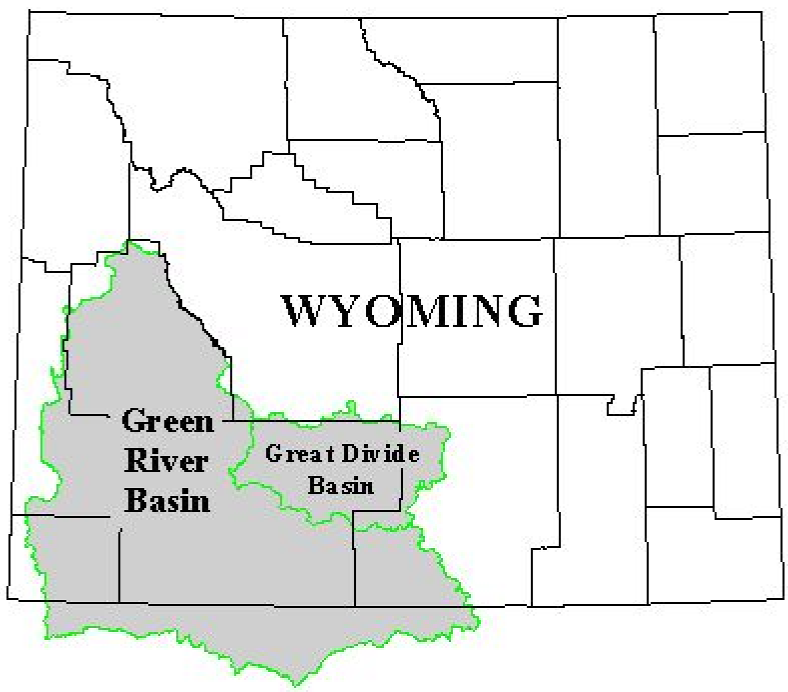
FINAL REPORT

Green River Basin
Water Planning Process

February, 2001



Prepared for:

Wyoming Water Development Commission
Basin Planning Program

States West Water Resources Corporation

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The Wyoming Department of Environmental Quality
The Wyoming State Geological Survey
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CHAPTER CONTENTS

(Individual Chapters have page number listings)

ACRONYM LIST

AF	Acre-feet
AFD	Acre-feet per day
BAG	Basin Advisory Group
BLM	U.S. Bureau of Land Management
BVJPB	Bridger Valley Joint Powers Board
CBM	coal bed methane
cfs	cubic-feet per second
CIR	Consumptive Irrigation Requirement
CRBSCP	Colorado River Basin Salinity Control Program
CRP	Conservation Reserve Program
CU	Consumptive Use
CULR	Consumptive Uses and Losses Report
CWA	Clean Water Act
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FONSI	finding of no significant impact
FSA	Farm Service Agency
GIS	Geographic Information Systems
GPCPD	Gallons per capita per day
GRRA	Green River Resource Area
GW	ground water
GWSI	U.S. Geological Survey's Ground Water Site Inventory
JPB	Joint Powers Board
KDJPB	Kemmerer-Diamondvill Joint Powers Board
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
NWI	National Wetland Inventory
NWR	National Wildlife Refuge
NWS	National Weather Service
RIP	Recovery Implementation Program
RS/GR/SC JPB	Rock Springs/Green River/Sweetwater County Joint Powers Board
SEO	Wyoming State Engineer's Office
SHS	State Historic Site
TDS	total dissolved solids
TMDL	total minimum daily load
USBR	U.S. Bureau of Reclamation
USCB	U.S. Census Bureau
USCOE	U.S. Army Corps of Engineers
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDAI	Wyoming Department of Administration and Information
WGF	Wyoming Game and Fish Department
WQD	Wyoming Dept. of Environmental Quality, Water Quality Division
WRDS	Water Resource Data System
WRP	Wetlands Reserve Program
WWDC	Wyoming Water Development Commission
WWPP	Wyoming Water Planning Program

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I Introduction

As with all chapters in this final plan report, explicit lists of references are not provided. Instead, all references to report, documents, maps, and personal communications are maintained in the Technical Memoranda that were prepared during the current planning process. Should the reader desire to review a complete list of references for the information presented in this chapter, the following memoranda should be consulted:

- **Wyoming Water Law Summary**
- **Summary of Interstate Compacts**

A. Introduction

The Green River Basin Water Planning Process document is one of two basin water plans compiled under initial efforts of the Wyoming Water Development Commission. Authorized by the Wyoming Legislature in 1999, the planning process' first task is the preparation of plans for the Green and Bear River Basins in Wyoming. Subsequent years will see plans developed for the northeast part of the State (Tongue, Powder, Belle Fourche, Cheyenne, and Niobrara Rivers), Big Horn/Wind, Snake/Salt, and Platte River Basins. It is the express desire of the program to revisit and update the basin planning documents every five years or so.

As authorized by the Wyoming Water Development Commission in its contract scope of work, this planning document presents current and proposed (estimated) future uses of water in Wyoming's Green River Basin. Uses to be inventoried include agricultural, municipal, industrial, environmental, and recreation. Both surface and ground water uses, as well as overall water quality are described. Given current uses, the availability of surface and ground water to meet future requirements is estimated. To lay the groundwork for future water development, a review of the current institutional and legal framework facing such projects is presented. Finally, thoughts are given to guide implementation of the water planning process.

The structure of this final report is to present findings in enough detail to explain the overall plan without deluging the reader in technical minutiae. Technical memoranda have been prepared which delve into the many individual topics in detail, and it is to these documents the reader should turn for answers to questions about details, methods, and for selected references. No separate list of citations is provided herein other than for the Technical Memoranda (which, individually, contain complete bibliographies).

B. Description

Location

The Green River Basin consists of lands in Wyoming, Colorado, and Utah that drain to the Green River, the largest tributary of the Colorado River. The Wyoming portion of the Basin comprises nearly 25,000 square miles. It is bordered on the east by the continental divide including the Wind River Range in the north and northeast, the Great Divide Basin centrally, and the Sierra Madre Range in the southeast. It is bordered on the south by the Wyoming-Colorado and Wyoming-Utah state lines. The Basin's western border is defined by the Tunp Range, which forms the division between the Green and Bear River Basins, and the Wyoming Range, which separates the Green from the Greys River Basin. The far northwest of the Basin abuts the Gros Ventre Range. While the Green River Basin includes the Great Divide Basin for purposes of this plan, this region is a closed basin, and does not contribute any run-off to the Green River. Figure I-1 (p.I-10) shows the study area, sometimes referred to as the Greater Green River Basin.

Counties that contribute large areas to the Basin are Sweetwater, Sublette, Carbon, Lincoln, and Uinta, with small areas in Fremont and Teton counties. This area is just larger than the State of West Virginia.

Topography

The Basin generally slopes to the south, with major portions of the area having elevations in the range of 6,000 to 7,000 feet above sea level. This area is characterized by the buttes, mesas, and badlands associated with high, arid desert plains. Mountainous peaks that form the majority of the Basin border frequently exceed 10,000 feet in elevation in the northern and northeastern reaches of the Basin, and 9,000 feet in the southern reaches in Wasatch National Forest. The highest point in the Basin (Gannett Peak, elevation 13,804) is also the highest point in the State, and the lowest point (elevation 6,040) occurs along the Green River where it passes into Utah at Flaming Gorge Reservoir.

Climate

Climate throughout the Basin varies, but generally follows the pattern of a high desert region. Higher precipitation and lower temperatures generally accompany higher altitudes. Precipitation data are available for about a dozen National Weather Service stations in the Basin for the past 30 years. The lowest average annual precipitation among these stations occurs at Fontenelle Dam in Lincoln County (7 inches), and the highest average annual precipitation occurs at Pinedale (11.4 inches). Precipitation in the range of 40 to 60 inches annually, most occurring as snow, falls in the highest mountains. While long, mild intensity rainfall events do occur in the Basin, the majority of the rainfall occurs in short, intense storms. Various climatological and physiographic factors combine to create a relatively short growing season throughout the Basin.
Figure I-2 (p. I-11) shows precipitation characteristics in the Basin.

Water Features

Most notable of the water features in the Green River Basin is the Flaming Gorge Reservoir along the Green River as it passes into Utah, and which is formed by the Flaming Gorge dam in the State of Utah. Other major bodies of water in the central and eastern part of the Basin include the Green River Lakes, New Fork Lake, Willow Lake, Fremont Lake, Halfmoon Lake, Burnt Lake, Boulder Lake, Big Sandy Reservoir, Eden Valley Reservoir, and Fontenelle Reservoir, in addition to numerous high mountain lakes in the Wind River Range. In the western part of the Basin are Viva Naughton and Kemmerer No. 1 Reservoirs. To the south, Meeks Cabin and Stateline Reservoirs serve various Wyoming users, although Stateline is located entirely in Utah.

Waterways leading to the Green River include numerous rivers and streams, many with multiple branches. Major tributaries include the New Fork, East Fork, and Big and Little Sandy Rivers in the northeast; the Little Snake River in the southeast; the Hams Fork, Blacks Fork and Henrys Fork of the Green in the southwest; and the Piney, LaBarge, Fontenelle, Cottonwood and Horse Creeks (among others) in the north and west. Many of the streams and creeks in the central and southern parts of the Basin are intermittent or ephemeral, flowing only in response to rainfall or snowmelt.

History

Although evidence of human occupation of the Green River Basin exists from 9000 BC, its modern history did not take shape until the 1800’s. The first white man reported to have entered the Basin, John Colter, was a member of the Lewis and Clark expedition, although the Basin was not a part of their explorations. After returning to St. Louis with Lewis and Clark, Colter assembled an exploration party of his own and returned to the area in 1807.

In 1824, General William H. Ashley explored the area around the Sweetwater River. He gave the Green River its name; until then it was known as the Spanish River. Ashley trapped for fur throughout the Basin. In 1825, Ashley began the first of several annual trapping rendezvous on Henrys Fork. In time, this rendezvous became not only an assembly of trappers, but others (especially Native Americans) who were interested in trading. In 1826, Ashley retired, and his interests were eventually bought by the Rocky Mountain Fur Company. In the 1830’s, the rendezvous was moved north to a site not far from present-day Daniel.

In May of 1832, Captain B.L.E. Bonneville led a large exploration party to the Basin. He established “Fort Nonsense” (as it was called) near the mouth of Horse Creek, not far from present-day Pinedale. Unlike other pioneers of the area, Bonneville was not really interested in furs. His fort was chiefly for the purpose of spying on British and Indian activities in the mountains. Antagonistic Indian attacks forced the almost immediate abandonment of “Fort Nonsense.”

Jim Bridger, perhaps the most well-known figure in Green River Basin history, was a member of General Ashley’s expedition. After Ashley’s retirement, Bridger continued to trap for furs in the Basin. With the fall of the fur business and the rise in emigrant travel through Wyoming, Bridger, as with many others, refocused his business on trading with the emigrants. In 1842, he built Fort Bridger with his partner, Louis Vasquez. Fort Bridger was strategically located to serve multiple trails. There, they made a rather profitable business. In 1848, the fort officially became a part of the United States as the region was ceded from Mexico. During this same year, gold was discovered in California. Gold had been found in the South Pass area six years earlier, but the strikes had not been as fruitful as in California. During the early 1850's, emigration through the Basin flourished, leading to increased trading business. In November of 1853, a crew of Mormons established Fort Supply, a dozen miles from Fort Bridger. In 1857, both forts were destroyed as the Mormons fled government troops. Fort Bridger was eventually rebuilt and became a military fort. During the construction of the Union Pacific Railroad, it housed troops protecting railroad surveyors and construction crews.

While the Fort Bridger area developed for trading, the South Pass area came into being due to gold prospecting. Gold had been discovered in the area in 1842, and serious prospecting continued for nearly 20 years. News of the finds trickled to emigrant centers such as Fort Bridger and Salt Lake City, and numerous explorers made their way to the area. This influx of people, while considerable, was never as great as that traveling on to California and Oregon. The region was still seen as an unforgiving and hostile area. Over the years, prospecting began to take a backseat to other business ventures. Many prospectors found hay production for emigrants and production of telegraph poles to be more lucrative than gold. Interest in gold was renewed in 1867 with the discovery of the Carissa Lode. Inflated tales of gold finds spread and the area experienced a boom in population. With the discovery that these tales were misleading, many prospectors left the area within a few years. Those who stayed realized the potential for grazing and ranching throughout the northern portion of the Basin.

Communication and transportation have played major roles in the development of the southern portion of the Basin during the majority of its history. This was especially true during the 1860's. Many of the towns existing today had their roots as stage or telegraph stations. In the late 1860's, the presence of coal in the Green River/Rock Springs area was the chief factor for Union Pacific Railroad's decision to build through southern Wyoming. This created not only the demand for coal, but also the means for conveying it to other regions. A common practice of the day was for a developer to speculate upon where railroads would set-up centers of business and create towns in anticipation of future prosperity. Green River was established in such a manner in the summer of 1868. By the end of 1868, the railroad had reached as far west as Evanston. Coal had also been discovered on Hams Fork in 1868, spurring the establishment of Diamondville in 1894 and Kemmerer in 1897.

Mineral interests continued to spur the creation of new towns throughout the late 19th and into the early 20th centuries. Around 1910, the State experienced an oil boom that resulted in the establishment of the town of LaBarge in the 1920's. In 1939, trona was discovered in Sweetwater County, and, by 1952, the first mining plant had been built.

C. Water-Related History of the Basin

Arguably, the most valuable resource in the Basin is water. As with much of the State, having good quality water at the right times has always been a challenge. Ancient Indian civilizations were known to have constructed small canals and ditches from streams to provide crop water. With the increase in nomadic tribes, these canals and ditches were not used as extensively. The first modern use of irrigation in the Basin is credited to the Mormon settlers of Fort Supply around 1854. Emigrants and other travelers were quite impressed with the results the Mormons achieved. In 1857, when the Mormons returned to Salt Lake, the irrigation projects were temporarily abandoned. Although the first water right filings from the Blacks Fork were not completed until 1862, irrigation diversions were known to have been in place at Fort Bridger by 1859. The first water rights filings in the upper portion of the Basin occurred around 1879 on Fontenelle Creek. Gradually, irrigation of bottomlands throughout the Basin became more and more commonplace. Beginning in the 1920's, reservoir storage rights were established on lakes such as Willow Lake, Boulder Lake, and Fremont Lake.

One of the most documented and oldest reclamation projects in the Basin is the Big Sandy project. In July of 1886, an official charter was granted to the Big Sandy Colony and Canal Company to build a dam on the Sandy River. This dam was later washed away by floods and the project abandoned. In 1906, the Eden-Farson Irrigation project was authorized. By 1914, the main canal had been finished. Over the course of the next 20 years, financial instability and mismanagement plagued the project, and it eventually came under the dominion of the Bureau of Reclamation. Further improvements were authorized, but construction did not begin until 1950 due to World War II. 1950 also marked the birth of the Eden Valley Irrigation and Drainage District. During the 1950's, improvements and expansions were completed for many aspects of the original canal project. Other reclamation projects that currently exist in the Basin include the Flaming Gorge Dam, completed in 1962, Fontenelle Dam, completed in 1964, the Meeks Cabin Dam, completed in 1971, and the Stateline Dam, completed in 1979.

Although the main use of surface water within the Basin is agricultural, the various streams in the area also provide water for domestic use. Many cities (such as Rock Springs and Green River, and the towns within the Bridger Valley) have a shared point of diversion and distribution system. In many cases, the water supply facilities were built and are currently maintained by private corporations.

Colorado River Basin

The Green River is the largest tributary within the Colorado River Basin (Figure I-3, p.I-12). In addition to land in Wyoming, the Colorado River Basin drains large portions of Utah, Colorado, all of Arizona, and small portions of New Mexico, California, Nevada, and Mexico, for a total of 244,000 square miles. In accordance with the Colorado River Compact, the large basin is divided into two main divisions: the Upper Basin, consisting of the land draining to the Colorado River upstream of Lee Ferry, Arizona; and the Lower Basin, consisting of the land draining to the river south of Lee Ferry. The Basin is further subdivided into the Green Division, the Grand Division, the San Juan Division, the Little Colorado Division, the Virgin Division, the Gila Division, and the Boulder Division.

D. Wyoming Water Law

One of the primary tenets established during conception of the current water planning process was that Wyoming Water Law would be respected throughout that process. That is, while many aspects of the use, availability, value and future demands of Wyoming's water would be under review, the principles of administration of that water by the State Engineer's Office would not.

As Engineer for the Territory of Wyoming, and later the first State Engineer, Elwood Mead understood that in a water short region, water must be administered in a fair and equitable fashion, and his method for doing so was to let the earlier developer have the better right to the water (the *priority* system). He also knew that the amount of any right must be affirmed by an agent of the State, lest the applicant greatly exaggerate the amount needed, and be based on the amount put to "beneficial use." Another stamp of Mead's early efforts in Wyoming is the resolution of water disputes via a "Board of Control," rather than the water court system used in the neighboring state of Colorado. In Wyoming, water rights are property rights in that they are attached to the land and can be transferred in use or in location only after application to and careful consideration, and possible modification, by the State Engineer if the water right is unadjudicated, otherwise by the Board of Control. The Board of Control is made up of the four water division superintendents and the State Engineer.

Water Law in the Constitution and Statutes

Water ownership and administration is defined in Article 8 of the Wyoming Constitution:

- Section 1 **declares water within the State to be the property of the State;**
- Section 2 **establishes the Board of Control and its composition;**
- Section 3 **establishes the priority system as giving the better right;**
- Section 4 **establishes four (4) water divisions within the State;**
- Section 5 **establishes the position and duties of State Engineer.**

Water law is defined and codified in the Wyoming State Statutes. The State Engineer's role is defined under Title 9, Chapter 1, Article 9, (W.S. 9-1-901 through 909), along with the authority to establish fees for services. Weather modification activities are placed under the authority of the State Engineer in this Article, and moisture in the clouds and atmosphere within the state boundaries is declared property of the State.

Title 41 is entitled "Water" and contains the bulk of Wyoming's laws related to water. Under this Title the following chapters are included:

- Chapter 1 – **General Provisions**
- Chapter 2 – **Planning and Development**
- Chapter 3 – **Water Rights; Administration and Control**
- Chapter 4 – **Board of Control; Adjudication of Water Rights**
- Chapter 5 – **Care, Maintenance and Protection of Irrigation Works**
- Chapter 6 – **Irrigation and Drainage Districts (Generally)**
- Chapter 7 – **Irrigation Districts**
- Chapter 8 – **Watershed Improvement Districts**
- Chapter 9 – **Drainage Districts**
- Chapter 10 – **Water and Sewer District Law**
- Chapter 11 – **Interstate Streams Commission**
- Chapter 12 – **Interstate Compacts**
- Chapter 13 – **Watercraft**
- Chapter 14 – **Storage of Water for Industrial and Municipal Uses**

Within Title 41, Chapters 3 and 4 contain the important laws relating to establishment, administration and adjudication of water rights in Wyoming. These relate to appropriation from all sources of water, whether they be live streams, still waters and reservoirs, or underground water (ground water).

The reader is referred to the Constitution and to these statutes for the complete language defining Wyoming Water Law. The monogram: *Wyoming Water Law: A Summary,* by James J. Jacobs, Gordon W. Fassett and Donald J. Brosz is included in the technical memorandum *Wyoming Water Law Summary*, as is a glossary of water-related terms.

E. Interstate Compacts

The Green River of Wyoming is the major tributary to the Colorado River, one of the most physically controlled and institutionally managed rivers in the world. It drains the largest river basin in the United States save the Mississippi. Prone to flooding and needed for irrigation, the river came under the control of several major dams in the 20th century. Management of these structures, of the water in the River, and the distribution of the water for various needs has resulted in a regulatory and legal framework now known as the "Law of the River." Documents comprising the *Law* include:

- Colorado River Compact – 1922
- Boulder Canyon Project Act – 1928
- California Limitation Act – 1929
- California Seven Party Agreement – 1931

- Mexican Water Treaty – 1944
- Upper Colorado River Basin Compact – 1948
- Colorado River Storage Project Act – 1956
- United States Supreme Court Decree in Arizona vs. California – 1964
- Colorado River Basin Project Act – 1968
- Minute 242 of the International Boundary and Water Commission, United States and Mexico – 1973
- Colorado River Basin Salinity Control Act – 1974, amended 1984, 1995, and 1996

Wyoming's ability to develop and consumptively use water in the Green River Basin primarily is constrained by the two interstate Compacts, the *Colorado River Compact* and the *Upper Colorado River Basin Compact*. Complete copies are contained in the technical memorandum entitled Summary of Interstate Compacts.

The Colorado River Compact

The states of the Colorado River System include Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming. By the 1920s, development of the Colorado River for irrigation had progressed more rapidly in the lower basin reaches than in the upper and the need for flood control and municipal water throughout the Basin was becoming more and more evident. Headwater states were growing nervous over development in the lower states and the concomitant threat that their own future uses could be curtailed. Because the many states each laid claim to Colorado River water within their boundaries, while the federal government asserted authority over this interstate (and, in fact, international) watercourse, some overarching agreement on the operation of the river was inevitable.

With the creation of the Colorado River Commission in January of 1922, and appointment of commissioners from the basin states and the federal government, work on the Compact began. Public hearings were held in all the affected states, and the resulting Compact was signed by each commissioner and a representative of the United States on November 24, 1922 in Santa Fe, New Mexico. Because the signatory states and the federal government each were required to ratify the Compact, the work was yet to be completed. The next year, six of the seven states (all but Arizona) ratified the Compact. Without unanimity, however, the Compact would not be binding. Legislation was passed in 1928 allowing the Compact to come into effect if six of the seven states (one of which had to be California) ratified it, and it did so. Arizona finally ratified the Compact in 1944.

The Colorado River Compact divided the Colorado River into two parts, an upper and a lower basin. The dividing point between the two is one mile below the mouth of the Paria River, at Lee Ferry, Arizona and is a natural point of demarcation. This point today is eight miles below Glen Canyon Dam. The *States of the Upper Division* were defined as Colorado, New Mexico, Utah and Wyoming and the *States of the Lower Division* included Arizona, California and Nevada. Under the hydrologic assumptions of the day, and based on the relatively short period of hydrologic record, the long-term yield of the total watershed was erroneously deemed to be in the range of 16 to 17 million acre-feet annually. To split the bounty, the Compact apportioned to each the upper and lower basins a total of 7,500,00 acre-feet of beneficial consumptive use annually. Additionally, the Compact granted the lower basin the right to increase its beneficial use by 1,000,000 acre-feet annually. Further, the Compact requires that the States of the Upper Division cannot cause the flow at Lee Ferry to be depleted below an aggregate 75,000,000 acre-feet during any consecutive 10-year period. The Compact also made allowances for future treaties with Mexico. Essentially, deficiencies in meeting any forthcoming treaty obligations with Mexico were to be borne equally by the upper and lower basins.

Unfortunately, the yield of the upper basin has not proved to be as robust as the Compact represents. Different estimates have put the yield available for consumption in the upper basin from as low as 5,800,000 acre-feet per year up to at least 6,300,000 acre-feet per year, the latter of which is the current position of the upper basin states.

The Upper Colorado River Basin Compact

While the lower basin states were initially unable to agree on how to use their Compact allocation, the States of the Upper Basin were able to establish a division of the water so that development could begin. The Upper Colorado River Basin Compact, signed in October of 1948, followed the format of and was subject to the provisions of the original Colorado River Compact. This Compact among the upper basin states apportioned 50,000 acre-feet of consumptive use to Arizona (which contains a small amount of area tributary to the Colorado above the Compact point at Lee Ferry) and to the remaining states the following percentages of the total quantity available for use each year in the upper basin as provided by the 1922 Compact (after deduction of Arizona's share):

- **Colorado = 51.75 percent;**
- **Utah = 23.00 percent;**
- **New Mexico = 11.25 percent;**
- **Wyoming = 14.00 percent.**

Taking into account the vagaries in knowledge of the actual yield of the upper basin, the likelihood that upper basin deliveries will be needed to help meet treaty obligations with Mexico, and a full 50,000 acre-foot development by Arizona, Wyoming's developable water under the two Compacts can be estimated at between 728,000 and 938,000 acre-feet per year. Using the most probable assumptions, the probable long-term available water supply for Wyoming from the Green River and its tributaries is 833,000 acre-feet per year. This number was recommended by the Wyoming State Engineer's Office, and memoranda describing its derivation are included in the Summary of Interstate Compacts Technical Memorandum.

Figure I-1 Greater Green River Basin: Study Area

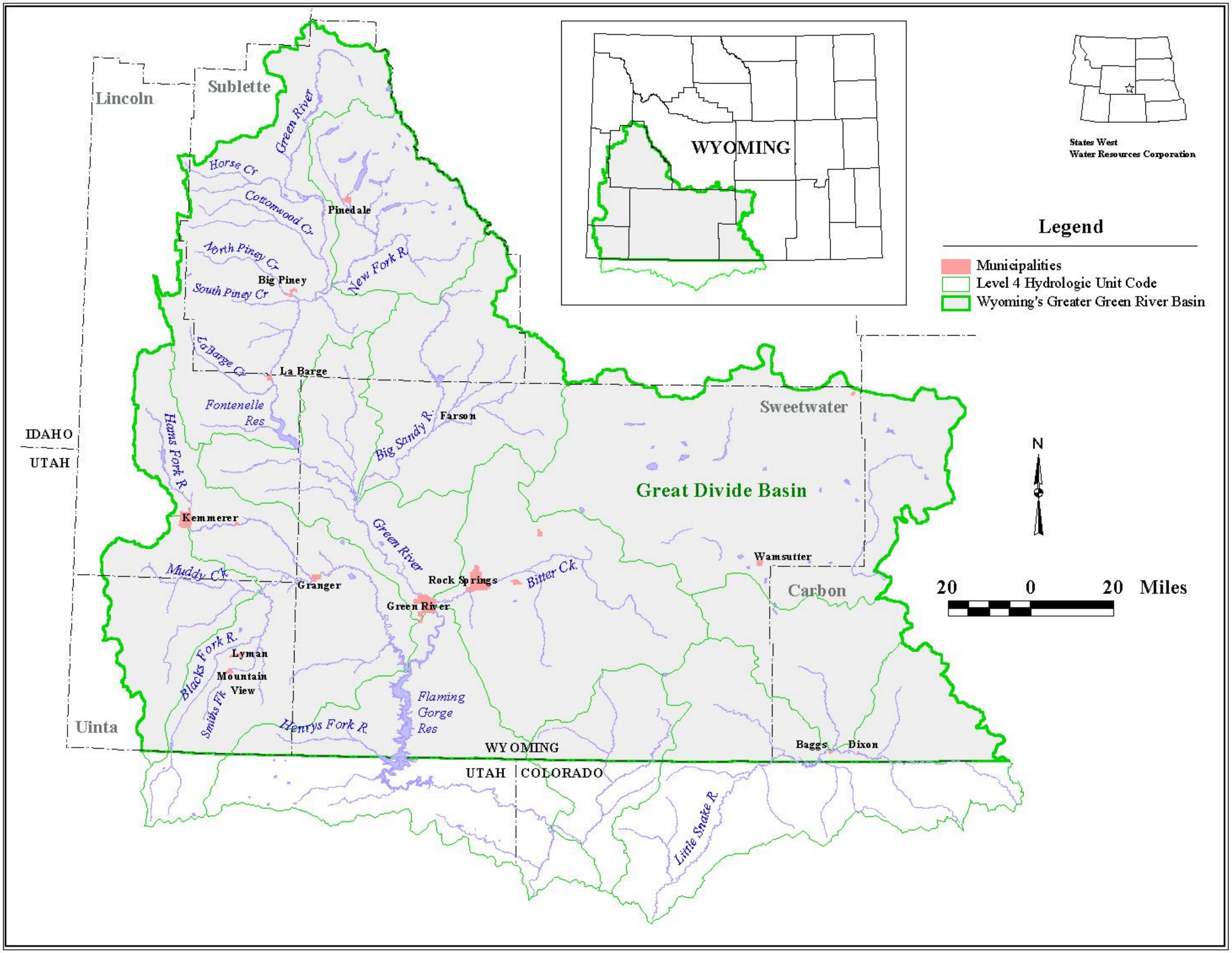


Figure I-2 Average Annual Precipitation

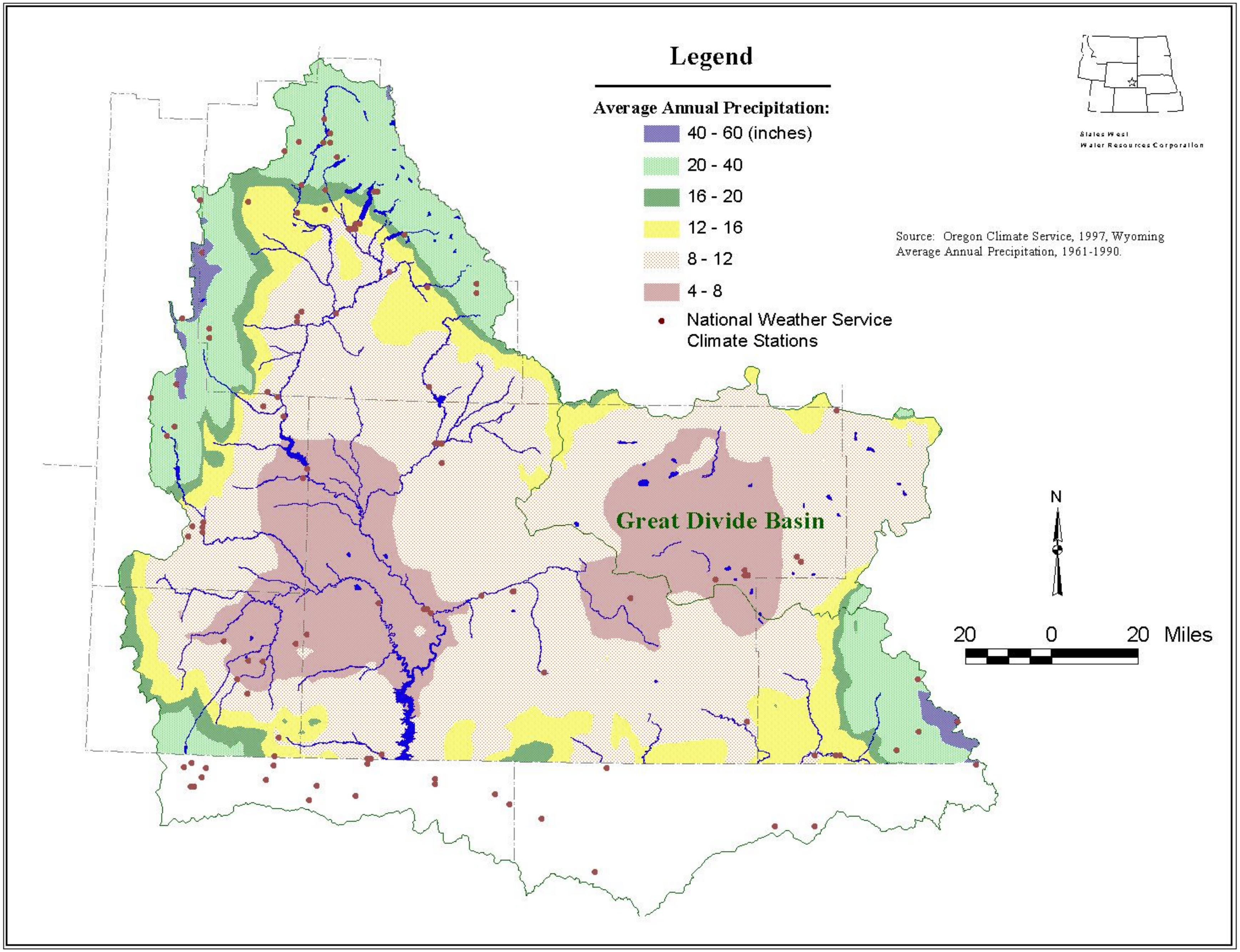
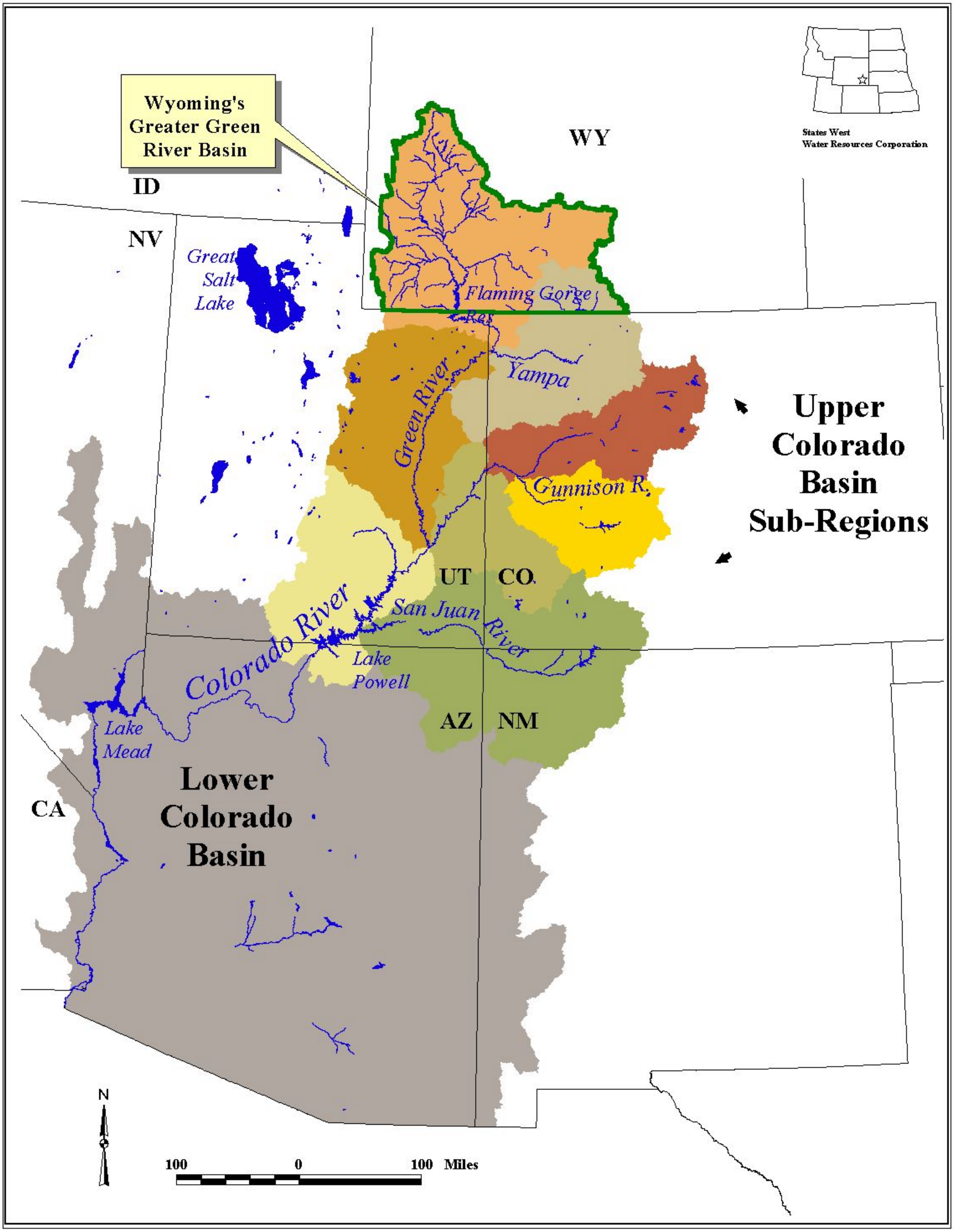


Figure I-3 Colorado River Basin



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A. Overview

This chapter describes and quantifies the various current uses made of water in the Green River Basin. The estimation of consumptive use of water is valuable for evaluating the overall use of water in the Basin relative to Compact allotments, the location of use relative to water supplies, and the relative amounts of the varying uses when growth is considered. In the following discussions, the terms consumptive use and depletion are often used interchangeably. Both refer to the degree to which a use actually reduces the water available at that point or downstream.

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- Basin Water Use Profile – Agricultural
- Irrigation Diversion Operation and Description
- Cropping Patterns in the Basin
- Irrigated Lands and Permit GIS Data
- Basin Water Use Profile – Municipal
- Basin Water Use Profile – Domestic
- Basin Water Use Profile – Industrial
- Recreational Uses
- Environmental Uses
- Major Reservoir Information
- Instream Flows in Wyoming
- Surface Water Quality
- Colorado River Basin Salinity Control Program

B. Agricultural Water Use

History of Agricultural Practices in the Basin

The Green River Basin of Wyoming has seen the use of water for beneficial agricultural purposes since Territorial days. Irrigated agriculture was the first large user of surface water in the Basin, and it remains the largest water consumer in the Basin and the State. In the 1970 Framework Water Plan (Wyoming Water Planning Program, 1970), the depletion attributable to agricultural uses totaled 267,900 acre-feet, or 90 percent of the total depletion of 296,100 acre-feet in the Basin. In the 1998 Bureau of Reclamation Consumptive Uses and Losses Report (CULR) irrigation depletions in Wyoming's Green River Basin were calculated to average 399,000 acre-feet for the 1986-1990 period, or about 79 percent of Wyoming's estimated average total depletions in the Basin of 502,000 acre-feet per year for the same period. The reason irrigation depletion estimates by the U.S. Bureau of Reclamation (USBR) exceed 1970 Framework Plan estimates, given that irrigated acres have not equally increased, is uncertain but probably is due to revised consumptive requirement values and the construction of reservoirs (e.g. Meeks Cabin and Stateline Reservoirs and Fremont Lake enlargement) which provide late season water. The reason irrigation depletions have reduced as a percentage of total basin use is largely attributable to increases in industrial use.

Historically, irrigation diversions occurred where lands "susceptible of irrigation" lay near a reliable watercourse from which water could be diverted with the least work. Bottomlands were developed first because of the relative ease with which they could be put under irrigation from a ditch. Reservoirs for irrigation water storage (and other uses) were constructed as direct flow rights eventually exceeded the reliable supply of streams. In the words of Elwood Mead in his first report as Territorial Engineer, storage was needed "…to hold the waste water of winter and the surplus from the summer floods….On many of our streams is already felt the pressing need for an auxiliary summer supply which the reservoir would furnish." Oftentimes, reservoir storage was developed in mountainous terrain where water levels in existing alpine lakes could easily be raised by the simple addition of a dike or small dam at the natural outlet. Fremont Lake near Pinedale is such an example.

Because of the relative aridity of the central Green River Basin, irrigation first began along the tributaries leading from the various mountain ranges that fringe the Basin. These included, as examples, the Little Snake, New Fork and Blacks Fork Rivers as well as other tributaries such as the Piney Creeks west of Big Piney, Smiths Fork Creek near Lyman and the Hams Fork. These and smaller streams and creeks not only provided water nearer the source, but headgates located thereon were less susceptible to washout and therefore more easily maintained than those constructed on the mainstem of the Green River. As happened early on in much of Wyoming, tributaries were more quickly developed than the larger watercourses they fed.

Today, the development of irrigation works in the Basin still is defined by these early efforts. The bulk of irrigation in the Basin occurs along tributaries, with the primary agricultural areas located in the Little Snake, Blacks Fork, Big Sandy and New Fork River valleys as well as along the numerous streams emanating from the northwest (Piney Creeks and others).

Storage Water

The majority of water in storage reservoirs within the Green River Basin is permitted for irrigation use. Other users, such as industry, municipal and recreation, are small in comparison. In sub-basins where storage is available, irrigation seasons are often lengthened and summer supplies more reliable than in other areas. For this reason, consumptive use of water for irrigation is typically higher in sub-basins with storage than without. The largest reservoir in the interior of the Basin, Fontenelle Reservoir, is downstream of virtually all of the upper Green River irrigated areas, unavailable to other sub-basins, and therefore is virtually unused for irrigation.

Since the Framework Plan was published, several reservoirs have been constructed in the Basin to assist with irrigation supplies. These include Viva Naughton, Meeks Cabin and Stateline Reservoirs. Meeks Cabin and Stateline provide supplemental irrigation water and are permitted as such. Viva Naughton is permitted for industrial use, but through informal arrangements, releases are made to assist Hams Fork irrigators when supplies are available. Also since 1970, enlargements to Boulder Lake, Fremont Lake and Fontenelle Reservoir have been constructed. In the case of Fontenelle Reservoir, the enlargement only activated previously inactive capacity and was not a physical enlargement. More recently, in 1997, ownership of Middle Piney Lake was transferred to the U.S. Forest Service. Since that time Middle Piney has not been used, or available, for supplemental irrigation supply.

The technical memorandum entitled Major Reservoir Information describes the larger (>1,000 ACRE-FEET) reservoirs in the Basin as well as some smaller ones. Aside from Fontenelle (very little irrigation use), Flaming Gorge (out of state), Viva Naughton (industrial), Kemmerer No. 1 (municipal) and High Savery (yet to be constructed) Reservoirs, the Basin contains approximately 212,000 acre-feet of storage primarily devoted to supplemental irrigation supply. The distribution of this storage within the Basin is uneven, meaning that some irrigated areas are well served by one or several reservoirs above them while others are devoid of storage of any size. The following lists storage available by sub-basin:

Storage Availability for Agricultural Uses, Green River Basin			
Sub-Basin	**Total Storage*, AF**	**Irrigated Acres**	**Available Storage, AF/Acre**
Little Snake	17,430	15,483	1.1
Henrys Fork	6,180	15,086	0.4
Blacks Fork	48,808	58,007	0.8
Hams Fork	1,198	9,942	0.1
Big Sandy	55,943	21,318	2.6
New Fork	94,315	50,447	1.9
Upper Green & Tribs	6,495	119,302	0.05
* Where irrigation is included with other uses, total storage is used in this comparison			

Irrigated Lands Mapping

Geographic Information System (GIS) mapping of irrigated lands, water rights, diversion points, and irrigation wells allowed for accurate, computerized spatial representation and analysis of current irrigation and acreage for use in modeling, estimation of potential shortages, and future storage development strategies, among other possible uses. The process of developing GIS mapping of all recently irrigated lands and associated water rights within Wyoming's Green River Basin included four phases:

1) Aerial and Satellite Interpretation and Mapping
2) Field Verification
3) Water Rights Attribution
4) Production of Final GIS Products and Databases

The current mapping project was performed much as it was for the first comprehensive irrigated lands mapping of the Basin, conducted for the Green River Basin Water Plan by the Wyoming Water Planning Program (WWPP) in 1970. Ortho-rectified, infra-red satellite imagery supplemented the aerial photography interpretation completed during the 1970 project. The process involved shifting some irrigated polygons to portray positional accuracy according to the rectified images, and adding or deleting represented lands according to 1997-1999 vintage images.

The water rights attached to each individual irrigated polygon were abstracted from the original records on file in the office of the Wyoming State Engineer and State Board of Control located in Cheyenne, Wyoming. These rights were attached as attributed point features within each associated irrigated polygon. The points of diversion for the irrigation ditches were plotted and attributed, as were all water wells permitted for over 50 gallons per minute.

Final coverages produced include irrigated lands, water rights, points of diversion, and water well permits. Information contained in the irrigated lands coverage includes acreage, irrigation type (irrigated or sub-irrigated), drainage designation, and the U.S. Geological Survey (USGS) 7.5-minute quadrangle in which the lands are located.

Table II-1 provides a summary of the irrigated acreage calculated from the GIS mapping for each sub-basin, the vast majority of which is irrigated from surface water sources. Figure II-1 (p.II-38) illustrates the irrigated lands, by sub-basin.

Table II-1 Irrigated Land Totals by Sub-Basin

BASIN	1999 Irrigated Lands	1999 Sub-Irrigated Lands	1999 TOTAL
	(acres)		
Green River Above Fontenelle	119,302	14,068	133,370
New Fork River	50,447	2,259	52,707
Big Sandy - Eden Farson	21,318	1,188	22,506
Henrys Fork	15,086	1,604	16,690
Blacks Fork River	61,337	13,836	75,173
Hams Fork River	9,942	345	10,287
Green River below Fontenelle Res.	2,042	-	2,042
Little Snake River	15,483	1,477	16,959
Vermilion, Red, Salt Wells Creeks	674	-	674
BASIN TOTALS	**295,631**	**34,777**	**330,408**

The points of diversion coverage represents actual locations where permits divert from their source. The water well permits coverage represents the approximate location to the nearest quarter-quarter section. Table II-2 provides a summary of permitted irrigated acreage from ground water supplies.

Table II-2 Ground Water Irrigated Lands by Sub-Basin

BASIN	1999 Original Supply Active Permitted Acres	1999 Additional Supply Active Permitted Acres
	(acres)	
Green River above Fontenelle	-	23 (2 wells)
Big Sandy - Eden Farson	122 (1 well)	237 (5 wells)
Henrys Fork	-	198 (9 wells)
Blacks Fork River	-	110 (2 wells)
TOTALS	**122 (1 well)**	**568 (18 wells)**

Agricultural Uses – Typical Crops

The Green River Basin of Wyoming is primarily a producer of forage for livestock. By far the most common use of irrigation is in the growth of grass hay for harvest and pasture. Alfalfa is grown in areas where the growing season and water supplies allow. Small grains and cash crops are very limited in extent and in no sub-basin do they comprise more than three percent of the irrigated acres.

Water supply and growing season are the factors most often given for the predominance of grasses under irrigation. In this sense, irrigated agriculture is tied very closely to the livestock industry because the only viable use for the hay is as forage. Typically the forage is used by the producers' herds although some is disposed through local sale or export from the Basin.

Consumptive Use

The depletion of water by irrigation is estimated, in general terms, using available water supply, the consumptive demand of the crops irrigated and the number of irrigated acres in the Basin.

To determine the amount of water consumed via irrigation, the concepts of consumptive use (CU) and consumptive irrigation demand (CIR) must be described. In essence, CU describes the total water uptake of a crop, and varies due to several climatologic factors as well as plant stage. CIR is that amount of the total CU needed to be applied by irrigation for a full harvest.

CIR data have been published by month for various crops at seven sites within the Green River Basin proper and at several other sites that lie adjacent to the Basin. Mean values were used for "normal" year CIR values. For those years identified as "dry" or "wet" in the "Study Period Selection" memorandum, the corresponding yearly CIR values were ascribed as applicable for calculating "wet" or "dry" year CIR totals. The resulting CIR values were then applied to the number of irrigation days for each scenario to compute the agricultural depletion associated with that scenario.

In the Green River Basin most irrigators get one cutting of grass hay. As seasonal water supplies and growing conditions allow, irrigators will get a second cutting of grass. Where alfalfa is grown, two cuttings are desirable. Even if a second cutting is not obtained, diversion will usually continue (if water is available) in late summer and fall to fill soil profiles and provide stock water. Late season water is also applied to pasture and fields that livestock will be turned into in the fall, in effect allowing for a "second cutting" achieved not by mechanical harvest but by actual animal feeding. Because of the variation in precipitation, temperature and frost-free days even in normal years, whether or not more than one cutting is obtained is a matter of speculation.

Irrigation Days

To estimate the effects of "supply limited" conditions, diversion and streamflow records in the various sub-basins within Wyoming's Green River Basin were reviewed. The goal of this work was to estimate the number of days water is diverted. For the normal year case, irrigation days describe the number of days water typically is diverted based on diversion records and interviews. These values are not intended to apply to individual headgates, but rather to a sub-basin or tributary as a whole.

In some cases, diversion records indicate sufficient water for irrigation throughout a normal year. However, State Engineer field personnel are almost unanimous in their opinions that many ditches are turned off at traditional times not only for harvest but for consistent operational scheduling. Actual irrigation days were generally reduced to account for this operational reduction, even if occasional diversion records indicate water use.

Agricultural Depletion Estimate

Irrigation depletions are defined herein as the consumption of water applied by man to irrigated crops and include consumption by incidentally irrigated areas. Incidentally irrigated areas may be subirrigated or irrigated by surface return flows from managed fields. While some incidentally irrigated areas may contain willows, small trees or other vegetation, all are treated as crops (grass, in most cases) for consumptive estimates.

Current normal-year irrigation depletion estimates are 401,000 acre-feet per year, with dry-year and wet-year depletions estimated at 375,000 and 432,000 acre-feet, respectively. Table II-3 shows the agricultural depletion estimate by sub-basin and water supply scenario. These estimates are shown graphically in Figure II-2 (p.II-39).

Table II-3 Agricultural Depletion Estimate by Sub-Basin and Water Supply Scenario

River Basin/Sub-basin	Irrigated Acres	Normal Year Total, AF	Wet Year Total, AF	Dry Year Total, AF
Upper & Mainstem Green River *includes Beaver Creeks* *Dry Piney Creek* *Piney Creeks* *Green River above Fontenelle* *Horse Creek* *Cottonwood Creek* *Beaver Creek*	121,938	139,419	170,620	129,157
Muddy Creek *LaBarge Creek* *Slate Creek* *Fontenelle Creek*	11,432	12,963	15,859	12,019
New Fork River *includes Boulder Creeks* *East Fork* *Muddy Creek, trib. East Fork* *New Fork and Willow Creek* *Pine and Pole Creeks* *Silver Creek*	52,707	60,910	64,364	58,996
Big/Little Sandy Rivers *includes Farson/Eden* *Upper Basin*	22,506	36,164	30,543	34,472
Green River Below Fontenelle	2,042	3,281	2,771	3,128
Blacks Fork *includes Blacks Fork* *Smiths Fork and Muddy Creek*	75,173	93,608	90,007	87,866
Hams Fork	10,287	12,772	12,276	11,990
Henrys Fork	16,690	20,659	19,851	19,397
Little Snake *above Baggs*	11,941	13,969	18,405	12,269
below Baggs	5,018	6,547	6,759	5,471
Vermilion/Salt Wells Creeks	674	741	810	612
Total	**330,408**	**401,034**	**432,266**	**375,377**

C. Municipal and Domestic Use

Municipal and domestic uses are a relatively small but important part of the overall water use in Wyoming's Green River Basin. Municipal and domestic needs are served by both surface and ground water.

Municipal Use

The purpose of this section is to provide water use information for the following 15 cities, towns, and joint power boards (JPB) that supply water to their citizens or customers:

Entities that obtain their primary water supply from surface water, and the sources, are:

- Town of Baggs - Little Snake River
- Bridger Valley Joint Powers Board - Smiths Fork and Blacks Fork
- City of Cheyenne - Tributaries to the Little Snake River
- Dixon - Little Snake River
- Town of Granger - Green River
- Kemmerer-Diamondville Joint Powers Board (KD JPB) - Hams Fork River
- Town of LaBarge - Green River
- Pinedale - Fremont Lake
- Rock Springs/Green River/Sweetwater County Joint Powers Board (RS/GR/SC JPB) - Green River

Entities with primary water supplies from ground water (and the source aquifer) are:

- Town of Bairoil (Battle Springs Formation)
- Town of Big Piney (Green River Formation)
- Town of Marbleton(Wasatch Formation)
- Town of Opal (Green River Formation)
- Town of Superior (Ericson Sandstone/Rock Springs Formation)
- Town of Wamsutter (Green River Formation)

Methodology

Primarily, information was obtained from the various municipalities through direct communication or from the municipalities' responses to the Wyoming Water Development Commission's (WWDC) 1999 Water Supply Survey. If neither of these sources were available, data from the WWDC's "1998 Water System Survey Report" were used.

Typically, municipalities provide water to customers outside their corporate limits. Therefore, the populations of the service areas are more pertinent than the census information. Further, some of the municipalities or joint powers boards sell water to surrounding water districts. For purposes of this analysis, water sales outside the corporate limits for domestic use are considered municipal water use and are included in the statistics for the various entities.

In addition, municipalities may sell water to industrial water users. For example, the Kemmerer-Diamondville Joint Powers Water Board and the Rock Springs/Green River/ Sweetwater County Joint Powers Water Board sell water to industries outside the corporate limits of their member municipalities. These water sales are not considered municipal water use in this analysis and are addressed as industrial water use.

Conclusions

Table II-4 provides a comparison of reported existing peak day demand with the reported system capacity and the capacity of the direct flow and storage water rights for the 14 suppliers in the Green River Basin (Cheyenne is not considered in this analysis):

Table II-4 Comparison of Existing Use and System Capacity

(AFD = acre-feet per day)				
Supplier	**Peak Day Demand (AFD)**	**System Capacity (AFD)**	**Water Right Capacity (AFD) (Direct Flow or GW)**	**Storage Rights (AF)**
Baggs	0.61	0.88	1.24	None
Bairoil	0.77	0.92	0.92	None
Big Piney	0.41	2.30	3.30	None
Bridger Valley JPB	6.60	12.10	15.10	800
Dixon	0.08	0.97	0.97	None
Granger	0.31	3.09	13.01	None
KD JPB	6.14	12.82	17.07	1,770
LaBarge	1.54	1.77	2.64	None
Marbleton	2.15	2.20	3.60	None
Opal	0.07	0.24	0.46	None
Pinedale	7.67	44.20	11.48	17,439
RS/GR/SC JPB	47.20	65.00	79.30	None
Superior	0.28	1.60	5.57	None
Wamsutter	0.61	3.09	1.51	None

Table II-4 is offered as an indication that the water suppliers have sufficient system and water right capacity to meet their existing demands, as well as the opportunity to meet the demands of some future growth.

Table II-5 describes the monthly and annual depletions by municipal use in the Basin.

Table II-5 Current Level Municipal Surface Water Depletions

(Using 1997-1999 Data, AF/Year)

City/Town	Pop.	GPCPD	River	Jan.	Feb.	Mar.	Apr.
Baggs	300	157	Little Snake	5.07	4.76	4.41	0.62
BV JPB	4,500	86	Smiths/Blacks Fk	19.12	16.41	18.83	21.30
Cheyenne	N.A.	N.A.	Little Snake trib.	21.67	7.67	6.33	145.00
Dixon	75	274	Little Snake	1.40	1.38	1.38	1.29
Granger	170	294	Green	0.62	0.47	0.58	0.94
KD JPB	3,950	80	Hams Fork	14.35	12.89	13.68	10.84
LaBarge	490	251	Green	6.73	6.07	6.12	6.09
Pinedale	1,480	474	Fremont Lake	30.69	6.14	15.34	42.96
RS/GR/SC JPB	36,500	115	Green	133.63	121.24	149.03	122.85
Total	47,465	113		233	177	216	352

City/Town Cont…	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total (AF)
Baggs	-0.65	2.25	9.51	7.60	5.84	4.22	3.98	5.14	53
BV JPB	28.73	38.82	104.49	65.16	51.71	25.51	25.19	15.89	431
Cheyenne	4132.33	9683.00	372.00	12.33	3.67	2.33	1.00	1.00	14,388
Dixon	1.72	2.69	3.74	2.72	2.30	1.55	1.55	1.31	23
Granger	12.67	28.24	4.68	3.12	1.94	1.01	0.78	0.93	56
KD JPB	23.55	43.02	87.91	68.13	32.96	14.71	14.73	17.64	354
LaBarge	11.04	17.20	27.75	21.26	12.22	7.37	5.97	9.92	138
Pinedale	61.38	30.69	153.45	162.65	110.48	95.14	27.62	49.10	786
RS/GR/SC JPB	464.89	707.93	984.99	823.48	505.56	225.27	212.48	246.71	4,698
Total	4,736	10,554	1,749	1,166	727	377	293	348	20,927

Figure II-3 (p.II-40) shows graphically the apportionment of use by municipality. In most cases, water use is based on 1997-1999 data to present the current-day situation. However, water users may have a situation that cannot be described with present information. The Rock Springs/Green River/Sweetwater County Joint Powers Water Board depletes more water than the other thirteen in-basin water suppliers combined. Recently, the Joint Powers Water Board completed a comprehensive expansion of its water treatment and supply facilities, which removed "bottlenecks" in the previous water supply system. Area water officials believe that water use, particularly in the Rock Springs area, may increase 15 percent or more as the water supply system can now meet the true demands of the water users.

It is interesting to note that the largest municipal water user in the Green River Basin is not located in the Basin. The City of Cheyenne presently diverts an average of approximately 14,400 acre-feet of water per year from the Little Snake River Basin to North Platte River Basin, where the water is ultimately exchanged to meet Cheyenne's needs in the South Platte River Basin. The 14 water suppliers located in the Green River Basin deplete approximately 7,350 acre-feet of water per year (including ground water) on an annual basis.

Domestic Use

Domestic water is defined as the water supply for rural homes, subdivisions, commercial establishments, parks, campgrounds, and other smaller water uses, and is typically provided by ground water. Subdivisions or public water supplies that obtain water from municipalities or joint powers boards are not included in this category, as their water use is considered municipal water use. Most of the remote industries in the Basin use a portion of their supplies for domestic use. However, as this water use was included in the estimated industrial water use for the Basin, it is not considered domestic water use.

Existing county populations within the Green River Basin are used as the basis for estimating domestic water use. Because county populations, as provided by the Wyoming Department of Administration and Information, include the service areas of the municipal water suppliers, it is necessary to subtract the populations of the municipal service areas to obtain the rural populations or domestic water users.

The total estimated current population of the Green River Basin in Wyoming is approximately 61,100, of which about 49,600 reside in municipal service areas. The estimated existing population of the areas outside of the service areas of municipal water suppliers is therefore approximately 11,500. For purposes of this estimate, it is assumed that this is the population that is served by domestic groundwater wells or independent public water supply systems. If it is assumed that this population consumes between 150 and 300 gallons per capita per day, the resulting estimated total domestic water use would range between 1,940 and 3,880 acre-feet per year in the Green River Basin.

D. Industrial Use

The purpose of this section is to describe water uses by the major industries in the Green River Basin. Industries that obtain their primary water supply from surface water are electric power generation, soda ash production, and other miscellaneous smaller users.

The industries that obtain their primary water supply from ground water are coal mining, uranium mining, and the oil and gas industries.

Methodology

Existing Industrial Surface Water Use

Information was obtained from the various industries through direct communication. However, many of the soda ash industries did not have records of their water use. Therefore, some estimates had to be gleaned from anecdotal information. For example, apparently there is a "rule of thumb" that it takes 200 gallons of water to produce one ton of soda ash. All of the soda ash facilities in the Green River area, with the exception of Solvay Minerals, Inc., have on-site power plants. It was estimated that the on-site power plants used an additional 250 gallons of water to generate the power necessary to produce one ton of soda ash.

All of the industries, with the exception of the Naughton Power Plant, have zero discharge facilities. Therefore, the depletions or impacts to surface water are equal to the amount of water diverted. Depletions for the Naughton Power Plant were calculated by deducting the estimated return flow from the estimated diversions. Soda ash producers typically reported water demands to be relatively constant throughout the year.

Existing Industrial Groundwater Use

There is very limited available information regarding industrial groundwater use. Industrial use of ground water is typically short-term and intermittent in nature. The best available information relating to industrial groundwater use is water rights issued by the Wyoming State Engineer's Office. Therefore, tabulations of water rights in each of the water districts in the Green River Basin were used as the basis for estimates of existing industrial groundwater use.

Conclusions

Existing Industrial Surface Water Use

Power plants are the largest industrial water users in the Green River Basin. The Jim Bridger and Naughton Power Plants, both owned and operated by Pacificorp, use or deplete approximately 47,800 acre-feet of water per year. Both power plants enjoy the security of storage water. Pacificorp maintains a contract for storage water from Fontenelle Reservoir for use at the Jim Bridger Power Plant during times of severe drought. Pacificorp owns and operates Viva Naughton Reservoir, which serves as the primary supply for the Naughton Power Plant. In both plants, water is used to produce steam for power production and is used in the cooling processes. The majority of the water is discharged through the cooling towers or lost through evaporation ponds. Some water is used for dust abatement and domestic use.

There are five (5) major producers of soda ash in the Green River Basin. FMC Granger, FMC Westvaco, General Chemical, OCI Wyoming, and Solvay Minerals, Inc. produced approximately 11.7 million tons of soda ash in 1999, which represents approximately 37 per cent of the world's demand. At current levels of production, these five producers deplete approximately 17,900 acre-feet of water from the Green River and, collectively, are the second highest industrial water users in the Green River Basin. Water is used in processing trona, and is also used for dust abatement and domestic supplies as well as power cogeneration discussed previously. All of the water at the facilities is discharged through cooling towers and evaporated from holding ponds.

Other industrial facilities in the Basin, including Church & Dwight, Exxon's Shute Creek plant, and FS Industries (which produce baking soda, natural gas, and chemical fertilizer, respectively) combine to deplete an additional 800 acre-feet per year.

Table II-6 (p.II-15) lists the estimated monthly and annual water use (depletions) for the ten largest users. The existing estimated industrial surface use for the ten major users is approximately 66,500 acre-feet per year.

Flows of the Green River are stored in and regulated through Fontenelle and Flaming Gorge Reservoirs. Both of these dams have hydroelectric generating facilities. The production of hydropower is basically considered a non-consumptive use of water other than the associated evaporation losses which are considered in other sections of this report.

Fontenelle Reservoir as an Industrial Water Supply

The water right for Fontenelle Reservoir indicates its primary purposes are irrigation, domestic, industrial, municipal, stockwatering, fish and wildlife and recreation; and when not required for the primary purposes, storage water can be used for power generation, the secondary purpose. However, the major existing benefits of Fontenelle Reservoir relate to industry.

The construction of Fontenelle Dam was completed in December, 1967, under water right Permit No. 6629 Res. In 1962, the State of Wyoming contracted with the Bureau of Reclamation for 60,000 acre-feet of the active capacity. In 1974, the State of Wyoming again contracted with the Bureau of Reclamation for 60,000 additional acre-feet of active capacity, thereby increasing its total interest in Fontenelle Reservoir to 120,000 acre-feet.

In the 1974 contract, 5,000 acre-feet was designated for the Seedskadee Wildlife Refuge. The United States reserved 65,000 acre-feet of capacity for its uses, subject to provisions that the Bureau of Reclamation would not compete with the State of Wyoming in the water market. This contract also required the United States and State of Wyoming to ensure operations that would provide for the maintenance of 50 cubic feet per second (cfs) downstream in the Green River at the USGS streamgage near Green River, Wyoming.

Table II-6 Average Monthly Industrial Water Use

(Acre-feet)							
Facility	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**
Jim Bridger Power Plant	1,900	1,900	2,850	2,850	3,600	3,750	3,860
Naughton Power Plant	1,100	1,000	1,100	1,100	1,200	1,200	1,200
FMC Granger	250	250	250	250	250	250	250
FMC Westvaco	500	500	500	500	500	500	500
General Chemical	300	300	300	300	300	300	300
OCI Wyoming	250	250	250	250	250	250	250
Solvay	190	190	190	190	190	190	190
Church & Dwight	15	15	15	15	20	20	25
Exxon Shute Creek	1	1	1	1	2	2	2
FS Industries	110	70	60	100	50	10	10
Total Average Monthly Use	4,616	4,476	5,516	5,556	6,362	6,472	6,587

Facility	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Total**
Jim Bridger Power Plant	3,860	3,100	2,850	1,900	1,900	34,320
Naughton Power Plant	1,200	1,100	1,100	1,100	1,100	13,500
FMC Granger	250	250	250	250	250	3,000
FMC Westvaco	500	500	500	500	500	6,000
General Chemical	300	300	300	300	300	3,600
OCI Wyoming	250	250	250	250	250	3,000
Solvay	190	190	190	190	190	2,280
Church & Dwight	20	20	20	15	15	215
Exxon Shute Creek	2	1	1	1	1	16
FS Industries	10	20	40	50	30	560
Total Average Monthly Use	6,582	5,731	5,501	4,556	4,536	66,491

Presently, the State of Wyoming, through the Wyoming Water Development Commission, has allocated 46,550 acre-feet of its entitlements to Fontenelle water through the following water supply or readiness to serve contracts: Jim Bridger Power Plant (35,000 acre-feet per year), FS Industries (10,000 acre-feet per year), Church and Dwight (1,250 acre-feet per year), and Exxon, USA (300 acre-feet per year).

<u>Existing Industrial Groundwater Use</u>

Overall groundwater use by industry in the Basin is estimated at 1,575 acre-feet annually. Coal mines primarily use water for dust abatement. Black Butte Coal Company and Bridger Coal Company provide coal to the Jim Bridger Power Plant. Kemmerer Coal

Company provides coal to the Naughton Power Plant. These companies have several permits for groundwater use. The water generally comes from wells or as a by-product of the mining operations. The Bridger Coal Company obtains water from the Jim Bridger Power Plant for domestic and fire protection use. The Kemmerer Coal Company obtains domestic and fire protection water from the Kemmerer/Diamondville Joint Powers Board.

The uranium industry is presently idle in the Green River Basin. Kennecott Uranium Company holds water rights for several groundwater wells at its inactive mine and processing facility in the Great Divide Basin. The water was used in the process that extracted the uranium from the ore.

Oil and gas companies often secure water rights to use water for on-site purposes, such as producing drilling mud and dust abatement. The actual water use at the wells during the drilling process is typically short term.

E. Recreational Use

Recreational uses of water are important and generally non-consumptive. Uses include boating, fishing, swimming and waterfowl hunting, among others. While consumption of water is usually not involved, the existence of a sufficient water supply for a quality experience is important. This section describes current water-based recreational opportunities in the Basin, whether current use rates exceed capacities for use, and provides quantitative information wherever possible.

Boating

Many of the Basin's rivers and lakes are destinations for recreationists desiring to boat, water-ski or float (either whitewater, scenic or fishing) using watercraft. Areas heavily used by watercraft include the large lakes and reservoirs with boat ramps, and the larger rivers (e.g. the Green River Proper and the New Fork River). Smaller craft such as rafts and canoes do not require boat ramps and have access to more bodies of water and reaches of river. Boating is considered a non-consumptive use of water in that it occurs at lake levels and river flows determined by other uses.

Little quantitative data exist on the numbers of watercraft using these facilities and whether numbers approach or exceed the carrying capacity of the water body used. The Bureau of Reclamation has indicated that, while not the rule on Wyoming waters, a ceiling capacity of one boat per ten surface acres of water is used elsewhere to measure use versus capacity. Unfortunately, current actual boating numbers on Green River Basin waters are generally not available from any of the land management agencies contacted.

One area where boating capacity is of concern relates to current use of the Green and New Fork Rivers. Recently receiving heavy pressure, these rivers are currently under study in areas where the managing agency maintains developed recreation sites and/or boating access. The Green River at Warren Bridge and also below Fontenelle Dam are examples of locations where heavy use is being evaluated.

A quality boating experience requires a water level (in lakes) or flow rate (in rivers) sufficient to support the reason for boating, whether it be fishing, water-skiing or some other sport. In this context, future water development projects must be evaluated for their effect on such levels, and due to state and federal regulations will to some extent be designed and operated based upon recreational considerations.

Fishing

Fishing is a major water-based recreational activity pursued in the Basin. From brook trout in tiny creeks in the Wind River and Wyoming Ranges to lake trout in Flaming Gorge Reservoir, fishing brings many visitors and residents to the region. As in boating, fishing is a non-consumptive use of water.

The State of Wyoming classifies trout streams under five designations:

- Class 1 – Premium trout waters – fisheries of national importance
- Class 2 – Very good trout waters – fisheries of statewide importance
- Class 3 – Important trout waters – fisheries of regional importance
- Class 4 – Low production trout waters – fisheries frequently of local importance, but generally incapable of sustaining substantial fishing pressure.
- Class 5 – Very low production waters – often incapable of sustaining a trout fishery

Figure II-4 (p.II-41) shows classifications of streams under this system within the Green River Basin. Interestingly, there exist no waters currently classified as Class 1 in the Basin. The only Class 2 streams in the Basin are certain segments of the main stem of the Green River above Flaming Gorge, and a segment of the New Fork River in the vicinity of Boulder. Nonetheless, the Green River Basin is considered by many to provide excellent fishing opportunities in its lakes, streams, rivers and backcountry areas.

The Wyoming Game and Fish Department (WGF) maintains the most complete database on fisheries and fisherman use in the State. In response to a request for fishing activity in the Green River Basin, the WGF provided the most recent estimate of annual standing water angling pressure. The breakdown by type of standing water is given below.

Recent Fishing Activity, Green River Basin: Angler Days by Standing Water Type			
	Pinedale Region	**Green River Region**	**Total**
Unsuitable	27	0	27
Natural Alpine Lake	59,286	2,974	62,260
Alpine Reservoir	7,875	1,029	8,904
Natural Lowland Lake	16,875	0	16,875
Lowland Reservoir	547	392,626	393,173
Trout Farm Pond	487	3,164	3,651
Mixed Farm Pond	0	680	680
Non-Trout Farm Pond	0	1	1
Total	85,097	400,474	485,571

Source: Mark Fowden, WGF, April 2000

From angler surveys in 1979, 1985 and 1991, stream angling data were provided for Region 4, which included the Bear River Basin. Upon review of the responses for 1985, it was determined that approximately 91 percent of the total is attributable to stream fishing in the Green River and its tributaries, leaving about nine percent occurring in the Bear River Basin. Absent other data, this factor was applied to subsequent totals which also included Bear River data as a correction factor to more properly represent the Green River Basin only. Stream angler days are described as follows:

Fishing Activity, Green River Basin: Stream Angler Days		
	Region 4	**As Corrected for Green River Basin Only**
1979	359,145	326,800*
1985	238,153	217,142 (actual)
1991	281,691	256,300*

**Stream Angler numbers have been reduced by 9% to remove Bear River Basin effects.*

The WGF also has published a document entitled: *A Strategic Plan for the Comprehensive Management of Wildlife in Wyoming, 1984-1989*. This document gives total stream and lake sport fishing data in fisherman-days for the entire state as divided into five regions. Region 4 includes the Green, Bear and Little Snake River drainages. While the Bear River Basin numbers are included, this basin is relatively quite small in comparison to the Green and Little Snake basins, both in geographic extent and in availability of fishable waters. Therefore, numbers provided for Region 4 have been reduced by nine percent as described above.

Not only are utilization (demand) data given, but this Strategic Plan document also estimates "supply" or "biological supply" of fishing opportunity available to the angler. As defined in the Strategic Plan, "Supply is based on present regulations, present stocking practices and the standards for success and size of fish which are present under 'Management Framework.'" For 1988, the most recent year for which data are given in the report, supply and demand numbers are as follows:

Fishing Opportunity: Supply vs Demand, 1988			
Fisherman-Days or %	***Supply on Public Lands or with Public Access***	***% on Public Lands or with Public Access***	***Total Supply***
Streams	212,700*	51.75%	411,000*
Lakes and Reservoirs	1,122,817	94.73%	1,185,235
Total	1,335,517	82.87%	1,596,235
Fisherman-Days	***Resident Demand***	***Nonresident Demand***	***Total Demand***
Streams	302,000*	73,100*	375,100*
Lakes and Reservoirs	274,509	146,968	421,477
Total	576,509	220,068	796,577

Source: A Strategic Plan for the Comprehensive Management of Wildlife in Wyoming, 1984-1989.
**Stream Angler numbers have been reduced by 9% to remove Bear River Basin effects; Lake Angler numbers were not.*

The primary limiting factor for stream fishing is the availability of public access. Other areas of potential use limitations are currently under evaluation by the Bureau of Land Management (BLM) and Seedskadee National Wildlife Refuge. Both of these agencies have experienced significant increases in commercial use by outfitters. The BLM, in concert with other agencies, has been involved in a study entitled "Green River Corridor Interagency Management Plan," which is intended to address use of the Green River in Wyoming from its headwaters to Flaming Gorge. In the Green River Basin above Fontenelle Reservoir, public access points are few and provide virtually the only access to the rivers which otherwise are bordered largely by private lands.

The resulting analysis of fishing use data indicates that overall utilization remains below the capacity of the resource, although stream fishing experiences some limitations due to access. Recent WGF planning documents have moved away from publishing "supply versus demand" analyses, so current utilization numbers are unavailable. Indications are, however, that the Green River Basin maintains a sufficient fishery resource for current and near future high-quality fishing experiences.

Waterfowl Hunting

The harvest of migratory waterfowl is a recreational pursuit affected by the presence or absence of water. Wetlands and open water are needed for breeding, nesting, rearing, feeding and isolation from land-based predators. In the Green River Basin of Wyoming, waterfowl hunting is pursued where sufficient local or migratory populations are available. The two most heavily hunted areas are the Seedskadee National Wildlife Refuge and the Farson-Eden-Big Sandy area. The Green and Little Snake River Basins are located in the Pacific Flyway.

Harvest objectives are not currently used (post-1993), because harvest is taken into account in the setting of season length and bag limits by the U.S. Fish and Wildlife Service (USFWS). In effect, the desired harvest is a prospective number using past hunter success, population effects, and regulations in concert with current-year populations. With current duck populations and hunting pressure, it appears there is a sufficient resource to provide a quality duck hunting experience now and in the near future, with the existing water resources of the Basin.

In like fashion, goose hunting seasons and bag limits are set under guidelines from the USFWS, although states have more flexibility in setting bag and possession limits. And like duck populations, goose populations are strong and increasing. Again, because of the recent upward trends in populations, it appears there is a sufficient resource to provide a quality goose hunting experience now and in the near future, with the existing water resources of the Basin. However, because the Rocky Mountain Population nests and breeds locally, it is possible for local water development projects to adversely affect local goose populations (and hunter success) if breeding and nesting sites suffer net loss, even as continental populations continue to rise.

Wild and Scenic River Candidates

The 1996 *Green River Resource Area Resource Management Plan*, administered by the BLM, studied a number of river segments in the Green River Basin for possible designation under the Wild and Scenic Rivers Act. Initially, 183 waterways or waterway segments were reviewed for eligibility. Of these, 175 were found "…not to have any outstandingly remarkable values and were dropped from further consideration."

The remaining eight waterways under consideration included the Red Creek Unit, Currant Creek Unit, Pacific Creek, North Fork of Bear Creek, Canyon Creek, and the Green and Big Sandy Rivers. These were reviewed for suitability for classification under the system. However, no segments in the Green River Basin were ultimately determined suitable for inclusion. The primary reasons given for the "Not Suitable" determination included landowner conflicts, inability to manage the segment, lack of interest for designation, and potential use conflicts.

The 1999 Upper Green Landscape Assessment (published by the Bridger-Teton National Forest) lists the entire segment of the Upper Green River, from its source to the Forest

Boundary, as a Study River for Wild and Scenic designation. The river is considered as eligible for designation as a Wild River above Green River Lakes, and as a Scenic River from Lower Green River Lake to the Forest Boundary. Two tributaries are also eligible as Wild Rivers: Tosi Creek and Roaring Fork Creek. Suitability determination information was unavailable, and formal designation has not yet been made.

No rivers on the Medicine Bow – Routt National Forest (Hayden District, east of Baggs/Dixon in the Little Snake River drainage) were determined eligible in the 1985 Forest Plan. However, segments of local importance are still under study and may be identified for eligibility in the near future. If any stream segments are determined eligible for designation, the Forest does not plan to immediately pursue suitability evaluation.

Wyoming State Parks and Historic Sites

There are no State Parks in the Green River Basin or the Great Divide Basin. The only State Historic Site (SHS) in either basin is at Fort Bridger, just west of the Town of Lyman. Data collected by the former Division of State Parks & Historic Sites (under the former Department of Commerce), however, does provide insight into travel habits and desires of recreationists visiting state sites, which is of value if extrapolated to tourist destinations in general.

The *Visitor Use Program* for 1993-1997 contains useful information concerning site visitation. Interestingly, for the 1993-1997 period, Fort Bridger SHS averaged 87,708 visitors per year, more than any other SHS. This value is also more than the attendance at 9 of 14 (64 percent) of the State Parks. The bulk of the visits occur in the June through September period.

The 1997 *Wyoming State Parks and Historic Sites Visitor Survey*, compiled by the University of Wyoming, Survey Research Center, provides additional information. About 86 percent of all visitation (to all parks and historic sites) occurs in the months of June, July and August, with attendance in each of those months almost equal. Slightly over half the visitors are first-time visitors. Approximately one in four visitors is traveling with a boat or canoe, indicating some water-based recreation is intended, either at that location or elsewhere on that particular trip. Approximately 58 percent of the visitors are from out of state.

F. Environmental Use

Previous studies have estimated the amount of water designated for or consumed by various environmental uses. These include but are not necessarily limited to instream flow water rights permitted by the Wyoming State Engineer, minimum reservoir pools, instream bypasses designated to enhance fisheries and wildlife habitat, wetlands, direct wildlife consumption, evaporation from conservation pools and maintenance of riparian areas. Environmental uses downstream on the Green and Colorado Rivers must also be considered.

Instream Flows

In 1986, the State of Wyoming enacted legislation defining "instream flow" as a beneficial use of water, and stipulated how instream flow water rights would be filed, evaluated, granted or denied, and ultimately regulated. The legislation is codified within Wyoming Statutes at Section 41-3-1001 to 1014. Instream flow rights are filed with the Wyoming State Engineer's Office, held by the Wyoming Water Development Commission, and managed by Wyoming Game and Fish.

The law allows for instream flow water rights to be filed and granted on unappropriated water originating as natural flow or from storage in existing or new reservoirs. For natural flow sources, the flow amount is defined as the minimum needed to "maintain or improve existing fisheries." The language relating to stored water is slightly different, defining the minimum needed to "establish or maintain new or existing fisheries." Generally speaking, instream flow is considered a non-consumptive beneficial use.

In the Green River Basin (including the Little Snake River Basin), there are currently 34 instream flow applications on file. Two of these filings have been granted permits as of the date of publication of this report. All 34 of these filings are tied to natural flow, although two are influenced by reservoirs above the segments. Instream flow segments are shown on Figure II-5 (p.II-42).

The two pending applications influenced by reservoirs include one on the Hams Fork (TF No. 26 3/332), where water is delivered from Viva Naughton Reservoir, and one on the East Fork Smith Fork (TF No. 28 2/84) below Stateline Dam (which is in Utah). Both of these applications are filed for water that enters the stream by virtue of the reservoir above them, and not on storage water in the reservoir.

The two permits that have been issued are No. 6IF on the Green River near Warren Bridge and No. 7IF on the West Fork of the New Fork River. Many of the remaining yet-to-be-granted filings are on streams containing Colorado River cutthroat trout, and are intended to help protect that species, which is being considered for listing as an endangered species under the federal Endangered Species Act.

Cutthroat Trout Management

The Wyoming Game and Fish Department has instituted a management program designed to protect and enhance the natural populations of Wyoming's native cutthroat trout. In the Green River Basin of Wyoming, this includes the native Colorado River cutthroat trout. Management of the trout is intended to prevent the species from becoming listed as threatened or endangered. An early strategic plan included the following:

- Identification and protection of waters containing pure cutthroat populations;
- Increase the distribution of cutthroat trout within their ancestral range through habitat protection and rehabilitation;

- Develop brood stock from pure populations; and
- Reintroduce cutthroat trout to native waters.

To achieve these strategic goals, a management plan with seven activities are being implemented:

1) Fish sampling to locate and evaluate populations;
2) Habitat surveys;
3) Implementation of special fishing regulations;
4) Instream flow water right filings;
5) Fish culture activities;
6) Non-native trout removal; and
7) Information and education efforts.

These activities have been undertaken and show promise for protecting the native trout. According to Game and Fish personnel, Colorado River cutthroat trout occupy 23 percent of the streams in the Green River Basin in reaches totaling 19 percent of the stream miles in the Basin. Work involved in protecting these native fish is considered non-consumptive (of water), although the use of instream flow water rights and habitat improvement will affect future water development activities in the immediate vicinity of such work. Protection of important native fish populations is an example of water-related work that can be accomplished without depletion, and shows that water resources can exhibit strong economic value (e.g. recreation) without consumptive use.

Reservoir Minimum Pools

Several reservoirs in the Basin have storage permitted for a variety of environmental uses. These uses, as they appear on the water rights, include fish, and fish and wildlife. Recreational uses defined on permits can be considered environmental to the extent that water in storage for recreational purposes, and not released for other consumptive or nonconsumptive uses, can be beneficial, in an environmental sense, for fish habitat and wildlife consumption. Reservoirs with permitted capacity for stock water similarly serve a dual environmental function. The reservoirs with fish or fish and wildlife uses or pools listed in their permitting documents include Boulder (1,621 acre-feet), High Savery (4,955 acre-feet), as well as three other reservoirs with an unsegregated portion of their total storage devoted to fish and wildlife (or similar use): Big Sandy, Flaming Gorge, and Fontenelle.

The Wyoming Game and Fish Department has provided data describing recommended lake or reservoir levels (given as surface acreage) for fish population purposes. These data are presented in Figure II-6 (p.II-43) for water bodies of 100 surface acres and larger.

Maintenance Flows

The Wyoming Game and Fish Department has also provided data on recommended maintenance flows for moving water. These flows are what the Department views as necessary to support game fish populations in the late season, low flow months. Figure II-7 (p.II-44) shows these flows for streams and rivers in the Basin where such flows are 10 cfs or greater.

Instream Bypasses

Only three reservoirs in the Green River Basin have minimum flow bypasses included in their permitting documents. These include Fontenelle (50 cfs at the town of Green River), Meeks Cabin (10 cfs) and Stateline (7 cfs) Reservoirs.

Wetlands Mapping

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of classification, wetlands must have one or more of the following three attributes:

1) at least periodically, the land supports predominantly hydrophytes;
2) the substrate is predominantly undrained hydric soil; and
3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

The National Wetlands Inventory (NWI) coverage for the Green River Basin is used to describe wetlands for this report. The wetlands mapping was overlaid on the GIS Irrigated Acreage coverage used in the Green River Basin plan. More than half of the defined irrigated acreage is classified in the wetlands mapping as “Emergent.” This may be due to the scale of the wetlands mapping, which varied between 1:20,000 and 1:132,000. It may be due also to the fact that the Emergent wetlands classification includes meadows, among others, and that almost all of the irrigated acreage in the Green River Basin is meadow composed of emergent plant types. Figure II-8 (p.II-45) shows NWI mapping for the Basin.

Wetlands in the Green River Basin provide significant nesting and breeding habitat for local populations of ducks and geese. In fact, the Green River Basin is an important contributor to Wyoming’s status as one of the largest waterfowl resident states in the western U.S., with total duck breeding pairs more than double the totals in Nebraska and Colorado combined for 1999. These local birds are the primary target of waterfowl hunters, and as such their reproductive success is important to future environmental and recreational pursuits. An area of future environmental concern, or cause for mitigation, is therefore the potential of destruction of breeding and nesting habitat for waterfowl. In the Green River Basin, areas near Farson and Eden and the Seedskadee National Wildlife Refuge are the most heavily hunted for waterfowl.

Seedskadee National Wildlife Refuge

Created initially as environmental mitigation following construction of Flaming Gorge and Fontenelle Reservoirs by the Bureau of Reclamation, Seedskadee National Wildlife Refuge (NWR) has become a popular destination for fishermen, hunters, sightseers, and birdwatchers. The Refuge contains 26,037 acres of land and covers over 36 miles of the main stem of the Green River from the upper boundary (approximately 2.5 miles below the CCC Bridge) to just below the "Big Island," approximately 20 miles northwest of Green River. While originally planned for protection and production of waterfowl, the Refuge has seen more intensive management of big game, fisheries, and other fauna and flora in recent years.

Seedskadee NWR provides significant water-related environmental benefits in an otherwise arid region. Habitats available on the refuge include riverine and backwater aquatic areas, wetland and riparian areas, and drier grassland/shrubland communities. The source of water for these uses is the Green River proper with contributions from the Big Sandy River. In a 1974 contract between the State of Wyoming and the Bureau of Reclamation, 5,000 acre-feet of reservoir water was designated for the Refuge. In addition, Seedskadee uses older pre-refuge irrigation works to distribute water for wetland development and maintenance, and benefits from 115 cfs of direct flow rights held by the U.S. Bureau of Reclamation.

With little use between Fontenelle Reservoir and the Refuge, the Green River provides a relatively reliable water supply to Seedskadee. Although minimum flows are to remain above 50 cfs (at the town of Green River) below Fontenelle, actual flows are historically much larger. According to the Bureau of Reclamation, August to April releases are typically 1,200 to 1,400 cfs with higher flows passed in the spring flooding season.

Consumption of water on the Refuge is limited to evapotranspiration from the wetland and riparian areas. Currently, the Refuge has no plans to create significant new wetlands, although maintenance of existing wetlands and reestablishment of pre-existing wetlands will continue. Currently there are approximately 335 acres of wetland habitat and 1,394 acres of riverine habitat on the Refuge.

Direct Wildlife Consumption

It was previously estimated that 100 acre-feet per year of water originating as ground water is consumed by wildlife. This estimate was revisited during the current study and it was concluded that this amount is not unreasonable. An earlier estimate of wildlife use of surface water of 400 acre-feet per year was revisited with WGF personnel for the current plan. No change to this value resulted.

Evaporation

Under the Bureau of Reclamation's "Consumptive Uses and Losses Report," a document prepared every five years as required by the Colorado River Basin Project Act of 1968, man-made losses such as evaporation from constructed or enlarged reservoirs are charged against the State's Compact allocation. Some authorities consider that part of calculated evaporation losses are "charged" to environmental uses, especially if a water body exists for the primary purpose of serving environmental needs. However, administratively, these amounts are calculated without regard to type of use. A more detailed discussion of evaporation losses is provided in Section G of this chapter (p.II-28).

Maintenance of Riparian Areas

In recent years the value and maintenance of riparian zones along stream corridors has been the subject of considerable study. Several interrelated topics emerge from this work, including the value of riparian zones for both aquatic and terrestrial wildlife, the ability of riparian zones to assist in maintaining base flows in streams, and the value of riparian areas in controlling erosion.

The United States Department of the Interior, Bureau of Land Management (BLM) has published several documents relating to riparian area management. These guides, however, are qualitative and do not provide quantitative estimates of, for example, potential storage capacity increase due to improved riparian condition. Case study histories exist of several projects where riparian improvement has resulted in improved base flow conditions in the subject streams.

Other recent studies provide a more quantitative assessment of the hydrogeologic response of an alluvial stream system to riparian improvements. Studies of Muddy Creek, which is tributary to the Little Snake River, reported phreatic surfaces 15 to 20 feet below ground in degraded riparian areas while the water surface was only a few feet below the surface in improved riparian zones. Instream structures reportedly added approximately 0.4 acre-feet of bank storage per thousand feet of channel in the improving riparian areas.

Another report used a groundwater model to assess the storage capacity of degraded, improving and improved riparian zones. This study also noted that while ground water levels are within a few feet of the ground surface in improved riparian areas, they may be tens of feet deeper in degraded reaches.

Other work did not look at riparian areas *per se*, but rather at the water budget associated with flood irrigation along the New Fork River in Sublette County, Wyoming. These findings reflect less the intentional management of water for riparian improvement, and more the actual result of flood irrigation in a typical setting. The study stated: "A large percentage of the diverted water returns to the stream system so there is no loss of beneficial surface flow to the downstream users and the release of stored water during the low flow winter months will help maintain a constant supply of water to the channel system. The saturated aquifer acts as a 24,000 acre-feet underground reservoir that releases most of this volume to the downstream users during the same irrigation season, without excessive evaporation losses."

Recovery Implementation Program for Endangered Fish Species

Section 2(c) (2) of the Endangered Species Act states: "the policy of Congress is that Federal agencies shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species." In 1988, the States of Wyoming, Colorado and Utah, the Secretary of the Interior and the Administrator of the Western Area Power Administration entered into a cooperative agreement to recover four endangered fish species in the Upper Colorado River Basin while allowing for continued and future water development. The species are the Colorado pikeminnow, razorback sucker, humpback chub and bonytail chub.

Parties to the agreement agreed to participate in and implement a recovery program with the following five principal elements:

- Habitat management through the provision of instream flows;
- Nonflow habitat development and maintenance;
- Native fish stocking;
- Management of nonnative species and sportfishing; and
- Research, data management and monitoring.

The program applies to the upper basin above Glen Canyon Dam, exclusive of the San Juan River Basin. Since adoption of the original agreement, a separate Recovery Implementation Program for the San Juan River Basin was instituted in 1992.

The intent of the Recovery Implementation Program (RIP) is to provide for the recovery and management of the identified species while continuing to allow for needed water development. It streamlines compliance with ESA requirements by making such compliance a function and responsibility of all the signatory parties. In Wyoming, the practical effect of the RIP is that it institutes a one-time charge for new depletions which is paid by the project proponent and is used, along with other funding sources, to implement the Program's projects. Originally established at ten dollars ($10) per acre-foot of new depletion, this charge is tied to consumer price indices, such that the fiscal year 2000 fee totals $14.36 per acre-foot.

Conservation Programs

Requests were made of the local USDA Natural Resources Conservation Service (NRCS) offices for a listing of lands currently enrolled in the various conservation programs under their direction. From these requests (not all counties responded) the current enrollments are provided.

<u>Conservation Reserve Program</u>

The Conservation Reserve Program (CRP) is administered by the USDA Farm Service Agency (FSA). This program offers rental payments, incentive payments, and cost-share assistance for certain conservation practices. This is a voluntary program for private land owners. The objective of the program is to improve wildlife habitat, water quality, and reduce wind and water erosion.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is administered by the NRCS. This program offers technical and financial assistance for restoring wetlands. This is a voluntary program for private land owners. The objective of the program in the Green River Basin is to diversify the types of wetlands and wildlife habitat in an area. Responding counties indicate that there exist 44 acres of land currently enrolled in this program in the Green River Basin.

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is administered by the NRCS. This program offers technical and financial assistance for projects which improve wildlife habitat. This is a voluntary program. Responding counties indicate there exist 240 acres of land currently enrolled in this program in the Green River Basin.

Among the various quantifiable uses, water consumed for environmental purposes in the Basin is estimated at about 2,000 acre-feet annually.

G. Evaporation Losses

The Green River Basin contains many large reservoirs used for various purposes including storage for irrigation, municipal, industrial, recreation, fish propagation and flood control uses, among others. These reservoirs help sustain what is otherwise arid to semi-arid land. The reservoirs are owned by various state, federal, industrial and private interests. For purposes of this plan, reservoirs larger than 1,000 acre-feet are focused upon although some that are smaller are also discussed. Figure II-9 (p.II-46) shows the locations of the major reservoirs in the Basin (not including all natural alpine or lowland lakes). The following lists reservoirs discussed in the Framework Water Plan (Wyoming Water Planning Program, 1970) and others that have been constructed, funded, or elevated in importance since.

Reservoir Name	Water Course	Maximum Storage, AF
Big Sandy	Big Sandy River	39,700
Black Joe Lake	Black Joe Creek	1,102
Boulder Lake	Boulder Creek	22,280
Bush Creek	Bush Creek	17,267
Bush Lake	Bush Creek	1,686
Divide Lake	Divide Creek	1,027
Eden	Big & Little Sandy Rivers	18,490*
Elkhorn	Little Sandy River	1,450
Flaming Gorge	Green River	3,789,000
Fontenelle	Green River	345,397
Fremont Lake	Pine Creek	30,899
Hay Reservoir	Red Creek	8,327
High Savery**	Savery Creek	22,400
Kemmerer No. 1	Hams Fork	1,058
McNinch No. 1	North Piney Creek	1,086
McNinch No. 2	North Piney Creek	198
Meeks Cabin	Blacks Fork	33,571
Middle Piney	Middle Piney Creek	4,201
New Fork Lake	West Fork New Fork River	20,340
Patterson Lake	Blacks Fork	1,237
Pacific No. 1	Pacific Creek	107
Pacific No. 2	Pacific Creek	1,394
Silver Lake	Silver Creek	933
Sixty-Seven	North Piney Creek	5,211
Stateline	East Fork Smiths Fork	14,000
Viva Naughton	Hams Fork	42,393
Willow Lake	Lake Creek	18,816

* currently reduced to 12,190 acre-feet because of stability concerns at higher water levels (Source: USBR DataWeb).

** not yet built; construction scheduled to be completed by 2003.

Evaporation

Evaporation from reservoirs constructed by man is a consumptive use associated with the beneficial use of water for other purposes and is counted as part of Wyoming's allocation under the Upper Colorado River Basin Compact. Traditionally, evaporation estimates are calculated by the Bureau of Reclamation and published in the "Consumptive Uses and Losses Report," (CULR) which is prepared every five years. In this report, the larger Bureau reservoirs in the Green and Colorado River Basins are classified as "main stem" reservoirs, the evaporation from which is tabulated separately from evaporation calculated for in-state reservoirs. Upper Colorado River Basin main stem reservoirs include Flaming Gorge, Blue Mesa, Morrow Point, Navajo, and Lake Powell.

For these main stem reservoirs, the aggregate evaporation counts against the various states' apportionments in the percentage allowed for each state by the Upper Colorado River Basin Compact, under *full development* (full use of allowed depletions). By this Compact Wyoming is allowed 14 percent of the total depletions allowed the States of the Upper Division (the Upper Basin States minus Arizona) by the Colorado River Compact; therefore at full development 14 percent of the Upper Basin mainstem evaporation is charged to Wyoming. Until then, Article V of the Upper Colorado River Basin Compact states that Wyoming's share will be calculated as the same fraction of main stem evaporation as Wyoming's consumptive use bears to the total consumptive use by states of the Upper Division.

For the years 1986-1990, Wyoming's fraction of the total consumptive use of the Upper Division states was 13.55 percent. In these same years, the average main stem evaporation was 653,000 acre-feet. Therefore, Wyoming's charge for main stem evaporation would be calculated as 88,500 acre-feet. This value, however, overstates the amount of Wyoming's main stem evaporation portion when the Basin sees full development. Under full development of all states' full Compact allotments, reservoir levels will average lower than they do now, due to increased drawdowns. Under this scenario the Bureau estimates a full development main stem evaporation of 520,000 acre-feet annually, from which Wyoming's 14 percent charge can be estimated to be 72,800 acre-feet annually.

Reservoirs not included in the main stem calculations are handled separately and the evaporation therefrom is charged totally to the state within which they reside. In Wyoming, the Bureau has identified 76 individual reservoirs in the Green River Basin for which evaporation is explicitly estimated. The net annual evaporation at each for the years 1986-1990, which is the last full five year period for which a final CULR is available, totals 26,500 acre-feet. The Bureau charges evaporation without regard to the uses for which a reservoir is permitted. That is, no separate accounting is kept for evaporation from irrigation, recreation, fish and wildlife or other pools. When evaporation losses for Muddy Creek wetlands and the future High Savery Reservoir are included, the total in-state evaporation estimate will total 27,700 acre-feet.

In the above numbers, Bureau evaporation values have been altered for New Fork, Boulder, Willow and Fremont Lakes. In the CULR supporting documentation for these lakes, all of which originally were natural lakes raised by dams added at their outlets, the evaporation calculated uses the full high water line areas in the computation. Because only that depletion caused by the actions of man should be counted against the Compact allocation, these estimates have been revised to reflect only the incremental evaporation loss due to the incremental surface area increase caused by raising the lakes. These changes result in a net reduction in evaporation loss of approximately 4,082 acre-feet, as described below:

HWL = High Water Level							
Reservoir	**Natural HWL Surface Area, ac**	**Enlarged HWL Surface Area, ac**	**Difference, acres**	**Net Evaporation, from CULR, in.**	**Actual Evaporation due to Man, AF**	**CULR Evap, as reported, AF**	**Difference, AF (savings)**
Boulder	1540	1676	136	22.3	253	1872	1619
Fremont	4888	5122	234	20	390	0	-390
New Fork	1296	1416	120	19	190	1345	1155
Willow	1800	1958	158	20	263	1961	1698
Total					***1096***	***5178***	***4082***

Two sources of data exist for estimating evaporative losses from reservoirs in Wyoming. These include the NOAA Technical Report NWS 33 and "Development of An Evaporation Map for The State Of Wyoming for Purposes of Estimating Evaporation And Evapotranspiration" by Larry E. Lewis (University of Wyoming M.S. Thesis, 1978). Because it is newer, of national scope, and used by the Bureau of Reclamation in its Consumptive Uses and Losses Report calculations, the NWS document is used for annual gross (free water surface) evaporation values herein. However, the NWS document does not give a monthly distribution of evaporation rates. For this, the distribution pattern for Pathfinder Dam in Lewis is used.

The CULR also estimates that approximately 5,100 acre-feet of evaporation may be apportioned to stock pond and livestock use. With this, the sum total of estimated current evaporation losses in the Basin total 121,300 acre-feet.

H. Water Quality Profile

The quality of water refers to its physical, chemical, radiological, biological and bacteriological properties. The concentration levels of various constituents within the water dictates the uses and potential uses of a water body. Quality of a water body can be impacted from the natural processes on the environment or from manmade actions. The success of a water development project is dependent upon the ability of the source to meet the water quality needs of the proposed use(s), as well as the propensity of the water development project to maintain the water quality.

Water Quality Standards

<u>Surface Water</u>

Pursuant to the Environmental Quality Act, the Water Quality Division (WQD) of the Wyoming Department of Environmental Quality developed and implemented surface water quality standards contained in Chapter 1, Wyoming Water Quality Rules and Regulations in 1974. Chapter 1 contains numerical and narrative standards to establish effluent limitations for those discharges requiring control via permits to discharge in the case of point sources and best management practices in the case of nonpoint sources.

Interstate Water Quality Standards

The Green River Basin and Little Snake River Basin are part of the Colorado River Basin. The Colorado River Basin Salinity Forum is an organization composed of water quality and water resource representatives of the states of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming with the responsibility for developing salinity standards and criteria for the waters of the Colorado River Basin. The basin-wide water quality standards for salinity consists of numeric water quality criteria at three lower Colorado River stations and a Plan of Implementation that describes the overall program. Under the federal Clean Water Act, the water quality standards for salinity are reviewed every three years and the Plan of Implementation is jointly revised and adjusted by the states and involved federal agencies.

Groundwater

In 1980, the WQD developed and implemented groundwater quality standards, contained in Chapter 8 of the Wyoming Water Quality Rules and Regulations, to protect existing and future groundwater uses. These regulations contain narrative and numerical standards used to classify ground waters of the State and provide criteria to determine acceptable concentration of discharges to ground water. These standards are also used to determine the degree of groundwater cleanup necessary to restore polluted ground water to pre-contamination use.

The WQD uses a two-tiered classification system. The first tier requires protection of existing uses regardless of water quality considerations. The second tier requires protection of all potential uses based on ambient groundwater quality. The highest standard of groundwater quality maintenance, given existing or potential uses, determines the governing tier. Maps showing groundwater classification are not available because the availability of well data and the diverse geology of the State prohibit accurate regional delineation of groundwater classification. Unlike surface water standards, groundwater classification is invoked only when a discharge to ground water has occurred or is proposed.

Basin Surface Water Quality

The Department of Environmental Quality has completed a stream classification for all surface water bodies in the project study area. The classification indicates whether a stream is currently supporting or has the potential to support the uses of that classification.

The streams in or near the mountains contain water quality rated as good. The water quality of these mountain streams deteriorates as it flows across the plains. The degradation of water quality is caused by both natural and manmade sources. The water quality of many streams originating in the plains is rated as fair to poor. The water quality of surface water bodies is obtained from U.S. Geological Survey reports of sampling accomplished from surface water stations. The systematic water quality sampling stations are shown in Figure II-10 (p.II-47).

The total dissolved solids concentrations at surface water stations in the project area are shown in Figure II-11 (p.II-48). All of the Green River Drainage above Fontenelle Reservoir and the Green River itself above Flaming Gorge Reservoir contain median dissolved solids concentrations of less than 500 mg/L. Flaming Gorge Reservoir has a median at or slightly above 500 mg/L. The Little Sandy River has a median less than 500 mg/L at the Sublette County line while monitoring stations downstream on the Big Sandy River show concentrations increasing up to about 3,000 mg/L before the confluence with the Green River. The Blacks Fork River Drainage and the Henrys Fork have median dissolved solids concentrations from 500 to 1,200 mg/L except for the Blacks Fork River near the Utah State line and the Hams Fork near Kemmerer which has medians below 500 mg/L. The Bitter Creek drainage has median dissolved solids concentrations ranging from approximately 750 to 2,900 mg/L with the exception of Killpecker Creek which has a median above 4,000mg/L. The Vermilion Creek Drainage has a median of approximately 1,000 mg/L.

All water bodies in the drainage system are within the acceptable water quality pH range of 6.5 to 9.0. However, pH readings for the Green River Basin indicate the water as being slightly alkaline. The temperature of water in the Green River Basin varies from 0 degrees Celsius in the winter to 25 degree Celsius in the summer.

The concentrations of total phosphorous in some streams frequently exceed the limits recommended to protect reservoirs and streams from nuisance growth of algae and other aquatic plants. Many of the reservoirs and lakes experience phytoplankton blooms in late summer and early fall.

The Department of Environmental Quality has recently increased surface water monitoring to address 1999 amendments to the Environmental Quality Act under W.S. 35-11-103 (c) & 302 (b) directed at "credible data." Part of this monitoring program will be directed at monitoring invertebrate communities in the Green River Basin. The invertebrate population surveys by USGS show water quality in the plains is not as good as water quality in mountain streams although overall basin invertebrate populations indicate good water quality. Invertebrates are important as a source of fish food for the high-quality fisheries in the Green River Basin.

Total Maximum Daily Loads/303 (D) List

All water bodies within the Green River Basin meet the existing classification uses with the exception of those water bodies contained in the 1998 303(d) list. Section 303(d) of the Clean Water Act (CWA) requires the State of Wyoming to identify water bodies that do not meet designated uses and are not expected to meet water quality standards after application of technology-based controls. It also requires the State to identify a priority ranking for each water quality limited segment and develop total maximum daily loads (TMDL) to restore each water body segment to pre-designated uses. The U.S. Environmental Protection Agency (EPA) requires each state to submit their lists of impaired or threatened water bodies every two years and is required to accomplish the work if a state fails to perform the required activities.

A simple explanation of TMDL is the ability of a water body to assimilate pollution and continue to meet its designated uses. A TMDL must be established for each pollutant which is a source of stream impairment. The TMDL process provides a way to document how water quality standards are being implemented. The process also provides the framework for thorough watershed planning for multiple sources or causes of impairment, provides states an opportunity to identify priorities based on risk and target TMDLs for completion, and promotes cost-effective solutions to pollution.

Salinity Control Projects in the Green River Basin

Water in the Colorado River and its tributaries has experienced an increase in levels of dissolved solids (or salts, hence the term *salinity*) almost since man's first use. The Basin largely lays on sediments derived from prehistoric seas, so that the soils naturally contain salts derived from that environment. Naturally occurring salinity comes from erosion of saline soils, saline springs and normal runoff.

The EPA promulgated a regulation in December 1974 which set forth a basinwide salinity control policy for the Colorado River Basin. The regulation specifically stated that salinity control was to be implemented while the Basin states continue to develop their Compact-apportioned water. This regulation also established a standards procedure, and required the Colorado River Basin states to adopt and submit for approval to the EPA water quality standards for salinity, including numeric criteria and a plan of implementation, consistent with the policy stated in the regulation.

The Basin states established the Colorado River Basin Salinity Control Forum in 1973. The Forum is composed of representatives from each of the seven Basin states appointed by the governors of the respective states. The Forum was created for interstate cooperation and to provide the states with the information necessary to comply with Section 303(a) and (b) of the Clean Water Act. The Salinity Control Act (Public Law 93-320), as amended by Public Laws 98-569, 104-20 and 104-127, authorizes the Secretaries of the U.S. Departments of Interior and Agriculture to enhance and protect the quality of water available in the Colorado River for use in the United States and the Republic of Mexico. Title II of the Act authorizes specific salinity control units and under this title was born the Colorado River Basin Salinity Control Program (CRBSCP) and the various components and successors thereof.

All salinity control projects have as their ultimate goal the maintenance of water quality so that numeric criteria (referred to as the 1972 levels) are not exceeded in the lower basin. These criteria are 723 mg/l below Hoover Dam, 747 mg/l below Parker Dam, and 879 mg/l at Imperial Dam. Title I of the Act authorizes construction of features to enable the United States to deliver water to Mexico having an average salinity no greater than

115 ppm (parts per million or mg/l) +/- 30 ppm over the annual average salinity of water at Imperial Dam. The Bureau of Reclamation, the U.S. Department of Agriculture and the Bureau of Land Management are undertaking ongoing salinity control programs.

The 1999 Review, *Water Quality Standards for Salinity, Colorado River System* outlines policies that affect existing and future development of water resources in Wyoming's Green River Basin.

Big Sandy Unit

In Wyoming, the only existing component of the Department of Agriculture's CRBSCP is the Big Sandy Unit. This unit, headquartered out of Farson, is reducing salinity derived from irrigation in the Farson and Eden areas. The USDA Big Sandy River Unit Plan was published in 1988 and implementation of the program at this unit began in 1989. The total salt load reduction for the Big Sandy Project, as outlined in the 1986 EIS and Definite Plan Report, is 52,900 tons of salt per year. Annual progress reports are prepared by the Farson Field Office of the USDA Natural Resources Conservation Service. A map of the Big Sandy Unit project area is given as Figure II-12 (p.II-49). Currently there are 18,370 acres in the project with water rights.

Briefly, salinity increases at the Big Sandy Unit are due to the deep percolation of irrigation water historically applied via flood irrigation. The Eden Valley Irrigation and Drainage District provides irrigation water to members from the Big Sandy and Eden Reservoirs. Excess flood irrigation results in excess soil moisture, movement of water vertically downward to a shale layer, and horizontal movement of water downgradient to various discharge points. Seepage points are evident near the confluence of Bone Draw and the Big Sandy River some 8.5 miles southwest of Farson. The mechanism for reducing salt loading at this project therefore is to reduce deep percolation by the application of more efficient on-farm water application techniques.

Improvements in irrigation practices on the unit include primarily the replacement of traditional uncontrolled flood irrigation methods with other practices that reduce deep percolation. Such practices include the installation of center pivot sprinkler systems, replacement of open conveyance ditches with gated pipe, and application of surge valves which alter the infiltration rate. Participation in all aspects of salinity control is voluntary on the part of private irrigators. Those who participate receive a cost share from the program such that their contribution is typically limited to approximately 30 percent of the cost of construction of the improvements.

As of February 2000, the following data describe implementation of salinity control measures at the Big Sandy Unit:

Project Goals and Achievements		
	Goal	**Achieved To Date**
Total Land in Contracts or Treated (acres)	15,700	10,293 (in contracts) 8,680 (treated)
Percent of Producers Benefiting (130 total producers in District)	85% (110)	58% (76)
Salt Reduction (tons/year)	52,900	32,534

West Green River Basin Watershed and Salinity Study Area

The NRCS is in the planning stages for a potential salinity reduction project for the "West Green River Basin Watershed and Salinity Study Area." This project will evaluate salinity reduction measures along the Hams Fork, Blacks Fork, Smith Fork and Henrys Fork drainages in southwest Wyoming and northeast Utah.

Originally applied for in 1990, this project has been recognized as having high potential for salinity reductions through the use of on-farm irrigation improvements. The project also has local support, evidenced at public meetings held at the time of the original application and reiterated at meetings held in the summer of 1999. The project has not been initiated to date due to changes in funding mechanisms over time and to the presence of other salinity control projects of higher priority. A monograph describing the history of this project has been prepared by the Wyoming State Engineer's Office.

Renewed need for an additional salinity control unit, in part due to the maturation of the Big Sandy Unit, resulted in the Colorado River Basin Salinity Control Forum recommending to the USDA in 1999 that it initiate planning for the West Green River project. Public meetings were held and considerable interest in the project was still in evidence. The NRCS has initiated a study which may lead to the preparation of a planning report and preparation of NEPA compliance documents. The completion of the Green River Basin Water Planning Study will provide data and information necessary for initiating this proposed salinity control project.

I. Basin Water Use Summary

Table II-7 lists a summary of the existing water uses (depletions) in the Basin, along with a comparison to the current estimate of water consumption allocated under Compacts.

Table II-7 Summary of Current Water Uses

	Normal	Wet	Dry
	(AF/Year)		
Municipal Use (includes City of Cheyenne at 14,400 AF/Yr.)	20,900	20,900	20,900
Industrial Use	66,500	66,500	66,500
Agricultural Use	401,000	432,300	375,400
Evaporation – Main Stem	88,500	88,500	88,500
Evaporation – In State	32,800	32,800	32,800
Recreation Use	Non-consumptive		
Environmental Use	2,000 +/-	2,000 +/-	2,000 +/-
TOTAL	611,700	643,000	586,100
Compact Allocation	833,000	833,000	833,000
Remaining Unused Compact Water	221,300	190,000	246,900

Figure II-1 Irrigated Lands by Sub-Basin

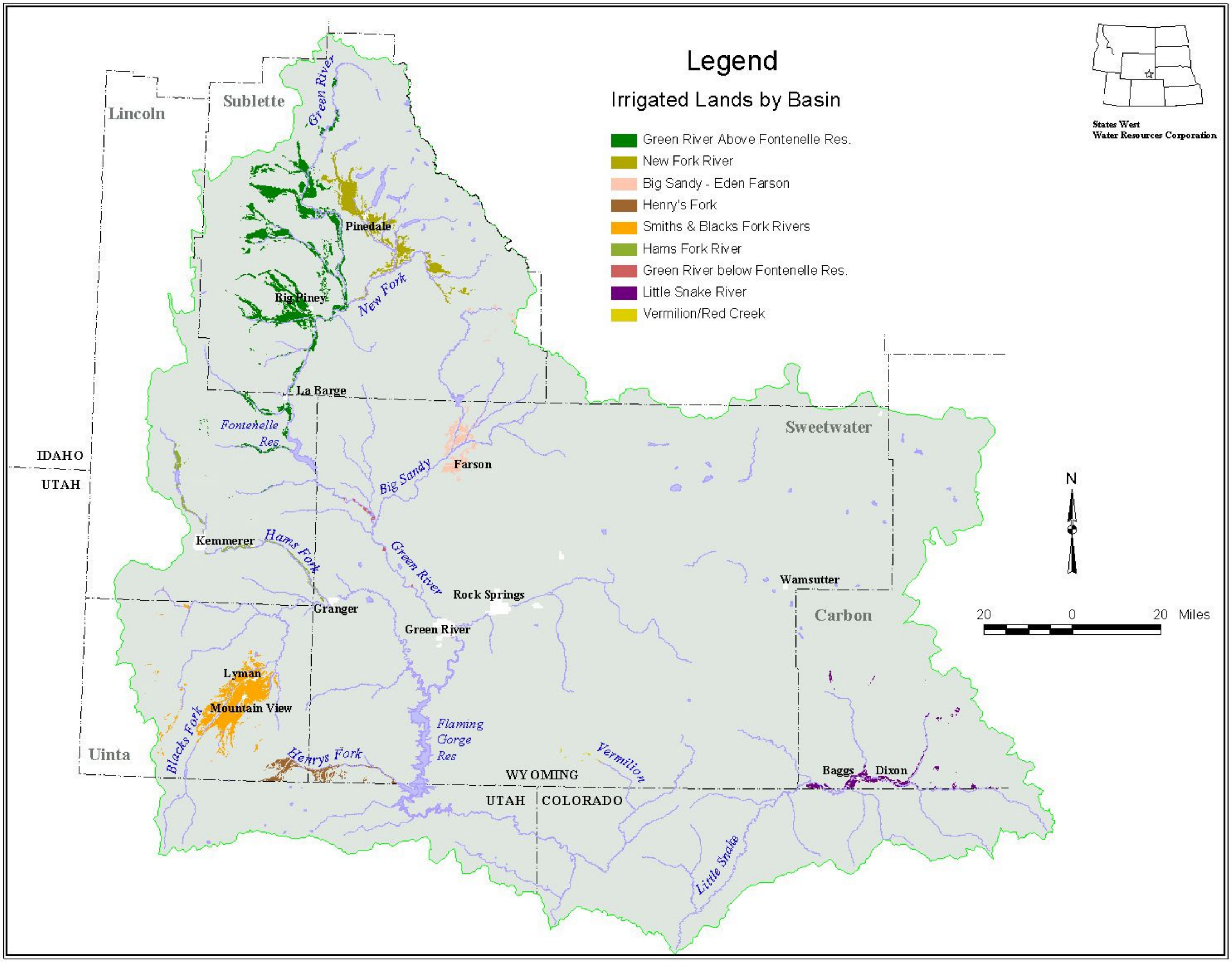


Figure II-2 Agricultural Depletion by Sub-Basin and Water Supply Scenario

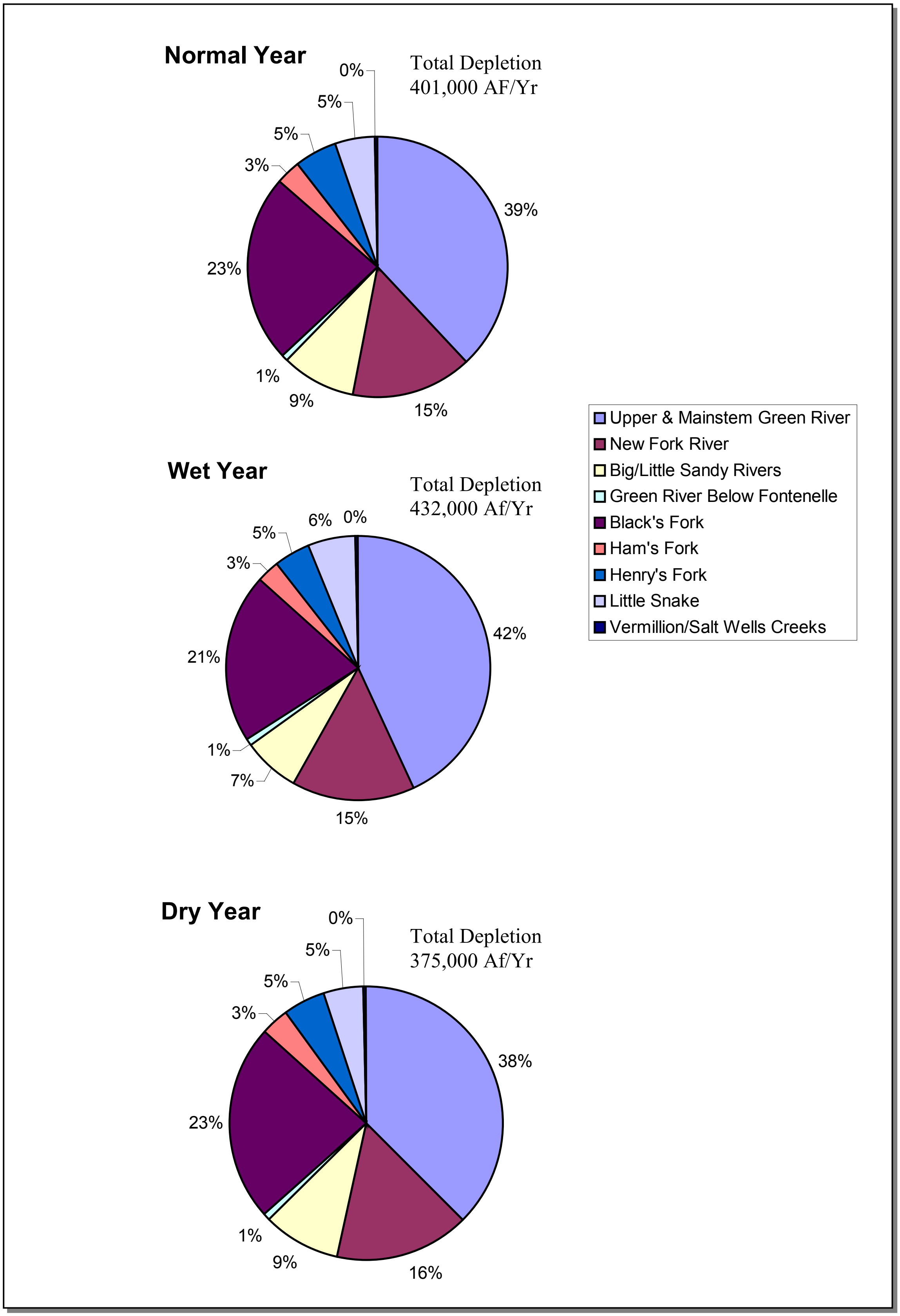
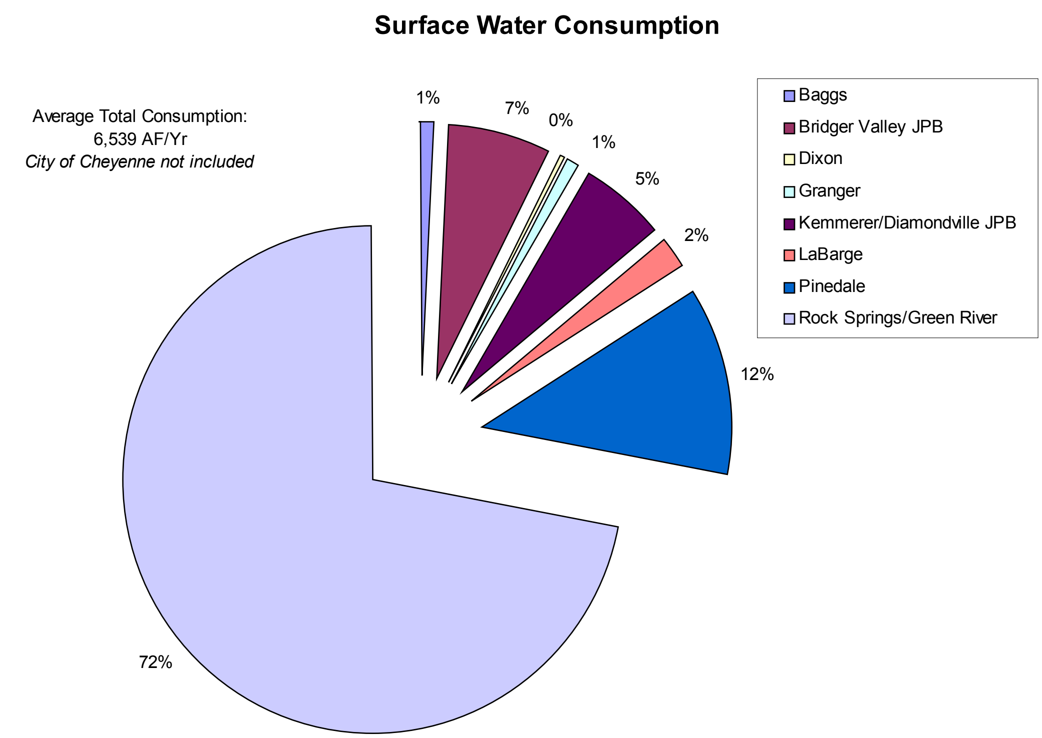


Figure II-3 Consumption by Municipality



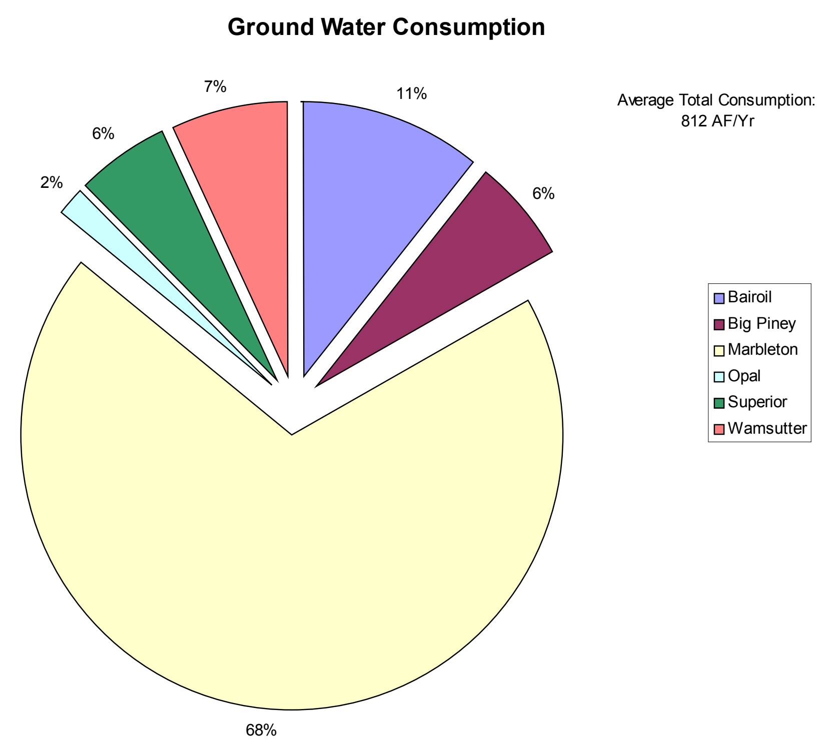


Figure II-4 Trout Stream Classification

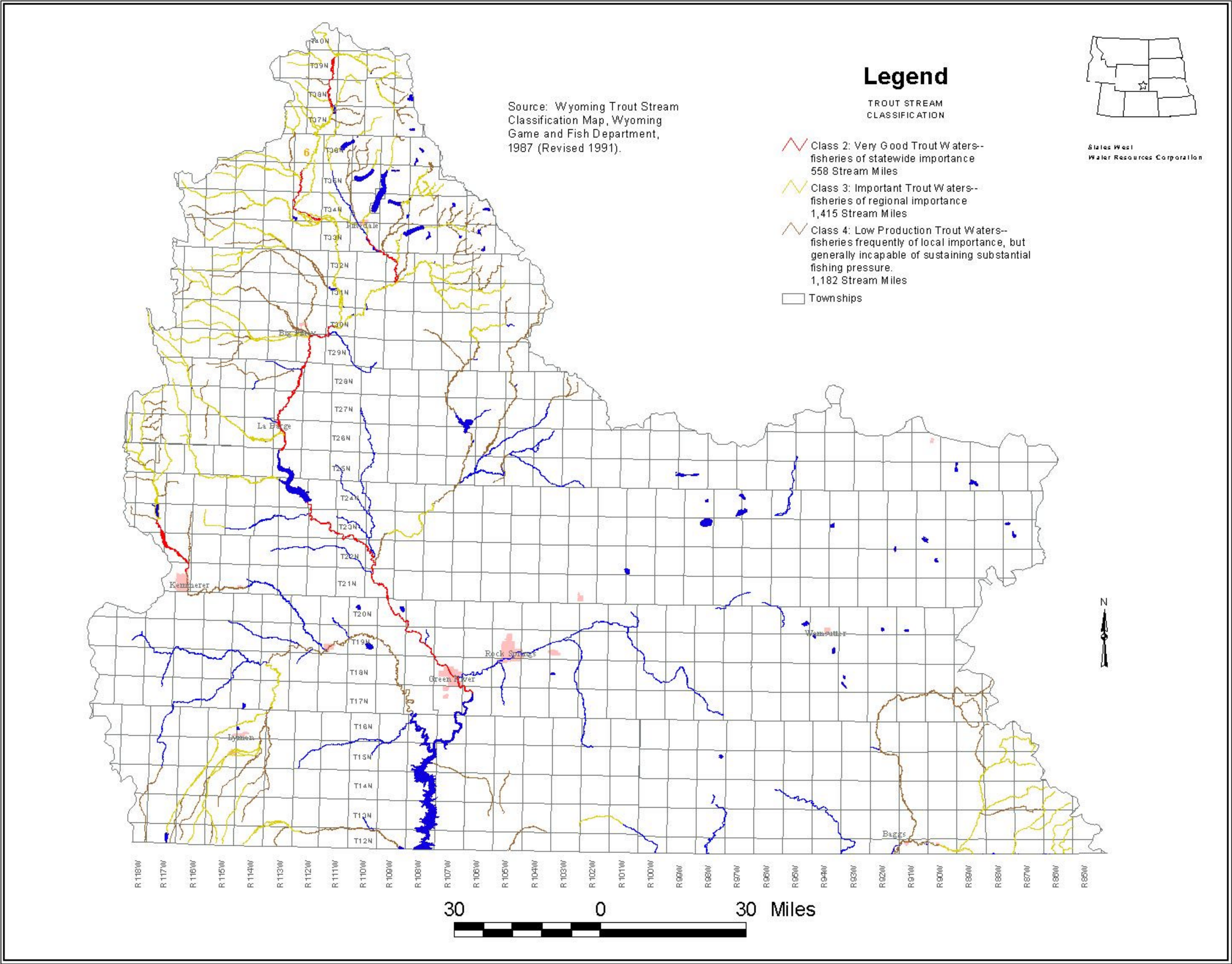


Figure II-5 Instream Flow Segments

SEQ	PRIORITY	STREAM	ISSUED	Length (mi)	CFS MIN	CFS MAX
6	01/10/89	Green R	01/07/92	9.84	101.0	350.0
7	02/02/89	Hams Fork		10.87	34.5	41.0
8	02/10/89	W Fk New Fork R	01/07/92	1.50	95.0	135.0
11	06/27/89	S Cottonwood or Lander Cr		2.93	17.0	
12	07/12/89	N Cottonwood Cr		8.90	16.0	35.0
16	12/17/90	LaBarge Cr		3.30	17.0	25.0
20	03/11/91	N Piney Cr		7.60	25.0	40.0
21	03/11/91	M Piney Cr		3.60	4.0	15.0
22	03/11/91	S Piney Cr		7.00	9.0	15.0
23	03/11/91	Fish Cr		4.20	6.0	10.0
25	06/21/91	N Fk Little Snake R		9.10	2.0	
26	06/21/91	Solomon Cr		3.20	1.0	
27	06/21/91	Rose Cr		1.90	0.8	
28	06/21/91	Granite Glch/Green Timber		1.70	1.0	
29	06/21/91	Harrison Cr		1.30	1.0	
30	06/21/91	Deadman Cr		0.80	2.0	
31	06/21/91	Ted Cr		0.30	1.0	
32	06/21/91	Third Cr		0.20	1.0	
33	06/21/91	W Fk N Fk Little Snake R		6.60	3.5	
34	06/21/91	Rabbit Cr		0.90	1.5	
42	01/21/93	E Fk Smiths Fk Cr		4.60	7.0	41.0
54	12/19/95	Dirtyman Fork Seg No. 1		0.90	0.5	1.4
57	12/19/95	Douglas Creek Seg No. 1		1.00	0.3	3.6
58	12/19/95	Deep Creek Seg No. 1		3.50	0.5	4.6
62	6/27/96	N.Fork Big Sandstone Ck Seg No. 1		0.70	1.6	19.0
63	6/27/96	Big Sandstone Ck Seg No. 1		3.00	3.5	22.0
65	6/27/96	Roaring Fork L. Snake R Seg No. 1		3.20	1.6	4.4
66	6/27/96	Mill Creek Seg No. 1		3.10	1.7	6.8
75	12/6/99	Little Gilbert Creek IF Segment No 1		1.70	0.2	3.5
76	12/6/99	Gilbert Creek IF Segment No 1		4.40	1.3	
77	12/6/99	Red Creek IF Segment No 1		5.70	0.7	4.8
78	12/6/99	Trout Creek IF Segment No 1		3.80	1.5	13.0
79	12/6/99	Sage Creek IF Segment No 1		3.60	1.1	3.9

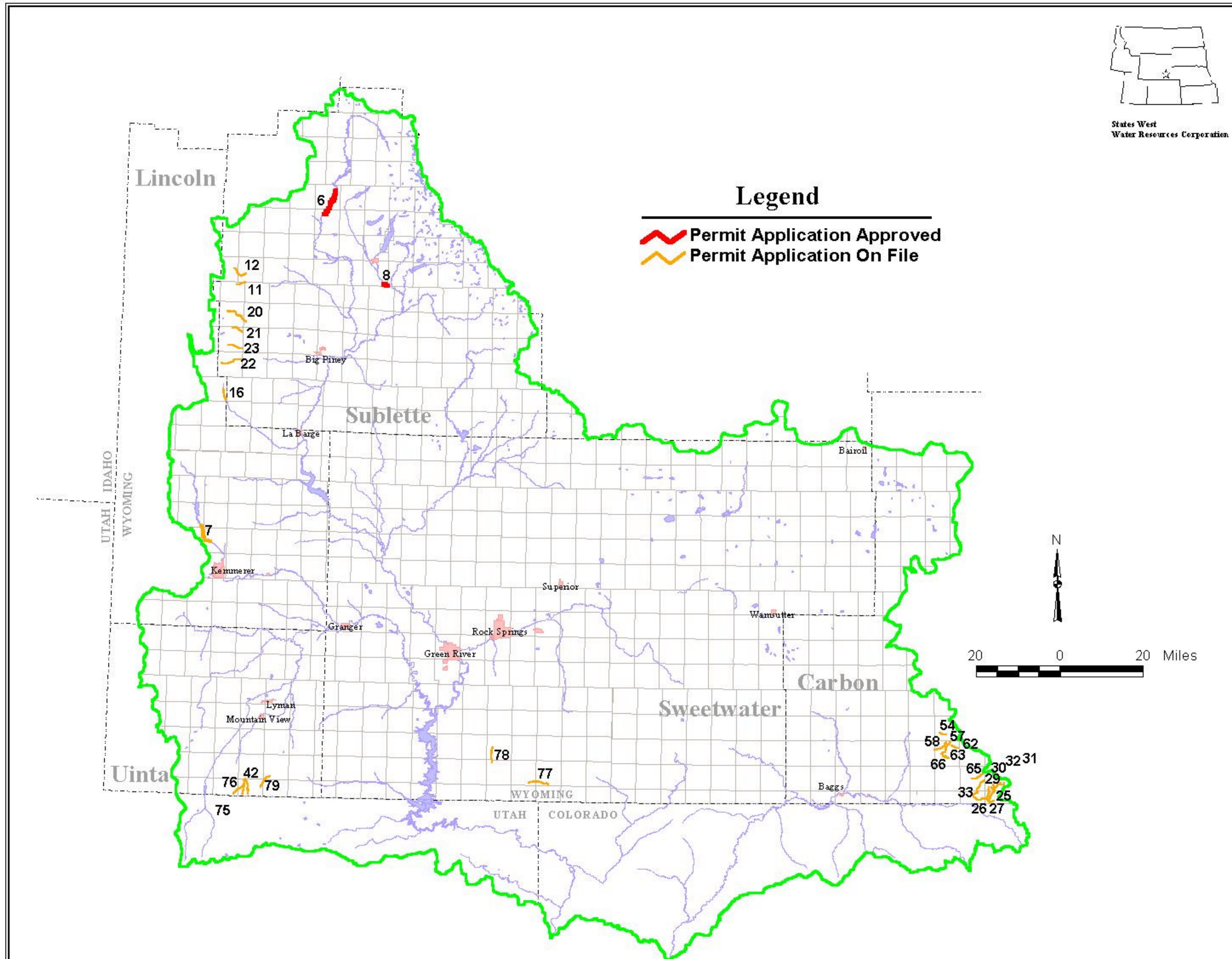


Figure II-6 WGF Recommended Water Levels

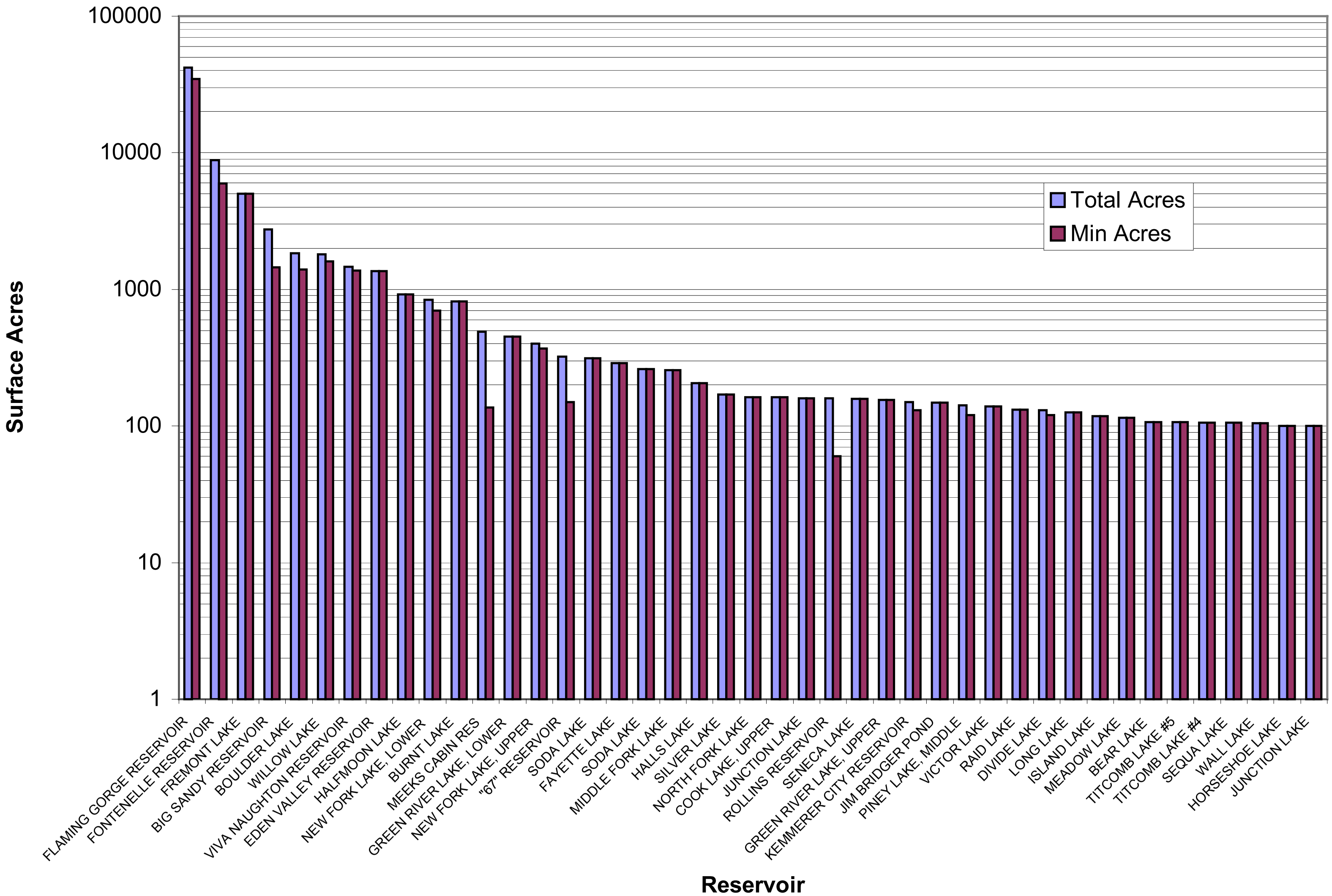


Figure II-7 WGF Recommended Maintenance Flows

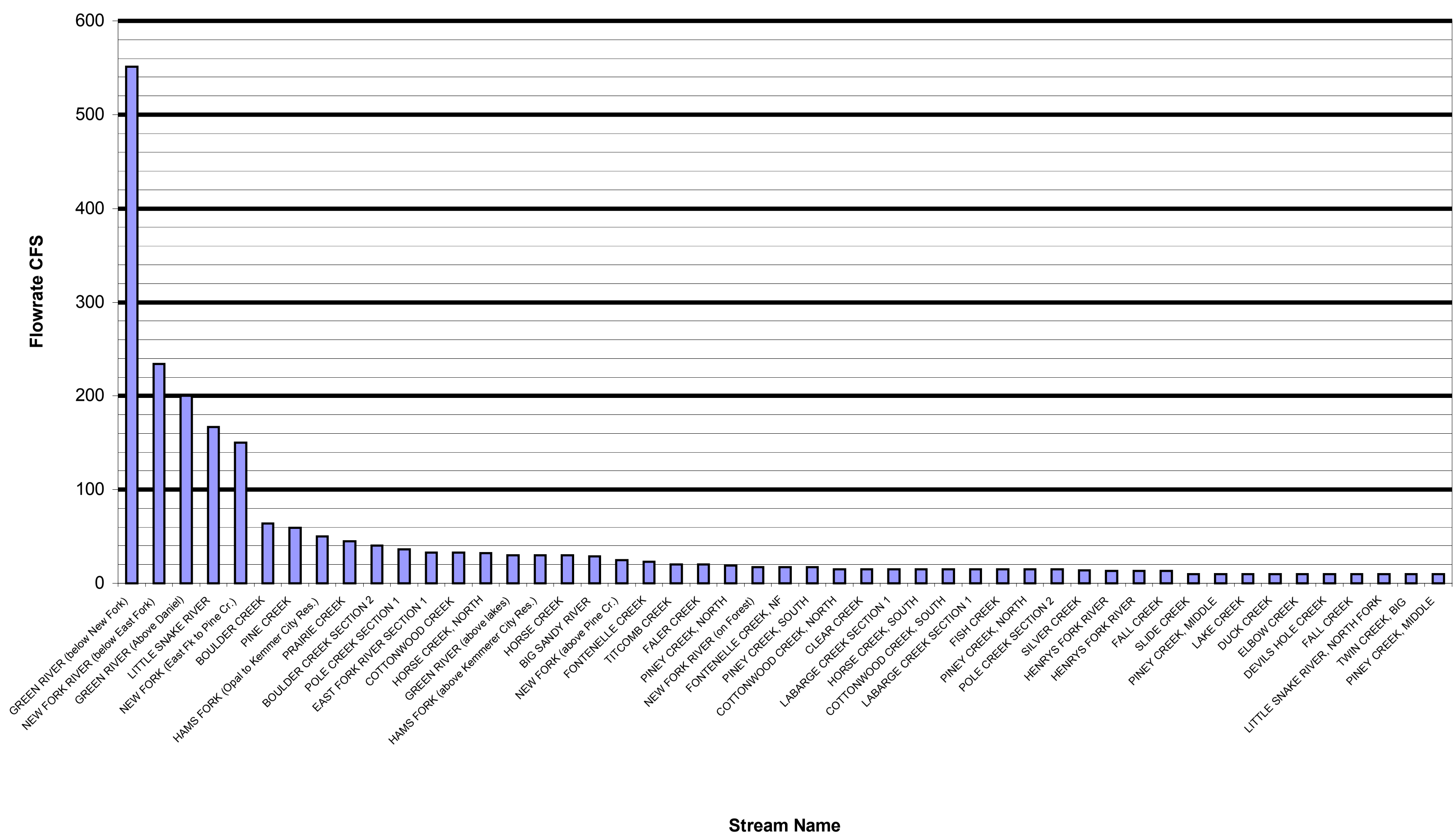
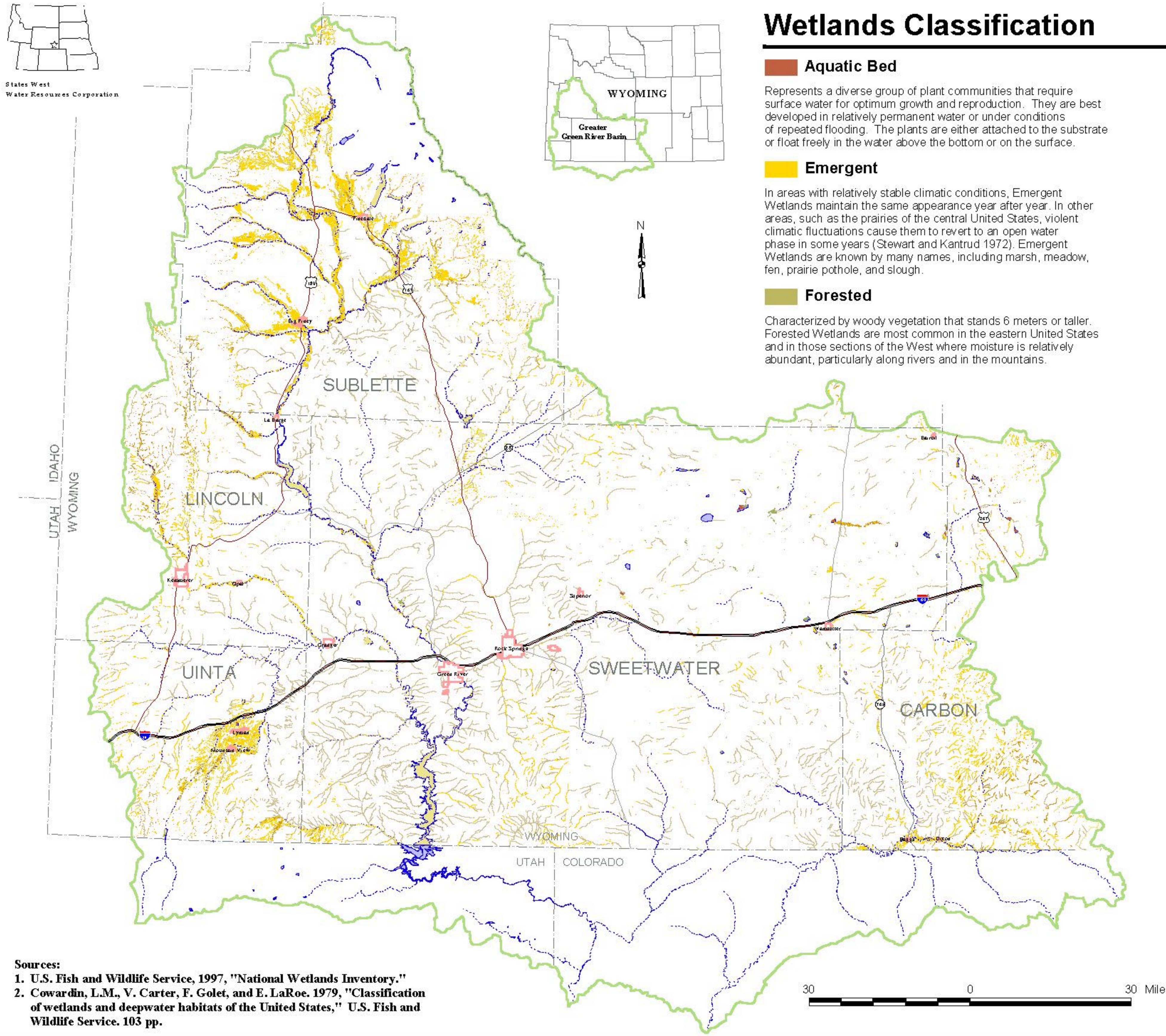


Figure II-8 National Wetlands Inventory Mapping



Wetlands Classification

Aquatic Bed

Represents a diverse group of plant communities that require surface water for optimum growth and reproduction. They are best developed in relatively permanent water or under conditions of repeated flooding. The plants are either attached to the substrate or float freely in the water above the bottom or on the surface.

Emergent

In areas with relatively stable climatic conditions, Emergent Wetlands maintain the same appearance year after year. In other areas, such as the prairies of the central United States, violent climatic fluctuations cause them to revert to an open water phase in some years (Stewart and Kantrud 1972). Emergent Wetlands are known by many names, including marsh, meadow, fen, prairie pothole, and slough.

Forested

Characterized by woody vegetation that stands 6 meters or taller. Forested Wetlands are most common in the eastern United States and in those sections of the West where moisture is relatively abundant, particularly along rivers and in the mountains.

Rock Bottom

Rock Bottoms are usually high-energy habitats with well aerated waters. Temperature, salinity, current, and light penetration are also important factors in determining the composition of the benthic community. Animals that live on the rocky surface are generally firmly attached by cement or by hooking or sucking devices. A few animals hide in rocky crevices and under rocks, some move rapidly enough to avoid being swept away, and others burrow into the finer substrates between boulders. Plants are also firmly attached (e.g., by hold fasts), and in the Riverine System both plants and animals are commonly streamlined or flattened in response to high water velocities.

Streambed

In most cases streambeds are not vegetated because of the scouring effect of moving water, however, they may be colonized by "pioneering" annuals or perennials during periods of low flow or they may have perennial emergents and shrubs that are too scattered to qualify the area for classification as Emergent Wetland or Scrub-Shrub Wetland.

Scrub - Shrub

Dominated by woody vegetation less than 6 m (20 feet) tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions.

Unconsolidated Bottom

Characterized by the lack of large stable surfaces for plant and animal attachment. They are usually found in areas with lower energy than Rock Bottoms, and may be very unstable. Exposure to wave and current action, temperature, salinity, and light penetration determines the composition and distribution of organisms.

Unconsolidated Shore

Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms such as beaches, bars, and flats, all of which are included in this Class.

Wetland Class	Irrigated Acres	% of Total Wetlands
Aquatic Bed	480	1.4
Emergent	136,500	62.3
Forested	630	0.4
Streambed	10	1.3
Scrub-Shrub	7,700	11.9
Unconsolidated Bottom	90	19.9
Unconsolidated Shore	90	2.8

Total Wetland Acres (Irrigated and Non-Irrigated) in Greater Green River Basin ~ 300,000

Note: Source Scale ranges from 1:20,000 to 1:134,000

Sources:

1. U.S. Fish and Wildlife Service, 1997, "National Wetlands Inventory."
2. Cowardin, L.M., V. Carter, F. Golet, and E. LaRoe. 1979, "Classification of wetlands and deepwater habitats of the United States," U.S. Fish and Wildlife Service. 103 pp.

Figure II-9 Major Reservoirs in the Greater Green River Basin

Reservoir Name	Water Course	Maximum Storage, AF
Big Sandy	Big Sandy River	39,700
Black Joe Lake	Black Joe Creek	1,102
Boulder Lake	Boulder Creek	22,280
Bush Creek	Bush Creek	17,267
Bush Lake	Bush Creek	1,686
Divide Lake	Divide Creek	1,027
Eden	Big & Little Sandy Rivers	18,490*
Elkhorn	Little Sandy River	1,450
Flaming Gorge	Green River	3,789,000
Fontenelle	Green River	345,397
Fremont Lake	Pine Creek	30,899
Hay Reservoir	Red Creek	8,327
High Savery**	Savery Creek	22,400
Kemmerer No. 1	Hams Fork	1,058
McNinch No. 1	North Piney Creek	1,086
McNinch No. 2	North Piney Creek	198
Meeks Cabin	Blacks Fork	33,571
Middle Piney	Middle Piney Creek	4,201
New Fork Lake	West Fork New Fork River	20,340
Patterson Lake	Blacks Fork	1,237
Pacific No. 1	Pacific Creek	107
Pacific No. 2	Pacific Creek	1,394
Silver Lake	Silver Creek	933
Sixty-Seven	North Piney Creek	5,211
Stateline	East Fork Smiths Fork	14,000
Viva Naughton	Hams Fork	42,393
Willow Lake	Lake Creek	18,816

* currently reduced to 12,190 acre-feet because of stability concerns at higher water levels (Source: USBR DataWeb)
** not yet built; construction scheduled to be completed by 2003.

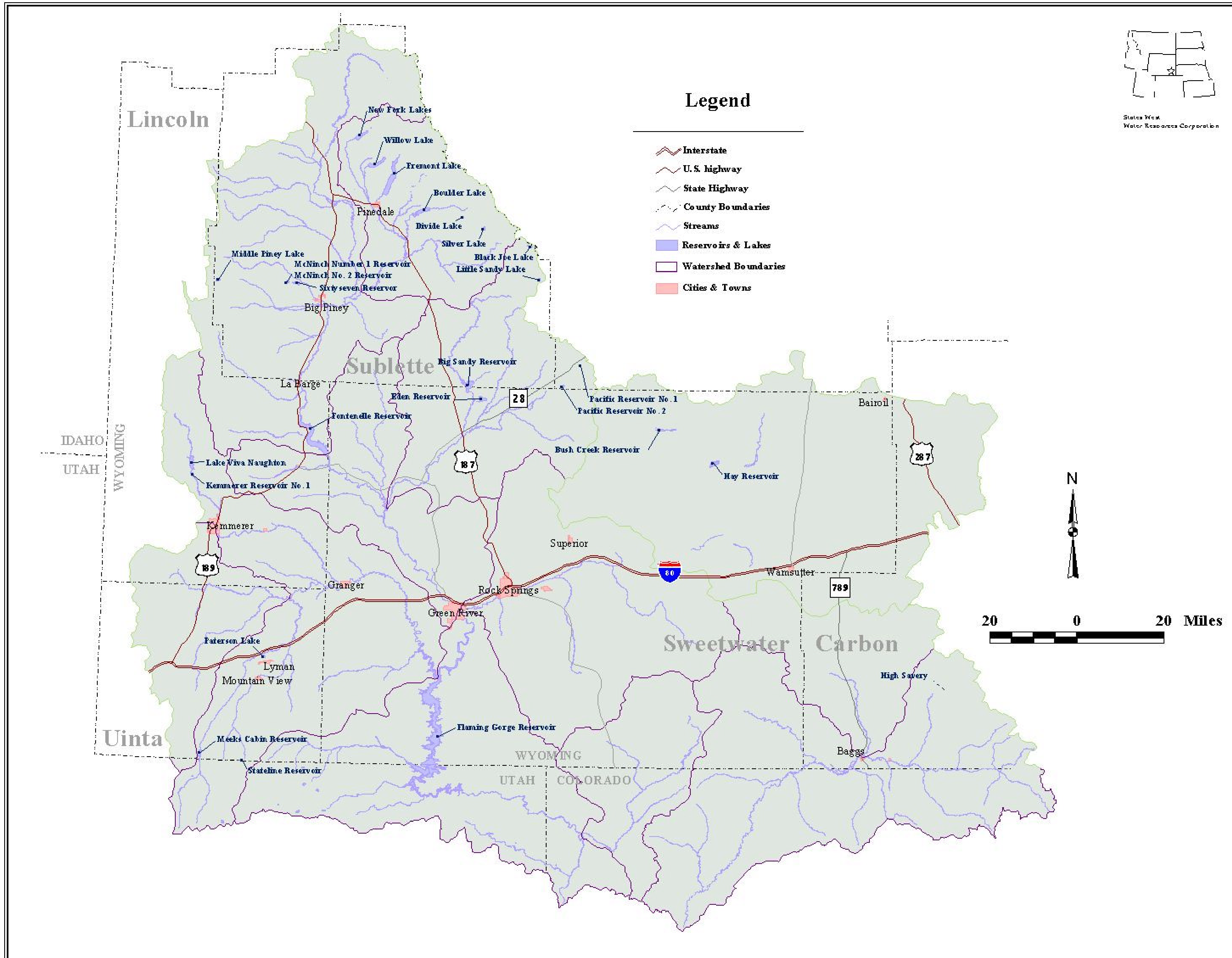


Figure II-10 Water Quality Sampling Stations

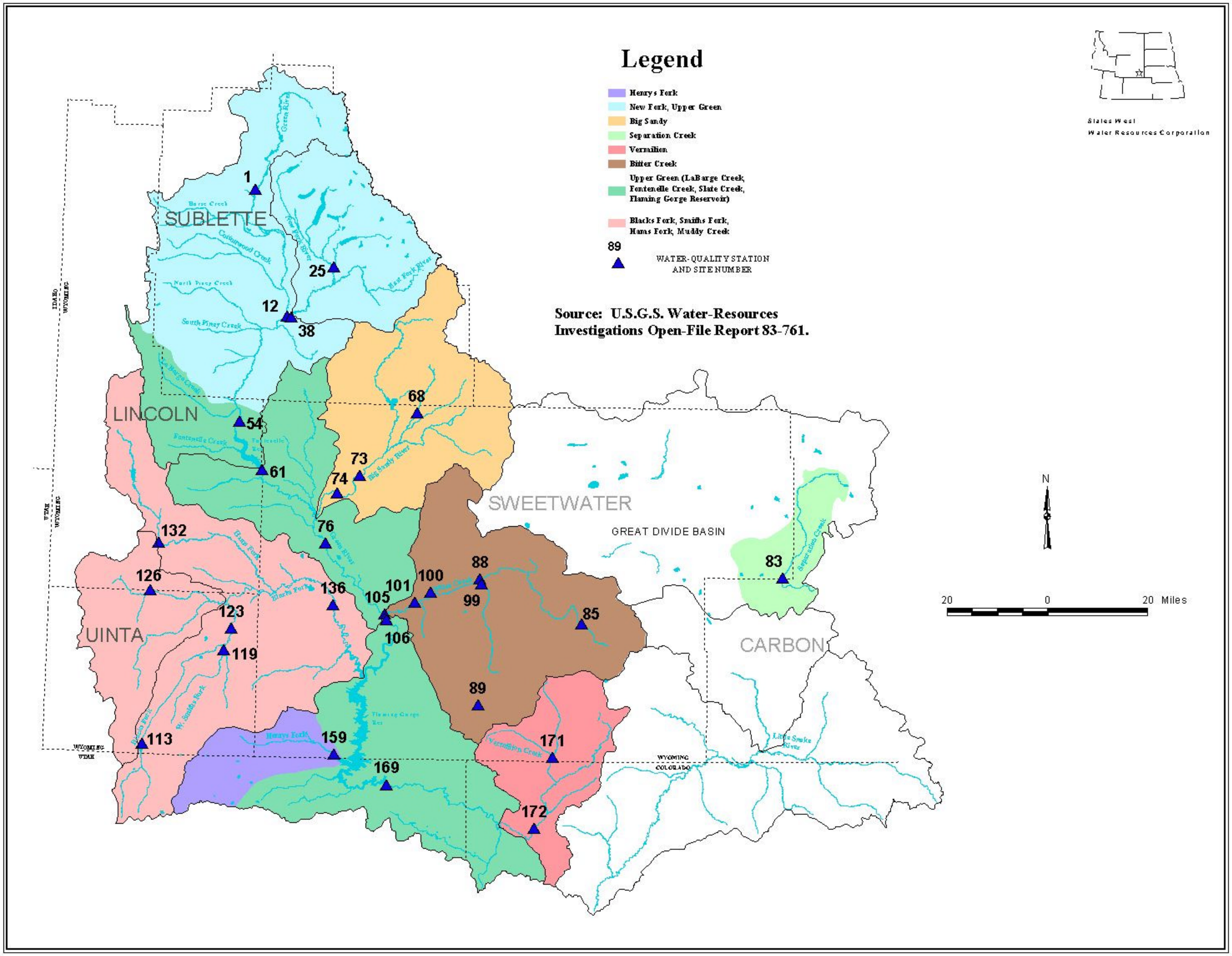
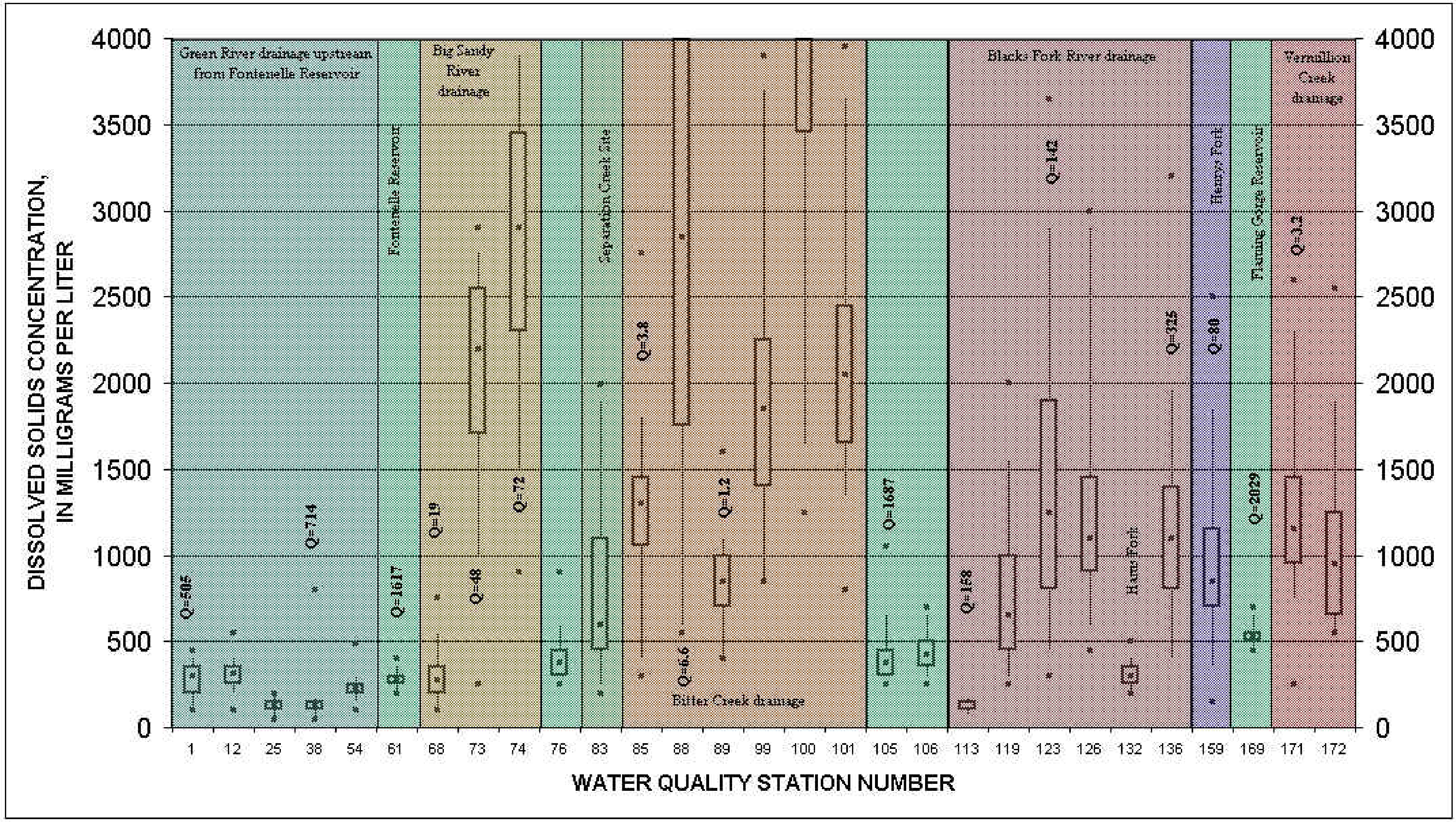
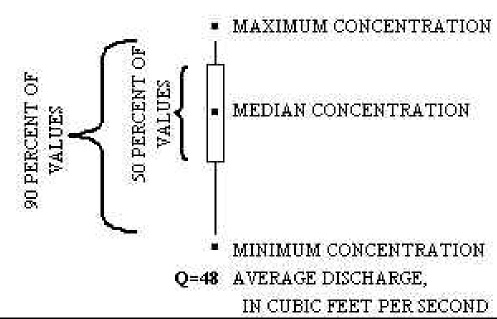


Figure II-11 Dissolved Solids Concentrations

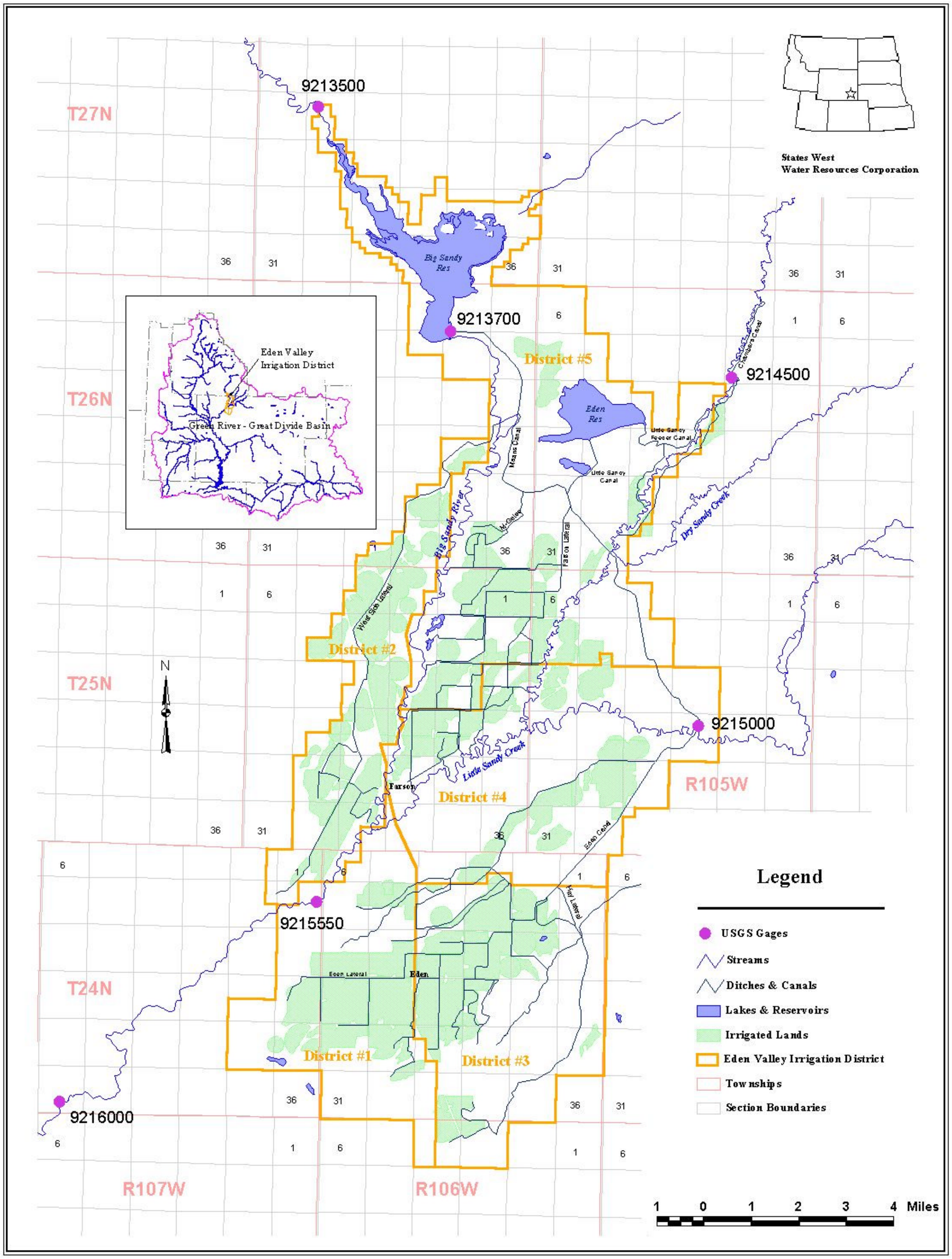


Stations from Figure II-10



Source: U.S.G.S. Water-Resources Investigations Open-File Report 83-761.

Figure II-12 Big Sandy Unit, Colorado River Salinity Control Program



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III Available Surface Water and Groundwater Determination

This chapter presents estimates of the availability of both surface water and ground water for future uses. Surface water availability is determined by naturally available water at various points in the Basin, minus existing uses. Groundwater availability is a function of hydrogeologic conditions and current use as described in existing reports and well records.

As with all chapters in this final plan report, explicit lists of references are not provided. Instead, all references to reports, documents, maps, and personal communications are maintained in the Technical Memoranda that were prepared during the current planning process. Should the reader desire to review a complete list of references for the information presented in this chapter, the following memoranda should be consulted:

- Surface Water Data Collection and Study Period Selection
- Surface Water Data Synthesis and Spreadsheet Model Development
- Available Surface Water Determination
- Available Groundwater Determination

A. Surface Water

The following subsections describe the analysis of existing surface water data, creation of a spreadsheet-based surface water model, and the use of model output to estimate water availability. It should be noted that the results described herein denote *physical availability over and above existing uses*, which is to be distinguished from legal or permitted availability. As projects are proposed in the future, surface water physical availability will be reduced due to environmental and administrative requirements. However, physical availability is the important first step in assessing the viability of any future project. Lack of physical availability of water for a project is an obvious fatal flaw for any water development.

Study Period Selection

Modeling the Green River Basin requires selection of an appropriate period of record for hydrologic analysis. The feasibility study determined that three 12-month spreadsheet models (one each representing normal-year, dry-year, and wet-year streamflows) constitute an appropriate level of detail for a modeling tool to verify existing uses and evaluate future surface water uses. Gage flows used in the three spreadsheets are to be typical of three different conditions and are to be developed by averaging observed streamflows that occurred during historical normal, wet, or dry years. Accordingly, the objectives of this task were to:

- determine the study period to be used to develop normal, wet, and dry year flow estimates for the Green River Basin spreadsheet models;
- select index gages and identify the historical normal, wet, and dry years out of the study period;
- assemble surface water information required for the spreadsheet.

Review of Reservoirs

Because a single annual cycle will be used to model each hydrologic condition, the normal data developed for input to the model is best derived from an operationally consistent time period. Construction or major modification of a reservoir during the study period would influence the downstream gages, hence reservoir history places significant control on selection of the study period. For this reason, major reservoirs (greater than 10,000 acre-feet) that have been constructed or modified during the past fifty years were reviewed to consider their influence on selection of the study period, with the following summarized results:

- Upper Green River - Construction of Fontenelle Reservoir was completed in April 1964 and the reservoir became fully functional during the late 1960's. During the late 1980's, Fontenelle Reservoir was drawn down for repair. This was taken into consideration during modeling, but not for selection of the proposed study period. Other major reservoirs (>10,000 ACRE-FEET) within the Upper Green River Basin, including Big Sandy, Eden, New Fork, Willow, Fremont and Boulder, were permitted and constructed prior to Fontenelle Reservoir. Fremont Lake was modified in the 1990's. As with the work on Fontenelle Reservoir, the impacts of this modification were taken into consideration during modeling.
- Blacks Fork River – Viva Naughton Reservoir was completed in 1960 and raised to its present level in 1967. Meeks Cabin Reservoir was completed in June 1971. Stateline Reservoir was completed in May 1979.
- Little Snake River –There are no major reservoirs currently in operation in this sub-basin. High Savery Dam, currently under design, can be included in future scenarios but does not influence choice of the historical study period.
- Henrys Fork River – There are no reservoirs within the Henrys Fork Basin of sufficient size to impact the study period selection.

Initial screening of current basin operations suggests that the study period begin in 1971 and end in 1998. By 1971, every major existing reservoir except for Stateline was in place. A twenty-year study period (1979-1998) consistent with the post-construction period of Stateline Reservoir may be too short for a quantitative analysis. An alternative is to select 1971 through 1998 and adjust the gage below Stateline Reservoir (09220000 – East Fork of Smith Fork below Robertson) from 1971 to 1979 to reflect representative operations of Stateline Reservoir, had it existed during this time period.

Review of Streamflow Records

Analysis of available streamflow data consisted of reviewing the USGS Water-Data Report, Volume 1, Surface Water. This report lists discontinued and active surface water discharge, water quality, sediment and biological stations. This information was supplemented by a review of data reported in the SEO Annual Hydrographers Report.

Review of Hydrologic Conditions

The reservoir history and availability of gage records led to a preliminary conclusion that 1971-1998 should serve as the study period. Ideally, the modeling study period should be representative of long-term hydrologic conditions in the Basin. To analyze this aspect of the proposed study period, annual flows were reviewed for the USGS gage 09188500 Green River at Warren Bridge near Daniel (Figure III-1 p.III-29). This gage has the longest record of the Green River Basin gages in Wyoming (1932-1998, excluding 1993), and as an indicator of long-term versus short-term statistics, is assumed applicable to the entire Basin. Characteristics of the long-term record and the proposed study period are tabulated below:

Characteristics of Annual Flow Series for 091885500 Green River at Warren Bridge near Daniel

	1932-1998 (excluding 1993) Record	1971-1998 (excluding 1993) Record
Mean (AF)	367,426	368,744
Standard Deviation	82,724	99,929
Three highest years	1986 / 1997 / 1971	1986 / 1997 / 1971
Three highest values (AF)	556,150 / 513,080 / 499,510	556,150 / 513,080 / 499,510
Three lowest years	1977 / 1934 /1992	1977 / 1992 / 1988
Three lowest values (AF)	203,260 / 208,720 / 213,910	203,260 / 213,910 / 232,330

The table shows that the means of the two periods are very similar. The standard deviation for the shorter period is higher due to the smaller sample size. Most notably, the short period includes the three highest annual flows of record, as well as two of the three driest. Furthermore, Figure III-1 shows that the most enduring drought of record (1987-1992) is captured in the model study period. Usually the concern is that the short period does not include extremes found in the longer record, but in this case, extremes of both wet and dry are clearly included in the proposed study period.

Selected Study Period

Based on available records, existence of reservoirs, and representativeness of the period, 1971-1998 is selected as the modeling study period. This 28-year period, on average, appears similar to long-term conditions, and includes wet, dry and normal years.

In this evaluation, traditional hydrologic techniques were used to estimate missing data. Typically, this means beginning by looking for a strong linear relationship between data that overlap in time at gages with similar hydrology. The basis of success for this procedure hinges on finding similarity in runoff characteristics between two streams, then using that similarity to "rebuild" missing data values at the deficient gage for the years when no overlap exists.

Index Gage Selection

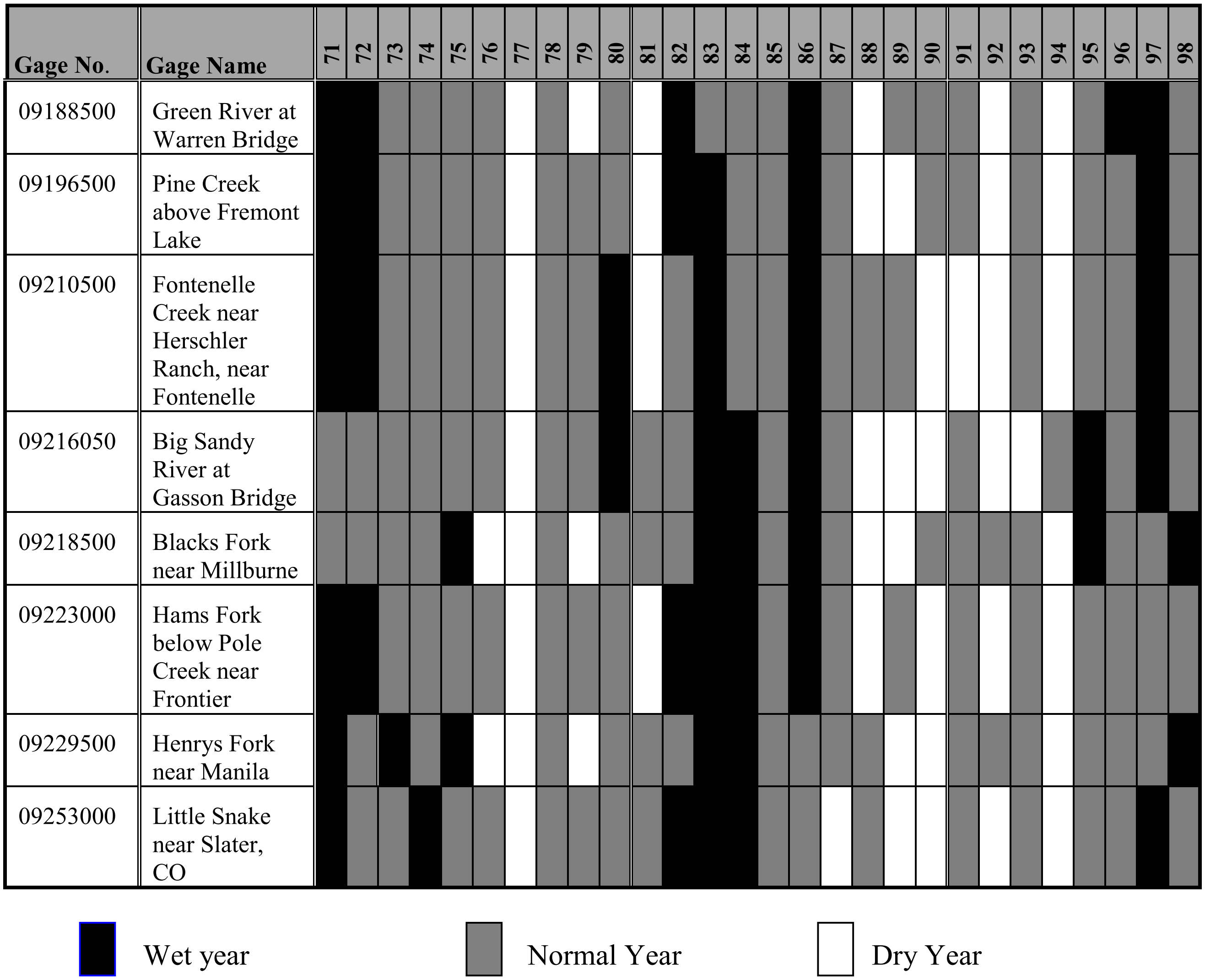
The objective of this work was to identify gages to be used to identify normal, wet and dry years by ranking of annual flows. The gages selected as representative for this purpose were termed "index" gages. Ultimately, the top (largest annual flow amounts) 20 percent of the years were designated as wet years, the middle 60 percent designated as normal years, and the 20 percent with lowest annual flows designated as dry years. The purpose of this subtask was to select gages for this ranking task that provided coverage of the Basin, were relatively free of influence by man's activities, and which were relatively complete during the study period. Gages in operation during most, if not all, of the study period were selected for evaluation as index gages. Additionally, if a gage was in operation seasonally throughout the study period, it was included in the evaluation as a potential index gage.

Results

The index gages and corresponding wet and dry year selection are shown in Table III-1. There was no exact duplication of hydrologic condition (i.e. wet and dry years did not correspond at all gages all the time), so all seven index gages were used, applied to geographical areas as follows (see Figure III-2 through Figure III-5 beginning on p.III-30):

- 09188500 Green River at Warren Bridge - Upper Green River mainstem and tributaries located upstream of this gage
- 09196500 Pine Creek above Fremont Lake - New Fork River and its tributaries
- 09210500 Fontenelle Creek near Herschler Ranch, near Fontenelle - Upper Green River tributaries that rise in the Wyoming Range
- 09216050 Big Sandy River at Gasson Bridge - Big Sandy River and its tributaries
- 09218500 Blacks Fork near Millburne - Blacks Fork, Smiths Fork and Henrys Fork and their tributaries
- 09223000 Hams Fork below Pole Creek near Frontier - Hams Fork and its tributaries.
- 09229500 Henrys Fork near Manila – Henrys Fork and its tributaries
- 09253000 Little Snake near Slater, CO - Little Snake River and its tributaries.

Table III-1 Wet, Normal and Dry Years for Green River Basin Index Gages



Spreadsheet Model Development

Spreadsheet models were developed to determine average monthly streamflow in the Basin during normal, wet, and dry years. The purpose of these models was to validate existing basin uses, assist in determining the timing and location of water available for future development, and help to assess impacts of future water supply alternatives.

This work resulted in the creation of twelve spreadsheet workbooks, one for each of the three hydrologic conditions and four distinct sub-basins:

- Upper Green River Basin from the Green River headwaters to Flaming Gorge
- Blacks Fork River Basin from the Blacks Fork and Smiths Fork headwaters to Flaming Gorge

- Henrys Fork River Basin from the Henrys Fork headwaters to Flaming Gorge, and
- Little Snake River Basin from the Little Snake headwaters to the USGS stream gaging station at Little Snake near Lily, CO.

The three workbooks for each sub-basin are yoked together with a simple menu-driven graphical user interface (GUI), effectively creating four sub-basin models.

Model Overview

For each Green River sub-basin, three models were developed, reflecting each of three hydrologic conditions: dry, normal, and wet year water supply. The spreadsheets each represent one calendar year of flows, on a monthly time step. The modelers relied on historical gage data from 1971 to 1998 to identify the hydrologic conditions for each year in the study period, as discussed in the technical memorandum for ***Surface Water Data Collection and Study Period Selection.*** Streamflow, consumptive use, diversions, irrigation returns, and reservoir conditions are the basic input data to the model. For all of these data, average values drawn from the dry, normal, or wet subset of the study period were computed for use in the spreadsheets. The models do not explicitly account for water rights, appropriations, or Compact allocations nor is the model operated based on these legal constraints. It is assumed that the historical data reflect effects of any limitations that may have been placed upon water users by water rights restrictions.

To mathematically represent each sub-basin system, the river system was divided into reaches based primarily upon the location of major tributary confluences. Each reach was then sub-divided by identifying a series of individual nodes representing diversions, reservoirs, tributary confluences, gages, or other significant water resources features. The resulting network is the simplification of the real world which the model represents. Figure III-2 through Figure III-5 (beginning on p. III-30) present node diagrams of the models developed for the Green River. Each numbered node in the figure is a node in the model.

Natural or virgin flow for each month is supplied to the model by specifying flow at every headwater node, and incremental stream gains and losses within each downstream reach. Where available, upper basin gages were selected as headwater nodes; in their absence, flow at the ungaged headwater point was estimated outside the spreadsheet.

Model output includes the diversion demand and simulated diversions at each of the diversion points, and streamflow at each of the Green River Basin nodes. Estimates of impacts associated with various water projects can be analyzed by changing input data, as decreases in available streamflow or as changes to diversions occur. New storage projects that alter the timing of streamflows or shortages may also be evaluated.

Model Development

The model was developed using Microsoft® Excel 97. The workbooks contain macros written in Microsoft® Excel Visual Basic programming language. The primary function of the macros is to facilitate navigation within the workbook. There are no macros that need to be executed to complete computation of any formulas or results. In other words, whenever a number is input into any cell anywhere in the workbook, the entire workbook is recalculated and updated automatically.

The delineation of a river basin by reaches and nodes is more an art than a science. The choice of nodes must consider the objectives of the study and the available data. It also must contain all the water resource features that govern the operation of the Basin. The analysis of results and their adequacy in addressing the objectives of the study are based on the input data and the configuration of the river basin by the computer model.

The following reaches and nodes are contained in each basin model:

- Upper Green River Basin: 24 reaches, 111 nodes
- Blacks Fork River Basin: 13 reaches, 44 nodes
- Henrys Fork River Basin: 7 reaches, 16 nodes
- Little Snake River Basin: 16 reaches, 48 nodes

<u>Gage Data</u>

Monthly stream gage data were obtained from the Wyoming Water Resources Data System (WRDS) for each of the stream gages used in the model. Linear regression techniques were used to estimate missing values for the many gages that had incomplete records. Once the gages were filled in for the study period, monthly values for Dry, Normal, and Wet conditions were averaged from the Dry, Normal, or Wet years of the study period.

Headwater inflow at several ungaged locations is also on the Gage Data worksheet. Different approaches to estimating the flow were used, depending on the complexity of the stream system and availability of data. The model uses estimated flow at ungaged headwater nodes as if they were gages.

<u>Diversion Data</u>

Diversions in the Green River Basin Models are attributable either to Municipal and Industrial use, or Agricultural use. The spreadsheets model only the consumptive portion of all municipal and industrial diversions. Agricultural diversion nodes fall into two categories: explicitly modeled structures, and aggregated structures. Explicitly modeled structures were structures for which adequate historical diversion records and a high confidence estimate of irrigated area were available. These structures generally served as indicators of irrigation practice throughout the Basin. Their entire diversions and resulting return flows were included in the model. For the aggregate structures, consumptive use only was modeled.

Data on the diversion data sheet are used to calculate ungaged reach gains and losses, and in some cases, inflow at ungaged headwater nodes. They are also used as the diversion demand in the Reach/Node worksheets.

Collection of agricultural diversion data is discussed in the technical memorandum ***Irrigation Diversion Operation and Description***. These data were reviewed and ditches that had sufficient diversion data for analysis of average dry, normal and wet year conditions were selected for explicit modeling. No attempts were made to fill missing records. Diversion data for explicitly modeled structures are the average dry, normal and wet year monthly diversions, calculated from the available records.

Diversions for aggregated structures were calculated as the product of estimated irrigated acreage, monthly consumptive irrigation requirement (CIR), and the fraction of the month in which diversion was practiced. Monthly CIR is estimated as a function of latitude, precipitation, and temperature, and therefore varies for dry, normal, and wet conditions.

Municipal and industrial diversions were taken from the technical memoranda ***Basin Water Use Profile – Municipal*** and ***Basin Water Use Profile – Industrial.*** Values reported in these memoranda represent the consumptive use portion of the municipal and industrial diversions. No attempts were made to estimate return flows. With the exception of the Cheyenne Stage I and II diversions discussed below, no attempts were made to develop dry, normal and wet year municipal and industrial diversions.

Surface Water Availability

The Green River Basin spreadsheet model is a tool for identifying flows that are available to Wyoming water users for future development, and evaluating yield and impacts of potential projects at a planning level. The purpose of this task is to analyze historical runs developed during spreadsheet calibration to determine location, quantity, and timing of available flows. The calibration spreadsheets represent conditions in the four sub-basins (Little Snake, Henrys Fork, Blacks Fork, and Green River) under current levels of development for three hydrologic conditions: Dry, Normal, and Wet year water supply. Background information on the spreadsheet model can be found in other technical memos prepared for this project.

Available Flow

Each basin model is divided into a number of reaches, each composed of several nodes, or water balance points. Reaches are typically defined by gages or confluences, and represent tributary basins or subsections of the mainstem. An output worksheet in each spreadsheet model summarizes monthly flow at the downstream end of each reach, and provides the basis of this analysis.

While simulated flow at the reach terminus indicates estimated amount of water physically present, it does not fully reflect availability. If a downstream diverter has historically diverted the entire stream at its headgate, the water supply at the upper point is not available for future development; it is already needed to meet current requirements.

Available Water Determination

To determine how much of the physical supply is actually available to future uses, "available water" at a reach terminus was defined as the minimum of the physically available flow at that point, and "available water" at all downstream reaches. Thus available flow must be defined first at the most downstream point, with upstream availability calculated in stream order. These calculations were made on a monthly basis, and annual availability was computed as the sum of monthly availabilities. Note that calculating annual availability in this way yields a different value than applying the same logic to annual flows for each reach. The summation of monthly values is more accurate, reflecting constraints of downstream use on a monthly basis.

Instream Flow Right Considerations

Instream flow rights exert a demand on the river but do not affect physical supply, because the water is not removed from the stream. Thus any reach terminus located immediately upstream of a reach that contained an instream flow right had to be handled specially. That is, available flow at the upstream reach terminus was determined as the minimum of physical flow at that point, and "available water" *less the instream flow requirement* at the downstream reach terminus.

The two permitted instream flow rights and 32 pending instream flow applications were reviewed for applicability of the special handling described above. (See the technical memorandum—*Instream Flows in Wyoming*) Except for one, all the instream flow rights are located high enough in the Basin that they have no upstream reach in the model. The exception is a 1.5-mile long reach of the West Fork New Fork River, under permit #7IF. Available water at the downstream terminus of Reach 8 in the Green River sub-basin spreadsheet was calculated taking the instream flow demand into consideration.

Compact Considerations

The spreadsheet models do not contain logic to simulate curtailment of water rights on a priority basis in order to meet the State's obligations under the Upper Colorado River Basin Compact (the Compact). The models were developed to portray historical use over the study period 1971-1998. Never during that time, nor since the Compact was ratified, have diversions been curtailed pursuant to Article IV of the Compact. While the principles under which such administration should be conducted are set forth in the Compact, actual details of their application have not been worked out by the Upper Colorado River Commission. Accordingly, simulation of curtailment was outside the scope of this effort. The models could be used, however, to test the impacts of a future downstream demand representing a Compact delivery obligation.

Article XI of the Compact addresses the division of the waters of the Little Snake River, whose tributaries lie on both sides of the Colorado-Wyoming state line, and whose mainstem crosses the boundary numerous times. The Compact identifies a point 100 feet below the mouth of Savery Creek, above which pre-Compact rights are not subject to calls emanating from below the point. This administrative nuance does not alter the definition of available flow for new or future uses above the so-called Compact point, however, since they could be regulated to satisfy senior pre-Compact priority date water rights below the Compact point. Post-Compact rights, including future uses, below the Compact point, "shall be administered on the basis of an interstate priority schedule prepared by the Commission in conformity with priority dates established by the laws of the respective States," according to Article XI. Therefore, calculation of "available water" in this part of the Basin must take into consideration the needs of downstream users in Colorado. To summarize, the method of calculating available water described above, when applied to the Little Snake including the Colorado sections of the river, is in accordance with Article XI of the Compact.

Results

Table III-2 through Table III-13 (beginning on p.III-11) summarize water availability for the four sub-basins and three hydrologic conditions on a monthly basis.

Figure III-6 through Figure III-8 (beginning on p. III-34) show the annual surface water physical availability for dry, wet, and normal year scenarios. The tabulations show annual available supply at the bottom of the system for each basin as follows:

Annual Available Supply—(acre-feet per year)			
Basin	**Dry Condition**	**Normal Condition**	**Wet Condition**
Little Snake	189,000	449,000	665,000
Henrys Fork	23,000	60,000	125,000
Blacks Fork	101,000	229,000	422,000
Green River	620,000	1,269,000	1,924,000

Table III-2 Available Flow for Little Snake River Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Fork Little Snake River	436.	431.	814.	3582.	7442.	3351.	492.	70.	268.	577.	508.	438.	18409.
2	Middle Fork Little Snake River	679.	668.	1457.	7156.	14971.	6257.	492.	70.	268.	969.	826.	684.	34497.
3	Little Snake River between Middle Fork and South Fork	1406.	1382.	3015.	14810.	31471.	14517.	492.	70.	268.	2006.	1710.	1416.	72563.
4	South Fork Little Snake River	257.	253.	552.	2711.	5617.	2195.	289.	70.	177.	367.	313.	259.	13060.
5	Little Snake River between South Fork and Roaring Fork Little Snake	1663.	1635.	3567.	17522.	37074.	16665.	492.	70.	268.	2373.	2023.	1675.	85027.
6	Little Snake River between Roaring Fork and Battle Creek	1663.	1635.	8814.	20377.	49645.	21963.	492.	70.	268.	2373.	2023.	1675.	111000.
7	Battle Creek	967.	993.	2070.	8308.	11464.	3490.	429.	70.	268.	1431.	1292.	1109.	31890.
8	Little Snake River between Battle Creek and Slater Creek	2378.	2628.	10885.	28685.	59873.	21963.	492.	70.	268.	3802.	3315.	2783.	137143.
9	Slater Creek	986.	1010.	2022.	7878.	10768.	3119.	318.	70.	268.	1422.	1291.	1119.	30272.
10	Little Snake River between Slater Creek and Savery Creek	2378.	3221.	12906.	36563.	59873.	21963.	492.	70.	268.	3802.	4406.	2966.	148911.
11	Savery Creek	1685.	1712.	3687.	12045.	11530.	3561.	376.	70.	268.	1870.	1937.	1873.	40615.
12	Little Snake River between Savery Creek and Willow Creek	2378.	3221.	16851.	49518.	59873.	21963.	492.	70.	268.	3802.	4406.	2966.	165810.
13	Willow Creek	134.	145.	264.	911.	973.	0.	112.	82.	94.	195.	181.	141.	3230.
14	Little Snake River between Willow Creek and Muddy Creek	3644.	4549.	16851.	49518.	59873.	22629.	911.	520.	436.	4425.	5454.	4256.	173067.
15	Muddy Creek	24.	18.	3150.	1560.	1025.	718.	238.	79.	113.	461.	195.	39.	7618.
16	Little Snake River between Muddy Creek and Little Snake River near Lily, CO gage	4472.	5365.	19805.	49918.	59873.	28243.	2878.	644.	436.	6087.	6620.	5095.	189437.

Table III-3 Available Flow for Little Snake River Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Fork Little Snake River	487.	482.	768.	3022.	14166.	12396.	2404.	629.	459.	605.	564.	518.	36500.
2	Middle Fork Little Snake River	784.	774.	1362.	6001.	28794.	24978.	4451.	1028.	617.	1027.	942.	848.	71608.
3	Little Snake River between Middle Fork and South Fork	1623.	1602.	2819.	12421.	60052.	52683.	10073.	1250.	617.	2126.	1950.	1754.	148971.
4	South Fork Little Snake River	297.	293.	516.	2274.	10847.	9329.	1569.	369.	260.	389.	357.	321.	26822.
5	Little Snake River between South Fork and Roaring Fork Little Snake	1921.	1895.	3335.	14694.	70882.	61977.	11611.	1250.	617.	2515.	2308.	2076.	175081.
6	Little Snake River between Roaring Fork and Battle Creek	1921.	3294.	11796.	17734.	75301.	75208.	17326.	1250.	617.	2515.	2308.	2076.	211345.
7	Battle Creek	1176.	1181.	2476.	8078.	28733.	19262.	3238.	667.	617.	1434.	1359.	1240.	69462.
8	Little Snake River between Battle Creek and Slater Creek	3097.	4475.	14272.	25812.	104034.	94470.	18004.	1250.	617.	3949.	3666.	3316.	276963.
9	Slater Creek	1182.	1187.	2403.	7663.	26974.	17985.	2961.	677.	617.	1424.	1354.	1242.	65669.
10	Little Snake River between Slater Creek and Savery Creek	4242.	5662.	16675.	33474.	130783.	111972.	18004.	1250.	617.	5275.	5020.	4558.	337534.
11	Savery Creek	2026.	1997.	3836.	12621.	34940.	22007.	3854.	1120.	617.	2073.	2101.	2048.	89242.
12	Little Snake River between Savery Creek and Willow Creek	4242.	7830.	20954.	47384.	160497.	120576.	18004.	1250.	617.	5275.	6134.	4616.	397380.
13	Willow Creek	180.	172.	449.	1289.	2226.	1688.	529.	218.	155.	216.	179.	177.	7478.
14	Little Snake River between Willow Creek and Muddy Creek	5619.	9450.	20954.	53211.	164610.	122097.	20187.	2176.	1117.	5459.	6569.	5945.	417394.
15	Muddy Creek	36.	30.	4765.	2871.	3080.	1180.	518.	132.	101.	400.	551.	109.	13772.
16	Little Snake River between Muddy Creek and Little Snake River near Lily, CO gage	6446.	10246.	24151.	56543.	168774.	127104.	25778.	4734.	2436.	7585.	8449.	6842.	449088.

Table III-4 Available Flow for Little Snake River Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Fork Little Snake River	657.	516.	818.	4190.	19920.	19855.	3965.	826.	680.	725.	631.	602.	53386.
2	Middle Fork Little Snake River	1133.	845.	1465.	8407.	40575.	40349.	7673.	1432.	1177.	1275.	1080.	1022.	106432.
3	Little Snake River between Middle Fork and South Fork	2346.	1748.	3032.	17398.	84631.	84445.	16714.	3115.	2448.	2639.	2234.	2115.	222864.
4	South Fork Little Snake River	429.	320.	555.	3185.	15284.	15160.	2794.	522.	445.	483.	409.	387.	39972.
5	Little Snake River between South Fork and Roaring Fork Little Snake	2775.	2068.	3587.	20583.	99890.	99571.	19478.	3631.	2889.	3122.	2643.	2502.	262740.
6	Little Snake River between Roaring Fork and Battle Creek	2775.	2068.	13301.	24224.	106992.	116728.	28786.	4799.	2889.	3122.	2643.	2502.	310829.
7	Battle Creek	1482.	1272.	2475.	8338.	38864.	27969.	5514.	1228.	1605.	2056.	1658.	1373.	93834.
8	Little Snake River between Battle Creek and Slater Creek	4257.	3341.	15776.	32561.	145856.	144697.	34300.	4799.	4366.	5178.	4302.	3874.	403306.
9	Slater Creek	1469.	1272.	2402.	7907.	36451.	26169.	5103.	1204.	1583.	2008.	1635.	1367.	88569.
10	Little Snake River between Slater Creek and Savery Creek	5726.	4613.	18178.	40468.	181986.	170408.	36612.	4799.	4366.	7186.	5937.	5241.	485518.
11	Savery Creek	2230.	2033.	3554.	12296.	48005.	33840.	6678.	1857.	2481.	2913.	2531.	2224.	120640.
12	Little Snake River between Savery Creek and Willow Creek	5974.	5981.	22288.	54464.	227350.	194067.	36612.	4799.	4366.	7857.	7732.	6221.	577710.
13	Willow Creek	255.	247.	558.	1700.	3139.	2611.	1004.	277.	266.	318.	250.	234.	10860.
14	Little Snake River between Willow Creek and Muddy Creek	7361.	7565.	23748.	63058.	240561.	211738.	42260.	5700.	5118.	8286.	8329.	7416.	631140.
15	Muddy Creek	36.	30.	4765.	2871.	3080.	1180.	518.	132.	101.	400.	551.	109.	13772.
16	Little Snake River between Muddy Creek and Little Snake River near Lily, CO gage	8177.	8373.	29155.	66325.	243117.	215717.	47410.	9398.	8268.	10852.	10250.	8303.	665345.

Table III-5 Available Flow for Henrys Fork Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Below Henrys Fork near Lonetree (09226000) and Beaver Creek	541.	473.	1000.	868.	1459.	3113.	236.	121.	59.	548.	626.	580.	9624.
2	Beaver Creek	965.	883.	1456.	1331.	1459.	3113.	236.	121.	59.	897.	1048.	1019.	12588.
3	Henrys Fork between Beaver Creek and Burnt Fork	1506.	1356.	2456.	1694.	1459.	3113.	236.	121.	59.	897.	1674.	1599.	16170.
4	Burnt Fork	464.	449.	495.	585.	2030.	2995.	581.	435.	298.	639.	562.	497.	10030.
5	Henrys Fork between Burnt Fork and Birch Creek	1970.	1805.	3049.	2279.	2030.	4004.	581.	435.	298.	1399.	2236.	2096.	22181.
6	Birch Creek	171.	166.	183.	216.	924.	1269.	419.	335.	199.	236.	207.	183.	4507.
7	Henrys Fork between Birch Creek and Henrys Fork near Manila, UT gage (09229500)	2116.	1939.	3231.	2336.	2030.	4004.	581.	435.	298.	1399.	2313.	2224.	22906.

Table III-6 Available Flow for Henrys Fork Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Below Henrys Fork near Lonetree (09226000) and Beaver Creek	844.	978.	1908.	1870.	6103.	9691.	3064.	1310.	588.	862.	1151.	937.	29305.
2	Beaver Creek	1259.	1388.	2378.	2418.	6439.	9150.	3620.	1397.	934.	1264.	1573.	1358.	33179.
3	Henrys Fork between Beaver Creek and Burnt Fork	2103.	2366.	4286.	4288.	8212.	12875.	3620.	1397.	1155.	2126.	2724.	2295.	47448.
4	Burnt Fork	532.	498.	551.	737.	3574.	6212.	2306.	1121.	612.	821.	654.	580.	18199.
5	Henrys Fork between Burnt Fork and Birch Creek	2636.	2942.	5179.	5112.	9994.	15472.	4599.	1954.	1666.	2841.	3379.	2874.	58645.
6	Birch Creek	196.	184.	203.	272.	1359.	2430.	959.	442.	259.	303.	241.	214.	7062.
7	Henrys Fork between Birch Creek and Henrys Fork near Manila, UT gage (09229500)	2817.	3126.	5382.	5384.	9994.	15472.	4599.	1954.	1666.	2841.	3547.	3042.	59821.

Table III-7 Available Flow for Henrys Fork Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Below Henrys Fork near Lonetree (09226000) and Beaver Creek	1343.	1012.	2405.	2735.	8557.	17944.	8138.	2781.	1586.	1904.	1583.	1244.	51233.
2	Beaver Creek	1760.	1420.	2886.	3668.	11101.	17226.	8992.	3459.	2162.	2301.	1999.	1653.	58627.
3	Henrys Fork between Beaver Creek and Burnt Fork	3103.	2433.	5291.	6403.	15595.	32654.	17072.	6193.	3742.	4205.	3582.	2897.	103169.
4	Burnt Fork	579.	535.	594.	925.	3501.	11749.	7713.	2618.	1359.	1000.	748.	644.	31963.
5	Henrys Fork between Burnt Fork and Birch Creek	3778.	3006.	6343.	7527.	18668.	38708.	20403.	7621.	4742.	5204.	4330.	3542.	123873.
6	Birch Creek	213.	197.	219.	341.	1328.	4454.	2940.	989.	511.	369.	276.	238.	12075.
7	Henrys Fork between Birch Creek and Henrys Fork near Manila, UT gage (09229500)	3992.	3204.	6562.	7868.	18668.	38708.	20403.	7621.	4742.	5286.	4554.	3750.	125358.

Table III-8 Available Flow for Blacks Fork Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Blacks Fork	775.	1134.	3462.	3180.	4225.	3718.	2049.	840.	644.	1200.	1050.	982.	23260.
2	West Fork of Smiths Fork	331.	506.	1554.	1387.	2696.	1269.	937.	113.	499.	372.	452.	420.	10534.
3	East Fork of Smiths Fork	478.	549.	1108.	1124.	4093.	4766.	2049.	840.	644.	793.	600.	529.	17573.
4	Smiths Fork	848.	1139.	3018.	2794.	4505.	4766.	2049.	840.	644.	1884.	1312.	1016.	24816.
5	Cottonwood Creek	140.	194.	541.	610.	1306.	77.	0.	0.	0.	195.	191.	171.	3424.
6	Smiths Fork between Cottonwood Creek and Blacks Fork River	988.	1332.	3559.	3404.	5811.	4766.	2049.	840.	644.	2079.	1503.	1186.	28163.
7	Blacks Fork between Smiths Fork and Muddy Creek	1763.	2466.	7021.	6584.	6888.	4766.	2049.	840.	644.	2481.	2433.	2168.	40105.
8	Little Muddy Creek	308.	487.	600.	971.	450.	167.	81.	139.	90.	241.	547.	479.	4560.
9	Upper Muddy Creek	0.	18.	343.	449.	224.	61.	0.	0.	0.	0.	139.	0.	1234.
10	Muddy Creek below Little Muddy Creek	308.	505.	943.	1420.	674.	228.	81.	139.	90.	241.	686.	479.	5794.
11	Blacks Fork between Muddy Creek and Hams Fork	2071.	3071.	10130.	10111.	10946.	5218.	2166.	979.	734.	2772.	3207.	2647.	54053.
12	Hams Fork River	961.	1069.	7058.	7762.	16874.	7251.	1578.	1448.	259.	1668.	1376.	1052.	48355.
13	Blacks Fork between Hams Fork and Blacks Fork nr Little America gage	2783.	4140.	17188.	17873.	27820.	12469.	3744.	1448.	832.	4439.	4583.	3622.	100941.

Table III-9 Available Flow for Blacks Fork Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Blacks Fork	1366.	1738.	5347.	7403.	10309.	11695.	4814.	2740.	2111.	1806.	1735.	1249.	52313.
2	West Fork of Smiths Fork	500.	714.	2286.	2584.	4749.	4078.	957.	377.	493.	436.	633.	461.	18266.
3	East Fork of Smiths Fork	704.	751.	1657.	1978.	4964.	10491.	5081.	2546.	1688.	1358.	884.	670.	32772.
4	Smiths Fork	1324.	1625.	4537.	5629.	9858.	11907.	6448.	3047.	2589.	2008.	1738.	1231.	51942.
5	Cottonwood Creek	192.	267.	771.	910.	2362.	1710.	109.	112.	64.	228.	281.	205.	7211.
6	Smiths Fork between Cottonwood Creek and Blacks Fork River	1516.	1892.	5308.	6538.	12219.	13617.	6557.	3047.	2589.	2236.	2020.	1436.	58976.
7	Blacks Fork between Smiths Fork and Muddy Creek	2882.	3630.	10655.	13941.	21421.	23177.	7073.	3047.	2589.	3188.	3755.	2684.	98042.
8	Little Muddy Creek	469.	718.	2168.	5353.	2348.	1257.	545.	314.	264.	342.	298.	404.	14479.
9	Upper Muddy Creek	111.	369.	2804.	2259.	6962.	2862.	400.	0.	0.	322.	412.	258.	16759.
10	Muddy Creek below Little Muddy Creek	580.	1086.	4972.	7612.	9310.	4119.	945.	314.	264.	664.	710.	663.	31238.
11	Blacks Fork between Muddy Creek and Hams Fork	3626.	4910.	16842.	22773.	33457.	27878.	8176.	3361.	2853.	3914.	4696.	3347.	135832.
12	Hams Fork River	2030.	1988.	6676.	12840.	28300.	24186.	7099.	3041.	3040.	1947.	2099.	1683.	94931.
13	Blacks Fork between Hams Fork and Blacks Fork nr Little America gage	5656.	6898.	23518.	35613.	61757.	52064.	15276.	5919.	4542.	5861.	6796.	4948.	228847.

Table III-10 Available Flow for Blacks Fork Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Blacks Fork	1773.	2157.	6603.	7841.	19093.	33210.	14269.	5162.	4046.	3109.	2517.	1755.	101534.
2	West Fork of Smiths Fork	649.	861.	2852.	2963.	6682.	9658.	4581.	1458.	1135.	890.	824.	600.	33152.
3	East Fork of Smiths Fork	849.	898.	1975.	2201.	6335.	18716.	12871.	4720.	3451.	1888.	1319.	882.	56104.
4	Smiths Fork	1654.	1964.	5553.	6185.	15240.	29056.	18554.	8654.	6329.	3775.	2693.	1639.	101297.
5	Cottonwood Creek	289.	346.	1009.	1081.	2367.	4688.	2107.	693.	563.	465.	427.	286.	14322.
6	Smiths Fork between Cottonwood Creek and Blacks Fork River	1943.	2310.	6562.	7266.	17607.	33744.	20661.	9347.	6892.	4240.	3120.	1926.	115619.
7	Blacks Fork between Smiths Fork and Muddy Creek	3717.	4467.	13164.	15107.	36700.	66954.	30869.	9998.	7379.	6365.	5531.	3680.	203932.
8	Little Muddy Creek	469.	718.	2168.	5353.	2348.	1257.	545.	314.	264.	342.	298.	404.	14479.
9	Upper Muddy Creek	111.	369.	2804.	2259.	6962.	2862.	400.	0.	0.	322.	412.	258.	16759.
10	Muddy Creek below Little Muddy Creek	580.	1086.	4972.	7612.	9310.	4119.	945.	314.	264.	664.	710.	663.	31238.
11	Blacks Fork between Muddy Creek and Hams Fork	4296.	5554.	18704.	22719.	46010.	77087.	33989.	11437.	8803.	7481.	6717.	4372.	247168.
12	Hams Fork River	4065.	5605.	8788.	14857.	46235.	62688.	21846.	6865.	5462.	3104.	3411.	2892.	185820.
13	Blacks Fork between Hams Fork and Blacks Fork nr Little America gage	7226.	9062.	27492.	32467.	89150.	139775.	55835.	18302.	14265.	10585.	10128.	7264.	421550.

Table III-11 Available Flow for Green River Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Green River above Warren Bridge	5935.	5567.	6802.	17403.	44939.	58043.	28074.	15919.	12146.	10460.	6890.	6658.	218836.
2	Beaver Creek	335.	305.	639.	2261.	1777.	870.	42.	39.	201.	277.	382.	359.	7487.
3	Green River between Beaver Creek and Horse Creek	6332.	5956.	7728.	19757.	44939.	58043.	28074.	15919.	12146.	10816.	7429.	7095.	224233.
4	Horse Creek	784.	899.	2417.	2513.	5072.	4289.	2453.	1634.	490.	1113.	1525.	916.	24105.
5	Green River between Horse Creek and Cottonwood Creek	7116.	6855.	10145.	22269.	48757.	58043.	28074.	15919.	12337.	11929.	8954.	8011.	238409.
6	Cottonwood Creek	856.	1012.	2842.	2638.	1597.	0.	1332.	525.	171.	1381.	1846.	1072.	15271.
7	Green River between Cottonwood Creek and New Fork River	7972.	7867.	12987.	24907.	49791.	58043.	28074.	15919.	12374.	13311.	10799.	9083.	251126.
8	West Fork New Fork River above Pine Creek	0.	0.	0.	1854.	15535.	29488.	7479.	0.	0.	1679.	617.	0.	56652.
9	Pine Creek	4218.	3460.	4645.	7507.	24818.	39148.	18092.	7787.	5583.	7520.	6270.	5319.	134368.
10	Pole Creek	5090.	4216.	5560.	9478.	24818.	39148.	20696.	8080.	5583.	9537.	7830.	6327.	146362.
11	Boulder Creek	5500.	4624.	6136.	10629.	42618.	66935.	30185.	11231.	7712.	11707.	8723.	6869.	212870.
12	East Fork New Fork River	2957.	3196.	4336.	3941.	21509.	17287.	8446.	4899.	4237.	4259.	4270.	3342.	82678.
13	New Fork River below confluence of West and East Forks	10873.	10550.	14118.	15055.	56830.	66935.	44057.	20146.	15270.	18493.	16228.	12823.	301380.
14	Green River between New Fork River and Piney Creeks	18969.	18586.	27678.	40148.	57368.	66935.	52932.	35771.	27534.	31961.	27341.	22062.	427285.
15	North Piney Creek	1112.	1274.	3429.	1858.	785.	0.	2204.	1629.	193.	1800.	2305.	1324.	17913.
16	Middle Piney Creek	992.	1213.	3496.	1527.	561.	0.	3435.	2653.	299.	1393.	2138.	1188.	18895.
17	South Piney Creek	902.	1035.	2786.	2888.	2800.	1062.	1282.	1426.	408.	1282.	1756.	1055.	18684.
18	Green River between Piney Creeks and LaBarge Creek	21967.	22102.	37383.	46416.	57368.	66935.	52932.	41508.	28513.	36476.	33556.	25624.	470781.
19	LaBarge Creek	2404.	2298.	3595.	4096.	6916.	3872.	2936.	2193.	1950.	2772.	3082.	2759.	38874.
20	Green River between La Barge Creek and Fontenelle Reservoir	24372.	24400.	40602.	50512.	57368.	66935.	52932.	43942.	30622.	39311.	36667.	28393.	496055.
21	Fontenelle Creek	1347.	1297.	1890.	3470.	4231.	2939.	610.	565.	934.	1793.	1607.	1413.	22095.

Table III-11 Available Flow for Green River Basin and Dry Hydrologic Condition (continued)

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
22	Green River Between Fontenelle Reservoir and Big Sandy River	50627.	41291.	40602.	61966.	57368.	66935.	52932.	51463.	39138.	47695.	49963.	53297.	613277.
23	Big Sandy River below Farson gage and Green River	1550.	1415.	3170.	2687.	2178.	2582.	2928.	3037.	2950.	3112.	2677.	1892.	30177.
24	Green River between Big Sandy River and Green River near Green River gage	50627.	42740.	44590.	63005.	57368.	66935.	52932.	51463.	39138.	47695.	49963.	53297.	619753.

Table III-12 Available Flow for Green River Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Green River above Warren Bridge	6689.	6159.	7726.	16510.	59720.	98850.	80423.	29914.	17985.	14043.	9305.	7553.	354878.
2	Beaver Creek	676.	635.	894.	7554.	6966.	3053.	48.	135.	197.	562.	813.	710.	22243.
3	Green River between Beaver Creek and Horse Creek	7391.	6842.	8780.	24321.	64490.	98850.	80423.	29914.	17985.	14618.	10216.	8300.	372130.
4	Horse Creek	1051.	1101.	2107.	6460.	15209.	16446.	5603.	3742.	1179.	1512.	1826.	1158.	57393.
5	Green River between Horse Creek and Cottonwood Creek	8442.	7943.	10887.	30782.	78265.	112263.	82733.	31262.	18595.	16129.	12042.	9458.	418801.
6	Cottonwood Creek	1299.	1350.	2752.	8430.	9787.	9073.	6528.	3599.	1256.	2043.	2302.	1430.	49850.
7	Green River between Cottonwood Creek and New Fork River	9741.	9293.	13639.	39212.	87407.	119973.	87781.	33785.	19595.	18172.	14344.	10888.	463832.
8	West Fork New Fork River above Pine Creek	0.	0.	39.	5777.	21286.	57224.	24194.	7536.	2124.	3047.	954.	0.	122181.
9	Pine Creek	4803.	4577.	5880.	11430.	34534.	98862.	51498.	16933.	10158.	8888.	6607.	5377.	259547.
10	Pole Creek	6169.	5857.	7252.	14054.	34828.	99118.	60537.	19678.	10158.	9275.	8057.	6754.	281736.
11	Boulder Creek	7262.	6806.	8348.	16319.	59468.	164908.	86225.	27205.	15343.	13019.	9694.	8022.	422619.
12	East Fork New Fork River	3188.	3237.	4597.	7165.	32042.	46727.	20547.	7246.	5110.	7659.	6468.	4232.	148218.
13	New Fork River below confluence of West and East Forks	12790.	12531.	16639.	27633.	80235.	181813.	116202.	39376.	23239.	25771.	21068.	15347.	572643.
14	Green River between New Fork River and Piney Creeks	22585.	21920.	30597.	67358.	163844.	246144.	196206.	73300.	42759.	43969.	35609.	26307.	970598.
15	North Piney Creek	1098.	1239.	2534.	4341.	4520.	8033.	8791.	5483.	1269.	1739.	2139.	1280.	42466.
16	Middle Piney Creek	756.	957.	2268.	3711.	2335.	3786.	8835.	6373.	1487.	1017.	1714.	906.	34147.
17	South Piney Creek	1207.	1265.	2425.	7428.	12187.	10004.	464.	2233.	254.	1736.	2100.	1331.	42636.
18	Green River between Piney Creeks and LaBarge Creek	25639.	25376.	37819.	82833.	163844.	246144.	196206.	88331.	46539.	48767.	41698.	29860.	1033054.
19	LaBarge Creek	3215.	3033.	4085.	7269.	13312.	9118.	6639.	4401.	3885.	4646.	4193.	3518.	67314.
20	Green River between La Barge Creek and Fontenelle Reservoir	28854.	28409.	41903.	90102.	163844.	246144.	196206.	93447.	51012.	53667.	45962.	33405.	1072953.
21	Fontenelle Creek	1643.	1537.	2084.	5729.	12740.	12740.	4518.	2062.	1765.	2086.	1925.	1751.	50583.

Table III-12 Available Flow for Green River Basin and Normal Hydrologic Condition (continued)

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
22	Green River Between Fontenelle Reservoir and Big Sandy River	56650.	56499.	65350.	95495.	163844.	246144.	196206.	105392.	61884.	59142.	55769.	54215.	1216590.
23	Big Sandy River below Farson gage and Green River	1980.	2034.	4730.	6111.	4234.	6747.	6033.	5123.	4542.	3822.	3171.	2484.	51011.
24	Green River between Big Sandy River and Green River near Green River gage	58891.	59204.	73947.	99523.	163844.	251899.	214389.	112609.	66028.	59142.	55769.	54255.	1269499.

Table III-13 Available Flow for Green River Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Green River above Warren Bridge	7632.	6557.	8645.	16682.	82151.	179777.	94945.	42993.	23604.	11568.	9572.	9557.	493682.
2	Beaver Creek	723.	646.	877.	9492.	16816.	7275.	1228.	638.	348.	702.	913.	810.	40467.
3	Green River between Beaver Creek and Horse Creek	8418.	7285.	9937.	26213.	95856.	183091.	94945.	42993.	23910.	12427.	10633.	10403.	526110.
4	Horse Creek	1248.	1322.	3731.	6418.	22623.	31328.	10557.	6290.	3109.	2571.	2328.	1132.	92658.
5	Green River between Horse Creek and Cottonwood Creek	9667.	8607.	13667.	32631.	116449.	211532.	102314.	46854.	26812.	14998.	12961.	11535.	608028.
6	Cottonwood Creek	1294.	1442.	4508.	12234.	19033.	24265.	16016.	7683.	3902.	2985.	2790.	1284.	97436.
7	Green River between Cottonwood Creek and New Fork River	10961.	10048.	18176.	44866.	134569.	234500.	116898.	53446.	30622.	17982.	15751.	12819.	700637.
8	West Fork New Fork River above Pine Creek	376.	537.	1451.	9676.	21227.	73459.	46053.	13197.	7022.	5134.	3492.	1092.	182717.
9	Pine Creek	6218.	5813.	7292.	15574.	37566.	124681.	91686.	28635.	15055.	10975.	9145.	6934.	359575.
10	Pole Creek	8165.	7561.	8848.	18843.	43672.	126058.	108776.	35334.	15055.	12209.	10504.	8768.	403794.
11	Boulder Creek	9448.	9164.	10948.	22327.	69011.	206329.	154498.	49157.	24758.	15568.	11922.	9924.	593052.
12	East Fork New Fork River	2590.	1850.	6723.	8598.	31331.	85624.	18685.	4659.	5067.	7389.	5308.	4011.	181835.
13	New Fork River below confluence of West and East Forks	13607.	12003.	23205.	36400.	80518.	303150.	156347.	54412.	31838.	27207.	20962.	16785.	776433.
14	Green River between New Fork River and Piney Creeks	24696.	22216.	42209.	81345.	214246.	520231.	273410.	108286.	62924.	45501.	37010.	29676.	1461752.
15	North Piney Creek	1387.	1554.	5142.	2552.	6330.	21756.	16382.	9059.	4735.	3277.	2656.	1229.	76060.
16	Middle Piney Creek	1131.	1322.	5096.	1495.	2798.	14140.	13315.	9123.	4681.	2695.	2258.	879.	58934.
17	South Piney Creek	1436.	1521.	4299.	7373.	21350.	23087.	2666.	5132.	2480.	2958.	2679.	1301.	76282.
18	Green River between Piney Creeks and LaBarge Creek	28644.	26608.	56741.	92758.	228370.	520231.	307332.	132680.	75892.	54809.	44760.	33139.	1601962.
19	LaBarge Creek	3268.	3459.	5894.	9530.	25619.	22859.	10135.	8637.	6493.	4723.	3912.	2903.	107432.
20	Green River between La Barge Creek and Fontenelle Reservoir	31912.	30067.	62635.	102288.	228370.	520231.	318376.	140233.	81387.	59707.	47877.	36075.	1659158.
21	Fontenelle Creek	1792.	1628.	2520.	9443.	23982.	26841.	7484.	3402.	2854.	2072.	1858.	1710.	85586.

Table III-13 Available Flow for Green River Basin and Wet Hydrologic Condition (continued)

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
22	Green River Between Fontenelle Reservoir and Big Sandy River	55141.	53517.	77604.	118211.	228370.	520231.	345100.	140233.	81387.	79281.	47877.	55499.	1802451.
23	Big Sandy River below Farson gage and Green River	2232.	2192.	9553.	12503.	8413.	19093.	12192.	6503.	5445.	4322.	3995.	2623.	89067.
24	Green River between Big Sandy River and Green River near Green River gage	57303.	55888.	91293.	140212.	261167.	537167.	345100.	140233.	81387.	92410.	64343.	57857.	1924360.

B. Ground Water

The following subsections describe groundwater conditions, groundwater quality, and groundwater development potential in the Greater Green River Basin of Wyoming.

Basin Overview

There has been relatively little development of the groundwater resources of Wyoming's Green River Basin. As a result, information on well yield, aquifer properties, water quality, and recharge and discharge relationships is sparse relative to other, more developed areas of the State. Well yield and aquifer data were inferred from available information from the existing wells and previous studies.

Basin Groundwater Conditions

Eight major aquifer *systems* have been identified within the study area. These aquifer systems (or in some cases individual aquifers) are identified by the geologic formation within which they occur. This definition allows for a simplified presentation of the relatively abundant and complex aquifers that underlie the Greater Green River Basin.

The eight major water-bearing systems are, in *ascending* order:

1) Flathead aquifer;
2) Paleozoic-age aquifer system (including the Madison Limestone);
3) (Sundance-) Nugget aquifer system;
4) Upper Jurassic-Lower Cretaceous age aquifers;
5) Frontier aquifer;
6) Mesaverde-Adaville aquifers;
7) Tertiary-age aquifers;
8) Quaternary-age sands and gravels associated with major river courses through the Basin.

The major aquifer systems are also identified and described in Figure III-9 (p.III-43), a Generalized Hydrostratigraphic Column. The majority of the bedrock surface exposures are Cretaceous and Tertiary age rocks. These rocks are host to several important aquifers, including the Frontier aquifer (western part of the Basin), the Mesaverde aquifer system, and the Tertiary aquifer system. The Tertiary aquifer system includes a number of water-bearing formations, including the Green River, Wasatch, Battle Springs, and Fort Union Formations.

Groundwater resources of the Basin are largely undeveloped at this time. Ground water is principally used for drinking water supplies and industrial use. The majority of the supplies are developed from Quaternary and Tertiary aquifers. Current groundwater use within the Greater Green River Basin is estimated to be between 5,300 and 7,200 acre-feet per year for all uses (estimates derived in this study).

A plot of well yields derived from the US Geological Survey's Groundwater Site Inventory, or GWSI database, vary over a broad range, as shown in Figure III-10 (p.III-44).

Basin Groundwater Quality

Water quality data were obtained from a groundwater quality database (GWSI database) maintained by the U.S. Geological Survey. Data were retrieved for 24 parameters including major cations, major ions, dissolved metals, dissolved solids, pH, and several other parameters that serve as useful indicators of the quality of water. The data obtained for this study contain reports for over 800 analyses obtained from a total of about 600 wells and springs.

A plot of the GWSI database shown in Figure III-11 (p.III-45) indicates no apparent tendencies in terms of the concentration of Total Dissolved Solids (TDS) by aquifer, nor does there appear to be a conspicuous tendency in the distribution of TDS concentrations across the Basin. Water quality likely varies by location within an aquifer, in relation to the depth of a well, and by aquifer.

Concentrations of TDS exceed the secondary drinking water standard in over one-half the wells sampled. Concentrations of sulfate exceed the secondary drinking water standards in about one-third of the wells sampled. Although these conditions do not necessarily prevent use of the water, there may be limitations on the types of uses for which this water is suitable. The quality of water at several locations is considered poor, and would require extensive treatment to render it suitable for drinking. There are insufficient data available to assess whether alternate groundwater sources of better quality might be available at these locations.

Groundwater Development Potential

There is virtually no information on the overall groundwater basin water budget, such that major inflow and outflow components may be quantified. Accordingly, it is difficult to evaluate the Basin's safe, long-term yield for purposes of defining future groundwater development potential.

The Basin has a total area of about 20,000 square miles (12.8 million acres). However, there are large areas of the Basin in which potential evapotranspiration (ET) significantly exceeds average rainfall. For purposes of this analysis, it is assumed that recharge is effectively zero in areas where ET significantly exceeds rainfall. In the remaining parts of the Basin, mainly the mountain and foothills areas, rainfall exceeds potential (ET). These areas have been mapped and are estimated to have an area of approximately 925,000 acres. The average "surplus" rainfall (where annual rainfall exceeds annual ET) is assumed to be about 6 inches. It is also assumed that approximately 10 percent of the surplus rainfall recharges the groundwater system. This approach yields an estimate of about 50,000 acre-feet per year of groundwater recharge, and is considered to be an approximation of basin groundwater yield. These estimates neglect the potential for interbasin movement of ground water. They also neglect the large quantity of ground water in storage that could potentially be developed without experiencing significant basin-wide impacts.

By comparison, the USGS (Martin, 1996; Glover, et al, 1998) estimates approximately 100,000 acre-feet per year of groundwater recharge by precipitation to the Tertiary-age rocks. For planning purposes, it is concluded that basin yield is on the order of between 50,000 and 100,000 acre-feet per year.

Currently, there is no evidence to suggest over-development of the principal aquifer systems. It may be concluded that there is significant potential for additional development of these aquifer systems, with little risk of depleting this resource. In fact, the lack of over-development means there is a smaller chance that aquifer storage and retrieval techniques will be successful.

There are many factors that may affect future development and availability of groundwater resources. In the case of the Quaternary-age alluvial aquifers, any future development of groundwater resources may be expected to have a direct and near-immediate impact on the adjacent rivers and streams within the alluvial system. Another factor is the potential development of ground water associated with the coal bed methane (CBM) extraction industry.

The extent to which CBM resources are developed will depend on a number of factors, including current and forecasted energy costs, and the economics of the CBM projects. One important factor affecting a project's economics is the quality of water co-produced in the recovery process. The quality of water associated with the coals is reportedly significantly worse in the Greater Green River Basin than in the Powder River Basin. Water quality standards for salinity in the Colorado River System (adopted by each state and approved by the EPA in 1974) may require that the co-produced water be reinjected or treated before discharge. The impacts of the added costs of treatment or reinjection are unclear, but may render some CBM projects uneconomical. At this time, it appears unlikely that the level of development of CBM resources in the Greater Green River Basin will match the levels of development anticipated in the Powder River Basin given current market conditions and environmental mandates.

Figure III-1 Green River at Warren Bridge, near Daniel, WY

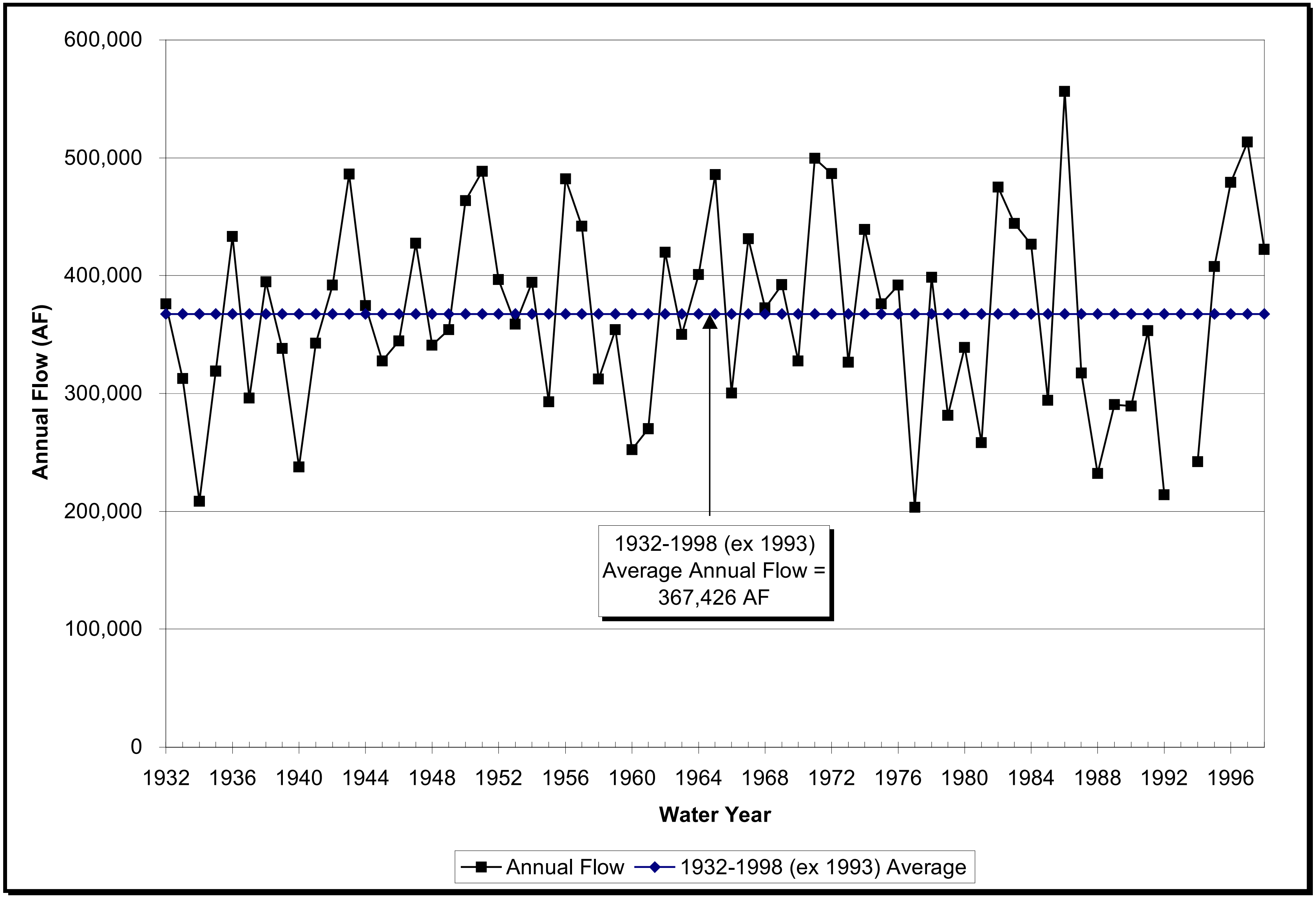


Figure III-2 Upper Green River Node Diagram

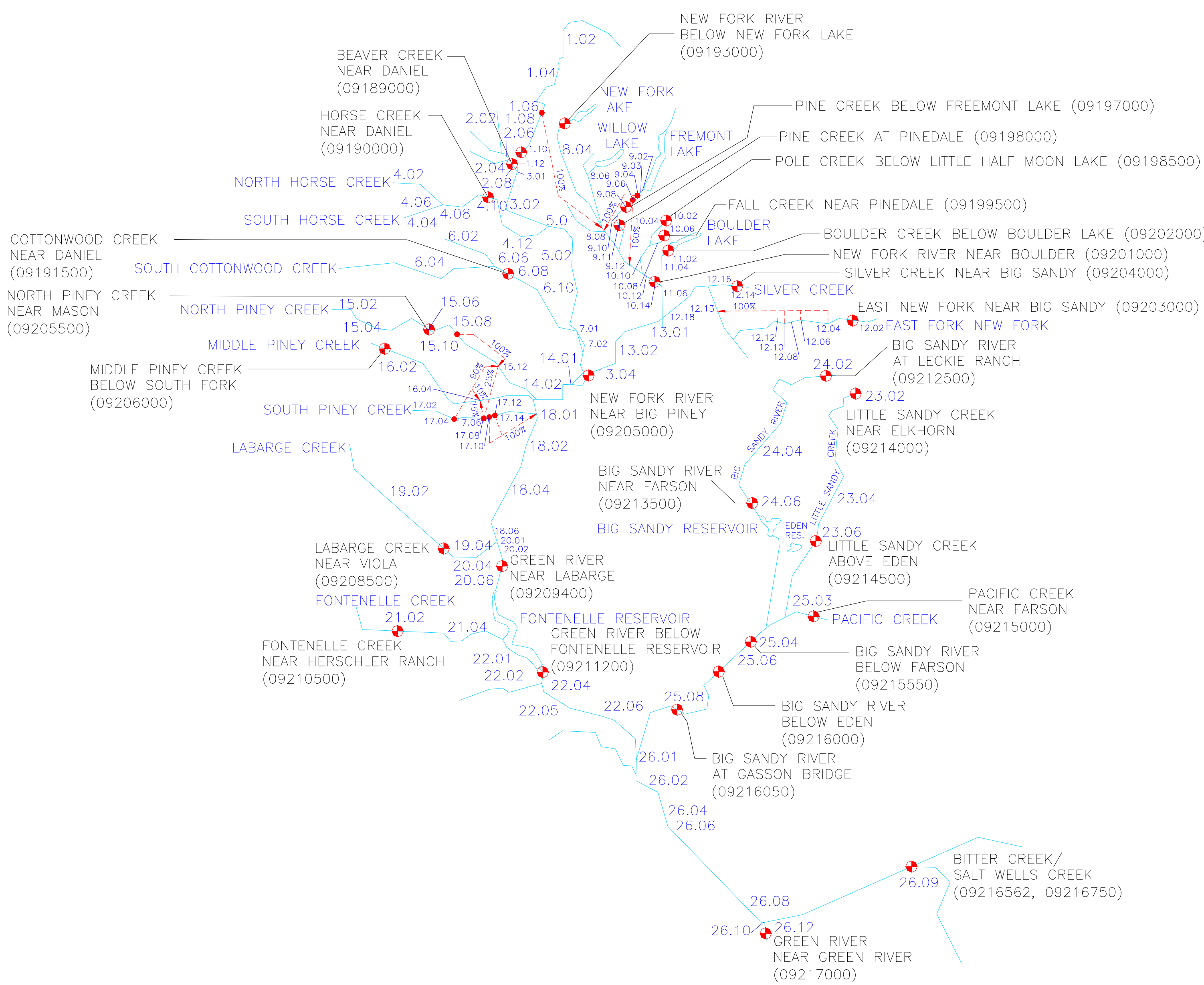


Figure III-3 Blacks Fork Node Diagram

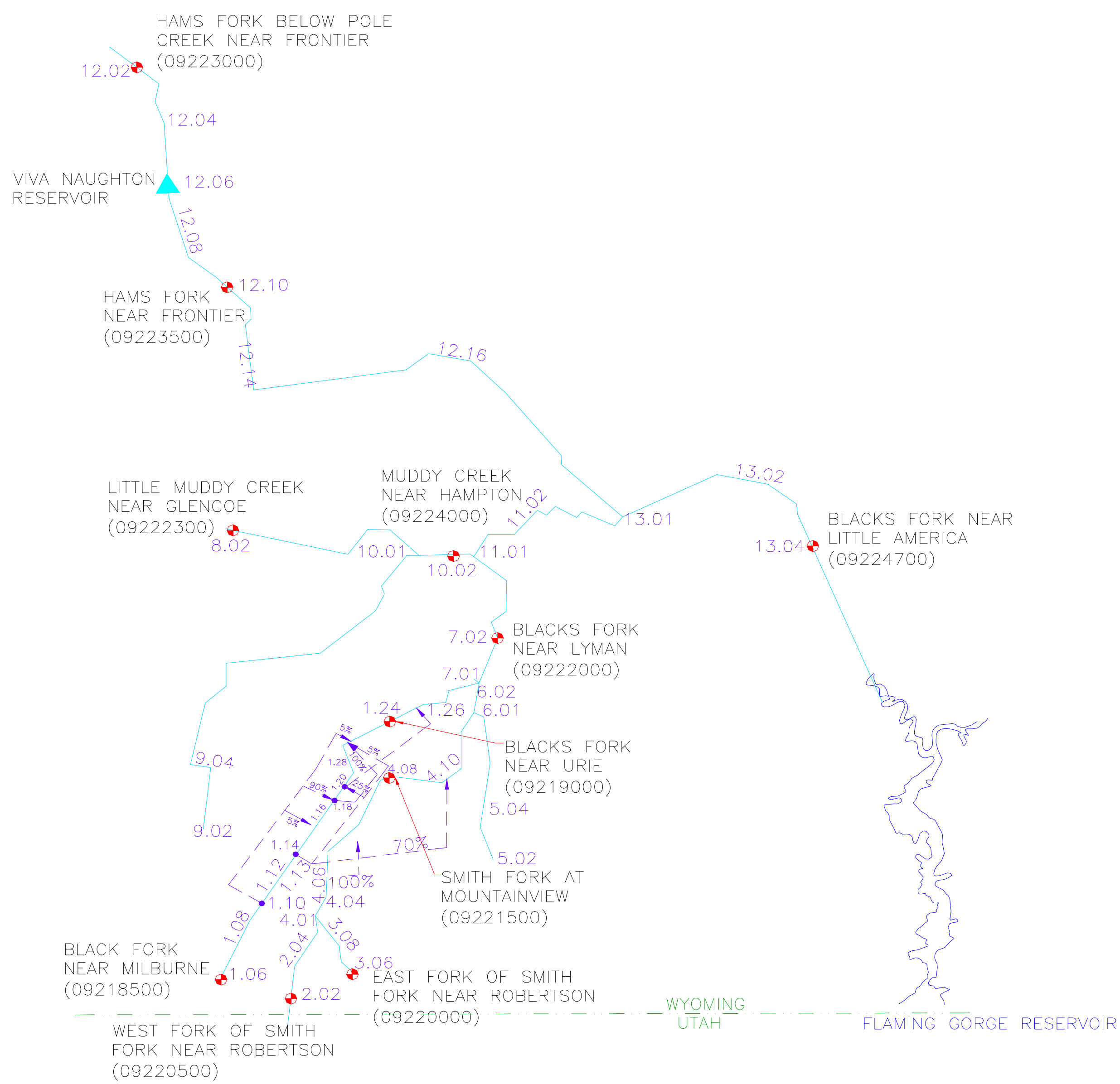


Figure III-4 Henrys Fork Node Diagram

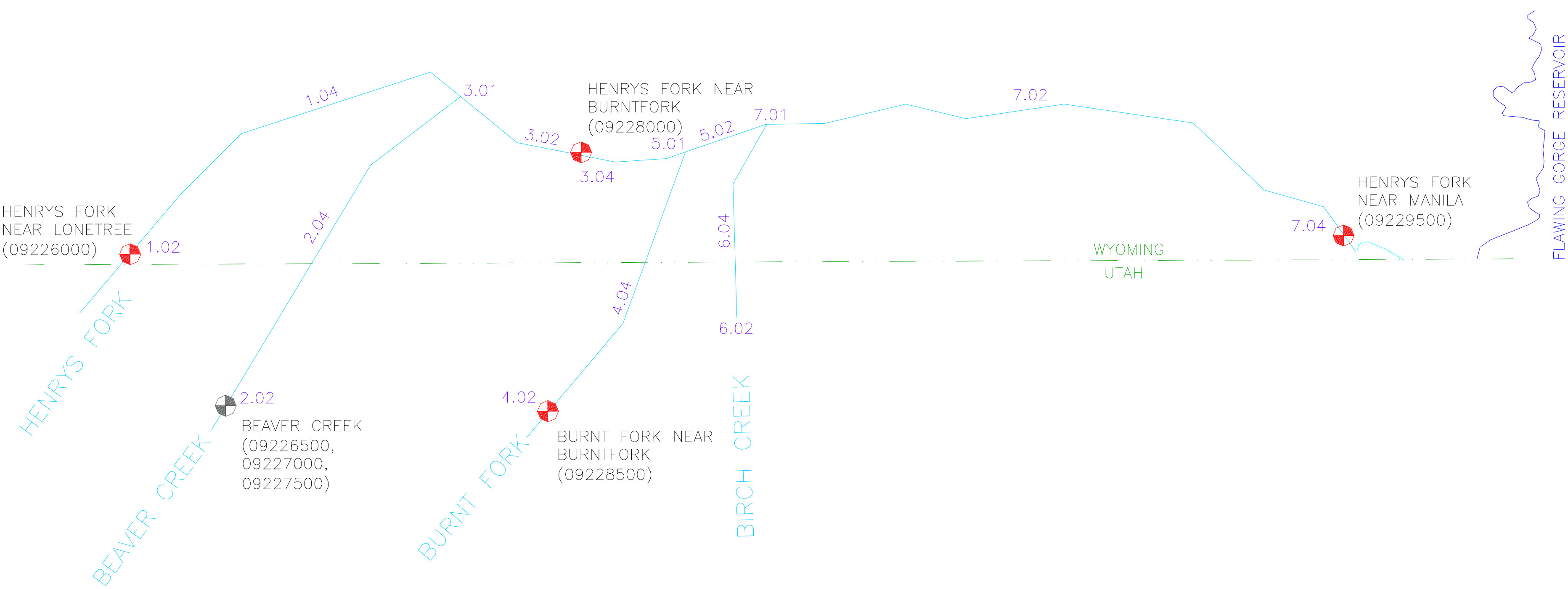


Figure III-5 Little Snake River Node Diagram

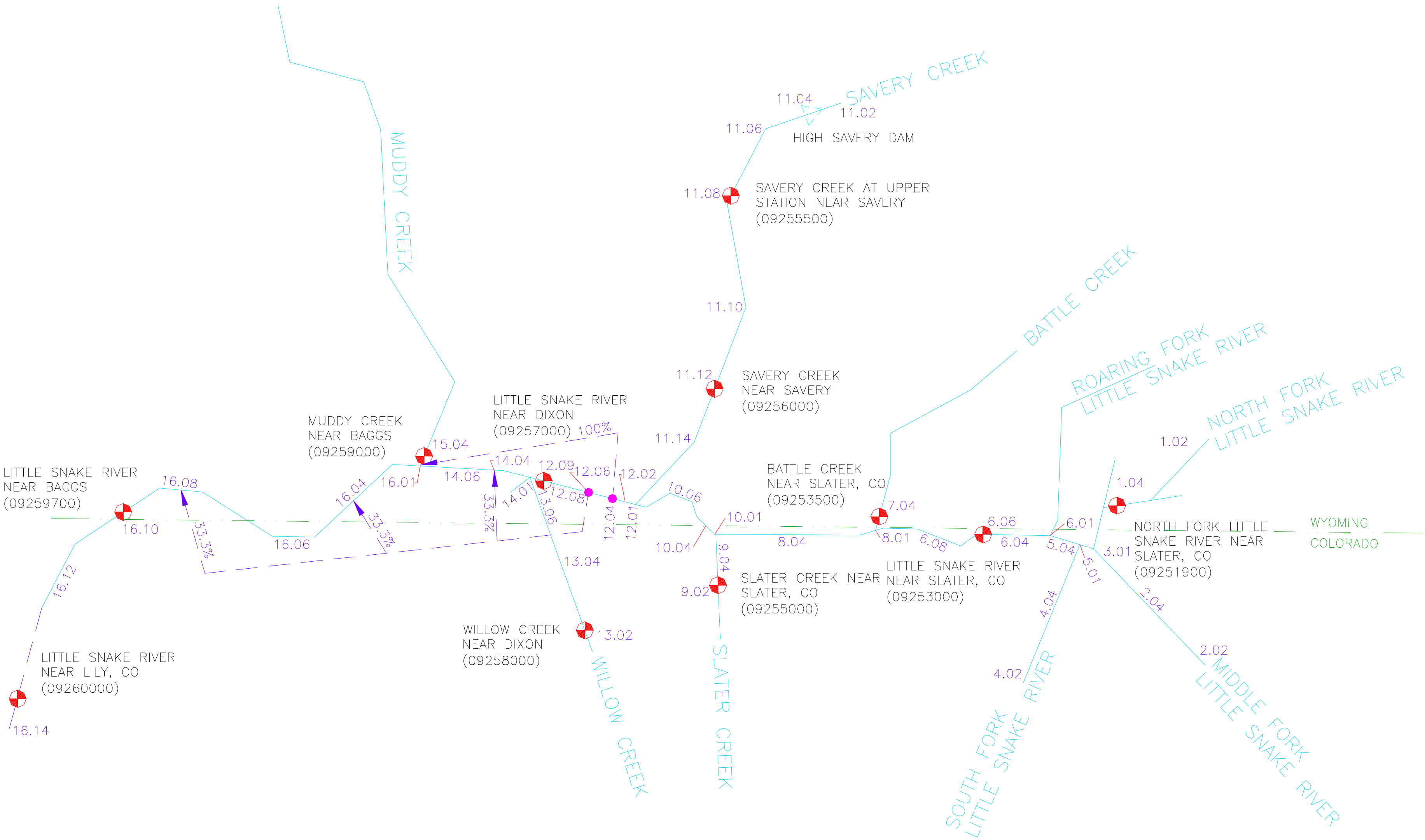
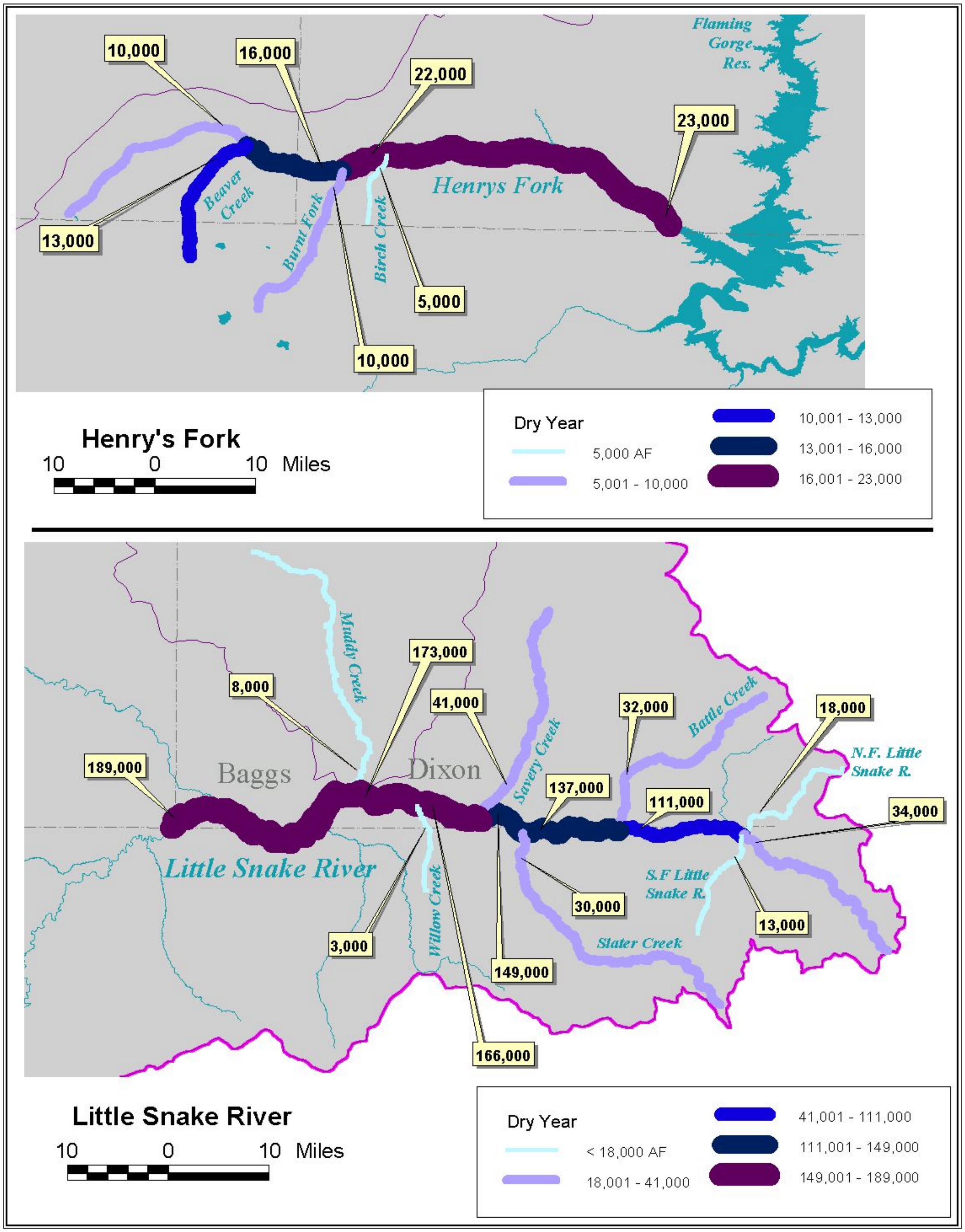
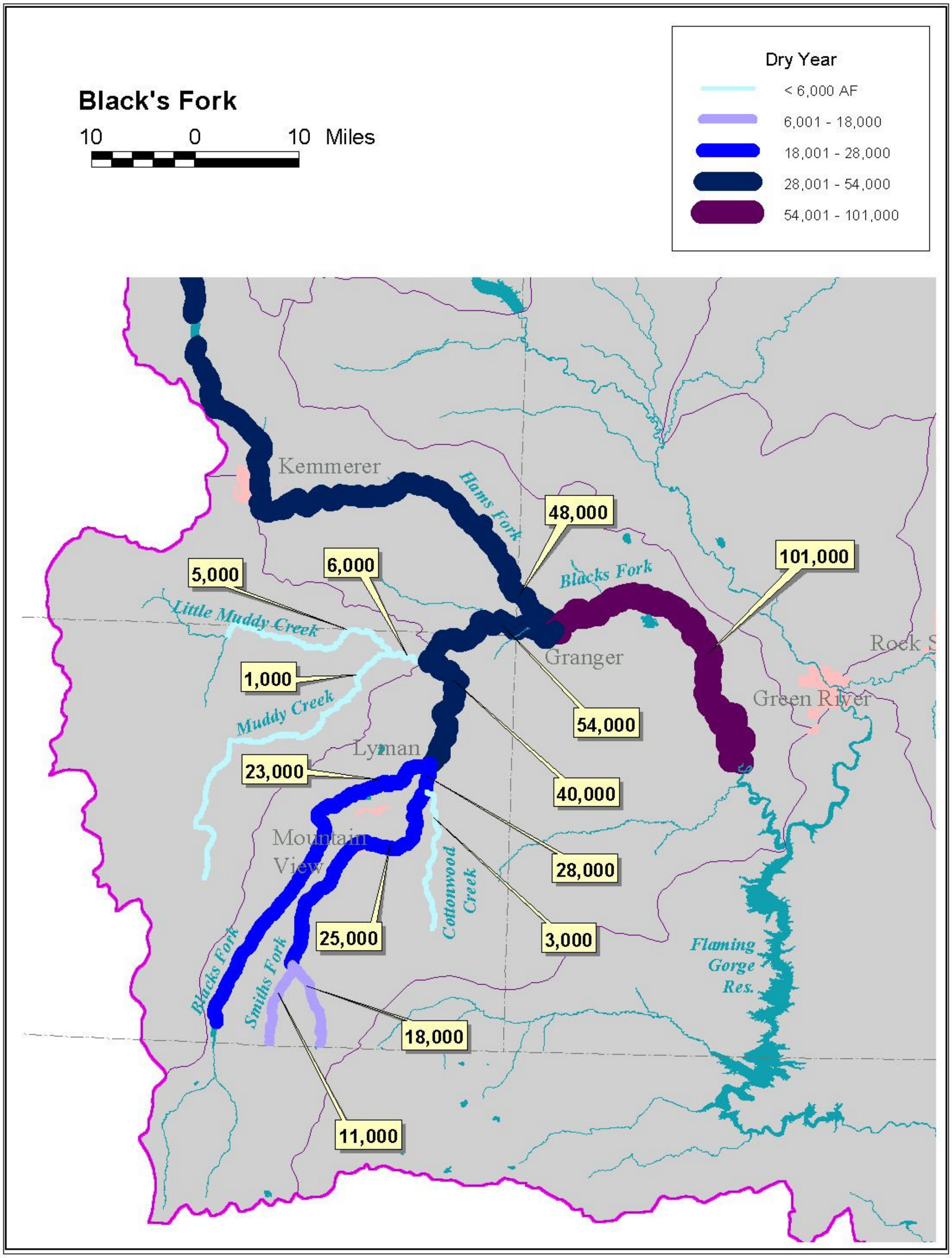


Figure III-6 Available Flow Modeling Results, Dry Year (3 pages)





Black's Fork
10 0 10 Miles
Dry Year
< 6,000 AF
6,001 - 18,000
18,001 - 28,000
28,001 - 54,000
54,001 - 101,000
Kemmerer
Hams Fork
48,000
Blacks Fork
101,000
5,000
6,000
Little Muddy Creek
Granger
Rock S
1,000
Muddy Creek
Green River
54,000
Lyman
23,000
40,000
Mountain View
28,000
Cottonwood Creek
25,000
3,000
Flaming Gorge Res.
Blacks Fork
Smiths Fork
18,000
11,000

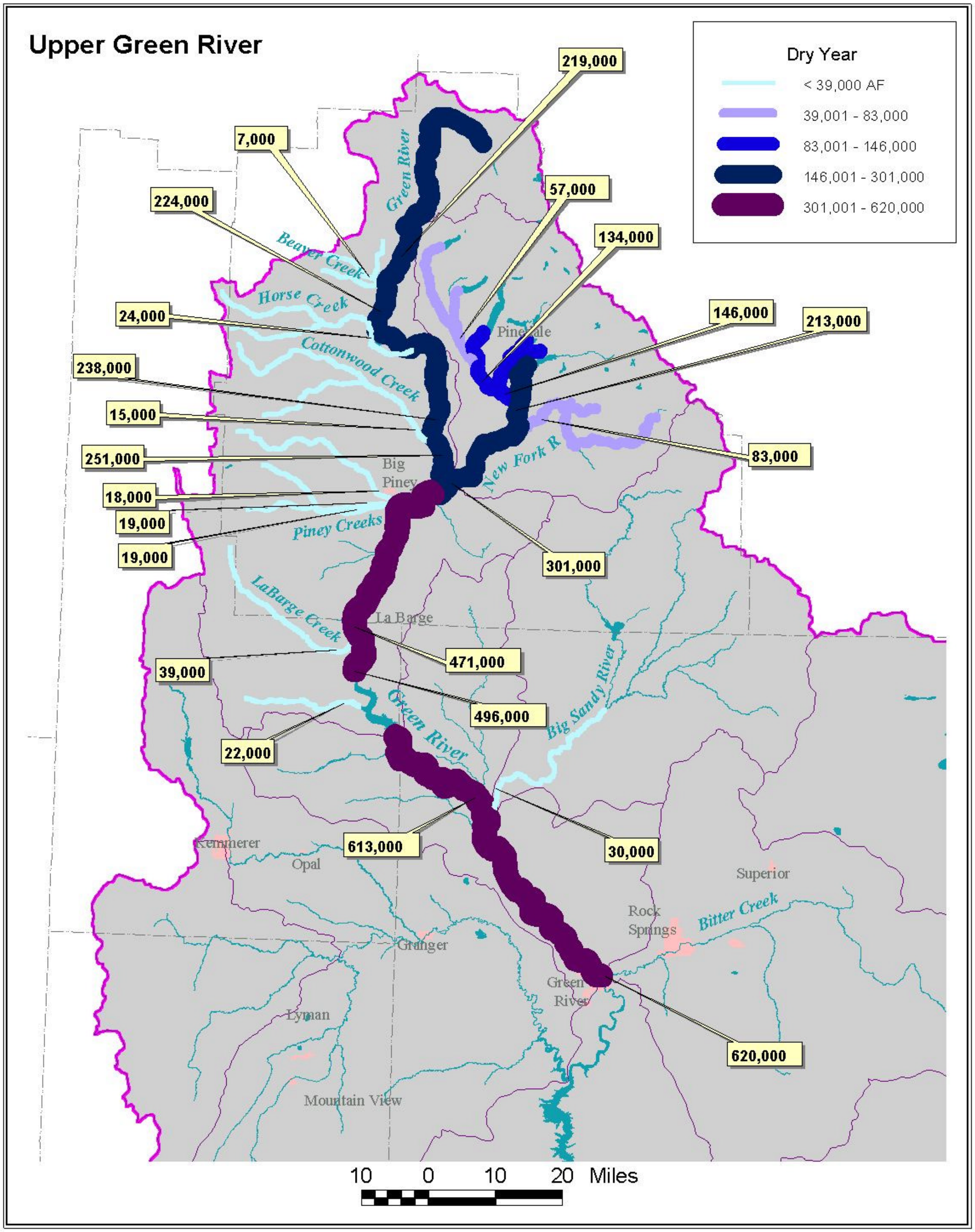
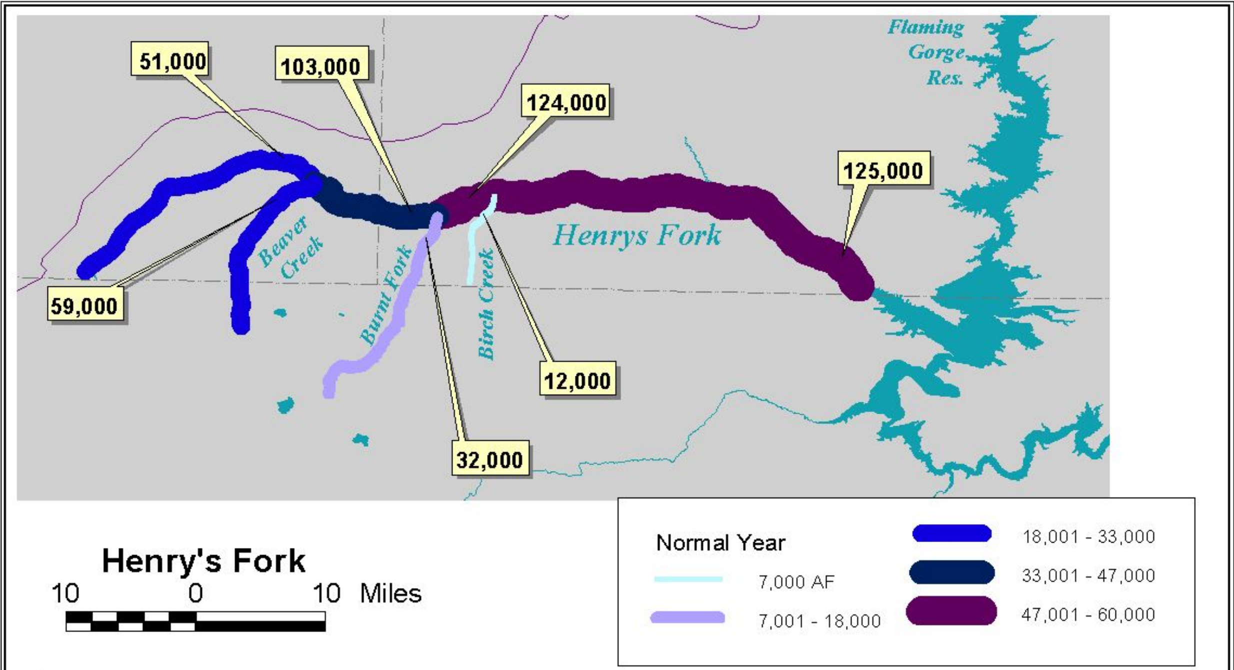
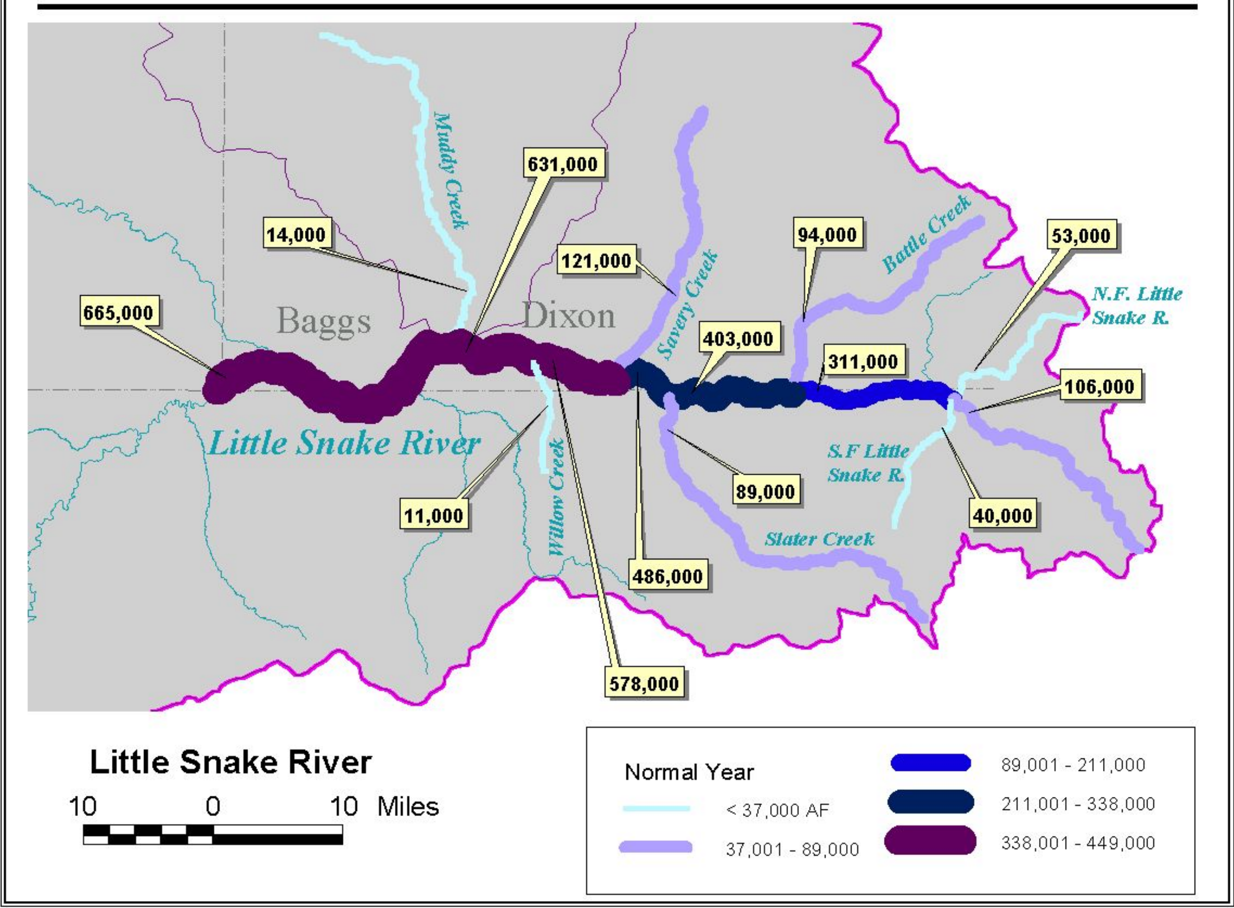
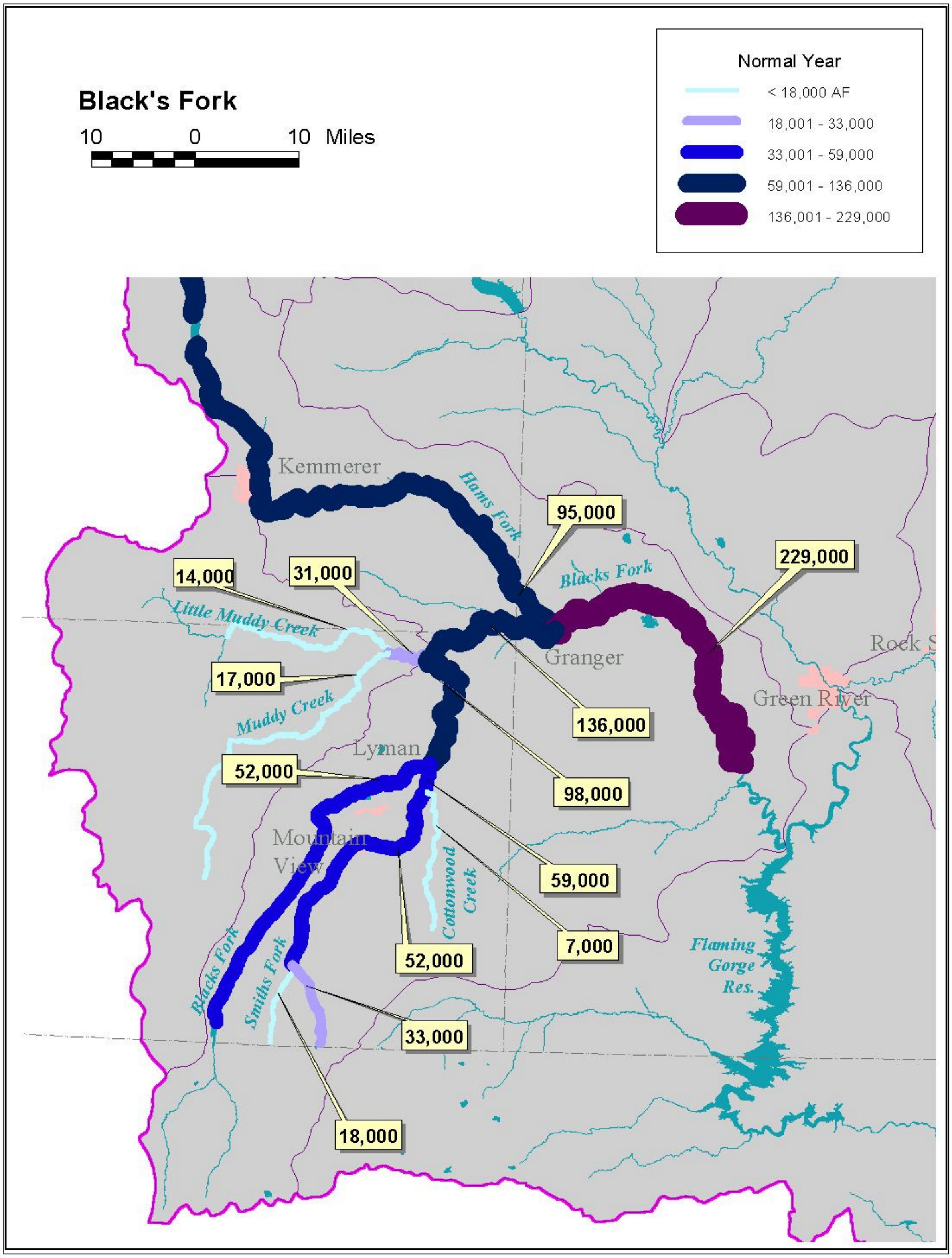

Upper Green River
Dry Year
< 39,000 AF
39,001 - 83,000
83,001 - 146,000
146,001 - 301,000
301,001 - 620,000
219,000
7,000
224,000
57,000
134,000
24,000
146,000
213,000
238,000
15,000
251,000
83,000
18,000
19,000
19,000
301,000
471,000
39,000
496,000
22,000
613,000
30,000
620,000
Green River
Beaver Creek
Horse Creek
Cottonwood Creek
New Fork R
Piney Creeks
LaBarge Creek
Big Sandy River
Bitter Creek
Pinedale
Big Piney
La Barge
Kemmerer
Opal
Superior
Rock Springs
Granger
Green River
Lyman
Mountain View
10 0 10 20 Miles

Figure III-7 Available Flow Modeling Results, Normal Year (3 pages)







Black's Fork
10 0 10 Miles
Normal Year
< 18,000 AF
18,001 - 33,000
33,001 - 59,000
59,001 - 136,000
136,001 - 229,000
Kemmerer
Hams Fork
95,000
Blacks Fork
229,000
14,000
31,000
Little Muddy Creek
Granger
Rock S
17,000
Muddy Creek
136,000
Green River
Lyman
52,000
98,000
Mountain View
59,000
Cottonwood Creek
7,000
52,000
Flaming Gorge Res.
Blacks Fork
Smiths Fork
33,000
18,000

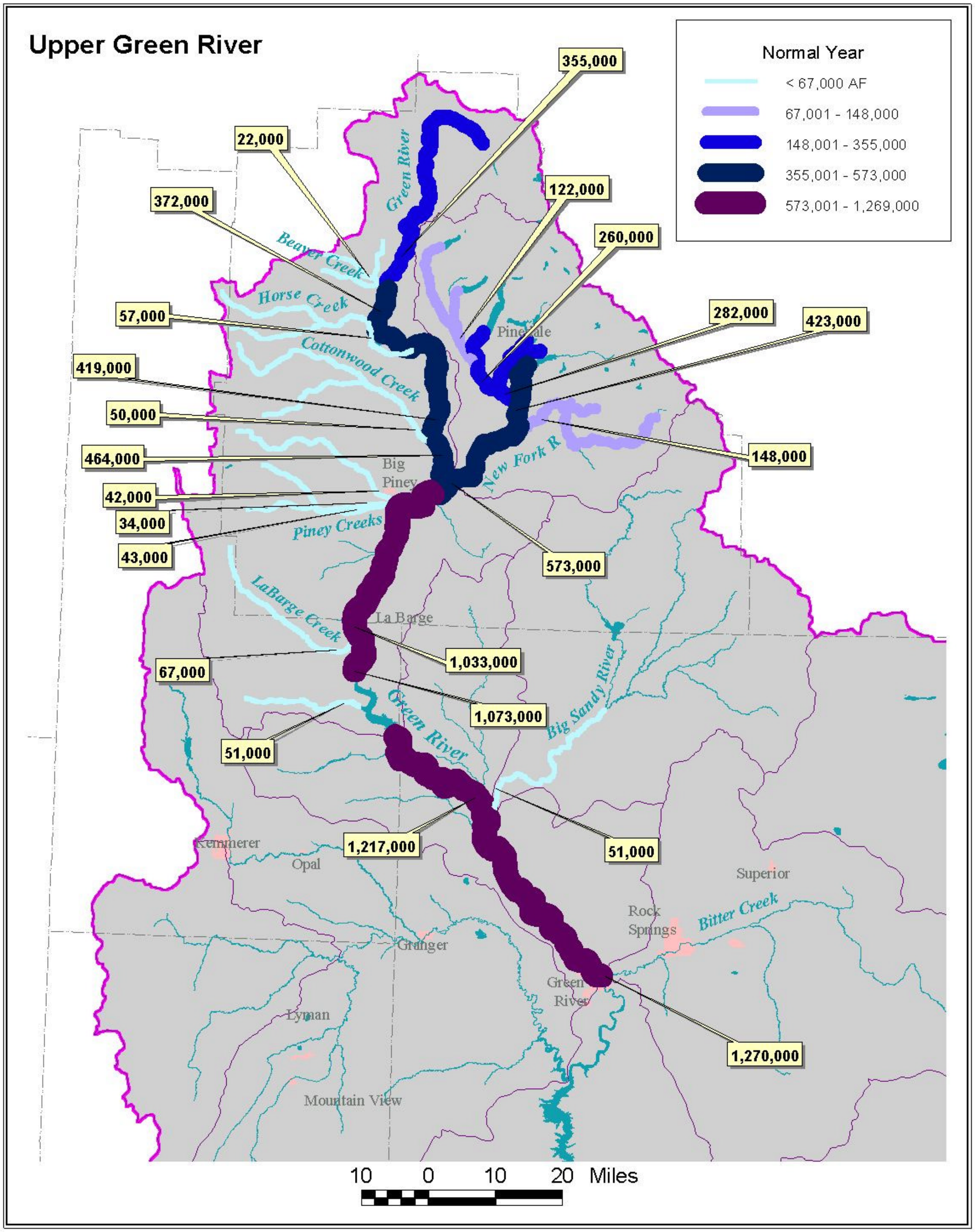
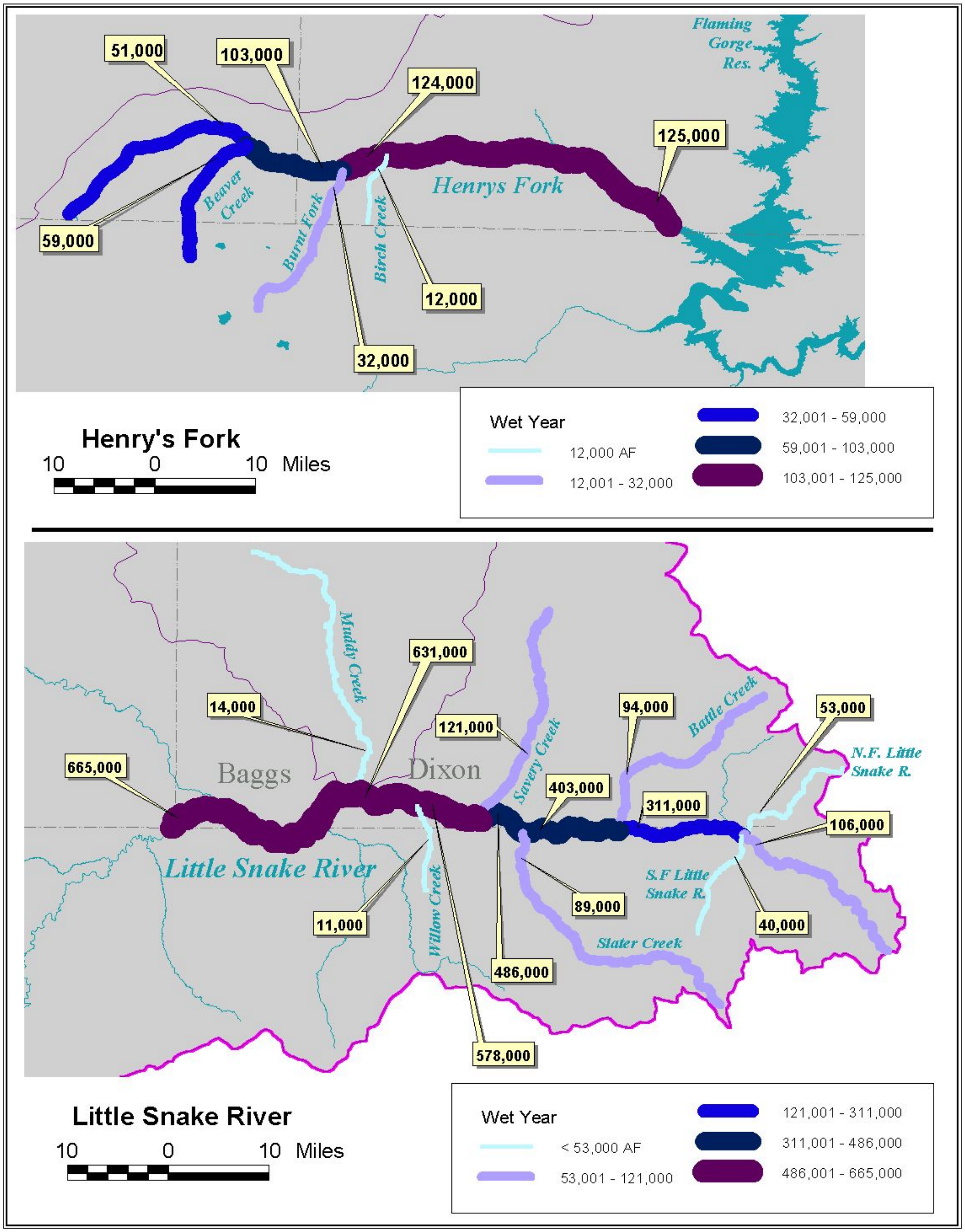
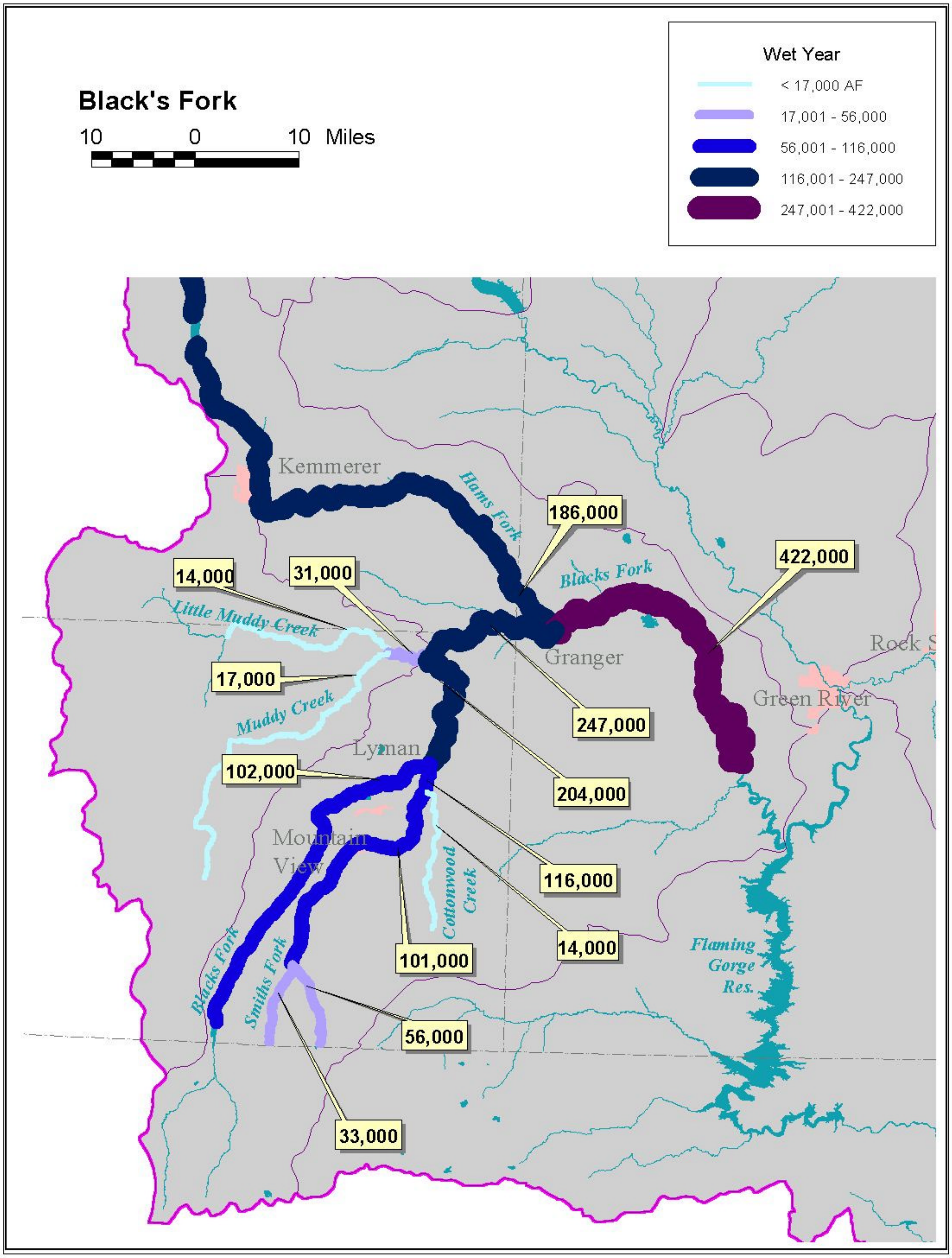
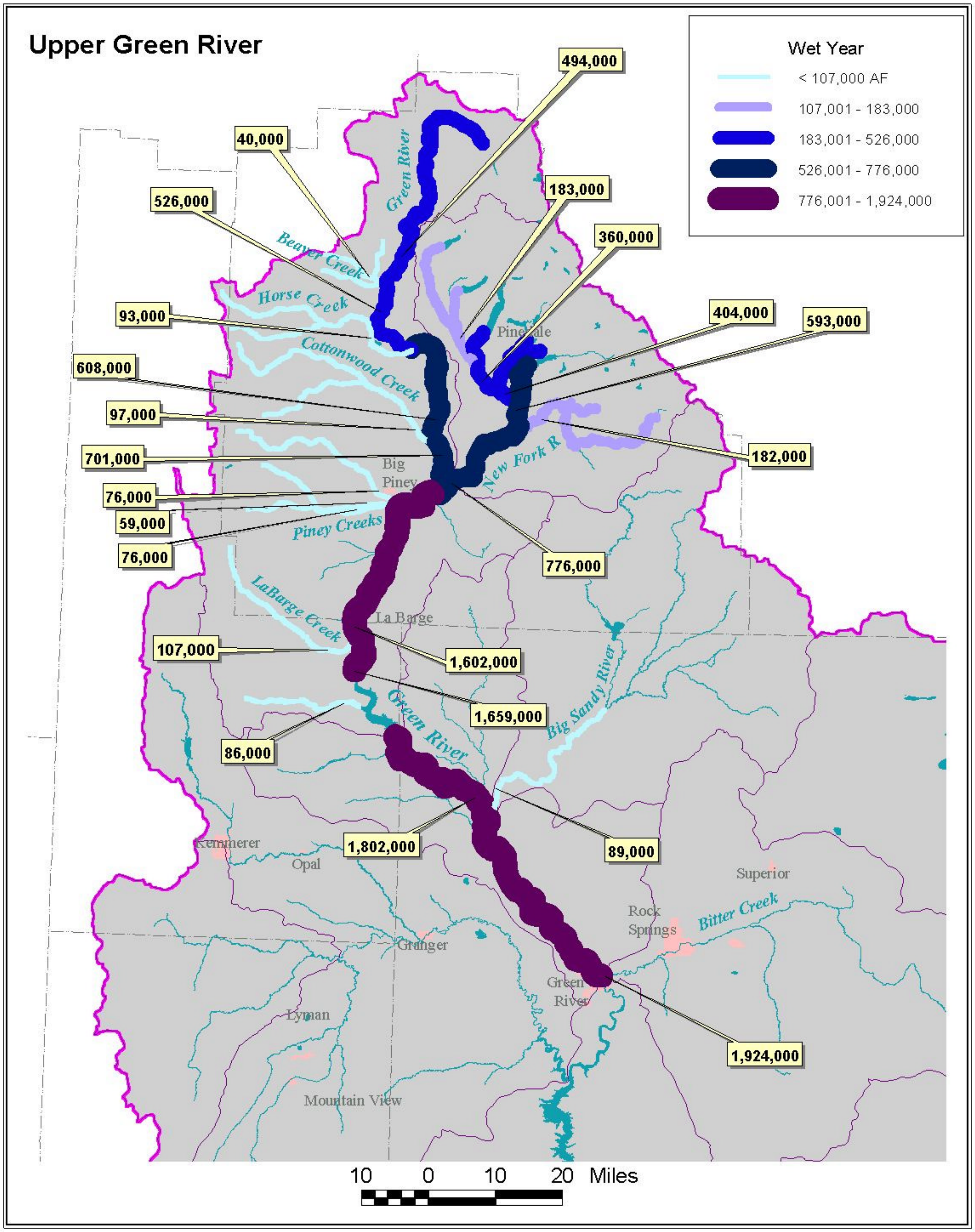

Upper Green River
Normal Year
< 67,000 AF
67,001 - 148,000
148,001 - 355,000
355,001 - 573,000
573,001 - 1,269,000
355,000
22,000
372,000
122,000
260,000
57,000
282,000
423,000
419,000
50,000
148,000
464,000
42,000
34,000
43,000
573,000
1,033,000
67,000
1,073,000
51,000
1,217,000
51,000
1,270,000
Green River
Beaver Creek
Horse Creek
Cottonwood Creek
Pinedale
New Fork R
Big Piney
Piney Creeks
LaBarge Creek
La Barge
Big Sandy River
Kemmerer
Opal
Superior
Rock Springs
Bitter Creek
Granger
Green River
Lyman
Mountain View
10 0 10 20 Miles

Figure III-8 Available Flow Modeling Results, Wet Year (3 pages)




Black's Fork
10 0 10 Miles
Wet Year
< 17,000 AF
17,001 - 56,000
56,001 - 116,000
116,001 - 247,000
247,001 - 422,000
Kemmerer
Hams Fork
186,000
Blacks Fork
422,000
14,000
31,000
Little Muddy Creek
Granger
Rock S
17,000
Green River
Muddy Creek
247,000
Lyman
102,000
204,000
Mountain View
116,000
Cottonwood Creek
14,000
101,000
Flaming Gorge Res.
Blacks Fork
Smiths Fork
56,000
33,000



Upper Green River
Wet Year
< 107,000 AF
107,001 - 183,000
183,001 - 526,000
526,001 - 776,000
776,001 - 1,924,000
494,000
40,000
526,000
183,000
360,000
93,000
404,000
593,000
608,000
97,000
182,000
701,000
76,000
59,000
76,000
776,000
107,000
1,602,000
1,659,000
86,000
1,802,000
89,000
1,924,000
Green River
Beaver Creek
Horse Creek
Cottonwood Creek
New Fork R
Piney Creeks
LaBarge Creek
Big Sandy River
Bitter Creek
Pinedale
Big Piney
La Barge
Kemmerer
Opal
Superior
Rock Springs
Granger
Green River
Lyman
Mountain View
10 0 10 20 Miles

[##] = thickness in feet

[1]Utah and Northwest Colorado terminology, used in Wyoming only in the subsurface.

Geologic Age	Overthrust Belt	Northwest Green River Basin	South & East Green River Basin	Great Divide, Washakie, and Little Snake River Basins	Hydrologic Unit	Description/Properties
Quaternary	Alluvial, terrace, glacial, landslide dep., slopewash and talus material. [50-410]	Alluvial, terrace, and glacial deposits [0-200]	Alluvial, floodplain, terrace, and glacial deposits [0-100]	Alluvial, dune, lacustrine, and glacial deposits [0-70]	Quaternary Aquifers	Discontinuous, major aquifer
Tertiary	Salt Lake Fm. [0-1000]	Camp Davis/Teewinot Fms. [2250-5200]	South Pass Fm. [0-200]	North Park/South Pass Fms. Browns Park/Bishop Conglomerate [0-1200]	Tertiary Aquifer System	North Park/South Pass is discontinuous, minor aquifer (topographically high and well-drained, predominantly).
		Browns Park/Bishop Conglomerate [~4400]	Browns Park/Bishop Conglomerate [0-200+]			
	Fowkes Fm. [500-2600]	Bridger Fm. [1700-2300]	Bridger Fm. [500-2300]	Bridger/Uinta Fms. [0-3200]		Complex intertonguing fluvial and lacustrine sediments. The Wasatch Formation, the Fowkes/Bridger Formations in the southwest Overthrust and Green River Basins near outcrop, as well as Ft Union in Great Divide, Washakie, and Little Snake Basins are major aquifers. Ft Union elsewhere, Evanston Formation, and Fox Hills SS are minor aquifers.
	Green River Fm. [400-600]		Green River Fm. (Wasatch-Cathedral Bluffs) [100-2800]	Green River Fm. (Interfingers with Wasatch) [0-1500]		
	Wasatch Fm. [2500-3600]	Wasatch Fm. [4100-5250]	Wasatch Fm. (Main Body) [0-7000]	Wasatch (South & West)/Battle Springs (Northeast) Fms. [0-4700]		
	Evanston Fm. [1350-2900]	Hoback Fm. [8000-18500]	Ft Union Fm. [0-2700]			
Upper Cretaceous		Harebell Fm.	Lance Fm./Fox Hills SS [0-4900]			
	Meeteetse Fm.		Lewis Shale [0-2700]		Aquitard	
		Mesaverde Fm.	Mesaverde Group: Almond [0-1000]	Mesaverde Fm. [0-5600]	Mesaverde Aquifer	Major aquifer: Rock Springs and Ericson formations are the most permeable units, as is the basal member of the Adaville Formation (Lazeart Sandstone).
			Ericson SS [400-700]			
			Rock Springs [900-1700]			
	Adaville Fm. [1400-5000]		Blair [900-1800]			
	Hilliard Shale [3000-6800]	Baxter Shale [2700-4500]		Cody Shale (Great Divide)/Baxter Shale (West)/Steele Shale & Niobrara Fm. (East) [2000-5000]	Aquitard (Recent, unpublished work by the Wyoming State Geological Survey suggest the possibility that a number of wells yield a reasonable water supply from portions of the Hilliard Shale).	
	Frontier Fm. [1100-3000]	Frontier Fm. [1800-2700]		Frontier Fm. [190-900]	Frontier Aquifer	Minor aquifer, greatest potential in Overthrust Belt and Western Green River Basin.
Lower Cretaceous	Aspen Shale [400-2200]		Mowry/Muddy/Thermopolis Fms. [100-1000]	Mowry/Muddy/Thermopolis Fms. [200-900]	Aquitard	
	Bear River Fm. [800-1500]				Upper Jurassic-Lower Cretaceous Aquifers	Discontinuous, minor aquifer; Cloverly major aquifer (esp. sandstones & conglomerates of lower member) near recharge area in Great Divide & Washakie Basin.
	Gannett Group "Lakota Conglomerate" [800-5000]	Cloverly Fm. "Dakota Sandstone"		Cloverly Fm. "Dakota Sandstone," "Lakota Conglomerate" [45-240]		
Jurassic		Morrison Fm. [170-450+]			Aquitard	
	Stump-Preuss Fms. [160-530]	Curtis Fm./Entrada SS [35-530]		Sundance Fm. [130-450+]	(Sundance-) Nugget Aquifer System	Nugget Sandstone is the major aquifer throughout the area, although the Nugget is absent in the far southeast. The lower part of the Twin Creek Limestone, and the Thaynes Limestone are minor, regional aquifers in the Overthrust Belt.
	Twin Creek LS [150-725]	Gypsum Spring Fm. [0-725]				
	Nugget SS [750-1300]	Nugget SS [400-700]		Nugget SS (absent SE) [0-650+]		
Triassic	Ankareh Fm. [330-500]	Chugwater [900-1500]		Chugwater Group [900-1500]		
	Thaynes LS [0-500]					
Lower Triassic	Woodside Shale/Dinwoody Fm. [600-1300]	Dinwoody Fm. [250-450]		Dinwoody/Phosphoria Fms. (Goose Egg Fm.) [170-460]	Aquitard	
Permian	Phosphoria Fm. [200-400]				Paleozoic Aquifer System	Major aquifers are the Bighorn Dolomite, Darby Formation, Madison Limestone, Tensleep Sandstone, and Phosphoria Formation. These are primarily carbonate, so significant yields occur where there are solution openings and fractures, especially in the Madison with its well-developed paleokarst. The Amsden and Phosphoria are locally confining, minor aquifers.
Pennsylvanian	Wells Fm. [450-1800]	Tensleep SS [350-700]	Weber SS/Morgan Fm./Round Valley LS [650-1300][1]	Tensleep SS [0-840]		
Mississippian	Amsden Fm. [300-700]			Amsden Fm. [0-260]		
	Madison LS, Darby Fm., Bighorn Dolomite [780-1800]		Madison LS, Darby Fm. [650-1300]	Madison LS [5-325]		
Devonian						
Ordovician						
Cambrian	Gallatin LS [0-200]			Undifferentiated Cambrian/Flathead SS [0-800]		
	Gros Ventre Fm. [500-1000]				Aquitard	
	Flathead SS [175-200]				Flathead Aquifer	May be good source to exploit due to characteristic permeable sandstone, basal conglomerate and secondary permeability along bedding plane partings in outcrop and where the rocks are highly fractured.
Precambrian	Precambrian Rocks					Minor aquifer where highly fractured and weathered in outcrop, or near the surface.

Figure III-9 - Generalized Hydrostratigaphic Column of the Greater Green River Basin, Wyoming

Modified from Ahern, et al, 1981, Collentine, et al, 1981, and Love, et al, 1993.

Figure III-10 Yields of Wells and Springs, GWSI Database

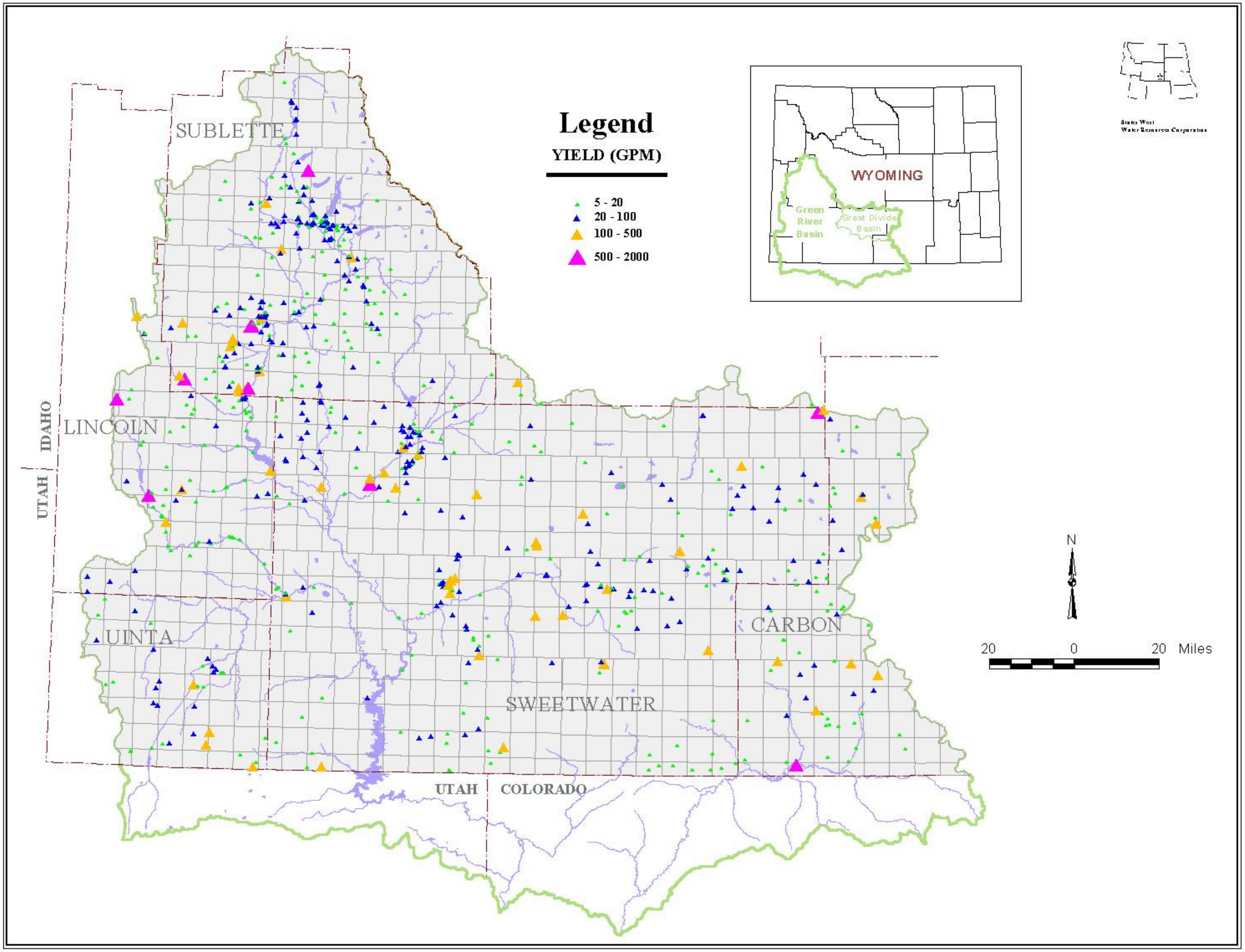
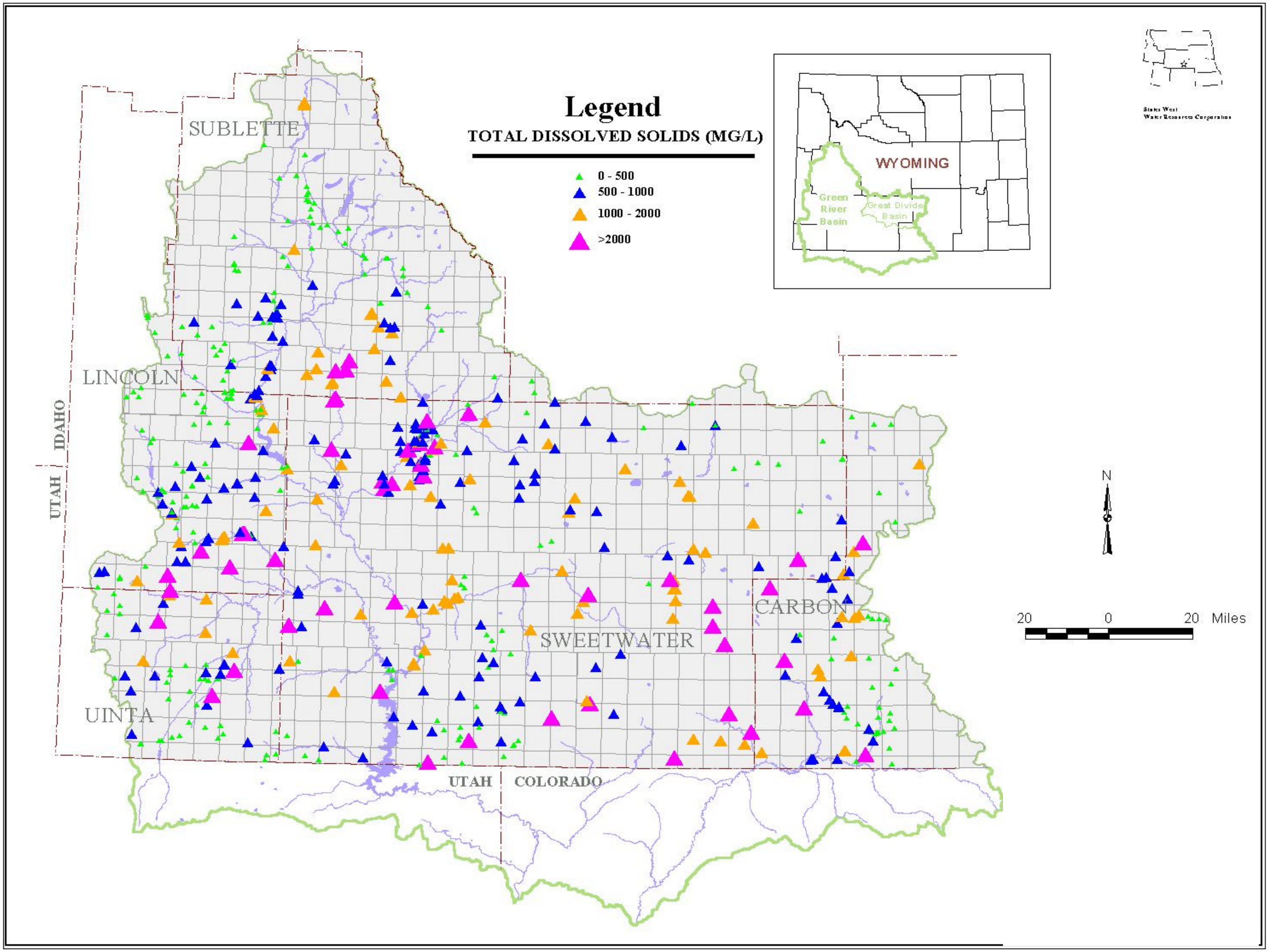


Figure III-11 Total Dissolved Solids, Wells and Springs in GWSI Database



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IV Demand Projections

For assessing the need for water into the future, this plan has developed estimates of water demand for each major use category out to year 2030. These estimates are discussed in detail in technical memoranda for each topic.

As with all chapters in this final plan report, explicit lists of references are not provided. Instead, all references to report, documents, maps, and personal communications are maintained in the Technical Memoranda that were prepared during the current planning process. Should the reader desire to review a complete list of references for the information presented in this chapter, the following memoranda should be consulted:

- Irrigation Water Needs and Demand Projections
- Population Projections
- Industrial Water Needs Projections
- Future Recreational and Environmental Water Requirements

A. Agricultural Demand Projections

Background

Irrigated agricultural production is the largest user of water in the Green River Basin. Currently, Basin irrigators consumptively use an estimated 401,000 acre-feet of water in an average year. This figure will rise to 408,000 acre-feet when High Savery Reservoir in the Little Snake Basin is completed. Irrigation water consumption varies considerably from year to year, however, depending upon water availability, rainfall, and other climatic conditions. In a typical dry year, Basin-wide irrigation water consumption drops to about 375,000 acre-feet. In a typical wet year, consumption rises to about 432,000 acre-feet annually.

The Wyoming Water Planning Program (WWPP) estimated that there were about 330,000 acres of land under irrigation in the Basin in 1970. The estimate of irrigated acreage developed for this study (330,408 acres) is very nearly identical.

The vast majority of irrigated land is devoted to the production of forage crops (alfalfa, grass hay, and irrigated pasture) in support of livestock operations. Small amounts of grain are grown on irrigated acreage along the Blacks Fork and Smiths Fork Rivers, the lower Little Snake Basin, and in the Eden Valley area, but the percentages of irrigated land devoted to grain production in these areas are less than three percent.

Not all of the acres of irrigated land in the Basin is mechanically harvested each year. Some land is devoted to irrigated pasture while other land is only irrigated on an intermittent basis. Figure IV-1 shows estimates of harvested forage acreage in the Basin for the period from 1979 through 1999 as developed by the Wyoming Agricultural Statistics Service. That figure shows that the number of acres of forage crops harvested each year varies from a low of slightly under 250,000 acres to a high of over 300,000. The distribution of harvested forage acreage by county is depicted in Figure IV-2 (p.IV-3). That figure shows that Sublette County is the largest forage producer in the Basin, producing over 40 percent of all forage harvested during the period from 1979 through 1999. Uinta County is the second largest producer with 20 percent of the total, followed by Lincoln, Carbon, and Sweetwater counties in that order.

Almost all irrigated lands in the Basin are served by surface water sources. Although there are a number of reservoirs in the Basin that store irrigation water, the availability of storage varies widely across the Basin, and agricultural production in some parts of the Basin is limited by inadequate or non-existent storage facilities. The Eden-Farson area and the New Fork River valley have the largest ratio of storage to irrigated acreage in the Basin (see Chapter II). The lack of storage is most notable on tributaries entering the Green River from the west above Fontenelle Reservoir (hereafter referred as the northwest tributaries). Only three small private reservoirs currently providing irrigation water are located in this part of the Basin, and over 80,000 acres of irrigated lands suffer from late season and dry year irrigation water shortages.

Figure IV-1 Total Green River Basin Forage Harvest (1979-1999)

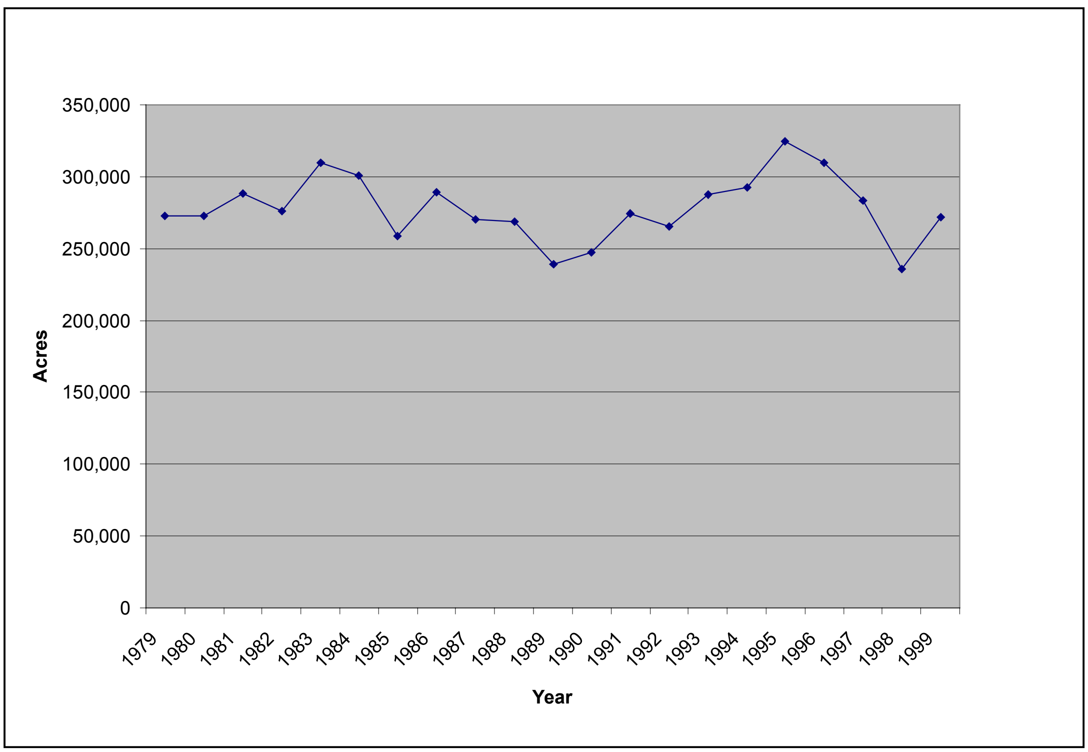
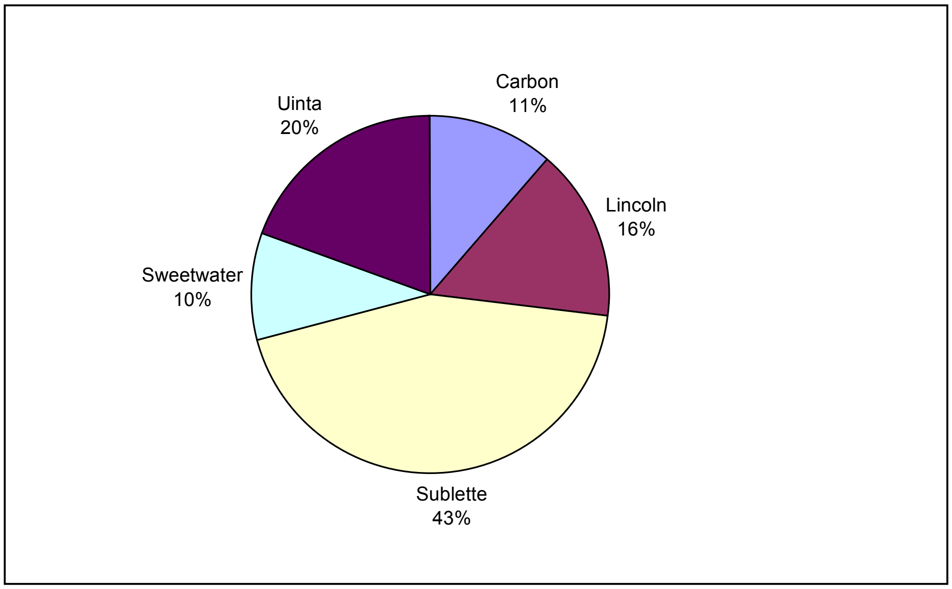


Figure IV-2 Distribution of Basin Forage Harvest by County (1979-1999 Average)



Trends in Livestock Production

Over the past two decades livestock production (cattle and sheep) in the Basin has remained relatively constant. There appear to be several interrelated reasons why this has occurred. One limiting factor with respect to herd size is the availability of summer range on federal lands, which constitute a large proportion of rangeland in the Basin. Both the U.S. Forest Service (USFS) and the Bureau of Land Management (BLM) have become more conservative in recent years with respect to the management of federal grazing allotments in an attempt to improve the quality of the range and provide adequate forage for wildlife. There has been little opportunity for producers with federal grazing allotments to increase their production on federal lands in recent years, and in some cases federal grazing rights have been restricted.

The only alternative available for increased livestock production in the Basin in recent years has been more intensive use and management of private lands, which necessitates either increasing forage production on existing irrigated acreage or bringing new acreage into production. Bringing new irrigated acreage into production is a capital-intensive process that has not been financially feasible for most producers. There has been some increase in forage production on existing irrigated lands through more use of fertilizer and better water management practices.

Future Water Needs and Demands

In discussing the future of irrigation in the Green River Basin, it is necessary to distinguish between needs and demands for irrigation water. A need for additional irrigation water is an identifiable current or future use that would enhance the economic well being of the irrigator and/or the economy of the Basin as a whole. Demands are distinguished from needs by the fact that they are measured in relationship to price. To give a simple example, an irrigator may need additional irrigation water in a dry year to grow enough hay to provide winter feed for his cattle. If additional water costs $500 per acre-foot, however, the irrigators demand for additional water would probably be zero because it would be more cost-effective either to buy additional forage from other producers or reduce the size of his herd.

In analyzing municipal and industrial water uses, needs and demands are often viewed interchangeably. The cost of water is usually a relatively minor part of the costs involved in water intensive manufacturing processes such as electric power production and soda ash production. As a result, it can be assumed that manufacturers and municipalities will demand the water needed to expand production over a reasonable range of prices. That convention was used for projecting municipal and industrial demands in this planning study.

Irrigated agriculture, however, is an industry in which producers are very sensitive to the price of water, and their demands for water can change dramatically as a function of price. Meetings with irrigators in the Basin and discussions with agricultural industry professionals indicate that there are several reasons why more water is needed now or may be needed in the future for irrigated crop production. One pressing current need is for storage water to meet late season and dry year crop requirements in those parts of the Basin where storage is not available or is inadequate to fully meet irrigation requirements. Additional storage would also allow more producers to adjust more readily to potential future changes in the management of federal grazing allotments.

The biggest practical problem associated with fulfilling the need for additional irrigation water in the Basin is that the returns from forage production in recent decades have not been sufficient to offset the costs of new water storage projects. Studies of irrigation water returns in the Little Snake Drainage and in other parts of Wyoming indicate that one acre-foot of irrigation water used for forage production in relatively high altitude areas of the State can be expected to generate a $15 to $25 increase in net farm income. The cost of developing new storage can be significantly higher than that figure even under very favorable circumstances.

Future demands for additional irrigation water in the Green River Basin are thus largely dependent upon factors that might either increase the returns that Basin irrigators receive from irrigation or reduce the cost to them of developing new storage. Possibilities for increasing economic returns to irrigated agriculture in the Basin include diversifying cropping patterns into higher valued crops, hay prices increasing to the point that it would be profitable to export hay from the Basin to other domestic markets, and/or cattle/sheep prices rising significantly over the next 30 years.

Although there are some opportunities for diversifying cropping patterns in the Basin, it is doubtful that diversification out of forage production will occur on a wide enough scale over the next thirty years to warrant significant new water development projects. Most of the Basin above Fontenelle Reservoir is characterized by high elevations, cool nights, and a short growing season, making forage crops the only practical alternative. Grains can be grown in some parts of the Basin. Malting barley is the only grain crop with significantly higher returns than alfalfa, however, and is typically grown in rotation with alfalfa in relatively small quantities.

Specialty crops, such as alfalfa seed or seed potatoes, could possibly be grown in some of the lower elevation areas of the Basin. Seed alfalfa production is moving into Wyoming's Big Horn Basin, where acreage has grown from 2,000 to 15,000 acres in recent years. Nevertheless, the Green River Basin will always have a competitive disadvantage with respect to specialty crops compared to lower elevation areas such as Wyoming's Big Horn Basin or lower North Platte River Basin.

Some trends in the agricultural industry in the western U.S. suggest that certain types of forage production will become more valuable in the future as cash crops. As more agricultural land is taken from production in the future, there will be less hay production because it is among the lower valued crops that can be grown in lower elevation areas.

Wyoming is currently a net exporter of alfalfa and Timothy grass hay. No official statistics are available on the magnitude of hay exports from Wyoming, but some experts put the figure at about 25 percent, and expect that percentage to increase in the future. The largest market for Wyoming hay is now Colorado, but some producers in the Big Horn Basin are shipping hay by rail to dairies as far away as Florida and other east coast states. The Green River Basin is in an ideal location for hay production as a cash crop for several reasons. First, producers have ready access to rail and truck shipping facilities along I-80 and the Union Pacific rail line through the southern part of the Basin. Second, the Basin is capable of producing high quality, low fiber content hay.

The types of hay expected to be in high demand in the future are alfalfa for dairies and Timothy hay for horses. Although alfalfa prices have been somewhat depressed in recent years, that trend is expected to reverse in the future as more land is taken out of production in fast-growing western states. Timothy hay is already bringing prices as high as $180 per ton in some parts of Wyoming. Alfalfa hay can be grown in lower elevation areas of the Basin, and Timothy hay can be grown in higher elevation areas. If future market prices for these crops stabilize at levels of well over $100 per ton, it may become practical for Green River Basin producers to develop additional storage and expand production of these crops for export markets.

Two other events could translate into more demand for irrigation water in the Basin over the next 30 years: A significant and long-term increase in cattle prices and/or an increase in the amount of financial assistance available to producers for reservoir construction from State and federal agencies.

Cattle prices have increased somewhat in recent years as per capita beef consumption in the U.S. has stabilized at around 67 pounds after many years of decline. But according to the Cattleman's Beef Production and Research Board, per-capita consumption is not expected to increase in the future and will most likely decrease from today's levels. The

USDA, however, is forecasting a significant increase in exports of U.S. beef over the next 10 years. The basis of this projection is the fact that demand for high quality beef in Pacific Rim nations is expected to increase significantly in the future as the economies of these countries recover from the 1998 financial crisis that affected the region.

The prospects for increased federal assistance for reservoir construction seem more remote than the projected increase in cattle prices. Federal assistance for agriculture and new reservoir construction has been declining in recent years, and there are no indications that this situation will change over the planning horizon. The WWDC also has tightened its funding criteria for new water project construction in recent years. This tightening has been primarily motivated by budget constraints, however, and the possibility exists that more state funds may be allocated to water development over the next 30 years than are available under current economic conditions.

For the reasons discussed above, the low, moderate, and high growth scenarios for future irrigation water demand in the Basin are based upon varying assumptions concerning the financial returns from beef and forage production and the availability of WWDC assistance for new project construction.

Low Growth Scenario

The low growth scenario is based upon the assumptions that irrigation in the Basin will continue to be dominated by forage production for winter livestock feed and that cattle and forage prices will not make sustained increases over the next 30 years relative to reservoir construction costs. This scenario also projects no increase in state funding available for new project construction and no change in WWDC criteria for financial assistance to project sponsors. As a result, irrigators will probably be unwilling to make long-term financial commitments to develop new storage following WWDC funding guidelines. Numerically, total consumptive water use for irrigation in the Basin is expected to remain relatively constant at 408,000 acre-feet in an average year for this scenario.

Moderate Growth Scenario

The moderate growth scenario is based upon the reasonably foreseeable possibility that cattle prices will increase significantly over the next 10 years as forecast by the USDA in response to increased demand for high quality beef in Pacific Rim markets. Cattle prices are projected to stabilize at these higher prices over the planning horizon. This scenario also assumes that the WWDC will increase its financial commitment to new storage projects.

The combination of higher cattle prices and increased WWDC assistance will allow irrigators to develop and fund some new storage projects in those parts of the Basin that are in the greatest need. A logical place for such developments to take place is along northwest tributaries of the Upper Green River, including Cottonwood Creek, Fontenelle Creek, Horse Creek, LaBarge Creek, and Piney Creek. This area has less storage per irrigated acre than any other part of the Basin, and irrigators market almost all of their hay through cattle. Reservoirs with 25,000 acre-feet of storage in this area would increase irrigation depletions in the Basin by 8,000 to 12,000 acre-feet annually.

In addition to new developments along the northwest tributaries, the Little Snake River Conservation District and private landowners in the Little Snake Drainage hope to bring some additional acreage into agricultural production in the future. If fully developed, these projects would result in a total irrigation depletion increase of about 10,000 acre-feet annually. For purposes of projecting future water use under the moderate growth scenario, it was assumed that 50 percent of the Little Snake projects would be developed over the 30-year planning horizon, with annual depletions of 5,000 acre-feet. Adding these depletion increases to those along the northwest tributaries yields a Basin-wide average annual irrigation depletion estimate of 421,000 to 425,000 acre-feet by the year 2030 under the moderate growth scenario.

<u>High Growth Scenario</u>

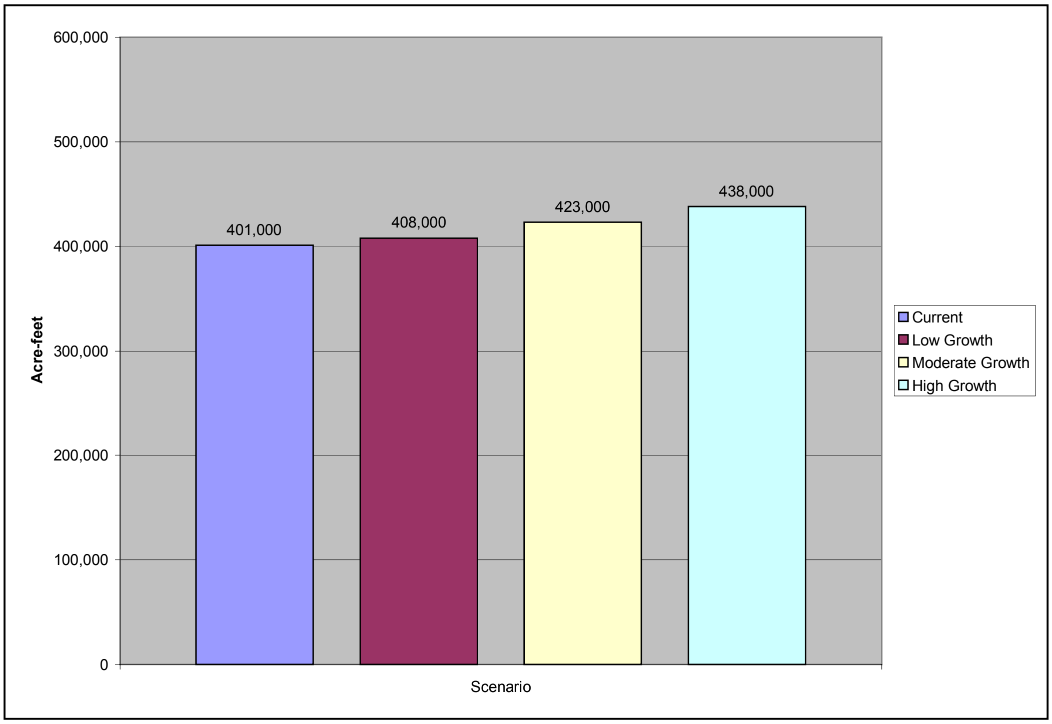
The high growth scenario is based not only upon the reasonably foreseeable possibility that cattle prices will increase over the planning horizon, but that reductions in forage production in high growth areas of the west will drive forage prices high enough to encourage Basin irrigators to produce alfalfa and Timothy hay as cash crops.

If forage prices stabilize at higher levels and WWDC funding is increased in the future, additional storage could be developed in the Basin to support increased forage production as a cash crop. The amount of additional storage that would be developed and the amount of additional water that would be consumptively used under this scenario are difficult to estimate because the outcome depends not only upon future financial returns to forage and beef production, but also upon the cost of developing additional storage in those areas where unappropriated water is available.

The preliminary water use projections for this scenario are that an additional 26,000 to 34,000 acre-feet of irrigation water will be consumptively used annually relative to the low growth scenario, bringing average annual consumptive use by Basin irrigators to 434,000 to 442,000 acre-feet annually. An increase of 8,000 to 12,000 acre-feet annually is associated with new storage projects along the northwest tributaries as described under the moderate growth scenario. Another 10,000 acre-feet of increased consumptive use are associated with future projects identified by the Little Snake River Water Conservation District. The remaining 8,000 to 12,000 acre-feet of new consumptive use is projected to occur in other parts of the Basin as cost-effective sites are identified during site-specific studies associated with an ongoing water planning process in the Basin.

For purposes of comparing the moderate and high scenarios above, midpoints in the projected ranges were used. These midpoints are 423,000 and 438,000 acre-feet per year respectively. All future agricultural use scenarios are shown on Figure IV-3.

Figure IV-3 Summary of Consumptive Irrigation Water Use Projections



B. Municipal and Domestic Demand Projections

Municipal and domestic use projections are created by combining current per capita use rates with population projections for the Green River Basin. Current municipal and domestic consumption was described in Chapter II.

Population Projections

This section presents population projections for the Green River Basin and its communities and rural areas for the time period from 2000 through 2030 for low, moderate and high growth planning scenarios. The projections also provide a basis for assessing water-based recreational resource needs.

Current Population Estimates

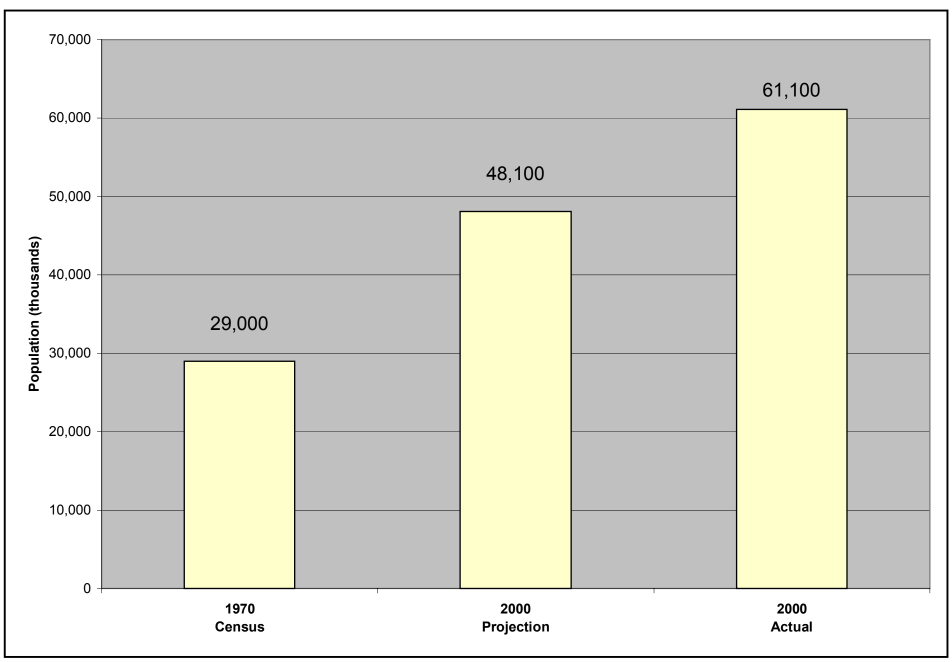
The first step in developing population projections for the Basin was to estimate its current population. Estimates are necessary because the results of the 2000 census are not available as of the date of this report. Furthermore, it would be useful to have a consistent data source for the current population of all river basins in the State, and the results of the 2000 census may not be current when other basin plans are developed.

The Division of Economic Analysis of the Wyoming Department of Administration and Information (WDAI) produces estimates of the population of Wyoming's counties, cities, and towns on an annual basis, and projects those estimates 10 years into the future. The WDAI forecasts for the year 2000 were used as current population estimates for this report and could be used to develop comparable current population baselines in other basins.

Because the geographical boundaries of the Green River Basin do not adhere to county lines, it was necessary to adjust the WDAI county population estimates to reflect only the proportion of each county that lies within the Basin's boundaries. The only exceptions to this adjustment involve Fremont and Teton Counties, each of which have a very small portion of rural land in the Basin. In both cases, these lands are in remote, lightly populated areas. As a result, a decision was made to exclude Fremont and Teton Counties from the Basin population projections.

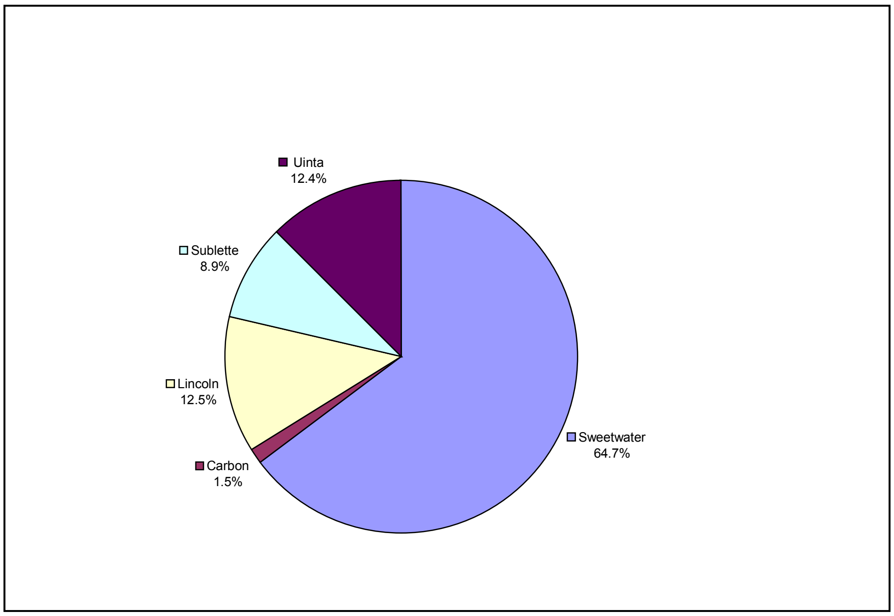
Based upon this work, the total current population of Wyoming's Green River Basin is estimated to be 61,100 persons. This estimate represents an increase of 111 percent over the 1970 total of approximately 29,000 persons. Figure IV-4 shows these population totals along with a population forecast for the year 2000 taken from Water Planning Report No. 3, the 1970 water planning document for the Basin. That forecast is 48,100 persons, or 21 percent lower than the current estimate for the Basin. The forecast from Water Planning Report No. 3 apparently did not anticipate the extent of population growth that resulted from energy and mineral development in the Basin during the 1970s and early 1980s.

Figure IV-4 Actual and Projected Population



The geographical distribution of the Basin's current population by county is depicted in Figure IV-5. That figure shows that almost two-thirds of the Basin's current population (64.7 percent) resides in Sweetwater County. Lincoln, Sublette, and Uinta Counties each have between 8 and 13 percent of the Basin's population, while Carbon County has only 1.5 percent. The relatively large population concentration in Sweetwater County is attributable to the fact that it contains the two largest communities in the Basin, Rock Springs and Green River. These two cities, with a combined population of about 32,500, account for 53 percent of the Basin's current population.

Figure IV-5 Distribution of Current Population by County



Extended WDAI Population Projections

The Division of Economic Analysis of the WDAI produces population forecasts for Wyoming counties, cities, and towns. The county population forecasts are based upon time series data from which growth rates are derived from variables such as population, sales tax collections, and school enrollments. These growth rates are used to forecast individual county population totals, and these county totals are adjusted to make them consistent with state-level population forecasts that incorporate elements of the cohort survival and employment-driven approaches.

The Division of Economic Analysis forecasts population only 10 or fewer years into the future because of the uncertainties associated with such projections. Its most recent projections are through the year 2008 and are relatively conservative, a reflection of the relatively slow economic growth that the Basin and many other parts of the State have witnessed in recent years. A reasonable set of low growth rate population projections for the Green River Basin can be derived by computing the WDAI's average annual population growth rates for Green River Basin communities and rural areas for the period from 1990 through 2008 and extending those growth rates through the year 2030.

Allocation of U.S. Census Bureau (USCB) Projections

The USCB periodically produces population forecasts for each of the 50 states using the cohort survival approach. The most recent forecasts for the State of Wyoming are two sets of population projections through the year 2025, the Series A and Series B forecasts.

Both series of projections indicate moderate future population growth for Wyoming based upon migration patterns in the early 1990s. During that period, there was a moderate influx of new residents into some parts of Wyoming from elsewhere in the country. The effects of this migration pattern are apparent in parts of the Green River Basin, including the Pinedale area. The USCB projections are based upon the assumption that this moderate rate of net in-migration will continue into the future.

Historical Growth Projections

A third set of Green River Basin population projections was created by assuming that the area would experience a total population increase during the period from 2000 to 2030 that is of the same magnitude that occurred during the 30-year period from 1960 to 1990. Although the possibility of the Basin experiencing a return to the boom conditions of the 1970s seems remote under present circumstances, the assumption that it might happen is a reasonable basis for a high growth scenario for population forecasting.

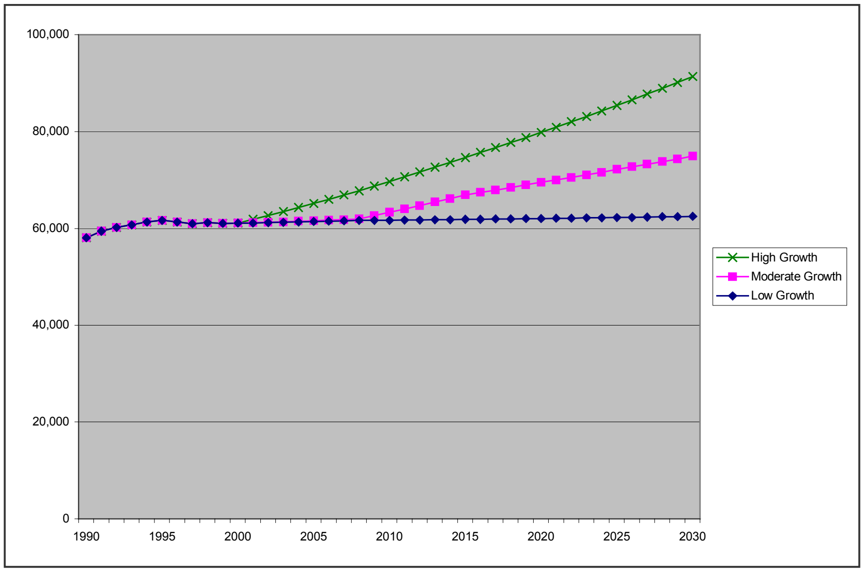
Low, Moderate, and High Growth Projections

The three methods described above were used to generate population forecasts through the year 2030 for each community and rural area in the Basin. Generally, the WDAI extended forecasts resulted in the smallest forecast for each community and rural area. The allocated USCB forecasts were generally middle of the road, and the historical growth projections generally produced the largest forecasts. There were some exceptions to these generalities, however. For example, Sublette County's population did not grow much during the period from 1960 to 1990 relative to other parts of the Basin. As a result, the historical growth scenario did not correspond to a reasonable high growth scenario for communities in Sublette County. On the other hand, the extended WDAI forecasts showed significantly faster population growth in Sublette County through the year 2030 than in other parts of the Basin.

To adjust for these anomalies, the high growth scenario for each community and rural area in the Basin was defined as the largest population forecast for 2030 produced by any of the three methods. Similarly, the low growth scenario was defined as the lowest 2030 population forecast, and the moderate growth scenario was defined as the middle 2030 population forecast.

The results of the low, moderate, and high growth projections for the entire Basin are depicted graphically in Figure IV-6.

Figure IV-6 Low, Moderate, and High Growth Population Projections



Municipal Use Projections

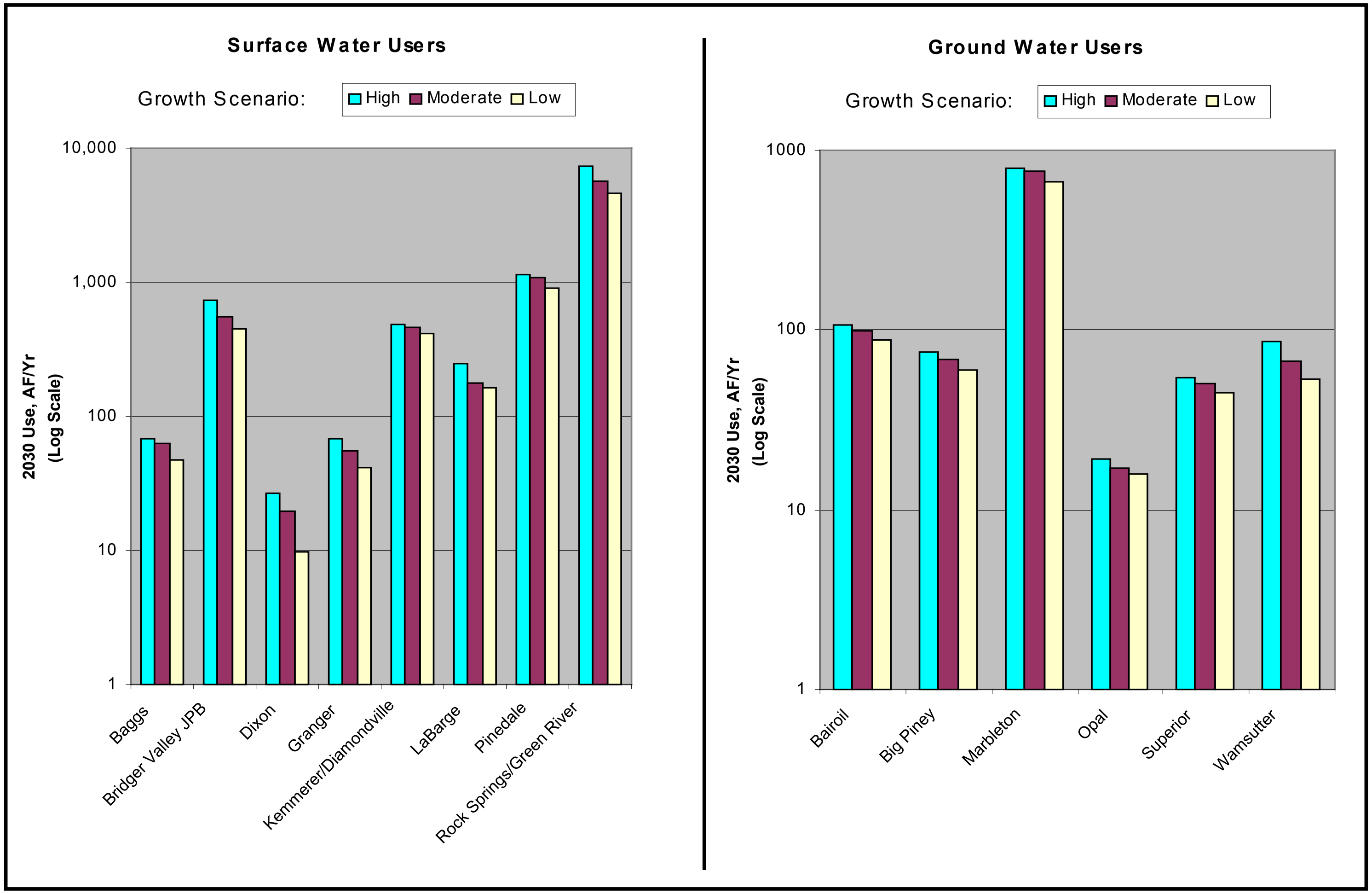
Per capita use rates for current municipal water consumption were presented in Chapter II. These rates were applied to population projections to estimate future municipal use. Table IV-1 presents the results of this calculation for the low, moderate and high growth rate scenarios. Figure IV-7 (p.IV-14) shows the municipal use projections in bar chart form. It should be noted that in some cases there is a small difference between current populations shown for municipalities in the Population Projections technical memorandum as compared to the Municipal Use technical memorandum. This difference is due to pure population estimates (given in the former) versus "service area" populations for municipal water service (from the latter). For projected municipal use calculations, the *service area population* was used with projections made using the *projected percent increases* for that municipality for each scenario from the Population Projections memo.

Not shown in these projections are future diversions from the upper Little Snake River Basin by the City of Cheyenne. These diversions are expected to peak at 22,700 acre-feet per year based on the system capacity and water rights currently held for this water system.

Table IV-1 Municipal Use Projections

City/Town	Current Population	Current use, gpcpd	2030 Population Projections, by Scenario Low	Moderate	High	2030 Use, by Scenario, gpd Low	Moderate	High	2030 Use, by Scenario, AF/Yr Low	Moderate	High
Surface Water Users											
Baggs	300	157	270	353	388	42,437	55,484	60,900	47.54	62.15	68.22
Bridger Valley JPB	4,500	86	4,698	5,684	7,641	404,028	488,781	657,126	452.60	547.54	736.13
Dixon	75	274	32	64	87	8,713	17,447	23,961	9.76	19.54	26.84
Granger	170	294	125	166	205	36,735	48,731	60,176	41.15	54.59	67.41
Kemmerer/Diamondville	3,950	80	4,689	5,080	5,449	375,092	406,376	435,922	420.19	455.23	488.33
LaBarge	490	251	576	630	872	144,513	158,042	218,922	161.89	177.04	245.24
Pinedale	1,480	474	1,714	2,019	2,152	812,360	956,873	1,020,010	910.02	1,071.91	1,142.64
Rock Springs/Green River	36,500	115	35,588	44,019	56,612	4,092,563	5,062,185	6,510,323	4,584.57	5,670.76	7,292.99
TOTAL	47,465		47,691	58,013	73,406	5,916,442	7,193,919	8,987,340	6,628	8,059	10,068
Ground Water Users											
Bairoil	250	314	250	280	302	78,500	87,920	94,828	87.94	98.49	106.23
Big Piney	496	90	590	679	745	53,100	61,110	67,050	59.48	68.46	75.11
Marbleton	635	787	755	866	907	594,185	681,542	713,809	665.62	763.48	799.62
Opal	100	120	117	128	142	14,040	15,360	17,040	15.73	17.21	19.09
Superior	300	133	303	336	363	40,299	44,688	48,279	45.14	50.06	54.08
Wamsutter	310	161	294	372	476	47,334	59,892	76,636	53.02	67.09	85.85
TOTAL	2,091		2,309	2,661	2,935	827,458	950,512	1,017,642	927	1,065	1,140
GRAND TOTAL	49,556		50,000	60,674	76,341	6,743,900	8,144,431	10,004,982	7,555	9,124	11,208

Figure IV-7 Municipal Use Projections



Domestic Use Projections

Chapter II presented current domestic uses, primarily served from ground water, estimated at 1,940 to 3,880 acre-feet per year (depending on per capita use assumption). Domestic users (the Basin's rural population), can be estimated as the difference between the total projected basin populations for the various growth scenarios and that part of the populace residing in established cities and towns. The cumulative projected domestic use totals can be estimated using the same per capita use rates as presented in Chapter II. The table below summarizes domestic use projections calculated in this manner.

Domestic Use Projections	Current	Low Growth Scenario	Moderate Growth Scenario	High Growth Scenario
Basin Population	61,100	62,500	75,000	91,400
Municipal Population	49,600	50,000	60,700	76,300
Rural Population	11,500	12,500	14,300	15,100
Domestic Use @ 150 GPCPD (in AF/Year)	1,940	2,100	2,400	2,540
Domestic Use @ 300 GPCPD (in AF/Year)	3,880	4,200	4,800	5,080

C. Industrial Demand Projections

This section presents projections of industrial water needs in the Green River Basin for the period from 2000 through 2030. These projections provide a basis for gauging the adequacy of current surface water and groundwater supplies in the Basin to meet potential future needs. Projections were developed for low, moderate and high growth planning scenarios.

Currently, the largest industrial water uses in the Basin are those associated with electric power generation and soda ash production. Future water needs for electric power production in the Basin will be largely determined by how electric utilities in the Basin and elsewhere in the west respond to growing demands and various actions and proposals to deregulate the industry. Scenarios for possible industry responses to deregulation are not easily developed. Similarly, future growth prospects for the soda ash industry are largely dictated by the ability of Wyoming producers to capture an increasing share of the international market in the face of volatile international economic conditions and the protective tariffs imposed by some foreign countries. The factors that influence the competitiveness of the Basin's soda ash producers in international markets are difficult to foresee.

The following sections discuss future growth prospects of the significant water using industries in the Basin and present low, medium, and high growth projections for future water use. The last section summarizes future industrial water needs.

Future Electric Power Production

Two coal-fired electric power plants are located in the Green River Basin; the Jim Bridger Power Plant near Point of Rocks in Sweetwater County and the Naughton Power Plant south of Kemmerer in Lincoln County. Both are owned and operated by Pacificorp, which is a subsidiary of Scottish Power. The Naughton Plant has a production capacity of 710 megawatts and consumptively uses approximately 13,500 acre-feet of water annually from the Hams Fork River. The Jim Bridger Plant has a production capacity of 2,000 megawatts and consumptively uses approximately 34,300 acre-feet of water annually from the Green River. Much of the power from the Naughton Plant is exported via transmission lines to Utah, while much of the power from the Jim Bridger Plant is exported to Pacificorp customers in the Pacific Northwest.

Restructuring of the electric utility industry offers both potential for future development and roadblocks to the development of additional generating capacity in the Green River Basin. Currently, electric generating capacity in the western U.S. is being fully utilized during peak periods of summer demand. The Department of Energy forecasted the possibility of brown outs in some parts of the West during the summer of 2000. This fact, coupled with various proposals to reduce hydropower production in the Pacific Northwest to lessen environmental impacts on endangered species, means that additional generating capacity will be needed in the near future to meet growing needs in the region. The availability of water and low sulfur coal resources in the Green River Basin makes it a logical location for new generating capacity to meet additional future power needs of the Rocky Mountain and West Coast regions.

One roadblock to developing additional generating capacity in the Basin is the possibility that industry restructuring will encourage large industrial power users in other states to develop co-generation facilities to meet their own needs and sell excess power to retail consumers. Another roadblock is the fact that the transmission lines that carry power out of the Basin to western markets are now at capacity, and Wyoming markets, where transmission capacity is adequate, are growing slowly. Thus, any substantial increase in generating capacity in the Basin would have to be accompanied by new transmission facilities to carry the power out of state.

The issue of how electrical utility industry restructuring evolves in the western U.S. will play an important role in determining the magnitude of future water requirements for electrical power generation in the Green River Basin. Three scenarios for future growth are described below.

Low Growth Scenario

The low growth scenario for future power generation projects current levels of water consumption for power generation to remain constant over the next thirty years. The low growth scenario is based upon the assumption that additional power needs in the western U.S. over the next 30 years will be met by the construction of new generating facilities outside of the Basin, possibly co-generation facilities developed in conjunction with industrial plants in other states. As a result, water requirements for power generation in the Basin will remain at current levels over the planning horizon. That level is approximately 47,800 acre-feet annually.

Moderate Growth Scenario

The moderate growth scenario is based upon the reasonably foreseeable possibility that co-generation facilities will not be developed at a rate sufficient to meet regional power needs over the next 30 years. It is also based on the assumption that the State of Wyoming and/or the Federal Energy Commission will take steps to solve the transmission bottleneck out of Wyoming and thus encourage the construction of additional electrical generating capacity in the Basin.

The logical location for a moderate expansion of generating capacity is the Jim Bridger Power Plant near Point of Rocks, east of Rock Springs. The facility was originally designed for up to six 500 MW coal-fired generating units, although only four such units have been installed. The existing units are among the most cost-efficient in the Pacific Power generating system, and an expansion to six coal-fired units at Jim Bridger would be a logical step to increase regional power production in a cost effective manner. The moderate growth scenario for electric power production in the Basin projects a 50 percent increase in water requirements for the Jim Bridger Power Plant over the next 30 years, with water requirements at the Naughton facility remaining constant at current levels. Total water use for the moderate growth scenario is projected to grow from a current rate of 47,800 acre-feet annually to approximately 65,000 acre-feet by the year 2030.

High Growth Scenario

The rapid economic growth that occurred in the Green River Basin during the 1970s and early 1980s was partially a result of political events that occurred beyond the Basin's boundaries. The threat of curtailed oil imports led the U.S. to mount a campaign for energy independence that emphasized developing and utilizing the nation's own energy resources, including oil and gas, uranium, and coal. The Green River Basin has abundant reserves of all of these natural resources, and high-energy prices and government programs to stimulate development of those resources led to a period of rapid growth in the Basin.

There are no immediate prospects for a disruption in international energy markets, and there is no evidence that the federal government is currently poised to reinstate programs to encourage domestic energy production. However, there is a possibility that over the next three decades international events will transpire in a manner that would place increasing emphasis on domestic energy production because of shortages of imported oil and/or surging energy prices. Such developments could lead the U.S. to institute incentives for developing new coal-fired electrical generating facilities to reduce the nation's dependence on foreign oil. The Green River Basin's water and coal reserves make it a natural place for such developments.

The high growth scenario for electrical energy production is based upon the reasonable possibility that high international energy prices and/or a disruption of oil imports into the U.S. will stimulate the construction of a significant addition to current electric generating capacity in the Basin. This scenario assumes that in addition to a 1,000-megawatt expansion of the Jim Bridger Power Plant, a new 3,000-megawatt coal-fired generating facility will be built in the vicinity of coal deposits near Creston Junction, utilizing water piped from the Green River.

The two existing coal-fired generating facilities in the Basin use approximately 47,800 acre-feet of water annually. At the same water utilization rate, the addition of 4,000 megawatts of generating capacity over the next 30 years would raise total water use for power production to 116,500 acre-feet annually. This figure represents a 144 percent increase over current levels.

Future Soda Ash Production

The trona patch in the vicinity of Green River, Wyoming is the site of five industrial facilities that convert trona to soda ash, an industrial product that is used in manufacturing glass, detergents, baking soda, and several other industrial and consumer products. As a group, these five facilities produced approximately 11.7 million tons of soda ash in 1999, and consumptively used about 17,900 acre-feet of water from the Green River. Not all of this water is used in soda ash production or related work; however, some soda ash facilities use cooling water for on-site electric power generation and sell their excess power. Total industry water usage for all purposes was estimated at about 18,100 acre-feet annually.

Future growth in soda ash production in the Basin will be largely dependent upon export markets. Domestic consumption has been relatively flat in recent years and is expected to grow by only 1.0 to 1.5 percent annually for the foreseeable future. This relatively low growth rate is attributable to the fact the U.S. market is relatively mature in terms of per capita consumption of soda ash products.

Foreign demand for soda ash, especially in developing countries, is expected to increase at a more rapid rate than in the U.S. over the next 30 years. As disposable income rises in developing countries, consumption of beverages in glass containers is expected to become commonplace. The increased use of glass containers in foreign markets is expected to translate into increased demand for U.S. soda ash because the U.S. has the world's largest deposits of trona and is the lowest cost producer of soda ash.

Other factors that affect future U.S. soda ash production include trade barriers that many countries have established to protect their domestic soda ash industries that, in some cases, utilize synthetic processes that are not cost competitive with natural soda ash imports. Over the next 30 years, efforts by the World Trade Organization and the U.S. government have the potential to lower these tariff barriers and open up new markets for U.S. soda ash. Soda ash exports from the Basin may also receive a boost from future cost savings in the production (using solution mining) and transportation of soda ash.

How all of these influences come together over time will largely determine the future growth rate of soda ash production in the Basin and the corresponding need for additional process water. Three scenarios for future water needs for the Basin's soda ash industry are described below.

Low Growth Scenario

The low growth scenario for future soda ash production projects no significant changes in the structure of domestic or international markets for soda ash over the 30 year planning horizon, and no significant changes in production and transportation costs for Wyoming producers. Under these conditions, Green River Basin producers would be expected to maintain their current shares of both domestic and international markets, and their production would be expected to grow roughly proportional to growth in consumption. The overall future growth rate for soda ash production in the Basin is projected to be 1.75 percent annually for the low growth scenario.

The amount of water used for soda ash production varies widely among producers. Based upon industry interviews, the overall average consumptive use rate for current production in the Green River patch is on the order of 450 gallons per ton of soda ash production. This figure was used to project future water requirements for the industry for the low growth scenario.

At a 1.75-percent annual growth rate, soda ash production in the Basin will grow from 11.7 million tons in 1999 to 20.0 million tons by the year 2030. The production increase of 8.3 million tons annually will require an estimated 3.735 billion gallons of additional water annually, the equivalent of approximately 11,500 acre-feet. That increase would bring total consumptive use up to 29,600 acre-feet by the year 2030, an increase of 64 percent over current levels.

Moderate Growth Scenario

The moderate growth scenario, like the low growth scenario, projects no significant changes in the structure of domestic or international markets for soda ash over the next 30 years. Unlike the low growth scenario, however, this scenario projects the reasonably foreseeable possibility that producers will be able to achieve an additional competitive advantage in the export marketplace through reductions in rail transportation costs and the implementation of solution mining for a portion of their future production.

Foreign soda ash consumption is estimated to be roughly 25.0 million tons annually of which approximately 20 percent is supplied by Wyoming producers. If foreign consumption increases at the projected rate of 2.5 percent annually, it will reach 53.8

million tons by the year 2030. Wyoming producers could reasonably expect to increase their share of foreign market penetration from 20 to 25 percent as a result of efficiencies described above, meaning that total foreign sales would approach 13.5 million tons annually by the year 2030. Assuming that domestic sales continue to grow at the project rate of 1.25 percent, total soda ash production would be 23.8 million tons by the year 2030, an increase of 12.1 million tons over current levels.

The water requirements associated with this scenario are more difficult to estimate than for the low growth scenario because of the assumption that solution mining would be employed for a portion of future production. For purposes of estimating water requirements for this scenario, it was assumed that 50 percent of future production increases would come from solution mining, and that solution mining techniques would require 750 gallons of water per ton of soda ash production. Based upon these assumptions, the consumptive use of water by soda ash industry in the Basin would grow by 22,300 acre-feet annually by the year 2030 to a total of 40,400 acre-feet. This figure represents a 123 percent increase over current water consumption levels.

High Growth Scenario

The high growth scenario for soda ash production in the Basin, like the moderate growth scenario, projects increasing efficiencies in production and transportation through solution mining and competition in rail transportation of the finished product. In addition, this scenario projects the possibility of structural changes in some overseas markets that will result from falling tariffs and the elimination of certain other trade barriers. If trade barriers to U.S. exports of soda ash are gradually lowered or eliminated over the next 30 years, Wyoming producers could be expected to benefit enormously because they have a competitive advantage with respect to production costs that few other suppliers can equal. The high growth scenario for Wyoming producers is based upon the assumption that they could reasonably capture one-third of the total world market of 53.8 million tons by the year 2030.

Assuming that domestic production in the patch will grow at 1.25 percent annually, and that exports will grow to one-third of foreign consumption by the year 2030, total estimated soda ash production in the Basin would be 28.1 million tons in 30 years. Assuming that 50 percent of the increased production comes from solution mining (750 gallons per ton) and 50 percent from conventional processes (450 gallons per ton), the increase in annual water requirements for the industry by the year 2030 will be 30,200 acre-feet. Total water requirements for the industry would be 48,300 acre-feet annually, an increase of 167 percent over current levels.

Other Surface Water Uses

Electrical power generation and soda ash production constitute the current major uses of surface water for industrial purposes in the Green River Basin. The only other surface water user of significance is FS Industries, which manufactures phosphate fertilizer in a plant near Rock Springs. This plant current consumptively uses about 560 acre-feet of water annually, which is purchased from the Rock Springs-Green River Water Supply

System. Future expansion of this facility is possible, although the timing and magnitude of expansion are uncertain. For purposes of projecting future water needs, the low growth scenario for this facility assumes no future growth in water needs over the 30 year planning horizon. For the moderate growth scenario, consumptive use is projected to increase to 1,000 acre-feet annually by the year 2030. For the high growth scenario, consumptive use is projected to increase to 1,500 acre-feet annually by the year 2030.

Groundwater Uses

The oil and gas industry is an important user of ground water in the Basin, although water requirements are generally small and spread over a large geographic area. Water is used to create mud during drilling and can be used for flooding during production. The Bureau of Land Management (BLM) has projected that the number of producing oil and gas wells in the Green River Resource Area (GRRA) through the year 2010. That projection shows that the total number of producing wells is expected to decline slightly from a total of 1,725 in the year 2000 to about 1,570 in the year 2010. Although the number of new wells drilled each year is expected to increase during this period, the number of wells abandoned each year is projected to more than offset the increase in drilling. Thus, there are no indications of a significant change in future water requirements for oil and gas drilling in the Basin.

There is a potential for coal-bed methane development to impact groundwater resources in a limited area of the Basin over the next 30 years. The extent of future development is uncertain at this time because the commercial viability of developing available reserves has not been established. According to the BLM, however, almost all potential reserves are located in an area north of Rock Springs and extending east and west from Eden. This area, encompassing less than 10 percent of the land area of Sweetwater County, is believed to contain up to 98 percent of the developable reserves in the GRRA. The BLM projects that up to 300 commercial wells could be developed in this area in the coming decade.

Coal-bed methane development is not a consumptive user of groundwater resources, but does produce ground water as a by-product of gas production. Several options for groundwater disposal may be available to methane producers, including reinjection, disposal ponds, discharge, and various combinations of these alternatives. The potential for coal-bed methane development to affect other industrial groundwater users in the Basin is unknown at this time.

The Kennecott Uranium Company also has a number of groundwater permits for its inactive mine and processing facility in the Great Basin northeast of Rawlins. When it was operational, the mine used well water in a process solution for extracting uranium from ore. Given current conditions in the world market for uranium and prospects for future growth, however, the prospects for the mine and processing facility reopening during the planning horizon of this study are remote.

Potential New Industrial Uses

The industrial water use projections for the Green River Basin described above focus on existing industries and their future water needs. The potential for new industries to locate in the Basin to take advantage of available water resources also merits discussion. According to the U.S. Census Bureau, four industry groups account for over 95 percent of all of the industrial water used in this country each year. These industries are (1) electric power producers, (2) chemical and allied products manufacturers, (3) primary metals producers, and (4) paper and allied products manufacturers. Electric power producers alone consume over 80 percent of all industrial water used in this country each year. The other three industry groups account for roughly 14 percent of all industrial water use.

The Green River Basin is already well represented with respect to electric power production and chemical manufacturers (the soda ash and phosphate industries fall into this group). The other two intensive water use industries, primary metals and paper producers, tend to locate near the source of their largest process inputs -- metals and wood respectively. It thus appears likely that any new water intensive industrial developments in the Basin over the next 30 years will fall into the electric power generation and/or chemical products categories.

Expansion of electric power production in the Basin is discussed earlier, as is the potential for expansion by the soda ash and phosphate fertilizer industries. The possibility remains that new industrial water uses not discussed in this report will develop over the next 30 years, but the nature and extent of such developments is not foreseeable at this time and water requirements for such developments are not included in the projections described in this memorandum.

Summary of Findings

Projected industrial water requirements for the Green River Basin are presented graphically in Figure IV-8, and the numerical results are summarized in Table IV-2. These projections are for surface water requirements for large industrial water users. The results show that for the low growth scenario, water requirements are expected to increase from a current level of 66,500 acre-feet to 78,000 acre-feet by 2030, an increase of 17 percent. The moderate growth scenario projects a reasonably foreseeable requirement of 106,400 acre-feet by 2030, an increase of 68 percent. For the high growth scenario, requirements are projected to grow to 166,300 acre-feet, an increase of 150 percent.

Figure IV-8 Total Industrial Water Use Projections

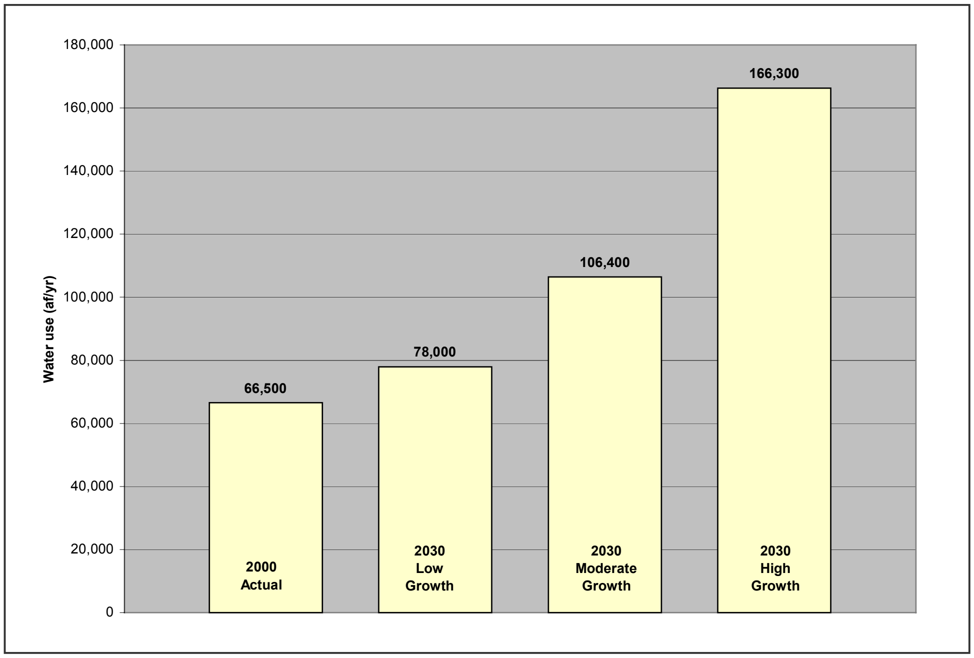


Table IV-2 Industrial Water Use Projections

Scenario/ Industry	Consumptive Use (af/yr) 2000	 2030	Percentage Change
Low Growth			
Electric power	47,800	47,800	0%
Soda ash[1]	18,100	29,600	64%
Other[2]	600	600	0%
Total	66,500	78,000	17%
Moderate Growth			
Electric power	47,800	65,000	36%
Soda ash[1]	18,100	40,400	123%
Other[2]	600	1,000	67%
Total	66,500	106,400	60%
High Growth			
Electric power	47,800	116,500	144%
Soda ash[1]	18,100	48,300	167%
Other[2]	600	1,500	150%
Total	66,500	166,300	150%

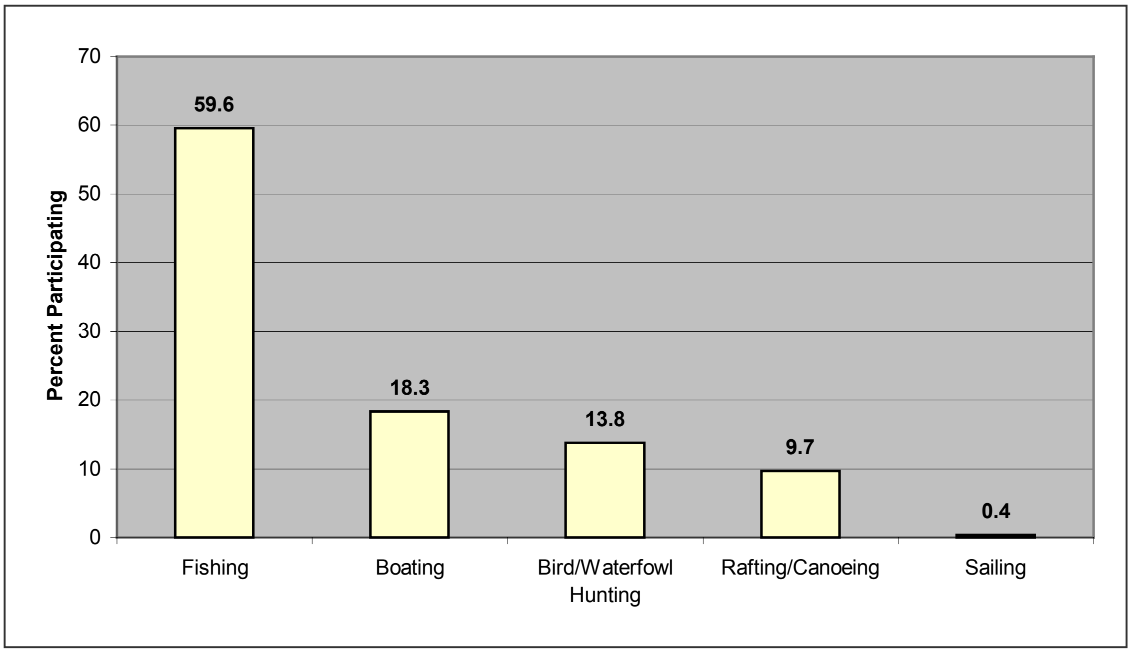
[1]Includes related production activities.
[2]Excludes groundwater and small municipal water users.

D. Recreational Demand Projections

Current Recreation Activity

Detailed descriptions of water-based recreational pursuits in the Basin are given in Chapter II. The most popular water-based recreational activity in the Green River Basin is fishing. About 60 percent of Basin residents participated in fishing activities in 1989, the most recent year for which detailed survey information is available. Other current water-based recreation participation rates are shown in comparison in Figure IV-9.

Figure IV-9 Resident Participation in Water-based Recreational Activities



The Wyoming Game and Fish Department (WGF) provided estimates of the current number of annual activity days of angling and waterfowl hunting in the Green River Basin (Chapter II). The results show that still water fishing on lakes and reservoirs in the Basin accounts for almost one-half million activity days annually. About 80 percent of this activity occurs on lowland reservoirs, the largest of which are Flaming Gorge and Fontenelle. Another 15 percent of still water fishing activity occurs on alpine lakes and reservoirs, which are concentrated on national forest lands in the Pinedale area. The remaining five percent of activity days involve fishing on farm ponds and natural lowland lakes scattered throughout the Basin.

Stream fishing in the Basin accounts for about 300,000 activity days annually. The main stem of the Green River above Flaming Gorge Reservoir and several of its tributaries in the northern part of the Basin provide very good trout fishing opportunities. The most popular areas for stream fishing in the Basin are the Green and New Fork Rivers in the Pinedale area and the Green River below Fontenelle Reservoir.

Waterfowl hunters spend about 10,600 days annually in the pursuit of ducks and geese that inhabit or pass through the Basin. The two most heavily hunted areas are the Seedskadee National Wildlife Refuge and the Eden-Farson-Big Sandy area.

Activity day estimates are not available for other water-based recreational pursuits, including boating, water skiing, rafting, canoeing, sailing, and wind surfing. Total visitation estimates are available for certain large bodies of water such as Flaming Gorge and Fontenelle Reservoirs, but these estimates are for all uses, including sightseeing, picnicking, and camping, regardless of whether water based recreation is involved.

Recreation Demand Projections

Future demands for recreational water resources in the Basin depend upon numerous factors, including population growth, tourism growth, and participation rates in various water-based recreational activities. Future participation rates depend upon changes in preferences over time as well as the availability of water resources and the amount of congestion encountered at recreational sites. Changes in future recreational preferences are hard to predict, so the projections described in this section are based upon the assumption that participation rates remain constant over the planning horizon. This assumption means that projected recreational demands are proportional to growth in population and tourism in the Basin.

Projections of population growth in the Basin are described earlier in this chapter. Those projections are summarized in Table IV-3 in terms of average annual growth rates for the low, moderate, and high growth planning scenarios. Table IV-3 also gives projections of tourism growth over the planning horizon for low, moderate, and high growth scenarios.

Table IV-3 Projected Annual Growth Rates: Population & Tourism (2000-2030)

Scenario	Average Annual Growth Rate (percent)	
	Basin Population	Tourism
Low growth	0.08	1.00
Moderate growth	0.68	2.00
High growth	1.35	3.00

The other information needed to project future recreation demand is a breakdown of recreational activity data between residents and nonresidents. According to the WGF, residents of the Basin account for about 68 percent of the fishing activity days on lakes and about 58 percent of the fishing activity days on streams. Residents also account for about 82 percent of the waterfowl hunting activity in the Basin and about 63 percent of the boating activity.

This information was used to project future recreational activity days over the 30-year planning horizon from 2000 to 2030. Those projections are given in Table IV-4. The demand for still water fishing, the most popular recreational activity in the Basin, is projected to expand significantly over the next three decades. Similar increases are projected for stream fishing demands in the Basin.

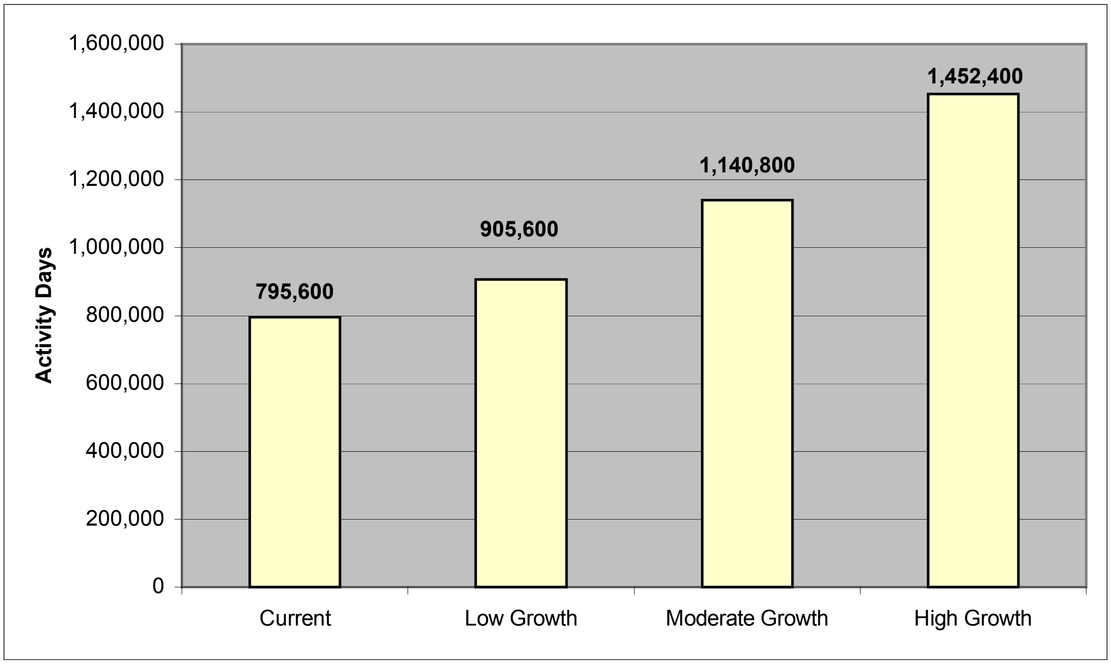
Table IV-4 Current and Projected Water-based Recreational Activity Days (2000-2030)

Activity	Activity Days			
	Current	Low growth	Moderate growth	High growth
Stillwater fishing	485,000	547,000	685,300	868,800
Stream fishing	281,700	326,900	414,500	531,400
Waterfowl hunting	10,600	11,500	14,100	17,600
Boating, rafting, etc.	n/a	+14%	+44%	+85%

The demand for waterfowl hunting is also expected to increase over the planning horizon, but at a lesser growth rate than for fishing. The last recreational activity described in Table IV-4 encompasses all forms of boating, rafting, canoeing, and sailing. No information is available concerning current Basin-wide boating activity days. The projections for this activity category in Table IV-4 show the percentage increases in demand that are expected for this activity, given projected increases in population and tourism in the Basin over the planning horizon.

A summary of current and projected recreational activity day demands is presented in Figure IV-10 for those activities for which data are available (fishing and waterfowl hunting). The results show that, currently, those activities account for about 796,000 user days annually. For the low growth scenario, that figure is expected to rise to 905,600 activity days by the year 2030, an increase of 14 percent. For the moderate and high growth scenarios, the projections are for 1,140,800 and 1,452,400 activity days, respectively, by the year 2030. These projections constitute increases of 43 and 83 percent over current recreational activity estimates.

Figure IV-10 Current and Projected Recreational Activity Days (2000-2030)



Adequacy of Existing Resources to Meet Projected Demands

The WGF in the past has estimated the supply of water resources available to meet the demands of fishermen in various regions of the State. These supply estimates were expressed in terms of fishermen days, and reflect the amount of pressure that the Department believed at that time (1988) that publicly accessible fisheries could withstand without significant deterioration. Although these estimates have not been updated in the past decade, they serve as one benchmark for judging the capacity of fisheries in the Green River Basin to meet projected future demands. It should be emphasized, however, that these supply estimates reflect not only resource availability in 1988, but also the management goals and objectives of the WGF in terms of fishing success rates and other factors.

According to the WGF, the Green River Basin and the Bear River Basin combined provide an annual supply of 1,122,800 activity days of lake and reservoir fishing opportunities. Almost all of this supply is located in the Green River Basin. When contrasted with current utilization rates of about 485,000 activity days of use annually, it is apparent that there is no current shortage of still water angling opportunities in the Basin. This observation is consistent with the observed fact that the region is endowed with numerous lake and reservoir fisheries ranging from small alpine lakes in the higher elevations of the Bridger-Teton National Forest to Flaming Gorge and Fontenelle Reservoirs in the lower part of the Basin.

Projections of future demands for still water fishing opportunities described above range from 547,000 to 870,000 activity days annually by the year 2030, depending upon the growth scenario used. None of these projections approach the estimated supply of over 1.1 million angling days, meaning that the supply of lake and reservoir fishery resources in the Basin should be adequate to meet projected needs for the foreseeable future, as shown in Figure IV-11.

Figure IV-11 Supply and Demand of Green River Basin Fishing

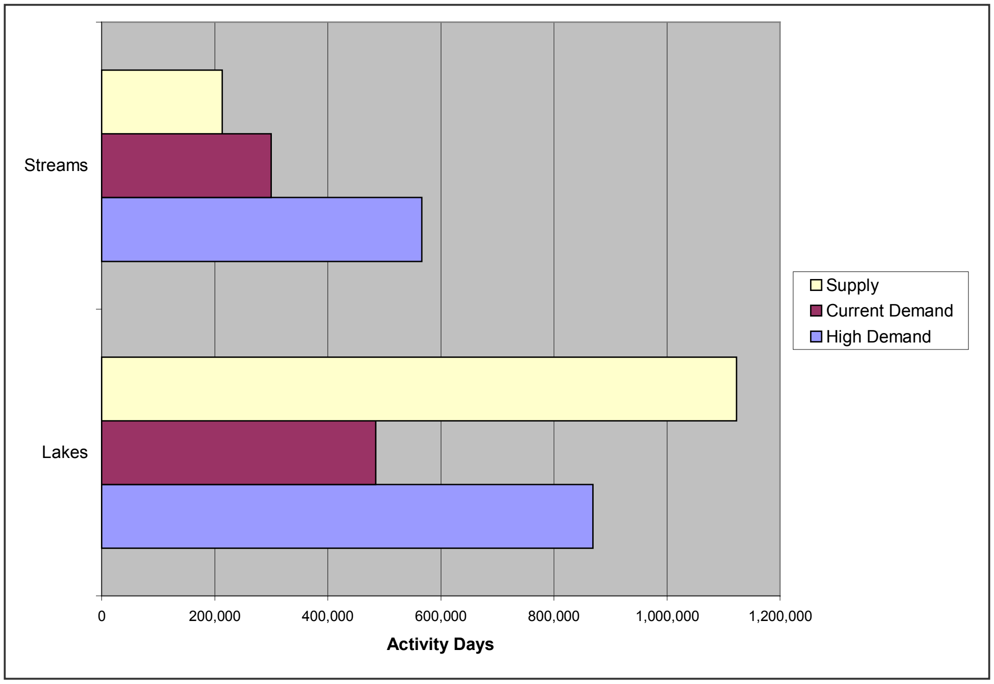


Figure IV-11 shows that a somewhat different conclusion applies to the Basin's stream fisheries. According to the WGF, in 1988 the Basin had a total supply of about 411,000 angler days of stream fishing opportunities available, but only about 213,000 angler days of this supply were in areas where public access was guaranteed. That figure contrasts with a current estimated annual use of about 300,000 angler days of activity, and projected demands in the range of 327,000 to 566,000 angler days of activity by the year 2030. These estimates indicate that the Basin's stream fisheries are at capacity now, on the average, and will come under increasing pressure in the future as its population increases and tourism related fishing pressure grows. Inside these numbers, there are likely some public streams that are underutilized because of remote location or where access is made difficult by private holdings. Likewise, easily accessible public reaches may be over utilized.

The implications of this latter conclusion are limited by the fact that there is a relatively fixed supply of streams in the Basin that are suitable for maintaining recreational fisheries. One inference that can be drawn is that any future water development activities in the Basin that would denigrate existing recreational stream fisheries could have significant negative recreational effects. On the other hand, new reservoir projects in the Basin could generate significant recreational benefits if they include provisions for establishing tailwater fisheries in areas where quality fisheries do not currently exist.

The other water-based recreational pursuit for which demand projections were developed is waterfowl hunting. Those projections indicate that demand is expected to rise from a current level of 10,600 activity days to between 11,500 and 17,600 activity days by the year 2030 (Table IV-4). The WGF has not estimated the supply of waterfowl hunting opportunities in the Basin, partially because populations are migratory and hunting seasons and bag limits are established in accordance with guidelines established by the U.S. Fish and Wildlife Service.

E. Environmental Demand Projections

Current environmental uses of water in the Green River Basin are described in Chapter II. Those uses include:

- instream flows and reservoir bypasses;
- minimum reservoir pools and channel maintenance flows;
- maintenance of wetlands, riparian habitat, and other wildlife habitat, and;
- direct wildlife consumption.

Unlike recreational water requirements, environmental water requirements are not necessarily related to changes in population or tourism in the Basin. Instead, environmental water requirements are at least partially a function of human desires concerning the type of environment in which people want to live. These desires are expressed in many ways, including environmental programs and regulations promulgated by elected representatives at the state and federal levels. Thus, future environmental water requirements in the Green River Basin will be determined, at least partially, by existing and new legislation dealing with environmental issues at the state and federal levels, and how that legislation is implemented by federal and state agencies.

Examples of such legislation include Wyoming Statutes S41-3-1001 to 1014, which stipulate that instream flows are a beneficial use of Wyoming's water and specify procedures for establishing such flows using unappropriated water. This legislation authorizes the WGF to specify stream segments and flow requirements for an instream flow filing. The WWDC is authorized to file an instream flow application with the State Engineer and perform hydrologic analyses on filings recommended by the WGF. The State Engineer can then issue a permit for an instream flow water right following a public hearing.

Future water requirements for instream flows in the Green River Basin (and other river basins throughout the State) depend largely upon how Wyoming's instream flow legislation is implemented over the 30-year planning horizon. Projecting the outcome of this process quantitatively would be difficult, and is perhaps unnecessary because instream flows and other environmental water uses are largely non-consumptive. Instream flow designations can conflict with potential new out-of-stream uses at specific locations, however, a topic that is discussed below.

Instream Flows and Reservoir Bypasses

Wyoming's instream flow statutes recognize the obvious economic fact that Green River Basin water resources have value in non-consumptive uses such as instream flows. Such flows not only contribute to aesthetic character and biological diversity of the Basin, they also support recreational fisheries that are important to Basin residents and to the Basin's economy.

The WGF has a goal of maintaining and enhancing existing fisheries in the Green River Basin through the statutory designation of instream flow segments and other management strategies. An important subsidiary objective of the Department is to protect existing populations of Colorado River cutthroat trout and increase the distribution of the species in their ancestral waters. The Department has implemented a management plan in cooperation with the U.S. Forest Service for managing Colorado River cutthroat populations in the Basin that includes seven elements, ranging from population and habitat surveys to non-native trout removal and instream flow reservations.

Although the WGF has not completed its assessment of instream flow needs in the Green River Basin, it does not anticipate developing additional flow recommendations during the next five years. If and when additional instream flow requests are forthcoming, they would likely be in conjunction with Department efforts to maintain and reestablish Colorado cutthroat trout populations in the northwest tributaries of the mainstem Green River in the Big Piney area, certain tributaries in the Pinedale area, and small streams in the Blacks Fork and Little Snake Drainages. The extent to which current and future instream flow requests may conflict with potential storage developments for supplemental irrigation water in the Basin is unknown, but the potential for conflicts does exist. These conflicts would have to be resolved on a case-by-case basis, weighing the potential benefits of water to the State in instream versus out-of stream uses.

Other groups in the Basin are pursuing alternative strategies to enhance stream flows while preserving traditional water uses. For example, Wyoming Trout Unlimited and private water rights holders in the Pinedale area have agreed to enhance the stream fishery below Fremont Lake through voluntary water releases during low flow periods. Such strategies will likely become more common in the future as the demand for stream fishing opportunities increases.

Another tool for maintaining fisheries habitat in the Basin is the provision of minimum flow bypasses at reservoir sites. Currently, only three reservoirs in the Basin have minimum flow bypasses included as requirements in their permitting documents;

Fontenelle, Meeks Cabin, and Stateline Reservoirs. The development of additional reservoir storage in the future would likely bring about requests by the WGF and others for such minimum flow bypass requirements.

Minimum Reservoir Pools and Channel Maintenance Flows

Another environmental water use is the provision of minimum reservoir pools for fish and wildlife purposes. Five reservoirs in the Basin have "fish" or "fish and wildlife" uses listed in their permitting documents; Big Sandy, Boulder, Flaming Gorge, Fontenelle, and High Savery. Of these, only two have a specific amount of storage committed to a minimum pool: Boulder with 1,621 acre-feet, and High Savery with 4,955 acre-feet. Given the current federal regulatory environment and the desires of the public to maintain and enhance recreational fisheries in the Basin, it is likely that any additional storage developed in the future will have a portion of its storage devoted to fish and wildlife purposes.

Only three reservoirs have flow bypasses required by permit. These are Fontenelle Reservoir (50 cfs at the City of Green River), Meeks Cabin Reservoir (10 cfs) and Stateline Reservoir (7 cfs).

The technical memorandum devoted to describing environmental uses further details the WGF estimates of recommended water levels in reservoirs and maintenance flows for live streams.

Wildlife Habitat

Another important environmental use of water in the Basin is the provision of habitat for wildlife. Wildlife habitat exists in wetland and riparian areas on public and private lands throughout the Basin, some of it occurring naturally and some of it as a result of human activity.

One federally managed area dedicated to the preservation and restoration of wildlife habitat is the Seedskadee National Wildlife Refuge, which contains approximately 26,000 acres of land along the Green River below Fontenelle Reservoir. One goal of the refuge is to reestablish a number of wetlands that existed prior to the construction of Fontenelle Reservoir. These wetlands were maintained by high early season flows that have been reduced since the reservoir became operational. No precise estimates are available for the number of wetland acres that might be reestablished in the future, but the refuge does have the right to divert up to 28,000 acre-feet of direct flow and storage water annually below Fontenelle Reservoir. Under high growth assumptions, depletions for wetlands reestablishment or forage may approach one-half of that amount on an annual basis.

Three federal programs, the Conservation Reserve Program (CRP), the Wetlands Reserve Program (WRP), and the Wildlife Habitat Incentives Program (WHIP) encourage the development of wildlife habitat on private lands. The CRP program is administered by the Farm Service Agency of the U.S. Department of Agriculture (USDA), and provides incentive payments for various conservation practices that will enhance wildlife habitat, as well as improve water quality and reduce erosion. Only a small amount of acreage in the Basin is currently enrolled in the CRP.

More lands in the Basin are expected to be enrolled in the CRP in the future, although no acreage estimates were made for purposes of this water plan. Most CRP lands do not involve consumptive use of surface water and thus will not affect future surface water availability for other uses.

The WRP is administered by the Natural Resources Conservation Service (NRCS) of the USDA. It is a voluntary program that provides financial and technical assistance to private landowners to reestablish wetlands on their property. Currently, there are 44 acres of land in the Basin enrolled in the WRP with an estimated annual consumptive water use of 110 acre-feet. These lands consumptively use water through evapotranspiration. Since the acreages in the WRP are relatively small, no projections of future depletions for this use were made.

The WHIP is also administered by the NRCS, and provides technical and financial assistance to private landowners interested in improving wildlife habitat on their property. Approximately 240 acres of land in the Basin is currently enrolled in the WHIP, but involve no consumptive use of surface or ground water. As a result, no projections of future water needs for such lands were developed as a part of this water plan.

The Little Snake River Conservation District has been active in establishing wetland areas in the Little Snake Drainage. These lands are not currently registered under the WRP, although they may be in the future. During the 1990s, 113.5 acres of wetlands were created, with an estimated consumptive use of 284 acre-feet. The District hopes to triple this acreage over the next 30 years, resulting in an annual depletion of almost 1,000 acre-feet.

Direct Wildlife Consumption

The only estimates of current consumptive water use by wildlife in the Basin are approximate. They indicate that big game and wild horses consumptively use about 500 acre-feet of water annually, 100 acre-feet from groundwater sources and 400 acre-feet from surface water sources. This level of consumptive use is relatively small and is not expected to change significantly over the planning horizon. These uses are not caused or imposed by man and therefore are not included in uses that count toward the Compact allocation.

Summary

For future man-made environmental uses in the Basin, the following scenarios were developed. Under low-growth assumptions, existing uses of 2,000 acre-feet per year are estimated to grow to about 10,000 acre-feet per year. The 8,000 acre-foot increment is presumed to include developments in the Little Snake River Basin (1,000 acre-feet), undifferentiated increases in enrollments in federal assistance programs, and additional environmental uses such as riparian improvements and evaporation from otherwise constructed environmental features. The moderate growth scenario assumes the base 10,000 acre-foot depletion in the low growth scenario plus an additional 7,000 acre-foot depletion at Seedskadee National Wildlife Refuge (14,000 acre-foot additional diversion at a 50 percent consumption rate). The high growth scenario is the low growth value plus 14,000 acre-foot depletion at Seedskadee (maximum 28,000 acre-foot diversion at a 50 percent consumption rate).

F. Summary of Projected Water Demands

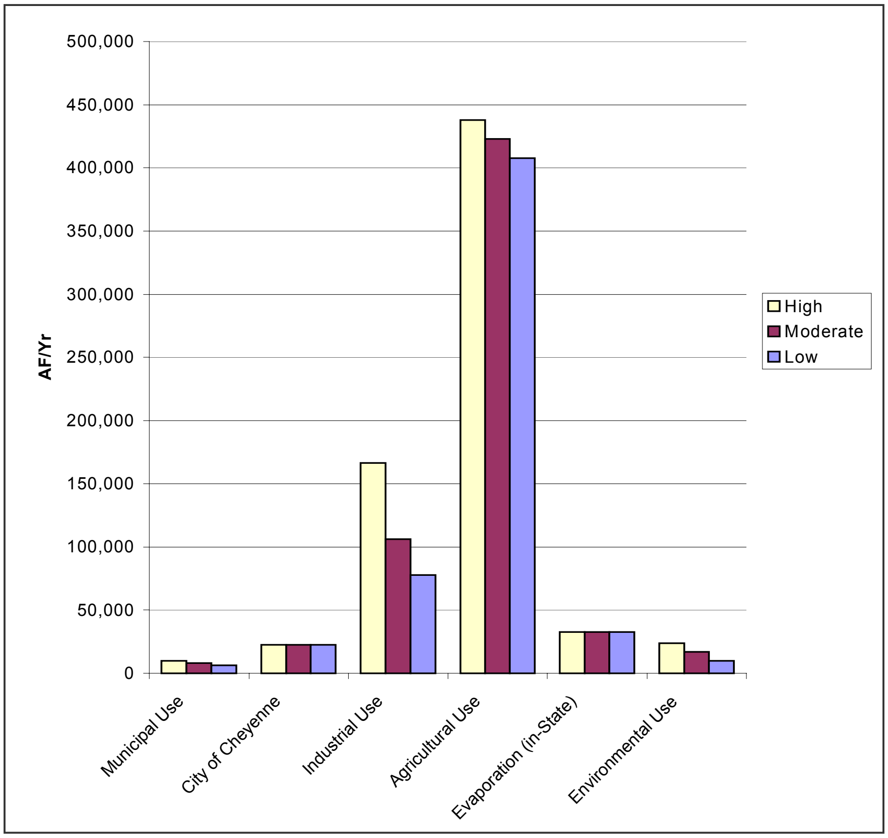
Table IV-5 presents water use projections for all sectors described in this chapter. Figure IV-12 shows this information graphically.

Table IV-5 Summary of Projected Uses

Surface Water	Projected Growth Scenario (AF/Year)		
	Low	Moderate	High
Municipal Use	6,600	8,100	10,100
City of Cheyenne	22,700	22,700	22,700
Industrial Use	78,000	106,400	166,300
Agricultural Use	408,000	423,000	438,000
Evaporation (in-State)	32,800	32,800	32,800
Recreation Use	non-consumptive		
Environmental Use	10,000	17,000	24,000
Total (rounded)	**558,100**	**610,000**	**693,900**
% Compact Allocation	**67%**	**73%**	**83%**
Main-Stem Evaporation Charge (Full Development)	**72,800**	**72,800**	**72,800**
Grand Total	**630,900**	**682,800**	**766,700**
% Compact Allocation	**76%**	**82%**	**92%**

(assumed allocation = 833,000 acre-feet per year)

Figure IV-12 Summary of Projected Uses



G. Future Uses as Related to Compact Allocation

Table IV-6 shows how these projected uses compare to the amount of consumption currently used as Wyoming's allotment under the Colorado River Compact and the Upper Colorado River Basin Compact as described in Chapter I.

Table IV-6 Projected Use of Compact Allocation

Surface Water	Projected Growth Scenario (AF/Year)		
	Low	Moderate	High
Wyoming's Share of the Upper Colorado River Water:	833,000	833,000	833,000
Estimated Depletions:	630,900	682,800	766,700
Remaining Compact Allotment:	202,100	150,200	66,300

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V Future Water Use Opportunities

As with all chapters in this final plan report, explicit lists of references are not provided. Instead, all references to report, documents, maps, and personal communications are maintained in the Technical Memoranda that were prepared during the current planning process. Should the reader desire to review a complete list of references for the information presented in this chapter, the following memoranda should be consulted:

- Criteria for Screening Future Water Use Opportunities
- Water Conservation
- Institutional Constraints

A. Review of Previous Planning Studies

Over the years many planning studies have been undertaken for Wyoming's Green River Basin. A summary outline of those most dedicated to additional development of water resources includes:

- Person, H.T., Lee, C.A., and Moir, C.D., Workers on WPA Project 65_83_107, February 1938, "Report on Water Resources of Colorado River Basin in Wyoming (Green River and Little Snake River)," Wyoming State Engineer's Office.

  ***Focus**: This was probably the first comprehensive hydrologic study of the Green and Little Snake River Basins in Wyoming. The report evaluated climate, runoff, irrigated lands, and future needs and studied 16 potential irrigation projects and 36 reservoir sites. A recommended plan of development was proposed which included three groups of priorities; those projects needed immediately, those that were desirable but needed further study, and those that could be deferred. The concept of transbasin diversion of water was discussed, but caution was advised in taking water that could ultimately be needed in-basin.*

- J. T. Banner & Associates, Inc., July 1969, "Report on Preliminary Reconnaissance of Potential Reservoirs: Green River Basin, Wyoming," Department of Economic Planning and Development, and Wyoming Water Planning Program, State Engineer's Office.

  ***Focus**: Discussed physical studies of Upper and Lower Kendall, New Fork Narrows, and Lower Green Reservoir sites. Did not review needs or depletions, but relied upon the Wyoming Water Planning Program for those details.*

- Wyoming Water Planning Program, September 1970, "Water and Related Land Resources of the Green River Basin, Wyoming," Wyoming Water Planning Program Report No. 3, Wyoming State Engineer's Office.

Focus: *The predecessor plan to the current study, this document evaluated water resources of the Basin and proposed alternative plans to meet future municipal, industrial, agricultural, recreation and environmental needs for water.*

- United States Bureau of Reclamation Region 4, May 1972, "Alternative Plans for Water Resource Developments: Green River Basin, Wyoming," United States Department of the Interior.

  Focus: *Another broad planning document, this report focused primarily on the Kendall, New Fork, Boulder Lake and Lower Green Reservoir sites. The study also evaluated delivery of significant amounts of water for industrial use to Baggs Junction and Point of Rocks. Out-of-basin diversions to the North Platte River drainage were included.*

- Tipton and Kalmbach, Inc., October 1972, "Engineering Report on the Development of Presently Unused Water Supplies of the Green River Basin in Wyoming: With Particular Reference to the Feasibility of Providing Additional Reservoir Storage," Wyoming Department of Economic Planning and Development.

  Focus: *This relatively complete planning study used depletion estimates from the WWPP Report No. 3 (above) for agricultural uses, although the report looked primarily at providing water for industrial use. At the time this report was prepared, significant industrial growth in the lower basin was anticipated. Storage evaluation was limited to the Plains and Lower Green sites. This report gives a relatively strong discussion of the effects of such development on Wyoming's Compact allotments.*

- Hanson, Michael L., Buhel R. Heckathorn and Robert A. Rathjen, April 1978, "Environmental Base Working Paper," Green River Basin Wyoming, Type IV Study, Based on a Cooperative Survey by the State of Wyoming – Wyoming State Engineer and the U.S. Department of Agriculture.

  Focus: *One of a series of working papers under the Type IV umbrella, this document presents a descriptive overview of environmental and recreational characteristics and needs in the Basin. Significant discussion is devoted to the fishing resource including relative "use vs. capacity" analyses.*

- Economics, Statistics, and Cooperatives Service, Forest Service, and Soil Conservation Service, September 1978, "Green River Basin, Wyoming: Cooperative River Basin Study," United States Department of Agriculture and State of Wyoming.

  Focus: *An overall planning study, this report is among the first to discuss in detail the recreational aspects of water development, and acknowledged the already-developing problem of limited stream fishing access. In addition to traditional water development via storage, this was also one of the first studies* *found to mention conservation of water by evaluating conveyance system efficiencies.*

- ARIX, January 1983, "Pre-Feasibility Study of the Upper Green River Drainage Potential Reservoir Sites," Wyoming Water Development Commission.

  ***Focus**: This report was confined to evaluation of supplemental irrigation supplies at eight small reservoir sites in the northwestern part of the Basin. Relatively complete analysis is provided including geotechnical evaluation of the dam sites, storable flow estimation (with water rights considerations) and construction cost estimates.*

- Western Water Consultants, Inc., November 1991, "Little Snake River Basin Planning Study, Level I Feasibility Study," Wyoming Water Development Commission.

  ***Focus**: This broad-based investigation evaluated 20 potential reservoir sites within the Little Snake River Basin and was preceded by several related studies. Most notably, previous work had focused upon Sandstone Dam and the City of Cheyenne's Stage I and Stage II (and also Stage III, preliminarily) studies. Further aspects of the 1991 work included studies of irrigation structure rehabilitation, evaluation of the West Side and First Mesa canals, and water supply for the Town of Baggs.*

For the current planning effort, these documents were reviewed to determine the extent to which previously identified projects could contribute to meeting current needs. While not an all-inclusive list of planning efforts in the Basin, the above documents were found most valuable in summarizing the extent and history of projects, storage sites, and other features suitable for analysis against newly minted demands.

B. Review of Future Basin Demands

To guide the process of evaluating projects to meet future needs and develop water under Wyoming's Compact entitlements, it was important to compare projected demands (and locations of those demands) to estimated water availability. In this process, several facts became clear. To summarize, the following study results lent direction to determination of future water use opportunities:

- Industrial growth projections in the Basin, while significant, fall below projections made in the planning studies of the 1970s. Projected growth in the trona and power generation industries in the lower basin (not including the Ham's Fork Naughton plant) can be served from storage space in Fontenelle Reservoir even under the high growth scenario. The Naughton plant holds unbuilt enlargement rights for Viva Naughton reservoir.
- Municipal demands from surface water are generally well below existing water rights held by the various towns and cities. The Rock Springs/Green River and Pinedale service areas, for example, have recently upgraded their supplies to meet significant future growth.
- No unmet current demands exist for industrial or municipal uses.

Considering consumptive uses, only agriculture currently sees shortages to existing needs. Predictably, these shortages are in areas not already served by storage to any significant extent. Unfortunately, the main reason these shortages exist is that agriculture is the economic sector least able to afford the high cost of storage construction, especially those operators focused upon raising forage instead of cash crops, to provide late season supplemental supplies. A situation is created where shortages are faced by users who cannot by themselves shoulder the entire financial burden of the work that would solve their problem, even when current funding programs can assist with large portions of the capital costs covered by grants.

Considering non-consumptive uses, such as recreational and some environmental applications (e.g. instream flows), funding is also a concern. In recent years, mitigation associated with reservoir construction has been used to replace or enhance environmental values with funding provided by others. There also exists the notion that environmental and recreational needs are not always compatible with storage. Where stream access for fishing is in short supply, the inundation of stream habitat by storage only exacerbates the problem. Where instream flows are desirable, the hydrology of the natural stream system still cannot put water in the river in a dry year unless those flows are tied to storage. Compounding the conflict, where run-of-the-river hydrology is favorable for aquatic and riparian habitats (and recreation pursuits), the reservation of flows for this purpose, while valuable, may preclude the use of this water for other consumptive needs allowed under the governing compacts. In fact, Wyoming's Instream Flow law requires that instream flow use "shall not result in more water leaving the State than the amount of water that is allocated by interstate compact or United States Supreme Court Decree for downstream uses outside of Wyoming."

Therefore, the general direction taken for recommending future use opportunities focused largely on providing supplemental irrigation supplies. However, the effects of the various projects on environmental and recreational values are very important and can result in otherwise similar projects being viewed quite differently. Where multiple uses are available, these are also investigated.

C. Compact Considerations

One possibility for the ultimate disposition of water under the compacts is the sale or lease of water to downstream out-of-state interests. This is an unpopular result largely because of the perceived irreversibility of the process. Once sold or leased, such water may never be retrievable for Wyoming should future demands need it. Additionally, under current state law, the sale of water outside the State is disallowed without legislative action. Any move in this direction would therefore require state legislature approval and would also have to be approved by the Upper Colorado River Commission (the coalition of upper basin states established by the Upper Colorado River Basin Compact).

In large part, the concept of sale or lease of Wyoming's unused share of Compact-allocated water is an understandable expression of the feeling that if not used or planned to be used, Wyoming may somehow lose its undeveloped water to thirsty downstream states. The compacts wisely anticipated such a situation, and the Law of the River includes language protecting Wyoming's future uses:

- Colorado River Compact, Article III (a):

    There is hereby apportioned from the Colorado River system ***in perpetuity*** *to the upper basin and to the lower basin the exclusive beneficial use of seven million five hundred thousand (7,500,000) acre-feet of water per annum, which shall include all water necessary* ***for the supply of any rights which may not exist****.* (emphasis added)

- Upper Colorado River Basin Compact, Article XVI:

    The failure of any state to use the water, or any part thereof, the use of which is apportioned to it under the terms of this Compact, ***shall not constitute a relinquishment of the right*** *to such use to the lower basin or to any other state,* ***nor shall it constitute a forfeiture or abandonment of the right*** *to such use.* (emphasis added)

There exists additional language in the junior Compact that protects states' rights to develop allocated water in accordance with any particular state's power of regulation, in effect allowing out-of-basin (but in-state) transfers of water:

- Upper Colorado River Basin Compact, Article XV (b):

    The provisions of this Compact shall not apply to or interfere with the right or power of any signatory state to regulate within its boundaries the appropriation, use and control of water, the consumptive use of which is apportioned and available to such state by this Compact.

Because both compacts contain language that preclude their termination without the consent of *all* signatory states, Wyoming alone can keep the above language in force as long as it remains in the State's best interest.

D. Long List of Water Supply Opportunities

From the planning studies previously listed, and from newer potential project ideas provided by Basin Advisory Group (BAG) members, over 80 projects were reviewed for potential application to current and future needs. Items such as groundwater use and conservation are not evaluated in the long list but do show up in the short list to follow.

Screening of the initial list resulted in the removal of certain projects from further consideration. Examples of these include most projects that exist on what now are dedicated Wilderness lands. While Wilderness boundaries have been known to be moved to allow project construction, such an action is singularly rare and in most cases creates a fatal flaw for that feature. The one project involving Wilderness boundary issues that made it past the initial cut was the BAG-suggested project involving the enlargement of Green River Lakes. This project was kept alive in the process for several reasons, notwithstanding the fact that the Wilderness issue could render it unbuildable: first, its location could serve many users currently experiencing agricultural shortages; second, review of earlier studies did not indicate that it had been studied in depth as yet; and finally, while there are obvious environmental impacts associated with construction of the project, the benefits associated with augmented late season flows have not been evaluated.

Another example of a previous project that did not pass initial muster is the oft-discussed Sandstone Dam in the Little Snake River Basin. The subject of considerable study in the 1980s, this project has been effectively replaced with the imminent construction of High Savery Dam in the same drainage.

From the long list, projects of minimal size were also deleted. Generally, if a project stored or depleted 1000 acre-feet or less, it was not considered further. This decision is not intended to reflect on the importance of small projects or to diminish their need. Instead, it is simply a matter of keeping the planning process from becoming unwieldy having to consider a multitude of smaller projects. If previous studies indicated a project to be uneconomical or undesirable, this also served as impetus to delete the project from short list consideration. Projects appearing in very early studies that no longer are attractive due to location, benefits, or because other nearby sites have garnered recent favorability have also been deleted.

The long list is shown in Table V-1. A map showing the locations of these features is given as Figure V-1 (p.V-21). Because the forecasted need for agricultural water (Chapter IV) describes a maximum of 50,000 acre-feet of storage development, no grand schemes involving multiple reservoirs are put forth. Instead, individual projects are evaluated on their own merits, and combinations thereof can be evaluated in further level I or level II studies at the pleasure of project sponsors. Where projects have been evaluated in combination by previous authors, such combinations are described in the technical memorandum on screening criteria.

Table V-1 Long List of Potential Reservoir Sites

PID**	NAME	SIZE (AF)	SOURCE	SECTION	TOWNSHIP	RANGE	USE
1	Fish Creek	1,400	Fish Creek	26	30	115	irr
2	Fontenelle No. 1	2,500	Fontenelle Creek	4	24	115	irr
3	Fontenelle Creek	15,950	Fontenelle Creek	30	26	115	irr
4	Green River Lakes Enl.	250,000	Green River	2	39	109	irr, pow
5	Green River Supplemental Supply Project	Canal Enlargement Only	Green River	4	33	110	irr
6	Kendall	100,000	Green River	33	36	111	ind, mun, irr
7	LaBarge Meadows	4,800	LaBarge Creek	8	29	116	irr
8	Lower Green Reservoir	450,000	Green River	25	19	108	irr
9	Lower Kendall	100,000	Green River	4	35	111	irr, rec, wl, pow
10	McNinch Wash	5,600	North Piney Creek	10	30	113	irr
11	Middle Piney Lake	4,200	Middle Piney Creek	8	30	115	irr
12	North Piney Cr	5,600	North Piney Creek	24	31	115	irr
13	Plains Reservoir	480,000	Green River	8	23	109	irr, ind, mun, wl
14	Sand Hill	14,100	Middle Piney Creek	36	30	113	irr
15	Seedskadee Project	57,000 ac	Green River		23	111	irr
16	Sixty-Seven Enl.	5,600	North Piney Creek	17	30	112	irr
17	Snider Basin	4,300	South Piney Creek	11	29	115	irr
18	South Cottonwood	6,000	Cottonwood Creek	12	32	115	irr
19	Warren Bridge Res	33,400	Green River	4	35	111	irr
20	Cottonwood No. 1*	1,465	S Cottonwood Cr	16	32	115	irr
21	Fogarty Creek*	700	Dry Piney Creek	24	28	114	irr
22	Horse Creek*	36,660	Horse Creek	7	34	114	irr
23	LaBarge Reservoir*	4,030	LaBarge Creek	12	29	116	irr
24	Middle Beaver Creek*	5,905	Middle Beaver Creek	29	36	112	irr
25	North Cottonwood Creek*	10,805	North Cottonwood Creek	24	33	115	irr
26	South Beaver Creek*	5,905	South Beaver Creek	24	35	114	irr
27	South Cottonwood Creek*	10,805	South Cottonwood Creek	11	32	115	irr
28	South Horse Creek*	36,660	South Horse Creek	30	34	114	irr
29	Straight Creek*	4,815	Straight Creek	4	30	115	irr
30	East Fork	2,100	East Fork River	10	31	106	irr
31	East Fork # 1	4,735	East Fork River	4	31	105	irr

PID**	NAME	SIZE (AF)	SOURCE	SECTION	TOWNSHIP	RANGE	USE
32	East Fork Gorge	unknown	East Fork River	12	31	106	irr
33	East Side Project	22,000 ac	East Fork River		30	106	irr
34	Burnt Lake	15,570	Fall Creek	31	34	107	irr
35	Halfmoon Enl.	95,000	Pole Creek	15	34	108	irr, pow
36	New Fork Narrows	100,000	New Fork River	14	30	110	irr, wl, rec
37	Silver Creek	17,740	Silver Creek	11	32	107	irr
38	Dad's Lake*	740	Dad's Creek	18	32	104	irr
39	East Fork River*	46,070	East Fork River	7	31	105	irr
40	Feltner*	1,280	Pole Creek	12	34	108	irr
41	Mack No. 1*	766	Skeleton Draw	5	30	108	irr
42	Marm's Lake*	562	Dad's Creek	7	32	104	irr
43	New Fork Lake Enl.*	45,937	New Fork River	15	36	110	irr, pow
44	Pyramid*	636	Pyramid Creek	17	33	104	irr
45	Eden No. 2 (Sander's Ranch)	60,000	Big Sandy Creek	17	30	104	irr, ind
46	Eden Reservoir Rehabilitation	6,300	Little Sandy River	17	26	105	irr
47	Eden Valley Improvements	3,100 ac	East Fork/Big Sandy		25	106	irr
48	Meeks Cabin Dam Enl.	unknown	Blacks Fork	11	12	117	irr
49	Stateline Enl.	unknown	E Smiths Fork Cr		Utah		irr
50	BB*	650	Blacks Fork	18	18	112	irr
51	Deer Lake*	1,000	E Smiths Fork Cr	29	13	115	irr
52	Hams Fork*	215,475	Hams Fork	12	21	116	irr, mun, ind
53	McWinn*	800	Hertley Hollow Cr.	16	22	117	irr
54	Uinta Canal No. 3*	16,790	Uinta Can. Blacks Fk	34	17	114	irr
55	Big Gulch	10,000	Big Gulch	19	13	88	irr
56	Dutch Joe Creek	14,000	Dutch Joe Creek	35	13	90	irr
57	Grieve Res.	4,860	Grieve Res.	5	12	88	irr
58	Lower Willow Creek, Wy	7,000	Lower Willow Creek, Wy	8	12	90	irr
59	Pot Hook, CO	20,000	Pot Hook, CO		Colo rado		irr
60	Upper Willow Creek, CO	10,000	Upper Willow Creek, CO		Colo rado		irr
61	Cottonwood Creek*	2,500	Cottonwood Creek	34	13	90	irr
62	East Willow*	12,000	East Willow, CO		Colorado		irr
63	Loco Creek*	3,000	Loco Creek	34	14	89	irr
64	Lower Battle Creek*	20,000	Lower Battle Creek	13	12	88	irr
65	Middle Battle Creek*	20,000	Middle Battle Creek	7	12	87	irr
66	Muddy Creek*	12,000	Muddy Creek	9	13	91	irr
67	Negro Creek*	1,000	Negro Creek	16	13	89	irr

PID**	NAME	SIZE (AF)	SOURCE	SECTION	TOWNSHIP	RANGE	USE
68	Old Upper Savery Cr*	20,000	Old Upper Savery Cr	36	15	89	irr
69	Roaring Fork*	5,000	Roaring Fork	28	13	86	irr
70	Sandstone*	20,000	Sandstone	2	13	89	irr
71	South Fork Little Snake*	17,000	South Fork Little Snake, CO		Colo rado		irr
72	Upper Battle Creek*	20,000	Upper Battle Creek	20	13	87	irr
73	Upper Slater*	20,000	Upper Slater, CO		Colo rado		irr
74	Big Basin Antelope*	107,680	Henrys Fork		Utah		irr
75	Vermilion/Red Creek Basin	unknown	Vermilion/Red Creek	19	13	101	irr

* Project deleted from short list consideration
* PID = point identification number on Figure V-1 (p.V-21)

E. Criteria for Ranking Future Water Use Opportunities

Based upon comments received during Basin Advisory Group (BAG) meetings, review of previously published criteria and questionnaire results, and the Scope of Services, the following procedure for screening opportunities for future water use was developed:

- From the notes and recordings of BAG meetings it was obvious that at least some BAG members would like to establish a set of priorities that are more general than project-specific criteria. For instance, the view that existing uses and economic dependencies should have first priority with respect to future plans seemed to enjoy general acceptance.
- A nested set of criteria were developed that take into consideration the comments of BAG members, the study results with respect to both current and future needs, and the previously proposed draft criteria.
- The individual criteria will be applied to projects grouped by priority as given below:

Priority	**Description**
1	Rehabilitation projects that preserve existing uses and economic dependencies.
2	Projects that rectify existing demands/needs/shortages.
3	Projects that meet projected future demands/needs/shortages
4	Trans-basin diversions of water that enhance in-state uses.

Six criteria will be evaluated under each of these priorities to present an overall picture of the favorability of a project or opportunity. These criteria, and the method by which they will be applied, are:

1 Water Availability

This criteria reflects the general ability of a project to function, given likely bypasses for environmental uses and prior rights. It is not a reflection of the relative size of the project.

2 Financial Feasibility

This criteria reflects the effects of the combination of technical feasibility (high or low construction cost) and economic use to which the water would be put (e.g. irrigation of native meadow vs. cultivation of alfalfa or row crops). The intent of this ranking is to indicate the likely ability to afford the project or meet Wyoming Water Development Commission (or other) funding source criteria. A low number represents a project with suspect ability to be repaid, whereas a high number represents a project that should more easily meet funding and repayment requirements.

3 Public Acceptance

This criteria reflects the extent to which a project will encounter or create public controversy (low number) versus a project that would likely engender broad public support (high number). For example, on-stream storage in environmentally sensitive areas would be very controversial, while off-channel storage in less sensitive areas would more likely be supported.

4 Number of sponsors/beneficiaries/participants

This criteria reflects the desirability, all other things being equal, that a project serving a larger segment of the population should rank higher (higher number) than one serving only a few (lower number).

5 Legal/Institutional concerns

This criteria reflects the perceived relative ease (high number) or difficulty (low number) with which a project could be authorized and permitted under existing state and federal law.

6 Environmental/Recreation benefits

This criteria reflects the net effect of positive environmental and recreational aspects of a project as offset, to the extent it can be determined, by potential negative impacts on these attributes.

F. Short List of Water Supply Opportunities

The planning project technical memorandum *Criteria For Screening Future Water Use Opportunities* contains descriptions of all projects considered in the first cut. Applying the criteria described above to those that remained resulted in the matrix shown on Table V-2. The projects listed in Table V-2 are the short list of water supply opportunities. Because many projects have different types of information available and many were studied in varying depth of detail, the process of ranking using these criteria was admittedly subjective. In many cases, the number of beneficiaries or the precise recreational and environmental benefits could not be known with certainty absent further study. As much as possible, ranking was performed based on experience with other recent projects, knowledge of basin conditions, and with the input of BAG members.

Some discussion of the scoring system used in Table V-2 is warranted. **First, the scores in and of themselves are meaningless other than to place the projects in some relative order.** The resulting ranking, with higher scores placing projects higher within their respective priorities, represents the relative likelihood that a project is desirable, functional and could receive enough public support to be constructed**. Projects with similar "scores" but under different priorities should not be considered equally desirable or equally likely, because the weighting factors for each criteria differ depending on the priority.** Potential projects are grouped by sub-basin so that plan readers can review the studied projects by geographic locale.

Conservation Opportunities

Improved irrigation practices, such as conversion from flood irrigation to sprinkler irrigation, is one means of improving the efficiency of water usage. Conveyance losses are another major factor contributing to inefficiency in agricultural use. Many ditches and canals in the Basin experience higher than normal conveyance losses, generally due to porous soils. Lining the canal with concrete or other material can greatly reduce the amount of flow lost to the surrounding soils.

Losses of 10 percent in irrigation ditches and canals are considered normal, or typical. Ditches and canals in sandy, cobbled, or alluvial soils, or fractured rock, where losses exceed 10 percent are potential candidates for rehabilitation. There are a number of canals in the Basin that exceed even 20 percent losses (see technical memorandum *Water Conservation*). These fall under the category of "Miscellaneous Canal Rehabilitation" in the short list of water supply opportunities.

Table V-2 Criteria Matrix

Priority Type	PID	Est. Yield(y), Cap(c) or Depl(d) (AF)	Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional	Environmental/ Recreation Benefits	Score* **
Priority 1*			***3***	***9***	***3***	***9***	***5***	***5***	
Eden Reservoir Rehabilitation**	46	6,300 c	6	9	9	8	8	2	248
Misc. Canal Rehab (Conservation)		unk	9	7	8	6	6	2	208
Middle Piney Reservoir	11	4,201 c	8	5	5	5	3	4	164
Sixty Seven Enlargement (off ch)	16	5,600 c	5	5	6	4	6	2	154
Grieve Reservoir	57	4,860 y	4	4	6	4	6	4	152
Priority 2			***8***	***5***	***8***	***6***	***10***	***3***	
Upper Green River									
Green River Supplemental Supply	5	22,000 d	7	6	6	8	5	2	238
Sand Hill (off ch)	14	14,100 c	5	6	7	6	6	3	231
Fontenelle Creek Narrows	2	2,500 c	6	5	6	4	6	5	220
McNinch Wash (off ch)	10	5,600 c	5	5	7	4	6	3	214
Snider Basin	17	4,300 c	6	6	5	5	5	5	213
South Cottonwood	18	6,000 c	6	5	5	5	5	5	208
Groundwater Development		unk	2	2	9	2	9	2	206
North Piney Creek	12	5,600 c	6	2	5	5	5	5	193
LaBarge Meadows	7	4,800 c	5	3	5	4	5	5	184
Warren Bridge	19	33,400 c	8	5	2	8	1	4	175
Fish Creek	1	1,400 c	3	5	5	2	5	4	163
Green River Lakes Enl.	4	<250,000 c	9	5	0	9	0	2	157
New Fork River									
East Fork	30	2,100 c	7	5	5	5	5	5	216
East Fork Gorge	32	unk	7	5	5	5	5	5	216
Boulder Lake Enl.		<120,000 c	8	7	4	6	3	5	212
Groundwater Development		unk	2	2	9	2	9	2	206
Silver/Spring Creeks	37	17,000 c	5	5	5	4	5	5	194
Burnt Lake Enl.	34	15,570 c	8	7	2	5	2	5	180
Halfmoon Enl.	35	<95,000 c	8	7	2	5	2	5	180
East Fork No.1	31	4,700 c	8	3	2	5	2	5	160

Priority Type	PID	Est. Yield(y), Cap(c) or Depl(d) (AF)	Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional	Environmental/ Recreation Benefits	Score* **
Priority 2			***8***	***5***	***8***	***6***	***10***	***3***	
Big Sandy River									
Sander's Ranch (Leckie Ranch)	45	60,000+ c	7	5	5	6	5	5	222
Groundwater Development		unk	2	3	9	2	9	2	211
Black's Fork River									
Groundwater Development		unk	2	2	9	2	9	2	206
Little Snake River									
Groundwater Development		unk	2	2	9	2	9	2	206
Lower Willow Creek	58	2,700 y	5	5	5	5	4	5	190
Big Gulch	55	5,250y	3	6	5	4	5	5	183
Upper Willow Creek (Co)	60	1,500 y	4	5	5	4	4	5	176
Pot Hook	59	6,700 y	6	4	4	6	1	5	161
Dutch Joe	56	5,000 y	4	6	5	5	2	3	161
Vermilion/Red Creek Basins									
Groundwater Development		unk	2	2	9	2	9	2	206
Storage Project	75	unk	5	4	7	3	5	4	196
Priority 3			***8***	***5***	***8***	***6***	***10***	***3***	
Green Below Fontenelle									
Groundwater Development		unk	2	2	9	2	9	2	206
Eden Project Improvements (USBR)	47	10,000 d	6	5	6	6	2	2	183
Seedskadee Project (USBR)		86,000 d	9	3	4	5	1	2	165
Upper Green River									
Green River Supplemental Supply	5	22,000 d	6	6	6	8	5	2	230
Groundwater Development		unk	2	2	9	2	9	2	206
East Side Project	33	32,000 d	6	5	4	4	3	3	168
Kendall (Upper Kendall)	6	>100,000 c	9	5	1	8	0	4	165
Lower Kendall	9	>100,000 c	9	5	1	8	0	4	165
New Fork Narrows	36	>100,000 c	9	4	1	5	0	4	142

Priority Type	PID	Est. Yield(y), Cap(c) or Depl(d) (AF)	Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional	Environmental/ Recreation Benefits	Score* **
Priority 3			***8***	***5***	***8***	***6***	***10***	***3***	
Black's Fork /Ham's Fork Rivers									
Viva Naughton Enlargement		36,000 c	7	5	6	5	5	6	227
Stateline Enlargement	49	unk	6	5	6	7	4	5	218
Meek's Cabin Enlargement	48	unk	5	5	6	7	4	5	210
Groundwater Development		unk	2	2	9	2	9	2	206
Little Snake River									
Groundwater Development		unk	2	2	9	2	9	2	206
Lower Willow Creek	58	2,700 y	5	5	5	5	4	5	190
Upper Willow Creek (Co)	60	1,500 y	4	5	5	4	4	5	176
Dolan Mesa Canal		2,700 d	5	3	5	3	4	4	165
Savery-Pot Hook Project (USBR)		5,000 y	6	4	4	6	1	5	161
Priority 4			***3***	***5***	***10***	***6***	***9***	***5***	
Green Below Fontenelle									
Plains Reservoir (off ch)	13	<480,000 c	9	3	3	3	1	4	89
Lower Green Reservoir	8	<450,000 c	9	2	2	2	1	3	73
Upper Green River									
Kendall (Upper Kendall)	6	>100,000 c	9	4	0	7	0	3	104
Lower Kendall	9	>100,000 c	9	4	0	7	0	3	104
New Fork Narrows	36	>100,000 c	9	3	0	5	0	3	87

Notes:

* Each criteria has a different weighting under each priority; 10 is most important, 1 is least important
** Under each project, the criteria are individually ranked; 10 means largely favorable, 0 is unfavorable
*** Scores are the additive result of multiplying each project criteria weighting by the associated priority criteria ranking

Priorities:

1. Preserves existing uses and dependencies
2. Addresses existing shortages
3. Addresses future projected needs
4. Addresses future out-of-basin, in-state needs

G. Legal and Institutional Constraints

In recent years, federal and state laws, rules, regulations and policies have affected the business of water development and management. The purpose of this section is to identify some of these institutional constraints to water development and to discuss some steps that a project proponent may take to address those constraints.

Federal Environmental Laws

In the late 1960's and early 1970's, Congress passed legislation to protect the environment. Prior to the passage of these laws, most water projects were designed and operated for specific consumptive uses for municipal, agricultural or industrial purposes. Environmental benefits derived from the projects were largely indirect and incidental to the purposes for which they were designed. With the passage of environmental laws, minimum flow releases became requirements of federal project permits. At the same time, the economic benefits of recreation and reservoir fisheries became more apparent, which resulted in minimum pools becoming a planned component of reservoir operations.

Actions relating to water supplies and development that might be requested of the federal government that initiate or "trigger" the federal environmental laws include, but are not necessarily limited to, the following:

1) Issuance of special use and right-of-way permits for new water projects on federal lands, including those lands administered by the Bureau of Land Management (BLM), the U.S. Forest Service (USFS), and other federal agencies.
2) Renewal of special use and right-of-way permits for existing water projects on federal lands, including those lands administered by the BLM, the USFS, and other federal agencies.
3) Contracting for storage water from federal reservoirs.
4) Renewal of existing contracts for storage water from federal reservoirs.
5) Actions that involve the discharge of dredged and/or fill material into waters of the United States, including rivers, streams, and wetlands, require the issuance of a Section 404 permit under the Clean Water Act. (e.g. the construction of dams, diversion dams, pipeline crossings, etc.)
6) Procurement and renewal of licenses from the Federal Energy Regulatory Commission (FERC) to produce hydropower.
7) Use of federal funds, loans or grants, to construct a new water project or rehabilitate an existing water project.

The only water development activity that presently falls outside the aegis of federal environmental laws is drilling a well with non-federal funds on non-federal lands outside the banks of rivers, streams, and wetlands. However, piping the water from such wells across federal lands or rivers, streams, and wetlands could initiate a federal environmental review.

Endangered Species Act

The Endangered Species Act of 1973 (ESA) requires the Secretary of Interior, through the U.S. Fish and Wildlife Service (USFWS), to determine whether wildlife and plant species are endangered or threatened based on the best available scientific information. The ESA constrains all federal agencies from taking any action that may jeopardize the continued existence of an endangered or threatened species. If a federal agency is considering an action that may jeopardize an endangered species, Section 7 of the ESA requires that the agency must consult with the USFWS.

National Environmental Policy Act

The National Environmental Policy Act of 1969 (NEPA) requires that federal agencies consider all reasonably foreseeable environmental consequences of their proposed actions. A review of that action under NEPA can be in the form of a simple finding of no significant impact (FONSI), an environmental assessment (EA), or an environmental impact statement (EIS). Further, NEPA requires federal decision makers to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." (42 USC 4321 et seq., Sec. 102(2)E). NEPA provides federal agencies the opportunity to determine which alternative, including no action, they feel best serves the applicant's purpose and need. The alternative selected by the federal agency may differ from the one preferred by the applicant.

Clean Water Act

Section 404 of the Clean Water Act of 1972 prohibits discharging dredged or fill materials into waters of the United States without a permit from the U.S. Army Corps of Engineers (USCOE). The waters of the United States include rivers and streams and, as of 1993, wetlands. USCOE policy requires applicants for 404 permits to avoid impacts to waters of the U.S. to the extent practicable, then minimize the remaining impacts, and finally, take measures to mitigate unavoidable impacts. In addition to the alternative review required by NEPA, Section 404 (b)(1) guidelines require an alternative review to define the least environmentally damaging practicable alternative.

Summary

The federal government, with the authorizations provided by the Endangered Species Act, the National Environmental Policy Act, and the Clean Water Act, has the tools to ensure the protection of endangered species, critical habitat, and other federal environmental interests.

Federal Lands

Approximately 68 percent of the Green River Basin is federal land. In particular, the Bureau of Land Management (BLM) administers about 58 percent, over 6 percent are national forests, while recreation areas, wilderness areas, and wildlife refuges combined comprise just under 4 percent. Moreover, there are candidate lands for wild and scenic designations. The BLM, the U.S. Forest Service, or others agencies managing the federal lands must assure that the requirements of the above laws are met before they can issue a special use permit authorizing a proposed action on federal lands, such as construction of a water project.

The scrutiny under which the federal laws will be applied is based on the sensitivity of the environment impacted or effected. For example, it may be a rather simple process to obtain a special use permit to construct a small water pipeline across the prairie within BLM jurisdiction. However, it would be virtually impossible to obtain a special use permit to construct a large dam within a wild and scenic river designation.

Project proponents must demonstrate a "purpose and need" for a project in order to obtain federal clearances for major water projects, whether or not the proposed project is located on federal lands. However, if the proposed location of the project is on federal lands, the "purpose and need" of the project proponent may be secondary to goals of the federal agency's management plans. Providing supplemental irrigation water has been recognized as sufficient purpose and need to justify a project.

As previously noted, NEPA provides federal agencies the opportunity to determine which alternative, including no action, they feel best serves the applicant's purpose and need. If the proposed project is located on federal lands and does not comply with the federal agency's management plan, project proponents may be faced with the task of convincing that federal agency that the proposed project at that specific location is the only alternative available to meet the proponent's purpose and need.

Wyoming Environmental Laws

The Section 401 Permit is the state certification of the Section 404 Dredge and Fill Permits required from the U.S. Army Corps of Engineers. A separate permit application is not required since all 404 Permit applications are automatically forwarded to the state in which a the 404 permit is being requested. The Section 401 permit also outlines those additional permits required prior to the initiation of construction activities.

Wyoming Water Law

Wyoming water law is based on the prior appropriation doctrine, or "first in time-first in right". Therefore, in times when there is not enough water to fulfill all the water rights, those water users having an earlier-priority-date water right are allowed to receive their full entitlement before those water users that have a later priority date or "junior" water right may receive any water under their right.

The priority date for a new project is established by the date the project proponent applies for a water right from the Wyoming State Engineer's Office. In order to determine the water supply a new project may achieve, it is important to evaluate the existing water rights that will be "senior" to the new project. Before the decision is made to pursue a project at a particular location, the potential yield of the project should be estimated. The firm yield is the water supply benefits the project proponent could expect under worst case or drought conditions. If the proposed project is located on a stream or river that has several "senior" water rights, a new project may not be able to achieve a water supply in the drier months, such as July and August, or during drought years. Under these conditions, the development of storage facilities would be required to store water when flows are surplus to existing water rights.

Due to the costs involved, water users are naturally interested in a firm supply before they are willing to invest in a water project. In fact, industrial water users are interested in the yield of a potential project under "doomsday" conditions, such as assuming that the worst water year of record occurs in consecutive years. These expectations of water users make the priority date of the water rights of new projects relative to existing water rights a critical factor in assessing the feasibility of new water development projects.

H. Solutions

The following is a list of actions project proponents may take to address the institutional constraints within federal and state laws, rules, regulations and policies.

Project Purpose

Project proponents should have a clear definition of the purpose of their project. There are several purposes for a project: agricultural, municipal, or industrial water use; power generation; flow control; recreation; fisheries and others. In fact, the project proponent may have several purposes in mind. For example, a reservoir could serve all of the above listed purposes. However, the alternatives analyses required by NEPA can become very complex, time consuming and costly for a multipurpose project. Each of the purposes for a proposed project will typically have its own individual alternative analysis.

Project Need

The project proponent must define the need for water to meet the defined purpose or purposes for the project. For example, if the purpose of a proposed agricultural project is to increase the yield of alfalfa or native hay, the amount of water needed for this purpose must be calculated. If the purpose of a proposed municipal project is to meet future water needs, the project proponent must complete population projections and future demand estimates in a manner that withstands the scrutiny of the federal permitting agencies. The needs analyses will have to quantify the amount of water that will be stored or diverted and consumed by the proposed action. Typically, the federal permitting agencies will require that future water conservation activities be considered in the needs analysis.

Alternative Analyses

Project proponents should have evaluated several alternatives prior to selecting the alternative that is going to be subjected to the federal review process. As previously noted, NEPA regulations require that the "no action" alternative be considered; all reasonable alternatives should be considered; and the reasons for eliminating potential alternatives must be provided. Therefore, project proponents should develop sufficient information for alternatives to evaluate how well the preferred alternative will fare under the federal review. The federal agencies will typically require that water conservation must be considered as an alternative to the project.

Selection of the Preferred Alternative

Cost and technical feasibility are the primary factors considered by project proponents in determining project feasibility. While these factors are also considered by federal permitting agencies, the federal perspective is more interested in the environmental damage that may occur if the project is constructed and implemented. Therefore, project proponents should consider potential environmental impacts in developing project alternatives.

Federal Lands

If possible, project proponents should avoid locating their project on national forests. It is virtually impossible to locate new water projects within wilderness areas, wildlife refuges, and wild and scenic designations.

Wyoming Water Development Program

Planning, constructing, and operating a water project is costly. Adding the costs to acquire state and federal permits can be overwhelming for public entities in Wyoming. In 1975, in recognition that water development was becoming more difficult and additional water development was necessary to meet the goals and objectives of the State, the Wyoming Legislature authorized the Wyoming Water Development Program and defined the program in W.S. 41-2-112(a), which states:

> *"The Wyoming water development program is established to foster, promote, and encourage the optimal development of the State's human, industrial, mineral, agricultural, water and recreation resources. The program shall provide through the commission, procedures and policies for the planning, selection, financing, construction, acquisition and operation of projects and facilities for the conservation, storage, distribution and use of water, necessary in the public interest to develop and preserve Wyoming's water and related land resources. The program shall encourage development of water facilities for irrigation, for reduction of flood damage, for abatement of pollution, for preservation and development of fish and wildlife resources [and] for protection and improvement of public lands and shall help make available the water of*

> *this State for all beneficial uses, including but not limited to municipal, domestic, agricultural, industrial, instream flows, hydroelectric power and recreational purposes, conservation of land resources and protection of the health, safety and general welfare of the people of the State of Wyoming."*

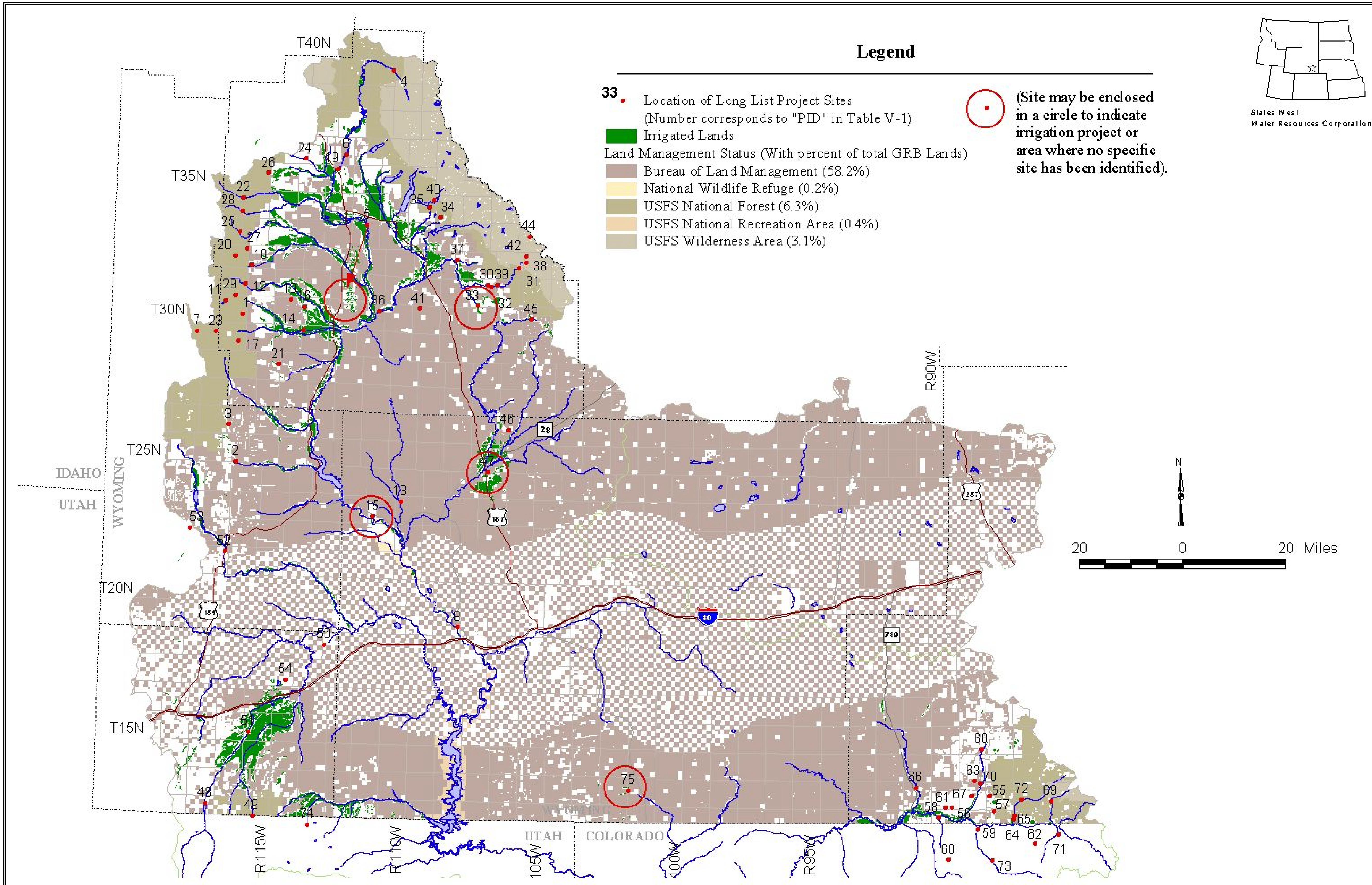
The Wyoming Water Development Commission can invest in water projects as state investments or can provide loans and grants to public entities (municipalities, irrigation districts and special districts) for the construction of projects specific to their water needs. The WWDC has adopted operating criteria to serve as "a general framework for the development of program/project recommendations and generation of information." Individuals and project entities interested in the development of specific water projects should seek information regarding the Wyoming Water Development Program and the possibility of obtaining financial and technical assistance for the development of those projects.

Upper Colorado River Recovery Implementation Program

The State of Wyoming has historically been proactive in dealing with institutional constraints that may impact its ability to develop its water resources as allocated by court decrees and interstate compacts. State representatives review proposed federal mandates ranging from new federal environmental legislation to forest management plans to interject the State's position on these matters and provide for a state perspective in their development and implementation.

One example deals directly with water development in the Green River Basin and the institutional constraints contained in the Endangered Species Act (ESA). In 1988, the States of Wyoming, Utah, and Colorado; the Department of the Interior; and the Western Area Power Administration executed a cooperative agreement to recover four endangered fish species in the Upper Colorado River Basin, while allowing water development to continue. Wyoming's participation in this Upper Colorado River Recovery Implementation Program has facilitated the process by which Wyoming water projects obtain federal clearances under ESA. Rather than spending thousands of dollars on evaluations of potential impacts to the fish species and developing expensive mitigation plans, a project proponent may be able to pay a one-time charge for new depletions which is paid into a fund to benefit the endangered fish. The one-time charge is approximately $14 per acre-foot of depletions, adjusted annually for inflation.

Figure V-1 Potential Reservoir Sites



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VI Implementation Process

Early in the process of preparing the Green River Basin plan, Basin Advisory Group members were nearly unanimous in their concern that the plan would be of little value without its implementation. In essence, they are correct. Implementation does not necessarily mean constructing a timetable for building the various projects put forth as solutions for current shortages or future needs. For purposes of this report, plan implementation is the series of tasks to be sequentially and periodically assessed and undertaken so that the planning information is current and accurate, funding mechanisms are protected or enhanced, and law and policy implications on plan implementation are both comprehended and closely monitored.

A. Use of the Planning Document

This reference document is intended for use by citizens of the State of Wyoming and a variety of agency personnel to understand the current state of water use and development in Wyoming's Greater Green River Basin. Numerous state agencies, including the Department of Agriculture, the Wyoming Game and Fish Department, the Department of Environmental Quality, the Attorney General's Office, and the Wyoming Business Council to name a few, need access to current, reliable data to make informed decisions. This document will assist in establishing purpose and need for future water development project work, and will be available to legislators as background material when evaluating future water development funding decisions. State water management personnel will, upon critical review and with experience from its use, find areas to be more closely evaluated in subsequent updates.

The Water Planning Web Site (http://waterplan.state.wy.us) provides a centralized repository of water planning documents and data, as well as references to statewide water-related information.

The surface water availability model(s) are intended to be used to evaluate the effects of future water development on physical water supplies.

B. Funding of Water Development Projects

Implementing future water development for citizens in the Basin requires the availability of a stable, predictable funding process. Industrial users are more likely to be able to finance water development internally, while municipal, agricultural and related (environmental) needs usually seek public funding of some sort. For public projects to advance, reliable funding is crucial.

The Wyoming Water Development Commission (WWDC) currently manages the most prominent state-sponsored funding mechanism for water projects. Funded from taxes on coal, oil, and gas production, this program uses the financial benefit of non-renewable resource development to support the study and construction of the renewable water resources of the State. This philosophy has proven sound and has provided significant water-related benefits to citizens for nearly twenty years. Over that time, the program has modified its funding and qualification criteria to adjust to changing needs. In the future, additional changes will likely arise to respond to changing economies. Flexibility in the program will allow it to continue to respond to needs for water use and development statewide. Continuation of this program is essential for water development in the State of Wyoming.

Other programs will also be valuable as long as they exist. Examples include the state revolving fund for water treatment facilities and federal assistance through the USDA Rural Development Program and various conservation programs (e.g. the Conservation Reserve Program and Wildlife Habitat Incentives Program). All these programs provide assistance not necessarily available through the WWDC. Additionally, these programs provide dollars for municipalities, irrigation districts and individuals to perform necessary and valuable work that they otherwise could not afford. Because water development in the form of water treatment improvements and environmental enhancements are desirable goals, these programs are vital to the overall quality of life in the Basin.

C. Policy Implications

Water development has become difficult and costly. However, if a project proponent has a need for water, patience, and financial resources, the federal permitting process can be successfully completed and permits obtained for construction of water projects. In fact, Wyoming must maintain its resolve to develop its water resources to meet the needs of its citizens.

The State of Wyoming has historically been proactive in dealing with institutional constraints that may impact its ability to develop its water resources as allocated by court decrees and interstate compacts. State representatives review proposed federal mandates ranging from new federal environmental legislation to forest management plans to interject the State's position on these matters and provide for a state perspective in their development and implementation. These efforts are important to Wyoming and must continue. There have been successes, as evidenced by the Upper Colorado River Recovery Implementation Program and the Colorado River Basin Salinity Control Program. Without such cooperative efforts, water development in Wyoming's Green River Basin would be much more difficult and costly.

Future Water Development

The publication of the "Green River Basin Plan" should foster discussion among water users and state officials relative to water development in the Green River Basin in Wyoming. The plan concludes that Wyoming has water to develop in the Basin. The water can be used for future municipal and industrial growth. There are existing agricultural water demands that could be met with the water. As previously noted, the

Wyoming Water Development Program can invest in state sponsored water projects or can provide loans and grants to public entities, such as irrigation districts, for the construction of projects. Historically, state sponsored water projects have been limited to larger, multi-purposes reservoirs such as the Buffalo Bill Enlargement and Fontenelle Reservoir. More recently, the WWDC recommended and the Wyoming Legislature authorized funding for the High Savery Reservoir.

High Savery Reservoir is a relatively small reservoir, with a capacity of approximately 22,400 acre-feet. Storage water from the reservoir will be used to provide late-season supplemental irrigation water, as well as to provide recreational and environmental benefits. Contrary to past practice, this reservoir is being constructed as a state sponsored project. There are several reasons that the State decided to make this investment. One of the most significant reasons was that the project proponents convinced the Legislature that the project was necessary to mitigate effects of the transbasin diversions from the Little Snake River Basin by the Cheyenne Stage I and Stage II Projects.

There are opportunities to construct smaller agricultural reservoirs in the Green River Basin. However, these development opportunities do not have the extraordinary history of the High Savery Dam. Therefore, these smaller agricultural projects may have to be sponsored by a public entity. The loan/grant mix criterion presently applied by the WWDC limits grant funding for project sponsors to 50 percent of the total project cost. Current Wyoming statutes authorize a maximum 75/25 grant/loan ratio for project sponsors. Even though the WWDC and Wyoming Legislature may agree to increase the grant percentage to the maximum 75 percent, it may be difficult for the agricultural water users to make the payments on even a 25 percent WWDC loan while also paying for the operation and maintenance of a dam and reservoir. However, when circumstances warrant, the WWDC and Wyoming Legislature will likely be asked to fund and construct smaller dams in the Green River Basin as state sponsored projects. Wyoming statute 41-2-121(a)(ii)(II) provides the following: *"Storage projects may be financed by grants for the full cost of the storage capacity but not to exceed public benefits as computed by the commission."*

The availability of water in the Green River Basin and the flexibility provided by the Upper Colorado River Basin Compact offers the potential for transbasin diversions. The City of Cheyenne has constructed its Cheyenne Stage I and Stage II Projects, which transport water from the Little Snake River Drainage to serve its municipal water needs. The State of Colorado has a long history of constructing and implementing water projects that divert and transport Colorado River water into the South Platte River Basin for the benefit of Denver, other front range municipalities, and irrigation canal companies and districts including the Northern Colorado Water Conservation District.

In the mid-1980s, the Wyoming Water Development Program, evaluated the feasibility of a Stage III Project which would again divert water from the Little Snake River Drainage, but this time, for the benefit of municipalities located in the North Platte River Basin. Those studies indicated that such a project was costly and could not be financially justified, even with favorable WWDC funding assistance. Therefore, efforts turned to the construction of the Deer Creek Dam and Reservoir to meet the future water supply needs of Casper and other North Platte municipalities. Presently, the Pathfinder Modification Project is being considered as a replacement for the Deer Creek Dam and Reservoir. If implemented, the Pathfinder Modification Project could meet the needs of the North Platte municipalities for quite some time. Recognizing that large complex projects take a long time to implement, the WWDC may wish to revisit reconnaissance level evaluations of transbasin projects that could serve the North Platte River Basin or other drainages surrounding the Green River Basin.

Wyoming Statute 41-2-121(a)(ii)(VIII) states: *"A project involving a transbasin diversion shall address the impact of the diversion and recommend measures to mitigate any adverse impact identified in the basin of origin."* This begs the question of whether the WWDC may construct or financially assist in the construction of agricultural reservoirs as state sponsored projects on the basis that these projects would mitigate for potential future transbasin diversion projects.

Water Marketing

As long as Wyoming has water to develop in the Green River Basin, there will be debate over proposals to sell or lease water to downstream interests. As previously noted, the sale or lease of natural flow allocated to Wyoming under the Colorado River Compacts is probably neither politically or institutionally feasible. Further, the long-term lease or perpetual sale of Wyoming's water would be short sighted. However, the lease of water that can be controlled may be a more feasible water marketing alternative. Storage water may offer revenue potential for the State. As the water supply can be turned on and off to meet specific demands, the possibility that water marketing would become irreversible becomes less likely. The water rights and leased water would remain under the control of Wyoming. At such time as Wyoming had a need for the water, the leases could be terminated, downstream deliveries stopped, and the water could be used in Wyoming. While such an alternative may be more feasible, there would still be risk and many political and institutional issues to address.

Future Water Planning

The "Green River Basin Plan" is an important step towards identifying and achieving Wyoming goals in the Green River Basin. It is important to update and maintain the "Green River Basin Plan" or it will simply be a glimpse of the status of the water use at the end of the twentieth century. Additional data acquisition can facilitate plan improvement. Most importantly, existing water use is a critical element of information in planning for the future. Without an understanding of the existing water use, it is very difficult to define the water available for future use. It may be time in Wyoming's history for installation of measuring devices and annual reporting of water use to become a requirement placed on water rights, with the exception of those water rights permitted for domestic, stock and other *de minimis* uses.