
Water Required, thousand A-F/year			15	30
Power Required, million kwh/year			24	48
<u>Synthetic Gas Plants</u>				
Number of Plants				2
Amount Produced, billion cu. ft./year				219
Value of Gas, million dollars				31.974
Number of Employees				400
Annual Payroll, million dollars				3.2
Capital Investment, million dollars				600
Water Required, thousand A-F/year				30
Power Required, million kwh/year				48

TABLE III-12 -- Continued

	<u>1967</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>Carbonizing Industry</u>				
Number of Plants	2	2	4	7
Production,				
million tons of coke	.061	.5	.75	1.5
Value of Coke, million dollars	.915	7.5	11.25	22.5
Number of Employees	40	40	70	102
Annual Payroll, million dollars	.32	.31	.55	.81
Capital Investment,				
million dollars	3	8	16	28
Water Required,				
thousand A-F/year	2	4	8	14
Power Required,				
million kwh/year	2.3	6.0	10.0	18.0
<u>Coal Mining Industry (for all purposes)</u>				
Number of Mines	3	4	7	18
Production, million tons	.864	8.02	20.12	82.61
Number of Employees	183	412	736	1,870
Annual Payroll, million dollars	1.65	3.71	6.62	16.82
Capital Investment,				
million dollars	5.5	26	59	226
Water Required,				
thousand A-F/year	---	---	---	---
Power Required,				
million kwh/year	3.7	49	111	375
<u>Summary of the Coal Industry</u>				
Number of Employees	270	604	1,158	3,184
Annual Payroll, million dollars	2.35	5.23	9.98	27.32
Capital Investment,				
million dollars	65.5	266	607	2,466
Amount of Coal Mined,				
million tons/year	.864	8.02	20.12	82.61
Water Required,				
thousand A-F/year	7	26	45	186
Power Required,				
million kwh/year	6	55	145	489

Water Resource Requirements

Table III-12 shows the present and future water requirements of the Green River Basin coal industry. The present consumptive use of about 7,000 acre-feet per year is forecasted to increase to 26,000 by year 1980, to 45,000 by year 2000, and to 186,000 acre-feet by year 2020.

Oil and GasExisting Conditions

Crude oil seeps were known to the Indians and early travelers but were of little interest before the advent of the automobile. The discovery of

the huge Salt Creek Field in Natrona County in 1906 resulted in a period of rapid growth of both oil and natural gas production to a peak high in 1923. Although the pace of early growth varied, there was a period of sustained exploration and increased oil and gas production from 1933 to the early 1960's. Present Wyoming production is about 140,000,000 barrels of oil and 270,000,000 cubic feet of gas annually.

Table III-13 shows the importance of the oil and gas industry in the Green River Basin.

TABLE III-13 -- Total Oil, Natural Gas, and Natural Gas Liquids Production and Gross Value for Counties Within the Green River Basin for 1967 and a Comparison with State Figures (Production occurs within Green River Basin boundaries)

County	CRUDE OIL		NATURAL GAS		NATURAL GAS LIQUIDS		TOTAL VALUE \$Million
	Gross Production, 1,000 Barrels	Gross Value \$Million	Gross Production Million Cubic Ft.	Gross Value \$Million	Gross Production 1,000 Barrels	Gross Value \$Million	
Lincoln	322	0.9	7,981	1.29	234	0.51	2.7
Sublette	3,569	10.0	75,415	12.09	2,213	4.80	26.9
Sweetwater	8,703	25.2	55,535	7.80	1,629	3.53	36.5
Uinta			4,721	.73	138	0.30	1.0
Green River Basin	12,594	36.1	143,652	21.91	4,214	9.14	67.1
Wyoming	138,666	357.8	265,848	38.71	7,798	16.9	413.4
U. S. A.	3,037,579	9,375.7	18,380,838	2,899.0	644,493	1,180	13,454.4
Green River Basin Share of Wyoming Total	9.1%	10.1%	54%	56.6%	54%	54%	16%
Wyoming Share of U. S. Total	4.6%	3.8%	1.4%	1.3%	1.2%	1.4%	3.1%

Reserves and Present Development

The Green River and Great Divide Basins of Wyoming have somewhat more than 50 percent of Wyoming's total gas reserves and annual (1967) production, but less than ten percent of the State's total oil reserves and production. Table III-13 shows the 1967 estimated gross production and gross field value of crude oil, natural gas, and natural gas liquids by county in the Green River Basin. The Basin totals are compared with Wyoming totals, which in turn are compared with the U. S. totals.

Figure III-5 shows the location of the oil and natural gas fields in the Basin.

Economic Importance

The oil and gas industry provides a significant payroll in Wyoming. In terms of taxes paid, the industry is the State's most important. In 1968 it paid slightly more than 30 percent of all property taxes collected in Wyoming.

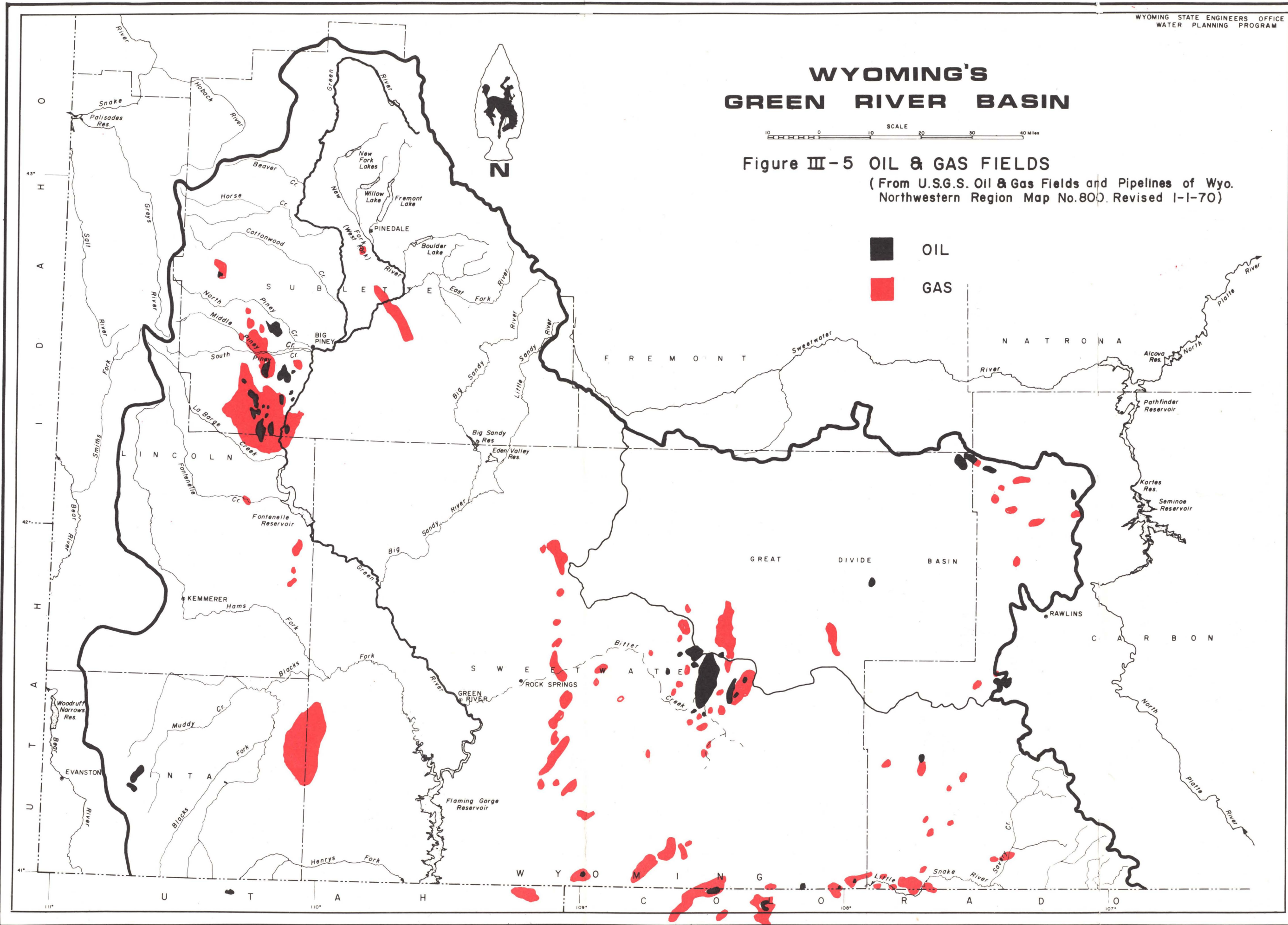
Benefits to the State accrue in the form of a production tax, a conservation tax, a severance tax, ad valorem property taxes, sales and use taxes, state royalties, the State's share of federal royalties, private

WYOMING'S GREEN RIVER BASIN



Figure III-5 OIL & GAS FIELDS
(From U.S.G.S. Oil & Gas Fields and Pipelines of Wyo.
Northwestern Region Map No.800. Revised 1-1-70)

- OIL
- GAS



royalties, and lease bonuses and filing fees. Other benefits are payroll unemployment taxes and vehicle registration and license fees.

Growth Factors

The oil and gas industry is extractive with an apparent finite limit of the resources. It must be recognized that the industry will decline and may in time pass out of existence.

Several factors may have an effect on the future of the industry. Some of these are:

1. No market constraint on production will be enacted because of the petroleum deficient situation in the United States. It appears that the domestic deficit will become more severe in the future.

2. Any significant change in economic parameters such as changes in prices, taxes, or import policies will affect the rate of discovery and production.

3. Any increase in the price of crude oil that encourages discovery and production will also hasten the development of alternative sources of liquid fuels such as coal and oil shale.

4. A decrease in the cost of exploration, or the development of new techniques would result in an increased rate of discovery.

The average crude oil production rate is projected to remain at its present level through 1972 and then decline until the year 1990, after which it will remain constant through the forecast period (Table III-14).

TABLE III-14 -- Projected Growth and Decline of the Petroleum Industry in the Green River Basin of Wyoming

	1967	1972	1980	2000	2020
Crude Oil					
Production, Million Barrels	13.70	14.10	7.60	2.90	2.90
Value, Million Dollars	35.34	36.38	10.61	7.48	7.48
Employment	250	300	155	80	80
Annual Payroll, Million Dollars	2.25	2.70	1.395	.72	.72
Water Consumed, Acre-Feet/Year	4,200	5,500	3,400	1,600	1,600
Power Required, Million kwh/Year	39.15	40.37	30.27	20.18	20.18
Natural Gas					
Production, Billion Cubic Feet	143.26	141.50	141.50	56.60	56.60
Value, Million Dollars	20.87	20.66	20.66	8.26	8.26
Employment ¹	212	372	202	142	112
Water Consumed, Acre-Feet/Year	11.50	11.50	11.50	11.50	11.50
Water Diverted, Acre-Feet/Year	23.00	23.00	23.00	23.00	23.00
Power Required, Million kwh/Year	1.12	1.12	1.12	.56	.56
Natural Gas Liquids					
Production, Million Barrels	2.06	1.66	1.66	.66	.66
Value, Million Dollars	3.76	3.02	3.02	1.20	1.20
Water Consumed, Acre-Feet/Year	300	300	200	200	200
Water Diverted, Acre-Feet/Year	1,600	1,500	1,400	600	600
Power Required, Million kwh/Year	.53	.53	.53	.26	.26
Other (Including Service Supply)					
Employment	530	530	310	150	150
Power Required, Million kwh/Year	1.39	1.39	.83	.28	.28
Total Petroleum Industry in the Green River Basin²					
Employment		1,200	670	370	340
Water Consumed, Acre-Feet/Year	4,500	5,800	3,600	1,800	1,800
Power Required, Million kwh/Year	42.19	43.41	32.75	21.28	21.28

¹ Includes natural gas liquids.

² Difference in industry totals due to rounding.

The production rate for natural gas is forecasted to remain at about its present level through 1980, then decline gradually to about one-quarter of its present rate by the year 2000, after which it will remain constant.

Water Resource Requirements

Table III-14 shows the present and future water requirements of the Green River Basin oil and gas industry. Total water consumed by the industry in 1967 was about 4,500 acre-feet, of which 4,200 acre-feet were used in the waterflood production of crude oil. It is common practice to use water produced along with the oil for waterflood operations. However, in practically all such operations, additional water is obtained from underground aquifers.

Oil Shale

Existing Conditions

The demand for liquid hydrocarbon fuels in the United States in 1968 exceeded the domestic supply by 2,700,000 barrels per day. The deficit was met by imports. Projections that include development of Alaskan north slope oil supplies show that the ability of the Nation to supply its own liquid fuel requirements from natural crude oil will probably decrease.

Oil shale and coal are available domestically in huge quantities and will be developed to help meet the Nation's liquid fuel deficiency. The technology for mining and processing oil shale is well developed. Other processes, such as in situ (in place) retorting, are being explored.

All of the oil shale lands in Wyoming are located within the boundaries of the Green River Basin; the Federal Government owns about 62 percent of these lands. A Federal oil shale policy has not been developed as yet, and Federal oil shale lands have not been leased. The State of Wyoming has not leased State-owned oil shale land. The development of an oil shale industry will be expedited by the solution of the legal and administrative problems relating to the oil shale lands.

Reserves and Present Development

The largest and most important oil shale formation in the United States, the Green River formation, covers a total of 11 million acres in Colorado, Utah, and Wyoming. Figure III-6 shows the extent of the oil shale deposits in Wyoming.

Acreages of oil shale lands within Wyoming, Utah, and Colorado are as follows:

<u>State</u>	<u>Acreage--Green River Formation</u>
Wyoming	4,260,000
Utah	4,917,000
Colorado	<u>1,826,000</u>
Total	11,003,000

Of those areas where the Green River formation will yield 25 to 65 gallons of oil per ton of shale, about 30 billion barrels are in the Green River Basin of Wyoming, about 90 billion barrels are in Utah, and 450 to 500 billion barrels of oil equivalent are in Colorado. Known deposits that yield 10 to 25 gallons of oil per ton contain 400 billion barrels of oil in Wyoming, 230 billion barrels in Utah, and about 800 billion barrels in Colorado.

Economic Importance

A commercial oil shale industry does not now exist in the United States. Such an industry in Wyoming, Colorado, and Utah appears to have great promise and would be of tremendous economic importance to the region. Considerable money has been spent by the Federal Government and private industry on research. For Fiscal Year 1969, \$3.1 million were appropriated for use by the Department of Interior for oil shale investigations. Of this amount, about \$2 million were allocated to the U. S. Bureau of Mines, Laramie Research Station.

Growth Factors

The United States requirement for synthetic liquid fuel is forecasted to be two million barrels per day by 1980 and should rapidly increase thereafter. Considering a probable time lag of five or more years between the initiation of a development program and commercial production from an operating facility, there is need for the early development of domestic sources of liquid fuels.

Given the need for synthetic fuels, it remains to be determined which of the competing resources (coal, tar sands, or oil shale) will be developed first. Cameron forecasts that both oil shale and coal will be developed in the United States at particular sites where special conditions will render the cost of production competitive with conventional petroleum. The chances for commercial oil shale development in Wyoming lie in special situations, since for the most part Colorado and Utah deposits are richer and thicker.

A portion (Washakie Basin) of the Green River Basin in southeastern Sweetwater County may contain shales as rich as 30 gallons per ton. This may permit commercial production by open-pit mining. There is also the possibility that open-pit mining is feasible in Wyoming at such low cost per ton of shale mined that it would be economical to mine and retort 20-gallons-per-ton shale.

The oil shale deposits in the Eden area are characterized by porosity and permeability which may make in situ retorting practical.

The projected growth of the oil shale industry is shown in Table III-15. Essentially all operations resulting from oil shale development will be concentrated in Sweetwater County. Nearly all the employees projected in Table III-15 would reside in Green River and Rock Springs, Wyoming.

TABLE III-15 -- Projected Growth of the Oil Shale Industry in the Green River Basin

	<u>1972</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
Production, Barrels of Syncrude (Shale Oil) Per Day	0	100,000	150,000	200,000
Water Requirements				
Gallons of Water Per Barrel of Syncrude	0	84	84	84
Acre-Feet Per Year	0	9,400	14,100	18,800
Capital Investments in Plant Facilities, million dollars (Total)	0	227	334	441
Electric Power Requirement, million kwh per year	0	190	240	290
Number of Employees	0	1,320	1,820	2,320

Water Resource Requirements

Table III-15 shows that the water requirements of the oil shale industry in Wyoming's Green River Basin will increase from zero at the present time to nearly 19,000 acre-feet by the year 2020.

Uranium

Existing Conditions

There is no uranium mining activity¹ in the Green River Basin, and the latest statistical data report published by the AEC provides no information regarding the presence of commercial uranium ore in the area. A number of companies, however, are presently involved in uranium exploration in the Basin. The Baggs-Poison Basin area, the Great Divide Basin, and the area immediately west of the Wind River Mountains offer the best possibility that exploration could define deposits of economic interest.

Interest in Wyoming uranium remains high because much of the ore is at a depth that permits open-pit mining. In Wyoming, approximately 77 percent of the ore comes from open-pit mines, compared with only 30 percent for the entire United States.

The gross value of Wyoming concentrates sold to the Atomic Energy Commission and to private and foreign interests since the inception of the industry in the early 1950's was \$372,000,000 through 1968. Of this total, only \$13,000,000 worth of concentrates was sold to private or foreign interests.

¹ Intermittent uranium production has been reported west of Baggs.

Reserves and Present Development

With the uranium industry in the midst of a transition from a government market to a competitive private market, most individual companies are reluctant to provide information pertaining to ore reserves. For this reason, the AEC will not subdivide the total reserve figure for the State into districts. However, as of January 1, 1968, the AEC reserve for Wyoming was 52,931 tons of contained U_3O_8 or 35.8 percent of the national total of 148,000 tons of U_3O_8 . These figures are for uranium mineable at eight dollars per pound price.

Economic Importance

The 1968 production value of \$46,274,000 ranks uranium second in the Wyoming mineral sector, being exceeded only by the value of oil and gas. Nationwide, Wyoming is second only to New Mexico in the production of uranium. Aside from limited exploration activities, the uranium industry provides no current economic input to Wyoming's Green River Basin.

Growth Factors

The uranium industry developed under urgent wartime conditions and under strict government control. Control over production is now shifting to private firms. The use of uranium for power generation has recently been accelerated. The potential for generating cheap power by development and use of nuclear breeder reactors will have a major impact on the use of Wyoming's uranium. The demand for uranium as an energy source for power generation should increase until the advent of the breeder reactor. Fuel from the breeder reactor would be such an efficient use of the uranium resource that it would do away with most of the market for newly mined uranium after the year 2020. When considering the future market for nuclear power and hence uranium, it should be noted that, because of its abundance of very low-cost coal and relatively low power demand, Wyoming may be among the last sections of the country to utilize nuclear generated electricity. The projected growth of the uranium industry in the Green River Basin is shown in Table III-16.

TABLE III-16 -- Projected Growth of the Uranium Industry in the Green River Basin

	<u>1967</u>	<u>1972</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
Uranium Ore Mined, million tons	0	0	.5	1.3	.6
Employment	0	0	400	700	200
Water Consumed, acre-feet per year	0	0	1,724	3,158	1,263
Power Required, million kwh per year	0	0	21.5	43	2
Capital Investment, million dollars	0	0	25	45	0

Water Resource Requirements

The potential water requirements of the uranium industry in the Green River Basin are shown in Table III-16. Essentially all of the water will be used in milling operations, since little water is used in the mining of uranium. Groundwater presently supplies all five of Wyoming's mills; this practice will probably continue.

Trona

Existing Conditions

Soda salts dissolved in groundwater were known in the Green River area in pioneer times. In 1938 a 10-foot bed of trona (a hydrous carbonate of sodium) was discovered in a nonproducing oil well. Further exploration defined a sizable deposit of trona in an area some 20 miles west of Green River, Wyoming (see Figure III-6).

In 1946 Westvaco (now Food Machinery Corporation) began producing soda ash from trona ore in a pilot plant; the operation was expanded into a commercial refinery in 1952. This 300,000-ton-per-year plant was the first pioneering effort in 40 years and was the first new soda ash facility constructed by the industry in 17 years. It was also a demonstration that "natural" soda ash was purer and could be produced more cheaply from the mineral trona than "synthetic" soda ash could be produced from salt by the Solvay process.

Today the Green River Basin is the center of the world's soda ash industry. The known commercial deposits of trona occur only in Wyoming and only in the Green River formation.

Reserves and Present Development

The U. S. Geological Survey reported (1966) that about 67 billion tons of trona are contained in 24 beds each more than three feet thick in the Wilkins Peak member of the Green River formation. These beds lie at depths of 400 to 3,500 feet in a 1,400 square mile area. Another 36 billion tons of mixed trona and halite (sodium chloride) are reported to occur in 14 beds with thicknesses greater than three feet each in the southern part of the area.

Excluding beds of mixed trona and halite, and all beds of trona less than 5.7 feet in average thickness, it is estimated that about 40 billion tons of trona ore are recoverable from easily mineable beds using mining methods that leave 25 percent of the ore in place for roof support.

In 1950 Wyoming's trona industry produced 0.42 percent of the Nation's soda ash. By 1967 Wyoming's share had increased to 22 percent. It should be noted that all of the growth of the soda ash industry since 1949 has occurred in the trona based sector. The "synthetic" sector of the industry has actually declined in recent years. Since 1950 the total production in Wyoming was 18,599,175 tons of ore, yielding a total of 11,549,309 tons of soda ash. The total 1968 production was 3,002,470 tons of trona mined and 1,864,233 tons of soda ash produced. Three companies operated soda ash

"refineries" in Wyoming in 1969, and another company was completing the construction of a mine shaft in preparation for future trona mining and refining operations.

Economic Importance

The soda ash industry in 1967 employed about 700 people in Sweetwater County, which represents the greatest number employed by a single industry in the Green River Basin. The payroll for the year was \$6,100,000. The total taxes paid by the industry in 1968 amounted to \$834,000. This figure will show a steady increase as new facilities become operational.

Additional economic data and projections are given in Table III-17.

TABLE III-17 -- Projected Growth of the Trona Industry in Sweetwater County in the Green River Basin

	1967	1972	1980	2000	2020
Trona Ore Mined, tons	2,323,475	5,300,000	7,400,000	9,100,000	10,000,000
Soda Ash Produced, tons	1,442,646	3,250,000	4,500,000	5,500,000	6,000,000
Sesquicarbonate Produced, tons	20,000	30,000	40,000	50,000	50,000
Tripolyphosphate Produced, tons	50,000	50,000	100,000	100,000	150,000
Bicarbonate Produced, tons	0	45,000	45,000	90,000	90,000
Employees	700	1,500	1,700	2,800	3,400
Natural Gas Required, million cu. ft.	9,377	21,125	29,250	35,750	39,000
Electric Power Required, million kwh per year	144	325	450	550	600
Water Consumed, acre-feet per year	4,428	10,000	13,800	16,800	18,500
Capital Investment, million dollars	126	162	225	275	300
Taxation, dollars					
Gross Production Tax	320,000	730,000	1,019,000	1,240,000	1,278,000
Ad Valorem Taxes	513,000	1,100,000	1,500,000	1,900,000	2,100,000
Severance Taxes	0	150,000	200,000	250,000	275,000

Growth Factors

The soda ash produced from trona is displacing the "synthetic" soda ash produced by the Solvay process. The most severe competition to the trona based soda ash production is the caustic soda (sodium hydroxide) produced as a by-product of the fast-growing chlorine gas industry. The demand for chlorine in the United States is expected to double over the ten-year period ending in 1975. The caustic soda produced as a by-product will be sold at a competitive price.

A second competitive factor is also present because development of oil shale may serve to expedite the development of related soda ash deposits. This could result in flooding the market with soda ash. The mineral "dawsonite," which is found in the oil shale, is expected to become an economical source of alumina and give more impetus to developing the multiple resource of oil shale.

Transportation costs to marketing areas are of great importance to the soda ash industry. Several secondary industries are already in the area,

and quite possibly more may be attracted because of the availability of low-cost soda ash. This would alleviate to some degree a reliance on favorable freight rates for marketing the raw product.

Water Resource Requirements

The water resource requirements and projected growth of the trona industry in the Green River Basin are shown in Table III-17. Essentially all of the water is consumed since the waste water from the plants is discharged into evaporation ponds.

Timber

Existing Conditions

Most of the demand for Wyoming wood products prior to 1950 was by the railroads for ties. Since 1950, however, the need for dimension lumber has been the major growth factor in the industry.

Although there are sizable acreages of commercial forest land located within the Green River Basin, the timber industry has been of relatively minor economic importance. In 1968 there were only seven facilities in the Basin for cutting or processing wood products. It appears likely, however, that the industry will play a more important economic role in the future.

Reserves and Present Development

A breakdown of the timber reserves and resources in the Green River Basin is not readily available. On a statewide basis there are 95 wood product firms in operation, and over one-half are lumber producing sawmills. A 1962 survey revealed that there are 4.7 million acres of commercial timber in the State, containing more than 28 billion board feet of live saw timber. According to the Cameron Report, the inventory increases yearly because new timber growth is exceeding removal by all causes.

Wyoming's forests are comprised almost exclusively of softwood trees. Ownership of commercial forest land in Wyoming is largely public, and most timber grows at elevations between 7,000 and 10,000 feet. The timber resources of the Green River Basin are largely within the Bridger National Forest rimming the northeastern part of the Basin, and the Wasatch National Forest in the southwestern corner.

Economic Importance

The timber industry is an important industry in Wyoming but is not of major economic importance in the Green River Basin. Within the counties comprising the southwestern corner of the State, it is reported that there are 226 people employed in timber-related activities. Of this number, probably not more than 60 are employed in the Green River Basin. The rest are employed in the Snake River and Bear River Basins.

Growth Factors

The demand for timber products in the United States is expected to more than double by the year 2020. The allowable timber cut in national forests

in Wyoming is limited by the need to protect recreation and watershed values. Improved forest management could lead to substantial increases in allowable-cut figures in the future. Better yields can be realized by proper thinning, reseedling, and protection from fire, insects, and disease. Lumber will continue to be the most important product of the Wyoming timber industry for at least the next 50 years. Little or no increase is expected in the use of Wyoming timber for such wood products as ties, posts, and poles. Full development of the Wyoming timber industry would probably include a fiber industry to utilize the State's reserve of small timber. A pulp and paper industry would offer the best opportunity for increasing timber production.

The fiber industry is able to use trees which are not suitable for the lumber industry. Therefore, in some cases the practice of nonselective clear cutting has proven economical. By this method, one area of forest is stripped of all timber and replanted; the process is then repeated in other areas. Increasing the allowable cut by more effective management practices is viewed unfavorably by conservationists.

The market potential for a pulp and paper industry would include Wyoming, Montana, Utah, Colorado, Nebraska, Kansas, Idaho, and South Dakota. The transportation network in the Green River Basin is adequate for conveying raw materials from forest to plant and shipping finished products to markets. An adequate water supply can be obtained from the Green River. A site near Green River, Wyoming, has been proposed for a kraft pulp and paper mill; the Cameron Report predicts the establishment of this mill in Sweetwater County sometime after 1980.

Problems of water pollution associated with the pulp-paper industry are acute. Any pulp mill constructed in the Green River Basin probably will be required to provide tertiary treatment for streamflow effluent in order to comply with Federal and State water quality standards for interstate streams. Tertiary treatment could be provided by lagoons and evaporation ponds. Another method would be to use pulp mill effluent for irrigation after secondary treatment.

Kraft mills contribute to air pollution because of the emission of particulate matters from stacks and because of sulfur dioxide odors released to the atmosphere. The removal of particulate matter from the stacks in a kraft mill can be done by conventional means. In a modern kraft mill, most odors are removed because it is profitable for the mill to recover and use the sulfur dioxide gas. However, the recovery is never perfect, and an odorless kraft mill is not yet possible.

Table III-18 shows the projected growth of the timber industry in the Green River Basin. The greatest single impact is projected to be the pulp and paper mill in Sweetwater County. Between the years 2000 and 2020, the construction of a new sawmill in Sublette County is also projected. The mill is estimated to cost approximately one million dollars and will produce 20 million board feet of lumber annually.

TABLE III-18 -- Projected Growth of the Timber Industry in the Green River Basin

	<u>1967</u>	<u>1972</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
Employment ¹	226	235	245	545	625
Electric Power Required, thousand kwh/year ¹	3,505	3,705	4,400	43,000	45,000
Water Required (Sweetwater County), acre-feet					
Diverted	0	0	50	32,200	32,200
Consumed	0	0	50	4,800	4,800
Capital Required, thousands of dollars	0	0	nil	30,000	1,000

¹ Employment and electric power are given for the four southwestern counties of Wyoming. Most of the increases are projected in the Green River Basin.

Water Resource Requirements

Table III-18 shows the water requirements of the timber industry in the Green River Basin through 2020.

The projected pulp and paper mill at Green River will use water at the rate of 70,000 gallons per ton of finished product, or 32,000 acre-feet annually. Only 15 percent of the water diverted will actually be consumed in paper manufacture. At present, total water consumption by all firms in the State's timber industry is less than 200 acre-feet annually.

Summary of Water Requirements for Industrial Purposes

TABLE III-19 -- Projection of Consumptive Industrial Water Requirements in the Green River Basin (1,000 Acre-Feet Per Year)

<u>Industry</u>	<u>1967</u>	<u>1972</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
Coal	7.0	12.0	26.0	45.0	186.0
Petroleum	4.5	5.8	3.6	1.85	1.8
Sodium (Trona)	4.428	10.0	13.8	16.8	18.52
Timber	0	0	.05	4.8	4.8
Oil Shale	0	0	9.4	14.1	18.8
Uranium	0	0	1.724	3.158	1.263
Total	15.93	27.80	54.57	85.71	231.18

Table III-19 shows a summary of the projected industrial water consumption requirements in the Green River Basin. The requirements increase from 15,930 acre-feet in 1967 to over 14 times that quantity, or 231,180 acre-feet by 2020. The greatest increase is by the coal industry, which will require 186,000 acre-feet per year by 2020, or nearly 27 times the 1967 requirement of 7,000 acre-feet per year.

Summary of Industrial Economic Factors

Table III-20 is a summary of projected economic factors.

TABLE III-20 -- Projection of Economic Factors of Industry in the Green River Basin¹

	<u>1967</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total Number of Industrial Employees	2,186	4,979	7,393	10,069
Approximate Annual Payroll, million dollars	19	44	65	90
Capital Investment, million dollars	260	808	1,354	3,268
Electric Power Required, million kwh/year	192	749	1,000	1,403

¹ Estimated where not forecast by Cameron Engineers (12).

MUNICIPAL, DOMESTIC, AND STOCK WATER USES

Municipal water is provided by privately owned public utility systems and municipally operated water systems. The water in some smaller communities is provided by small privately owned systems. Table III-21, extracted from data collected in a survey conducted by the University of Wyoming, gives the sources of municipal water supply and the 1970 population of the majority of towns in the Basin. Two suppliers, the city of Kemmerer and the Pacific Power and Light Company, serve approximately 19,130 people, nearly 78 percent of the total municipal population in the Basin.

The term "water consumption" is often used in connection with municipal water usage to mean treated water delivered into the municipal distribution system. In this report the term "diversions" from a water source, "returns" to a water source, and "consumptive uses," which are the diversions less the returns, are used.

A diversion of one acre-foot per year normally is required to serve five people. This is equivalent to an average diversion of 180 gallons per day per person. Approximately one-half of the annual municipal water diverted is consumptively used, and the balance may be considered a "return."

TABLE III-21 -- Municipal Water Supplies in the Basin

Town	Drainage Basin ¹	1970 Population Served ²	Supply System		Supply	
			Munic.	Private	Surface Water	Ground-water
Bairoil	3	300 ³	X			X
Baggs	2	146	X			X
Big Piney	1	570	X			X
Daniel	1	110 ³		X		X
Diamondville ⁴	1	485	X		X	
Dixon	2	72	X		X	
Eden	1	220 ³		X		X
Farson	1	20 ³		X		X
Ft. Bridger	1	150 ³		X		X
Frontier ⁴	1	500 ³	X		X	
Granger	1	137	X			X
Green River ⁵	1	4,196	X		X	
Kemmerer ⁴	1	2,292	X		X	
La Barge	1	700 ³		X		X
Lamont	3	100 ³		X		X
Little America	1	75 ³	X			X
Lyman	1	643	X			X
Marbleton	1	223	X			X
Mountain View	1	400 ³		X		X
Opal	1	34		X		X
Pinedale	1	948	X		X	
Reliance	1	300 ³	X			X
Rock Springs ⁵	1	11,657	X		X	
South Superior	1	197	X			X
Wamsutter	3	139	X			X
Total Population		24,614				

Population Served by:

a. Municipal systems	22,880	
b. Private systems		1,734

Population Served by:

a. Surface water	20,150	
b. Groundwater		4,464

¹ The numbers in this column refer to the drainage basin in which the corresponding town is located. These basins are numbered as follows: (1) Green River Basin, (2) Little Snake River Basin, (3) Great Divide Basin.

² These figures do not include rural population.

³ Figure given is from 1960 census since 1970 figures were not yet available.

⁴ Supplied by Kemmerer Water System.

⁵ Supplied by Pacific Power and Light Water System.

Source--Municipal Water and Sewerage Systems in Wyoming-- A Source Book of Data, University of Wyoming, WRRRI, R. Keith Schwer, February 1968.

Domestic and stock water is supplied from lakes, streams, ponds, ditches, water wells, and reservoirs. Although extremely important to agriculture, the quantity of water used for domestic and stock purposes is not reliably known. However, the quantity of water is small compared to other uses.

Table III-22 shows the projected municipal, domestic, and stock water requirements in the Green River Basin through the year 2020. Nearly all the increase in required water will be for municipal uses, with some increase in stock water use and little or no increase in rural domestic uses.

TABLE III-22 -- Projected Municipal, Domestic, and Stock Water Requirements in the Green River Basin

	<u>1972</u>	<u>1980</u>	<u>2000</u>	<u>2020</u>
Basin Population, rounded to nearest hundred	32,000	37,600	48,100	59,800
Municipal and Domestic Diversion Requirement, acre-feet	6,398	7,512	9,638	11,962
Consumptive Use, acre-feet	3,199	3,756	4,819	5,981
Stock Water Depletions, acre-feet based on pounds of beef produced	2,000	2,200	2,400	3,000
Total Depletion, acre-feet, rounded to nearest thousand	5,000	6,000	7,000	9,000

RECREATION, FISH AND WILDLIFE²

Outdoor recreation is a large and growing industry in the Rocky Mountain West and the Green River Basin. The recreational opportunities afforded by Flaming Gorge Reservoir have attracted Nationwide attention. The nearness of the Basin to Yellowstone and Teton National Parks is probably a factor influencing growth of the recreation industry in the Basin. Fishing, hunting, boating and other water sports, skiing, mountain climbing, hiking, and other recreational activities all have potential for growth in Wyoming's Green River Basin.

The Green River Basin in Wyoming boasts some of the better trout fishing in the Rocky Mountain Region. The reach of the Green River proper from the Green River Lakes to Fontenelle Reservoir and from Fontenelle Reservoir to the Big Island has an excellent distribution of pools and riffles where trout can rest and feed. Rainbow trout, brown trout, mackinaw trout, brook trout, cutthroat trout and mountain whitefish inhabit the waters of the lower and middle drainages. The potential for increased sport fishing in the entire Green River Basin is excellent. As fishing pressure increases, the quality fisheries of this area will become increasingly popular,

² Taken from material supplied by the Wyoming Game and Fish Commission. Much of the information was originally assembled for the Upper Colorado Region Comprehensive Framework Study.

especially to the residents of nearby population centers in Wyoming, northern Utah, and Colorado.

The Green River Basin also contains some of the most varied and unique wildlife habitat in the United States. Excellent environments for several big game species exist. Antelope and mule deer are found from the lower Basin desert areas to the foothills and irrigated pastures of the middle and upper drainages. Resident and wintering populations of elk and moose inhabit the upper Basin. Of special significance are key wintering grounds and migration routes for moose and elk in the bottoms of almost every drainage in the middle and upper Basin. Sage grouse populations exist in the Green River Basin in greater numbers than anywhere else in the State.

Fish

The fishery habitat varies from clear, cold, cascading small streams and brooks at the higher elevations to the larger rivers in the valleys, with clear cold-water lakes and impoundments in between.

In the Green River Basin there are 2,520 miles of classified streams and approximately 70,000 surface acres of lakes and impoundments providing cold-water fishery habitat. The Wyoming Game and Fish Commission's classification of streams has been made on the basis of present conditions of aesthetics, availability, and productivity. The following categories were established:

- Class 1 - Waters of nationwide importance.
- Class 2 - Waters of statewide importance.
- Class 3 - Waters of importance to large areas less than statewide.
- Class 4 - Waters of importance to small areas such as counties.
- Class 5 - Waters of potential importance to fisheries now polluted or otherwise seriously limited or degraded.

Of the classified streams in the Green River drainage, 95 miles are presently of national importance, with another 187.5 miles considered significant at the State level. The Little Snake drainage currently does not have any stream miles in the first two classes. The Great Divide Basin has no fisheries of significant value.

Tables III-23 and III-24 summarize the classified streams and bodies of water in the Green River Basin of Wyoming, each with its annual fishing use and capacity.

TABLE III-23 -- Estimated Use and Capacity of Streams in the
Green River Basin of Wyoming
Which Provide a Game Fishery - 1969

<u>Streams - Cold Water</u>	<u>Miles</u>	<u>Annual Fisherman Days - Use</u>	<u>Annual Fisherman Days - Capacity</u>
Class 1	95.0	50,146	76,339
Class 2	187.5	99,215	207,128
Class 3	1,205.3	152,526	354,468
Class 4	977.9	20,435	62,270
Class 5	<u>54.5</u>	<u>353</u>	<u>1,756</u>
Total	2,520.2	322,675	701,961

TABLE III-24 -- Estimated Use and Capacity of Lakes and Impoundments
in the Green River Basin of Wyoming
Which Provide a Game Fishery

<u>Type</u>	<u>Number</u>	<u>Acres</u>	<u>Annual Fisherman Days - Use</u>	<u>Annual Fisherman Days - Capacity</u>
Alpine Lakes	304	22,854.8	30,764	81,687
Alpine Reservoirs	2	1,178.0	4,942	6,927
Lowland Lakes	0	0	0	0
Lowland Reservoirs	13	45,725.8	390,211	465,784
Trout Farm Ponds	27	55.6	1,118	1,118
Mixed Farm Ponds	0	0	0	0
Non-Trout Farm Ponds	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	346	69,814.2	427,035	555,516

The rainbow trout is the most important game fish in the Green River drainage and is well established throughout the length of the Green River proper and quite abundant in many tributaries, lakes, and reservoirs, including Flaming Gorge. Other species that have been stocked in adapted waters include California golden trout, mackinaw or lake trout, Montana grayling, German brown, and brook trout.

Fish populations in the Little Snake drainage are predominantly brook and cutthroat trout in the higher reaches, and brown and rainbow trout at lower elevations.

Current Fisherman Use and Harvest

Fisherman use of much of the Green River drainage historically has been light because the Basin is relatively unknown. However, due to the publicity associated with the Flaming Gorge Reservoir, the entire basin is beginning to show a sharp increase in fishing activity, with many of the Flaming Gorge visitors exploring the fishing potential of the entire drainage. Much of the Green River is floatable, and with the recent development of excellent rainbow and brown trout fishing, the past four years have realized a marked increase in the float-fishing sport. The estimated number of fishermen in 1969 was 111,280. Their estimated harvest was 945,000 fish.

The principal limiting factors affecting resident fish resources include erosion, diversions and dewatering, bank trampling, and siltation resulting in some deterioration of stream habitat. Lakes seem to be relatively more stable and provide good fishing even where natural reproduction does not occur. At the present time Fontenelle Reservoir is being operated under temporary criteria prior to completion of the Seedskaadee Project. These interim operating criteria have established a minimum flow downstream of 500 cfs (cubic feet per second) and are providing the habitat for an excellent fishery. When the Seedskaadee Project is completed, this habitat will be maintained, although possibly with reduced flows.

Economic Importance of Sport Fishing

The long-range potential of sport fishing in the Green River Basin is still comparatively unknown. The total 1966 reservoir fishing use for Flaming Gorge Reservoir was about 267,000 fisherman-days. This figure is substantially larger than the originally projected estimates for the year 1970 and gives an indication of the general increase in regional fishing interest.

An economic study completed by the Statistics Department of the University of Wyoming in 1966, based upon a random sampling of the 1965 license holders, indicates that fishing generated a total income of \$1,307,348 to Sweetwater County and \$1,800,964 to Sublette County. The survey further indicated that the resident fisherman spends an average of \$220 per year, and the nonresident fisherman spends \$142 during his stay in Wyoming. An updated study will be completed in July 1971, by the University.

Wildlife

Wildlife is certainly dependent upon water as a factor in its habitat. For this reason, wildlife must be considered along with fish in the economics of water resources and their development.

The Basin provides a variety of habitats for wildlife. Elk find abundant summer feed in the mountain and forest areas, but winter forage is scarce because man has encroached upon the winter range. The Wyoming Game and Fish Commission has established eight elk feeding grounds and two winter pastures to supplement native winter range. Mule deer reside in nearly all the Basin. Summer range is in ample supply for deer at all the higher elevations, but winter range is somewhat limited as deer must compete with domestic livestock and elk. Moose are found in large willow bottoms, at

higher elevations in the summer and lower elevations in the winter. Antelope are found on the desert, grasslands, and forest lands. The antelope migration patterns are constantly changing because of fences, sagebrush eradication projects, and snow depth. Black bear are present in a few areas of the Basin, primarily at higher elevations. Bighorn sheep frequent the high elevations in the Wind River Mountain range. Upland game (sage grouse, blue and ruffed grouse, partridge) and cottontail rabbit enjoy a good habitat within the Basin.

Fur-bearing animals that once lured trappers into the area are still abundant. Beaver, mink, muskrat, and otter are found near sloughs, marshes, rivers, and lakes. Marten, red fox, skunk, weasel, raccoon, jackrabbit, badger, coyote, bobcat, lynx, mountain lion, and small numbers of fisher and wolverine are found in the mountains or sparsely populated lowlands.

Waterfowl are found in the Basin except during the winter. Marshes, flooded meadows, lakes, streams, and ponds are the spring-to-fall homes of many ducks, some geese, and fewer numbers of swans and cranes.

Current Hunter Use

The Wyoming Game and Fish Commission has furnished information regarding hunting activity in the Basin for the year 1969. About 37,828 hunters were active in the Basin, and they spent about 135,240 days in pursuit of game. The most popular game animal with hunters was mule deer, followed by elk. Sage grouse was by far the most popular game bird. It is estimated that an additional 25,000 hunter days could be supplied through increased harvest without damaging the resource.

Economic Importance of Hunting

An economic study was made by the Statistics Department of the University of Wyoming in 1965 from a random sampling of that year's license holders. Hunting expenditures, shown in Table III-25, included transportation, food, commercial lodging, arms and ammunition, camping equipment, trailers, and guides.

TABLE III-25 -- Hunting Expenditures in Green River Basin, 1965

<u>County</u>	<u>Resident</u>	<u>Nonresident</u>	<u>Total</u>
Lincoln	\$ 345,001	\$1,174,967	\$1,519,968
Sublette	636,047	1,635,295	2,271,342
Sweetwater	1,338,938	131,405	1,470,343
Uinta	628,621	44,494	673,115
Total	\$2,948,607	\$2,986,161	\$5,934,768

Water Sports and Boating

The Green River Basin has a great potential for water sports and boating. Flaming Gorge, Fontenelle, and Big Sandy Reservoirs, and Fremont and Boulder Lakes provide boaters with many hours of water-oriented recreational activities. In recent years, float trips on the Green River have become very popular.

The Division of Business and Economic Research, University of Wyoming, reports that the most popular boating activity of Wyoming boaters is fishing. Water-skiing is the second most popular, and pleasure cruising is third, as shown in the chart below.

A Comparison of Preferred Boating Activity for Boaters
From Selected Wyoming Cities, 1967¹

Place of Residence	Preferred Boating Activity		
	<u>Pleasure Cruising & Sightseeing</u>	<u>Fishing</u>	<u>Water Skiing</u>
Green River	16%	47%	37%
Rock Springs	17%	64%	19%

¹ Preferred boating activity is one to which the boater devoted most of his total boating time.

The University of Wyoming's study made use of information solicited from nearly 1,800 boaters. Flaming Gorge Reservoir was the most popular area in the Basin with Wyoming boaters. Of the 438 Wyoming boaters who preferred the Flaming Gorge area, 67 percent preferred fishing, 21 percent preferred water skiing, and 12 percent preferred pleasure cruising. The respondents who preferred Fremont Lake indicated that 61 percent preferred fishing, 32 percent pleasure cruising, and 7 percent water skiing. Wyoming boaters each averaged 17.4 boating days for the 1967 season.

The nearness of Flaming Gorge Reservoir to metropolitan areas in Utah and Colorado accounts for its widespread popularity. In a non-resident questionnaire, more than one-third of those surveyed listed Flaming Gorge as a Wyoming boating area which they visited. The survey of out-of-state boaters visiting Flaming Gorge indicates that 89 percent prefer fishing, 7 percent prefer pleasure cruising, and 4 percent prefer water skiing. The average number of trips to Flaming Gorge was 2.7, and the average length of stay was 5.7 days.

Future Demands and Desires

Sport Fisheries

Increasing populations in and adjacent to Wyoming's Green River Basin will influence utilization of the area by fishermen, especially if the present environmental quality of the aquatic habitat is maintained.

A projection of the 1968 fishermen utilization in the Wyoming Green River drainage indicates that the level of angler use will have increased

approximately 12 percent by 1980 and 43 percent by 2000. Compared to the Upper Colorado Region as a whole, these figures are modest and could be altered drastically by future industrialization of the Green River Basin and continued growth of cities in northern Colorado and Utah. Projections obtained from a study conducted for the Wyoming Recreation Commission indicate an estimated increase from 1967 to 1985 of 28 percent (Figure III-7).

The projected demand for sport fishing and the estimated capability of the present aquatic habitat to handle these demands were compiled as part of Wyoming's contribution to a Federal comprehensive survey of the Upper Colorado River drainage system. Estimated potential use is defined as the capacity of present waters to provide fishing. This capacity is regulated by the productivity of the water, location, accessibility, aesthetic conditions, and present trout stocking rates. This is also premised on the assumption that there will be no further stream degradation by pollution or flow depletion by competing uses.

Using these criteria and projecting levels of fisherman use to the year 2000, it appears that future fishing can be accommodated on existing waters. As water development projects are undertaken, aquatic habitats will be altered and present fishery potentials will be diminished in some areas. Fish stocking and other fisheries management programs will be required.

In the Green River Basin, emphasis is on quality habitat, and projected levels of public use have been taken into consideration. Stream environments are relatively unspoiled. One of the major concerns of the fishery management program is maintenance of the running water habitat. As water demands increase, this problem will become more severe. The diversion and dewatering of streams substantially affect the fishery habitat by reducing living space for fish, limiting food production, increasing water temperatures, and changing water chemistry.

Multipurpose projects could have beneficial effects on the water quality in the Lower Green River. Benefits from a reduction in silt load would be almost immediate. Additional water released downstream from Fontenelle Reservoir would benefit fisheries and recreational possibilities. Development of the Eden Project could improve stream conditions in the Big Sandy drainage. Appropriate planning could provide a reservoir fishery.

Big Game

The demand for hunting opportunities within the Basin is expected to increase substantially during the next 30 years. Resident demand has increased even though the State population has not changed appreciably over the past 10 years. Non-resident demand will continue to show percentage increases exceeding national population growth figures. High quality game habitat in the Green River Basin is already in short supply, and demand for hunting opportunities will be much greater than those projected in other parts of the Upper Colorado River Region.

Hunting within the Basin is expected to increase 15 percent by the year 1980 and 32 percent by the year 2000. By 1980 the demand for big game

hunting will exceed capabilities by approximately three percent and by the year 2000 approximately 40 percent. These figures are based on present habitat conditions.

Water development in the Green River Basin may result in changes in vegetative cover in certain areas and a reduction in the quality of the habitat for big game. This is especially true of upstream projects centered on wintering habitat for moose.

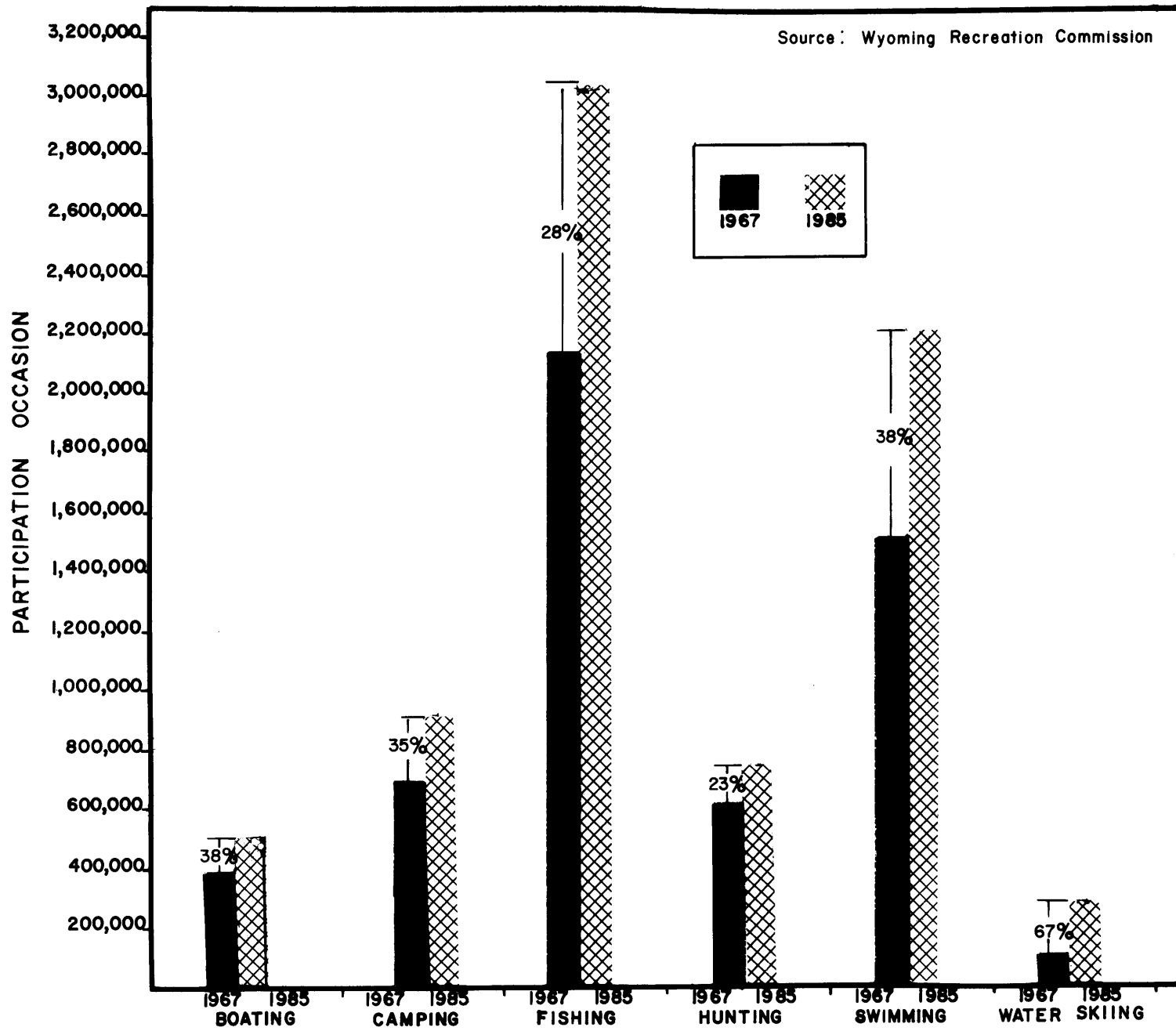
Water Resource Requirements

The present consumptive uses assigned directly to recreation and fish and wildlife activities are small. The present consumptive uses by recreation (primarily campgrounds) and by fish and wildlife are 200 and 100 acre-feet per year respectively. Other present uses for recreation are nonconsumptive, although some stock pond evaporation could probably be assigned to wildlife use.

Future recreation water demands will be met primarily in conjunction with providing water for other purposes. The Seedskaadeé National Wildlife Refuge will consumptively use an estimated 20,000 acre-feet per year.

The Wyoming Game and Fish Commission has suggested several provisions and considerations for inclusion in water development projects regarding recreation and fish and wildlife, including the following:

1. All reservoirs should have minimum pools of sufficient depth and size to maintain a permanent fishery. Conditions requiring a minimum of stocking effort to produce a quality fishery should be maintained.
2. Storage capacity should be adequate for continuous downstream releases in sufficient quantity to sustain the stream trout fishery.
3. If there are alternate sites available for reservoir construction, consideration should be given to selecting the site which is least detrimental to the stream fishery. This is particularly important to the Upper Green River blue ribbon trout waters.
4. Funds for fisheries management purposes such as fish screens, rough fish control, or silt settling basins for water quality control should be included as part of the project costs.
5. Reservoir functions and operations, including downstream water releases, should be planned on a cooperative basis with appropriate State and Federal agencies.
6. Water conservation practices such as lining ditches, the use of sprinkler irrigation, and the efficient application of water should be a consideration in any project planning to reduce water quality deterioration.
7. Cost of land necessary for public access to streams and lakes to replace present public use areas should be included in project funding.



**PARTICIPATION ESTIMATES FOR SELECTED RECREATION ACTIVITIES
WYOMING FOR 1967 and 1985**

Figure III-7

8. Cost of land to replace big game wintering areas should be included in project funding.

9. Big game migration routes, including bridges over irrigation canals, should be included in project funding.

HYDROELECTRIC POWER

The 10,000-kilowatt power plant at Fontenelle Dam, a facility of the authorized Seedskadee Project, is the only hydroelectric power plant currently operating in the Basin. The power plant at Flaming Gorge Dam in Utah has an installed capacity of 108,000 kilowatts furnished by three 36,000-kilowatt generators. Electrical energy from the Fontenelle power plant is transmitted to the Flaming Gorge switchyard where it is combined with other Colorado River Storage Project (CRSP) power for sale through Bureau of Reclamation facilities. The purpose of CRSP power production is to repay costs of the CRSP storage facilities and to generate revenues to assist in repaying costs of participating units of the CRSP. In Wyoming, authorized participating units of the CRSP are the Eden, Seedskadee, Lyman, and Savery-Pot Hook Projects.

Demands for electrical power in the Nation are projected to nearly double every ten years. Since remaining hydropower potentials in the Nation cannot add significant amounts of power, thermal and nuclear power plants are required to meet present and projected power demands. Hydropower has certain advantages over other kinds of power production that should be considered. Hydroelectric plants will cause neither air pollution nor thermal water pollution. Hydropower is better suited to meeting peaking demands than other conventional plants. With the several thermal plants that are projected in the Basin, a peaking operation would be an attractive addition to the system. A pumped storage peaking plant utilizing Boulder Reservoir and Burnt Lake has a very definite potential which the Bureau of Reclamation may analyze in the near future.

The plans presented in Chapter IV do not include power production as a project purpose. However, there are limited potentials for including hydropower in the alternative plans. Power generated at one or more of the proposed dams could be used to pump water for municipal, industrial, and irrigation supplies.

SUMMARY OF WATER RESOURCE REQUIREMENTS

The present water uses and projected demands for water in Wyoming's Green River Basin have been discussed in detail in previous sections of this chapter. Present consumptive uses, which total about 296,100 acre-feet per year, are summarized in Table III-26. Consumptive uses include agricultural, municipal and domestic, industrial, recreation, fish and wildlife, and the diversion from the Little Snake River to the Platte River Basin for the City of Cheyenne.

Table III-27 presents a summary of present and projected consumptive water uses in the Green River Basin in Wyoming. A fifty-year projection is

shown to conform with other projections made in this report. It is possible that additional irrigation projects could be constructed that would increase irrigation depletions to greater amounts than those shown in Table III-27. The undertaking of such projects will depend upon decisions made by the people of the Green River Basin and the State of Wyoming.

TABLE III-26 -- Present (1968) Depletions from the Green River Basin in Wyoming at Sites of Use

Water Uses	Average Annual Depletion Acre-Feet
Agricultural	267,900
Municipal and Domestic and Stock	4,700
Industrial	16,200
Recreation, Fish and Wildlife	300
Cheyenne Diversion	7,000
Total Present Wyoming Depletions at Sites of Use	296,100

TABLE III-27 -- Summary of Present and Projected Consumptive Water Uses in the Green River Basin, Wyoming

	(1,000 Acre-Feet Per Year)			
	Present	1980	2000	2020
Agricultural	268	339	408	415
Industrial	16	55	86	231
Municipal and Domestic and Stock	5	6	7	9
Recreation, Fish and Wildlife ¹	---	20	20	20
Cheyenne Diversion	7	15	31	31
Colorado River Storage Project Evaporation	---	92	92	92
Total	296	526	644	798
Potential Additional Consumption from Irrigation in the Green River Basin ²				0 to 164
Potential Transbasin Diversion ²				39 to 272

¹ Recreational water use is presently less than 1,000 acre-feet per year. Future recreational water use was not estimated for this report. The 20,000 acre-feet per year given is the depletion on the Seedskadee Wildlife Refuge. Some reservoir evaporation could be assigned to recreation.

² The amount of these potential uses will depend upon the demands for water that develop in the future and the amount of water determined ultimately available under the Colorado River Compacts and from imports of water from other sources.

Studies being conducted by the Wyoming Water Planning Program indicate that some other river basins in the State may have water demands which exceed the water available in those basins. Since the Green River Basin has water in excess of projected needs, it is possible that the Green River water could be used to make up shortages in other areas. A potential transbasin diversion from the Green River is shown in Table III-27. The timing of the potential diversion is not projected. Such a diversion will depend upon the needs for water, the availability of water, and the decisions to fund the project.

CHAPTER IV

POTENTIAL SOURCES OF WATER TO MEET
REQUIREMENTS AND ALTERNATIVES
OF DEVELOPMENT

POTENTIAL SOURCES OF WATER TO MEET
REQUIREMENTS AND ALTERNATIVES
OF DEVELOPMENT

AVAILABLE WATER SUPPLIES

The water resources of the Basin and the amounts of water available for development in Wyoming under interstate compacts were discussed in Chapter II. Wyoming is entitled to 1,043,000 acre-feet of consumptive use per year under the Colorado River and Upper Colorado River Compacts. When these compacts were negotiated, it was thought that the Colorado River and its tributaries would yield at least enough water to permit 15 million acre-feet of use annually in the compact states. A recent estimate shows that Wyoming may be limited to about 875,000 acre-feet of consumptive uses annually.

Table IV-1 is a summary of Green River water uses in Wyoming. The present and projected uses are shown along with the water supply available for potential uses that were not specifically projected in Chapter III. Figures are shown in Table IV-1 for assumptions of water available under the Colorado River Compacts. Assumption "A" is that 6.3 million acre-feet of use is available to the Upper Basin states under the compact because of a limited water supply. Assumption "B" shows the use available to Wyoming if 7.5 million acre-feet are available to the Upper Basin as stated in the Colorado River Compact.

TABLE IV-1 -- Green River Water Uses Available to Wyoming
(Acre-Feet Per Year)

	Projected Increases in Consumptive Uses by 2020	Source of Data ¹	Water Supply Assumption	
			A	B
Available to Upper Colorado River Basin States		Chapter II	6.3 million	7.5 million
Wyoming's Share		Chapter II	875,000	1,043,000
Present Uses		Table III-26	- 296,000 ²	- 296,000 ²
Presently Available for Development			579,000	747,000
Projected Consumptive Uses				
Bureau of Reclamation				
Irrigation Projects				
Seedskadee				
Irrigation	86,000	Table III-10		
Wildlife Refuge	20,000	Table III-27		
Lyman	10,000	Table III-10		
Savery-Pot Hook	12,000	Table III-10		
Cheyenne Diversion	24,000 ³	Table III-27		
Colorado River Storage Project				
Evaporation	92,000	Table III-27		
Private Irrigation Projects	29,000	Table III-10		
Eden Project Improvement	10,000	Table III-10		
Green River Basin M & I	192,000 ⁴	Tables III-19, 22, 27		
Total Projected Increases in Consumptive Uses	475,000		- 475,000	- 475,000
Available for Other Development			104,000	272,000

¹ The projected depletions by the year 2020 given in Chapter III have been identified by water development projects in this chapter. Reference is given to the source of the data in Chapter III.

² Figure rounded to nearest 1,000 acre-feet. Present uses include: 267,900 - agriculture; 4,700 - municipal and domestic; 16,200 - industrial; 300 - fish and wildlife and recreation; and 7,000 - Cheyenne diversion.

³ Total year 2020 Cheyenne diversion is projected to be 31,000 acre-feet per year, which is an increase of 24,000 over the present use of 7,000 acre-feet per year.

⁴ The year 2020 municipal and domestic plus industrial consumptive uses total an estimated 240,000 acre-feet per year. After accounting for the present M & I uses of 21,000 acre-feet per year and a projected use of 27,000 acre-feet of groundwater per year, the increased M & I use of Green River water is 192,000 acre-feet per year. A part of the future uses can be supplied from Fontenelle Reservoir, a unit of the Seedskadee Project.

The present consumptive uses amount to 296,000 acre-feet of water per year. The projected increases in consumptive uses total 475,000 acre-feet per year. In Water Supply Assumption "A" Wyoming has 104,000 acre-feet available for other water uses that were not projected. In the compact apportionment of water (Water Supply Assumption "B") the State has 272,000 acre-feet of beneficial consumptive uses that could be developed for other projects not forecasted. The potentials for utilizing this water include irrigation projects and a transbasin diversion to other parts of the State.

The potential sources of water to meet future requirements are surface water development, improved water uses, and groundwater development.

Potential Surface Water Development

A considerable amount of surface water is available for development in the Green River Basin. Many projects have been proposed to utilize this water. Several authorized U. S. Bureau of Reclamation projects commit uses of water to specific developments. There are private developments, both for irrigation and industry, that are partially constructed and represent commitments of a portion of the State's allocation of water. Many of the water supplies needed for future uses could be developed by various plans of surface water development. Projects are discussed individually in this chapter, and alternates are presented.

Improved Water Uses

Improved efficiency in existing water uses will enhance present operations and provide water for additional uses. Improvements of water uses will probably occur when they appear justified for economic reasons. The kinds of improved irrigation water uses that will most likely occur in the Green River Basin will be the lining of canals and ditches, the application of more efficient irrigation methods, the use of sprinklers, and the construction of reservoirs to regulate water supplies for more efficient distribution. Border irrigation is being used on the Eden Project and is coming into use in other areas of the Basin where alfalfa hay is grown. Sprinkler systems are being considered for new developments in the Basin but may be limited because the short growing season affects the economic feasibility of sprinkler irrigation.

Industries in the Green River Basin are currently utilizing recirculating water systems, and most of the diverted water is for makeup and cooling water lost in the recirculating process. It is anticipated that industries will utilize water in the same way in the future.

Municipal water consumption in the Basin currently is minor and is forecasted to increase from 5,000 acre-feet to 9,000 acre-feet per year by the year 2020. It is not anticipated that recycling of water for municipal purposes will occur in the Basin unless local water supply problems make it necessary.

Potential Groundwater Development

The groundwater resource has been developed to the extent of providing water of suitable quantity and quality for municipal, domestic, and live-stock uses. Industry also uses a small amount of groundwater.

Most past groundwater developments have been directly related to supplying domestic and stock water for ranching. More recently groundwater supplies have been developed by mineral industries in the Basin. The forecasted expansion of industry will be the major factor in increasing groundwater withdrawals. The industrial use of groundwater (4,000 acre-feet per year) is projected to increase to 31,000 acre-feet annually by the year 2020. Water of suitable quality for irrigation can be obtained from groundwater aquifers and probably would support small-scale irrigation locally. Supporting a large irrigation project solely with groundwater could be expensive and could deplete aquifers faster than they could be naturally recharged.

Unconsolidated Aquifers

Floodplain alluvium along major streams of the Basin is a significant source of groundwater (Figure II-4). Most of the wells tapping alluvial aquifers have small yields, but a properly constructed well which penetrates a sufficient thickness of saturated sand and gravel may yield up to several hundred gallons of water per minute. Alluvial aquifers provide the base flows of streams during times of low water and lose water to the atmosphere by evapotranspiration.

Gravel benches or terraces are topographically higher than the floodplains and are remnants of earlier stream deposits. If the average saturated thickness is sufficient, gravels may yield up to several hundred gallons of water per minute through properly constructed wells. Gravels are recharged by precipitation and runoff from higher elevations and are depleted by gravity drainage and evapotranspiration. Water seeping out of terrace gravels recharges aquifers at lower elevations. An extensive area of glacial deposits, gravels, and alluvium of the New Fork River appears to be hydraulically interconnected along the southwestern flank of the Wind River Range. The available information indicates an alluvium thickness of about 30 to 60 feet and a terrace gravel thickness of about 20 to 100 feet in this area. Well yields of 70 gpm and less are reported, with most considerably less than 70 gpm. The extensive deposit of unconsolidated sands and gravels close to the mountain recharge area suggests a groundwater potential greater than indicated by available well records. However, any large-scale development should not be contemplated without adequate aquifer testing and evaluation.

The U. S. Geological Survey reports that small to moderate quantities of groundwater can be obtained from alluvium and terrace gravels in the Lyman-Mountain View area (Uinta County). Domestic water is obtained almost entirely from groundwater supplies (not all from unconsolidated aquifers). Groundwater is also used for livestock, although the principal sources of both stock and irrigation water are Blacks and Smiths Forks. The deposits of alluvium and gravels are more than 40 feet thick locally. Where the saturated thickness and permeability are sufficient, well yields of a few hundred gpm might be possible. The sustained yield of wells depends upon the areal extent of the aquifer and the rate of recharge to it. Both the floodplain alluvium and the terrace gravel are recharged by irrigation water. This supplements the amount of water available, but may cause the water to be unsuitable for domestic use.

Deposits of floodplain alluvium and terrace gravels elsewhere in the Basin, such as along the Green River, the Piney Creeks, Cottonwood Creek,

Big Sandy River, Hams Fork, and intermittent streams in the Great Divide Basin have an unknown potential. A few wells having small yields are reported; large yields (a few hundred gpm) may be possible locally.

Consolidated Aquifers

Numerous wells in the Basin produce water that has been stored underground in consolidated sandstone. The most widely used consolidated aquifers are sandstones of the Wasatch and Fort Union formations (Table II-2). Sandstone permeability is generally low, but due to a gross aquifer thickness of several thousand feet and an areal distribution of hundreds of square miles, the Wasatch formation may be capable of supporting wells that yield more than 500 gpm. The Fort Union formation may yield 200 or 300 gpm per well. In order to obtain maximum yields, properly constructed wells must penetrate the entire formation thickness.

In Sublette County, in the northwestern part of the Basin, the Wasatch is exposed and therefore has lost the upper part of the formation due to erosion. Wells are 40 to 500 feet deep in the Wasatch and have small water yields. Flowing yields of one to 50 gpm are common. Due to structural deformation of the Basin, the rock strata are inclined away from the mountains and towards the Green River. The topographic basin is also a structural basin. The exposed Wasatch formation dips into the subsurface and is overlain by younger formations in Uinta and western Sweetwater Counties. In Uinta County, Wasatch wells reportedly are 1,200 to 2,800 feet deep. They are more than 2,000 feet deep in southwestern Sweetwater County. Even though wells are drilled more than 2,000 feet below ground level, they penetrate only the upper part of the Wasatch aquifer due to an overlying sequence of younger rocks. Well yields (some flowing) are in the range of only three to 50 gpm. Greater yields could be obtained if wells were constructed through the entire Wasatch interval, but this would require drilling to approximately 5,000 feet below the surface.

The Rock Springs Uplift is void of Tertiary rocks excepting along its flanks. The pre-Tertiary rocks contain aquifers at intermediate depths. Some of the better aquifers (in the Mesaverde group) are absent from the top of the uplift due to erosion but are exposed on the flanks and are present in the subsurface of the surrounding area. An outcrop of Tertiary conglomerate and sandstone (Bishop conglomerate) makes up a small portion of the southwestern flank of the uplift. The Bishop conglomerate has a fair groundwater potential locally. One well is known (1966) to yield 42 gpm with a concentration of total dissolved solids of about 600 ppm; spring water issuing from the formation has a concentration of 350 ppm.

Southeast of the Rock Springs Uplift the groundwater potential is comparable to that of Uinta and western Sweetwater Counties: The Wasatch is overlain by younger formations (Tipton shale, Cathedral Bluffs, Laney shale, and Bridger/Uinta formation in ascending order) and would require relatively deep drilling to be effectively utilized as an aquifer. A small exposure of Browns Park formation is found along the state line.

Northeast of the Rock Springs Uplift is a wide expanse of sand and sandstone of the Red Desert (Great Divide Basin). The sandstone is predominantly of the Wasatch formation and has a groundwater potential similar to the Wasatch

in the northwestern part of the Green River Basin. The potential is fair to good depending on the saturated aquifer thickness. In the eastern half of the Great Divide Basin the Wasatch sandstone undergoes a formation change into arkosic sandstone of the Battle Spring formation. The groundwater potential of the Battle Spring formation is very good, and the yield of a well penetrating the entire formation (approximately 4,000 feet thick) might exceed 1,000 gpm. The concentration of total dissolved solids probably would range from less than 200 to about 1,000 ppm.

Aquifer Potential

Based on the areal extent and known thickness of the subsurface sedimentary rock-section, it is estimated that millions of acre-feet of water are stored underground in the Green River Basin. Not all of this water is available to wells, but even if a tenth were available, it would be a vast undeveloped resource. The yield at a specific well site is dependent upon the extent of the aquifer, its saturated thickness, and its permeability. The costs of drilling, developing, and completing wells, pumps and attachments, and pumping-energy are important factors affecting groundwater development. Costs are directly related to aquifer characteristics; a poorly permeable aquifer requires more and deeper wells than an aquifer with good permeability to produce the same yield. The cost of a flowing well is less than a pumping well, but most flowing yields are adequate only for domestic or stock uses.

The water tables of alluvial aquifers in the floodplains of the major streams fluctuate with the season, changes in river-stage, and water-use patterns. Alluvial aquifers normally are more permeable than consolidated aquifers but are not nearly as thick or extensive; alluvial aquifers are more readily polluted or contaminated than deeper consolidated aquifers. Shallow alluvial aquifers are usually found in proximity to surface water; therefore, the development of alluvial groundwater may take place supplemental to or conjunctive with the development of surface water.

Recharge to underground reservoirs in the Green River Basin is slight. Large sustained withdrawals of groundwater from consolidated aquifers would remove water from storage and cause a lowering of pressure surfaces. The net long-range result would be the necessity of continually drilling deeper wells to obtain moderate or large yields. The greatest potential for groundwater development appears to be in the northwestern part of the Green River Basin and in the Great Divide Basin where relatively thick intervals of extensive saturated aquifers are present 2,000 to 4,000 feet below the surface.

SURFACE WATER PROJECTS

In Chapter III potential projects were identified to meet the future irrigation water needs, and other irrigation projects were identified that might be constructed if feasible and desired by the people of the Basin. The future municipal and industrial water supplies could be developed for individual industries or towns, or for several industries and towns jointly. Recreation facilities and allowances for fish and wildlife enhancement can be included in the projects. The projected water resource developments to

the year 2020 are shown in Table IV-1. A discussion of the tabulated projects and the other projects identified in Chapter III is presented in this section of the report.

The Bureau of Reclamation is preparing a study of alternate projects that might be constructed with Federal funds. The report on this investigation is scheduled for release early in 1971. Alternatives of development of irrigation, provisions for municipal and industrial water supplies, regulation of water supplies for transbasin diversion, and provisions for multipurpose uses for fish and wildlife enhancement, recreation, and power will be included in the Bureau report.

Eden Project Improvement

The Eden Project was constructed in 1907 as a private development under the Carey Act. The project suffered from poor drainage and inadequate maintenance. During the 1930's the Bureau of Reclamation investigated rehabilitating and expanding the project; a Bureau of Reclamation project was authorized in 1940, but construction was delayed until after the end of World War II. The project was again authorized in 1949 and construction began in 1950. The Bureau of Reclamation constructed Big Sandy Reservoir, Means Canal, and a system of laterals, and rehabilitated Eden Reservoir and the original canal and lateral system to irrigate an authorized project of 20,200 acres. The water supply requirement was estimated to be about 65,000 acre-feet per year (71). Construction was completed in 1960.

After about 17,550 acres of the project were prepared for settlement, it became evident that water supplies were inadequate for the entire 20,200 acres authorized for development (58). Water supply shortages and other problems have caused investigations to be made for improved water uses and to locate additional water supplies for the project. In 1967 a program was initiated to line and enlarge canals and laterals and to pump return flows back onto the project for reuse. With this improvement program, the Bureau of Reclamation estimates that about 54,400 acre-feet of water per year will be available for the nearly 17,100 acres presently under irrigation.

The remaining 3,100 acres of the authorized project could be irrigated with an increased water supply. A diversion from East Fork and other tributaries of the New Fork River into Big Sandy River would provide additional water supplies for the project. The proposed Sanders Ranch Reservoir on Big Sandy River would be required for streamflow regulation. A project to improve the Eden water supply could be constructed as an individual project, or as a unit of a larger development that could include the East Side Project, which is discussed in a following section of this chapter.

It is estimated that the improved water supply for the Eden Project Improvement will increase Wyoming's Colorado River depletion by 10,000 acre-feet per year. This depletion is shown in Table IV-1.

The benefits from supplementing the Eden Project water supply and enlarging the project to its authorized 20,200 acres were reported by the Bureau of Reclamation in 1964. Annual irrigation benefits were estimated to be \$508,700 and recreation and fish and wildlife benefits to be \$99,100, for a total annual benefit of \$607,800. The benefit-cost ratio was reported to be 1.30:1.

Lyman, Savery-Pot Hook, and Seedskadee Projects

Congress has authorized construction of three Bureau of Reclamation projects in the Basin in addition to the existing Eden Project. These are the Lyman, Savery-Pot Hook, and Seedskadee Projects. Water supplies are considered to be committed for these projects since they are authorized and two are partially constructed. The Lyman Project is under construction and consists of providing a supplemental water supply to 36,000 acres by constructing the Meeks Cabin Dam on Blacks Fork and China Meadows Dam on Smiths Fork. The Savery-Pot Hook Project on the Little Snake River will provide supplemental water to lands in Wyoming and Colorado and bring new lands under irrigation to allow for enlarging the size of existing farm units. The Wyoming portion of the project will include 6,980 acres which will receive a supplemental water supply and 10,690 acres of new irrigated land. The Seedskadee Project on the Green River is authorized to bring 57,000 acres of new land under irrigation. Fontenelle Reservoir, a storage facility of the project, is already constructed. The reservoir has an active capacity of 150,000 acre-feet, including 60,000 acre-feet of M & I storage owned by the State, in addition to irrigation storage.

The estimated streamflow depletions from these projects are: Lyman 10,000 acre-feet per year; Savery-Pot Hook 12,000 acre-feet per year, and Seedskadee 106,000 acre-feet per year (86,000 for irrigation plus 20,000 for the Wildlife Refuge). All the depletions are included in the projection shown in Table IV-1.

The economic benefits and costs of these projects have been estimated by the Bureau and reported in Feasibility and Definite Plan reports. The following tabulation summarizes the annual benefits and the benefit-cost ratios for the projects:

Project	(Dollar Values in 1,000's)				Year of Report
	Irrigation Benefits (\$1,000)	Recreation, Fish & Wildlife Benefits (\$1,000)	Total Benefits (\$1,000)	Benefit-Cost Ratio	
Lyman	\$ 405.7	\$ 96.4	\$ 502.1	1.17:1	1962
Savery-Pot Hook	861.5	11.7 ¹	873.2	1.47:1	1959
Seedskadee	2,037.8	323.5	2,361.3	1.41:1	1959

¹ Includes benefits in Colorado.

Upper Green River Area Irrigation Projects

The irrigation potential of the Upper Green River Basin (Study Area 1, Figure III-2) has been investigated for many years by the Bureau of Reclamation. Development projects identified by the Bureau include the Sublette, La Barge, and the Fontenelle Projects.

The Sublette Project included plans to develop water supplies for two divisions. The West Side Division would irrigate lands adjacent to Beaver, Horse, Cottonwood, and the Piney Creeks west of the Green River. The Buckskin Division (now called East Side Project) would provide water for new

irrigation east of the New Fork River. Bureau of Reclamation investigations were temporarily discontinued in 1960. The Boulder Creek Watershed Project, covering a unit of the Buckskin Division, was constructed by the Soil Conservation Service under Public Law 566 in 1965.

The Bureau of Reclamation made plans to irrigate lands along the Green River near La Barge, Wyoming. Soil deficiencies were found on a portion of the La Barge Project lands during the definite planning investigations in 1961, and construction of the project has been deferred.

Investigations on the Bureau's Fontenelle Project on Fontenelle Creek were terminated because the project benefits did not exceed the costs at the time of the studies.

In 1968 the Bureau of Reclamation renewed investigations in the Green River Basin at the request of the State. The irrigation project potentials have been reexamined in this effort. Two projects that include the best development potentials are the East Side Project and the West Side Project.

East Side Project

The current investigation has defined the best remaining potential of the Buckskin Division to be about 22,000 acres of new lands adjacent to and south of lands presently irrigated from the East Fork River (see Figure III-1). The East Side Project would also develop supplemental water supplies for about 11,000 acres presently irrigated from the East Fork and its tributaries. A project for these purposes would probably include enlargements of the existing Fremont Lake and Boulder Lake Reservoirs. The existing 10,000-acre-foot Fremont Lake Reservoir would be enlarged by constructing an outlet three feet below the present lake level, enabling about 15,000 acre-feet of storage to be developed with a three-foot reservoir fluctuation. A new dam would be constructed at Boulder Lake, and the capacity would be increased to about 155,000 acre-feet. This storage capacity plus streamflow surplus would be utilized to develop the project water supply. The East Side Project could be a unit of a larger project that could also include the Eden Project Improvement and a transbasin diversion to the North Platte River.

It is estimated that the East Side Project would have a stream depletion of 32,000 acre-feet per year. The East Side Project was not included in the projections given in Tables III-10 and IV-1 because project feasibility has not been determined. Consumptive use on this project would be part of uses "Available for Other Development" in Table IV-1. Details of the costs and benefits of the East Side Project are not yet available from the Bureau. There are indications that the project may be economically feasible by itself or as a unit of a larger project.

West Side Project

As envisioned by the Bureau, the West Side Project would develop new lands and provide supplemental water for lands west of the Green River irrigated from the River and its tributaries. The project water supply would be developed from the Green River, and storage would be provided in the proposed Kendall Reservoir. For a maximum development, the West Side Canal would be constructed from Kendall Dam to South Piney Creek, and about 25,000 acres of new lands would be included in the project.

In 1966 the Bureau reported that the West Side Project did not appear feasible because the direct irrigation benefits were only 57 percent of the project costs. The recent investigations are reported to reach a similar conclusion about economic feasibility. This factor and problems of land ownership exceeding Bureau acreage limitations may delay further consideration of the project for many years. Therefore, the project has not been included as a projected development (Tables III-10 and IV-1).

Private Irrigation Projects

By the year 2020 an estimated 29,000 acres of new lands will be developed by private irrigation projects in the Basin. This acreage and the corresponding streamflow depletion of 29,000 acre-feet per year are included in the projections of Chapter III and Table IV-1.

New lands totaling 15,000 acres can be developed under five privately constructed canals in the Upper Green River area. Developments utilizing the New Fork River and tributaries for water supply include: Approximately 1,200 acres under the Highland Canal near Pinedale, Wyoming; about 1,500 acres under the Paradise Canal, which diverts from the New Fork River near Boulder, Wyoming; and about 1,000 acres in the Boulder Creek Watershed Project near Boulder, Wyoming. New lands that can be developed utilizing water from the Green River are: 2,700 acres on 40 Rod Flat under Canyon Canal (Figure III-1); and 8,600 acres under the Green River Supply Canal and the Cottonwood Canal near Big Piney, Wyoming. These acreages were determined by the Water Planning Program from an examination of aerial photographs and water right records, and from land classification surveys. In some cases additional lands are included within the water right application that were judged to be unsuitable for irrigation.

Water supply studies indicate that lands irrigated under the 40 Rod Flat Project and Green River Supply-Cottonwood Canals would have water supply shortages under the projected full development. The proposed Kendall Reservoir could provide a supplemental water supply for these lands.

The annual benefits to the Basin from the development of the total 29,000 acres were estimated to be about \$153,000. This estimate assumes the net return to the land on these projects would be the same as the average for the presently irrigated lands in the Basin (see Table III-5).

A large private irrigation project has been proposed by the Uinta Development Company northwest of the town of Green River, in the Lower Green River and Lower Blacks Fork areas. Diversions from the Green River would irrigate 58,000 acres in the Union Pacific Railroad alternate-section ownership area. The feasibility of the project has not been investigated, and the project is not included in the projections. The project may be included in a plan for industrial development. Irrigation has been suggested in the treatment of effluent from a potential pulp and paper mill in the project area (see Chapter III - Timber).

Green River Supplemental Supply Project

The feasibility of enlarging and extending the Green River Supply Canal into the Piney Creeks area was recently investigated for the Piney Water

Association (5). According to that investigation a total of about 6,200 acres can be irrigated with the Green River Supply Canal which now ends at Cottonwood Creek. The enlargement and extension of the canal beyond Cottonwood Creek into the Big Piney area would bring about 6,400 acres of new land under the canal and about 22,600 acres of lands presently irrigated from the Piney Creeks under the canal. The new lands are a part of the 8,600 acres projected for private irrigation projects. Lands to be provided a supplemental water supply would include the 22,600 acres receiving Green River water in exchange for Piney Creeks water, plus 15,600 acres above the Green River Supply Canal that would receive Piney Creeks water made available by the exchange of Green River water.

Water supply studies by the Water Planning Program staff indicate that there will be severe water shortages to lands under the Green River Supply Canal and the Big Piney area supplemental supply when the project is fully developed. The 40 Rod Flat Project also will have severe water shortages after being fully developed. The proposed Kendall Reservoir could supply the supplemental water requirements to both projects.

The annual benefits from the supplemental water supplies will depend upon the extent to which irrigated native hay and pasture are converted to improved grasses and alfalfa crops. A 1967 Soil Conservation Service report to the Big Piney Soil and Water Conservation District showed that the annual net return from the present irrigation could be more than doubled by providing a full season water supply eight years in ten, and by improving the types of hay crops grown.

The consumptive use of water on the new lands in the 40 Rod Flat and Green River Supply Canal Projects is included in Table IV-1, in the total for private irrigation projects. The streamflow depletion associated with supplementing water supplies for the 40 Rod Flat Project, the Green River Supply Canal, and the Big Piney area (hereafter termed Green River Supplemental Supply Project) is estimated to be about 22,000 acre-feet per year.

Green River Basin Municipal and Industrial Water Supplies

Existing Green River Basin industrial plants are located between Rock Springs and Kemmerer, Wyoming. One steam-electric plant uses Hams Fork water. Trona mining and processing plants use water pumped from the Green River. The projected coal, oil shale, trona, uranium, and timber industries will be located primarily in the central part of the Basin and could be supplied water diverted from the Green River below Fontenelle Reservoir.

Most industries require a firm water supply to support their investments. Industries with water rights junior to the Seedskadee Project will need storage water to firm up direct flow water rights from the Green River. This is evidenced by the recent demand by industries to purchase water from Fontenelle Reservoir. Fontenelle Reservoir and the potential Kendall, New Fork Narrows, or Lower Green Reservoirs would provide the required storage (see section on Alternative Water Resource Developments, page 126).

The consumptive uses of M & I water now total 21,000 acre-feet per year and are projected to increase to 240,000 acre-feet per year. As was shown in Table III-20, the industrial expansion by the year 2020 will result in

benefits to the area of an increase in employment and capital investment. The increase in capital investment will provide a substantial increase in the tax base of the area. The increased direct employment and associated population growth will create additional needs for services, which will cause a secondary population growth.

Most existing industries in the Basin discharge effluents into ponds and lagoons, from which there is nearly total evaporation. In this way industry has little adverse effect upon the water quality. Industrial water uses may affect the quality of water available to Green River and Rock Springs, however, if large quantities of water are diverted above Green River, Wyoming. It will be imperative for industries and municipalities to continue to provide treatment of sewage effluent to insure that Wyoming's water quality standards are met.

Transbasin Diversion of Water

The report by Cameron Engineers, Wyoming Mineral Industries--Review and Forecast, describes the future water requirements for industry in the State of Wyoming. This report not only shows a large increase in industrial water requirements in the Green River Basin but also in the Platte and Powder River Basins of Wyoming. The projected growth of industry is based upon ample water supplies being available. Increased industrial growth will bring about an increase in the population of the municipal centers of the State, with an increased demand for municipal water supplies. The water supplies will have to be derived from all available sources, including the transfer of water resources from areas of surplus into areas of shortage. An example of such a transfer of water is the Cheyenne diversion from the Little Snake River into the North Platte River Basin.

There are several ways of diverting water into the North Platte River from the Green River Basin: 1) For a relatively small diversion, water from New Fork River tributaries could be diverted into the Big Sandy River in exchange for water diverted into the North Platte River via the Sweetwater River. 2) A conveyance system could be constructed from the proposed Kendall Reservoir to the Sweetwater River. 3) A facility could convey water from the proposed New Fork Narrows Reservoir into the Sweetwater River. 4) Water could be pumped from the New Fork Narrows Reservoir and conveyed across the Great Divide Basin into the North Platte River. 5) A fifth alternate would be to pump water from the Green River near the town of Green River and convey it across the Great Divide Basin into the North Platte River upstream from Seminoe Reservoir. Other alternatives exist but would be modifications or combinations of these five schemes.

As much as 272,000 acre-feet of consumptive uses per year can be diverted from the Green River into other basins. The amount that may actually be diverted depends upon three factors: The amount ultimately made available to Wyoming under the Colorado River Compacts; the amount used to satisfy Green River Basin demands; and the finances available for the diversion project.

A large portion of the forecasted Green River Basin industrial water requirement will be needed for coal-based industries. The coal resource centers are in the western part of the Basin near Kemmerer, east of the Green

River near Rock Springs, and in the Great Divide Basin. Analysis of the Cameron Report reveals that of the total Green River industrial water requirements for the year 2020, about 100,000 acre-feet of the demand is associated with forecasted developments east of the Green River. Delivery of water for these industries could be made in joint-use facilities that would also deliver water to the North Platte River. A conveyance system for both Green River Basin industrial water deliveries and transbasin diversion to the North Platte River appears economically desirable.

ALTERNATIVE WATER RESOURCE DEVELOPMENTS

The objective of this report is to illustrate the possible alternatives of water resource developments that will meet the projected future water needs of the area and utilize Wyoming's Compact allocation of the Colorado River. The developments projected in the Basin by 2020 are shown in Table IV-1 and include:

Seedskaadee (irrigation of 57,000 acres new land and the Wildlife Refuge)

Lyman (supplemental supply for 36,000 acres)

Savery-Pot Hook (6,980 acres of new land and supplemental supply for 10,690 acres)

Cheyenne Diversion (31,000 acre-feet per year by 2020)

Private Irrigation Projects (29,000 acres new land by 2020)

Eden Project Improvement (3,100 acres new land and supplemental supply for 17,100 acres)

Green River Basin M & I Water Supply (total of 240,000 acre-feet per year by 2020, 27,000 acre-feet of which would be groundwater)

If no major reservoirs are constructed on the main stem of the Green or New Fork River, the projected water needs cannot be met. An estimate of the water uses without major reservoirs or a transbasin diversion is given in Table IV-2. Certain assumptions must be made in order to estimate the amount of development under these conditions:

1. The Lyman and Savery-Pot Hook Projects would be completed. Dams for these projects are small and on tributaries. Meeks Cabin Dam of the Lyman Project is under construction, and China Meadows Dam will be constructed as soon as Federal funds are available. The Savery Dam of the Savery-Pot Hook Project is in the final design stage.

2. The Eden Project Improvement would be constructed. This will require an interbasin diversion from the East Fork River to the Big Sandy River and construction of the Sanders Ranch Dam on Big Sandy River.

3. Private irrigation projects totaling 29,000 acres would be completed. As has been discussed, two of these projects will have water supply shortages unless storage is provided by Kendall Dam. It is further assumed that the Uinta Development Company Project would not be constructed and the Green River Supplemental Supply Project would not be undertaken because of lack of storage.

4. The Seedskadee Project would be constructed as authorized to irrigate 57,000 acres.

5. The year 2020 M & I use of surface water will be an increase of 119,000 acre-feet over present uses.

6. Boulder Lake and Fremont Lake reservoir enlargements and the East Side Project would not be constructed.

TABLE IV-2 -- Uses of Green River Water if Reservoirs and Transbasin Diversions Are Not Constructed (Acre-Feet Per Year)

	Projected Increases in Consumptive Uses by 2020	Water Supply Assumption	
		A	B
Wyoming's Share of Compact Water Uses		875,000	1,043,000
Present Uses		- 296,000	- 296,000
Presently Available for Development		579,000	747,000
Without New Reservoirs			
Lyman	10,000		
Savery-Pot Hook	12,000		
Eden Project Improvement	10,000		
Private Irrigation Projects	29,000		
Seedskadee			
Irrigation	86,000		
Wildlife Refuge	20,000		
Green River Basin M & I	119,000 ¹		
Cheyenne Diversion	24,000		
Colorado River Storage Project Evaporation	92,000		
	402,000	- 402,000	- 402,000
Unused		177,000	345,000

¹ Increased use of surface water over present use of 21,000 acre-feet per year. Total use of 140,000 acre-feet per year would be about 110,000 acre-feet from the Green River and about 30,000 acre-feet from Hams Fork. This is 73,000 acre-feet less than the projected increase in Table IV-1.

The effect of not permitting new reservoir construction would be to restrict the development of the Basin. Between 177,000 and 345,000 acre-feet per year of consumptive uses of water from Wyoming's compact allocation would not be utilized (Table IV-2). A comparison of Tables IV-1 and IV-2 shows that all of the projected development except the total M & I growth could take place. Perhaps the M & I development could occur, but a corresponding decrease in upstream irrigation would also occur.

A transbasin diversion would probably not be constructed without a reservoir because it would be undependable at the level of development shown. It will be seen that the restriction on the water available for transbasin diversions is considered to be the level of development undertaken in the Green River Basin itself.

Stored water will be required to meet the projected water needs, and three potential dam sites are proposed to provide reservoir storage on the Green River. One or more of these three key reservoir alternatives could be constructed, depending upon the ultimate amount of water resources developed. The proposed reservoirs are: 1) Kendall, on the Green River above Beaver Creek; 2) New Fork Narrows, near the mouth of the New Fork River near Big Piney; and 3) the Lower Green Reservoir on the Green River about three miles upstream from Interstate Highway I-80, near the town of Green River.

Considerations were given in the planning process to using Flaming Gorge Reservoir or an enlargement of Fontenelle Reservoir to develop water supplies. A cost analysis revealed that pumping from Flaming Gorge Reservoir resulted in higher water costs than using any of the other potential reservoirs. Previous foundation problems at Fontenelle Dam seem to preclude an enlargement. Neither of these reservoirs is presented as an alternative in this report.¹

Alternative plans related to each of the three reservoirs were formulated. The water needs of projects listed in Table IV-1 were satisfied in each plan. Between 104,000 and 272,000 acre-feet per year are available for development. This water supply and the M & I water supply could be developed by one or more of the reservoirs. Plans 1, 2, and 3 each show how one of the three reservoirs would be used to develop the water available under Assumption "A." Plan 4 is a modification of Plan 1 in which Wyoming's original compact allocation of water is developed (Water Supply Assumption "B").

Water supply studies considered the relative dates of priority of water rights for both direct flow uses and storage facilities. It was assumed that a minimum streamflow in the Green River below Fontenelle Dam of 300 cfs would be provided which could be diverted below the Seedskafee Project for M & I purposes. This minimum flow would provide a fishery throughout the Seedskafee Wildlife Refuge. The assumption has the effect of requiring winter bypasses of streamflows from either Kendall or New Fork Narrows Reservoir. The winter streamflows and irrigation and M & I water uses below these dams would provide a stream fishery along most of the Green River in Wyoming.

Plan 1 -- Kendall Reservoir

The construction of Kendall Dam would help provide maximum water resource development within the Green River Basin. Kendall Reservoir would provide storage for Green River Basin M & I water supplies. If the M & I water and the Green River Supplemental Supply Project were included as uses of Kendall storage, Fremont and Boulder Lake Reservoir enlargements would be required for the East Side and Eden Improvement Projects. The prior rights for irrigation along the Green River between the Kendall Damsite and the confluence of the New Fork River limit the water supply available to Kendall Reservoir. If the Green River Supplemental Supply Project were not desired, a portion of the Kendall water supply could be used on the East Side Project or for transbasin diversion. A transbasin diversion from the Upper Green River area over the Continental Divide would require less pumping lift than a diversion from any other place in the Basin.

Plan 1-A

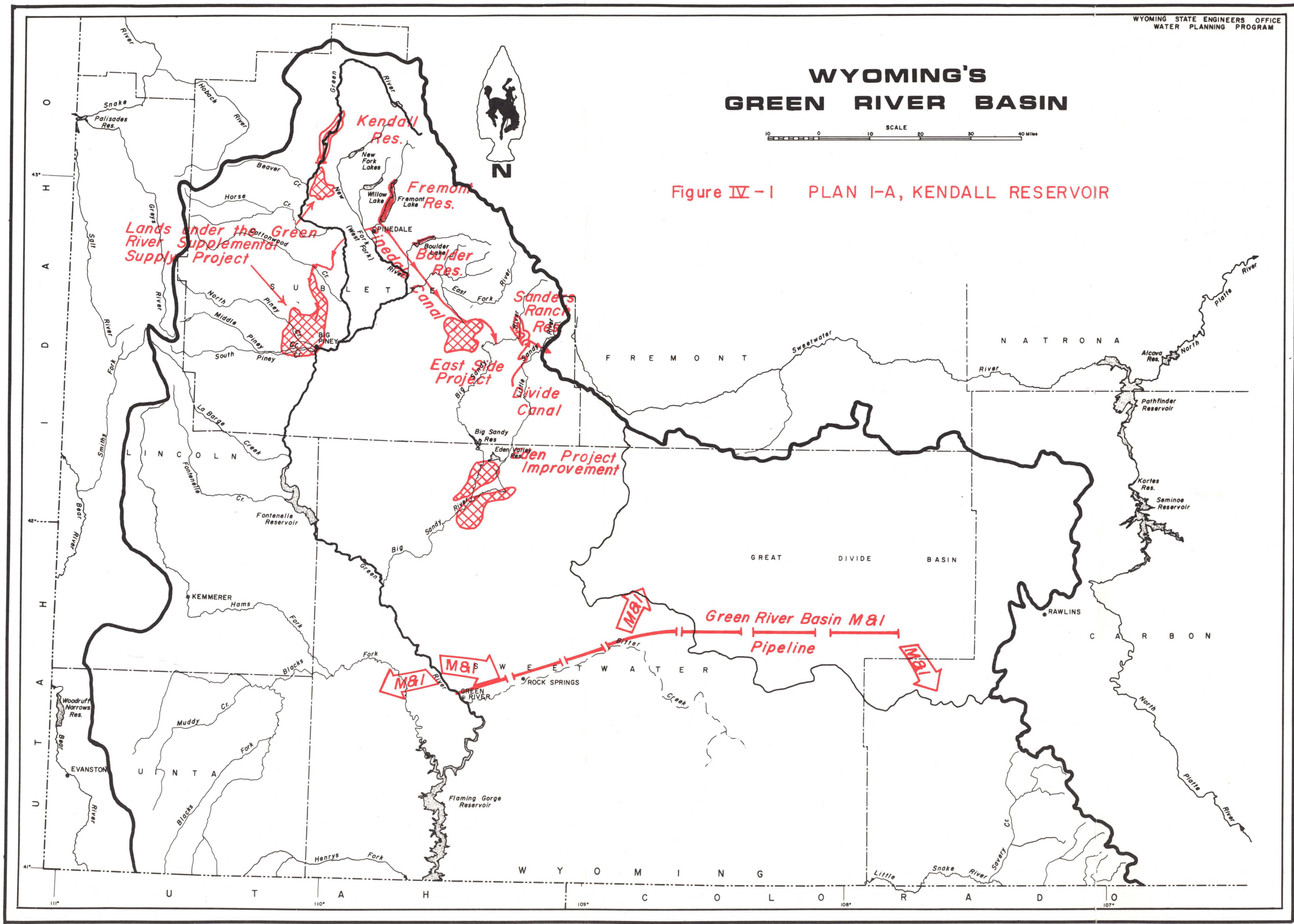
Kendall Reservoir would provide storage for the Green River Supplemental Supply Project and Green River Basin M & I water supplies. The East Side Project, Eden Improvement Project, and a transbasin diversion would be joint features of a project utilizing Fremont, Boulder, and Sanders Ranch Reservoirs (see Figure IV-1). Streamflow depletions from the Green River Basin M & I water uses were included in the projection shown in Table IV-1.

¹ The Bureau of Reclamation reportedly is considering an enlargement of Fontenelle Reservoir.

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Figure IV - I PLAN I-A, KENDALL RESERVOIR



The uses identified in Table IV-1 as "Available for Other Development" would be as follows:

East Side Project	32,000	acre-feet per year
Green River Supplemental Supply Project	22,000	
Transbasin Diversion	39,000	
Kendall Reservoir Evaporation	<u>11,000</u>	
Total	104,000	

Plan 1-B

If Kendall Reservoir storage were not committed to the Green River Supplemental Supply Project, the Fremont Lake Reservoir enlargement could be eliminated, and the amount of transbasin diversion could be increased. Kendall Reservoir would provide storage for Green River Basin M & I water supplies and the transbasin diversion. If the East Side Project were not constructed, the amount of transbasin diversion could be further enlarged. The transbasin diversion could be conveyed from Kendall Reservoir, or it could be diverted with Green River Basin M & I water supplies near Green River, Wyoming, and conveyed across the Great Divide Basin to the North Platte River (see Figure IV-2).

The uses identified in Table IV-1 as "Available for Other Development" would be as follows:

East Side Project	32,000	acre-feet per year
Transbasin Diversion	61,000	
Kendall Reservoir Evaporation	<u>11,000</u>	
Total	104,000	

or

Transbasin Diversion	93,000	acre-feet per year
Kendall Reservoir Evaporation	<u>11,000</u>	
Total	104,000	

Water supply studies indicate that about 290,000 acre-feet of active storage space in Kendall Reservoir would be required for both Plan 1-A and Plan 1-B. To divert water into the Canyon Canal for the 40 Rod Flat Project, a dead storage pool of 15,000 acre-feet must be maintained below the diversion level. If an inactive (minimum) pool of 100,000 acre-feet were provided for recreation and a fishery pool, the total required reservoir capacity would be 390,000 acre-feet.

Plan 2 -- New Fork Narrows Reservoir

New Fork Narrows Reservoir could provide storage for Green River Basin M & I water supplies and transbasin diversion. Irrigation in the Lower Green River area could receive New Fork Narrows storage water via the Green River, but Upper Green River area irrigation from this supply would require pumping from the reservoir. The reservoir site has a potential storage capacity of more than a million acre-feet, but major relocations, including a portion of U. S. Highway 187, would be required if the reservoir were

constructed with a capacity greater than about 400,000 acre-feet. It appears at this time that a 400,000-acre-foot reservoir would be sufficient for the purposes anticipated for Water Supply Assumption "A." Figures IV-3 and IV-4 show the alternate facilities considered for Plan 2.

Plan 2-A

The largest amount of in-basin water use (under Water Supply Assumption "A") with New Fork Narrows Dam is shown in this plan. The East Side Project and Eden Improvement Project would be joint features of a project utilizing water from tributaries of the New Fork River. New Fork Narrows Reservoir would provide Green River Basin M & I water and storage to support a transbasin diversion. A pipeline from the Green River near the town of Green River would supply M & I water in the Basin and deliver about 64,000 acre-feet per year to the North Platte River.

The uses identified as "Available for Other Development" in Table IV-1 would be as follows:

East Side Project	32,000	acre-feet per year
Transbasin Diversion	64,000	
Reservoir Evaporation	8,000	
Total	104,000	

Water supply studies indicated a 250,000-acre-foot New Fork Narrows Reservoir could be used in Plan 2-A, providing active storage of 180,000 acre-feet and a minimum pool of 70,000 acre-feet for recreation and a fishery.

Plan 2-B

This is the same as Plan 2-A without the East Side Project. Figure IV-4 shows the plan; Green River Basin M & I and transbasin diversion water could be diverted either near Green River, Wyoming, or at the New Fork Narrows Dam. A larger reservoir is required for the latter diversion because the New Fork River must supply all of the water, while the Green River would supply some water for the diversion at Green River, Wyoming.

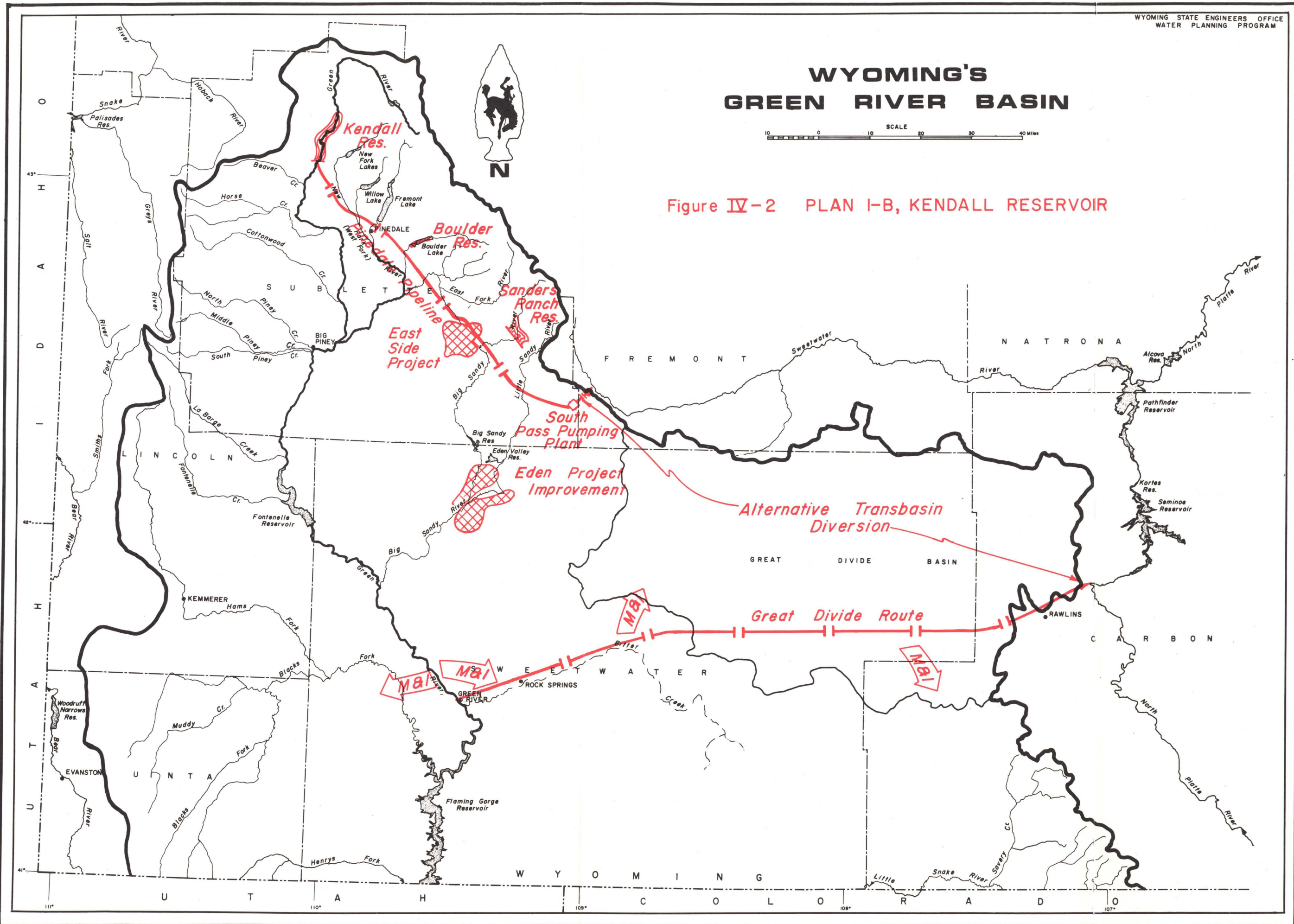
A 250,000-acre-foot New Fork Narrows Reservoir would supply the M & I pipeline from Green River, Wyoming, and provide a 70,000-acre-foot minimum pool. A 400,000-acre-foot reservoir would supply the diversion from the reservoir and provide a 35,000-acre-foot minimum pool. The uses "Available for Other Development" would be as follows:

	Streamflow Depletions in Acre-Feet Per Year for Reservoir Sizes of:	
	<u>250,000 acre-feet</u>	<u>400,000 acre-feet</u>
Transbasin Diversion	96,000	93,000
Reservoir Evaporation	8,000	11,000
Total	104,000	104,000

WYOMING'S GREEN RIVER BASIN



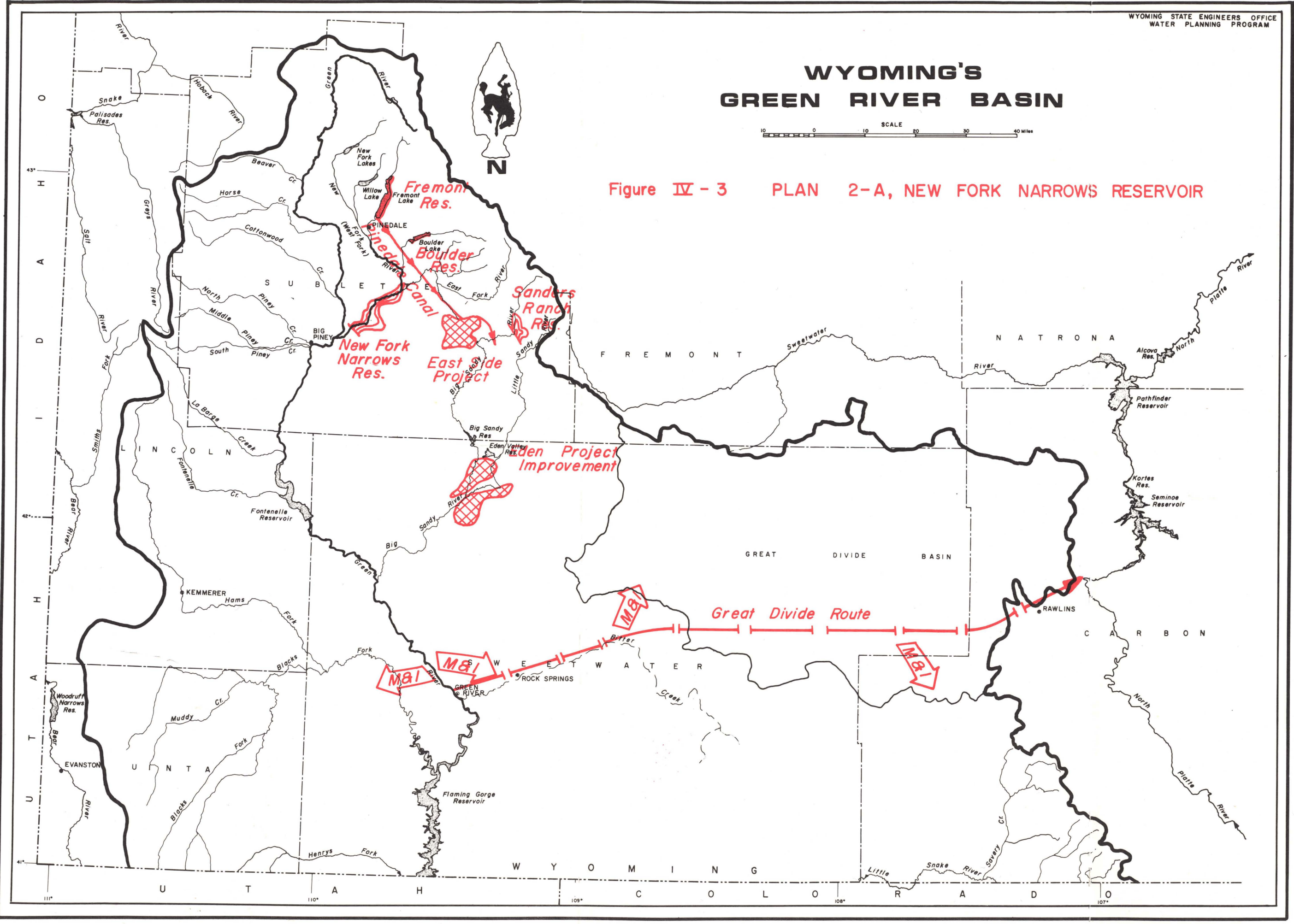
Figure IV-2 PLAN I-B, KENDALL RESERVOIR



WYOMING'S GREEN RIVER BASIN



Figure IV - 3 PLAN 2-A, NEW FORK NARROWS RESERVOIR



Plan 3 -- Lower Green Reservoir

The Lower Green Reservoir would provide river reregulation below the Seedskaadee Project (see Figure IV-5). Storage would be provided for Green River Basin M & I water and transbasin diversion. Irrigation water for the Uinta Development Company Project could be provided, although this possibility is not included as part of this plan. Within this plan the East Side Project could also be constructed as a separate project.

The existing Stauffer Chemical Company trona plant restricts the capacity of the Lower Green Reservoir to about 266,000 acre-feet. Any larger capacity would require relocation of the mine and processing plant at a cost of many millions of dollars. Although the mine is approximately 800 feet beneath the ground surface at the upstream end of the proposed reservoir, and it is believed that the reservoir would not affect the mine, further investigation should be made before implementing the plan.

Water quality regulation is a primary consideration for the use of the Lower Green Dam. Under Water Supply Assumption "A," a 266,000-acre-foot reservoir would provide the year 2020 Green River Basin M & I water needs, an 86,000-acre-foot transbasin diversion, and water quality regulation, assuming the East Side Project were not constructed. The 104,000-acre-foot consumptive uses identified as "Available for Other Development" under Water Supply Assumption "A" in Table IV-1 would all be utilized in transbasin diversion and reservoir evaporation.

Plan 4

Development of the full Wyoming compact allocation of 1,043,000 acre-feet of beneficial consumptive uses (Water Supply Assumption "B," Table IV-1) in the Green River Basin would require two of the three reservoirs. The plan could be essentially the same as Plan 1-A with additional reservoir capacity to provide storage for the transbasin diversion across the Great Divide Basin, the Uinta Development Company Project, and provide river regulation for water quality and fishery management. All of the projected developments shown in Table IV-1 would be constructed. The East Side Project and the Eden Project Improvement would be built, using the Fremont and Boulder Lake Reservoir enlargements, and Kendall Reservoir would serve the Green River Supplemental Supply Project and Green River Basin M & I needs. The New Fork Narrows Reservoir built to a capacity of 400,000 acre-feet would be used to provide storage for transbasin diversion, the Uinta Development Company Project, and for water quality and fisheries management (see Figure IV-6).

The Lower Green Reservoir could be included in Plan 4 rather than the New Fork Narrows Reservoir. However, minimum streamflows in the Green River below the Lower Green Dam or the minimum pool in the reservoir would be limited unless the Stauffer Chemical Plant were relocated, or another storage facility were provided.

The potential Burnt Lake to Boulder Lake pump-storage hydroelectric project is shown on Figure IV-6. This peaking-power facility could be a desirable project for use with the several thermal-electric plants projected for the future.

The uses "Available for Other Development" in Table IV-1 would be as follows:

East Side Project	32,000	acre-feet per year
Green River Supplemental Supply Project . .	22,000	
Uinta Development Company		
Irrigation Project	82,000	
Transbasin Diversion and		
Reservoir Evaporation	<u>136,000</u>	
Total	272,000	

or

East Side Project	32,000
Green River Supplemental Supply Project . .	22,000
Transbasin Diversion and	
Reservoir Evaporation	<u>218,000</u>
Total	272,000

Water Quality Considerations

The two basic causes of salinity increases in a stream are salt loading and salt concentrating. Salt loading results from the discharge of additional minerals from the soil or from natural sources into a stream. Salt concentrating occurs as a result of the diversion and consumptive use of water. In other words, the salt in the stream remains constant, but the salt concentration increases because water is lost from the stream.

The effects of the Eden Project Improvement on the water quality of the Green River at Green River, Wyoming, would be quite small. The depletion of streamflow will result in an increase in total dissolved solids (TDS) of about three parts per million (ppm), and the salt loading from the project might increase the TDS at Green River town as much as another four ppm.

Inasmuch as the Lyman Project will provide a supplemental water supply to existing irrigated lands and no new irrigation is contemplated, it is assumed that there will be no salt loading effect from the project. The Lyman Project and industry located on Hams Fork will affect the water quality of Blacks Fork by increasing the concentration of total dissolved solids of Blacks Fork by about 57 ppm, which is an increase of 11 percent.

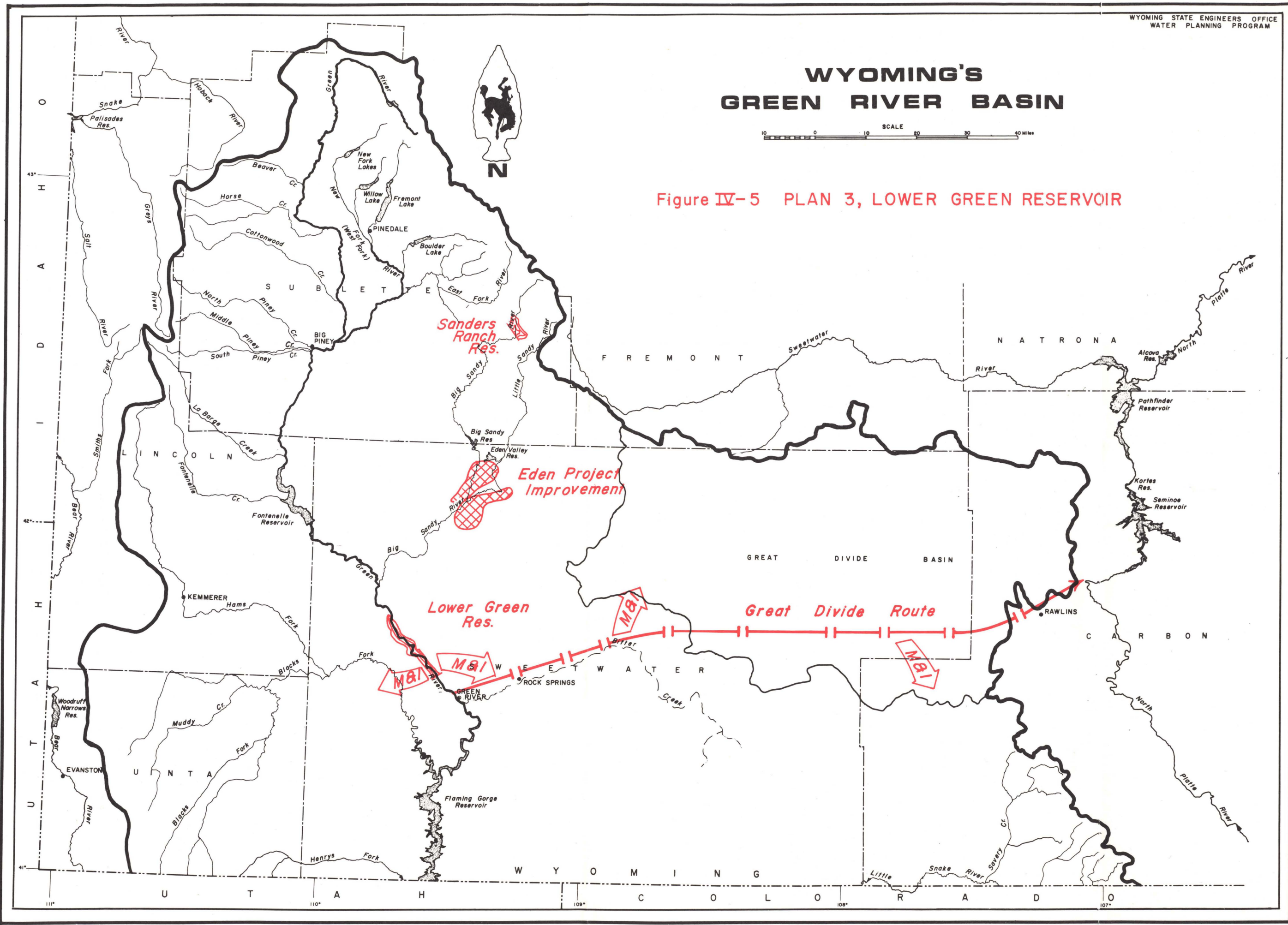
The concentrating effect of the Savery-Pot Hook Project will be to increase the TDS of the Little Snake River at Baggs, Wyoming, by 14 ppm or about eight percent. A part of this increase will be due to irrigation consumptive use in Colorado.

The effects of the Seedskaelee Project on water quality will be measurable at the gaging station on the Green River at Green River, Wyoming. There will be a concentration of total dissolved solids from the consumption of water on the project, and some concern has been expressed, especially by downstream M & I water users, that there will be salt loading in the Green River due to return flows from the project. Since the definite plan for the

WYOMING'S GREEN RIVER BASIN



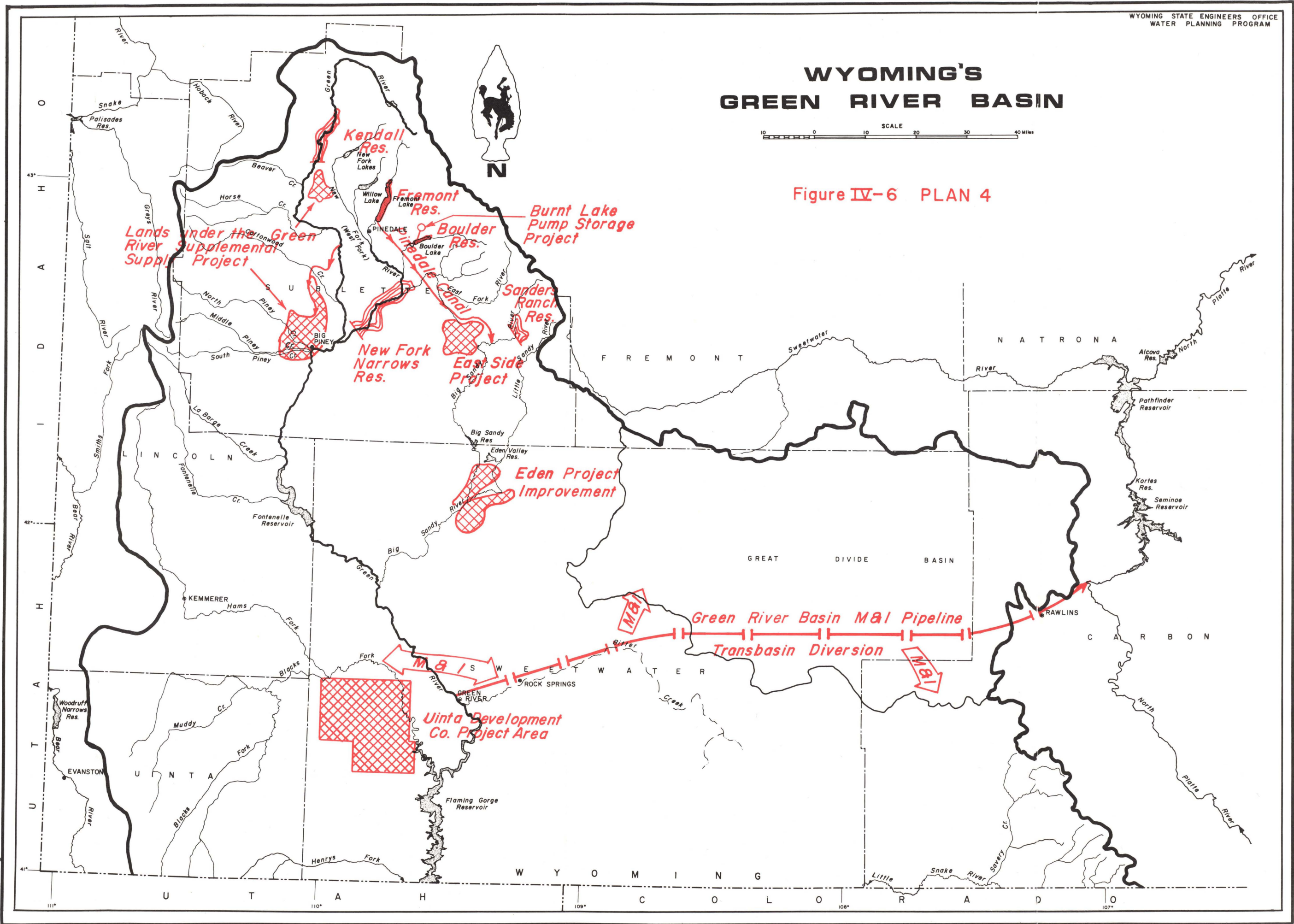
Figure IV-5 PLAN 3, LOWER GREEN RESERVOIR



WYOMING'S GREEN RIVER BASIN

SCALE 0 10 20 30 40 Miles

Figure IV-6 PLAN 4



project is not complete, an estimate of the amount of return flow and accompanying salts is not available. If sprinklers are used on the project, as presently contemplated, return flows and accompanying salts will be minimized. It will be many years after the project is in operation before its long-term effects are known. For comparative purposes, the river flows at Green River, Wyoming, and the concentration of total dissolved solids are given to illustrate the effects of the Seedskaadee Project under full development, assuming no salt loading and assuming salt loading of two tons of salts per year per acre in the return flow (46):

	<u>Green River at Green River, Wyoming - Acre-Feet/Year</u>	<u>Total Dissolved Solids - ppm</u>
Present Modified Flow	1,200,000	320
Flow after Seedskaadee (no salt loading)	1,092,000	350
Condition with two tons per year per acre salt loading	1,092,000	430

The effect of the East Side Project on water quality of the Green River at Green River, Wyoming, is estimated to be minimal (an increase in the concentration of total dissolved solids of nine ppm).

The effects of private irrigation projects on the water quality of the Green River at Green River, Wyoming, will be slight. Private irrigation projects identified in this report are estimated to increase the salinity (TDS) at Green River, Wyoming, by four ppm if no salt loading occurs, and by 11 ppm if there is salt loading.

The consumptive use of water in the Green River Supplemental Supply Project would increase the concentration of total dissolved solids in the Green River at Green River, Wyoming, by about six ppm.

Three upstream developments--Seedskaadee, Eden Project Improvement, and private irrigation projects--are included in all plans. The upstream Green River Supplemental Supply Project is included in Plan 1-A. The upstream East Side Project is included in Plans 1-A, 1-B, and 2-A. The salt concentrating effects from depletions on these projects will affect the water quality available for use at Green River, Wyoming. A transbasin diversion from the headwaters of the Green River will also have a small effect on the water quality at Green River. Plan 1 included a diversion from the headwaters as did an alternative in Plan 2-B, while Plans 2-A, 2-B, and 3 included the diversion with the Green River Basin M & I diversions at Green River, Wyoming. The combined salt concentrating effects would result in water available for use at Green River, Wyoming, with the following characteristics:

Plan	<u>Weighted Annual Average</u>	
	<u>Total Dissolved Solids (ppm)</u>	<u>Increase in TDS with Plan</u>
Present Condition	320	0
1-A	390	70
1-B (with East Side Project)	387	67
1-B (without East Side Project)	384	64
2-A	370	50
2-B (M & I and transbasin diversion at Green River, Wyoming)	360	40
3	360	40

Irrigation of new lands in some areas of the Basin above Green River, Wyoming, may produce some salt loading. Only after the irrigation projects are in operation will the actual water quality at Green River be known. If salt loading occurs under conditions assumed in this report, the total dissolved solids in the Green River, near Green River, Wyoming, under Plan 1-A would be 480 ppm.

The figures of dissolved solids used in this chapter are the weighted average annual concentrations. The monthly salt concentrations under present conditions are shown in Figure IV-7. Concentrations during low-flow months are presently much higher than the annual weighted average. With higher than present annual concentrations, the monthly values would also be higher. By mixing the waters of all seasons, the Lower Green Reservoir would provide uniform water quality in the Lower Green River. New Fork Narrows Reservoir could provide water quality enhancement by providing minimum flows in the Green River from Fontenelle Dam to Flaming Gorge Reservoir. New Fork Narrows Reservoir, however, will not provide the mixing that would be obtained in Lower Green Reservoir.

Recreation and Fish and Wildlife Considerations²

The authorized Seedskafee, Lyman, and Savery-Pot Hook Projects include provisions for recreation and fish and wildlife protection and enhancement. Fontenelle Reservoir of the Seedskafee Project, in addition to irrigation storage, has an inactive pool of about 195,000 acre-feet which presently provides for recreation and a fishery. The Seedskafee National Wildlife Refuge provides management for waterfowl and other wildlife habitat. Present Fontenelle Reservoir releases provide a stream fishery. Meeks Cabin and China Meadows Reservoirs, storage facilities of the Lyman Project, will have minimum reservoir pools of 3,000 and 2,000 acre-feet, respectively, for recreation and fish and wildlife purposes. Preliminary plans for the Savery-Pot Hook Project include provisions for maintenance of minimum fish flows and recreation facilities.

The proposed Eden Project Improvement would enhance fishing by the inclusion of a minimum pool in Sanders Ranch Reservoir and by the maintenance and stabilization of stream flows in Big Sandy River between Sanders Ranch and Big Sandy Reservoirs. The Big game habitat in the Eden area would not be measurably affected by the Eden Improvement except for some loss of moose habitat at the Sanders Ranch Reservoir site.

The Wyoming Game and Fish Commission reviewed the preliminary plans presented herein and advised the Water Planning Program of the impact of the various plans on game and fish resources in the following summary.

Kendall Reservoir

The reservoir on the Upper Green River at the Kendall site would have the following impact:

1. Approximately 26 stream-miles of excellent trout habitat, spawning and brooding areas would be inundated. This reach of the Green River is

² Prepared cooperatively by Game and Fish Commission and Water Planning Program personnel.

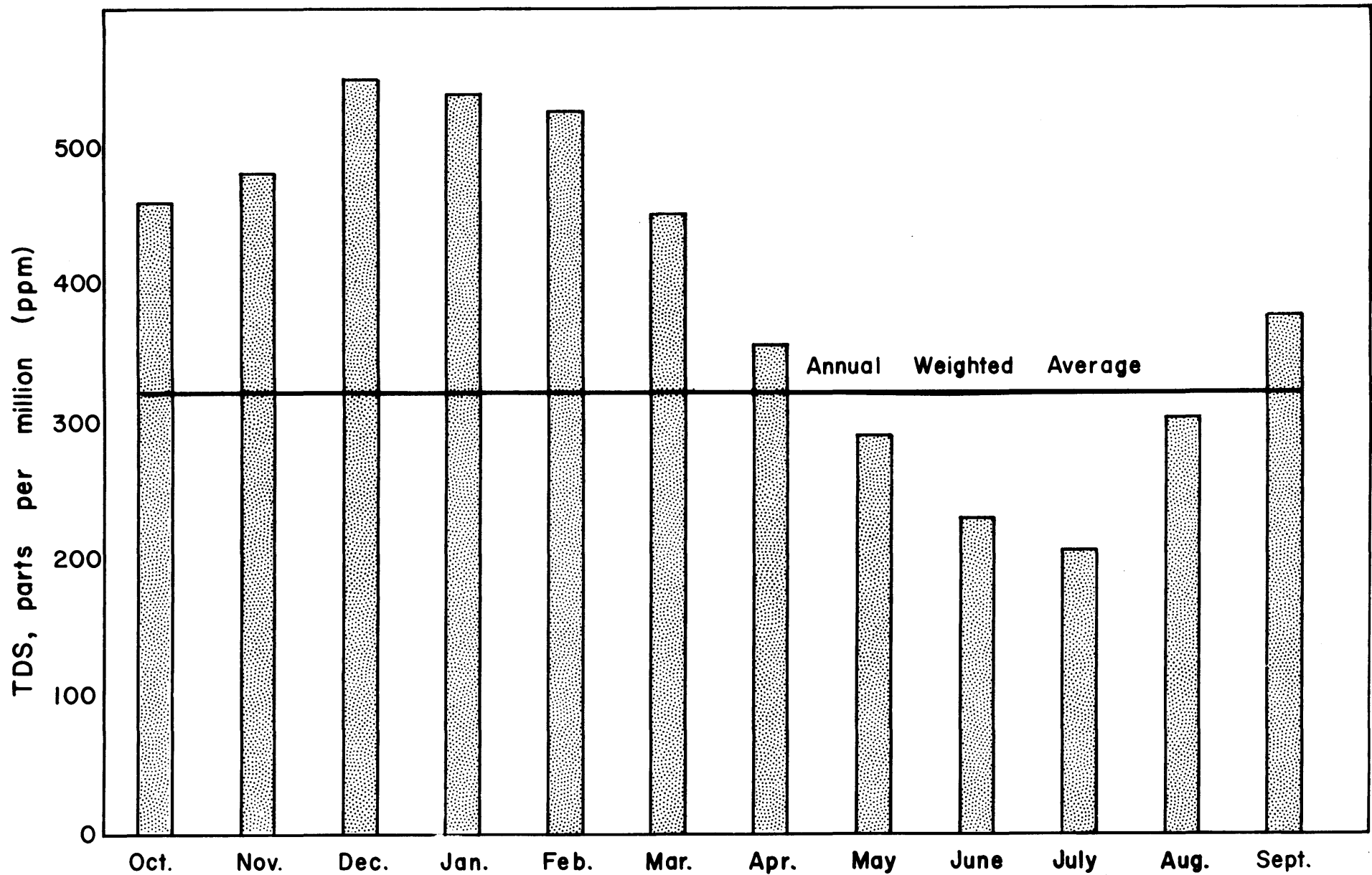


FIGURE IV-7 Historical Monthly Average Concentrations of Total Dissolved Solids, Green River near Green River, Wyoming.

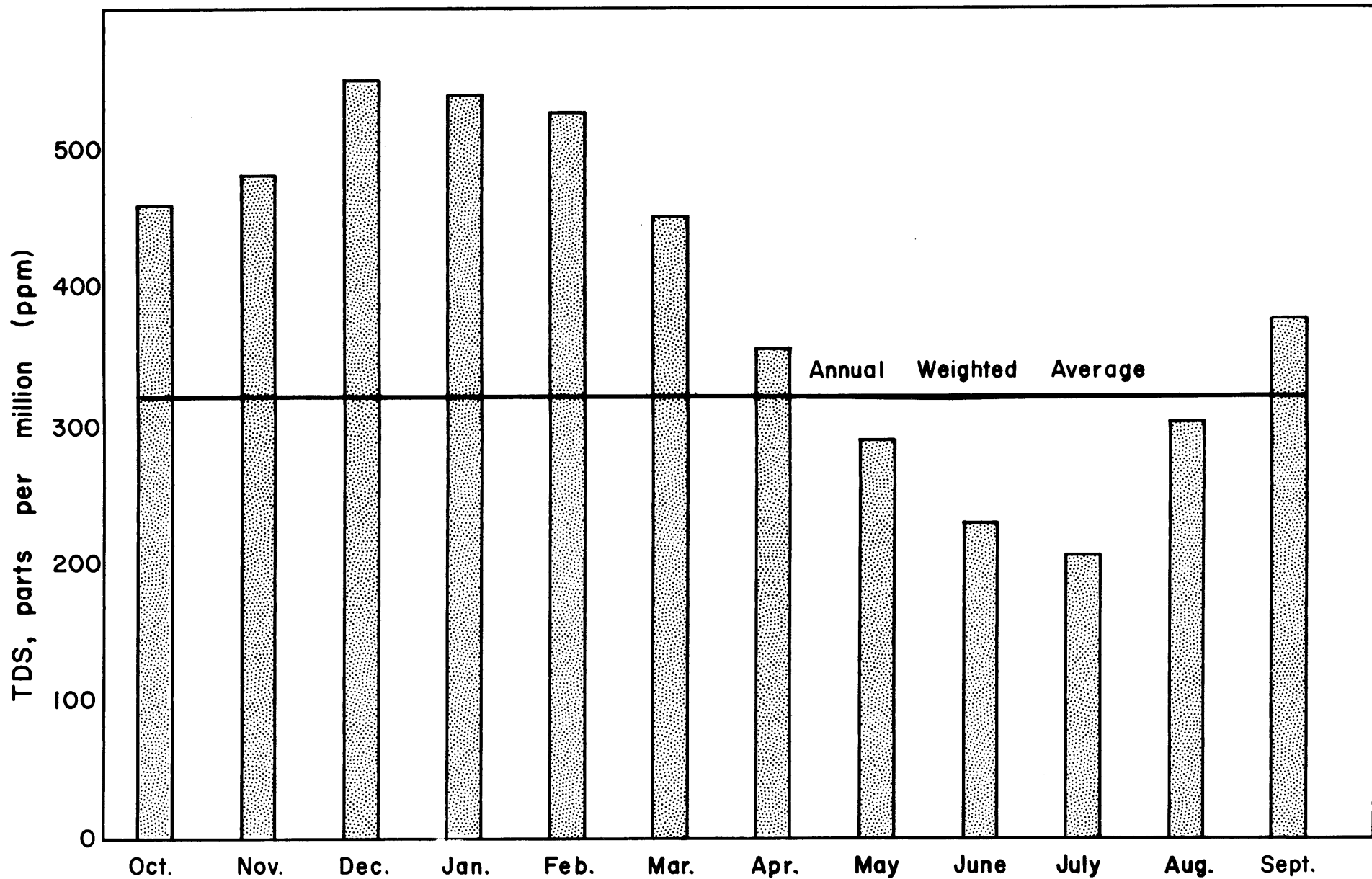


FIGURE IV-7 Historical Monthly Average Concentrations of Total Dissolved Solids, Green River near Green River, Wyoming.

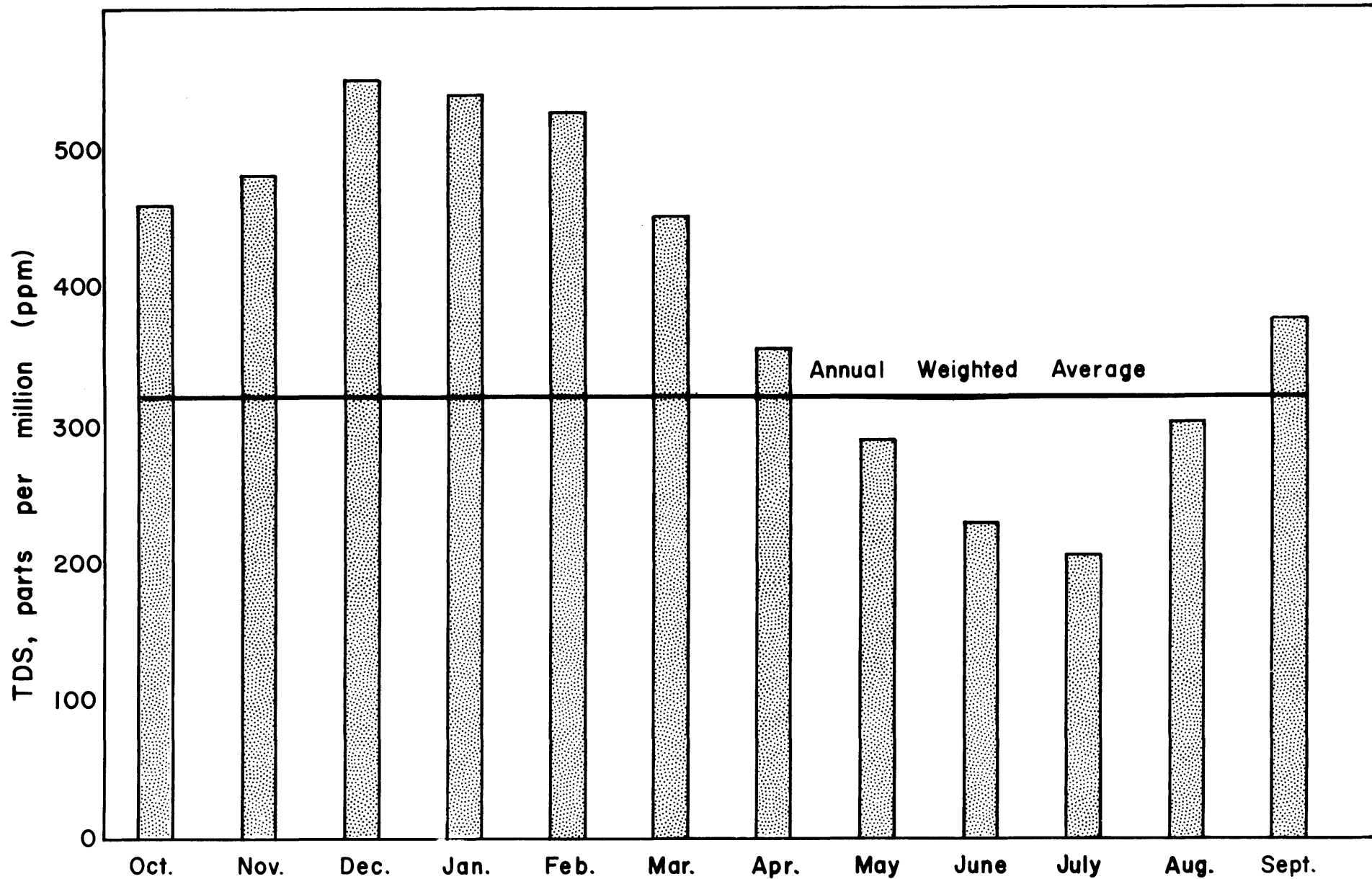


FIGURE IV-7 Historical Monthly Average Concentrations of Total Dissolved Solids, Green River near Green River, Wyoming.

designated as premium trout water, and only four percent of Wyoming's 13,552 miles of rivers and streams providing a fishery are classified as premium trout water. Changing the character of the river to a fluctuating reservoir will generally favor less desirable non-game fish at the expense of trout.

2. More than 11 miles of river adjacent to public lands and 15 camping units would be inundated. This access is valued at \$132,000 based upon the cost to purchase comparable access in the immediate area.

3. Approximately 26 stream-miles of the existing 51-mile "long reach" float fishing water from Green River Lakes to Warren Bridge would be inundated.

4. When the active reservoir pool is emptied to the minimum pool during drought periods, about 7,300 acres of the total 12,500-surface-acre reservoir area would be exposed, and this area would be largely mud flats. This acreage is based on a 390,000-acre-foot reservoir with a 100,000-acre-foot minimum pool (5,200 surface acres).

5. The Kendall Reservoir area provides winter habitat for some 600 to 700 moose. During normal winters at least three-fourths of the moose herd obtains winter forage in the bottoms that would be inundated by Kendall Reservoir. A loss of this river bottom would be a serious threat to the Upper Green River moose, and only a small fraction of the existing population could be maintained. There is no replacement for the winter moose forage in this area. This loss could not be mitigated.

6. The Game and Fish Commission maintains a feedground at Black Butte, where from 150 to 200 elk are fed each winter. Approximately one-half of these elk move across the Green River from the west side. The reservoir would create a barrier for these elk in their movement. Also, the feedground would be inundated; thus, it would require the purchasing of land at another site and construction of new hay corrals and sheds. The problems and expense of moving elk to a new feedground location are difficult to predict. Deer and antelope migration in this area is generally in a north-south direction. The reservoir, along with additional structures, such as concrete-lined canals, would drastically interfere with their movement. Approximately 1,500 deer and 500 antelope could be affected adversely. Fur-bearing animal habitat within the reservoir section would be destroyed.

On the basis of preliminary plans, the Game and Fish Commission recommends a minimum pool in Kendall Reservoir of 90,000 acre-feet or a surface area of approximately one-third of the maximum acreage. At this elevation, which is 7,630 feet, the surface area would be approximately 4,900 acres. The minimum pool requirement is for fisheries maintenance purposes. The Commission also recommends the maintenance of stream flows in the stream below the reservoir of 300 to 400 cfs during July, August, and September, and 200 cfs during the winter months. These flows will stabilize the river and are considered a partial replacement of the stream that will be lost as a result of the reservoir. Without a fisheries maintenance streamflow of 200 cfs a reach of approximately 60 miles of premium trout water will be depreciated. The quality of remaining river flows in reaches under the influence of water diversions and without minimum flow considerations could be depreciated chemically and physically. Flow manipulations and periods of the year when maintenance is particularly critical would be contingent on project operation plans which are tentative at this time.

Fish screening devices for all major gravity canal diversions and over-passes for the passage of big game should be a mitigating feature of all plans.

In Plan 1, a minimum pool of 100,000 acre-feet would be included in Kendall Reservoir for fishery and recreation purposes. Water supply studies indicated that the average yearly reservoir fluctuation would be on the order of five feet, and drought period drawdowns of up to 32 feet would occur three times in the 35-year study period.

New Fork Narrows Reservoir

A reservoir at the New Fork Narrows site, not larger than 400,000 acre-feet, would cause the following environmental changes to take place:

1. Approximately 18 stream-miles of good to excellent trout habitat and excellent spawning and brooding areas would be inundated on the New Fork River. The fluctuating reservoir environment will generally favor non-game fish species.

2. More than 10 miles of river adjacent to public lands would be inundated. This access is valued at \$100,000 based upon the cost of purchase of comparable access in the immediate area.

3. Approximately 18 stream-miles of the existing 42 miles of "long reach" float fishing water would be inundated.

4. Operation of the 400,000-acre-foot reservoir during drought periods to provide Green River Basin M & I and transbasin diversion water supplies would expose about 11,000 acres of the total 13,000-acre reservoir area. Operation of the 250,000-acre-foot reservoir during drought periods, to provide the Basin M & I and transbasin diversion from the Green River at Green River, Wyoming, would expose about 5,000 acres of the approximately 8,000-acre total reservoir area.

5. The inundation of river bottom land would eliminate habitat for about 150 moose and a few deer. A reservoir in this area of the New Fork would seriously affect the migration routes of approximately 6,000 antelope because the winter range between Green River and the New Fork River is receiving maximum winter use, and an attempt is being made to encourage some of these antelope to move south across the New Fork River to other range. Some years, because of weather conditions, it is necessary for these antelope to move into the desert south of New Fork in order to survive. Also, the reservoir would destroy habitat for an abundant duck and goose population and a fair population of furbearing animals.

An analysis of the proposed operations of the New Fork Narrows Reservoir indicates that yearly fluctuations will average five to eight feet over a 35-year period. Maximum drawdowns of 32 feet and 60 feet, depending upon the size of reservoir, will be possible. The Game and Fish Commission points out that extreme fluctuations at any time or drawdown exceeding eight feet would represent a reduction in fish habitat. A quality fisheries habitat and dependable recreational facilities are contingent on the maintenance of the normal average annual fluctuation.

The Wyoming Game and Fish Commission suggested minimum flow releases of 225 cfs during the winter and 400 cfs recreation flow during June, July, August, and the first week of September. This would maintain the fishery of approximately five miles of stream in the New Fork River between the dam and the Green River.

Lower Green Reservoir

The Lower Green Reservoir would be the least damaging to fisheries and other water-oriented recreational interests of the three main stream reservoirs proposed. The reservoir would not encroach upon the Seedska-dee Wildlife Refuge area except for causing backwater in the stream channels on both sides of Big Island in the Lower Refuge area. The reservoir would also lessen the silt load entering the upper end of Flaming Gorge Reservoir. A primary consideration for the reservoir is for water-quality regulation, a feature which will also benefit the fisheries upstream from Flaming Gorge Reservoir.

The following environmental changes would result from the Lower Green Reservoir:

1. A reservoir of approximately 270,000 acre-feet capacity would inundate about 21 stream-miles of river. The reservoir environment would favor non-game fish over trout. The loss of the stream habitat at the Lower Green Reservoir site would have less impact on the Green River stream fisheries than at the other two sites being considered.
2. If the reservoir were drawn down to a dead-storage pool of about 15,000 acre-feet, about 7,500 acres of previously inundated area would be exposed.
3. Public access to about 14 miles of river fisheries would be lost. This would be partially mitigated by adequate public access to the reservoir.
4. At the present time, several hundred deer and 20 to 30 moose utilize the area which would be inundated by the reservoir. These populations would undoubtedly be lost for a stretch of about 15 miles. Antelope utilize this area also, but the impact would be very minimal upon this species. Waterfowl would benefit from a reservoir, which would create a brooding area. The Lower Green River Reservoir would have the least detrimental impact upon game of all water developments in the Basin.

The Game and Fish Commission recommended a minimum pool in the Lower Green Reservoir of 58,000 acre-feet for recreation and fishery purposes.

Boulder Lake and Fremont Lake Reservoirs

The utilization of Boulder Lake Reservoir as a part of the East Side Project would have ramifications to both game and fish populations. However, these may be of somewhat less concern than at other reservoir sites because of present water development activities in the drainage.

The enlargement of Fremont Lake Reservoir in which a three-foot fluctuation is proposed would probably not have a severe effect on either game

or fish. A three-foot fluctuation would probably have little effect on the recreational use of the lake, although the exposure of three feet of steep shoreline might have some effect on aesthetic qualities of this area. A large fluctuation of Fremont Lake could reduce or eliminate the natural spawning of mackinaw trout and could have a severe impact on recreational values.

Transbasin Diversion to the North Platte River

Diversions of water into the North Platte River could enhance the fishery and recreational values in that river system. If the North Platte River reservoirs could be maintained at higher levels, both fishery and other water-based recreation would be enhanced. Waters added to the North Platte River above Seminole Reservoir could enable favorable reservoir and river manipulation in the entire North Platte Reservoir system to the advantage of all water-based recreational development in this drainage. Diversions into the Sweetwater River from the Green River could have benefits to the fishery habitat. Advantages to habitat in the Sweetwater River, however, would be contingent on flow release patterns that would not deteriorate the natural stream channel by erosion or through man-made re-channelization to handle the increased flow expected with the diversion.

Cost Estimates

Several projects are included in all of the plans presented. Three Bureau of Reclamation Projects--Seedskadee, Lyman, and Savery-Pot Hook--are authorized as Participating Projects of the Colorado River Storage Project (CRSP). Costs of these projects allocated to recreation and fish and wildlife enhancement are to be repaid by the general public. Costs allocated to irrigation beyond the estimated ability of the irrigators to repay are to be repaid from CRSP hydroelectric power revenues. The Eden Project was also authorized to be funded with the CRSP revenues. It is assumed that the Eden Project Improvement and the East Side Project would be Bureau projects similarly authorized to receive CRSP funding. Up-to-date cost estimates of the East Side and Eden Improvement Projects are not available.

Costs of small private irrigation developments are not reported. Several of these developments are already partially constructed, and many of the developments involve extending and enlarging existing irrigation systems. Part of the financing may be accomplished with loans from the Wyoming Farm Loan Board.

An enlargement and extension of the Green River Supply Canal is required to irrigate the new lands under that system and to provide supplemental water to the Piney Creeks area. Construction of the canal extension is required before Kendall storage water can be supplied to the Piney Creeks under the Green River Supplemental Supply Project. The enlargement and extension of the Green River Supply Canal is estimated to cost 2.1 million dollars. Additional sums would be required to develop the new lands under the canal system.

Inasmuch as the State of Wyoming is considering a storage project on the Green River, cost estimates were made to provide a basis of comparison among the plans (see Table IV-3). The cost of the dam is only a part of the

cost of water delivery; therefore, the cost estimates include the cost of the dam, cost of Green River Basin M & I water east of the Green River, and cost of a transbasin diversion. The cost of supplying M & I water to other areas of the Green River Basin were not included because it was assumed that these would be the same for all plans and would be private undertakings. The delivery of M & I water east of the River, however, can be made separately or with a facility that also delivers water to the North Platte River.

TABLE IV-3 -- Summary of Reservoirs and Diversions and Costs of Proposed Projects

Plan or Alternate	Reservoirs & Capacity (Acre-Feet)	M & I Diversion (Acre-Feet)	Transbasin Diversion (Acre-Feet)	Cost of Reservoir (\$ Million)	Systems Cost		Total Cost (\$ Million)	Approximate Annual Repayment Cost Per Acre-Foot	
					M & I Pipeline (\$ Million)	Transbasin Diversion (\$ Million)		M & I (\$)	Transbasin Diversion (\$)
1-A	Kendall 390,000	105,000	39,000	6.6	40.1	21.1 ¹	67.7 ⁵	27 & 50 ⁶	45
1-B	390,000	105,000	61,000	6.6	40.1	34.8 ²	81.5	27 & 50 ⁶	47
	390,000	105,000	93,000	6.6	40.1	99.2 ²	145.9	27 & 50 ⁶	87
					Combined Systems Cost (\$ Million)				
	390,000	105,000	61,000	6.6	92.3 ³		98.9	27 & 50 ⁶	82
	390,000	105,000	93,000	6.6	117.1 ³		123.7	27 & 50 ⁶	77
2-A	New Fork Narrows 250,000	105,000	64,000	8.0	97.8 ³		105.8	27 & 50 ⁶	85
2-B	250,000	105,000	96,000	8.0	117.1 ³		125.1	27 & 50 ⁶	74
	400,000	105,000	93,000	11.3	149.8 ⁴		161.1	46 & 67 ⁶	85
3	Lower Green 270,000	105,000	86,000	8.4	112.6 ³		121.0	27 & 50 ⁶	79
4	Kendall 390,000 and New Fork Narrows 400,000			6.6					
		105,000	207,000	<u>11.3</u> 17.9	175.2 ³		193.1	27 & 50 ⁶	56

- ¹ Incremental costs of adding a transbasin diversion to the East Side Project.
- ² Pipeline from Kendall Reservoir; includes cost of water control in the Sweetwater River drainage area.
- ³ Pipeline from Green River, Wyoming.
- ⁴ Pipeline from New Fork Narrows Reservoir.
- ⁵ Does not include \$2.1 million required for the enlargement of the Green River Supply Canal, to use Kendall Reservoir for irrigation.
- ⁶ First number refers to cost of delivery at eastern edge of the Rock Springs Uplift, and the second is the cost of delivery to the eastern Great Divide Basin.

Cost figures for dams were taken from a "Report on Preliminary Reconnaissance of Potential Reservoirs, Green River Basin, Wyoming," prepared by J. T. Banner and Associates for the State of Wyoming. This report contains cost estimates for various heights of dams at the Kendall, New Fork Narrows, and Lower Green damsites. An alternate to the Kendall Dam was also reported. The costs of the so-called Lower Kendall were found to be much higher than Kendall, and the resulting reservoirs would cover essentially the same lands at comparable reservoir capacities. Costs of canals and pipelines were estimated from preliminary map studies and cost curves. The cost estimates include construction costs, engineering, and contingencies. Right-of-way costs are included at agricultural and rangeland prices. It is recognized

that there are certain other real costs such as required for replacement, protection, and enhancement of recreation and fish and wildlife, and there are costs that must be placed upon the environmental effects of each development. A dollar-cost has not been placed on these items because adequate data are not available. The section of the chapter on Recreation and Fish and Wildlife Considerations, however, qualitatively discusses some of these factors. No agency overhead has been included in the costs.

The total costs shown in Table IV-3 vary with the reservoir used, the amount of transbasin diversion, and the delivery route used for the transbasin diversion. In Plan 1, with a transbasin diversion of 93,000 acre-feet, the least-cost project would be one which conveyed the M & I and transbasin diversion in a pipeline from Green River, Wyoming, rather than one which delivered the transbasin water along the Sweetwater River to the North Platte River (\$123,700,000 vs. \$145,900,000). The Plan 2 alternate using New Fork Narrows Reservoir and a Great Divide Basin pipeline for M & I and transbasin diversion would cost about \$125,100,000. Plan 3 would cost slightly less--\$121,000,000. Plan 4, with both Kendall and New Fork Narrows Reservoirs, would cost about \$193,100,000.

A better cost comparison can be made from the annual repayment cost per acre-foot of water delivered in the various plans. Annual costs were estimated as eight percent of construction costs for overhead (including repayment of construction costs plus interest, operation--except pumping energy--and maintenance) and four mills per kilowatt-hour for pumping power. The annual cost per acre-foot is shown in Table IV-3. M & I water costs are the per-acre-foot cost of delivering water to the coal fields east of Rock Springs at the eastern edge of the Rock Springs Uplift (Figure III-4) and to coal fields in the eastern part of the Great Divide Basin. These costs were \$27 and \$50 per acre-foot respectively in all but one plan. Transbasin-diversion costs vary from \$45 per acre-foot for a 39,000 acre-feet per year delivery to a maximum of \$85 per acre-foot for a 93,000 acre-feet per year delivery. The least-cost plan to deliver 96,000 acre-feet to the North Platte River is Plan 2-B (\$74 per year per acre-foot). For a smaller diversion (39,000 acre-feet per year) constructed jointly with irrigation facilities, the \$45 per acre-foot in Plan 1-A is attractive. The largest diversion (207,000 acre-feet), as part of Plan 4, would cost \$56 per acre-foot per year.

As soon as the most desirable plan and projects within the plan are determined, detailed engineering, economic, and environmental investigations should be initiated. The present program of preliminary damsite investigations needs to be expanded, and investigations of pipelines, canals, and other facilities need to be initiated for feasibility studies and design purposes.

CHAPTER V

SUMMARY, CONCLUSIONS,
AND RECOMMENDATIONS

S U M M A R Y , C O N C L U S I O N S ,
A N D R E C O M M E N D A T I O N S

SUMMARY

Wyoming's Green River Basin is a high desert plateau with low precipitation (except in the mountains), cool temperatures, and a short growing season. Crop production is limited by climate to forage and small grains which provide winter feed for the livestock industry. The livestock industry is an important part of the Green River Basin's economic base. The Basin is rich in mineral wealth, and the industrial development of coal, petroleum, and trona are the principal components of the mineral sector presently contributing to the economy of the Basin. These and oil shale are of great future importance.

The Green River and its tributaries are part of the Colorado River system. The water resources of Wyoming's Green River Basin have been developed primarily for irrigation. Irrigation water is obtained primarily by direct streamflow-diversion. Streamflow is largely the result of snowmelt-runoff that normally is diminished by the end of July. Most parts of the Basin have inadequate reservoir storage for late season water supplies. Industry uses large quantities of water for a coal-fueled power plant and several trona processing plants. Municipal water systems served about 24,600 persons in 17 Basin communities in 1970. Fishing, hunting, boating, camping, and other recreation activities are important nonconsumptive uses of the water resources of the Basin. Flaming Gorge Reservoir, the natural lakes, and the many miles of fishing streams of the region are gaining national popularity.

Groundwater is widely used for domestic and livestock purposes, and locally used for municipal and industrial purposes. The Basin has an abundance of groundwater resources, only a relatively small portion of which has been developed. Industry uses groundwater at present, and industry probably will be in the forefront of any extensive future development of this resource.

The consumptive use of water in the Colorado River system is allocated among individual states by interstate compacts. Wyoming's full share under the provisions of existing interstate compact agreements would be 1,043,000 acre-feet of consumptive use per year. However, Wyoming may be limited to a consumptive use of only 875,000 acre-feet per year. This estimate was derived from a water supply study made for the Upper Colorado River Commission in 1965.

Wyoming's consumptive uses of water at present total 296,000 acre-feet per year in the Basin, leaving from 579,000 to 747,000 acre-feet per year available for other development. Projected future consumptive uses include the Seedskaadee, Lyman, and Savery-Pot Hook Reclamation Projects, the Cheyenne transbasin diversion, and Colorado River Storage Project reservoir evaporation losses allocated to Wyoming. These projects, private irrigation, the Eden Project Improvement, and the projected increases of Basin M & I water consumption could use 475,000 acre-feet per year. The remaining available

water (104,000 to 272,000 acre-feet per year) could be used for other development such as (1) irrigation of the East Side and West Side Projects (or supplementing private lands in the West Side area); (2) an irrigation project in the Lower Green River area of Wyoming that might be developed along with industry; and (3) transbasin diversion of water to the North Platte River.

The report presents several alternate plans of multiple water resource development in the Green River Basin. Without new construction the development of the Basin would be restricted. Construction of one or more of the three proposed reservoirs would provide storage to satisfy Basin needs and water for transbasin diversion. The proposed dams and reservoirs are Kendall (Plan 1), New Fork Narrows (Plan 2), and Lower Green (Plan 3). Provisions for minimum reservoir pools and sustained streamflows are included in the plans.

Plan 1: Kendall Dam and Reservoir would provide municipal and industrial (M & I) water, and water for either irrigation or transbasin diversion. Kendall Reservoir is required for maximum development within the Basin.

Plan 2: New Fork Narrows Dam and Reservoir would provide M & I water and water for transbasin diversion. Irrigation water could be provided in the plan.

Plan 3: Lower Green Reservoir would regulate water quality in the Green River below the Seedskaadee Project. It would provide M & I water and water for transbasin diversion.

Plan 4: Similar to Plan 1, but requires the construction of Kendall and New Fork Narrows Dams and Reservoirs to develop the full compact allocation of water available to Wyoming. Plan 4 would develop Wyoming's full compact allocation of 1,043,000 acre-feet for M & I and irrigation uses and transbasin diversion. It would also provide river regulation for water quality and fishery management.

If irrigation in the Upper Green River Basin is not desired, either the New Fork Narrows or Lower Green Dam could satisfy the M & I water needs of the Basin and provide for a transbasin diversion. However, the New Fork Narrows Dam will better provide for the ultimate use of Wyoming's water, especially if water quality and fishery habitat are to be maintained.

CONCLUSIONS

1. Further development of Green River Basin water resources is required to meet the projected water needs of the people of the Basin and the State.
2. A key factor in determining the level of development within the Green River Basin is whether or not irrigation of new lands will develop. The choice of a development plan will depend on the amount of irrigation desired, along with factors relating to other uses.
3. If none of the three proposed dams and reservoirs is constructed, Wyoming will likely forfeit from 177,000 to 345,000 acre-feet per year of beneficial consumptive uses to which the State is entitled under interstate compacts.
4. Water resource development will have an impact on water quality and the game and fish resources of the Basin. Good water quality can be maintained with proper project planning and water management. Provisions for minimum pools in reservoirs and for sustained streamflows can mitigate some of the adverse impact on fish resources and provide fisheries enhancement on the Big Sandy and Lower Green Rivers.
5. Groundwater will continue to be utilized for stock and domestic purposes. The mineral industries will also continue to use groundwater, and in the future may significantly increase the amount used. Shallow groundwater and surface water are so interrelated that development of one can affect the distribution and availability of the other. Groundwater in natural underground storage in consolidated aquifers is abundant, but recharge is slight and may limit the sustained yield. The costs of deep large-yield wells may be prohibitive for other than municipal and industrial uses.

RECOMMENDATIONS

1. In formulating a State Water Plan, water needs of the Green River Basin should be considered in conjunction with the water needs of the State of Wyoming.
2. The water development plans presented in this report should be reviewed by the citizens of the Green River Basin and the State.
3. Public meetings should be held to determine public opinion regarding the best plan of development considering:
 - a. Desired levels of development in the Green River Basin.
 - b. The economic impact of the alternatives.
 - c. The economic impact of no development.
 - d. The impact of development on environmental qualities of the area.
4. Detailed feasibility studies of the individual project-components of the plans should be undertaken to evaluate engineering and economic factors such as direct and indirect project benefits, construction costs, and recreational and environmental values.
5. Sources of financing, such as Federal funds, State loans and bonds, and others, should be reviewed. State laws should be reviewed to determine what legislation would be desirable and necessary for State financing of water development projects.
6. The best plan should be determined from public opinion, feasibility studies, and financial considerations.
7. Short-range and long-range goals should be established and implementation procedures outlined.
8. The type of State or other organization required to administer the construction of water development projects should be determined and established.
9. Soil and water conservation practices in the Basin should be promulgated and implemented through programs of the U. S. Department of Agriculture and others. The possibilities of improving water supplies by watershed management, water management, and flood control measures should be investigated.

CHAPTER VI

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