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VOLUME I

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FINAL ENVIRONMENTAL IMPACT STATEMENT

Eastern Powder River Coal Basin of Wyoming

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DEPARTMENT OF THE INTERIOR

FINAL
ENVIRONMENTAL STATEMENT

Proposed

DEVELOPMENT OF COAL RESOURCES
IN THE EASTERN POWDER RIVER
COAL BASIN OF WYOMING

BUREAU OF LAND MANAGEMENT
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Prepared by
Department of Agriculture
Interstate Commerce Commission
Department of the Interior
(October 18, 1974)

Curt Berklund
Director

SUMMARY SHEET

SUMMARY

( ) Draft (X) Final Environmental Statement

Director, Department of the Interior,
Bureau of Land Management
Washington, D. C. 20240

1. Type of action: (X) Administrative ( ) Legislative

2. Brief description of action:

The statement covers the probable impact of the possible development of 11 new coal strip mines, 4 new mine mouth coal fired generating plants (1780-megawatts), 2 gasification plants, and a 113-mile long mainline railroad by 1990 within the Eastern Powder River Coal Basin.

In addition to the regional portion of the statement which analyzes all of the above stated development on a regional basis, the statement also analyzes on a site specific basis, development or expansion of four mines (Wyodak, Carter, A.R.Co. and Kerr-McGee) and the 113-mile railroad. The Federal Government has been asked to approve the mining plans of these four companies and to grant the necessary rights-of-way for construction of the railroad.

3. Summary of environmental impacts (by 1990)
   - A. Ambient air quality will be lowered
   - B. Altitude of land surface will be lowered where coal is removed
   - C. Vegetation will be destroyed from mining and construction of attendent facilities
   - D. Soil structure and parent material will be disrupted and altered on the area to be strip mined
   - E. Valuable energy resources will be made available for utilization
   - F. Water utilization and consumption will increase for industrial uses, possibly reducing amount available for other uses (agriculture, wildlife, recreation)
   - G. Unknown archeological and paleontological values may be destroyed
   - H. Scenic views will be changed and altered
   - I. Wildlife habitats will be altered and some populations will be reduced while others will increase
   - J. Recreation use will be intensified
   - K. Livestock forage will be reduced during mining operations
   - L. Possible overall reduction of the productivity of the mined areas even after reclamation
   - M. New transportation networks will be created
   - N. Population in the study area will increase
   - O. Employment in the study area will be increased
   - P. Tax and royalty income will be increased in the study area
   - Q. Income levels will increase within the study area
   - R. All infrastructual facilities will be impacted

4. <u>Alternatives considered</u>
   A. No new development
   B. Restrict development
   C. Complete exportation of all coal mined
   D. Different extraction methods
   E. Various reclamation objectives
   F. Alternate to private industry development
   G. Different modes of distribution
   H. Different utilization methods
   I. Alternate energy sources

Comments on the draft were requested from the following:

Environmental Protection Agency

United States Department of the Interior
- Bureau of Sport Fisheries and Wildlife
- Bureau of Outdoor Recreation
- National Park Service
- Bureau of Land Mangement
- Office of Oil and Gas
- Geological Survey
- Office of Coal Research
- Bureau of Mines
- Office of Land Use and Water Planning
- Office of Water Resources Research
- Bureau of Indian Affairs
- Office of Environmental Project Review
- Office of Solicitor
- Bureau of Reclamation

Northern Great Plains Resource Program

United States Department of Agriculture
- Forest Service
- Soil Conservation Service

Federal Power Commission

United States Department of Health, Education and Welfare

Interstate Commerce Commission

Atomic Energy Commission

Department of Transportation

State of Wyoming Offices
- Governors Clearing House
- Attorney General
- Agriculture
- Economic Planning and Development
- Education

State Engineer
Environmental Quality
Game and Fish
Geological Survey
Health and Social Services
Highway Department
Occupational Health and Safety
Public Lands
Public Service Commission
Recreation Commission
State Archeologist
State Historic Preservation Office
University of Wyoming

Board of County Commissioners of
Campbell County
Converse County
Johnson County
Weston County
Niobrara County
Natrona County
Crook County
Sheridan County

Other Organizations
Advisory Council on Historic Preservation
Wyoming Outdoor Council
Sierra Club, Northern Great Plains Office
Wyoming Environmental Institute
Wyoming Audubon Society
Izaak Walton League - Wyoming Division
Wyoming Wildlife Federation
Powder River Basin Resources Council
Western Region, Wilderness Society
Rocky Mountain Center on Environment
The Wildlife Society
Wyoming Geological Association
Society for Range Management
Wyoming Stock Growers Association
Wyoming Wool Growers Association
Wyoming Archeological Association
Wyoming State Historical Society
Northern Plains Resource Council
Wyoming Mining Association
Petroleum Association of Wyoming
American Association of Petroleum Geologists
American Institute of Mining Engineers

Comments were received from:
Department of Interior
National Park Service
Bureau of Reclamation
Office of Coal Research
Bureau of Sport Fisheries & Wildlife
Bureau of Outdoor Recreation

Bureau of Mines

Department of Agriculture
Environmental Quality Activities
Forest Service
Office of the Secretary
Intermountain Forest and Range Experiment Station
Rocky Mountain Forest and Range Experiment Station

Department of Commerce
The Ass't Secretary for Science and Technology

Department of Health, Education and Welfare

Department of Transportation
Federal Highway Administration

Atomic Energy Commission

Environmental Protection Agency

Federal Energy Administration

State of Wyoming (Governors Clearing House)

Board of County Commissioners
Niobrara County

Other Organizations

Cheyenne High Plains Audubon Society
Burgess and Davis, Attorneys - Landowners
Wilderness Society
Wyoming Farm Bureau Federation
University of Wyoming (Black Thunder Project)
Environmental Defense Fund
Wyoming Sierra Club Group
Wyoming Chapter, Wildlife Society
Sierra Club
Institute of Ecology
National Resources Defense Council, Inc.
Upper Snake River Group, Sierra Club
Geothermal Energy Institute

Industry

Amax Coal Company
Middle South Utilities
Central Louisiana Electric Company

Getty Oil Company
Panhandle Eastern Pipeline Company
Southwestern Public Service Company
Oklahoma Gas and Electric Company
Texas Utilities Services, Inc.
Atlantic Richfield Company
Carter Oil Company
Kerr-McGee Coal Corporation
Black Hills Power and Light Company
VTN Mineral Development Corporation
Nebraska Public Power District
Gulf States Utilities Company
Gulf Energy and Minerals Company

Individuals

Bob Rourke
Homer A. Robinson
Thomas E. Horobik
Otis C. Copeland
Barbara Gilfillan
Faye C. Hart
John E. Mooney
R. Marrimer Orum
John R. Swanson
Mr. and Mrs. Richard J. Ball
Eileen Dunnebecke
Leland J. Turner
Pat Ford

Date draft statement made available to Council on Environmental Quality:
May 31, 1974

Date final statement made available to Council on Environmental Quality:
October 18, 1974

CONTENTS

This is Volume I. It contains Chapters I through IV of Part I, the regional analysis.

SUMMARY TABLE OF CONTENTS

This environmental statement is presented in six parts as follows:

A detailed table of contents of this volume begins on the following page.

VOLUME I

PREFACE

PART I. REGIONAL ANALYSIS

PREFACE

This statement represents an analysis of broad cumulative impacts on the environment of coal resource development in the Eastern Powder River Coal Basin of Wyoming and analyses of specific impacts of pending applications before the Federal Government.

A number of companies holding leases on federally owned coal deposits in the Gillette-Douglas, Wyoming, area have submitted proposed mining and reclamation plans for their respective leaseholds to the U.S. Geological Survey for approval in accordance with existing federal law and regulations. Some of these plans cover totally new mines to be opened; others cover expansion of present mines onto existing federal leaseholds. A number of similar submissions of mining and reclamation plans on other leaseholds in this area can be anticipated in the near future.

Burlington Northern Inc. and Chicago and North Western Transportation Company have jointly applied to the Interstate Commerce Commission for a certificate of public convenience and necessity authorizing the construction and operation of a new railroad which would link an existing line near Douglas, Wyoming, with one near Gillette, Wyoming, thereby providing a transportation facility which could be utilized by anticipated mining activity. Short spur lines to the various mines would also be required in some cases.

Federal land holdings in the area require authorizations by the Bureau of Land Management, Department of the Interior, or the Forest Service, Department of Agriculture, for the occupancy or use of federal lands.

Other related activities will follow, should the federal approval actions ensue, many of which may or may not require additional federal authorizations. For example, development of electric powerlines, mine mouth power generating facilities, coal gasification plants, water supplies for various operations, roadway and other communication facilities, new residence and business communities and increased facilities of all kinds in existing communities may occur.

The four federal agencies have determined that approval of the pending applications would collectively constitute a major federal action having a significant effect on the quality of human environment. Therefore, the agencies have determined that to protect the public interests most effectively and to meet their individual responsibilities under the National Environmental Policy Act of 1969 most efficiently, they should jointly undertake the preparation of a single environmental impact statement which would consider not only the impacts of the several proposals but also the collective, cumulative impacts, primary and secondary, of the development of the coal resource in the area.

Further, to meet the intent of the Act in the most productive fashion, it is necessary to examine the general geographic area of the proposed and potential actions. The geographic area for basic consideration is that part of the Powder River Coal Basin in Wyoming lying generally eastward from the Powder River to the outcrop line of the coal resource and from somewhat north of Gillette to a point somewhat south of Douglas. The area deliniation is based in part on present and anticipated levels of mining activity, differing quality of the coal resource, different physical arrangement of the coal beds, somewhat different mining techniques required and differing physical reclamation requirements. Those considerations having a broader scope of geographic impact such as social conditions, economic factors, atmospheric influence, water resources, and recreation uses are treated on a larger regional basis than the primary study area. This statement discusses the existing environment, evaluates the collective impact of the proposed actions and, insofar as now possible, the impacts of potential future coal mining within the geographic area described above. This statement also examines in detail certain proposed activities for which federal actions are required.

PART I
REGIONAL ANALYSIS

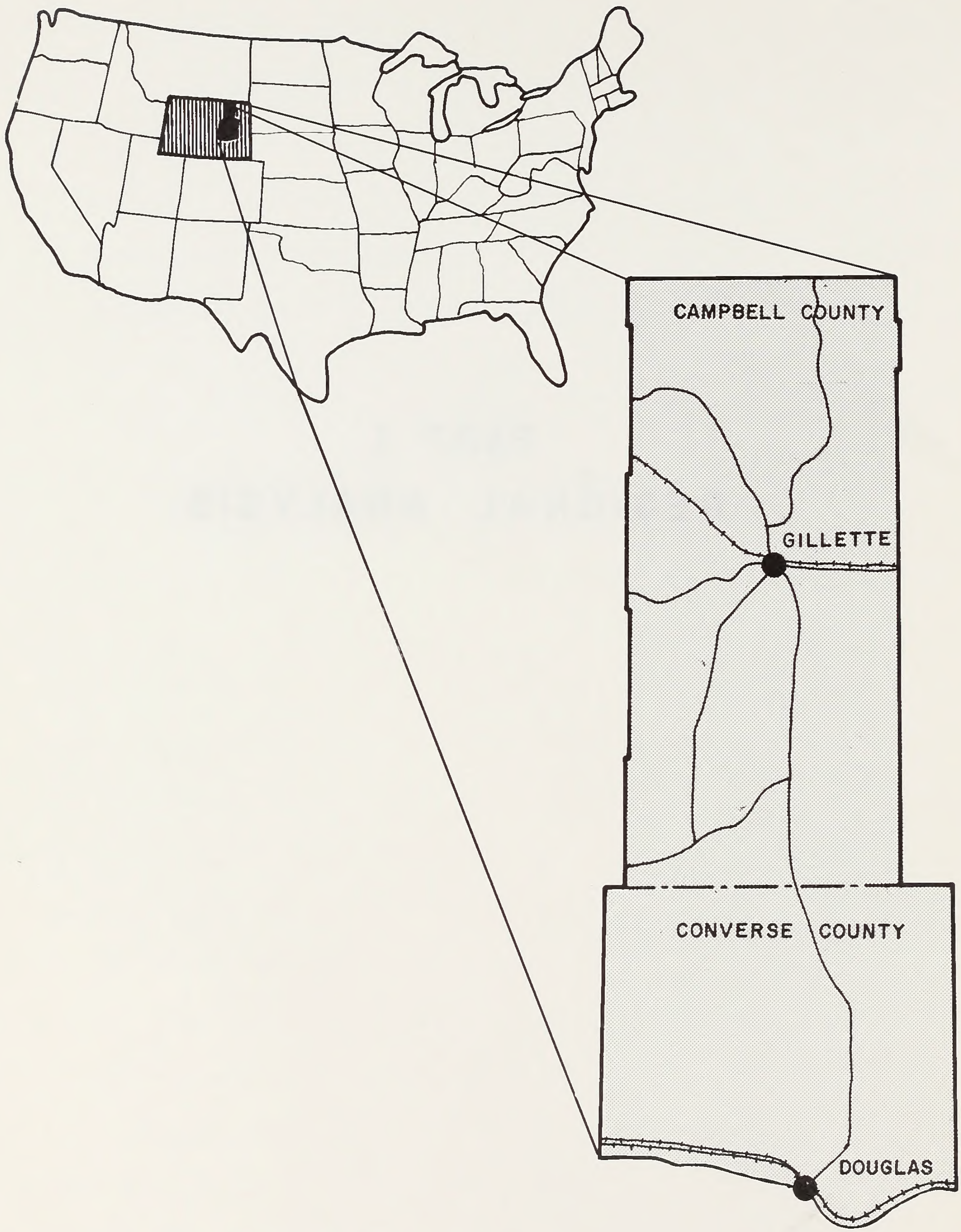

Figure 1
Basic Study Area Location Map.
(EASTERN POWDER RIVER COAL BASIN)

CHAPTER I

INTRODUCTION

Involved agencies of the Federal Government have pending before them several industry proposals (Map 3, Appendix A). The proposals are briefly outlined in this chapter to provide a perspective for analysis of regional impacts. Each proposal is the subject of a detailed analysis in Parts II, III, IV, V, and VI of this report. This chapter also includes a brief summary of the roles of the several involved federal agencies in authorizing proposed development actions.

Specific Applications

Railroad

Initially, Burlington Northern Inc. and Chicago and North Western Transportation Company planned separate rail lines to serve planned coal development in the Eastern Powder River Coal Basin. However, on January 31, 1974, the companies filed with the Interstate Commerce Commission a joint application to build one line from the present main line at Fisher and Shawnee (respectively 15 and 19 miles east of Douglas) to the vicinity of the present Amax coal mine about 15 miles southeast of Gillette. Total distance of mainline construction will be 113 miles; there will be additional spurs which are considered part of the respective mining operations. The proposed route crosses about 2 miles of land managed by the Bureau of Land Management, 21 miles of Forest Service managed lands, and 7 miles of land owned by the State of Wyoming. Rights-of-way must be filed with these agencies. The proposed route is shown on Map 3, Appendix A.

Atlantic Richfield Company

The Atlantic Richfield Company has submitted to the Geological Survey mining and reclamation plans detailing its proposal to open a conventional surface coal mine on federal coal lease W-2313 about 40 miles south of Gillette (Figure 2). The company plans to start production in 1975 and to ship the coal to electric utilities in Nebraska, Oklahoma, and Texas. Ownership in acres of the lease area is shown below.

	Surface	Coal
United States	3844*	5884
State of Wyoming	640	640
Private	2040	0
Total	6524	6524

*Forest Service

Target production for the mine, to be known as the Black Thunder mine, is 10 million tons per year by 1979. This could be doubled by opening a second operating area at the mine.

Carter Oil Company

Carter Oil Company has also submitted mining and reclamation plans detailing its proposal to open a conventional surface coal mine on federal coal lease W-5036 about eight miles north of Gillette. Production at this mine, the North Rawhide mine, is scheduled to begin in 1976 and rise to five million tons per year by 1978. Present plans are for a full production of 11 million tons. Coal will be exported from the basin to the Michigan-Indiana Power Company. Ownership of this mine area is as follows:

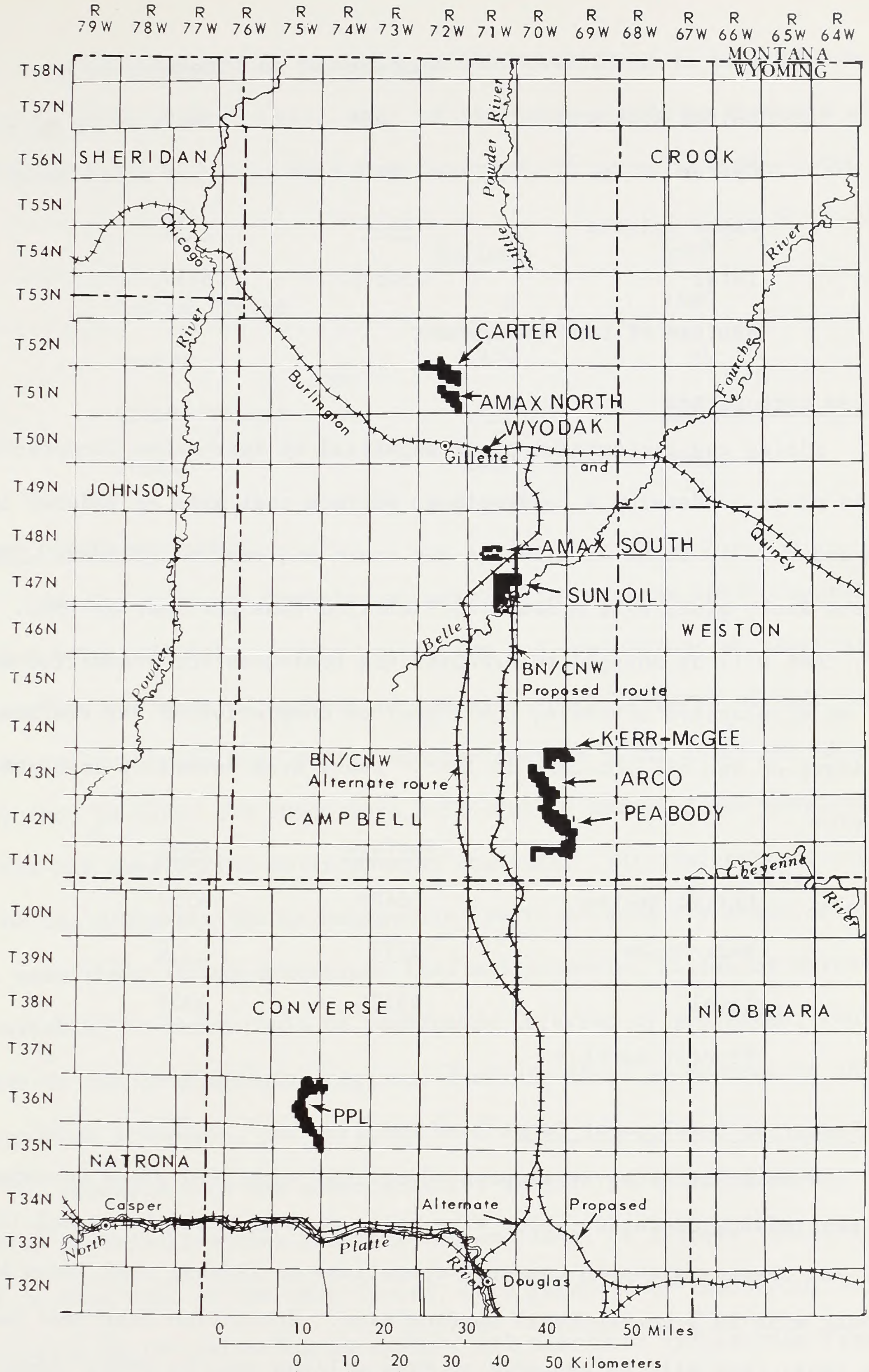

Figure 2

Index Map Showing Locations of Some Federal Coal Leases in the Eastern Powder River Basin, Wyoming

	Surface	Coal
United States	40*	5417
Carter	960	0
Other private	4457	40
Total	5457	5457

*Bureau of Land Management

Kerr-McGee Corporation

Mining and reclamation plans submitted by Kerr-McGee Corporation set forth its plans to develop a conventional surface coal mine on federal leases W-23928 and W-24710 about 40 miles to the south and east of Gillette. This mine, the Jacobs Ranch mine, will produce 15.9 million tons per year by 1982. Beginning in 1977, coal will be shipped to Arkansas and Louisiana for production of electric power. An accelerated schedule, contingent on completion of the railroad, calls for delivery of two million tons in 1976. Lease area ownership in acres is shown below.

	Surface	Coal
United States	640*	4352
Kerr-McGee	3712	0
Total	4352	4352

*Forest Service

Wyodak Resources Development Corp.

Wyodak Resources Development Corp. has submitted plans to expand its present mining operation about five miles east of Gillette on U.S. Highway 14-16. The company plans to commence operations on federal coal lease W-073289. The Wyodak mine is a conventional surface mine. Production last year was 725,000 tons; this will be expanded to five million tons by 1982. About 1.5

million tons of this will be burned in a new power plant to be built at the site and to go on line in 1977. Most of the balance will be consumed elsewhere in the Black Hills region. Mine area ownership in acres is shown below.

	Surface	Coal
United States	0	1880
Wyodak	1920	40
Other Private	160	160
Total	2080	2080

Proposed future actions

Having made the decision to prepare the present environmental statement, and initiated related data collection and evaluation, an administrative determination was made to include in the site specific parts of this statement only the railroad and those mining and reclamation plans described above and already then in hand, and which were sufficiently detailed and complete to enable immediate and substantial environmental analysis. This determination brought the scope of the statement within manageable limits at an early stage of preparation. At the same time, it was determined that all potential mining of which knowledge was available, or which could be reasonably inferred or projected, would be included in the comprehensive regional analysis (Part I) portion of this present environmental statement, and this has been done.

Subsequent to the administrative definition of scope of the present EIS, five additional mining and reclamation plans, or letters indicating an intent to mine coal in the near future, were received by the Geological Survey. As indicated in the preceding paragraph, all pertinent information from these documents and available related data from the companies concerned have been fully utilized in Part I of this statement, but these later proposals have not been analyzed on a site specific basis.

The five later proposals include: mining and reclamation plans for the Belle Ayr South mine (Amax Coal Company), the Rochelle mine and coal gasification complex (Peabody Coal Company to supply the Panhandle Eastern Pipe Line Company complex and other customers), and the Belle Fourche mine (Sun Oil Company). Letters of intent to mine coal at the Belle Ayr North mine (Amax Coal Company) and at the Antelope holdings (Pacific Power and Light Company) are also in the hands of the U.S. Geological Survey, pending receipt of formal mining and reclamation plans.

The Belle Ayr complex of Amax Coal Company is scheduled to produce more than 35 million tons of coal per year by 1982, the Rochelle mine 11 million tons by 1980, and the Belle Fourche mine 12 million tons by 1981. All proposed mines are scheduled to begin production in 1977 and 1978.

These plans are now under intensive study and environmental analyses are being prepared. After completion of these analyses the Department of the Interior will decide what additional actions are required by the National Environmental Policy Act of 1969.

Institutional Arrangements

A number of federal agencies have responsibility for authorizing proposed development actions analyzed in this report. Agencies with primary responsibility are the Forest Service, Bureau of Land Management, Interstate Commerce Commission, and Geological Survey. Other federal, state and local governmental agencies have a secondary responsibility in that they administer portions or phases of the developments once authorized.

Authority

Authority for management of public lands is contained in a great many laws (Public Land Law Review Commission, 1968). Many deal specifically with the resource or actions involved, e.g., grazing, rights-of-way, while others are more broad. Only a few of the key acts will be mentioned here.

The Act of March 3, 1875 (18 Stat. 482; 43 U.S.C. 932-939, known as the Railroad Right-of-Way Act) grants rights-of-way to railroad companies through public lands of the United States. Rights-of-way on acquired lands in the National Grasslands are granted under authority of the Bankhead-Jones Farm Tenant Act (50 Stat. 525; 7 U.S.C. 1010-1013).

The statutory authority for leasing all federal public domain coal deposits is contained in the Act of February 25, 1920, known as the "Mineral Leasing Act of 1920" (41 Stat. 437, as amended; 30 U.S.C. 181 et seq).

Lands excluded from operation of the Mineral Leasing Act of 1920 include lands in incorporated municipalities, in national parks and monuments, lands within naval petroleum and oil shale reserves, those acquired under the Appalachian Forest Act and Lands acquired by the United States under other authorities.

Lands disposed of with reservations of coal (and/or other mineral) deposits to the United States are also subject to the provisions of the Mineral

Leasing Act of 1920. Coal is subject to disposition by leasing only, with the exception of permits to take coal for local domestic needs.

Authority for leasing coal on federally acquired lands is contained in the Act of August 7, 1947, known as the "Mineral Leasing Act for Acquired Lands," (61 Stat. 913; 30 U.S.C. 351-359). Lands excepted from the Act include those acquired specifically for development of mineral deposits, lands within incorporated municipalities, and lands within national parks or monuments. Acquired lands considered in this report include portions of the Thunder Basin National Grasslands. For the most part, the basic leasing provisions and conditions under both leasing acts are similar. However, the Mineral Leasing Act for Acquired Lands requires consent of the head of the federal agency having administrative jurisdiction over the lands before a deposit is leased. If coal or other minerals were reserved to the United States in the original transfer of title and the land was later reacquired by the United States, provisions of the Mineral Leasing Act of 1920 apply.

Both laws give the Secretary of the Interior broad authority to make rules and regulations necessary to carry out the mineral leasing program. The Secretary has delegated his authority to issue leases to the Director, Bureau of Land Management, and the Director has redelegated his authority to the State Directors. Likewise, the Secretary has delegated his authority to administer operations conducted under leases to the Director, Geological Survey.

Regulations governing the leasing of Federal coal and operations under such leases are found in Title 43 Code of Federal Regulations (CFR), Parts 23 and 3500 and in Title 30 CFR Part 211.

The statutory authority for construction and operation of a new line of railroad is contained in Section 1(18) of the Interstate Commerce Act (49 Stat. 543; 49 U.S.C. ∅ 1(18). A certificate of public convenience and necessity issued by the Interstate Commerce Commission is required before the start of construction. Spur, industrial team switching, or side tracks located wholly within one state are exempted from the act.

Federal agencies

The Bureau of Land Management (BLM) classifies and manages national resource lands and their related resources according to principles of multiple use, sustained yield, and environmental quality. In the federal coal leasing program, the Bureau of Land Management exercises the Secretary of the Interior's discretionary authority under the mineral leasing acts to determine whether or not leases, permits, or licenses are to be issued. It is responsible for issuing leases and for formulating the surface, non-mineral resource protection and rehabilitation requirements to be incorporated in them. With respect to federal coal deposits where BLM has surface management responsibilities and on private surface overlying federal coal, BLM determines the adequacy of environmental protection and rehabilitation aspects of all mining operation plans. BLM also is responsible for compliance examinations on prospecting permit or license lands beyond operating areas.

In addition to managing the national resource lands, administering mining laws applicable to all federal lands, and conducting cadastral surveys of all federal lands, the Bureau of Land Management also maintains the official land status records (title records) for all federal lands.

The Geological Survey is the principal federal agency concerned with preparing maps of the physical features of the country and providing earth science information essential to use and conservation of the nation's land, mineral, and water resources.

The Conservation Division of the Geological Survey is responsible for geologic, engineering, and economic value determinations needed for federal coal leasing and for supervision of coal mining on federal lands under the terms of leases issued by the Bureau of Land Management. It approves operating plans which meet requirements of the mineral leasing acts, regulations, and lease terms and conditions, including environmental and rehabilitation stipulations. It makes compliance examinations of operations under federal mineral leases and maintains records of operations of lessees, permittees, and licensees.

The Forest Service manages the national forests and national grasslands. All lands under Forest Service jurisdiction are managed in accordance with the principles of multiple use and sustained yield, as expressed in the Multiple-Use Sustained-Yield Act of 1960 (74 Stat. 2.5, 16 U.S.C. 528-531). In addition, the Forest Service conducts cooperative programs of state and private forestry and an extensive forestry and forest products research program.

Historically, lands managed by the Forest Service have been subject to mineral exploration and mining. Coal leasing is subject to the constraints and direction developed in multiple use planning. A summary of Forest Service objectives and procedures concerning coal leasing is found in Appendix C.

The Interstate Commerce Commission (ICC) is an independent regulatory agency which implements the aims of national transportation policy and the Interstate Commerce Act. It regulates the surface transportation system by requiring prior authorization for the institution of expansion of existing operations and for termination or consolidation of services. It administers its programs to recognize and preserve inherent advantages of different modes of transportation and to promote sound economic conditions by fostering competition among individual carriers and avoiding unnecessary and duplicative facilities. The ICC predicates its findings upon a determination that the present or future public convenience and necessity require or will require a proposed service or operation.

The Environmental Protection Agency (EPA) administers both the Clean Air Act and the Federal Water Pollution Control Act. The Clean Air Act requires that any entity proposing a new industrial facility (fossil fuel-fired steam generators) must obtain a permit certifying that the plant complies with EPA's new source performance standards. These standards are established separately for each category of plant. The heart of the water quality program is also a permit system which requires any entity discharging pollutants that may enter navigable waters to obtain a permit. EPA effluent guidelines and standards determine whether any specific permit may be issued. Authority for handling both permit systems may be delegated by EPA to the states, but neither has yet been delegated to Wyoming. In carrying out the permit programs, however, EPA works closely with the Wyoming Department of Environmental Quality.

The Federal Power Commission (FPC) issues certificates for the construction and operation of interstate natural gas pipeline facilities and interstate power transmission lines. Its standards for such construction include requirements for protection of the environment. FPC has disclaimed jurisdiction over pipelines transmitting only manufactured gas, such as gas derived from coal.

Safety standards for natural gas pipelines are administered by the Department of Transportation (DOT) under the Natural Gas Pipeline Safety Act. The DOT also has jurisdiction over liquid pipeline safety under the Transportation of Explosives Act. The Department's Federal Railroad Administration is responsible for administering federal laws concerned with railroad safety.

The DOT's Federal Highway Administration oversees the federal aid highway program of financial assistance to the states for highway construction. In the allocation of federal matching funds for highways, it establishes and administers standards for highway safety, design, construction, and maintenance.

The Mining Enforcement and Safety Administration of the Interior Department enforces federal health and safety standards on all mining operations.

State agencies

A number of state agencies also have control over some of the development described in this statement.

The Wyoming Department of Environmental Quality (DEQ) has enforcement authority concerning air quality standards, water quality standards, and mined land reclamation. The Wyoming Environmental Quality Act grants authority to DEQ to institute permit systems in air, land and water quality matters. Permittees must comply with both state and federal standards. The DEQ is active in both air and water quality, particularly with air pollution enforcement and is working to obtain full delegation from EPA of authority to administer both programs. Any facility that may cause air pollution emissions must obtain a construction permit from DEQ. In addition, operating permits are required for all mobile sources and permanent sources after an initial 120-day start-up period.

The portions of the Wyoming Environmental Quality Act pertaining to mined land reclamation apply to all solid mineral prospecting and mining activities except those conducted by government agencies or their contractors and certain noncommercial or minor operations. The Land Quality Division issues permits and licenses to mine, or to explore for minerals by dozing, upon its approval of a mining and reclamation plan submitted by the applicant. Each mining permit applicant must post a performance bond with the state to insure mined land reclamation. Licenses to mine may be revoked or suspended for substantial violation of their terms.

Regulations under the Act, which became effective July 1973, have not all been issued. Air Quality Standards and Regulations became effective June 3, 1974, and Land Quality Regulations are in the public hearing stage.

The Wyoming Inspector of Mines also has some jurisdiction over mining operations, particularly for assuring safe working conditions for mine employees and the protection of public safety. The latter responsibility relates to laws and regulations covering abandonment of mines.

All public utilities in Wyoming are regulated by the Wyoming Public Service Commission. Its jurisdiction extends to rate, safety, and environmental aspects of powerlines and facilities, telephone lines and facilities, gas lines and facilities, and railroads. Interstate natural gas lines and rail lines which are regulated by federal agencies do not fall under the Public

Service Commission's jurisdiction. The commission had adopted Utility Environmental Protection Rules which apply to proposed electric generating plants, electric transmission lines and substations of 69 kv capacity or more, gas transmission lines designed for pressures greater than 125 pounds per square inch, railroads, and certain other significant facilities.

The Wyoming State Engineer and the Wyoming State Board of Control administer state water laws which regulate use of surface and ground waters of the State. Applications for new water rights are filed with the State Engineer and petitions for transfer of existing water rights with the State Engineer or the Board of Control depending on the status of the existing rights. Requests are normally approved if it is determined that approval will not jeopardize prior water rights.

The act admitting Wyoming into the United States granted the state certain lands for support of common schools. The lands granted are referred to as public lands of the state and are administered by the State Board of Land Commissioners which is responsible for the granting of rights-of-way (such as may be required for the railroad) and mineral leases on these lands. Rights to coal on the state public lands may be obtained by lease only.

Counties and cities in Wyoming have authority under state law to regulate land uses by comprehensive planning and by zoning.

<u>Relationships with private interests</u>

Interaction between private and federal property interests occurs frequently in the Powder River Basin, resulting from the historical federal practice of conveying land to private ownership with reservation to the United States of some or all minerals underlying the land. The Acts of June 22, 1910

(30 U.S.C. 83-85) and July 17, 1914 (30 U.S.C. 121-124) were the earliest federal statutes calling for this reservation. The reservations required by those acts were limited to specific minerals, most commonly oil and gas or coal.

In the case of reservation of coal, the Act of June 22, 1910, provides that any person having rights to prospect for or mine the coal may enter and occupy the land for that purpose. He must first pay the surface owner for damages caused by his operation or post a bond to cover those damages.

By far the most common reservation of minerals occurs with lands which passed to private ownership under the Stockraising Homestead Act of December 29, 1916 (39 Stat 862; 43 U.S.C. 291-302). Section 9 of that Act provides that all conveyances of land under its provisions shall contain a reservation to the United States of all minerals, together with the right to prospect for, mine, and remove them. In addition, the law spells out in some detail the relative rights of the surface owner and the holder of mineral rights. Again, there is provision for posting of bond by the holder of any mineral rights (lease) for the benefit of the surface owner if agreement with the surface owner cannot be reached. Liability of the holder of mineral rights is limited to damage to crops (including forage) or other tangible improvements. Damages for reduction in the value of land for grazing can be awarded pursuant to the Act of June 21, 1949 (63 Stat 215; 30 U.S.C. 54).

Bonds posted under the above Acts are filed with the Bureau of Land Management (BLM). If amounts of the bonds are protested as inadequate by the landowner, BLM must decide the proper amount.

In recent years, BLM has further concerned itself with protecting interests of surface landowners when it proposes to issue new coal leases by consulting with the landowners when preparing stipulations for inclusion in the leases. Protection of facilities critical to the landowners' ranching operations is of particular concern. BLM field offices make similar contact with landowners when reviewing lessees' proposed mining plans which are submitted to BLM by Geological Survey for comment and recommendations.

The Wyoming Environmental Quality Act also has provisions for considering interests of surface landowners where the surface and mineral estates are split. In such instances, a mining permit may not be issued without consent of the surface owner or the posting of a bond for the surface owner's benefit to secure payment of any damages "to the surface estate, to the crops and forage, or to the tangible improvements" of the landowner. Under both federal and state laws, if the extent of compensable damages cannot be agreed on by the parties, the landowner must sue for damages in court.

Private interests do not have any legal control over location of railroads or other public utility facilities in Wyoming, for such utilities are authorized by state law to condemn lands where needed for their purposes, subject only to compensation for the market value of the taking.

Geographic Area Relationship

The Powder River Basin is the western extension of the great plains in Wyoming. The basin covers nearly half of northeastern Wyoming and parts of southeastern Montana. The structural or geologic basin is bound by the Bighorn Mountains on the west, the Black Hills on the east, the Laramie Mountain Range on the south, and the Cedar Creek Anticline in Montana on the north. The Wyoming portion of the basin contains approximately 8,000,000 acres.

The basic study area, the "Eastern Powder River Coal Basin," contains all of Campbell County and that part of Converse County north of the Platte River as outlined on Figure 1. It includes 4,978,560 acres. Gillette and Douglas, the major communities, are the county seats of Campbell and Converse, respectively. Glenrock, Moorcroft, and Arvada are other small communities located on edges of the study area. Rural post offices, country stores, gasoline stations, rural schools, and oil camps are scattered throughout the area at places such as Weston, Spotted Horse, Recluse, Reno Junction, Bill, Hilight, etc.

Large tracts of land are leased for coal development extending from 25 miles north of Gillette to 70 miles southeast of that city. An additional area approximately 22 miles long and located about 32 miles northwest of Douglas is also covered by several leases. Map 5, Appendix A, illustrates the extent of coal leasing in the study area, and Map 6 shows the mines expected to be developed by 1985.

Present indications are that there will be two centers of coal development in the time frame of this report although it is probable that most of the large leases will eventually be developed. The first of these centers is the Gillette vicinity. Two mines are now active near Gillette, the Wyodak mine about five miles east and the Amax mine about 14 miles southeast. In addition, Carter Oil Company plans to develop a mine about eight miles north of Gillette. Finally, it is expected that before 1985 a second Amax mine will be developed north of Gillette and Sun Oil Company will develop a mine about 17 miles to the southeast. The Carter mine and expansion of the Wyodak mine are examined in detail in Parts IV and VI of this report. These mines, centered around Gillette, will create a population and activity center with that city as nucleus.

A second center of mining activity will be about 12 miles southeast of Reno Junction, the Junction of State Highways 59 and 387. Here leases of Atlantic Richfield Company and Kerr-McGee Coal Corporation are scheduled for early development. Also in this area, the lease of Peabody Coal Company is to be developed in conjunction with a coal gasification plant to be built by Panhandle Eastern. Location of the plant site has not been announced, but it could be at or near the mine. Lying just to the west of the Peabody and Atlantic Richfield lease is a large lease block held by Pacific Power and Light Company. Development of the Peabody and Pacific Power leases is expected prior to 1985. Commuting distances are about 50 miles from Gillette and 80 miles from Douglas. Because of these distances, some employees may choose to settle closer to their work in order to cut down commuting time.

The Douglas vicinity may be a third development area. The second principal alternate site for the Panhandle Eastern coal gasification plant is near Douglas. In addition, some employees of the Altantic-Kerr-McGee-Peabody-Pacific Power mine complex may choose to live in Douglas in spite of the longer commuting distance.

Certain potential impacts of coal development within the Eastern Powder River Coal Basin are not confined to the study area. Considerations of socio-economic conditions, land use controls and constraints, transportation, history, archeology and paleontology, air quality, water resources, and climate have been analyzed basinwide (Figure 3) and include the eight-county area of Sheridan, Johnson, Natrona, Campbell, Converse, Crook, Weston, and Niobrara Counties. Analysis of recreation impacts extends beyond the Powder River Basin proper into Montana, South Dakota, and eastern Wyoming so that major, popular recreation opportunities available to residents of the basin could be identified. Such analyses as topography, soils, minerals, aesthetics, vegetation, wildlife, and agriculture are primarily confined to the basic study area with such minor exceptions to accommodate data sources aggregated on some other geographic basis.

Ownership of land within Campbell and Converse Counties is shown in acres below (State of Wyoming 1973):

County	Federal	State & Local	Private	Total
Campbell	384,647 (12.7%)	199,759 (6.6%)	2,450,205 (80.7%)	3,034,614
Converse	344,327 (13.0%)	260,638 (9.8%)	2,048,319 (77.2%)	2,653,284

Federal lands within Campbell and Converse Counties are principally under the jurisdiction of the Bureau of Land Management and Forest Service. The Bureau of Reclamation has small holdings within each county and the Defense Department has small holdings within Converse County. In Campbell County, 221,721 acres are national resource lands administered by the Bureau of Land Management. BLM managed lands are scattered throughout Campbell County, and no area could be considered a large block of national resource lands (Map 1, Appendix A). Forest Service managed lands in Campbell County

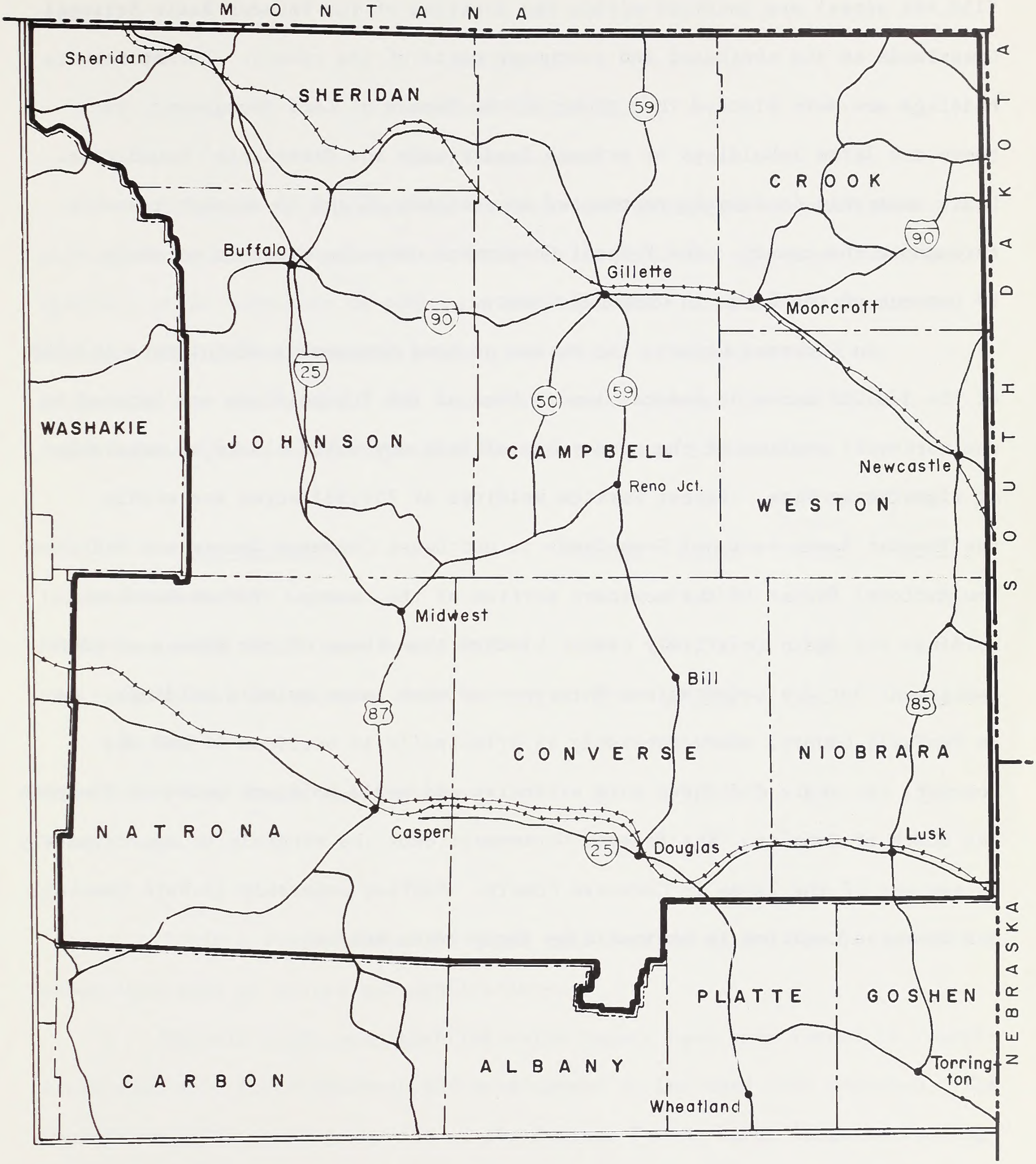

Figure 3
EIGHT COUNTY BASIN AREA

(158,484 acres) are confined within two portions of the Thunder Basin National Grasslands in the northeast and southeast parts of the county. Forest Service holdings are more blocked than those of the Bureau of Land Management, but there are large inholdings of private land within the Grasslands' boundaries. State ownership is largely restricted to sections 16 and 36 of each township throughout the county. The Federal Government owns the minerals on about 85 percent of the lands in Campbell County.

In Converse County, the Bureau of Land Management administers 107,656 of the 370,010 acres of federal land. Most of the BLM holdings are located in the northwest portion of the county but without any solid blocks of ownership of significant size. Forest Service holdings of 257,523 acres are within the Thunder Basin National Grasslands in northeast Converse County and Medicine Bow National Forest in the southern portion of the county. Forest Service holdings are again relatively better blocked than those of the Bureau of Land Management but are nevertheless interspersed with large private holdings. As in Campbell County, state ownership is principally in sections 16 and 36; however, the state does have more extensive and solid holdings south of Glenrock and south of Douglas. The Federal Government owns the minerals on approximately 75 percent of the lands in Converse County. Surface ownership in both Campbell and Converse Counties is dominated by the private sector.

CHAPTER II

POTENTIAL DEVELOPMENT

Coal Development

In order to appraise the environmental impact of proposed coal mining in the Eastern Powder River Basin in Campbell and Converse Counties, Wyoming, it is necessary to summarize the importance of the coal resources, indicate likely development patterns, and arrive at a coal production projection for the future. The number and total acreage of coal leases, lease applications, and permits for federal coal are given below.

			Percent of	
Action Status	Number	Acres	County Area	Study Area
Issued Federal Coal Leases	42	93,075	1.6	1.9
Preference Right Coal Lease Applications	44	96,517	1.7	1.9
Outstanding Coal Prospecting Permits	28	64,252	1.1	1.3
Subtotal	114	253,844	4.4	5.1
Competitive Coal Lease Applications	20	157,861	2.7	3.2
Total	134	411,705	7.1	8.3

Table 1 lists holders of these coal interests, and Map 5, Appendix A, shows locations of leases and applications.

Of this land, only that for which leases have been issued is immediately available for commitment and development of included coal reserves. The importance of the coal resources of the Eastern Powder River Basin in Wyoming is indicated by the estimate that 12.4 billion tons of economically strippable recoverable coal reserves are in Campbell and Converse Counties, that 13.3 billion tons are in the Northern Great Plains of Wyoming, and that 36.5 billion tons of economically strippable recoverable coal and lignite reserves are in the Northern Great Plains of Montana, North Dakota, South Dakota, and Wyoming. The national strippable coal reserve was estimated by the U.S. Bureau of Mines in 1971 to be about 45 billion tons. The national reserve has been increased by new coal discovery since 1971. The Eastern Powder River Basin contains a significant portion of the Nation's economically recoverable strippable coal reserves.

The immense coal reserves and resources of the Eastern Powder River Basin can be mined effectively by both opencast and underground methods depending upon coalbed thickness and the thickness of overburden. Coal resources are sufficient to satisfy future mining and coal demand with due regard for economic and physical constraints.

The relatively thick coalbeds are overlain by thin overburden in many places. Thus, large tonnages of coal can be exposed and mined near the outcrop with little overburden handling. As the working faces of active mines are advanced basinward down the dip of the coalbeds, the overburden increases in thickness and becomes thicker than can be economically removed by surface-mining methods. At this point the coal must be mined underground if it is to be recovered. Portions of coalbeds in excess of about 12 feet in thickness cannot be recovered by underground methods. Thus, underground methods employed in thick coalbeds lead to poor recovery and resulting waste of coal resources. Ongoing underground mining research by industry and government is directed to the development of new mining techniques and methods to recover a much higher percentage of coal than is possible with present methods. Coal production from the Eastern Powder River Basin in the next few years will most likely be entirely from the development and expansion of strip mines at land surface where full economic advantage of thin overburden occurrences can be realized. Present plans of mining companies include only surface mining. Underground mining can be expected in the future but only as areas amenable to surface mining are no longer available.

Table 1

Coal Interests
Campbell and Converse Counties
North of Platte River

Issued Leases

Atlantic Richfield

Serial Number	Acres
W-2313	5,844
W-3446	5,800
W-36094	40
	11,684

Wayne Brannan

B-031719	40

The Carter Oil Company

W-3397	5,251
W-5035	4,782
W-5036	5,457
	15,490

Concho and J. C. Karcher

W-0256663	756
W-0220516	1,571
	2,327

Farmers Union Central Exchange, Inc.

W-0325878	599

(Continued)

Table 1 (Continued)

Humac Company

Serial Number	Acres
W-0136195	1,477
W-0136196	1,560
W-0136194	322
	3,359

Kerr-McGee Corporation

W-23928	4,192
W-24710	160
W-0311810	1,263
W-0312311	880
W-0313668	2,200
	8,695

Meadowlark Farms, Inc.

W-0313773	3,520
W-0317682	2,440
	5,960

Mobil Oil Corp.

W-23929	4,000

Pacific Power & Light

W-038597	1,400
W-038602	2,000
C-054769	120
W-041355	560
W-0244167	1,803
W-0312918	3,780
W-0322255	1,869
W-0321780	2,980
	14,440

(Continued)

Table 1 (Continued

Peabody Coal Co.

Serial Number	Acres
W-37829	40
W-0271199	640
W-0271200	760
W-0271201	2,180
W-0313667	2,560
W-0321779	11,101
	17,281

Summit Exploration & Development Co.

W-0310712	40
W-0324701	680
	720

Sun Oil Company

W-8385	6,560

Wyodak Resources Development Corp.

W-073289	240
W-0111833	80
W-0313666	1,560
B-037423	40
	1,920

Issued Leases	Total Acres
42	93,075

(Continued)

Table 1 (Continued)

Preference Right Lease Applications

Peabody

Serial Number	Acres
W-916	3,318
W-917	320
W-25717	200
W-25718	160
W-26198	2,508
W-26199	640
W-32061	80
W-32062	160
W-32063	520
W-32064	1,560
W-32065	280
W-25719	680
W-32506	835
W-32067	80
W-32068	240
	11,581

E. L. Lockhart

W-1595	5,120
W-1596	2,520
W-1597	3,592
W-1598	4,200
W-1599	5,110
W-2273	2,443
W-2274	4,274
W-2275	4,958
W-2276	3,815
W-4996	2,616
W-4997	2,668
W-4998	1,737
W-16313	2,205
	45,258

Coal Conversion Corp.

W-4995	2,557

Thomas Woodward

Serial Number	Acres
W-8307	4,756
W-8308	3,224
W-8309	2,229
W-8310	3,400
W-8311	3,966
W-8312	1,575
	19,150

J & P Corp. (Wold)

W-9033	240
W-9036	80
	320

Peter Wold

W-11128	1,359

Eugene Stevens

W-12767	1,281
W-14355	4,352
W-14390	3,928
W-14392	3,655
	13,216

Pioneer Nuclear Corp.

W-21515	800
W-21516	2,276
	3,076

Preference Right Lease Applications	Total Acres
44	96,517

In the United States about 600 million tons of coal annually are mined and consumed or exported. Of this amount, less than 1 percent is produced from the Eastern Powder River Basin. However, because of the presence of shallow, thick coalbeds, industry plans to mine significant quantities of coal in the next few years from the basin.

There are four active coal mines (Figure 2) in the Eastern Powder River Basin, the Antelope mine of Brannon (not included in compilation because of limited coal production), the Belle Ayr South mine of Amax Coal Company, the Dave Johnston mine of Pacific Power and Light Company, and the Wyodak mine of Wyodak Resources Development Corp. Most production from the Dave Johnston and Wyodak mines is used to fuel coal-fired, steam-electric generating plants near the mines. Other coal produced from mines is used locally for space heating or exported for domestic consumption. Of these four companies, Wyodak Resources Development Corp. plans to increase coal production to fuel power plants. In addition to Wyodak, three companies plan to open new coal mines to satisfy out-of-state demand. The Black Thunder mine of Atlantic, the Jacobs Ranch mine of Kerr-McGee Corporation, and the North Rawhide mine of Carter Oil Company are all scheduled to begin production no later than early 1977. As stated in Chapter I, several companies are making final plans or have started extensive studies directed toward the opening of new mines or increasing production from active mines. Thus, for purposes of estimating potential coal development of the Eastern Powder River Basin, there are three active mines (two of which plan expansions) and seven proposed mines. There are also two power plants, one proposed power plant, and one proposed coal gasification plant directly related to existing or proposed coal mining activities.

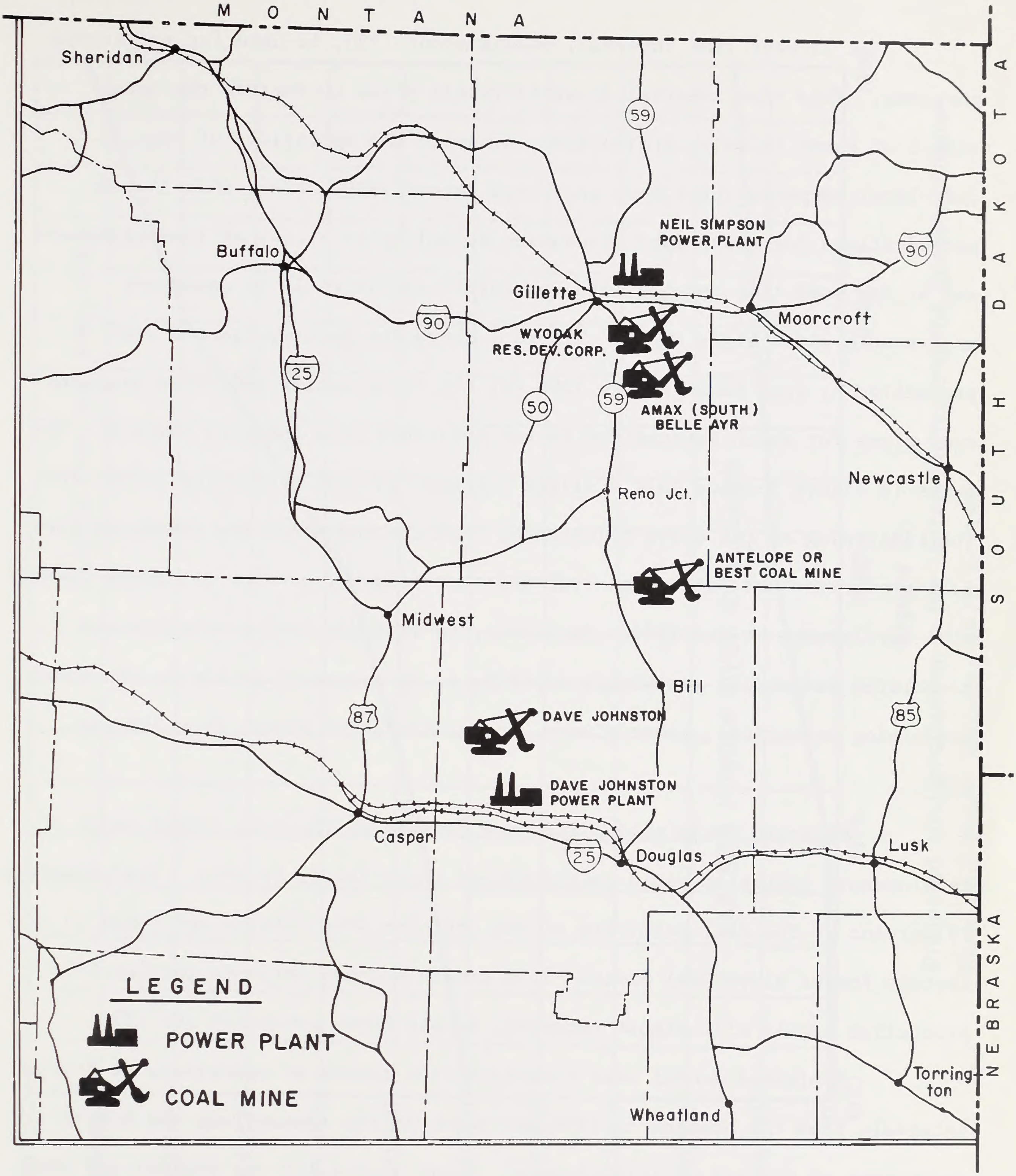

Figure 2

Existing Power Plants and Coal Mines Within the Study Area (1974)

A 15-year time interval, ending about 1990, is used for projection purposes. This time interval is sufficiently great to include the total effect of known industry projections, although the operations of some individual companies have been projected beyond 1990. Also, this 15-year period allows for convenient discussion by multiples of 5-year time intervals and at the same time extends into the future sufficiently to encompass most events which might occur. Figure 3 shows the total projected coal production by year from 1970 to 1990 for the three active and seven proposed coal mines for which information is now available from industry sources. The curve in Figure 3 shows only a slight increase in coal production after 1983. The flattening of the curve illustrates that the ten mines are scheduled for full production not later than 1982 and that industry has not projected further mine development beyond 1983. Therefore, to estimate coal production and associated industrial activities to 1990, it is necessary to add to the model new mining operations, power plants, and gasification plants from 1983 to 1990.

Although these projections are considered the most likely level of development, expansion could extend beyond these levels by 1990. Approximately 75 percent of the coal resources of the Northern Great Plains are found in the Eastern Powder River Coal Basin. If a growth economy persists through 1995, production levels will almost certainly exceed those projected for 1990.

Projected annual coal production and number of operations at 5-year intervals from the present to 1990 are shown in the Assumptions and Analysis Guidelines at the end of this chapter. Items listed for the present and 1980 are based solely upon known plans and projections of industry. Items listed for 1985 and 1990 are based upon modest industrial and mine expansion after 1983. Changes in the annual rate of coal production beyond 1983 are based on

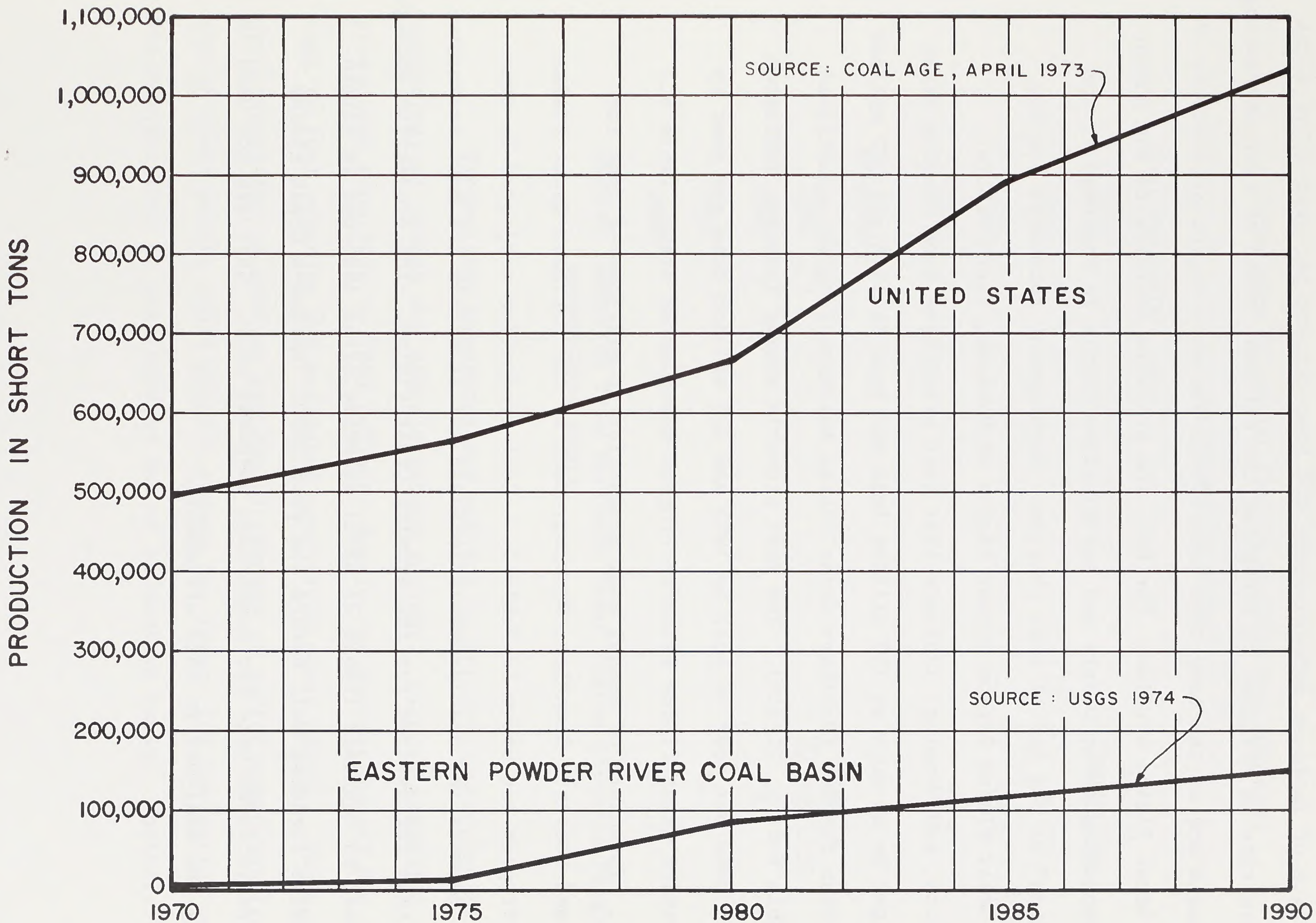

Figure 3
Projected coal production in the United States and the Eastern Powder River Coal Basin, Wyoming 1970 to 1990.

a modest rate of increase between three and four percent per year after about 1983. This rate is designed to recognize the national trend of ever increasing energy demand and at the same time stay within the most recent projections of Northern Great Plains studies. Further, the probable increase in the number of coal-consuming power plants and gasification plants is included in the "Assumptions" at the end of this chapter. Development forecasts for the Northern Great Plains Region (Great Plains of Montana, North Dakota, South Dakota, and Wyoming) indicate that coal production from Wyoming Great Plains might be as much as 153 million tons per year in 1985 and 387 million tons per year in 2000 (Northern Great Plains Resource Program unpublished draft, Table E-1, p. II-110). The most probable energy forecast indicates 75 million tons per year of coal by 1985 and 110 million tons per year by 2000 (Northern Great Plains Resource Program unpublished draft, Table 6.1 p. II-87). Forecasts of annual coal production in millions of tons for Campbell and Converse Counties, Wyoming, made by the Northern Great Plains Resource Program are shown in Table 2. Coal production projected in this statement exceeds the most probable forecast but is within the most extensive forecast thus far derived for the Wyoming Great Plains. The projection exceeds the forecast by counties (Table 2) until sometime after 1985 but is within the extensive forecast well before the year 2000. Northern Great Plains figures are included here for comparison purposes only. They are not used in developing the analyses in this statement.

Table 2

Forecasts of Annual Coal Production for Campbell and Converse Counties, Wyoming (millions of tons)

Most Probable

Year	Annual Production
1980	34
1985	58.5
2000	72.2

Extensive

Year	Annual Production
1980	34
1985	122.7
2000	285.7

Source: Modified from Northern Great Plains Resource Program unpublished draft.

Projections presented are subject to serious distortion by possible technological trends and administrative actions. Planned expansion of coal production from 1974 to 1983 reflects mostly the present demand for low-sulfur coal to fuel existing and projected coal-fired power plants. The successful desulfurization of coal or successful removal of sulfur compounds from the stack gas of power plants could greatly reduce the demand for low-sulfur western coal which might then be displaced by use of midwestern coals. Further, the immense fuel consumption of large power plants might yield from stacks sufficient quantities of sulfur compounds that even low-sulfur coal would be administratively determined to be an undesirable fuel. The extent to which nuclear power is used and the rate at which nuclear power is phased into the nation's energy supply is of direct consequence to the coal industry and bears directly upon the future coal production from the Eastern Powder River Basin. Extensive and rapid development and use of nuclear power plants would decrease the rate of development of the coal resources of the basin. Conversely, western coal before transport is available more cheaply than coal from the midwest and might be used in large quantities for conversion to gas and liquid, especially as domestic and foreign oil and gas is depleted in the future.

Exportation of Coal

Most coal produced will be exported from the basin largely to satisfy electric utility demand in the midwest and south-central United States.

In 1965, Amax Coal Company acquired its first lease, and when market conditions improved in 1971, development of the Belle Ayr mine 14 miles southeast of Gillette was started. Reserves of 350 million tons are located on 2,440 acres of federal land and 640 acres of private land. Initial production of the Belle Ayr mine in 1973 was 1.3 million tons, but plans are to mine three to four million tons in 1974 and ten million tons in 1976. The quarry type mining method is used. Of the initial production, one million tons were shipped in 1973 to the Public Service Company in Pueblo, Colorado.

Present plans are to export coal out of the basin to power plants as far south and east as the Gulf Coast and central Mississippi Valley. The production schedule through 1985 for four operations indicated in Chapter I is shown in Table 3. Also shown in this table are the quantity and destination by state of the scheduled production. Some production is presently scheduled for future contracts or for destinations not yet firm. Where destination is not known, the receiving organization is given. Additional companies are expected to be mining Powder River coal in this time period.

Table 4 presents the cumulative amounts of coal mined and approximate tonnage shipped out of the region.

Table 3

Production Schedules of Four Companies and the Destinations by State of the Coal Produced
(millions of short tons)

Company and Destination	Years 1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
ARCO			1.2	3.8	6.6	10.0	10.0	(10.0)*	(10.0)*	(10.0)*	(10.0)*	(10.0)*
Nebraska												
Oklahoma												
Texas												
Carter Oil Co.			.5	3.6	5.0	5.0	5.0	5.0	5.0	12.0	12.0	12.0
Indiana and Michigan Electric Co.			.5	3.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Kerr-McGee Corp.				1.227#	5.035	9.2	9.665		12.62	15.9	15.9	15.9
Arkansas				.465	2.965	5.0	5.0	5.46	7.5	7.5	7.5	7.5
Louisiana				.762	2.070	4.2	4.2	4.66	5.9	5.9	5.9	5.9
Wyodak Res. Dev. Corp.	.7	.7	.7	2.5	2.5	2.5	2.5	2.5	5.0	5.0	5.0	5.0
Wyoming	.7	.7	.7	2.5	2.5	2.5	2.5	2.5	5.0	5.0	5.0	5.0
Total Scheduled Production	.7	.7	2.4	11.127	19.135	26.7	27.165		30.12	35.9	42.9	42.9

*Production schedule ends in 1980, mine capable of an ultimate production of 15 to 20 million tons per year.
**Receiving organization, destination not firm.
#Numbers are not rounded because they reflect firm scheduling by the company. Thus, payment will be received for all amounts of coal delivered, here scheduled to the nearest 1,000 short tons.

Table 4

Cumulative Coal Mined and Exported (Million Ton)*

	1980	1985	1990
Total Mined	296	858	1,543
Exported	237	666	1,170
Percent Exported	80	78	76

*Based on total projected coal development in the study area

Mine Mouth Power Generation

Large scale mining for power generation did not begin in the Powder River Basin until 1956. Wyodak Resources Development Corp., a subsidiary of Black Hills Power and Light Company, acquired leases six miles east of Gillette. Coal from the Wyodak mine in Donkey Creek Valley is burned at the Black Hills Power and Light Company's plants at Wyodak and Osage, Wyoming, and Kirk and Rapid City, South Dakota. In 1969, Unit No. 5 was added to the Neil Simpson Station adjacent to the Wyodak mine. This unit features the first air cooled condenser on a steam turbine generating plant in the Western Hemisphere. It has a capacity of 21 megawatts. A major new air cooled power plant of 330-megawatt capacity is planned to be on line in 1977 in conjunction with expansion of the Wyodak mine.

In 1955 Pacific Power and Light Company(PP&L) was issued a coal prospecting permit which proved successful and resulted in the filing of a preference right lease in April 1956. Six miles east of the Town of Glenrock, ground breaking for the 100-megawatt Dave Johnston steam-electric plant began June 30, 1956, with an additional 200 megawatts being added during construction in 1958. The center of the Dave Johnston coal field is about 20 miles northeast of Glenrock. The 18-foot thick Badger Seam is separated from the underlying 35-foot thick School Seam by an interval of 100 feet in the northern part of the field and 180 feet in the southern portion.

In 1964 a railroad was built to haul coal from the mine to the power plant and construction began on an additional 200-megawatt generating capacity. By 1965 mine production had reached 1,140,000 tons per year, and the mine force consisted of about 35 men. Originally, all coal mined in Converse County, with the exception of the Best Coal Mine, was destined for the Dave Johnston power plant, but in 1968, Food Machinery and Chemical Company began to purchase from PP&L about 1,000 tons per year of outcrop coal to be used in the manufacturing of fertilizer material. This continued through 1972 but has never become a major alternate market. An additional 330 megawatts were installed at the Dave Johnston facility in 1969, and a major change in mining methods was planned to increase production for the additional power units. Coal production increased from 1.8 million tons to over 3 million tons per year, and the work force increased to 92 men. Electric generating capacity is now rated at 750 megawatts. A total of 864 acres was disturbed from 1958 to 1973; about 104 acres were disturbed last year.

Although no plans have been announced for new power plants in addition to the Wyodak expansion, it is projected that one plant will be built by 1985 and another by 1990. A 500-megawatt water-cooled plant requires about 2.25 million tons of coal and 5,500 acre-feet of water annually. Each plant would occupy about 1,000 acres and require mining which would disturb about 20 acres each year. Transmission lines require about 23 acres per mile.

Gasification

Plans for one coal gasification plant have been announced. This project is a joint venture of Panhandle Eastern Pipeline Company and Peabody Coal Company. The mine, to be operated by a subsidiary known as Rochelle Coal Company, is located about 48 miles north of Douglas. A plant site has not been selected; two principal sites are being considered. The first is near Douglas, about 30 miles south of the mine, and the other is near the mine. The gasification plant would be operated by a subsidiary company known as Wyoming Coal Gas Company.

Mine

The coal reserve dedicated to the gasification plant is 550,000,000 tons underlying 6,800 acres. The firm has 694,951,400 tons of coal reserves under lease or option underlying 8,588 acres.

Twelve miles of access road are planned by the company, and a railroad spur will be constructed to the proposed mainline of the Burlington Northern/Chicago North Western railroad. Deep water wells are expected to supply 1,200 acre-feet per year to meet water requirements at the mine. An electric power transmission line will be constructed to supply power for construction and for mining machines and other operating needs.

Plant

The gasification plant will require 1,000 acres for facilities, plus additional acreage for access roads, railroad spur line, and pipelines. It will process 11,000,000 tons of coal annually and will require 5,000 to 10,000 acre-feet of water. From this, 250 million cubic feet per day of 960-970 Btu/cu. ft. gas will be produced. By-products would be 8,000 barrels of liquid petroleum products and 100 tons of sulfur per day.

The company has proposed constructing a power plant of 60-megawatt capacity to supply electrical needs of the plant.

Unconfirmed plants

One other firm, Carter Oil Company, has proposed a gasification plant but no location has been announced. It is assumed that the plant will be of a size comparable to the Panhandle Eastern-Peabody plant, and it is very likely that the Carter plant will be in the vicinity of the Carter mine six miles north of Gillette. Other gasification plants have been rumored but not confirmed.

Detailed analyses of the gasification projects are not included in this study; an environmental analysis will be prepared at the time specific gasification projects are proposed to determine if approval of applications by federal agencies would constitute major federal action significantly affecting the quality of the human environment.

Other Industrialization

Other industries in the study area will be influenced in a variety of ways by coal development activities. Construction industry impacts will relate directly to basin growth while agriculture will be indirectly affected. Development of other energy commodities such as uranium, oil, and gas will be affected in the sense of competing for high demand goods, services, and resources.

The construction industry will experience enormous growth during the short term (ten years) with a subsequent leveling off in rate of expansion. Construction of coal gasification and electric power generating plants requires large labor forces and heavy capital investment. Other construction necessary for housing and related services needed to accommodate growth in the basin will be sustained for a much longer period and thus provide long-term growth in the industry after the peak energy related facilities are completed. Many million cubic yards of sand and gravel will be required for concrete structures. Because these materials are limited in the area, large quantities will have to be imported from the nearest economic source.

The same situation prevails for wood products. While some timber is harvested in the northeastern part of the area, yields will not approach the high demands required for community and industry development. Timber will be imported from the nearest economic source. With respect to employment, the present base of 3,200 is projected to reach an estimated 6,800 by 1990.

The outlook for the agricultural industry, particularly in view of a ten-year historical perspective, is one of continuing decline in percent of the total economy of the impacted area. Energy development in the basin will compete with agriculture for both water and employment. Doubtless, these resources will be attracted away from agriculture by higher prices. Projected agricultural employment will drop from the present level of 3,800 to 3,300 by 1990.

Oil and natural gas reserves in the basin will become increasingly depleted by present extraction, and this industry will be faced with the ever present problem of resource availability. However, a highly active oil and gas exploration program is continuing to add new fields and zones to the discovery list each year. In fact, exploration activity for new fields in 1974 is again at an all time peak owing to the energy crisis and the unprecedented prices being paid for new oil and gas. Future prospecting can be expected to result in discovery of many more oil and gas fields and producing zones. Also, new recovery methods will improve ultimate production, resulting in extension and continuation of oil and gas operations in the basin for at least another 50 years. Despite increased exploration activity, the current employment level of 5,000 will probably reach only an estimated 5,150 by 1990.

Uranium mining and milling are presently conducted in the basin at the Exxon Corporation, Teton Exploration Drilling Company, and Kerr-McGee mines. Industry surveys conducted by the State of Wyoming Department of Economic Planning and Development and the Bureau of Land Management have identified four more prospective uranium operations that may be developed in the basin.

The Northern Great Plains Resource Program report states that:

> "Assuming that these plant developments are operative by 1980, employment in uranium mining and milling in 1980 should be approximately 1,472. The assumption is made that uranium activity will continue to increase to 1985 and then decline as breeder reactors become a source of fuel. On this basis, uranium mining and milling employment is projected to reach 1,772 by 1985 and then decline to the 1980 level by 2000."

No projection has been made for light industry, sales, and service growth that will occur in conjunction with area development. Since major industrial outlets and manufacturing centers are located long distances from the basin, the transportation and distribution of a wide variety of material will constitute a significant enterprise.

Modes of Distribution

Railroads

Rapid continuous transport of coal is essential to efficient mining operations. Coal production of 5 to 15 million tons per year for each mine requires a transportation system capable of rapidly handling large volumes. A railroad is one system that meets this requirement. The mining companies propose to export coal from the region by unit trains of approximately 100 cars (Figure 4) using the Burlington Northern's and Chicago and North Western Transportation Company's proposed Gillette to Douglas railroad line. The theoretical capacity of the proposed line as presently considered for construction, with sidings at 12.5-mile intervals and a 25-mph average train speed, would be 48 unit trains per day including returning empties or a 365-day yearly transportation capacity of approximately 96 million tons of coal. This capacity would be reduced significantly by smaller train sizes, unequal return train times, transportation failure, and railroad maintenance. Based on the projected coal production, full theoretical rail line capacity would be achieved before 1983.

Each operation requires a spur line connecting the mine site to the mainline. The spur normally has a loop and storage silos to facilitate rapid, continuous loading. Proposed spur lines are built to heavy-duty standards to carry heavy, continuous traffic. A large loop permits trains to move through loading silos at a constant rate and return to the spur line without switching or stopping. Two to five 12,000-ton, drive-through storage silos are required on each loop. The loading capacities will range from 2,000 to over 4,000 tons per hour, or a continuous loading capacity of as much as 100,000 tons per day.

Figure 4

100 Car Unit-Train on Its Way to Loading Facility

With computerized weighing and optical accounting of cars, the coal tonnage of each train will be continuously and accurately monitored. In addition to a coal loading loop, another track may be necessary for handling ash and waste material from a gasification plant. A switch will give the ash train access to the loop, and it will use the same spur to the mine site that the coal train uses.

Carter Oil Company proposes to connect the North Rawhide mine site to the Burlington Northern mainline at Gillette by a nine-mile branch line. The same branch will also serve the proposed Belle Ayr North mine of Amax Coal Company. In order to carry the ultimate production of 15 to 20 million tons per year, double track may be required for the branch. Where the proposed Burlington Northern/Chicago and North Western mainline crosses the mine leases, the train loops will connect directly to the mainline. A seven-mile spur from this mainline will serve both the Altantic Richfield and Kerr-McGee mines. This spur may also require double track if the proposed ultimate production of 30 million tons of these mines is achieved. At the Peabody Coal Company site, a nine-mile spur will be required to connect the mine to the proposed Gillette-Douglas mainline. This spur will permit high-capacity coal and ash transportation seven days per week.

Pacific Power and Light Company presently maintains its own 16-mile railroad between its mine and power plant. Amax ships its coal by unit train to Pueblo, Colorado. An 18-mile spur line was constructed by Burlington Northern Inc. to connect the mine to the main railroad. The Wyodak mine uses part of its production at the Neil Simpson Power Plant adjacent to the mine and ships the remaining portion by unit trains.

Upon completion of mining activities and abandonment of the mine leases, spur track, silos, etc., will be removed and the right-of-way revegetated.

Figure 5 illustrates a typical mine site layout including unit train loop and loading silos.

Roads

Prime all-weather access roads 5 to 20 miles long will connect the mine sites with major state routes. The roads will be designed for light truck and commuter traffic. Within the mine area, haul roads are proposed for use by heavy-duty trucks having a 100- to 200-ton capacity. These roads extend from the mine pits to storage and processing facilities near the unit train loops. Haul roads will be wide enough to accommodate large draglines, drill rigs, bulldozers, shovels, and other heavy mine equipment. An estimated 24 miles of new mainline, state or county roads will be constructed by 1990.

At the North Rawhide mine site, State Route 59 will be relocated southeastward from its present location over coal deposits. The new road will pass around the mine facilities at the southeast margin of the lease.

Pipelines

The Northern Great Plains Resource Program study estimated 999 miles of major pipelines presently within Campbell and Converse Counties. These pipelines are for transportation of crude oil and natural gas. Additional pipelines are proposed and assumed for development of coal resources. New pipelines would transport coal as a slurry, gas derived from coal, and water to support the above. Water would also be transported for use by new or expanded communities and possibly new power generating plants.

There is a proposal by Energy Transportation Systems Inc. to construct a 1,040-mile, 38-inch pipeline to export coal from the study area to Arkansas in the form of a coal-water slurry. A slurry pipeline rapidly handles large volumes of coal and is an alternative to rail transportation.

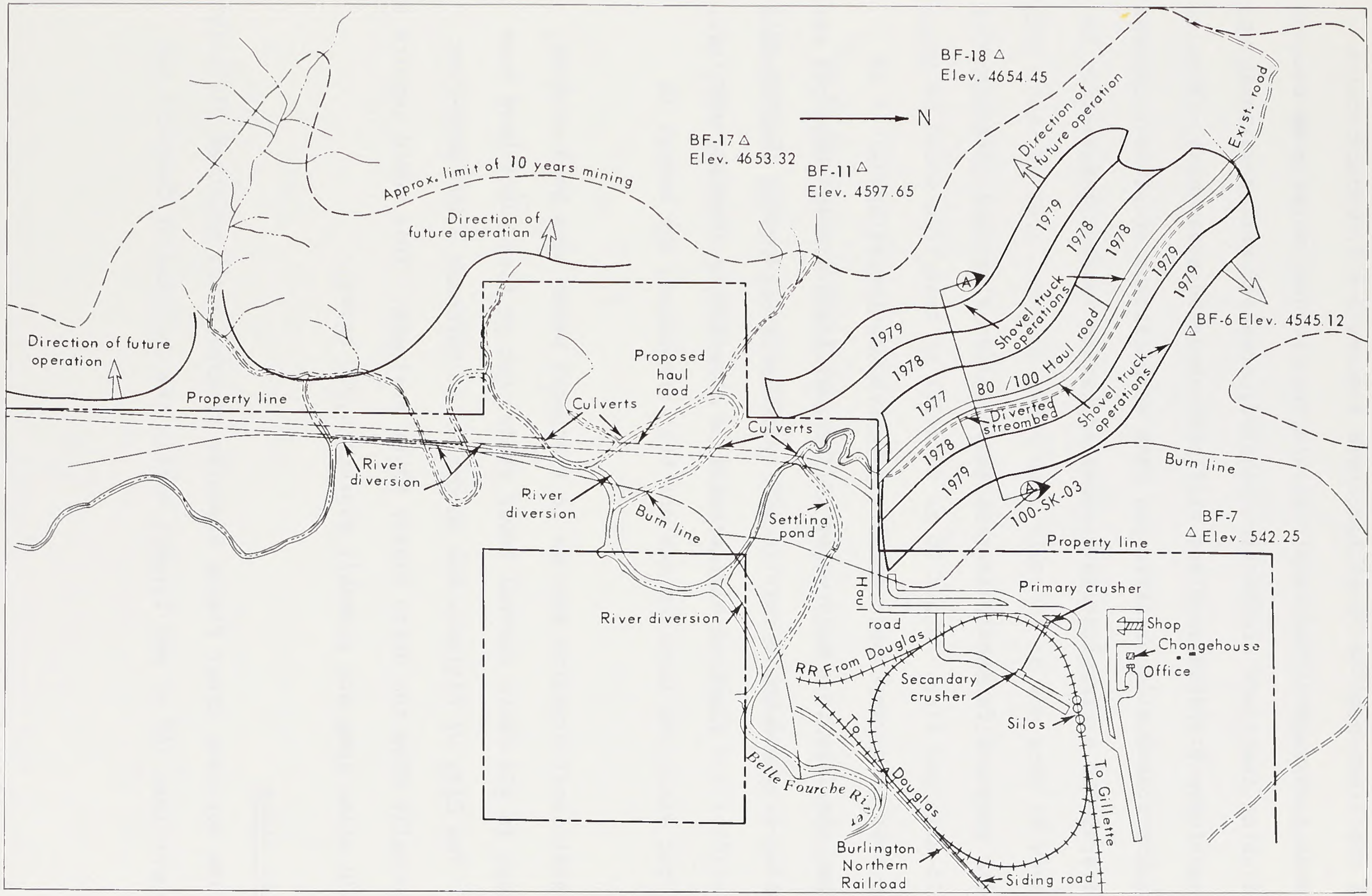

Figure 5

Typical Plan for Unit-Train Loop, Loading Silos, Haulage and Access Roads, Office and Shop Facilities, and Areas Disturbed (Mined) Annually (After Sun Oil Co.).

Capacity of the line would be 25 million tons a year, and it would require 15,000 acre-feet of water. Deep aquifers are the proposed water sources. About 30 miles of the route are within the study area and will require about 360 acres; a slurry preparation plant will need about 60 acres more. The environmental problems will be addressed when applications are filed. Accounts of a second proposed slurry line have appeared but no further information is available.

The proposed Panhandle Eastern gasification plant will require a 24-inch, 475-mile gas line. About 20 to 30 miles of this line would be in the area of this study and would require 200 to 350 acres of land. It is expected that the line to supply water to the gasification plant would be 10 to 30 miles long and would require 100 to 200 acres. Another (Carter Oil) possible gasification plant of similar size is expected to require land for pipelines, but since the location has not been announced, the amount is uncertain.

Additional pipeline systems to transport water have been studied, such as those in the North Central Power study, but no firm plans have been announced. The City of Gillette has an option to purchase 1,000 acre-feet of water annually from the North Platte River drainage. This would require a pipeline 130 miles long and probably disrupt 1,000 acres.

Transmission lines

The Northern Great Plains Resource Program study reported 370 miles of major powerlines (69 kv and larger) within the Counties of Campbell and Converse.

Black Hills Power and Light and Pacific Power and Light Companies propose 44 miles of 230-kv transmission lines within the study area from the new plant to be constructed at Wyodak coal mine. The lines will total 153 miles for power transmission to Buffalo and Spearfish. These lines are scheduled to be in operation by 1980 and will occupy 900 to 1,000 acres.

Pacific Power and Light Company has proposed a 230-kv transmission line from the Dave Johnston plant near Glenrock to the area of Wyodak. This 120-mile-long line is to be constructed by 1985 and will occupy about 3,000 acres.

An additional 145 miles of transmission lines will be needed to serve the two power plants projected in this report and to serve expanded (or new) communities, mines, and processing plants. Other lines may cross the study area from generating plants to be constructed outside.

Water Requirements

Quantity

Development, exportation, and consumption of coal resources, together with associated industrial growth within the region, will require substantial supplies of water for consumptive purposes. Specific actions which would require large additional amounts of water include coal-fired power plants, coal gasification/liquefaction plants, coal slurry pipelines, and community growth (municipal). Minimal amounts of irrigation water would also be needed for reclamation during droughty years. Sources of water to meet these needs could be provided from available and unused ground and surface water or by transfer from present uses (irrigation, etc.). Table 5 gives estimates of present and projected water requirements for various types of uses in the study area for the years 1974, 1980, 1985, and 1990. In addition to the tabulated uses, other lesser but important annual water requirements include livestock water, domestic uses, wildlife needs, and recreation uses. Other short-term uses include construction activities associated with development.

Table 5

Estimated Water Requirements for Largest Users of Water in the Study Area

Type of Use	Annual Water Requirements (acre-feet) 1974	1980	1985	1990
Irrigation	10,000	10,000	10,000	10,000
Reservoir Evaporation	30,000	30,000	30,000	30,000
Municipal**	8,000	15,400	18,600	20,000
Oil Field (water-flood)	12,000	12,000	12,000	12,000
Power Plants	8,430*	8,650*	14,150*	19,650*
Gasification Plants	------	7,000	14,000	14,000
Slurry Pipelines	------	15,000	15,000	15,000
Totals	68,430	98,050	113,750	120,650

*Includes Neil Simpson air-cooled and Dave Johnston water-cooled plants.
**Includes use outside study area resulting from development in study area.

Sources

Some sources of water that will be required for industrial growth in the region have been identified by the companies proposing developments. These are described below for identified sources.

Additional water requirements in 1980 for power plants include a small amount (220 acre-feet per year) for the new air-cooled plant at Wyodak. This water will be furnished by existing wells at the Neil Simpson Station. Water required for the 500-megawatt, water-cooled plant by 1985 and another by 1990 will total 5,500 acre-feet in 1985 and 11,000 acre-feet in 1990. The sources for these plants have not been identified.

With construction of Panhandle Eastern's coal gasification plant by 1980, approximately 7,000 acre-feet per year are proposed to be pumped and piped to the plant site from a proposed reservoir to be constructed near the North Platte River just north of Douglas and from two well fields. Water for the reservoir could come from the North Platte River. Additional water is proposed to be pumped from well fields north of the reservoir site and south of the North Platte River. The second gasification plant would require an additional 7,000 acre-feet per year by 1985. The source of water for this plant has not been identified.

By 1980 a coal slurry pipeline will be in operation which will require an annual water supply of 15,000 acre-feet. This water is proposed to be pumped from a well field in eastern Wyoming north of Lusk.

Increased population growth both within and outside the study area during the period 1974 to 1990 will require additional municipal water. These increased needs are estimated at 7,400 acre-feet per year by 1980, 10,600 acre-feet per year by 1985, and 12,000 acre-feet per year by 1990. The population growth at Gillette will require a substantial increase in annual water use. A large part of this increase is proposed to be piped in from new reservoirs proposed for construction in southern Converse County south of the North Platte River (including Deer Creek, La Bonte Creek, and Wagonhound Creek Reservoirs). Other municipal water will likely be pumped from existing and new water well fields.

Projected water requirements for irrigation (10,000 acre-feet per year) and oil field water flood (12,000 acre-feet per year) indicate no change over the period 1974 through 1990. However, during years of drought, minimal increases in irrigation use would be required for reclamation purposes. An exchange of use may occur during or subsequent to this period with some transfer of use from irrigation to other uses associated with regional coal development.

The potential for ground water development will exist for an infinitely long time based on annual recharge to the aquifers estimated at 150,000 acre-feet per year. This recharge volume is more than enough to satisfy the total increase in demand for water estimated at 50,000 acre-feet per year by 1990 within the study area. Much of the water is not suitable for some uses, such as municipal, domestic, and boiler feed supplies without desalting. Water quality requirements for other uses in the coal development industries have not been clearly specified.

Assumption and Analysis Guidelines

Assumptions

The following tables were developed, based on projected coal and ancillary developments for the study area, to establish parameters and guidelines for the analysis of cumulative regional impacts. They are set forth here in order that the reader may follow how the causes were related to effects and magnitude of impact established. These tables also make it possible for the impacts to be revised in the future, based on amount of actual development which takes place. As new development information becomes available, these tables can be utilized to determine cumulative magnitude of additional impact due to additional development.

Projected Cumulative Development Data for the Study Area (1974 Base)

	Base	1980	1985	1990
Number of Mines	3	10	12	14
Number of Power Plants[1]	2[2]	3[3]	5[4]	6[5]
Number of Gasification Plants	-	1	2	2
Cumulative Tons of Coal Mined (millions)	-	297	858	1,543
Population Increase (1,000's)[6]	-	37	53	60
Miles of New Road	-	16	20	24
Miles of New Powerline	-	44	164	225
Miles of Slurry Pipeline[7]	-	1040	1040	1040
Miles of New Railroad[8]	-	140	145	150

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[1] It is assumed that the 500-MW power plants will be water cooled.

[2] Dave Johnston and Neil Simpson

[3] Plus Wyodak 330 MW

[4] Plus Wyodak 450 MW and new 500 MW

[5] Plus new 500 MW

[6] Population base is 1970. Increase is for eight-county area. Socio-economic impacts are analyzed on an eight-county basis. Projected cumulative population increases for the Campbell and Converse counties are 27,000 - 1980; 42,000 - 1985; and 47,000 - 1990.

[7] Miles of slurry pipeline include only the miles of the one firm proposal which has been made to private industry by Energy Transportation Systems. The pipeline will be an estimated 30 miles long in the study area.

[8] Miles of railroad includes the proposed single track as analyzed in Part II and estimated cumulative miles of spur line to be constructed by 1990.

Projected Coal Production for the Study Area
(million tons/year)

Year	Production	Year	Production
1974	8	1982	109
1975	11	1983	118
1976	16	1984	120
1977	32	1985	122
1978	62	1986	124
1979	79	1987	131
1980	88	1988	137
1981	99	1989	143
		1990	150

Acreage Requirement Used to Analyze Impacts

Facility	Acreage Required (Acres)
Gasification Plant	1,000 per plant
Power Plant (water cooled)	2 per megawatt
Mine[5]	100 per mine
Slurry Preparation Plant	60 per plant
Slurry Pipeline (100' R/W)	12 per mile
Powerlines (230 kv)	23 per mile
Roads (2 lane, 175' R/W)	21 per mile
Per 1,000 Population Increase[6]	50
Per Million Tons of Coal Mined	9 surface acres

[5] Includes mine buildings, shops, etc.

[6] Calculated on the basis of six single-family units per acre and 3.4 persons per family unit.

Water Requirements Used to Analyze Impacts

Facility	Acre-feet/yr.
Gasification plant (250 million cubic feet per day)	7,000
Power Plants (water cooled)	11 per megawatt
Slurry Pipeline (25 million ton coal per year)	15,000
Per 1,000 Population Increase	200

Projected Increased Water Needs for the Study Area

Type of Use	1974	Annual Water Requirements (acre-feet) 1980	Inc.[1]	1985	Inc.[1]	1990	Inc.[1]
Irrigation	10,000	10,000	0	10,000	0	10,000	0
Municipal[2]	8,000	15,400	7,400	18,600	10,600	20,000	12,000
Oil Field (Water-flood)	12,000	12,000	0	12,000	0	12,000	0
Power Plants[3]	8,430	8,650	220	14,150	5,720	19,650	11,220
Gasification Plants	------	7,000	7,000	14,000	14,000	14,000	14,000
Slurry Pipelines	------	15,000	15,000	15,000	15,000	15,000	15,000
Totals	38,430	68,050	29,620	83,750	45,320	90,650	52,220

[1]Increase over base year (1974).

[2]Includes need for the projected population for eight county socio-economic analysis area.

[3]Includes Neil Simpson air-cooled and Dave Johnston water-cooled plants.

Cumulative Disturbed and Reclaimed Acreages in the Study Area Based On Projected Development and Acreage Requirement Units

Type	Year 1980	1985	1990
Coal Disturbed	2,664	7,722	13,887
Coal Reclaimed[1]	0	1,372	4,132
R/W Disturbed	3,108	6,002	7,539
R/W Reclaimed	0	1,372	4,132
Total Disturbed	8,882	19,784	28,936
Total Reclaimed	171	4,036	11,854
Permanently Removed			
R/W's[2]	1,736	1,870	2,004
Facilities[3]	1,760	3,960	5,160
Population (in study area)	1,350	2,100	2,350
Total Permanently Removed	4,846	7,930	9,514

[1]Five year time lag assumed (see item 4 below).

[2]For railroad this will consist of an 80' wide average strip, and for roads a 100' wide average strip.

[3]Facilities include mine facilities, power plants, gasification plants.

Analysis Guidelines

1. Cumulative impacts will be analyzed for three time points (1980 - 1985 - 1990).

2. Level of mining technology will not change significantly through 1990.

3. Mined areas will be reclaimed for livestock grazing (grass species).

4. There will be a 5-year time lag in reclamation efforts for mined areas. After first 5 years, the same amount of area mined will be reclaimed each year.

5. For rights-of-way, railroad, powerlines, roads, there will be a 2-year time lag for vegetation restoration.

6. The following reclamation schedule will be used for proper restoration to a livestock grazing land use:

   1st year - reshaping and topsoiling

   2nd year - fallowing and mulching to allow moisture accumulation

   3rd year - seeding and rest for plant establishment

   4th year - rest for plant establishment

   5th year - allow grazing

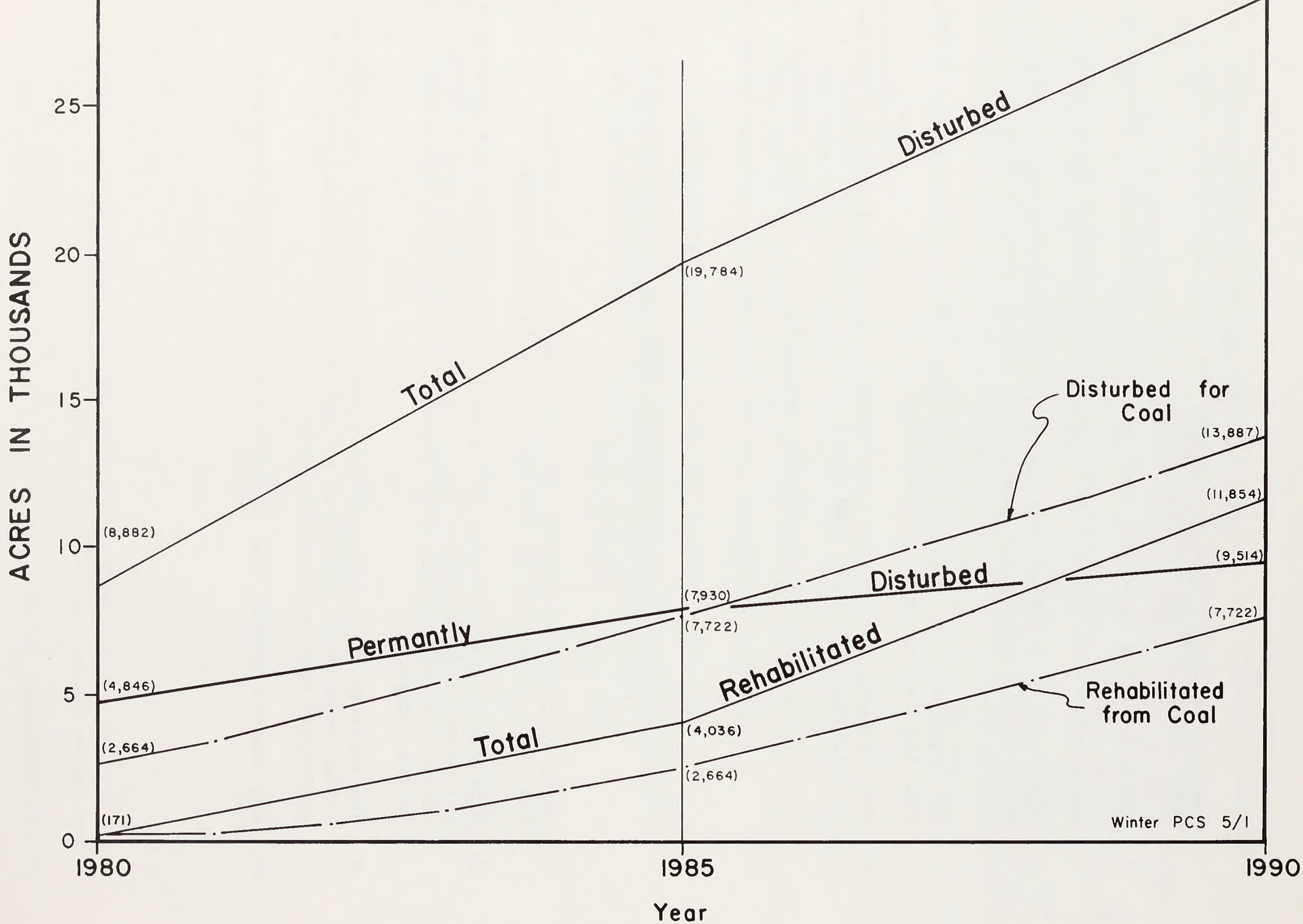
7. There will be a 50 percent loss in productivity for grazing purposes. This will occur even if the entire area is revegetated.

8. Mining plan site analyses will cover, beside the mine and mine facilities, all associated facilities (i.e., powerlines, roads, spur railroad track, acres involved in population increase, living facilities bought or planned by the company).

9. The railroad site analysis will cover construction of the railroad, access roads, powerlines, operation and maintenance and population increase associated with railroad employment.

10. Any impacts lasting over 30 years will be considered permanent.

Figure 6
Cumulative Disturbed and Rehabilitated Acreage



CHAPTER III

DESCRIPTION OF DEVELOPMENT, ENERGY CONVERSION AND DISTRIBUTION SYSTEM MODELS

Mining Operations

Surface mining

Powder River Basin coal, averaging 70 feet in thickness, occurs as a single bed in some parts of the basin but may be split into as many as four beds separated by shale partings in other areas. Coal present on the outcrop is weathered or burned and as such is unmarketable. Initial mining will therefore begin as far down dip as necessary to avoid this unmarketable coal and will progress into the coal-bearing area.

All proposed operating methods are similar in design but differ as to type of equipment to be used based, in part, on variations in thickness of coal and partings. Extraction operations can be divided into three distinct phases: (1) topsoil removal, (2) overburden removal, and (3) coal removal.

Topsoil removal

Topsoil over most areas to be mined is less than 24 inches thick and, therefore, can be easily removed by self-loading scrapers. Scrapers will be utilized at all operations presently proposed and are expected to be used for any operations developed in the near future. Companies will be required to salvage topsoil in accordance with recommendations of the Wyoming State Department of Environmental Quality, and/or the federal agency having jurisdiction over the land surface.

Prior to initial mining in any area, all available topsoil capable of sustaining plant growth is removed and stored for eventual redistribution during land reclamation. Topsoil covering initial pits, boxcut overburden areas, roads, and plant sites will be stockpiled outside the coal outcrop in areas that will not be disturbed by mining or covered with overburden. The topsoil initially removed from mine areas and facility sites will probably be stockpiled for an extended period of time and will be seeded to reduce erosion.

Topsoil removed in advance of mining, except for that initially stockpiled, will be placed directly onto the graded spoils. This procedure will reduce the amount of soil material that must be stockpiled and rehandled. Soil material from stockpile areas will be used when direct placement cannot be done and will ultimately be used to cover the areas disturbed by the final cuts and highwall sloping operations.

The nature and thickness of available topsoil shall be determined by detailed soil surveys of prospective mining sites. Grading plans will be based on the data thus provided. The objective of such grading shall be to create the soil best suited for plant growth, making optimal use of the available soil materials.

A number of the mining companies have contracted with research organizations to investigate the possible use of various geologic strata in the overburden to support plant growth in addition to existing topsoil. Most of these research projects are presently underway, and no definitive results or conclusions have yet been made.

Overburden removal

After the soil material is removed, the earth and rock overlying the coalbed (overburden) will be excavated from the first cut and placed on land which is otherwise undisturbed and located outside of the area to be mined. Overburden from subsequent cuts will be used to backfill the pit created by the previous cut. The cuts will vary from 100 to 400 feet in width depending on type of equipment used and thickness of overburden.

Strata overlying the coal consists of Wasatch Formation and slope detritus. The Wasatch Formation is made up of sandstone, siltstone, gray shale, carbonaceous shale, and in some areas, thin coal beds. The bedding is lenticular so that uniform overburden characteristics do not extend over large areas.

Most operators plan to drill and blast overburden material so that it can be more easily and efficiently handled. Those companies which plan no blasting initially will probably have to drill and blast as overburden becomes thicker and less weathered. Bulldozer-equipped crawler tractors will prepare a bench for drills at approximately the desired width of the cut. Then blast holes will be drilled on a predetermined pattern to a depth near the top of the coal bed. Overburden drills will be electrically powered and use relatively large bits. They will be mounted on trucks or crawlers (Figure 1). Drill hole spacings are any combination that will give an economic ratio of pounds of explosive to cubic yards of overburden and produce a material that can be easily handled by the stripping equipment. Holes will be loaded with an ammonium nitrate-fuel oil mixture and detonated.

Blasting can be expected on a daily basis, generally in the afternoon during the period between shifts. Electric delay blasting caps will be used to maximize the breaking effect and minimize seismic shock. The amount of explosive used in each hole will depend on the depth of the hole, the materials encountered in the hole, the location of the various strata that must be broken, and the spacing of adjacent holes.

Typical blasting patterns will range from 18 feet by 18 feet to 25 feet by 25 feet for coal and 20 feet by 20 feet to 30 feet by 30 feet for overburden. Thirty to 60 holes could be detonated at any one time and could

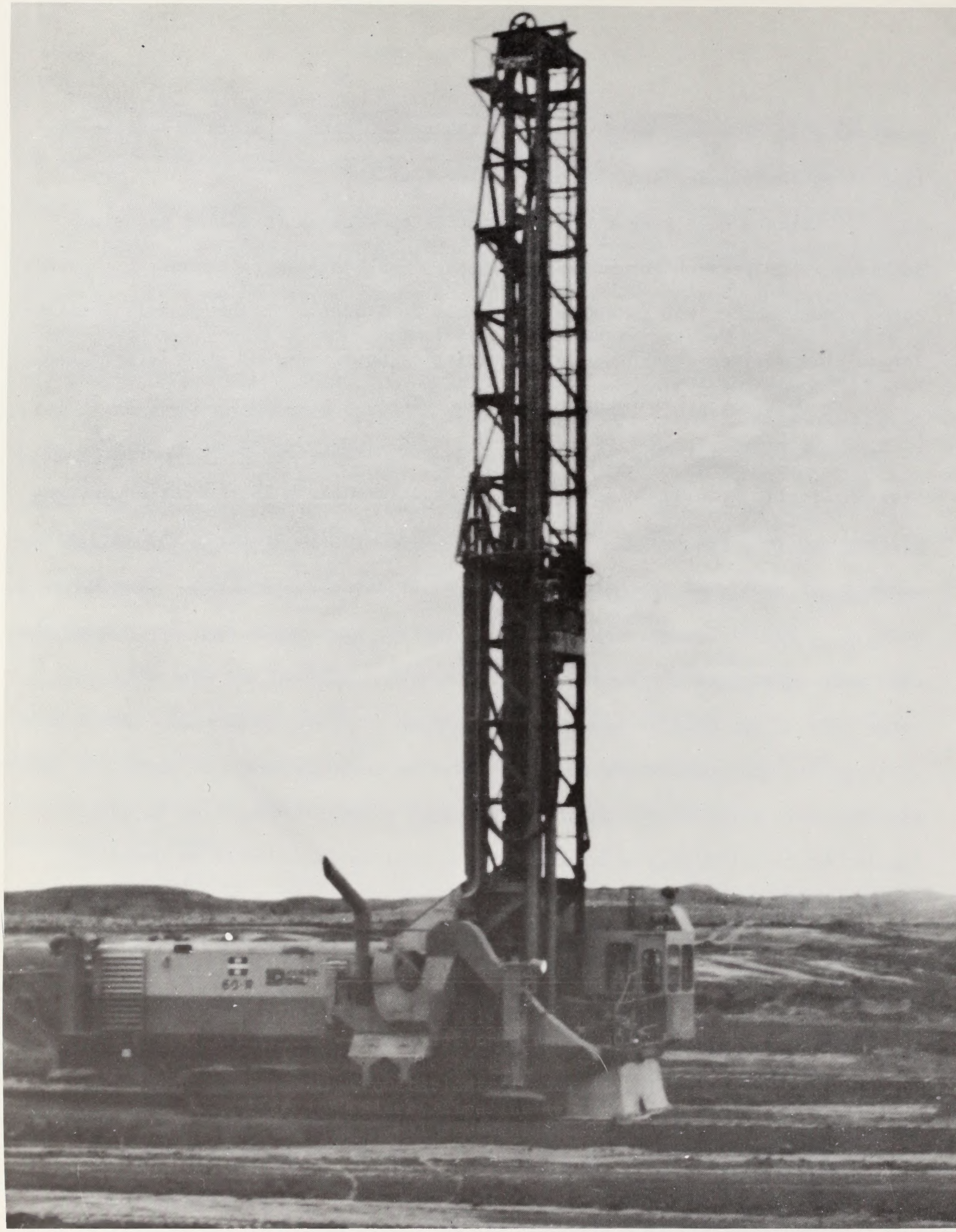


Figure 1

Crawler-mounted, electric-powered, overburden blast-hole drill contain as much as 30 tons of explosive; however, most blasts will be in the 5- to 12-ton range.

After the overburden has been blasted, it will be removed by either large walking draglines (Figure 2) or by a combination of trucks and power shovels. The walking dragline will move along adjacent to the blasted material and will cast the overburden into the previous pit or, in the case of the initial boxcut, onto ground outside the outcrop line of the coal. When the dragline reaches the end of the pit it will be moved back to begin the next cut.

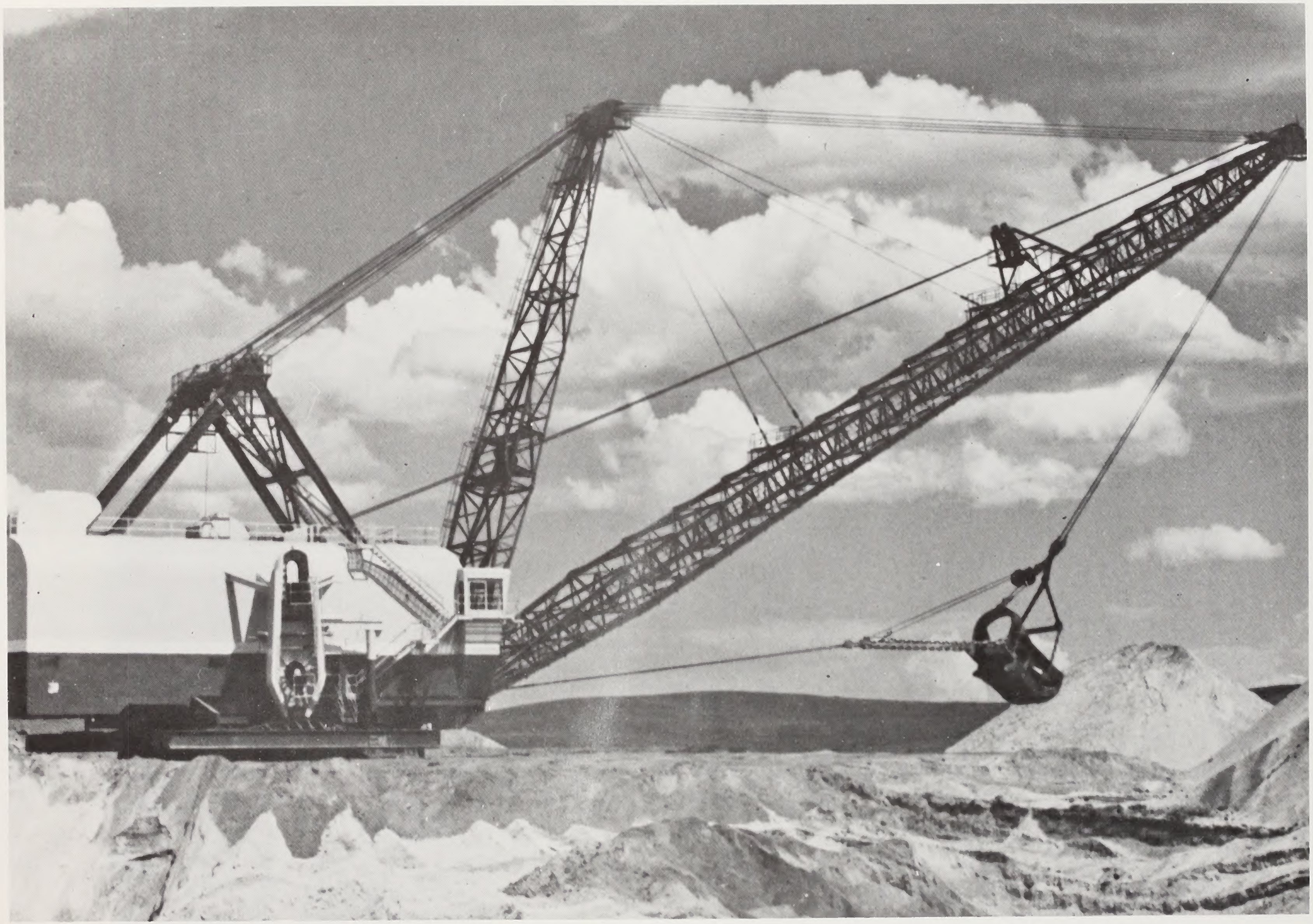
Most companies propose to remove the shale partings between coal-beds with scrapers; however, the use of a small dragline for parting removal and spoil rehandling has been proposed by one company. Figures 3 and 4 give two different views of dragline stripping operations.

The truck and shovel operation for overburden removal will be conducted on benches 35 to 50 feet in height in the blasted overburden. Electric crawler-mounted shovels will load the overburden into off-highway, end dump trucks for transfer to the spoil disposal area where it will be pushed into the pit and leveled using bulldozer-equipped crawler tractors. Figures 5, 6, and 7 give some views of truck and shovel overburden removal operations.

One other method of overburden removal has been proposed utilizing bucketwheel excavators and conveyor belts. Figure 8 shows two excavators working, removing overburden which travels on conveyor belts to the spoil area for disposal. Two other excavators are loading the coal which passes from the pit to the crusher on another set of conveyor belts.

Figure 2

39-Cubic Yard Capacity Electric-Powered Walking Dragline



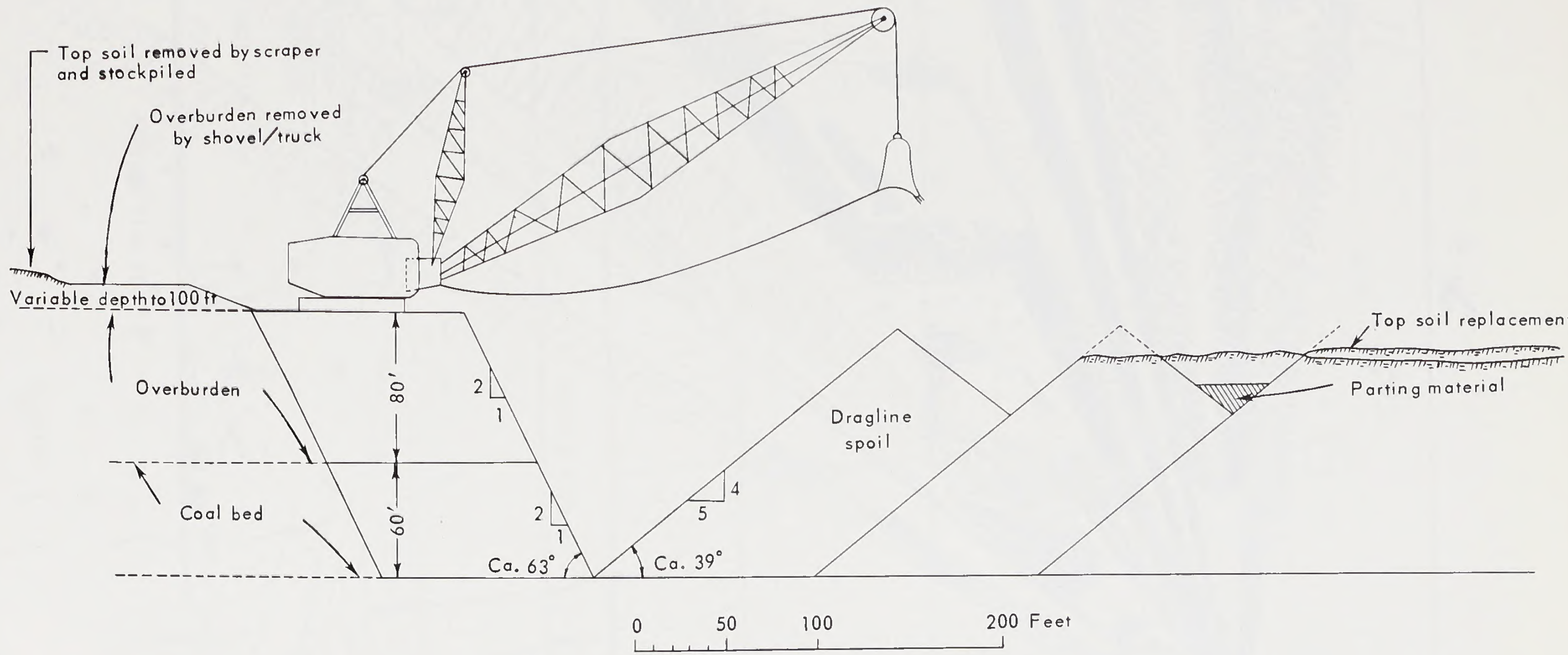
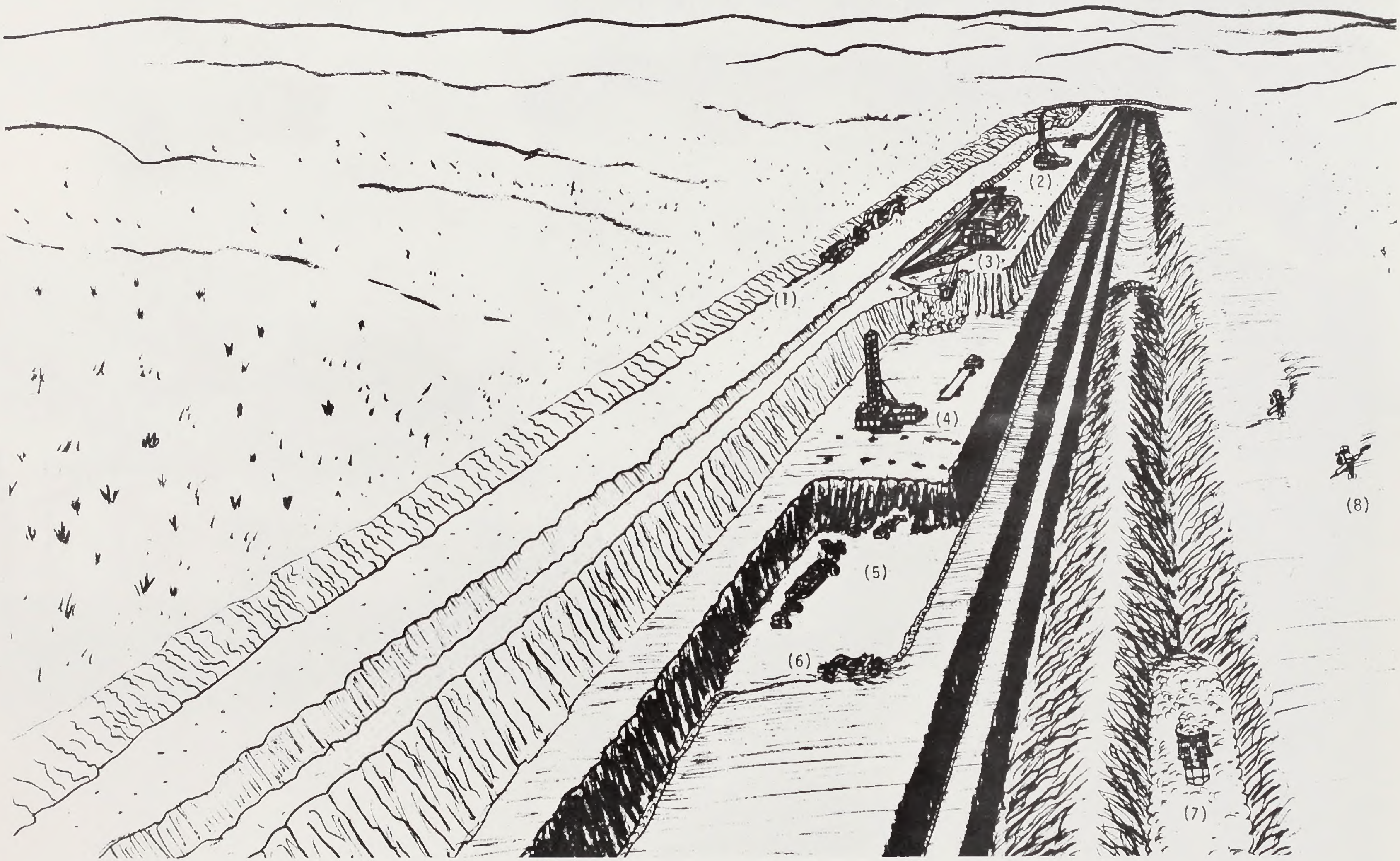


Figure 3

Cross section of typical dragline surface mining operation

Figure 4

View of Pit Operation and Reclaimed Area



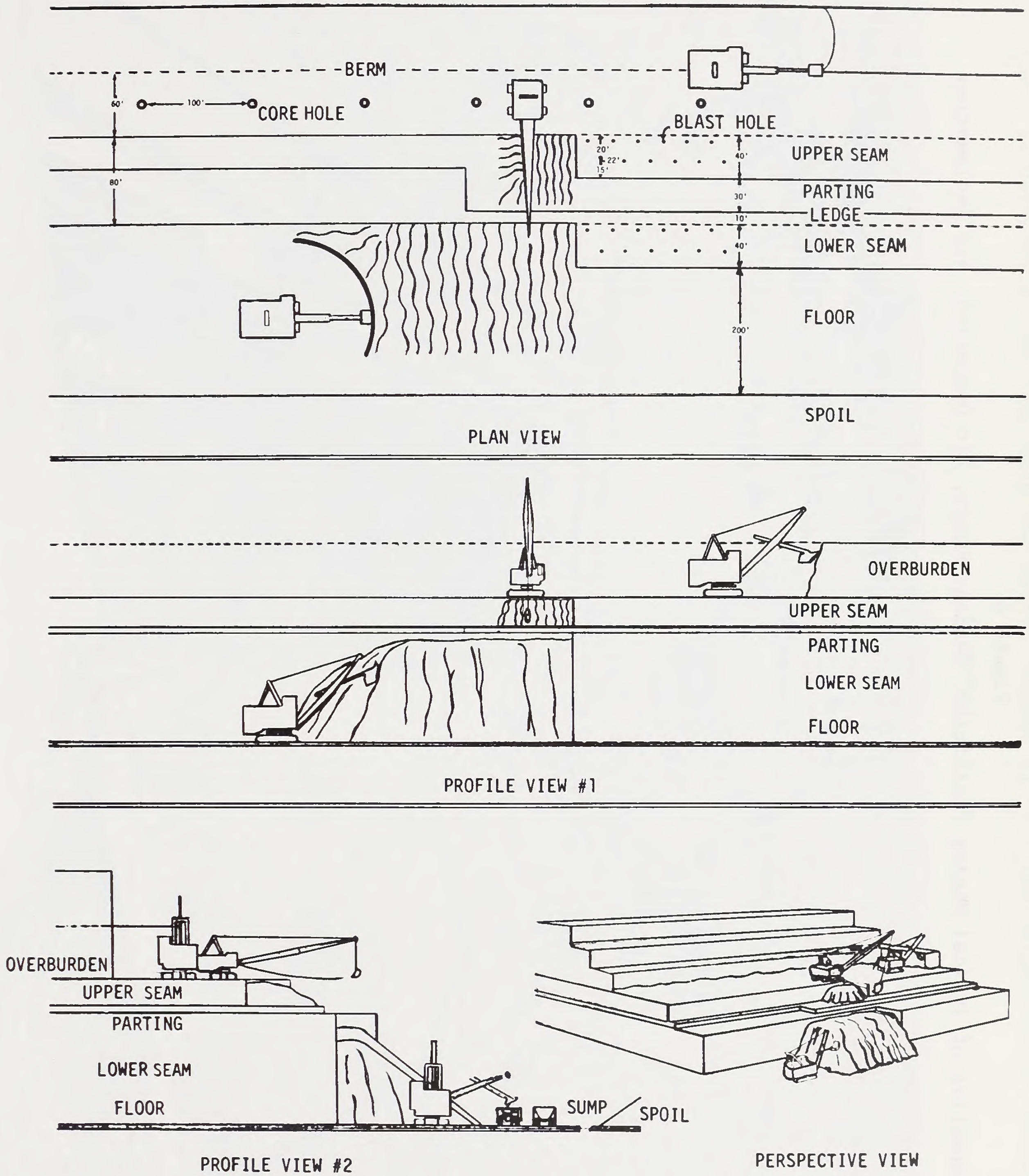
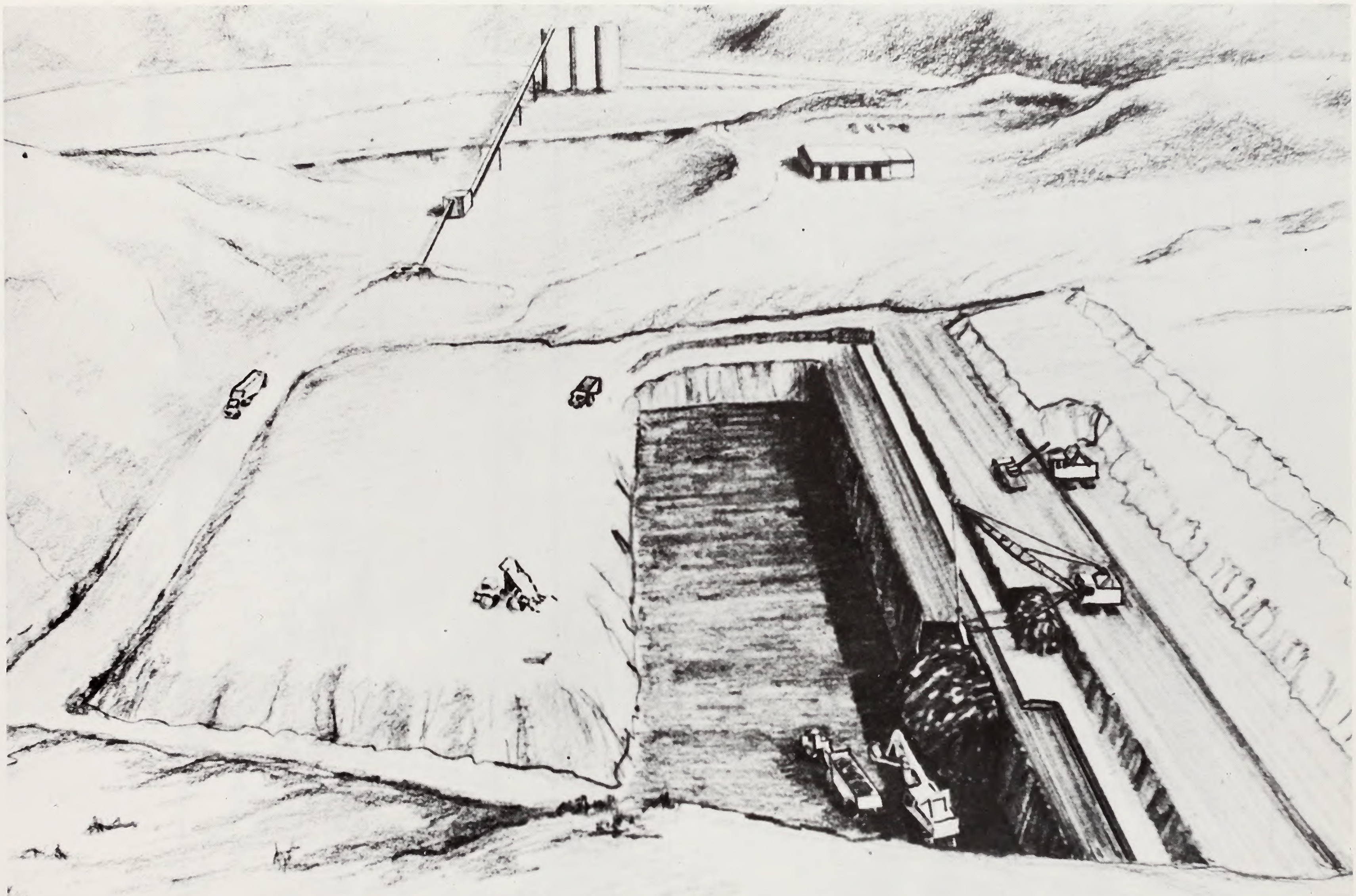


Figure 5

Mining of coal by combined shovel and dragline operation

Figure 6

Perspective of Typical Mining Facilities, Haulage Roads, Pit Operation, and Reclamation



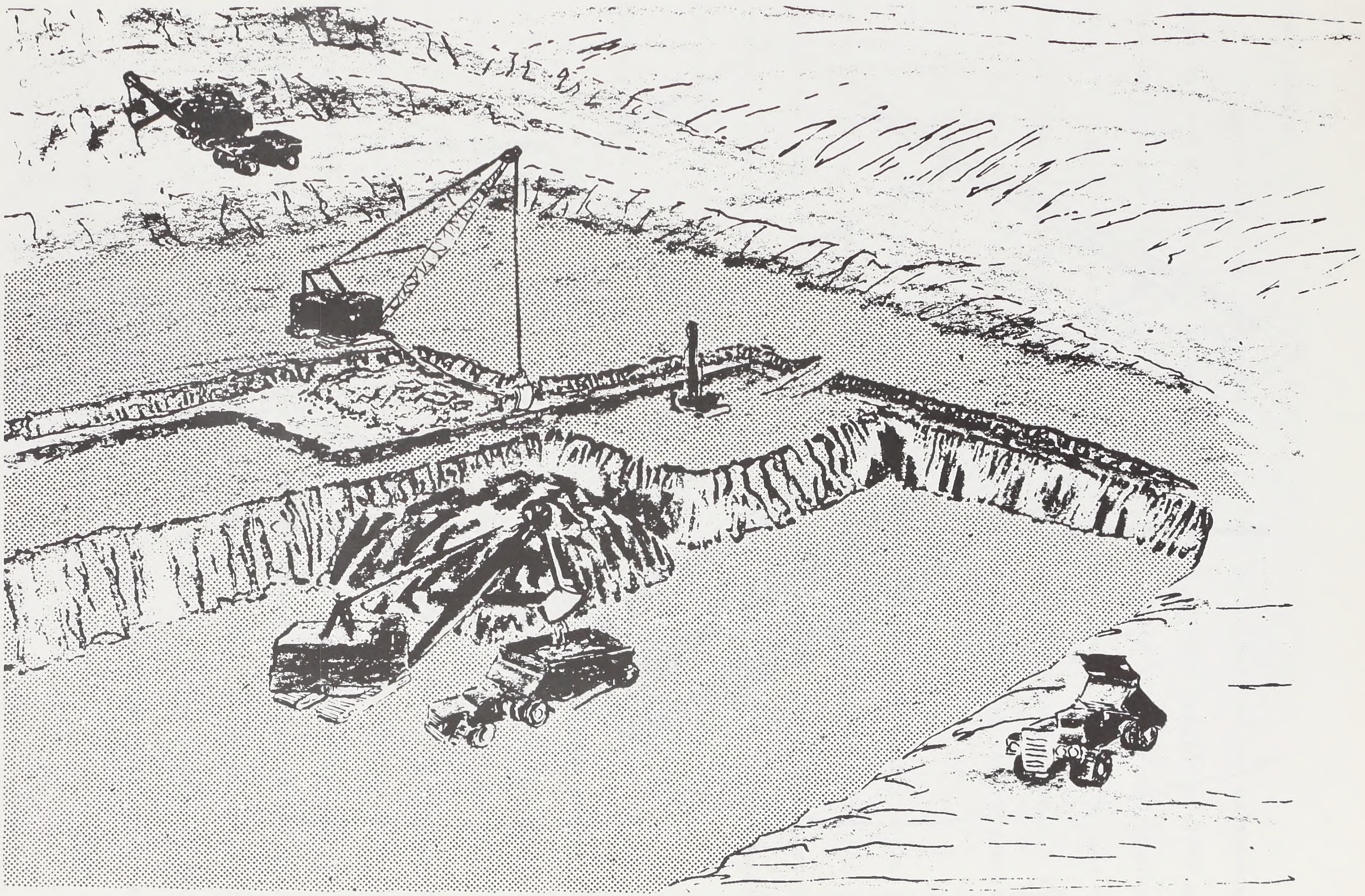
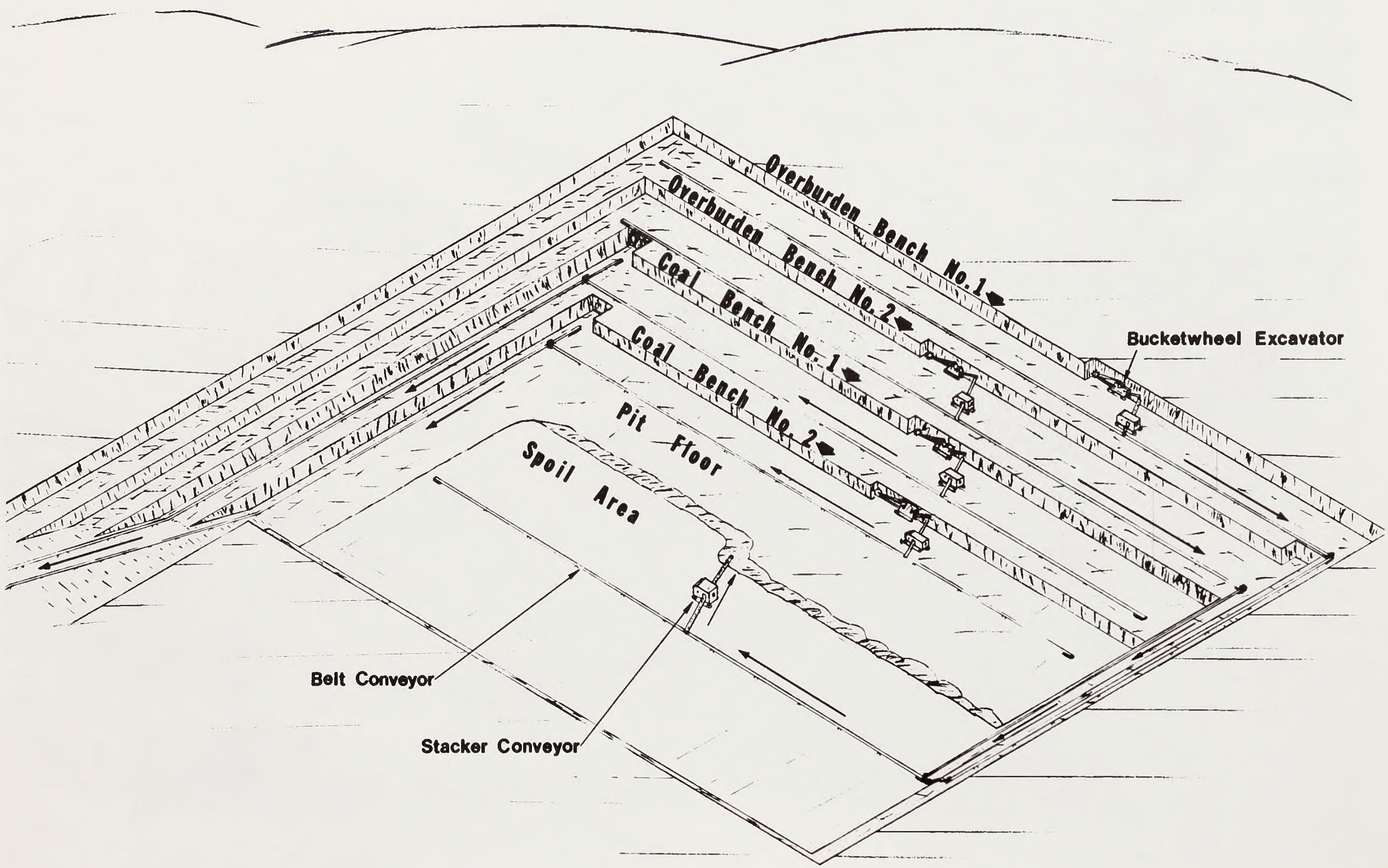


Figure 7

Multilevel removal of overburden and coal by shovel, trucks and dragline, and reclamation by truck

Figure 8

Isometric View of Bucketwheel Excavator-Conveyor Belt System of Mining



Coal removal

Once the coal is uncovered, it will be cleaned of any extraneous material and slack coal by a bulldozer-equipped crawler tractor or road grader, then drilled and blasted. Broken coal will be loaded by front-end loaders or electric crawler-mounted shovels into off-highway trucks (Figure 9) and taken from the pit to receiving hoppers (Figure 10) at the primary crusher. Figures 4, 5, 6, and 7 give different views of shovel and front-end loader operations for coal removal.

A bucketwheel excavator-conveyor belt system for mining could also be used for coal removal (Figure 8). Another method proposed is to load the broken coal with a dragline into a large mobile hopper with a self-contained crusher. A short conveyor beneath the crusher will transfer coal to trucks for removal to the receiving hopper.

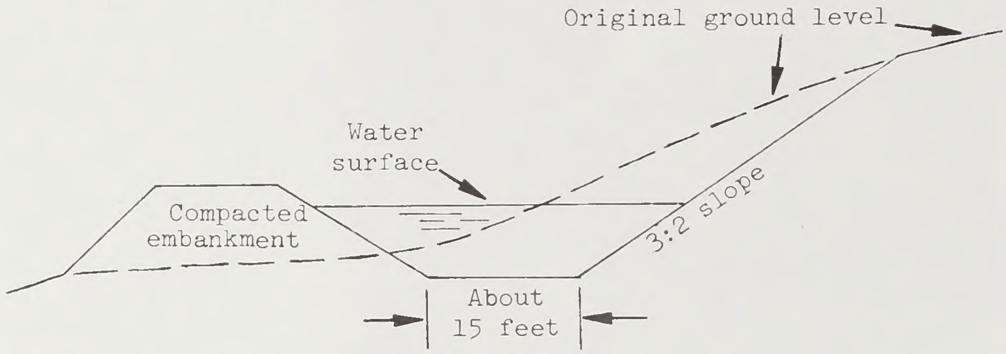
Drainage structures

To protect the mine area from collecting excess water during periods of heavy precipitation and runoff, perimeter ditches (Figures 11 and 12) will be established above the working areas of the mine. These ditches will carry runoff to a series of small (less than 10 acres) settling ponds where suspended solids will settle out. Overflow from the ponds will be directed to a natural stream channel. Culverts will be installed under roads and railroads to ensure drainage and the unrestricted flow of water. Check dams (Figure 11) will be constructed to create settling ponds and in areas where rapid runoff would create excessive erosion. These dams will create catchment basins to retard the flow rate, provide an area in which solid materials can settle, and also provide a watering source for local animal populations.

Figure 9
10-Cubic Yard Electric, Crawler-Mounted Shovel Loading Coal From a 39-Foot Thick Coalbed into a 65-Ton Off-Highway End-Dumping Coal Truck

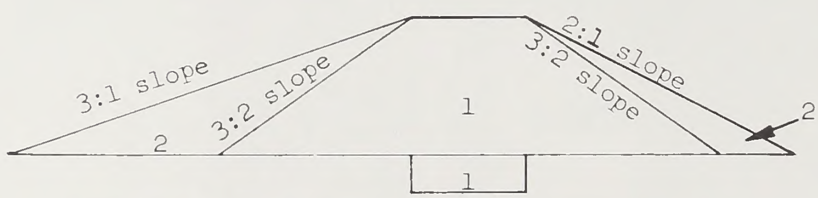
Figure 10

Off-highway truck dumping into hopper at unit train loading facility



A. Typical Ditch Section. Slopes Cut at 3:2; Bottom of Ditch Width of Bulldozer Blade.

Ratio distance to rise	Percent grade	Angle of slope
3:2	67	33.7°
2:1	50	26.6°
3:1	33	18.5°
5:1	20	11.3°



1. Impervious clay or clay sand and shale
2. Semi-pervious material of selected stability, graduated in coarseness to outer slopes; compacted.

B. Typical Earth Fill Dam Section. Core Trench Depth One-Fourth of Dam Height; Top of Dam and Core Trench 15 Feet Wide.

Figure 11

Sections of ditch and dam showing slopes of embankments

Figure 12

View of typical diversion ditch

Monitoring

Hydrologic monitoring wells will be drilled to assess ground water quality, quantity, and flow. These wells will be drilled at various locations on and adjacent to the leases. Pumping tests will be performed to measure drawdown and recovery to determine hydrologic characteristics of the aquifer.

Gauging stations will be installed in drainages and data collected on surface water quality and quantity. These stations will be located above and below the mine areas so that the effects of the operation on surface water can be determined. Surface meteorological and air quality stations will be built in various places near the operations and will record wind speed and direction, air temperature, precipitation, relative humidity, and air quality.

Underground mining

No underground development activities are proposed in the near future for coal deposits in the Eastern Powder River Basin. Also, no underground development or mining has been proposed for uranium, sand and gravel, bentonite, or clinker deposits in the areas of the federal coal leases or near proposed or active coal mines.

Reclamation of mined lands

Climate, especially in relation to available soil moisture, will be a major determining factor to successful rehabilitation of mined lands. Climate has controlled the character of land prior to disturbance and will determine what can be maintained after rehabilitation. The National Academy of Sciences study committee on the potential for rehabilitating lands surface mined for coal in the western United States considered -

> "The mixed grass area of the Northern Great Plains also offers a rather high probability for satisfactory rehabilitation. Rainfall is generally adequate for establishing vegetation by seeding. This has been demonstrated in rangeland seeding

projects through this region. Predicting such results assumes that the best technology will be applied, including the addition of topsoil and selective sorting of spoils to avoid placement of clays and toxic substances on or near the surface."

Reclamation research is a continuing process involving the operators and local, state, and federal agencies. Soil blending, fertilizer application techniques, compaction, acclimated agronomic species selection, seed selection irrigation, wind studies, soil erosion, physical and chemical soil analysis, grading, and growth rates are but some of the areas which are being researched in order to achieve a successful reclamation program.

Results of research studies into the characteristics of overburden and its revegetation potential have, so far, been inconclusive. They do, however, indicate that most spoil material is capable of sustaining plant growth. The only strata suspected of not being conducive to good plant growth are the shale partings between coalbeds. As a result, all operators propose to bury this material within the spoils. Much of the plant growth research to date has been conducted in greenhouses, and the companies propose to conduct onsite research with spoil obtained from initial box cuts. Generally, operating surface mines have not been in production for a sufficient length of time to provide a full assessment of reclamation techniques on land subjected to surface mining within the region. Currently, the most extensive reclamation research within the Powder River Basin is being conducted in Montana.

Reestablishment of vegetative conditions that existed previous to mining is technically impossible at present. Duplication of a near climax vegetative type is prevented due to the disruption of soil structure, accompanying loss of fertility, and unavailability of a suitable means of propagating most native plant species.

An attainable reclamation objective would be to leave a final topography shaped to suitable ecological conditions and to meet proper drainage and hydrologic conditions. The land surface should offer proper conditions for land stability, drainage control, and maintenance of vegetation. Some failures are anticipated owing to extreme climatic conditions, applications of improper reclamation techniques, and unanticipated circumstances. Pressures such as excessive grazing and recreation will contribute to failures, especially where unstable surface conditions exist on unconsolidated spoil materials.

Reclamation of mined land will commence with removal of topsoil in advance of mining to be stockpiled where required or spread over graded spoil prior to seeding or planting. Land will be reclaimed to a terrain compatible with present topography and planted to provide soil stability and reestablish a viable land use.

Overburden deposited by draglines will form parallel ridges of spoil, Figures 3 and 4, which will be leveled and shaped by bulldozers, sometimes aided by smaller draglines. Shaping work for truck and shovel overburden removal is performed on an almost continuous basis. As each truck of overburden is dumped, it is pushed into the pit and shapes a portion of the spoil (Figure 6). Graded areas will be sloped no steeper than 3 to 1 (33%) to provide optimum surface stability and to reduce erosion. As appropriate, the area may be mulched to produce a permeable, less erodable land surface.

Topsoil will be spread on the graded spoil using self-loading scrapers, bulldozers, or road graders. Finally, resoiled areas will be mulched and seeded with predominantly native species. Figures 13, 14, 15, and 16 illustrate the various stages of reclamation.

Reclamation objectives

Reclamation objectives are to leave soil of such a quality that the land has the maximum number of alternative uses and the maximum productivity for priority uses, including the growth of plants necessary to maximize environmental quality after mining. To this end, spoil will be graded to a topography compatible with the land use objectives and the surrounding natural land surface. Final graded initial boxcut spoil piles will be covered with previously stockpiled topsoil prior to seeding.

Once reclamation work has started, it will continue concurrently with mining. Topsoil will no longer be stockpiled; instead, newly stripped

Figure 13
Overburden dump area showing unreclaimed spoil piles in center with leveled and planted spoils in foreground

Figure 14

Shaped and Topsoiled Spoils Prior to Seeding

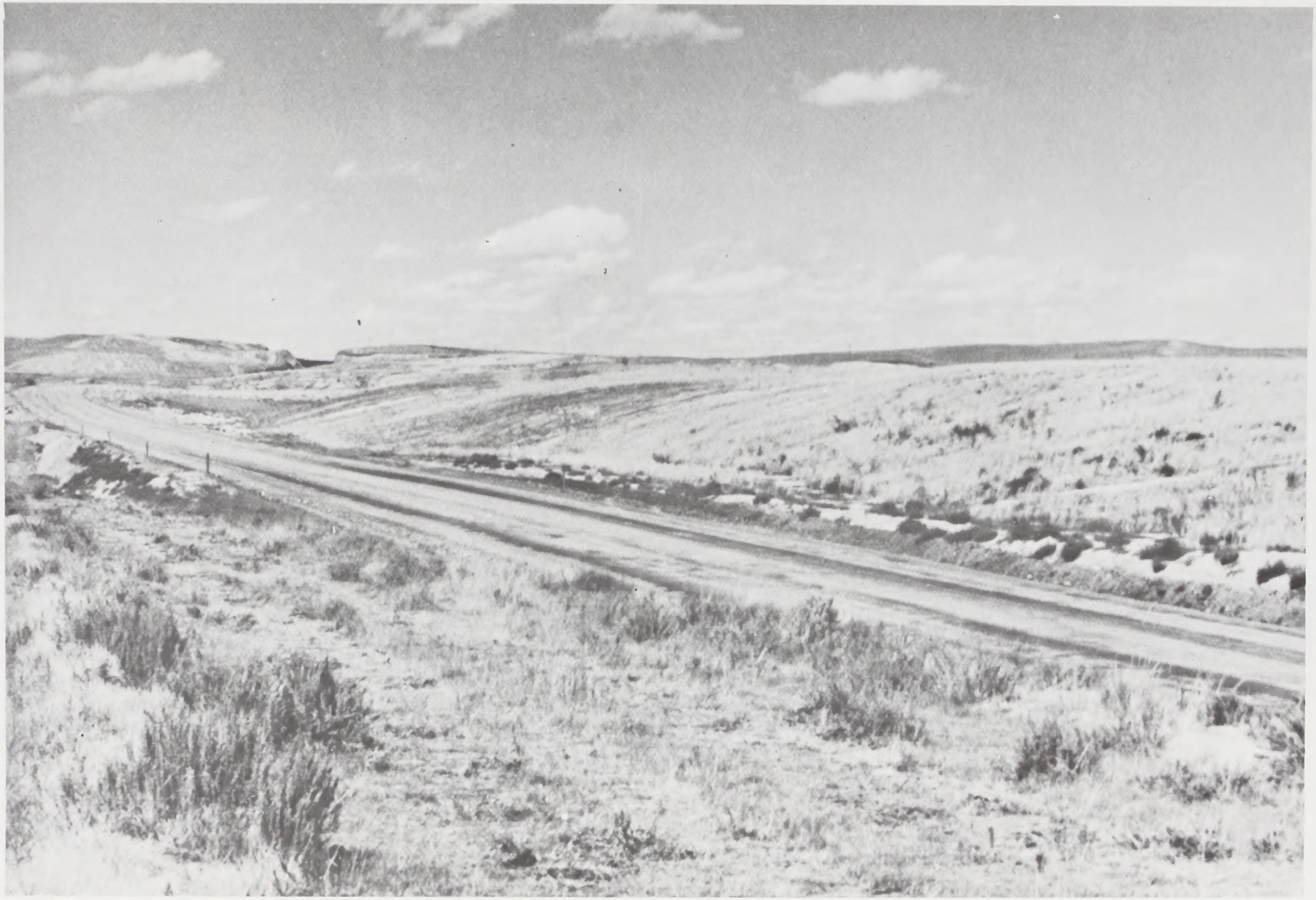


Figure 15
Mine area showing natural vegetation in foreground and reclaimed spoil above road, active pit in center left

Figure 16

Planted Area After Two Growing Seasons

soil will be spread directly on previously graded spoil. Thereafter, topsoil will be stockpiled only when a new series of boxcuts is begun.

The highwalls of final cuts will be reduced by blasting and by grading the spoil back against the blasted highwall. Material from the highwall and adjacent spoil bank will cover the face of the coalbed and fill the cut. Final grading, redistribution of topsoil on the spoil and highwall, and seeding may complete reclamation.

Because of thickness of coal and shallowness of overburden in some areas, several companies have proposed constructing lakes within their mine area. As in the highwall reduction method, all coal exposures would be covered with spoil. Highwalls are covered to control generation of acid water in the coal and to prevent spontaneous or accidental ignition of the coalbeds. The companies will consult with officials of the Forest Service, the Bureau of Land Management, Wyoming Department of Environmental Quality, and with the U.S. Geological Survey to determine where further reclamation of the final cut or other mined areas is needed.

Mining equipment and facilities

Mining equipment used in the Powder River Basin may vary in size and quantity depending on the production and mining methods used at each mine but in general can consist of the following: Large bulldozer-equipped crawler tractors, e.g., D-8, D-9 Caterpillar tractors, self-loading, rubber-tired scrapers, and roadgrader type tractors can be used to remove the vegetation and topsoil in preparation of overburden removal. If necessary, the overburden will be drilled with large rotary blast hole drills, e.g., 60-R Bucyrus Erie rotary drill. Smaller drills will be used for the coal. Explosives equipment may consist of a truck to haul ammonium nitrate-fuel oil (ANFO) explosive components. Overburden can be removed either by a combination of 100- to 200-ton capacity trucks loaded by 10- to 30-yard capacity front-end loaders, power shovels, or a walking dragline of 30- to 70-cubic yard capacity. Bucketwheel excavators combined with converyor belts or trucks can also be used.

Facilities for storing explosives will be necessary. These could consist of an appropriate building, storage silo, and tanks for ANFO or an area to park tractor-trailer type trucks in which explosives are delivered and stored until used. Whatever the type of structure, explosives will be stored and handled in accordance with all applicable state and federal safety regulations.

Broken coal may be loaded by rubber-tired 20- to 30-yard front-end loaders, crawler type 20- to 30-yard power shovels, or possibly a small dragline. Coal will be loaded into 100- to 200-ton trucks (Figure 17) and hauled to a dumping bin. Another method may use a large mobile storage bin into which coal can be loaded directly by dragline, then crushed and loaded into trucks.

Other supplemental mine equipment may include water trucks, fuel trucks, pickup trucks, ambulance and fire equipment, supply and service trucks (maintenance, welding, and lubrication), motor graders, and a mobile crane.

Processing equipment will include primary and secondary crushers in which the coal will be reduced to minus 2-inch size, belt conveyors for transporting coal during processing, weighing devices for recording accurate weight of coal, various in-process surge bins, and final storage silos from which the coal can be loaded into unit trains. Storage silos will vary in diameter, height, and number depending on mine production and train scheduling. Silos 180 feet high by 60 feet in diameter are typical. Figures 18 and 19 show typical silos and coal loading facilities.

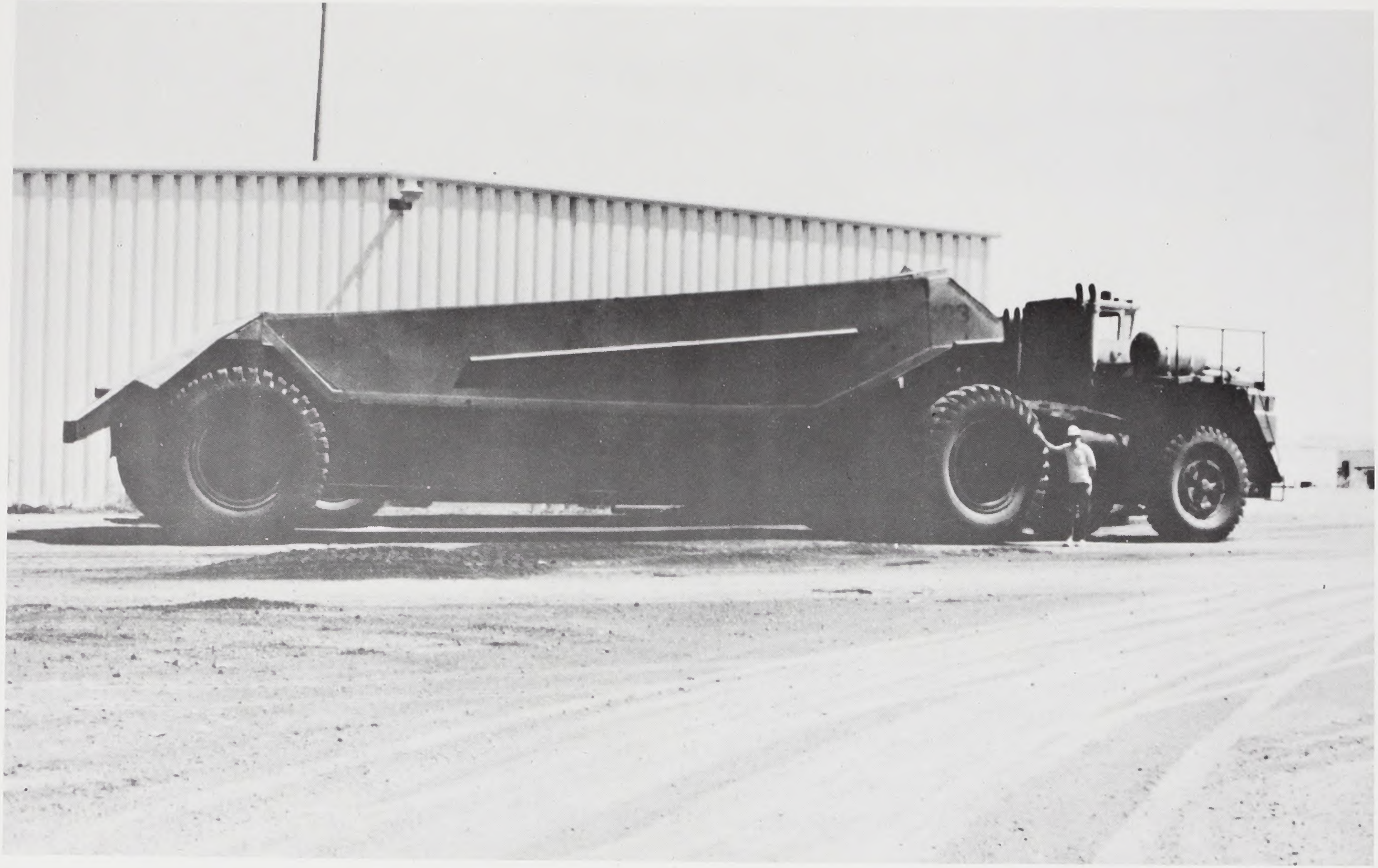


Figure 17

100-ton capacity, off-highway coal truck

Figure 18

Two 12,000-ton capacity gravity-loading storage silos

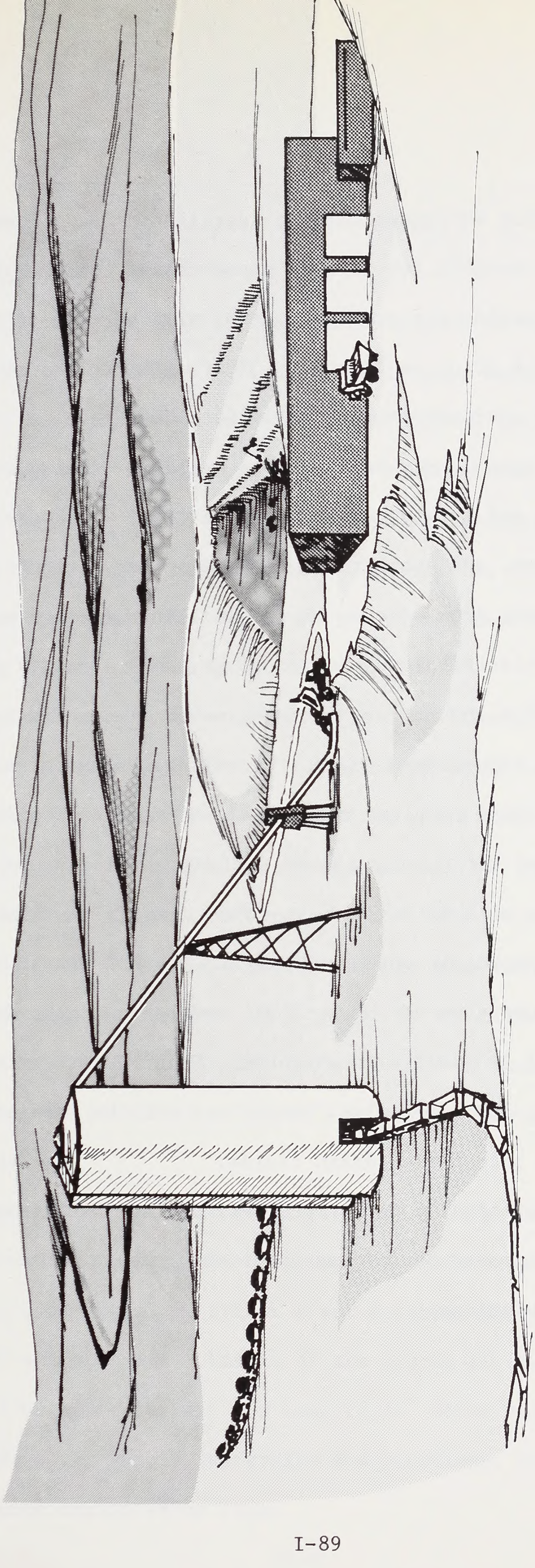


FIGURE 19
Mine Layout

Coal weighing equipment will be installed at rail loading facilities to maintain accurate weights for royalty payments and consumer billing purposes. Collection of coal samples for quality control will be done at the rail loading facility or in the pit prior to blasting. This will be done so that the operation can maintain a customer product of uniform quality.

Each mine usually may have a large building housing mine offices (engineering, health and safety, and administrative), warehouse, shower and change room facilities, and another large building for equipment repair. Actual configuration will vary from mine to mine. Smaller buildings may house the heavy-welding shop, electrical supply warehouse, and materials inventory. An area will be needed for the primary electric substation where incoming high voltage power may be transformed to desired voltages for operations. On the periphery of the building complex, a materials storage area will be required. Finally, a parking lot and security guard building will also be necessary.

Water wells will be drilled to supply the office, shower room, equipment, and for dust control in coal handling and on haul roads. Water that accumulates in the sump area of the mine pit and behind check dams may also be used for dust control if quality is suitable. Waste water and sewage from offices, changehouse, and other plant facilities will be treated in septic tanks and discharged into buried drain fields.

At the completion of operations, all surface facilities and structures will be removed or disposed of in accordance with the terms of the leases and other applicable regulations.

Utilization Processes

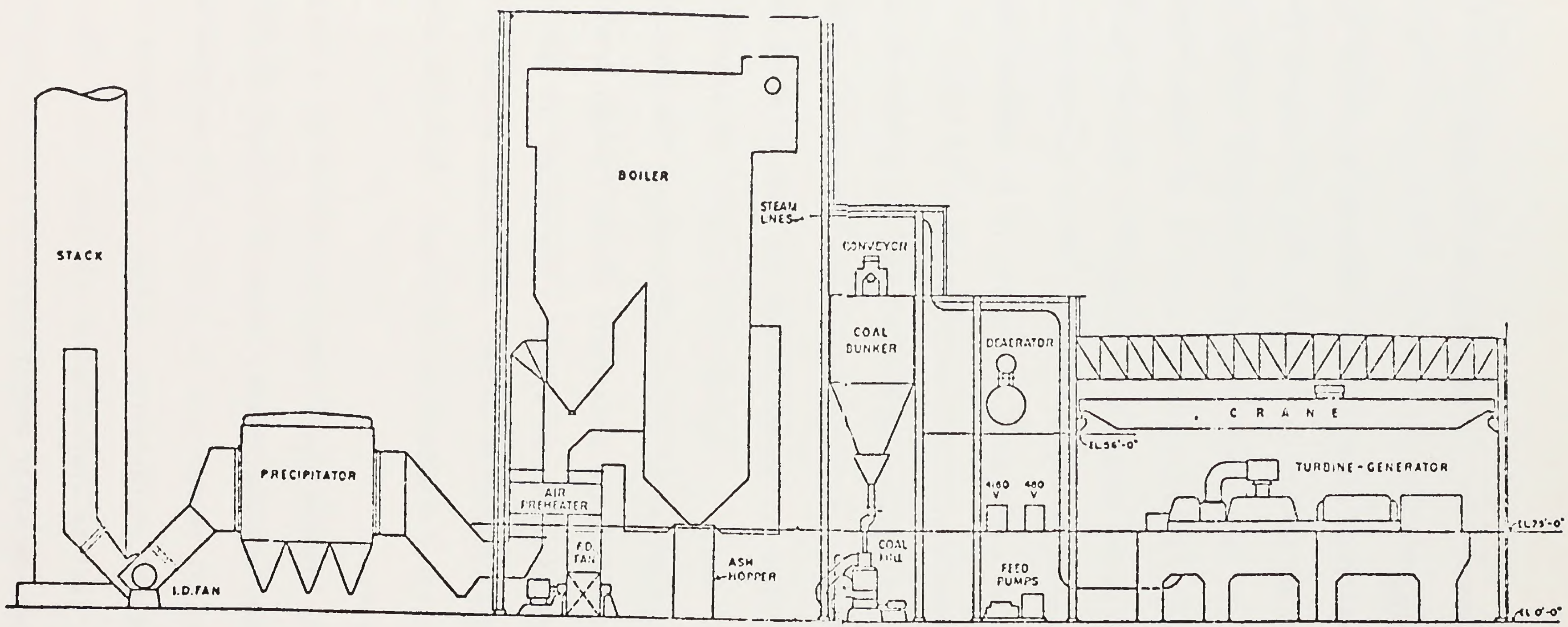
Power generation

Coal-fired steam-electric generating plants in Wyoming vary from one megawatt (MW) to 500 MW per unit with the largest being the Jim Bridger Plant which will have three (and possibly four) 500-MW units when completed. The only definitely proposed new plant in the Powder River Basin is a 330-MW unit adjacent to an existing 30-MW plant at Wyodak, Wyoming. Two additional plants of 30 to 60 MW may be constructed in conjunction with coal gasification plants now under consideration. Also, it is assumed that two additional mine mouth generating plants will be constructed by 1990.

The generation system consists of a coal-fired steam boiler and a turbine generator. See Figure 20 for a simplified cross section of the equipment. Steam from the boiler passes the turbine where heat energy is converted to mechanical energy. Mechanical energy is transmitted to the generator where it is converted to electrical energy. The unrecovered portion of the heat is released to the atmosphere either through evaporative cooling towers or an air-cooled condenser system. The former is the common method, and it requires large amounts of water. The latter method is used at the Wyodak plant due to the limited availability of water. No steam plume is visible in the air-cooled system.

The typical appurtenant facilities for a large power plant include a power house, cooling system, emission control systems, and stacks. The emission control system will be either a wet scrubber system or more likely an electrostatic precipitator. Height of the stacks of the only known planned power plant will be approximately 400 feet tall. Other land uses adjoining the plant may include water supply reservoirs and pipelines, haul roads, evaporation ponds, and electric transmission lines.

Figure 20
Cross Section of Power House Building with Stack and Flue Gas System
for Electrostatic Precipitator



Two options for emission control are available, electrostatic precipitators and the wet scrubber. Air is forced into the furnace where it is combined with coal and sustains combustion of the coal. Combustion releases heat and flue gases containing particulate matter (fly ash), carbon dioxide, water vapor, impurities from the coal, and oxides of sulfur and nitrogen. Flue gas enters the emission control system where about 99 percent of the ash and lesser portions of the gases are removed; it is then discharged through the 50- to 500-foot stack. Stack height depends on the size of unit and also location.

If a wet scrubber is used, ash is filtered or settled out of the water. Water is then recycled and the ash can be returned to the mine for landfill. With the use of the electrostatic precipitator, ash is removed dry and hauled directly to the mine.

Water requirements are dependent upon size, cooling system, and emission control system. For example, a typical plant with air cooling and precipitator control will use an estimated 200 to 300 gallons per minute. With a scrubber instead of a precipitator, consumption is estimated to be 700 to 800 gallons per minute. Water losses in all plants will include boiler blowdown, neutralized demineralizer regeneration wastes, evaporation from the settling pond, treated sanitary wastes, equipment wash water, and floor and equipment drainage. Evaporative cooling towers would consume large amounts of water, and a scrubber would consume water by evaporation within the unit and by wet ash disposal. A conventional water-cooled generating plant requires a total of 11 acre feet of water annually per megawatt of generating capacity. A typical air-cooled plant with precipitator would use 1.45 acre-feet of water annually per megawatt, while the unit with a scrubber would use 3.76 acre-feet annually per megawatt.

Coal gasification

Test projects for different gasification methods are currently underway by both private industry and the Federal Government. All known full-scale commercial projects now being planned or constructed in the United States are based on variations of a German process called the Lurgi process. The Lurgi process has been used for many years on a small scale as a means of producing low Btu gas, commonly referred to as "town gas." By adding a methanation process, this gas can be upgraded to "pipeline quality" comparable to natural gas.

Other gasification processes are being extensively tested and are showing promise, but none have been proved on a commercial scale. Table 1 lists the tests and their present status.

In addition to the various gasification methods for mined coal, the U.S. Bureau of Mines is working on an in situ gasification project near Hanna, Wyoming. Although still in experimental stages, this process shows potential, especially under certain circumstances. In situ gasification has the following advantages:

(1) Coal which cannot be economically mined can be gasified (coal seam too deep, thin, etc.).

(2) No open pit or underground mining is required.

(3) Water needs are minimal.

(4) Employment needs are low.

In situ should probably be considered as an additional method for only certain circumstances rather than an alternative to gasification. Land surface subsidence is a possible problem associated with in situ gasification process.

Since the Lurgi process is the only method currently being considered for large-scale use, this method will be described in some detail. Figures 21 and 22 give schematic diagrams of the Lurgi gasifier and the flow within a gasification plant. Statistics for a typical plant are outlined in Table 2.

Gasifiers require coal to be crushed to a size between one and one-half inches and a #4 mesh. Disposition of the remaining fines, amounting to 20 to 30 percent, can be handled in various ways.

If a power generating plant is a part of the facility, the fines can be used for coal or, if a market is available, the fines can be sold. Experiments in briqueting fines into a useable size are now taking place.

A typical large-scale unit contains about 30 Lurgi gasifiers with three or four being spares for use during maintenance and repair. Each unit is nearly 100 feet high and 14 feet in diameter. Coal is fed in at the top and distributed evenly over a moving bed. Oxygen and steam are introduced through the ash removal grate at the bottom. Fourteen percent of the coal is burned in the process, and this provides the heat for the gasification reaction process which takes place at 1150°F to 1600°F. Temperature and steam-oxygen ratio are dependent upon the exact nature of coal.

About 86 percent of the coal is gasified and passes to the gas scrubber where hot gas is quenched and washed before continuing on through a cooling system. The ash is continually removed through the grate at the bottom and returned to the mine for fill material. Crude gas leaving the gasifier contains carbonization products such as tar, oil, naphtha, phenols, ammonia, and traces of coal and ash dust are bonded to tar and removed. Part of the gas is directed through a shift conversion to convert it to a more favorable composition before entering the methanation section. The crude gas is further cooled to remove hydrocarbon oils and water containing phenols and ammonia. The next step, the rectisol unit, selectively removes hydrogen sulfide, carbon dioxide, and carbon monoxide. Utilizing temperatures down to -50°F, all hydrocarbons heavier than

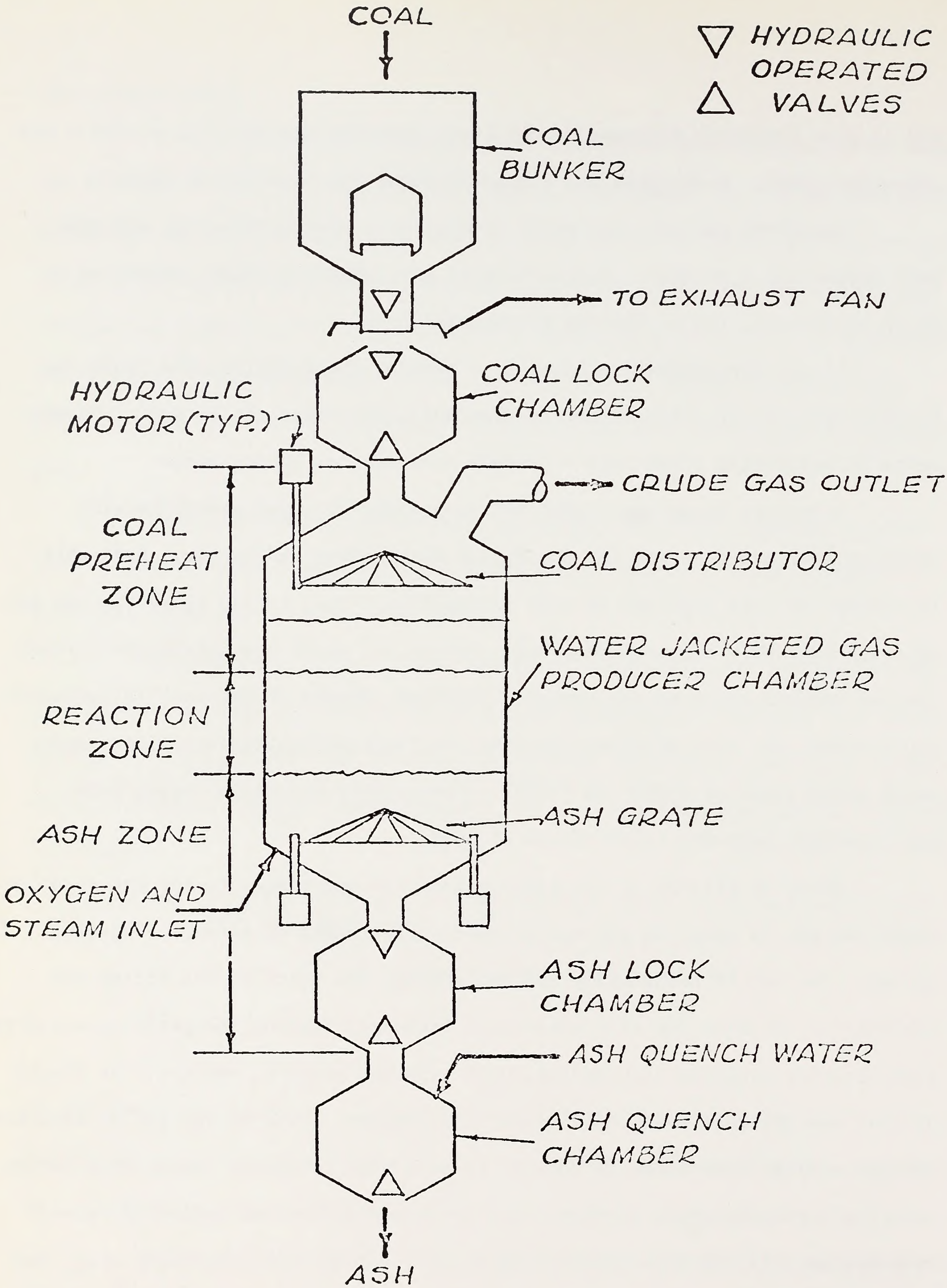


Figure 21

Schematic Diagram of Lurgi Gasifier (Batelle E.A. for Wesco)

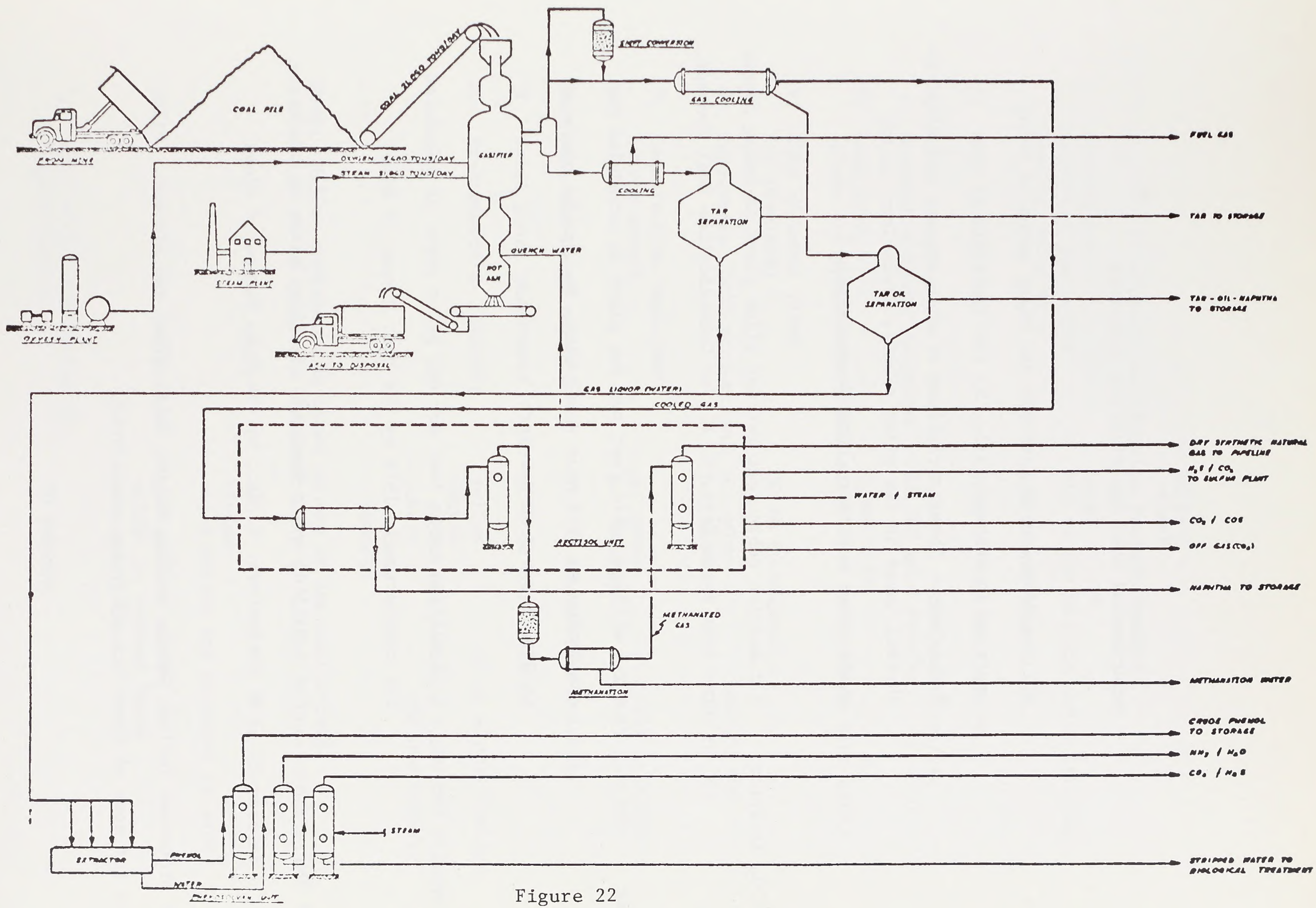


Figure 22

Schematic Flow Diagram of Coal Gasification Plant (Battelle E.A. for Wesco)

Table 1

Experimental Coal Gasification Processes

HYGAS	A 1.5 million cubic feet per day pilot plant is being operated in Chicago, Ill., by the Institute of Gas Technology. Three variations of this process are Electro-thermal (used in the pilot plant), Steam-Iron (pilot plant under contract), and Steam Oxygen.
CSG (CO_2 Acceptor)	A 2 million cubic feet per day pilot plant is being operated near Rapid City, S. D., by Consolidation Coal Company.
Bi-Gas	A 2.4 million cubic feet per day plant is scheduled for completion in 1974 near Homer City, Pa., to be operated by Bituminous Coal Research.
Synthane	A 1½ million cubic feet per day pilot plant is scheduled for completion in 1974 by the U.S. Bureau of Mines.
Fixed Bed	A 2.2 million cubic feet per day pilot plant is operating at Morgantown, W. Va., by the U.S. Bureau of Mines.

Other processes include COGAS, Kellogg Molten Salt, ATGAS and Hydrane. Pilot plants for some of these are now being considered.

Table 2

Typical Gasification Project Summary

1.	Process used	Lurgi	
	Synthetic gas output	250 to 300 million cubic feet/day	
	Heating value of pipeline gas	950 to 980 Btu/cu. ft.	
2.	Coal consumption	9 to 11 million tons/yr.	
3.	Water requirements	5,000 to 9,500 acre feet/yr.	
	Maximum of known estimates	17,000 acre feet/yr.	
4.	Land needs (plant and appurtenant facilities; does not include mine area)	1,000 acres	
5.	Size of power plant (if required)	30 to 60 megawatts	
6.	Employment (full production)	a. plant	600 to 800
		b. mine	200 to 300
7.	Construction employment (three years)	a. peak	2,500 to 3,500
		b. average	1,500 to 2,000
8.	Mine and plant payroll	$12 to $16 million annually	
9.	Total plant investment	$370 to $500 million	
10.	By-products a. salable	sulfur	30 to 40,000 tons/yr.
		liquid petroleum products	3,000,000 bbls/yr.
		others ammonia phenols	100,000 tons/yr

Note: Sulfur production is based on use of low-sulfur coal (.5 to .7% sulfur). Marketability of sulfur is questionable.

	b. waste	ash	6 to 10 percent
		sludge	
		Solid wastes are returned to mine	
	c. emissions	particulate matter	
		sulfur in various forms	
		nitrogen oxides	
11.	Heat efficiency rating of gasification	70 percent	

C_2 are removed, leaving a clean gas to enter the methanation unit. The methanation process upgrades the gas to 950 to 980 Btu/cubic feet, which is comparable to natural gas. A pipeline about 24 inches in diameter will be required to transport the gas to market.

Resources used, output, and by-products are shown in Table 2.

An electric power plant of about 60 MW is required for the plant and mine. The plant may have its own generator with alternatives for fuel being coal fines or product gas and/or by-products or necessary power may be purchased from existing sources.

About 1,000 acres are required for plant and related facilities. This includes coal preparation and storage area, power plants, raw water storage reservoir, evaporation ponds, haul and access roads, and other general plant facilities. Most estimates for water needs range from 5,000 to 9,500 acre feet per year.

Apparently there is a ready market for all by-products except sulfur. Adequate storage facilities for nonsalable by-products will be required. Solid wastes are normally returned to the mine and used as fill material.

Mr. Kenneth Ancell of Panhandle Eastern in reply to a request supplied the following data: Tests on the coal to be gasified indicate that the average ash content is 5.58 percent and sulfur content averages 0.32 percent. The tests also indicated that the ash content of the coal fines averaged 11 percent. These fines will be used as fuel for a power plant. See Table 3 for summary of material balance for overall gasification plant using Wyodak zone coal from Peabody Coal Company lease area.

Construction time for a gasification plant is about three years with employment averaging 2,000, with a maximum of 3,500. Production should begin in the third year with full operating employment for both mine and plant reaching 900 to 1,000 by the fourth year. Mine and plant payrolls should be between $12 and $16 million annually at full production.

Total plant investment has been estimated to be between $370 and $500 million.

Detailed analyses of the gasification projects are not included in this study; an environmental impact statement would be prepared at the time specific gasification projects are proposed.

Table 3

Summary Material Balance for Overall Gasification Plant

Inputs	Short Tons/Day	Percentage
Coal to gasifiers	22,728	19.0
Coal to boilers	4,870	4.1
Coal to sales	4,870	4.1
Water	13,701	11.4
Air to oxygen plant	23,625	19.7
Air to boilers and incinerators	49,707	41.6
Air to sulfur recovery unit	134	0.1
Chemicals	55	---
Total	119,690	100.0

Outputs	Short Tons/Day	Percentage
SPG Product gas	5,744	4.8
Coal Lines to sales	4,870	4.1
Sulfur	62	---
Ammonia	101	0.1
Phenols	115	0.1
Tar, oil and naphtha	1,023	0.9
Boiler stack gases	45,005	37.6
Incinerator off gases	28,821	24.1
Final CO_2 removal off gases	2,380	2.0
Boiler ash (bottom and reg)	532	0.5
Gasifier ash	1,409	1.2
Sludges	550	0.4
Waste nitrogen	17,729	14.8
Cooling tower losses	9,120	7.6
Water with ash	582	0.5
Evaporation losses	1,647	1.3
Total	119,690	100.0

Liquefaction of coal

Studies of coal liquefaction processes have been continuing for several years in the United States, but there is not yet any commercial developments here. Most early pilot developments were aimed at producing synthetic gasoline which so far has proved uneconomical. As prices rise for gasoline made from petroleum, interest may be revived in this process. Present emphasis is on a cheaper, simpler conversion to produce a fuel oil containing very little sulfur. Four processes are receiving the most attention and are described below.

The Solvent-Refined-Coal Process is the project of Pittsburgh and Midway Coal Co., a subsidiary of Gulf Oil, and is the most heavily funded project. This process is based upon extraction of coal with a solvent that is a distillate fraction of the product extract. Ash and pyritic sulfur are removed by filtering dissolved extract. Recent modifications call for adding hydrogen or carbon monoxide under pressure to react with coal, thus releasing organic sulfur. Removal is adequate to meet air quality standards when high-sulfur coals are used. If not, this process may be limited to low-sulfur coals such as are found in the west.

Hydrocarbon Research, Inc., supported by a consortium of petroleum companies, is working on the H-coal process. The pilot plant reactor contains a recycle oil-coal-catalyst medium ebullated by hydrogen to liquefy the coal. Scale-up plans are unknown, but high conversion and good catalyst recovery are claimed for the pilot.

FMC Corporation is developing the COED process which uses fractional carbonization of coal to maximize yield of tar and the product fuel oil after hydrotreating. Yield of liquid fuels is lower, and the product char may contain sulfur exceeding air quality standards. Depending on the sulfur content of the feed coal, desulfurization of the feed coal may be required.

The most information is available about the Bureau of Mines' hydrodesulfurization coal-to-oil process. Raw coal conveyed in a recycled portion of its own product oil is propelled by rapid, turbulent flow of hydrogen through a reactor packed with immobilized (fixed-bed) catalyst pellets. The combined effect is to liquefy and desulfurize the coal at high yields and high throughput. Sulfur is removed as hydrogen sulfide which can be converted for industrial use or converted and stored as inert elemental sulfur. This process attempts to use a minimum amount of hydrogen, with the main aim being to remove sulfur rather than to totally liquefy the coal. The U.S. Bureau of Mines is now expanding its project and feels that in two or three years this process may be ready for commercial consideration.

Development of liquefaction is a few years behind gasification, and it is not expected to be an alternative process prior to 1980 or 1985.

Distribution Systems

Railroads

The first step in railroad construction operations is clearing the right-of-way. All vegetative materials will be removed from areas to be excavated or where embankments will be constructed. This refuse is stripped off the ground by bulldozing.

At approximately the same time, culvert and cattle pass structures will be transported to planned locations. A bed for the culvert or cattle passes will be prepared by grading equipment, after which the culvert sections are set in place. Backfill is then placed carefully around the pipe.

As the installation of culverts proceeds, grading work will be underway. This involves movement of earth material from excavation areas to embankment areas to create a roadbed shaped to its final elevation. Movement of earth material is generally accomplished by self-powered scrapers. Where rock is encountered in excavation, it is customary to use a ripper drawn by a large caterpillar-type tractor to loosen the rock so it can be moved. Blasting may be used to loosen massive consolidated rock formations.

As material is brought into embankment areas, it will be compacted to provide a dense fill that will not settle. To accomplish this, the material is spread in layers less than 12 inches thick and rolled. Water content of earth material must be at the proper level if desired compaction is to be obtained. This normally requires that water trucks sprinkle water on the fill. Motor graders are used to shape and smooth the side slopes of the excavation and embankment areas and to finish the roadbed surface when the desired elevation has been attained.

Bridges are constructed as soon as embankment sections and bridge ends are in place. Construction sequences of bridges vary according to the type of structure designed.

A layer of good quality granular material will be placed on the finished roadbed surface. This material is screened at the source of supply to remove particles over three inches in diameter and trucked to the construction area. This material is rolled and compacted to a dense smooth layer approximately 12 inches thick. Track ties are then installed to correct alignment and spacing on the finished roadbed surface.

Rail used for the line is transported to the point of beginning on special trains. Rail is pulled off the train and onto the track ties by a special piece of equipment that straddles the ties as it runs along the line pulling the rail from the train. As soon as the rail sections have been pulled off the train, aligned and spaced, they are spiked to the ties, the rail carrying train moves ahead on the new line, and the operation is repeated.

Following behind the rail placement operation is a ballast train which places rock ballast between the ties to the top of rail elevation. Track is then jacked up through the ballast as a tamping machine packs the ballast to a dense condition.

Roads

Construction operations for a road are similar to those just described for a railroad up through excavation and shaping of the roadbed.

If the road is to be surfaced, the next step will be to add surfacing base. This is normally graded, crushed rock. Aggregate will be spread in even layers not exceeding six inches thick and compacted by rolling.

The last step would be the application of the surface material, whether it is graded aggregate, bituminous, or concrete surfacing. The various steps are detailed in site specific analyses. After surfacing is completed, the road is ready for use.

Roads on mine properties will consist of main haul roads which will carry large 150-200 ton capacity trucks and smaller access roads for lighter equipment and trucks. Haul roads will be between 50 and 80 feet wide and elevated one to three feet to provide drainage and minimize snow drifting. Roadbeds will consist of graded and compacted overburden, sandy shale of the Wasatch Formation, and will be surfaced with coarsely crushed clinker from nearby deposits. Where these roads cross natural drainages, culverts and drainage ditches will be required. Where silt and sand may wash from haul roads or from mined areas, silt settling basins will be provided downstream to temporarily collect runoff and settle suspended solids.

Water trucks will control dust by spraying the road surface and adjacent berm. The porous road materials readily drain water, and runoff is negligible. Shoulders of access and haul roads will be revegetated. When a road is no longer needed, the surface material or crushed clinker will be removed for disposal within the mining area. If the subgrade material is not suitable for revegetation, it will also be removed and the remaining material scarified, shaped, topsoiled, and seeded.

Pipelines

The first construction operations in building a pipeline consist of clearing the right-of-way of all vegetative materials and litter. A bulldozer is normally used to scrape this material to the sides of right-of-way for disposal.

At approximately the same time, work begins on access roads to the construction site. These roads are not normally intended for public use and are built to low standards. Excavation of cut material and placement of fill is usually immediately adjacent and bulldozers are used for most of this cut and fill operation. A minimum of culverts are placed as construction progresses. Motor graders are used for grooming culvert sites, cut and fill side slopes, and the road surface. When construction access roads and clearing have been completed, work may proceed on pipeline construction.

First, a wheel trencher digs the pipeline trench. This machine can dig the trench in most unconsolidated materials. However, massive consolidated material may require ripping with a crawler-type tractor drawn ripper or possibly even a blasting operation. Final removal of this type material is done with backhoe type machinery.

While the trench is being excavated, the pipe to be used is transported to and spaced along the route. Three separate operations are performed on the pipe before it is placed in the trench.

The first pipe operation is welding the individual sections together. A special pipe welding machine places each section in precise alignment with the previous section and then makes the weld to assure a joint which will withstand the anticipated pressure. Immediately following welding, a special machine bends the pipe to conform to the shape of the trench. Finally, the pipe is given a bituminous coating, wrapped with a protective covering and given another bituminous coating.

At this time, the pipe is lowered into the trench. This step is accomplished in a continuous moving operation employing specially equipped short lift machines. Special bedding material is not used under or around the pipe except in sharp rock formations.

The final step is filling the trench, thereby covering, protecting and supporting the pipe. The material that was excavated from the trench is pushed into the trench by a bulldozer or loader. A tamping machine straddles the trench and tamps the fill material. However, since the material placed in the trench is not compacted to a specified density as in most other construction operations, some subsidence does occur. This is minimized by placing excess material in a windrow along the trench centerline after tamping.

Transmission lines

The first operation in construction of a transmission line is a joint operation of clearing the right-of-way and constructing necessary access roads. All vegetative materials will be removed from areas to be excavated or in which embankments will be constructed. This refuse is bulldozed off the ground for disposal.

Concurrent with clearing operations, access roads are being constructed. These roads are not intended for normal public road usage and are built to low standards. Most grading will be accomplished with bulldozer equipped crawler tractors. Culverts are placed and backfilled to specifications. Motor graders are used to dress cut slopes and the running surface of the final grade. Once access roads and tower site clearing have been completed, construction of the transmission line commences.

First, tower footings are placed. Holes for footings are usually excavated with a backhoe. Reinforcing materials are placed in the excavation and concrete is poured to make the footing. After the concrete has cured, tower placement begins. Towers are usually fabricated from materials trucked to the site. Crews fabricate the towers in sections by bolting individual pieces together. Cranes lift the sections into place, first over the footings and so on until the result is a finished tower.

After the towers are complete, transmission cable and jerrie cable are brought to the site. Cable is on large spools that are spaced along the transmission line route for the line stringing. Jerrie cable is placed between the towers first to add strength to the tower system. The most common method is to place the spool of cable on a crawler-type tractor and unroll it along the line route. Cranes raise the jerrie cable into position for attaching to the towers. Next, power conductor cables are attached to insulators suspended from the towers. After cable installation is complete, all that is necessary to use the system is to connect conductors to the generating station or sub-station power source.

Recently helicopters have often been used to transport materials to the site, erect towers and string cable. This method is becoming increasingly popular to lessen environmental impacts and costs of constructing access roads in rough terrain.

A variation of clearing procedures calls for minimal clearing at each stage of construction. Final clearing to provide adequate clearance for conductor cables is postponed until cable stringing operations are complete. This method, although more expensive and time consuming, results in much less impact on the environment. This process is referred to as the "grooming process."

Waste Disposal Systems

Coal and energy development in the Powder River Basin will result in solid and liquid by-products that are not economically marketable and will have to be disposed of as waste.

Needs for municipal waste treatment facilities are included in Chapter V. This analysis of disposal systems will first consider waste generated in industrial processes then discuss domestic and construction wastes associated with building and operating the facility.

Process wastes

Process wastes are defined as nonmarketable by-products resulting from converting one product to another. More specifically here, they are residues from various coal combustion processes that also use water. Ash from coal and minerals from water used will be the primary waste products for the processes expected in the Powder River Basin.

The magnitude of waste products that must be handled is indicated by the following generalized computations.

Gasification plant (250 million cu. ft. of gas per day) yields:

Boiler ash	530 tons per day
Gasifier ash	1,400 tons per day
Sludges	550 tons per day
Total	2,480 tons per day

Power plant (500 MW--250 tons/hour of coal, 10 percent ash) yields:

Fly ash	450 tons per day
Bottom ash	150 tons per day
Mineral residues	unknown
Total	600 tons per day plus minerals.

Two techniques are commonly used to dispose of these wastes. Where the plant is operated in conjunction with a surface mine, process waste is usually placed in mined-out areas and covered with spoil. If the plant is remote, surface storage using an evaporation or tailings pond is commonly used for liquid wastes. For the 1,500-MW Jim Bridger southwestern Wyoming power plant, an evaporation pond 500 acres in size is being designed to store and evaporate mineralized wastes from the water consumed. Ash is placed in the strip mine.

Domestic and construction wastes

Domestic and construction wastes include sanitary wastes from construction and operating employees, debris from packaging, and used construction material.

Sewage treatment systems vary with amount of sewage to be treated. Larger sewage systems consist of collector lines transporting sewage to a treatment site. Basic treatment for this type of system is the lagoon method. Sewage flows into holding ponds and bacteria convert the sewage to an effluent which will meet discharge standards. The next basic addition to the system to enable it to handle larger volumes of sewage is an aeration system. This equipment sprays sewage into the air to enrich it with oxygen. Oxygen enhances the bacterial action and speeds the process of conversion to an acceptable discharge standard.

High volume systems include sludge conversion capability. The discharge liquid is returned to settling ponds until the sludge reaches a predetermined depth. The liquid is then diverted to other settling ponds while the first is cleared of sludge. Liquid is drained off and the sludge is mechanically stirred to aid drying. After the sludge has dried to an acceptable level, it is removed from the settling ponds for disposal.

Several different package units are available for treatment of sewage, but they all use the same basic process with variations to meet special disposal conditions. They can also include treatment of effluent with chlorine to further purify the final product and reduce odors from bacterial action.

A sanitary treatment system for use at the Wyodak Power Plant has been described as follows by the companies proposing the project:

During construction of the proposed steam-electric generating plant, sanitary wastes from the station and the nearby residential community will be treated in an extended aeration treatment facility. Following construction, sanitary wastes will be treated by a packaged treatment plant.

The treatment will consist of primary settling, extended aeration, and gas postchlorination. The dissolved oxygen content of the effluent will be maintained continuously at 2 ppm or more. The system will be designed to treat approximately 3,500 gallons per day of sanitary waste. The system will include a 4,000-gallon aeration, a 1,000-gallon settling tank, and 1,200-gallon sludge tank.

The Wyodak proposal will evidently use an aerated sewage lagoon for treatment of wastes from onsite temporary housing and an estimated 600 construction workers and a package system to meet the needs of 50 to 60 people operating the power plant.

A rule of thumb for sizing community sewage lagoons is one acre per 100 population. Thus, a construction force of 1,000 could require a 10-acre sewage lagoon. The size could be reduced if no onsite housing of workers and families is comtemplated.

Solid waste disposal at construction sites ordinarily involves both burning and landfill techniques. Flammable material is burned to reduce bulk either in incinerators or, at remote sites, by open burning. Ash and other residue can be placed in selected landfill sites or incorporated into strip mine spoils.

CHAPTER IV

DESCRIPTION OF THE EXISTING ENVIRONMENT

Climate

The climate of the Powder River Basin is directly influenced by major topographic features, the Coastal and Rocky Mountain ranges, and locally by the Bighorn Mountains which flank the western edge of the basin. The mountain ranges are situated at right angles to the prevailing westerly air flow which affects wind, precipitation, and temperature patterns. Pacific air currents drop much of their moisture prior to entering eastern Wyoming. According to the Koppen Climate Classification System, the basin has a middle latitude steppes climate shut off by mountains from invasions of maritime air masses and is semiarid with great annual temperature variations between summer and winter.

The major weather stations for which detailed information and analyses are available for the study area are located at Gillette and Douglas. Information for these stations is contained in Table 1. A comparison of available climatological data for other selected stations located within the study area is made on Table 2. Additional information is contained in the various tables and charts in Appendix C.

Precipitation

Precipitation in the Powder River Basin varies by location in relation to the Bighorn Mountains. Rates diminish in both an easterly direction from the mountains and in a southerly direction down through the basin. Northern Campbell County stations generally receive the greatest amounts and those

Table 1

Mean and Extreme Precipitation Totals (inches)
Gillette, Wyoming
For the 30-Year Period 1931-1960

Month	Mean monthly amount of precipitation	Greatest daily amount of precipitation	Year	Mean amount of snow/sleet	Maximum monthly snow/sleet	Year	Greatest daily snow/sleet	Year	
Jan	0.63	0.70	1943	7.1	25.4	1943	6.0	1948	3
Feb	0.50	0.85	1954	5.6	20.4	1959	12.0	1953	2
Mar	1.06	1.60	1933	9.9	23.0	1944	18.0	1933	4
Apr	1.66	1.78	1941	6.3	20.0	1950	10.0	1933	5
May	2.22	2.00	1952	1.1	8.0	1950	8.0	1950	6
June	2.59	1.95	1947	0.1	4.0	1937	4.0	1937	6
July	1.24	1.70	1932	0.0	0.0	----	0.0	----	4
Aug	0.95	2.82	1960	T	T	1955	0.0	----	2
Sept	1.09	1.65	1951	0.5	4.0	1934	2.0	1949	3
Oct	0.71	0.78	1946	2.8	9.0	1932	7.0	1949	3
Nov	0.75	0.80	1945	7.1	23.0	1947	8.0	1956	3
Dec	0.61	0.80	1943	7.3	16.9	1955	7.0	1935	3
Year	14.00	2.82	Aug. 1960	47.8	25.4	Jan. 1943	18.0	Mar. 1933	44

Mean number of days with precipitation of .10 inch or more

Table 1 (Cont'd)

Mean and Extreme Precipitation Totals (inches)
Douglas, Wyoming
For the 30-Year Period 1931-1960

Month	Mean monthly amount of precipitation	Greatest daily amount of precipitation	Year	Mean amount of snow/sleet	Maximum monthly snow/sleet	Year	Greatest daily snow/sleet	Year	Mean number of days with precipitation of .10 inch or more
Jan	0.43	1.26	1949	6.0	24.0	1949	14.0	1949	2
Feb	0.53	0.64	1948	7.1	14.8	1948	8.0	1936	2
Mar	0.77	0.82	1954	8.0	29.7	1944	8.0	1954	3
Apr	1.82	2.16	1941	9.1	41.9	1945	22.0	1945	4
May	2.32	1.31	1942	2.0	17.5	1942	8.6	1957	6
June	1.83	1.68	1946	0.3	7.0	1951	7.0	1951	5
July	1.34	2.02	1933	0.0	T	1952	0.0		3
Aug	1.05	1.31	1947	0.0	T	1954	0.0		3
Sep	1.13	1.74	1938	0.1	2.0	1944	2.0	1944	3
Oct	1.11	0.84	1942	3.3	15.5	1949	8.0	1942	3
Nov	0.62	0.70	1956	6.7	23.9	1956	13.0	1956	3
Dec	0.55	0.75	1945	7.2	16.1	1945	7.5	1944	2
Year	13.50	2.16	Apr. 1941	49.8	41.9	Apr. 1945	22.0	Apr. 1945	39

Table 2

Comparison of Climatological Data for Selected Stations
Campbell and Converse Counties

Station*	Average Annual Precipitation (inches)	Average Annual Snowfall (inches)	Average January Temperatures (degrees F)			Average July Temperatures (degrees F)			Average Growing Season Based on 32° (days)	Elevation (feet)
			Max.	Min.	Ave.	Max.	Min.	Ave.		
Rocky Point	17.21	57.2	----	----	19.2	----	----	71.4	123	3,892
Recluse	14.73	42.9	----	----	14.9	----	----	71.1	118	4,200
Gillette	14.00	47.8	32.7	11.1	21.9	87.8	56.0	71.9	127	4,556
Rochelle	12.76	34.6	34.2	7.1	20.7	88.8	55.0	72.3	111	4,496
Dull Center	11.97	38.0	36.8	9.3	23.1	89.4	55.6	72.5	130	4,415
Douglas	13.50	49.8	35.7	10.7	23.2	86.1	54.3	70.2	121	4,853

*Stations are listed from north to south.

stations located in Converse County to the south receive comparatively lesser amounts of total annual precipitation. Maximum precipitation occurs in spring and early summer, and a lesser peak occurs in the fall, usually in the form of early snowstorms. During the summer months, rain showers are frequent but light Mean annual precipitation is shown on an isobar map, Figure 3, Appendix C.

Droughts are common. Adequate distribution of monthly rainfall for April, May, and June is critical for vegetative production and establishment. Although the average precipitation may exceed normals, frequently it does not occur during the critical period of the growing season. For this reason, mean values are at times meaningless when considering reclamation needs, especially when rainfall is often characterized by scattered thunderstorm occurrences.

The record 24-hour storm for the State of Wyoming occurred at Dull Center, located in the east central portion of the study area, which received 5.50 inches during a 24-hour period.

Rapid runoff from heavy thunderstorms causes flash flood conditions and contributes to extensive erosion and other damages. The Thunder Basin is aptly named owing to the frequent thunderstorm conditions associated with the area. Severe hailstorms occur frequently and are often extremely destructive.

Snow is common from November through May but is generally light to moderate though several storms exceeding five inches can be expected annually. Heaviest storms leave ten to 15 inches of snow. Winds frequently accompany or follow a snow storm and pile snow into drifts several feet deep. Wind with snow quite often causes blizzard or near blizzard conditions for a few hours. Blizzards seldom last for any length of time in terms of days.

Heaviest snow fall of record for lower elevations occurred in Sheridan, located in the northwest corner of the basin, in 1955. The total accumulation from one storm for a 43-hour period was 39.01 inches containing a water equivalent of 4.30 inches.

Isopluvial maps have been developed for maximum precipitation amounts that can be expected in 2-, 10-, 25-, 50-, and 100-year 24-hour storms.

These frequencies are presented in Figures 4 through 8 of Appendix C. Probability occurrence within selected time periods is shown in Table 3. To clarify use of Table 3, for any 100-year period, there is an 87 percent probability that a 50-year flood or rain will occur and a 73 percent probability that a 100-year event will occur.

Table 3

Probability That an Event of Given Recurrence Intervals Will be Equaled or Exceeded During Periods of Various Lengths

Period Year	1	5	10	25	50	100	200	500
				Probability				
Recurrence Interval								
2	0.5	0.97	0.999	*	*	*	*	*
10	0.1	0.41	0.65	0.93	0.995	*	*	*
50	0.02	0.10	0.18	0.40	0.64	0.87	0.98	*
100	0.01	0.05	0.10	0.22	0.40	0.63	0.87	0.993
200	0.005	0.02	0.05	0.12	0.22	0.39	0.63	0.92

* In these cases probability can never be exactly 1, but for all practical purposes its value may be taken as unity.

Temperature

The Powder River Basin has a relatively cool climate. The temperature range is wide between both summer and winter and daily maximums and minimums. The high elevations and dry air cause a rapid incoming and outgoing of radiation. January is usually the coldest month and July the warmest. Frequent changes between mild periods and cold spells are characteristic of winter weather.

During the winter, average daily minimums range between 5°F and 40°F. It is common, however, for temperatures to drop considerably below 0° from December through February, and daytime temperatures may rise to 50° during mild periods.

The basin is particularly subject to cold air invasions from the north. During winter warm spells, chinook winds are common along the eastern mountain slopes.

Summers are generally mild with short periods of temperatures exceeding 100 degrees. The mean maximum daily temperature for July is 90 degrees; nights are usually cool despite high daytime readings. Mean and extreme temperature information for Gillette and Douglas weather stations is contained in Tables 4 and 5. Figures 9 through 12 and Tables 5 through 8 of Appendix C contain temperature information and maximum-minimum probabilities for Douglas, Dull Center, Recluse and Gillette.

Wind

Studies of wind flow patterns indicate that Wyoming is usually covered by Pacific air with short periods of cool air masses from Canada. Seldom does air from the Gulf of Mexico extend this far north.

Wind is a significant factor in Wyoming's climate; the prevailing winds are westerly. The high elevations and large expanse of rolling plains in the basin result in high average annual wind, especially during the colder months from November through March. Winds often reach 30 to 40 miles an hour with occasional, higher gusts. These rates are from spillage through the lower

Table 4

Mean and Extreme Temperatures (^{o}F) for Gillette, Wyoming
For the 30-Year Period 1931-1960

Month	Means			Extremes				Mean Degree Days**	Mean Number of Days			
									Maximum		Minimum	
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year		90° and Above	32° and Below	32° and Below	0° and Below
(a)	30	30	30	30		30			30	30	30	30
Jan.	32.7	11.1	21.9	62	1953+	-32	1949	1336	0	12	30	6
Feb.	35.8	13.4	24.6	67	1932	-40	1936	1131	0	10	27	5
Mar.	42.3	19.8	31.1	78	1943	-23	1960	1051	0	6	28	3
Apr.	55.2	30.4	42.8	84	1936	-12	1936	666	0	1	18	*
May	66.1	40.1	53.1	95	1934	11	1954	375	*	*	5	0
June	75.4	47.8	61.6	104	1954	29	1943	168	2	0	*	0
July	87.8	56.0	71.9	107	1931	39	1956	22	15	0	0	0
Aug.	86.2	54.2	70.2	106	1949	35	1936+	25	13	0	0	0
Sep.	75.0	44.4	59.7	98	1959+	14	1942	217	3	*	2	0
Oct.	62.0	34.7	48.4	89	1957	-1	1935	524	0	*	12	*
Nov.	44.3	22.1	33.2	73	1931	-26	1959	954	0	5	26	2
Dec.	36.9	16.0	26.5	69	1939	-23	1932	1194	0	10	30	4
Year	58.3	32.5	45.4	107	July 1931	-40	Feb. 1936	7663	33	44	178	20

(a) Average length of record, years
* Less than one-half
\+ Also on earlier dates, months, or years
** Base 65° F; values computed from mean temperature

Source: U.S. Department of Commerce, Weather Bureau, Climatological Summary.

Month	Mean			Extremes				Mean Degree Days**	Mean Number of Days			
									Maximum		Minimum	
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year		90° and Above	32° and Below	32° and Below	0° and Below
(a)	30	30	30	30		30			30	30	30	30
Jan.	35.7	10.7	23.2	65	1953	-35	1959	1296	0	9	29	7
Feb.	39.1	14.1	26.6	69	1954	-38	1936	1075	0	7	26	4
Mar.	45.7	20.7	33.2	76	1953	-27	1956	986	0	5	27	2
Apr.	57.0	30.1	43.6	86	1952	-13	1936	642	0	1	17	*
May	66.8	39.0	52.9	93	1934	13	1954	388	*	*	4	0
June	77.6	48.2	62.9	102	1931	29	1947	144	4	0	*	0
July	86.1	54.3	70.2	106	1931	36	1959	22	13	0	0	0
Aug.	84.1	52.2	68.2	100	1954+	33	1939	34	8	0	0	0
Sep.	74.3	42.1	58.2	98	1960	20	1945+	234	2	0	3	0
Oct.	61.4	31.4	46.4	86	1958+	0	1935	577	0	*	16	*
Nov.	47.1	19.9	33.5	74	1953+	-23	1952	945	0	5	26	2
Dec.	37.6	13.6	25.6	68	1941	-27	1932	1221	0	7	29	5
Year	59.4	31.4	45.4	106	July 1931	-38	Feb. 1936	7564	27	34	177	20

(a) Average length of record, years
* Less than one-half
\+ Also on earlier dates, months, or years
** Base 65° F; values computed from mean temperature

Source: U.S. Department of Commerce, Weather Bureau, Climatological Summary.

Table 5

Mean and Extreme Temperatures (°F) for Douglas, Wyoming
For the 30-Year Period 1931-1960

mountain passes of cold air trapped in the Great Basin of the southwest. Surface wind velocity and direction data are greatly influenced by local situations and, therefore, reliable only for the immediate vicinity of the data collection point. The only detailed wind information of long-term value was compiled at the Sheridan weather service station and the variability of patterns makes extrapolation difficult.

More information concerning winds, inversions, and related data are included in the Air Quality section of this chapter.

Humidity

Average relative humidity is usually quite low. During warmest periods, the humidity drops to 25-30 percent, and conversely during low temperature periods rises to 65-75 percent.

Evapotranspiration

Relative humidity, temperatures, and wind influence evapotranspiration rates. Evapotranspiration is important in terms of affect on water supply and vegetative growth, especially where available water is marginal.

Transpiration rates have a distinct annual fluctuation responding mainly to mean temperatures. During the winter months when precipitation rates exceed evapotranspiration, water will be available for recharge to soil water storage. From late spring through fall, evapotranspiration greatly exceeds precipitation; streamflow becomes intermittent and runoff is low. Irrigation is necessary to grow high-yield crops. The area has an annual deficit precipitation-evaporation budget, shown in Figure 1, which varies from -9.5 inches at Douglas to -12.10 inches at Dull Center. Table 9 of Appendix C compares precipitation and evapotranspiration data.

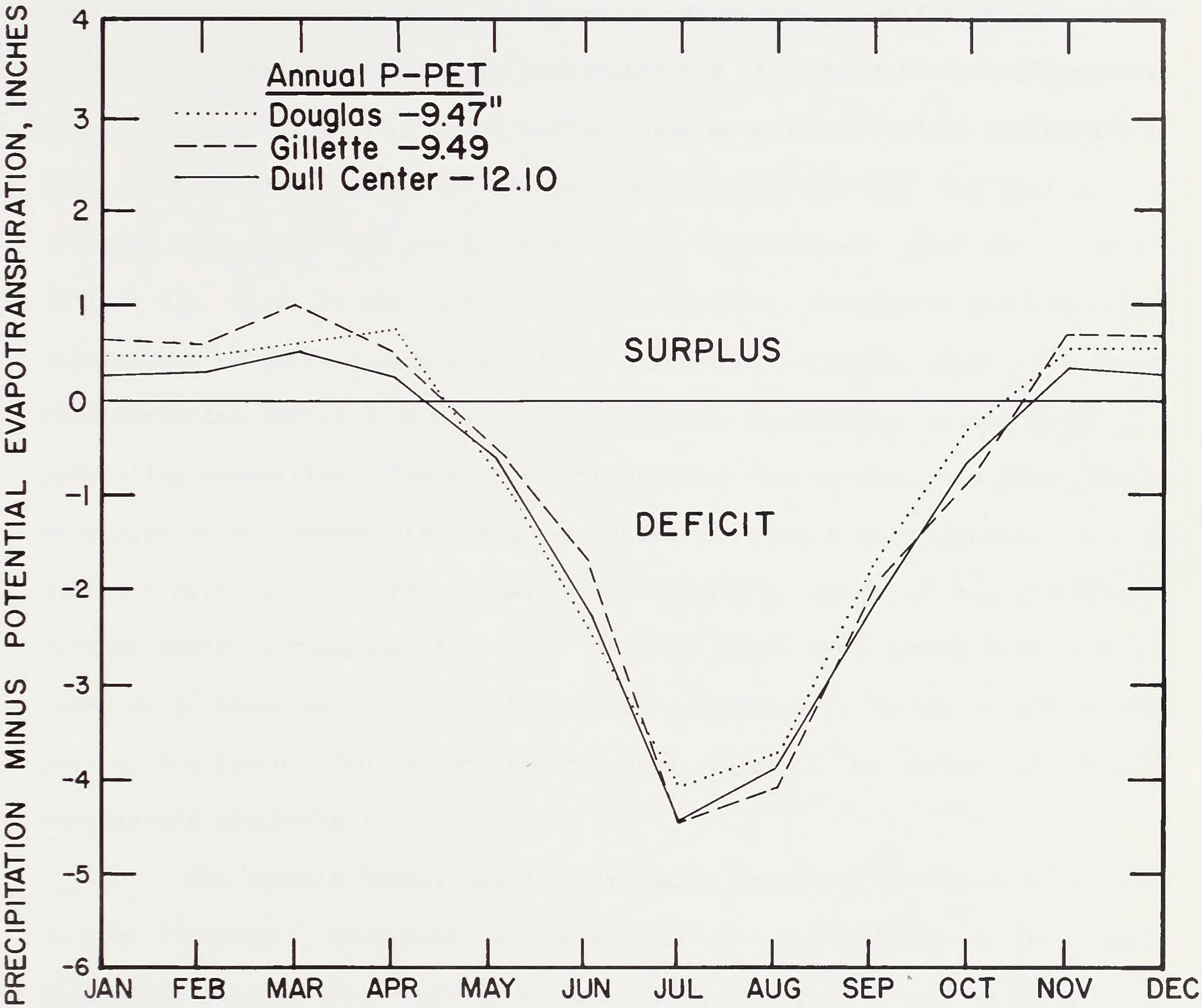


Figure 1
Annual precipitation—evapotranspiration moisture budget.

Sunshine

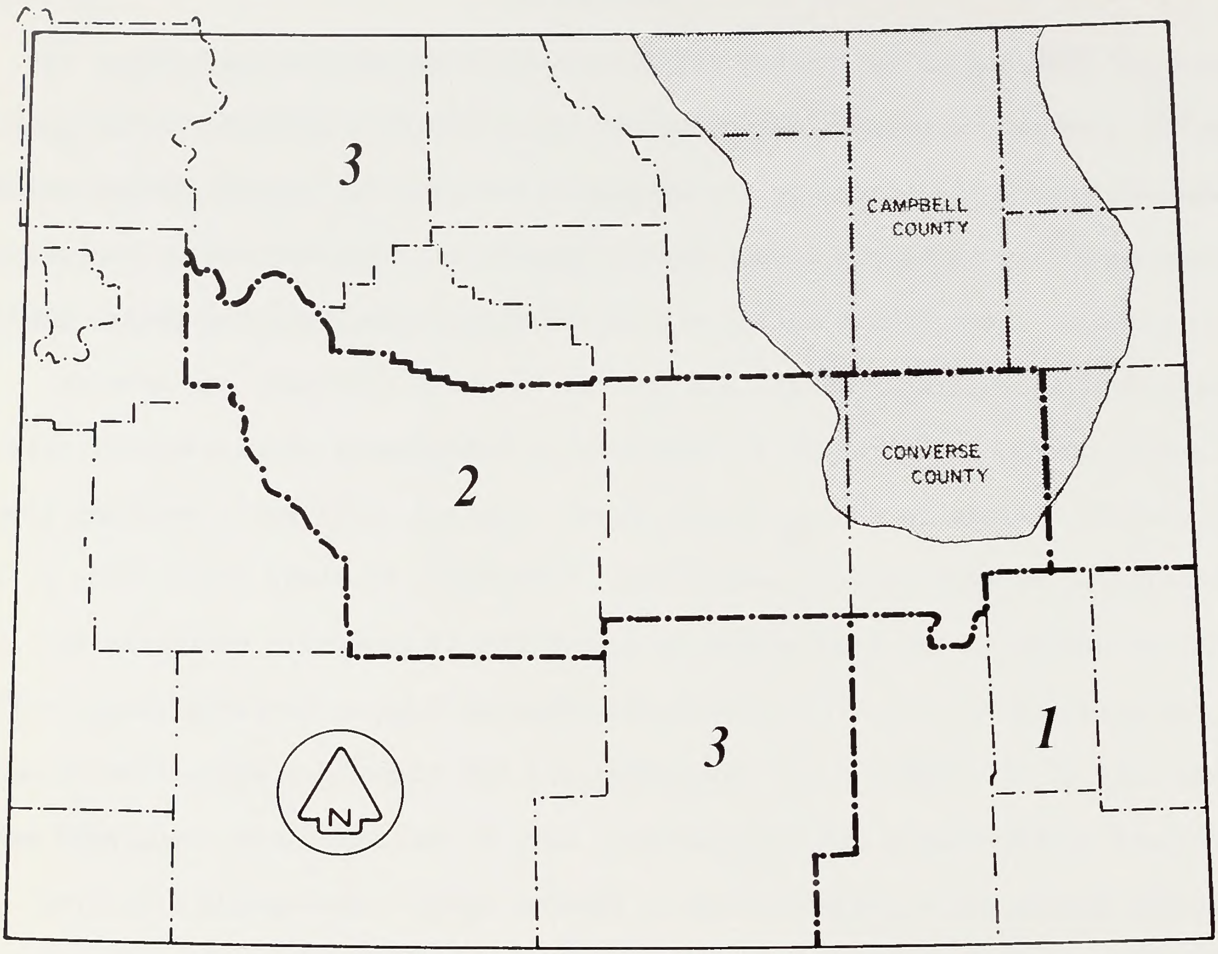
Although no records of percent sunshine are kept by weather stations within the study area, estimates are that sunshine ranges from about 55 percent of the available time in winter to 75 percent in summer. Sunlight intensities are usually very high owing to the relatively high altitudes and limited amount of atmosphere to filter the sunlight.

Air Quality

The region is located partially within two of Wyoming's three air quality control regions as designated by the Environmental Protection Agency. Campbell County is located in the Wyoming Intrastate Air Quality Region while Converse County is in the Casper Region (Figure 2). Neither region represents homogeneous climatological areas within the state. However, the Powder River Basin, which contains Campbell and most of Converse Counties, has similar climatic characteristics and is considered a homogeneous climatological area (Figure 2). Winds in the basin are fairly constant, frequently reaching high velocities, thereby causing significant atmospheric flushing (Ward 1972, p. 1). Wind direction varies from season to season but is generally dominated by prevailing westerlies. The north-south oriented Bighorn Mountain Range on the west side of the Powder River Basin modifies the prevailing westerlies to more dominant northwesterly and southwesterly wind flows, and local topography may further modify prevailing direction. Average annual wind speeds vary from eight to 12 miles per hour with the higher velocities occurring in the southern part of the basin. (For other climatic data, refer to the section on climate, immediately preceding.)

The basin's prevailing dry air causes low-level nocturnal inversions to form frequently, especially during the winter. Such inversions are usually dissipated shortly after sunrise due to rising temperatures and increased wind speeds. In general, low-level inversions occur from 40 to 55 percent of the time in fall and winter, and from 30 to 40 percent of the time in spring and summer (Hosler 1961, p. 332).

The potential for air pollution is influenced both by mixing heights and average wind velocities in these mixing layers. Data taken from a recent study (Environmental Protection Agency 1972, Figures 1-20) indicate that the



1 CHEYENNE INTRASTATE AIR QUALITY CONTROL REGION

2 CASPER INTRASTATE AIR QUALITY CONTROL REGION

3 WYOMING INTRASTATE AIR QUALITY CONTROL REGION

POWDER RIVER BASIN

Source: Chuck Ward, Wyoming's Air Quality Program, August 1972, Figures 1 & 2.

Fig. 2
Wyoming Air Quality Control Regions

Powder River Basin has mean mixing heights and corresponding wind speeds near the values shown on Table 6 for annual and seasonal periods of the year.

The data show a large diurnal variation of mixing heights between morning and afternoon. Seasonal variation of morning mixing heights in the basin are small while those of the afternoon are rather large. Shallower mixing heights are less effective in diluting or dispersing pollution that are released within the mixing layer.

Wind speeds in the afternoon are typically higher than morning values while summer speeds are less than those in winter. The higher wind speeds, of course, are more effective in transport and diffusion of pollutants.

A combination of shallow mixing heights and low wind speeds inhibits dispersion of pollutants. Therefore, it is significant to note that the greatest pollution potential in the basin occurs during the winter when both morning and afternoon mixing heights and wind speeds are relatively low. During this period, inversions may form for extended periods of time and create serious air pollution problems.

Upper-level (above 500 feet) inversions may result in stagnant air conditions that last for several days, particularly during the winter. This region can be expected to have an average of 40 stagnation-episode days per year, and an average of 15 of these episodes lasting at least two consecutive days (EPA 1972, Figures 51-71). Episode conditions lasting at least five days occur on an average of four times per year. Some recent temperature sounding observations indicate that a persistent inversion may exist over the area during most of the winter and most of each spring (Marwitz, Hearings Statement, 6-26-74).

Unstable atmospheric conditions are characterized by large variations in wind direction and result in effective dispersion of effluents with the

Table 6

Powder River Basin Estimated Mean Mixing Heights and Wind Speeds*

Type of Data	Annual		Winter		Spring		Summer		Autumn	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Mixing heights (feet)	980	6,560	980	3,610	1,310	8,530	980	9,840	820	6,230
Wind Speed (MPH)	11	16	11	13	12	18	9	15	9	15

* Average values for the basin.

(AM-morning; PM-afternoon; MPH-miles per hour)

Source: EPA, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States (January 1972), figures 1-20.

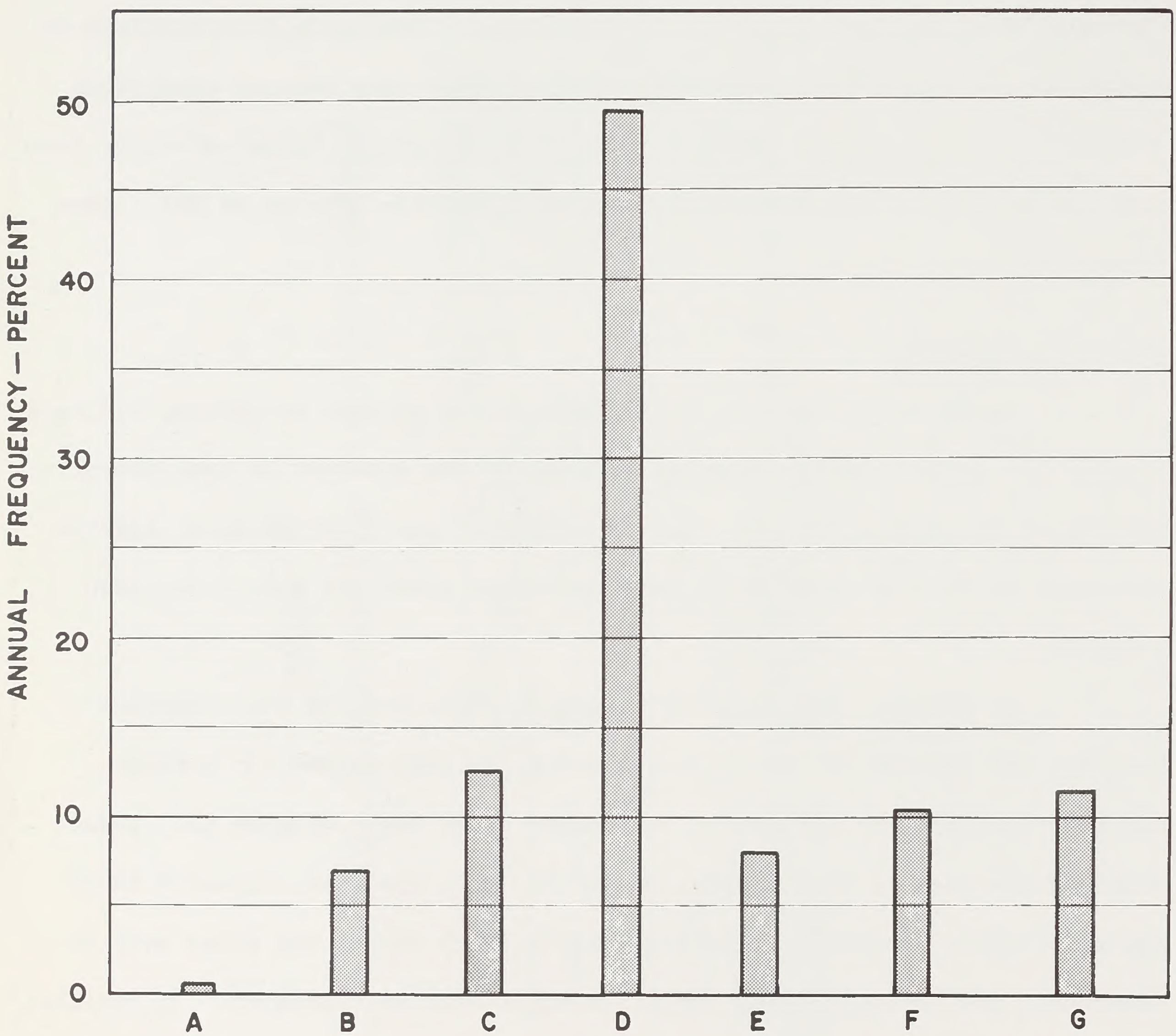
greatest ground level concentrations in close proximity to the effluent source. Conversely, stable atmospheric conditions are characterized by small variations in wind direction and result in slow effluent dispersion with lower ground level concentrations in close proximity to the source. Frequency distributions of atmospheric stability for Moorcroft, Wyoming, show that neutral conditions (Class D) are most common while very unstable conditions (Class A) occur less than one percent of the time (NOAA Environmental Data Service 1973b). (See Figure 3.)

Ambient air quality

Until recent months, little ambient air quality monitoring had been carried out in the basin. However, with plans for substantial development of the region becoming a reality, several companies and agencies have recently initiated monitoring programs or have developed plans for initiating such programs.

At present, the State of Wyoming's Department of Environmental Quality, Air Quality Division, is operating six high volume air quality samplers (particulate matter) in the Powder River Basin (Figure 4). These stations are located at Gillette, Moorcroft, Reno Junction, Stoddard Ranch (about 15 miles northwest of Bill), Burke's Ranch (about six miles east of Glenrock), and Gordon's Ranch (about 12 miles west of Clareton). In addition to the six stations within the basin, the Air Quality Division also operates one high volume sampling station in the Bighorn Mountains. Data collection from five of the seven stations was initiated in late 1973 or early 1974. The Gillette and Burke's Ranch stations were activated in June 1972 and January 1973, respectively. Preliminary data indicate a possible mean suspended particulate range of 13 to 190 micrograms per cubic meter (ug/m_3) (Eric Highberger 1974).

Source: USDC, NOAA Environmental Data Service, Monthly and Annual Wind Distribution by Pasquill Stability Classes, Moorcroft, Wyoming, 1973



PASQUILL STABILITY CLASS

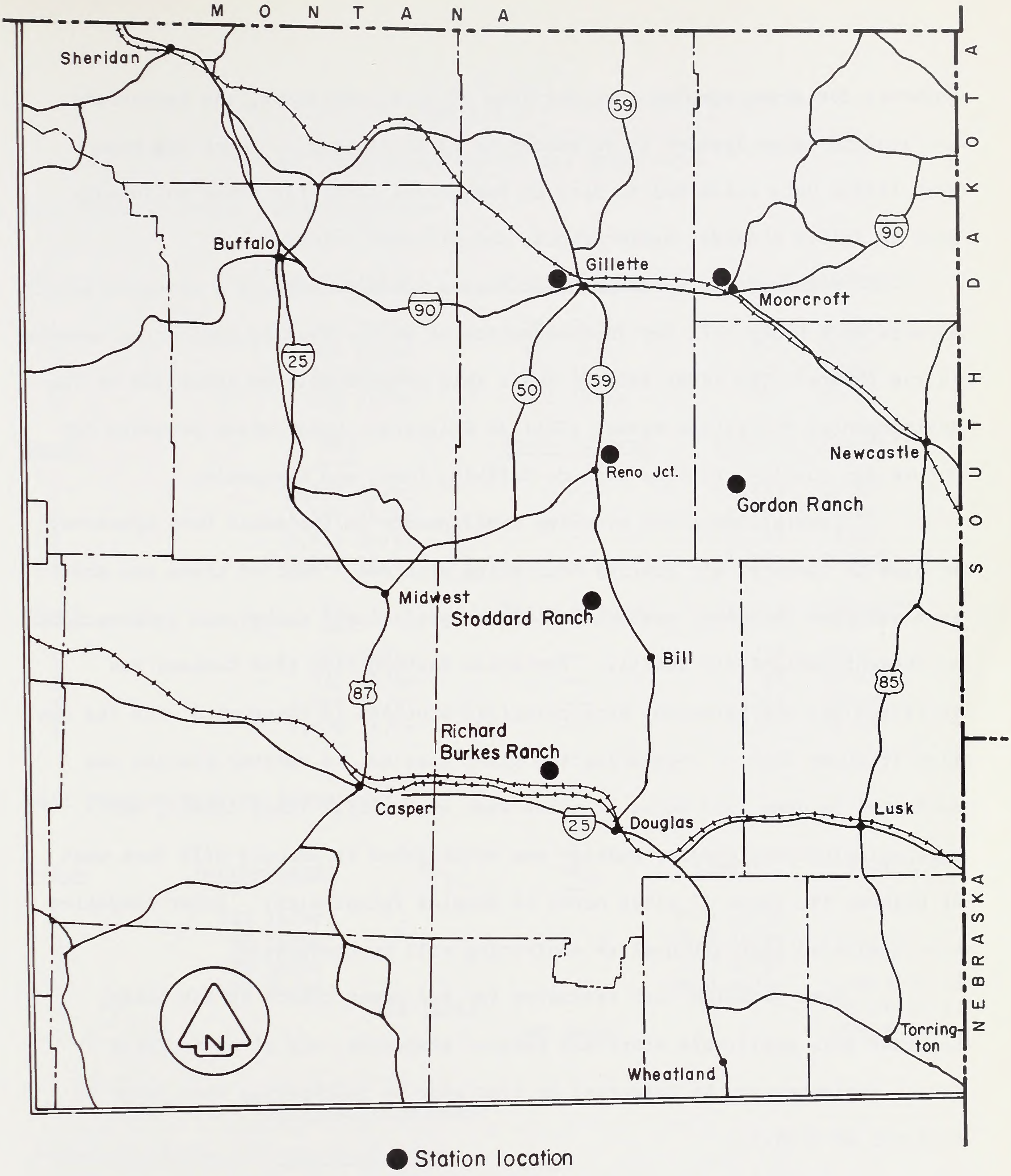
(A=VERY UNSTABLE, G=VERY STABLE)

FIGURE 3

STABILITY FREQUENCY

MOORCROFT, WYOMING

1/50 7/52



Source: Eric Highberger, Wyoming Department of Environmental Quality, Personal Communication.

Fig. 4
Air Quality Monitoring Stations in the Powder River Basin

However, for areas sampled that are free of local emissions, the background particulate range appears to be nearer to 13 to 21 ug/m_3. There has been very little data collected to date on background level for other pollutants such as sulfur dioxide, hydrocarbons, and nitrogen oxides.

Plans of the Northern Great Plains Resource Program's Atmospheric Aspects Work Group call for implementation of an air quality monitoring network in the future. The first station under this program will be installed by the Environmental Protection Agency (EPA) at Gillette. Other sites proposed for future air quality stations include Buffalo, Lusk, and Newcastle.

Several companies planning developments in the basin have operated, or plan to operate, air quality monitoring stations. Most of these are short-term stations (studies) designed to obtain preliminary background information on present ambient air quality. Panhandle Eastern Pipe Line Company has initiated two semipermanent meteorological stations in connection with its coal mine (Peabody Coal Co.)-gasification plant complex. A weather station was activated in June 1973 about 12 miles west of Rochelle (coal lease), and a meteorological/air quality station was established in January 1974 just west of Highway 59, about 15 miles north of Douglas (plant site). Other companies have indicated that air quality monitoring will be conducted.

Some emission rate estimates for two power plants in the basin, together with applicable state and federal standards, are given in Table 7. (These estimates may be converted to tons/year by multiplying each value by a factor of 4.38.)

Conclusion

Present ambient air quality in the basin is very good according to all available information. Some exceptions might include localized areas

Table 7

Power Plant Emissions in the Study Area

Dave Johnston Power Plant Emissions[1]

Stack	Particulates	State Allowed*	Federal Allowed**
1	2,588 lb/hr	285 lb/hr	105.4 lb/hr
2	2,588 lb/hr	285 lb/hr	105.4 lb/hr
3	5,293 lb/hr	532 lb/hr	221.5 lb/hr
4	345 lb/hr	821 lb/hr	359 lb/hr

Stack	SO_2	State Allowed	Federal Allowed**
1	1,197 lb/hr	---	1,265 lb/hr
2	1,197 lb/hr	---	1,265 lb/hr
3	2,412 lb/hr	---	2,658 lb/hr
4	2,170 lb/hr	---	4,294 lb/hr

Stack	NO_x	State Allowed	Federal Allowed**
1	767 lb/hr	---	738 lb/hr
2	767 lb/hr	---	738 lb/hr
3	1,568 lb/hr	---	1,551 lb/hr
4	2,428 lb/hr	---	2,505 lb/hr

Neil Simpson Station Emissions[2]

Stack	Particulates	NO_x	SO_2	State*	Federal**
1	202 lb/hr			31.9 lb/hr	
3	90 lb/hr			22.0 lb/hr	
4	130 lb/hr			22.0 lb/hr	
5	475 lb/hr			98.0 lb/hr	28.8 lb/hr
5		288 lb/hr			201.6 lb/hr
5			320 lb/hr		375.6 lb/hr

*State limits for Existing Facilities.

**Federal limits for New Facilities.

[1]Current (1974) data furnished by Pacific Power & Light Company, 7-10-74.

[2]Emission data taken from Black Hills Power and Light Company Environmental Report, dated May 1973.

surrounding the Dave Johnston Power Plant at Glenrock, the Neil Simpson Station at Wyodak, various oil fields, and the Cities of Douglas and Gillette. (A list of emission sources in Wyoming has been compiled, Ward 1972.) Emissions currently generated at these locations cause local air pollution problems. This is particularly true of the Dave Johnston Power Plant's emissions and plume which sometimes drift downstream along the North Platte River to Douglas. Fugitive dust from disturbed areas (unpaved streets and roads; construction, stockpiling and handling of dusty materials; cultivated farm lands; etc.) as well as from undisturbed areas eroding during periods of strong winds adds considerably to airborne pollutants. Vehicular traffic within the basin is widely dispersed and probably contributes little to air pollution.

Topography

The Eastern Powder River Coal Basin lies wholly within the unglaciated part of the Missouri Plateau (Upper Missouri Basin) of the Northern Great Plains Physiographic Province of Fenneman (1931). The entire region is within the drainage basin of the eastward and southeastward-flowing Missouri River. The North Platte flowing southeastward, Powder flowing northward, Belle Fourche and Cheyenne Rivers flowing eastward are tributaries (Figure 5). The basin of the Powder River drains only the western part of the coal basin, which lies on the eastern flank of a large topographic depression in superposition with the structural basin. In the Cheyenne River valley altitudes rise from 4,400 feet to 4,800 feet on the uplands, from 4,400 feet in the Belle Fourche River valley to 5,000 feet on the prairie, and from 3,600 feet in the Little Powder River valley to about 4,800 feet on the ridges. The larger streams are well entrenched, have wide flat floors, and broad floodplains. Floodplains are bordered by remnants of alluvial terraces. The landscape is dominated by plains and low-lying hills and tablelands, interrupted here and there by entrenched river valleys and by isolated uplands, flat-topped buttes and mesas, long narrow divides and even-crested ridges that rise 100 to 500 feet above valley floors.

The coal basin is part of the topographic depression between the Bighorn Mountains and the Black Hills. A broad plateau or upland area, the crest of which parallels the north-south State Highway 59, comprises the central part of the topographic basin. The strippable coal lies near the eastern edge of this rolling grass-covered upland. An irregular zone of rough, broken, hummocky terrain borders these shallow coal deposits. Eastward, erosion has reduced this terrain to knobs and ridges.

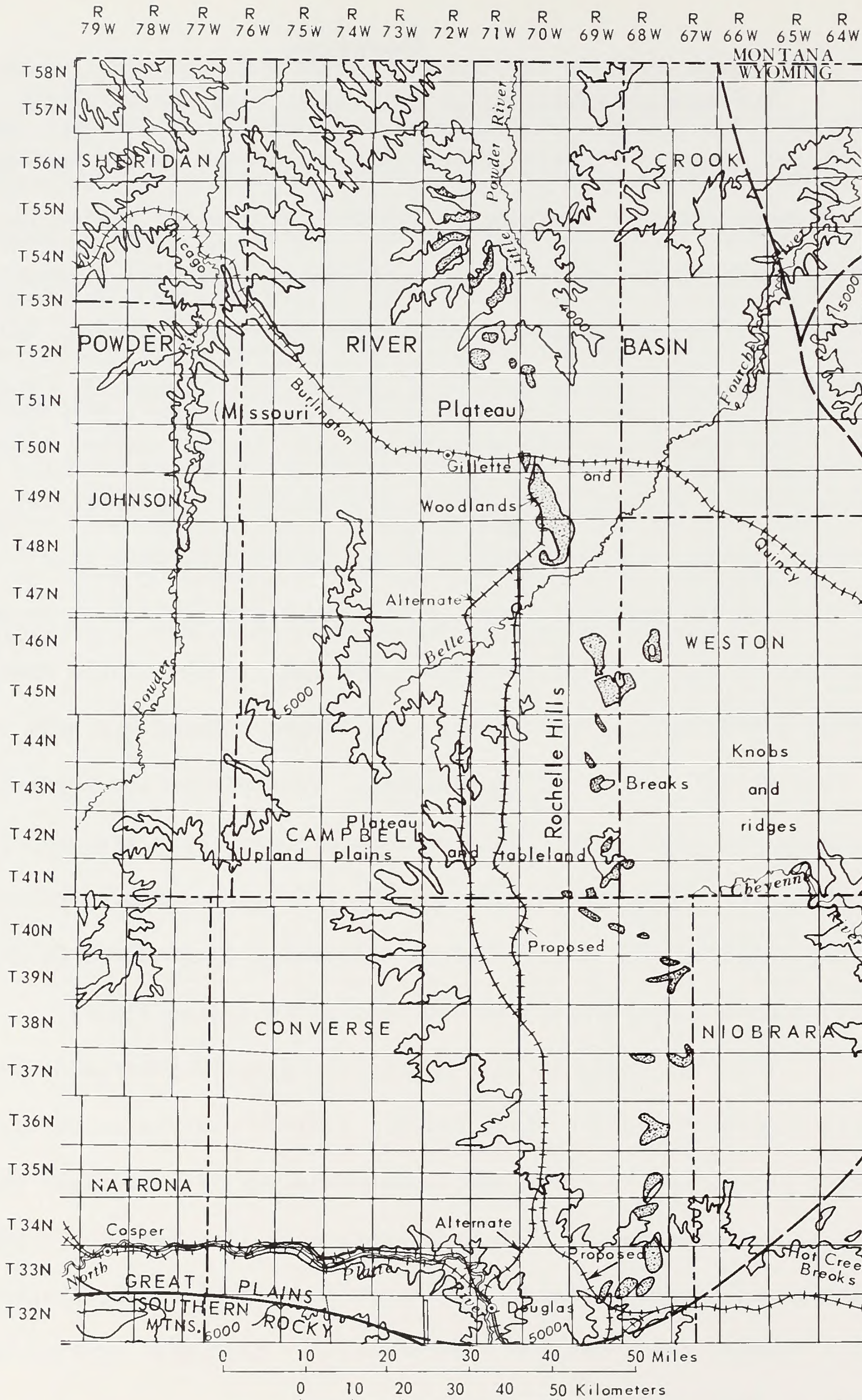


Figure 5

Topography of the Eastern Part of the Powder River Basin

Dark stippled woodland mark the Rochelle Hills, which separate the upland plains from the knobs and ridges.

Geology and climate mainly control the topography or landforms. Flat-lying lenticular beds of clay, silt, and sand easily erode, whereas resistant beds of clinker or natural slag (Figure 6) and massive sandstone form rough hummocky terrain of cliffs, escarpments, ridges and knobs. The rain shadow of high mountains produces low rainfall and a semiarid environment. Local torrential thunderstorms and accompanying sheetwash cause much of the erosion.

The topographic basin is characterized by high open hills north of Gillette and plains and tablelands south of Gillette. The open hill country has a local relief of 400 to 800 feet; less than half of the area is gently sloping. The predominantly gently sloping plains and tablelands have local relief of 200 to 400 feet. Badland topography commonly breaks the steep slopes adjacent to the major drainage. The southern part of the basin is less incised than its eastern border and is characterized by rolling grasscovered prairie having conspicuous erosion escarpments separated and dissected by broad stream valleys.

In the eastern side of the basin the upper part, the Tongue River Member of the Fort Union Formation forms bluffs and rugged dissected hills in contrast to the subdued and rolling topography developed on the underlying Lebo Shale. Topography on the friable sand and interbedded clay of the Eocene Wasatch Formation is more subdued and commonly forms shallow depressions having internal drainage. These small lakes are intermittent; all are shallow and range from small ponds to lakes a mile across. These small basins may be caused by subsidence over a local coal burn and may relate to thin coal. The Wasatch and Fort Union Formations crop out in a north-south belt.

Clinker beds, or natural slag, caused by burning the Wyodak coal in the outcrop, have protected the underlying Fort Union strata and have formed a striking and prominent flat-topped ridge, locally called the Rochelle

Figure 6

Fused Clinker

Hills. This eastward-facing escarpment has sufficient relief to have caused localized climatic effects such as increased wind. The Rochelle escarpment separates a broken and dissected plain on the east from a higher rolling grass-covered plateau on the west. Fort Union beds in the vicinity of the Rochelle Hills are eroded by deep narrow channels into badlands and isolated mesas. Locally the baked clinker along the burnline forms small ridges and hills. In some areas decreased volume because of burnt coal has resulted in slump and faulting of overburden causing hummocky topography. Erosion of the Wasatch strata to the west left a stripped surface or plateau and the prominent, flat-topped Pumpkin Buttes, the most conspicuous features of the basin. The buttes are on a divide that separates the Belle Fourche and Powder River systems. Some higher flat areas such as the Pine Ridge hogback along the west edge of Campbell County and the high-level terraces along the North Platte River, called Top of the World and Highland Flats, also are conspicuous features.

Soils

Soils of the Powder River Basin have developed mostly with short grass vegetative cover common to the semi-arid Great Plains. Due to prevailing climate and vegetative conditions, organic matter is accumulated slowly, and soils have developed with light colored surfaces. Subsoil colors are normally light brown or reddish brown and substratum colors are often influenced by white powdery lime carbonate accumulations caused by low rainfall and insufficient leaching. Soils of the basin are mostly residual (developed in place) formed from weathered sedimentary bedrock, mostly sandstone and shale.

On gently rolling uplands, slightly altered bedrock is usually not more than 36 inches below the surface; on more rolling lands the depth to bedrock is about 20 to 30 inches; and on steep slopes, only a few inches of soil or soil material overlies the partly weathered bedrock. Rock outcrops are common on the steepest slopes.

To a marked degree, developed soils reflect the character of the bedrock. Areas of sandy and medium-textured friable soils are underlain by sandstone and sandy shale, and heavy clay soils are underlain by clayey shale.

The sandy loam and loam soils absorb moisture readily. They have friable or only moderately compact subsoils, and they are thicker than the heavy, or fine-textured soils. Surface layers are well supplied with organic matter and are neutral or only slightly alkaline. Lower subsoils are calcareous and are represented by a lime carbonate accumulation zone at depths of 16 to 30 inches.

The gray, heavy clay shale weathers slowly, and the soils developed from it are shallow. These shallow soils have a medium to fine-textured surface and a dense or compact subsoil. They absorb moisture slowly, and runoff is rapid on the more sloping areas. On steeper slopes, little or no soil development has taken place due to geological erosion. Level areas within the gently undulating or rolling uplands are characterized by a micro-relief of small hummocks and depressions with salty spots. These soils are mostly neutral to slightly alkaline. The horizon of lime enrichment may be weakly developed or absent.

Scoria, reddish-brown "burned" shale beds of clinker in areas where coal seams have burned, gives rise to brown or reddish-brown, medium-textured, shallow, gravelly and rocky soils.

Miscellaneous areas include rough broken land, rockland, gullied land, and shale/rock outcrops occupying lands of steep relief characterized by exposed beds of sandstone, shale, and clinker. A complex soil pattern occurs as residual soils between the dissections. These soils are not classified since geology and forces of nature are the controlling factors of these landscapes.

Alluvial soils are developed from a variety of material washed from the uplands and high landscapes and redeposited along stream courses. They occupy comparatively narrow, elongated, continuous or broken strips along most of the main drainages. The soils have a grayish-brown to dark grayish-brown friable surface that contains a fair amount of organic matter, and they are calcareous at or near the surface. Soluble salts in varying quantities are present in some of these soils.

Management problems associated with soils of the Powder River Basin are strongly related to the climatic and geologic setting. This relationship radiates from soils having relief and physical properties favorable to absorption of nearly all the low precipitation of the area. Although present vegetation is sparse due to the short growing season and distribution of effective moisture, the productive capacity ranges from 200 pounds per acre on rough, broken lands to 3,000 pounds per acre on bottomlands. The wind and water erosion hazard will increase from medium to very high if vegetation is removed and topsoil disturbed. In addition, these soils are easily compacted and highly susceptible to shrinking when dry or swelling when wet. These factors, coupled with low infiltration and permeability rates, will increase the hazard for erosion, reduce revegetation success, increase water runoff and flooding, and limit their suitability for reservoirs and as a source of topsoil, roadbed material and other construction.

Runoff water is generated from slopes having poor vegetative cover since physical properties of the soil will not allow adequate infiltration to store the moisture. This moisture is lost in runoff that carries along unwanted sediment and soluble salts to be deposited in low areas, along streams, or to remain suspended in water systems, thereby lowering the quality of these areas. The most common natural soil problems of the area are (1) clayey textures (having high shrink-swell potentials, low infiltration rates, slow permeabilities and poor plant-soil moisture relationships), (2) high wind and water erosion hazards (due to poor ground cover, interrelated to slope, soil texture, sedimentary parent materials, short growing season and low available soil moisture), and (3) high levels of soluble salts detrimental to plant growth (concentrated due to ponded water from runoff, high evapotranspiration rates, poor leaching related to slow permeability and exposed saline and alkaline shales).

In order to express soil location within the basin, a soil association map was prepared from existing USDA Soil Conservation Service Generalized County Soils Maps. The original maps were prepared over a period of several years by different personnel using soil classification systems of the Great Soil Groups (1938), 7th approximation (1964) and New Soil Taxonomy (1971).

The compiled Soil Association Map of the Powder River Basin was correlated using existing information dating back to 1953 and yet interpreted according to modern classification concepts. This identifies an element of questionable accuracy in the basic soil association map.

The nature of soil associations is basically a grouping of soils similar to each other according to pattern and position and not on the basis of capability or expected response. Soil associations are named according to the dominant soils occurring within the delineations. For example, an association may contain ten known soil series but only the three major soils represent the unit. Consequently, minor soils which may be significant to management are not considered in the map unit description or in the interpretative evaluations. Quantitative evaluations of the map units are impossible since major series may differ widely in characteristics. Individual evaluations of the component major soil series have limited value since the percent composition within the unit is unknown.

Table 8, Soil Interpretations for Regional Soil Associations, provides the physical, chemical and management interpretations for the soil series included in each soil association. Tables 10 through 28 of Appendix C, Soil Series Descriptions, provide the estimated physical, chemical and behavior characteristics. Map 7, Appendix A shows soil associations of the study area.

Soil Association descriptions

Bankard-Haverson-Kim-Riverwash Association (no.1)

This unit occurs as nearly level, well drained to moderately deep soils on flood plains and alluvial fans. Soils in this association developed in alluvium along sandy shifting bottomlands along rivers and major streams. They may occupy undulating fans, terraces, and bottom lands.

Table 8

Soil Interpretations for Regional Soil Association Map I Powder River Basin

Soil Series / Assoc. Occurrence	Classification	Typical Text. of Surface Layer	Parent Material	Natural Soil Drainage Class	Depth of Rooting Zone (in)	Available Water Capacity (in)	Permeability Least Perm. layer (in/hr)	Potential Frost Action	Shrink-Swell Potential	Hydrologic Soil Group	Erodibility	Inherent Fertility	Potential 1/ Production (#/ac, dry wt)	Degrees of Limitation for and Soil Features Affecting: Irrigation	Dwellings	Final Cover for Mined Land: Inches Available	Final Cover for Mined Land: Suitability	Transportation Routes	Depth of Surface Layer (Inches)	Soil Reaction (pH)	Salinity (mmhos/cm)
Arvada 14, 19	Ustollic Natrargid fine, montmorillonitic, mesic	Fine sandy loam	Alluvuim	Well drained	60"	5-6"	< 0.06	Low	High	D	Very high	Low	250-650	Severe, all slopes, excess alkali, slow permeability	Severe, all slopes. high shrink-swell	0-5"	Poor, clay content alkali	Severe, high shrink-swell, low strength	3-6"	7.4->9.0	< 2-8
Bankard 1,	Ustic Torrifluvent sandy, mixed calcareous mesic	Loamy fine sand	Sandy Alluvium	Somewhat excessively drained	60"	3-4"	6.0 - 20.0	Moderate	Low	A	Very high wind erosion	Low	1,400-2,500	Severe, rapid permeability, low available water capacity	Severe, occasional flooding	4-8"	Fair, sandy	Moderate, occasional flooding, moderate frost action	3-8"	7.9-8.4	2-8
Bone 14,	Ustic Torriorthent fine, montmorillonitic, (calcareous) mesic	Loam	Alluvium	Moderately well drained	60"	4-5"	< 0.06"	Moderate to high	High	D	Very high	Low	450-1200	Severe, excess alkali, slow permeability	Severe, high shrink-swell, clay content	0	Poor, high clay content alkali	Severe, clay texture, high shrink-swell	<1"	9.2-9.6	2-8
Briggsdale 11, 14, 15, 16	Ustollic Paleargid fine, montmorillonitic, mesic	Loam	Interbedded sandstone & shale	Well drained	30"	4-6"	0.2 - 0.6	High	Moderate	C	High	Medium	850-1500	Severe, slow permeability	Severe, high frost action	10-20"	Fair-clay content	Severe, high frost action texture, plastic	3-8"	6.6-8.8	<2
Cushman 6, 9,	Ustollic Haplargid fine-loamy, mixed mesic	Sandy loam	Interbedded shale & sandstone	Well drained	30"	5-7"	0.2 - 0.6"	Low	Moderate	C	High	Medium	750-1800	Moderate, permeability rooting depth	Moderate low strength, shrink-swell	6-10"	Fair to good	Moderate low strength	1-3"	7.9-8.4	0-4
Dwyer 17, 18, 21,	Ustic Torripsamments mixed, mesic	Fine sand	Aeolian sand	Excessively drained	60"	3-4"	6.0 - 20.0"	Low	Low	A	Very high wind erosion	Low	1,000-2,100	Severe, rapid permeability	Slight for 3-8% slopes moderate 8-15% slopes	4-10"	Fair-sandy	Slight-slopes <8%, Moderate-8-15% slopes	4-8"	7.9-8.4	0-4
Haverson 1,	Ustic Torrifluvent fine-loamy mixed (calcareous) mesic	Loam	Stratified alluvium	Well drained	60"	6-10"	0.6 - 2.0"	Low	Low	B	High wind if cultivated Low water erosion	Medium	850-2000	Slight	Severe, subject to flooding	3-6"	Good	Moderate flooding, low strength	3-6"	7.9-8.4	0-4
Kim 1, 13, 20	Ustic Torriorthent fine-loamy, mixed (calcareous) mesic	Loam	Alluvium	Well drained	60"	10-12"	0.6 - 2.0"	Low	Low	B	High	Medium	850-2000	Slight to moderate	Moderate-slopes <15% low strength, severe slopes >15%	6-12"	Good	Moderate, slopes <8%, severe, slopes >8%	6-9"	7.9-8.4	0-4
Maysdorf 3, 14	Ustollic Haplargid fine-loamy, mixed	Sandy Loam	Alluvial	Well drained	60"	7-9"	0.6 - 2.0"	Moderate	Low to moderate	B	Medium	Medium	850-1500	Moderate, permeability	Moderate, frost action	30-40"	Fair	Moderate, moderate frost action	4-6"	6.6-8.4	<2
Mitchell 17,	Ustic Torriorthent coarse-silty, mixed (calcareous) mesic	Silt loam	Alluvium and loess	Well drained	60"	10-10"	0.6 - 2.0"	Low	Low	B	High	Medium	1400	Slight	Slight	5-10"	Fair, lime content	Slight	1-4"	8.0-8.5	
Olney 20	Ustollic Haplargids fine loamy, mixed mesic	Loam	Alluvial sediments from interbedded shale and sandstone	Well drained	60"	6-9"	0.6 - 2.0"	High	Low to moderate	B	Medium	Medium to high	1500-3000	Slight	Severe, frost action	15-20"	Fair	Severe, frost action	4-6"	7.0-8.4	<2-4
Otero 20	Ustic Torriorthent coarse-loamy mixed (calcareous) mesic	Sandy loam	Aeolian & alluvial sand	Well drained	60"	6-8"	2.0 - 6.0"	Low	Low	B	High wind erosion	Low	1000-2100	Slight	Slight-<8% slopes Moderate-8-15% slopes Severe->15% slopes	4-8"	Fair, sandy loam	Slight-<8% slopes Moderate-8-15% slopes Severe-slopes >15%	4-8"	7.9-8.4	0-4
Pugsley 15,	Ustollic Haplargid, fine-loamy mixed mesic	Sandy loam	Sandstone	Well drained	24"	2-4"	2.0 - 6.0"	Moderate	Low to moderate	B	Medium	Medium	850-1500	Moderate, bedrock at 20-40"	Moderate, to severe bedrock at 20-40"	20-40"	Fair	Moderate, bedrock at 20-40"	4-8"	6.6-7.3	<2
Rauzi 19	Ustollic Haplargid, fine-loamy mixed mesic	Sandy loam	Alluvial sediments from interbedded shale and sandstone	Well drained	60"	7-9"	0.6 - 2.0"	Moderate	Low to moderate	B	Medium	Medium	850-1500	Moderate, permeability	Moderate, frost action	60"	Fair	Moderate frost action	4-6"	6.6-7.0	<2
Razor 2,	Ustollic Camborthid, fine, montmorillonitic, mesic	Silty clay loam	Shale	Well drained	24"	3-4"	.06 - 0.2"	Moderate	High	C	High	Low	750-1500	Severe, slow permeability	Severe, high shrink-swell	10-20"	Poor, clay content	Severe, high shrink-swell potential	2-4"	8.2-8.6	2-4
Recluse 19	Ustollic Haplargids fine montmorillonitic mesic	Loam	Sandstone and shale	Well drained	30"	5-6"	0.06-0.2"	High	High	C	High	Medium	750-1800	Moderate, due to permeability	Severe, high shrink-swell	15-30"	Fair, clay content	Severe, high shrink-swell potential	3-6"	6.8-8.6	0-4
Renohill 3, 5, 6, 8, 9, 10 11, 15, 16	Ustollic Haplargids fine montmorillonitic mesic	Clay loam	Shale	Well drained	30"	5-6"	0.06-0.2"	High	High	C	High	Medium	750-1800	Moderate, permeability	Severe, high shrink-swell	10-20"	Fair, clay content	Severe, high shrink-swell potential	3-6"	7.0-8.6	<2

1/ Low figure for unfavorable years, high figure for favorable years, normal years are average of high and low.

Soil Series / Assoc. Occurrence	Classification	Typical Text of Surface Layer	Parent Material	Natural Soil Drainage Class	Depth of Rooting Zone (In)	Available Water Capacity (In)	Permeability Least Perm. layer(in/hr)	Potential Frost Action	Shrink-Swell Potential	Hydrologic Soil Group	Erodibility	Inherent Fertility	Potential 1/ Production (#/ac. dry wet)	Degrees of Limitation for and Soil Features Affecting: Irrigation	Dwellings	Final Cover for Mined Land: Inches Available	Final Cover for Mined Land: Suitability	Transportation Routes	Depth of Surface Layer (Inches)	Soil Reaction (pH)	Salinity (mmhos/cm)
Shingle 2, 5, 8, 10, 13, 17, 20,	Ustic Torriorthents loamy, mixed (calcareous) mesic, shallow	Clay loam	Interbedded sandstone, shale and loamstona	Well drained	15"	2-3"	0.2 - 0.6"	Low	Moderate	C	Very high	Low	450-1200	Severe, shallow to bedrock	Severe, shallow to bedrock	3-6"	Poor, clay content	Severe-4-15% slopes, low strength, Severe, 15-50% slopes, low strength and slope	3-6"	7.9-9.0	0-4
Tassel 8, 16, 17, 18, 20	Ustic Torriorthent loamy, mixed (calcareous) mesic, shallow	Fine sandy loam	Soft sandstone	Well drained	15"	1-2"	2.0 - 6.0"	Low	Low	D	Very high erosion	Low	600-1400	Severe, shallow to bedrock	Severe, shallow to bedrock	3-6"	Fair	Severe, Bedrock at 10-20 inches	3-9"	7.9-8.4	0-4
Terry 5, 10, 12, 18, 20,	Ustollic Haplargid coarse-loamy, mixed, mesic	Fine sandy loam	Soft sandstone	Well drained	36"	4-5"	2.0 - 6.0"	Moderate	Low	C	High wind erosion	Low	1000-2000	Moderate, limited rooting depth	Moderate to severe, slope, bedrock at 20-40"	10-20"	Fair	Moderate, bedrock at 20-40"	4-6"	6.8-8.6	<2
Trelona 17.	Torriorthentic Haplustoll, loamy, mixed, mesic shallow	Fine sandy loam	Soft sandstone	Well drained	15"	1-2"	2.0 - 6.0"	Low	Low	B	Very high wind erosion	Low	1200	Severe, Steep slope & shallow to bedrock	Moderate-10-15% slopes Severe->15% slopes	15"	Fair-sandy, shallow	Moderate-10-15% slopes Severe-15% slopes	3-9"	6.8-7.5	<2
Ulm 3, 11, 14, 15, 16	Ustollic Haplargids fine, montmorillonitic, mesic	Loam	Interbedded shale & sandstone	Well drained	60"	10-12"	0.6 - 2.0"	High	Moderate to high	B	High	Medium	850-1500	Moderate, slow permeability	Severe, high frost action potential	15-30"	Fair clay content	Severe, high frost action potential	3-6"	6.6-8.6	<2
Valent 21	Ustic Torripsamments mixed, mesic	Loamy sand	Aeolian sand	Excessively drained	60"	3-5"	6.0 - 20.0"	Low	Low	A	Very high wind erosion	Low	1000-2100	Severe, droughty soils	Slight-<8% slopes Moderate-8-15% slopes Severe->15% slopes	40-60"	Poor	Slight-<8% slopes Moderate-8-15% slopes Severe->15% slopes	3-5"	7.9-8.4	0-4
Wibaux 7, 8	Ustic Torriorthent loamy-skeletal over fragmental, mixed, nonacid, mesic	Channery loam	Channery material over scoria beds	Well to somewhat excessively drained	15"	2-3"	0.6 - 2.0"	Low	Low	D	High	Low	450-1200	Severe, shallow to bedrock	Severe, shallow to bedrock	<15"	Poor, very gravelly	Severe, bedrock at 10-20", steep slopes	2-4"	7.8-8.6	<2
Wyarno 6,	Ustollic Haplargid, fine, montmorillonitic, mesic	Clay loam	Alluvium from shales	Well drained	60"	10-12"	0.2 - 0.6"	Moderate	High	B	Medium	Medium	750-1800	Moderate, due to permeability	Severe, high shrink-swell potential	6-15"	Fair, Clay content	Severe, high shrink-swell potential	3-7"	6.8-8.6	<2

1/ Low figure for unfavorable years, high figure for favorable years, normal years are average of high and low.

Definitions applicable to the columns of the Soil Interpretations for Regional Soil Association Map

Soil Series name and the distribution of the soil series within the different soil associations of the Powder River Basin study area.

Classification given is according to Soil Taxonomy for each series.

Typical texture of the surface refers to the relative proportions of the various size groups of individual soil grain, i.e. sands, silt, and clay.

Parent Material is the assumed geologic material the soil developed from.

Natural Soil Drainage Class is an expression of surface soil-moisture relationships.

Depth of Rooting Zone is an indicator of the thickness plant roots can penetrate.

Available Water Capacity refers to the potential amount of water a soil can hold for plant use.

Permeability least Permeable layer is the rate at which water and air may move through the soil.

Potential Frost Action refers to the probable effects on structures results from the freezing of soil material.

Shrink-Swell Potential refers to the quality of a soil that determines its volume change resulting from wetting and drying.

Hydrologic Soil Groups are ranking of soils from A to D referring to runoff potential ranging from A, having the lowest rates to D with the highest rates.

Erodibility Class - The susceptibility of a soil to erosion when no cover is present. Rate of soil displacement is influenced primarily by soil qualities, physical properties, rainfall intensity, and slope gradient. Considered was each of six items listed within each of the three classes when classifying the area. Classes and rating items are as follows:

Class

Low
- Potential erosion is not significant to reduce productivity
- They contain water stable aggregates;
- They have good infiltration and percolation rates;
- They have adequate depth to store most of the normal precipitation;
- They contain no restrictive layers;
- They occur on gentle slopes.

Medium
- Potential erosion is significant to reduce productivity but not to the point of entirely restricting production;
- They contain aggregates that are not water stable;
- They have moderate infiltration and percolation rates;
- They have moderate depths to store only part of the normal precipitation (AWC);
- They may contain restrictive layers;
- They occur on moderate slopes.

High
- Potential erosion will cause a reduction in productivity to practically zero;
- They contain very unstable aggregates;
- They have slow infiltration and percolation rates;
- They have little soil for water storage;
- They contain restrictive layers;
- They occur on steep slopes.

Where wind erosion is a hazard, it is mentioned specifically.

Inherent fertility - the following criteria were used for rating the soils:

Low — Soils low in available P or K, or with pH below 5.0 in the A and upper B horizons, or soils having levels of alkalinity or salinity such that choice of plants or growth of plants is severely limited.

Medium — Soils intermediate between low and high in inherent fertility.

High — Soils high in available P and K, with pH of 5.5 or more in A and upper B horizons, levels of salinity or alkalinity are sufficiently low that choices or growth of plants are not limited.

The degrees of limitation for Irrigation, Dwellings, and Transportation Routes are listed as slight, moderate or severe and give restrictive features if degree of limitation is other than slight. The definition of limitations are listed below.

Definition of Limitations

Slight soil limitation is the rating given soils that have properties favorable for the rated use. The degree of limitation is minor and can be overcome easily. Good performance and low maintenance can be expected.

Moderate soil limitation is the rating given soils that have properties moderately favorable for the rated use. This degree of limitation can be overcome or modified by special planning, design or maintenance. Some soils rated moderate require treatment such as artificial drainage, runoff control to reduce erosion, extended sewage absorption fields, extra excavation or some modification of certain features through manipulation of the soil.

Severe soil limitation is the rating given soils that have one or more properties unfavorable for the rated use such as steep slopes, bedrock near the surface, high shrink-swell potential, a seasonal high water table, flooding hazard or low bearing strength. This degree of limitation generally requires major soil reclamation, special design or intensive maintenance. Some of these soils, however, can be improved by reducing or removing the soil feature that limits use, but in most situations, it is difficult and costly to alter the soil or to design a structure so as to compensate for a severe degree of limitation.

Depth of surface layer (inches) refers to depth of darker colored A horizon in inches.

Soil reaction (pH) The degree of acidity or alkalinity of a soil expressed as a pH value. Descriptive terms commonly associated with certain ranges in pH are: slightly acid, 6.1-6.5; neutral, 6.6-7.3; slightly alkaline, 7.4-7.8; moderately alkaline 7.9-8.4; strongly alkaline, 8.5-9.0; and very strongly alkaline, 9.1.

Salinity(mmhos/cm) refers to the soluble salts in a soil, based on the electrical conductivity of the saturation extract, as expressed in millimhos per centimeter (mmhos/cm) at 25 C.

Salinity Rating	mmhos/cm
Low	4
Moderate	4-8
High	8

Table 8 (Cont'd)
Soil Interpretations for Regional Soil Association Map 1 Powder River Basin

Table 8 (Cont'd)

The Bankard series is on the flood plains, fans, and level terraces; Haverson soils are situated on the bottom lands; and Kim soils are found on alluvial fans below upland areas.

The soils of this association are moderately alkaline and subject to flooding during spring and early summer. They are highly susceptible to wind erosion. The acreage of this soil association is estimated to be 184,134 acres.

Razor-Shingle Association (No. 2)

This unit includes very shallow to moderately deep, well drained, loamy, sandy and clayey soils from sandstone and shale on sloping to steep uplands.

This association consists primarily of shallow soils and bedrock exposures on steeply sloping badlands bordering the larger streams and in areas where the bedrock has been uplifted. Razor and Shingle soils are found on steep slopes with shale and sandstone bedrock at less than 20 inches. These soils produce very little vegetation. Revegetation opportunities are very poor and the soils are highly erodible. The acreage of this soil association is estimated to be 351,228 acres.

Renohill-Maysdorf-Ulm Association (No. 3)

This unit represents shallow to deep, well drained, loamy, sandy and clayey soils on level to nearly level alluvial fans and sloping to steep uplands.

This association consists of shallow soils interspersed with deep, moderately coarse textured soils. Renohill soils occur on ridgetops and ridgecrests; Ulm soils are situated on nearly level upland fans and terraces; and Maysdorf soils are found on moderately sloping upland hills and valley sideslopes.

Soils of this association are highly erodible. Productivity potential is considered moderate. The acreage of this soil association is estimated to be 378,745 acres.

Unnamed Association (No. 4)

These soils are known to be deep to shallow, well drained, loam and clay loams on gently sloping alluvial fans and sloping to moderately steep uplands.

Soil series names have not been identified for these soils; however, the following information can be assumed from their classification. These soils are considered to be mostly medium-textured, including textural families of fine-loamy and fine. Depth is variable, ranging from less than 20 inches to greater than 40 inches over bedrock. The clay fraction of the fine family has montmorillonitic minerology. The representative soils of this unit range from (1) Ustollic Paleargids, fine, montmorillonitic, mesic indicating relict soils on the oldest stable erosion surfaces with fine textured B horizons having abrupt upper boundaries, (2) Ustollic Haplargids, fine-loamy, mixed, mesic, shallow, medium-textured soils, less than 20 inches to soft bedrock with normal alluvial B horizons having simple morphology, and (3) Ustic Torriorthents, fine-loamy, mixed calcareous, mesic representing recent soils on erosional surfaces either alluvial or eolian; they are calcareous with little pedogentic development. Productivity is assumed to be low to moderate; erodibility is high. The estimated acreage of this soil association is 250,382 acres.

Renohill-Terry-Shingle Association (No. 5)

The soils are moderately deep and shallow, well drained, fine sandy loam, loam and clay loams on moderately steep to steep uplands, ridges, and sidehills.

Renohill soils are moderately deep, fine-textured soils on ridgetops and underlain by shale, Terry soils are moderately coarse-textured soils occurring on side slopes and underlain by sandstone. Shingle soils occur on steep upland ridges, usually dissected with numerous drainages and underlain with shale.

These soils are highly erodible and have low productivity potentials. The estimated acreage of the association is 280,102 acres.

Renohill-Wyarno-Cushman Association (No. 6)

These soils are deep and moderately deep, well drained loam and clay loams on nearly level to sloping alluvial fans and gently sloping to moderately steep uplands. They overlie interbedded sandstones, shales, and siltstone.

Renohill soils are moderately deep, fine-textured, and occur on ridgetops and ridgecrests; Wyarno soils are deep, well drained, and formed in alluvium; and Cushman soils occupy moderately steep upland positions underlain by soft sandstone at depths of 30 inches. Productivity potential is considered to be moderate, and erodibility is high. The acreage estimated is 259,441 acres for the association.

Wibaux Association (No. 7)

This unit includes shallow and moderately deep, well drained sandy loam, clay loam and channery loam soils on sloping to steep uplands and rough broken land with shallow, sandy to medium-textured soils. This association occupies rolling to steep topography. It is characterized by numerous outcrops of scoria and scoria chips in the profile. Thirty to sixty percent of the surface has large scoria clinkers. These soils are highly erodible and the productivity potential is low. The estimated acreage of this association is 220,274 acres.

Renohill-Wibaux-Tassel-Shingle-Rockland Association (No. 8)

This unit includes deep and moderately deep, well drained, sandy loam, clay loam and channery loam soils on sloping to steep uplands and rough broken land with shallow, sandy to medium-textured soils.

The Renohill soils are moderately deep, fine textured, and occur on ridgetops and ridgecrests; Wibaux soils are shallow and moderately deep, well drained, medium textured and gravelly, occurring on sloping to steep uplands; and Tassel and Shingle soils are shallow to moderately deep sandy soils on rolling to steeply rolling slopes. Rockland within the unit consists of miscellaneous soil materials that are sandy to clayey on steep broken slopes with exposed bedrock.

These soils are moderately to highly erodible with productivity potentials low to moderate. Acreage estimates for this association are 145,124 acres.

Cushman-Renohill Association (No. 9)

This unit includes moderately deep, well drained, loam and clay loam soils on nearly level to moderately steep uplands. The Cushman soils are moderately deep soils on nearly level to gently sloping upland plains while Renohill soils are situated on ridges and side slopes. Productivity potential and erodibility are considered moderate. The estimated acreage of the association is 275,548 acres.

Renohill-Shingle-Terry Association (No. 10)

This association occupies the steep to very steep upland ridges and sidehills which are usually dissected with numerous drainages. The Renohill soils are moderately deep and fine textured and occur on ridgetops and ridgecrests. The Shingle and Terry soils are shallow and medium-textured soils of steeply sloping sidehills. Productivity potential is low and erodibility is high. The estimated acreage of this association is 148,224 acres.

Briggsdale-Ulm-Renohill Association (No. 11)

This unit is represented by deep and moderately deep, well drained loam and clay loam soils on nearly level to sloping alluvial fans and nearly level to moderately steep uplands.

The Briggsdale and Renohill soils occur on nearly level to moderately steep uplands underlain by soft shale at depths of about 20 inches. The Ulm soils are situated on nearly level upland fans and terraces which are subject to short periods of overflow in the spring and summer. These soils have fine textured subsoils which exhibit moderate to high shrink-swell potentials. The productivity potential and erodibility of these units are considered moderate. The acreage estimate of the association is 591,737 acres.

Terry Association (No. 12)

This unit includes deep to shallow, well to excessively drained, loamy fine sand, sandy loam and fine sandy loam soils on nearly level to moderately steep uplands underlain with sandstone. These soils are moderately to highly erodible and have low productivity potentials. The acreage estimate for this association is 37,239 acres.

Shingle-Kim-Shale-Rock Outcrops Association (No. 13)

This unit consists of a narrow band of rolling, gullied uplands on shale-sandstone foothills and stream terraces. Shingle soils are shallow and located on the steeper slopes. Kim soils are on alluvial fans. Vegetative production is poor. A moderate to severe erosion hazard exists. The estimated acreage of the association is 240,425 acres.

Arvada-Bone-Briggsdale Association (No. 14)

This unit consists of deep and moderately deep, medium to fine textured soils on level to gentle slopes developed in alluvium derived from alkaline shales. Arvada and Bone soils are strongly saline, impervious to water, and occur as alkali panspots. Briggsdale soils are fine textured and underlain by soft shale at a depth of about 20 inches. The productivity potential is low and erodibility is high. The estimated acreage is 171,557 acres.

Renohill-Pugsley-Briggsdale Association (No. 15)

This unit includes moderately deep, nearly level to steep soils on uplands, upland ridges, ridgecrests and sidehill slopes. The Renohill and Briggsdale are derived from shale; Pugsley soils form from sandstone. These soils are highly erodible and have low to moderate productivity potentials. The estimated acreage of the association is 70,246 acres.

Renohill-Briggsdale-Ulm-Tassel Association (No. 16)

This unit includes shallow and moderately deep silty clays, loams and clay loams on gently sloping to very steep slopes.

The Renohill, Briggsdale, and Tassel soils are situated on moderately steep to steep uplands. Ulm soils are found on nearly level to sloping alluvial fans. The Briggsdale and Ulm soils exhibit moderate to high shrink-swell potentials. The Ulm soils are subject to short periods of overflow. The productivity potential is low to moderate and erodibility is high. This association contains an estimated 138,500 acres.

Shingle-Tassel-Dwyer-Mitchell-Trelona Association (No. 17)

This unit consists of shallow to moderately deep sandy soils on rolling to steeply rolling slopes, including upland ridges and sidehills dissected by numerous drainages.

The Shingle, Tassel, Mitchell, and Trelona soils are generally less than 20 inches deep over sandstone and shale bedrock. Hummocks and dune topography is associated with the deep sandy Dwyer soils. This unit is subject to severe wind erosion hazards and moderately erodible by water. The productivity potential is low to moderate. The acreage estimate for the association is 74,712 acres.

Rauzi-Recluse-Arvada Association (No. 19)

These are shallow, moderately deep and deep fine loamy and fine soils on rolling, steep slopes over interbedded sandstone and shale.

This association of soils occurs on moderately sloping hills, ridges, and alluvial fans underlain by soft shale at shallow depths. The Rauzi soils are deep and medium textured formed from sandstone and shale; Recluse soils are deep and fine textured developing in interbedded sandstone and shale; and Arvada soils are saline and alkali developing on alluvial deposits. The erosion hazard is severe and the productivity potential is low. The estimated acreage of this association is 307,800 acres.

Tassel-Shingle-Terry-Olney-Kim Association (No. 20)

This unit consists of shallow, moderately deep and deep, moderately sandy soils developed from sandstone and shale occupying rolling to steep topography with gentle to steep slopes dissected by many small drainages. The Tassel, Shingle, and Terry soils are shallow and occur on the steeply sloping uplands. The Olney and Kim soils occur on side and foot slopes. The productivity potential is moderate. These soils are subject to severe wind erosion and moderate water erosion. The estimated acreage of the association is 444,450 acres.

Valen-Dwyer-Duneland Association (No. 21)

This association occurs on undulating to rolling, hummocky dune topography and is made up of deep aeolian sands and some active dunes. The soils are excessively drained, deep, loose sands. Wind erosion is severe and water erosion is moderate. Productivity potential is moderate. The estimated acreage of this association is 98,912 acres.

Mineral Resources

Campbell and Converse Counties in the Powder River Basin of Wyoming contain tremendous resources of the important energy producing minerals--coal, oil, gas, and uranium. Thick coalbeds amenable to surface mining are interbedded with almost flat-lying, relatively soft and easily removed shale, siltstone, and sandstone (Figure 7). Coals that have been analyzed are low in both sulfur and ash and contain no abnormally high contents of toxic trace elements. The Powder River Basin in Wyoming contains an estimated 610 billion tons of coal under less than 3,000 feet of overburden. Of that total, about 12.35 billion tons of coal are economically recoverable by present day surface mining methods to a depth of about 200 feet. Additional coal can be produced through mining by underground methods and, in the future, if proper economic conditions exist, additional coal may be produced by surface mining to depths more than 200 feet. Oil and gas have been produced from about 210 fields within the study area. The main producing zones are at depths generally between 5,000 and 10,000 feet. The shallow depths and a high percentage discovery rate make the area attractive to drilling investors. Remaining recoverable reserves of the 210 fields are conservatively estimated at 221 million barrels of oil and 508 billion cubic feet of natural gas. Uranium resources occur in sandstone beds mainly in the southern part of the basin. Ore reserves of about 40,000 tons of U_3O_8 have been estimated. The following tabulation shows the potentially recoverable energy resource in the two counties. The occurrences are described in the discussions of individual minerals on subsequent pages.

Figure 7

Coal, About 37 Feet Thick, Overburden of Shale and Sandstone, and Spoil Piles at Active Surface Mine

Energy Source	Recoverable Reserve	Btu Equivalent
Coal	12.35 billion tons	$212,420 \times 10^{12}$
Oil	221 million barrels	$1,282 \times 10^{12}$
Gas	508 billion cubic feet	52.5×10^{12}
Uranium (U_3O_8)	40,000 tons	*

*Yield in Btu is dependent upon the thermal efficiency and load factors of reactor systems. For nuclear plants 1 kw hr is equivalent to 10,582 Btu fossil fuel input.

Geologic setting

Broad, flat-floored intermontane basins separated by prominent mountain ranges characterize Wyoming. The largest intermontane basin in Wyoming is the Powder River Basin, a structural and topographic depression about 250 miles long and more than 100 miles wide. The basin lies between the Bighorn Uplift and Casper Arch to the west and the Black Hills Uplift to the east (Figure 8). The basin is bounded on the south by the Laramie Uplift and the Hartville Uplift and on the north by the Miles City Arch, the Porcupine Dome, and the low arch within the Asland syncline (Howard, Williams, and Raisz 1972).

The Powder River Basin contains a rock sequence ranging in age from Precambrian to Recent. The generalized nomenclature, thickness, and lithologic descriptions of the sedimentary succession are shown in Table 9 and Figure 9. Many reports that describe the geology of the basin in detail are listed in the bibliography. The Precambrian igneous and metamorphic rock complex is exposed in the cores of the surrounding mountain ranges; progressively younger sedimentary rocks thicken toward the center of the basin away from these mountainous areas. Bedrock exposed in Campbell and Converse Counties, Wyoming, north of the North Platte River is late Cretaceous and Tertiary in age (Figure 10). The

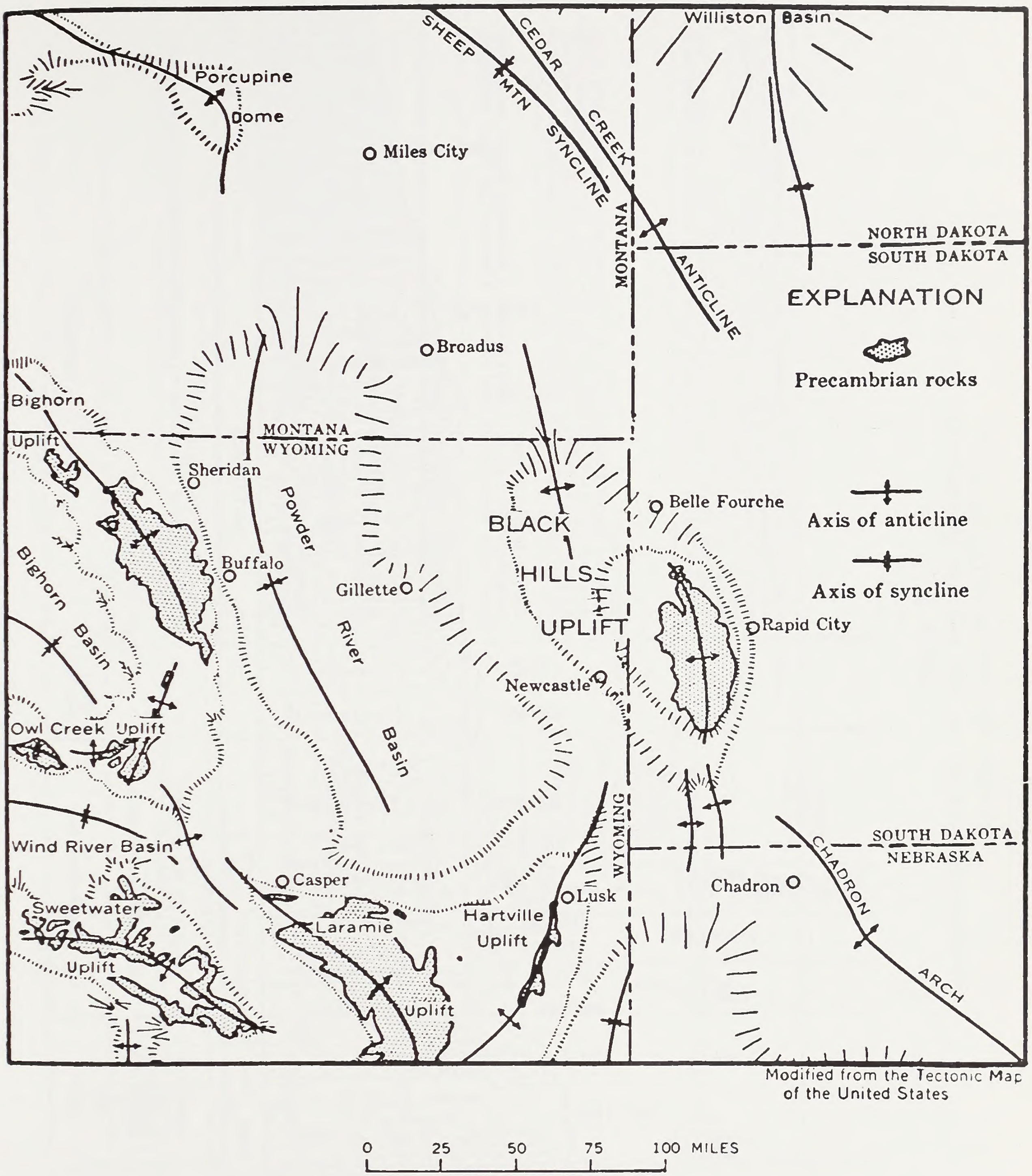


Figure 8
Generalized Map Showing the Powder River Basin
in Relation to Nearby Structural Features

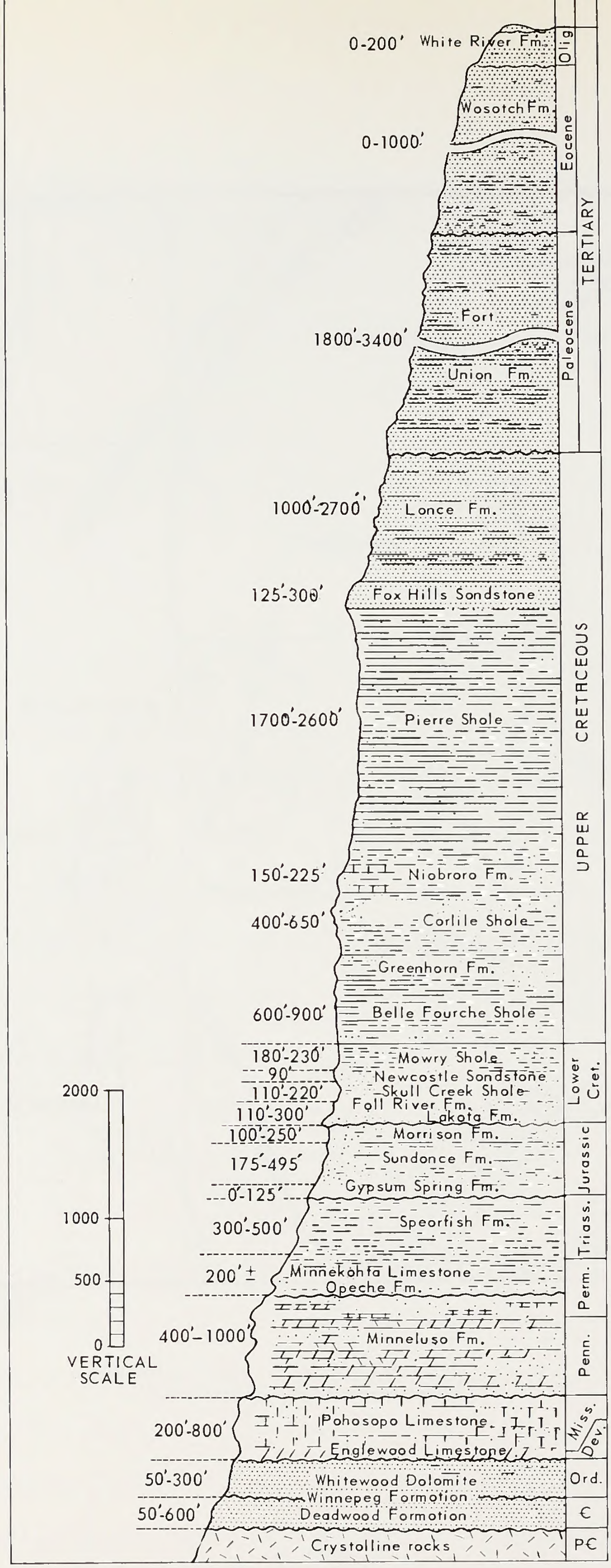


Figure 9
Vertical Section Showing Rock Sequence in the Eastern Powder River Basin

System	Series	Stratigraphic unit	Thickness (feet)	Description
Quaternary	Recent and Pleistocene	Alluvium and stream terraces		Silt, sand, and gravel.
		—Unconformity—		
Tertiary	Oligocene	White River formation	0 - 200	Light-gray medium- to coarse-grained sandstone at base overlain by light brownish-gray claystone and siltstone.
		—Unconformity—		
	Eocene	Wasatch formation	0 - 1000	Grayish-yellow sandstones and gray shale, numerous coal beds.
	Paleocene	Fort Union formation: Tongue River member	600 - 1200	Yellowish-gray massive sandstone and light-gray shale; numerous coal beds: thickest in Montana; thins southward.
		Fort Union formation: Lebo shale member	250 - 900	Medium- to dark-gray shale, light-gray sandstone, and a few thin coal beds.
		Fort Union formation: Tullock member	950 - 1300	Light-gray and light brown sandstone, gray shale, and numerous thin coal beds: thinnest in Montana; thickens southward.
		Lance formation	1000 - 2700	Gray to yellowish-gray sandstone and gray shale; a few thin beds of carbonaceous shale; thinnest in Montana; thickens southward.
		Montana group: Fox Hills sandstone: Colgate member, 50-100 ft.	125- 300	Brown sandy shale and siltstone, light-gray sandstone, and brown ferruginous sandstone concretions; the Colgate member, a prominent massive white sandstone, at top in Montana.
		Montana group: Pierre shale: Upper part: Kara bentonitic member, 100±ft.; Monument Hill bentonitic member, 150-220 ft.	400 - 800	Dark-gray shale and claystone; locally beds of siltstone; abundant limestone concretions some fossiliferous in upper and lower parts: thickens southward from Montana. Kara and Monument Hill bentonitic members, gray bentonitic shale and impure bentonite with a few limestone concretions and small barite concretions.
		Montana group: Pierre shale: Mitten black shale member.	145-1,000	Dark-gray to black shale with beds of yellowish-gray bentonite at base and numerous large yellowish-brown-weathering fossiliferous septarian limestone concretions in upper part; thickens southward from Montana.
		Montana group: Pierre shale: Gammon ferruginous member: Groat sandstone bed, 0-125 ft.	0-1,000	Light-gray claystone and shale with abundant reddish-brown iron-stained concretions and thin lenses of siderite. Groat sandstone bed, mapped north of T. 55 N., consists of gray fine-grained glauconitic and ferruginous sandstone.

Table 9
Generalized Section of the Exposed Sedimentary Rock in the Eastern Powder River Coal Basin

Table 9 (Cont'd)

Generalized Section of the Exposed Sedimentary Rock in the Eastern Powder River Coal Basin

System	Series	Group	Formation	Member	Thickness (feet)	Description
Cretaceous	Upper Cretaceous	Colorado group	Niobrara formation		150– 225	Chalk marl and calcareous shale; numerous thin beds of bentonite, dark gray when fresh, weathers light yellow.
			Carlile shale	Sage Breaks member	200– 300	Grayish-black noncalcareous shale with numerous beds of septarian limestone concretions that weather light gray.
				Turner sandy member	150– 260	Dark-gray shale, locally sandy and silty, with numerous beds of light-yellow and red silty limestone concretions; commonly a thin bed of light-gray medium-grained sandstone at the base.
				Lower unnamed number	40– 130	Dark-gray shale with a few limestone concretions; locally slightly silty and sandy; thickest in Montana.
			Greenhorn formation		70– 370	In northeastern and southeastern parts; gray calcareous shale and marl with some light-gray, thin-bedded limestone; in central part; gray noncalcareous shale containing prominent light-gray weathering septarian limestone concretions; thins westward.
			Belle Fourche shale		350– 850	Dark-gray to black shale with numerous dark purplish-red weathering siderite concretions in lower part, and several beds of light gray and yellow-weathering limestone concretions in middle and upper parts; thickens westward.
Cretaceous	Lower Cretaceous	Colorado group	Mowry shale		180– 230	Dark-gray siliceous shale, weathers light gray; numerous fish scales along partings; many thin bentonite beds; Clay Spur bentonite bed at top.
			Newcastle sandstone		0– 90	Lenticular beds of light-gray sandstone and siltstone and dark-gray shale and claystone; a few beds of impure coal and bentonite; thickness varies within short distances, but averages about 40 feet.
			Skull Creek shale		110– 220	Black shale with a few dark-red ferruginous concretions.
		Inyan Kara group	Fall River formation		110 – 300	Fine- to medium-grained light yellowish-brown to brown sandstone with interbedded gray and black shale and gray siltstone; averages about 135 feet in thickness near its outcrop.
			—Unconformity—			
			Lakota formation			Light yellowish-gray to white fine- to coarse-grained sandstone and conglomeratic sandstone irregularly interbedded with red, green, yellow, gray, and black claystone; coal beds near base locally; thickness varies within short distances.
Jurassic	Upper Jurassic		Morrison formation		100 – 250	Greenish-gray, green, and grayish-red claystone with a few thin discontinuous beds of light-gray sandstone and limestone; thickness at most places between 80 and 120 feet.
			Sundance formation	Redwater shale member	30– 195	Greenish-gray soft fissile sandy and silty shale; includes some thin beds of glauconitic sandstone and oolitic and coquinoid limestone; thickness at most places between 160 and 190 feet.
				Lak member	40– 80	Yellow and pink crudely bedded fine-grained sandstone and siltstone.
				Hulett sandstone member	55– 90	Yellowish-gray fine-grained thin-bedded to massive calcareous sandstone; locally pink northeast of Devils Tower.
				Stockade Beaver shale member	50– 90	Soft gray calcareous shale with some thin beds of yellowish-gray sandstone.
				Canyon Springs sandstone member	0– 40	Friable yellowish-gray or pink sandstone, some light greenish-gray siltstone.

System	Series	Formation	Thickness (feet)	Description
		Unconformity		
	Middle Jurassic	Gypsum Spring formation	0- 125	At base, massive white gypsum with interbedded red gypsiferous claystone; overlain near Hulett by interbedded gray cherty limestone and red claystone; thins southward from a maximum observed thickness of 125 feet near the junction of Deer Creek and the Belle Fourche River (SW¼ sec. 13, T. 55 N., R. 64 W.).
		Unconformity		
Triassic and Permian		Spearfish formation	300- 500	Red sandy shale, siltstone, and sandstone; beds of massive white gypsum in lower half.
Permian		Minnekahta limestone	200	Light-gray thin-bedded limestone, pink on outcrop.
		Opeche formation		Reddish-brown and maroon fine-grained sandstone, siltstone, and shale.
		Unconformity		
Permian and Pennsylvanian		Minnelusa formation	400- 1000	Light-gray and red sandstone, gray limestone and dolomite, red shale, local gypsum and anhydrite.
		Unconformity		
Carboniferous — Mississippian		Pahasapa limestone	200 - 800	Light-gray limestone, locally dolomitic.
Carboniferous — Mississippian	Lower Mississippian	Englewood limestone	50- 60	Pink or purplish-gray thin-bedded limestone; locally shaly.
		Unconformity		
Ordovician	Upper Ordovician	Whitewood dolomite	300	Mottled grayish-yellow massively bedded dolomite, locally cherty near top.
	Middle Ordovician	Winnipeg formation		Upper part greenish-gray siltstone, lower part greenish-gray shale (Furnish, Barragy, and Miller, 1936; Carlson, 1958).
		Unconformity		
Cambrian and Ordovician	Upper Cambrian and Lower Ordovician	Deadwood formation	50-600	Brown sandstone, gray glauconitic limestone and edgewise limestone conglomerate, and green shale.
		Unconformity		
Precambrian				Metamorphic and igneous rocks.

Source: U.S. Geological Survey 1964a

Table 9 (Cont'd)

Generalized Section of the Exposed Sedimentary Rocks in the Eastern

Powder River Coal Basin

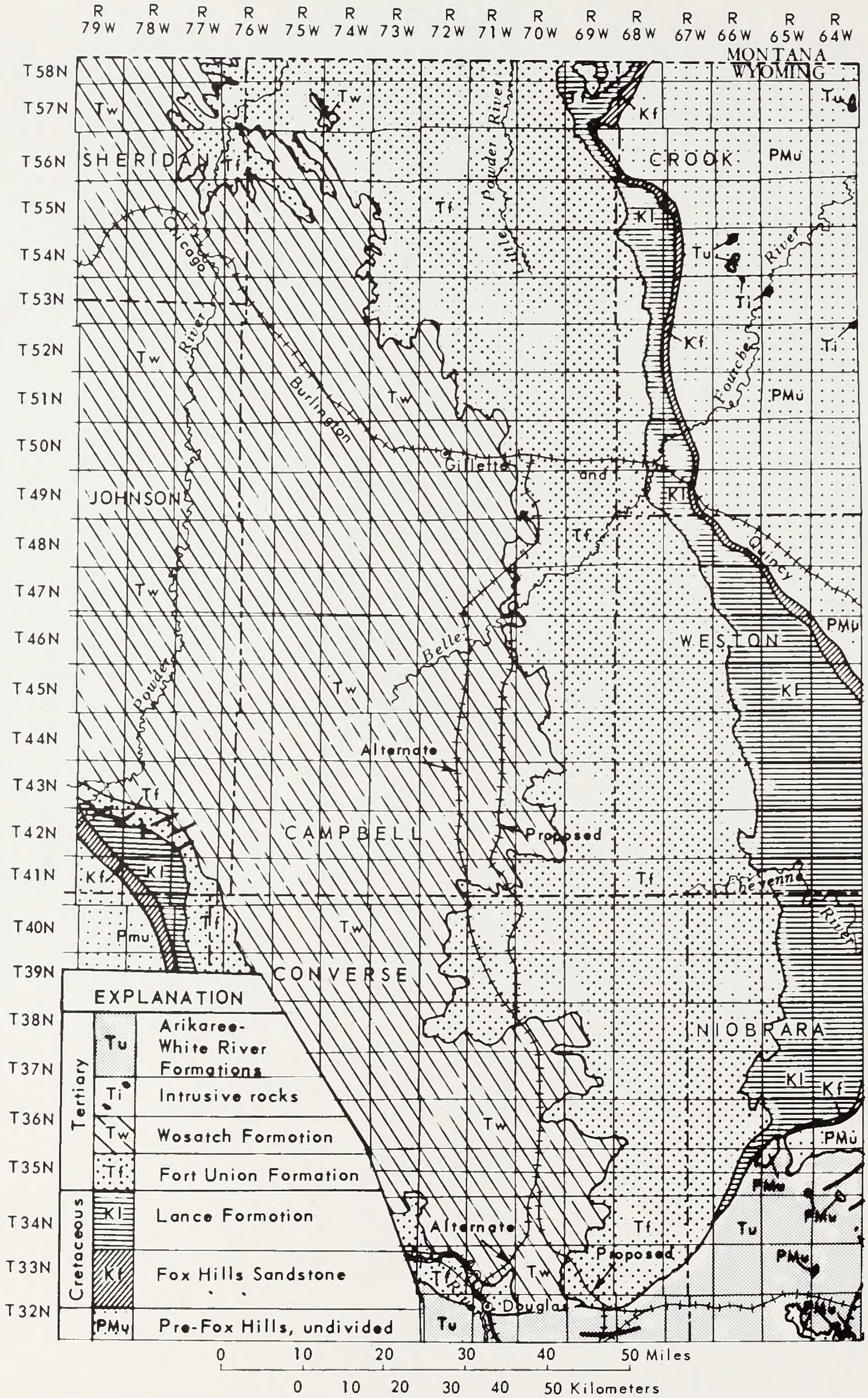


Figure 9. Generalized geologic map of the eastern Powder River Basin, Wyoming

Generalized geologic map of the eastern Powder River Basin, Wyoming

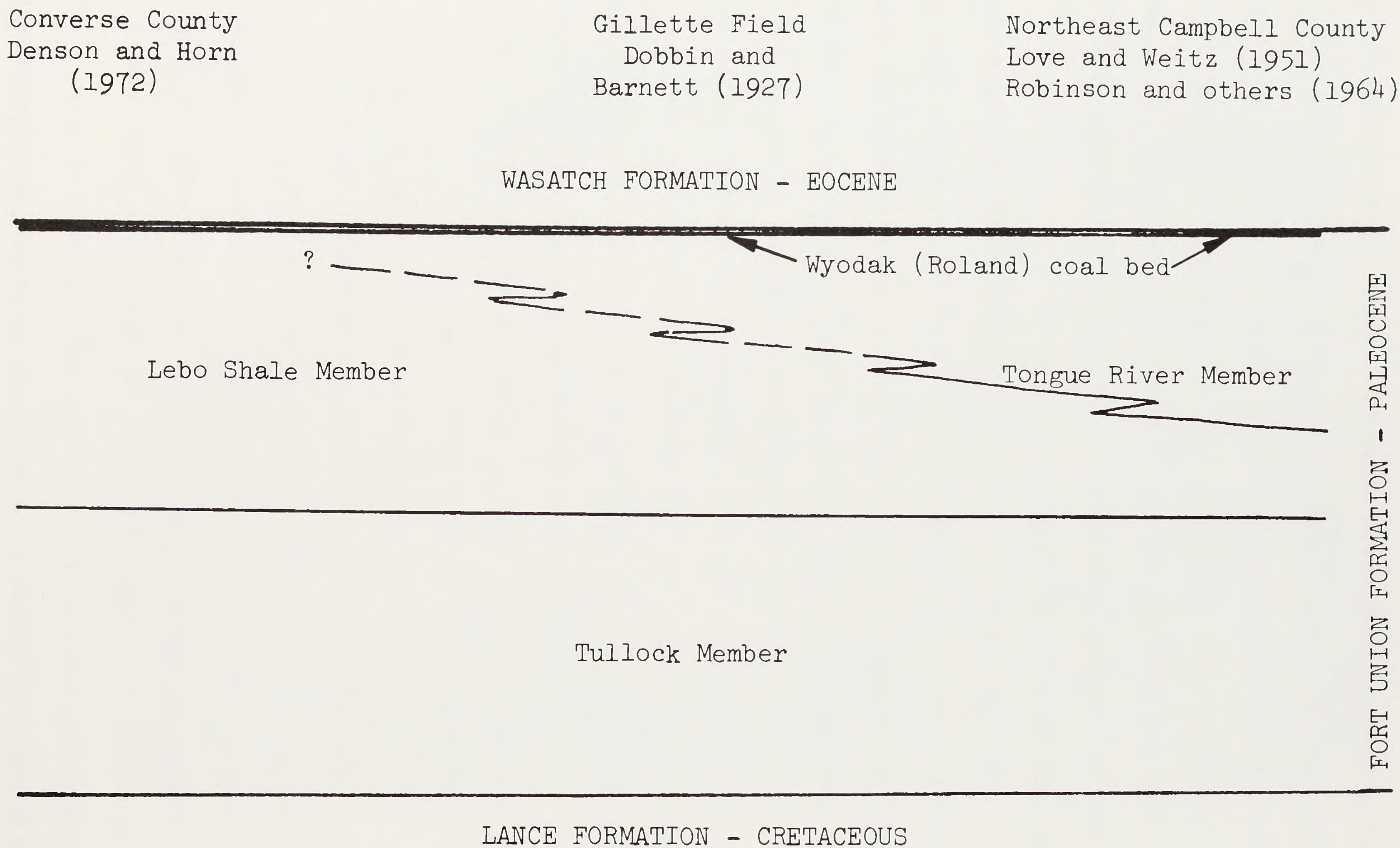
Cretaceous rocks include, from older to younger, the Pierre Shale, the Fox Hills Sandstone, and the Lance Formation; the Tertiary rocks are the Fort Union Formation of Paleocene age, the Wasatch Formation of Eocene age, the White River Formation of Oligocene age, and the Arikaree Formation of Miocene Age. Pleistocene and Holocene deposits consist of unconsolidated clay, silt, sand, and gravel as terrace deposits and valley-fill alluvium along major stream courses, and locally the wind-blown dune sand.

As shown in Table 9, the Fort Union Formation contains three members, the Tullock (lowest), the Lebo Shale (middle) and the Tongue River (uppermost). This distinct threefold subdivision can be mapped with certainty only in the extreme northeastern part of Campbell County (U.S. Geological Survey 1951, 1964a, and 1972a). Dobbin and Barnett (U.S. Geological Survey 1927) mapped as the Tongue River Member the rocks exposed in the eastward-facing Rochelle Hills escarpment; they mapped the Lebo Shale in the lowlands to the east. The top of the Wyodak coalbed (the D, Roland, and/or Smith coalbed of older reports) is near the top of the Fort Union Formation and the top of the Tongue River Member where it can be differentiated. Figure 11 shows diagramatically the general relationships of the members of the Fort Union Formation.

The Tullock Member consists of light-gray to tan, massive to thin even bedded sandstone; dark-gray and brown siltstone, shale and carbonaceous shale; and thin coalbeds. It ranges from about 950 to 1,300 feet thick with a general thickening to the southwest. The Lebo Shale Member, as its name implies, is predominantly medium and dark gray shale and claystone with varying amounts of interbedded siltstone, light-gray, fine-grained to conglomeratic sandstone, brownish carbonaceous shale, and thin to thick coalbeds. Purplish and rusty weathering siltstone concretions and discontinuous

Figure 11

The Relationship of the Members of the Fort Union Formation
-Paleocene- Eastern Powder River Basin, Wyoming



ferruginous sandstone beds distinctively mark the member, and hard dense quartzitic or calcareous sandstone concretions are common. Where the Lebo Shale and Tongue River Members cannot be differentiated, the undivided unit ranges in thickness from 1,700 to 2,800 feet. Where it can be differentiated in the northeastern part of Campbell County, the Tongue River Member is about 800 feet thick and consists of interbedded light-gray fine-grained sandstone, siltstone, sandy shale and coalbeds.

The Wasatch Formation covers a large area in the central part of the Powder River Basin in Wyoming (Figure 10). The remaining uneroded thickness in the basin may be as much as 1,600 feet in the vicinity of the Pumpkin Buttes, T43 and 44N, R75 and 76W. (U.S. Geological Survey 1964b) but generally a thickness less than 1,000 feet is preserved. Rocks of the Wasatch are predominantly yellowish-gray, fine-grained to conglomeratic, arkosic sandstone discontinuously interbedded with siltstone, carbonaceous shale, gray clay-shale, and numerous coalbeds.

Coalbeds in the Powder River Basin have burned extensively along their outcrops during the geologic past, probably during Pleistocene. This is especially characteristic of the Wyodak coalbed at the top of the Fort Union Formation and of several beds in the Wasatch Formation. As the coal burned, a unique rock type was formed when the overlying shale and sandstone became baked and fused into a red indurated, gravelly rock or natural slag commonly called clinker, scoria, or porcellanite (Figure 6, Topography Section of this Chapter). Clinker as much as 50 feet thick forms conspicuous outcropping masses generally as caps on buttes, hills, pinnacles, and escarpments in the Wasatch Formation throughout the basin. The clinker is a valuable resource for road surface material and railroad ballast.

The White River Formation of the Oligocene Age is exposed in the extreme southern part of the Powder River Basin in Converse County, Wyoming (Figure 10). The rocks consist of a basal conglomerate made up of igneous and metamorphic rock pebbles and cobbles, which ranges from 0 to 60 feet in thickness and is overlain by brown, pink, gray and green tuffaceous siltstone, sandstone, and conglomerate beds with local beds of limestone and volcanic ash. The formation may have been as much as 1,000 feet thick, but preserved thicknesses average less than 500 feet.

The Arikaree Formation of Miocene Age occurs in Converse County near Shawnee and Lost Springs in the extreme southern part of the Powder River Basin (included in Tu in Figure 10). The beds are gray to tan fine-grained sandstone, siltstone, limestone, volcanic ash, and locally, a basal conglomerate. As much as 600 feet of the formation may be present in the area.

The Wyoming Highway Department encountered no difficult engineering or construction problems in cuts for an interstate highway through the Fort Union and Wasatch Formations in Campbell County; however, all rocks were near surface and weathered, thus were rippable with standard equipment, and blasting was not required (Sherman 1974). The unweathered bedrock in surface mines may have to be blasted before removal. Unweathered bedrock in the two formations commonly is found at depths less than 25 feet and has a bearing strength of 3 to 7 tons per square foot. Landslides and other slope stability problems were encountered only on a local scale in oversteepened cuts. When used in fills, shale from the formations breaks down and deteriorates after about 6 months to 1 year. This results in consolidation and differential settling of the fill grade especially those fills 15 feet or more in height. Shrinkage of fill material composed of shale ranges from 10 to 20 percent and the shale material was unstable in fills with slope ratios greater than 2:1 (vertical to horizontal). Some clay in the formations was found to be compressible, but fills built over such clay were stable unless slope ratios exceeded 2:1 (Sherman 1974).

Structurally, the basin is a broad, downwarped asymmetric syncline overlying the relatively stable foreland of the Cordilleran system (Wyoming Geological Association 1958). The structural relief from a high point in northeastern Campbell County to the deepest part in western Converse County is about 9,000 feet (Figure 12). This value is based on the thickening of the nonmarine Upper Cretaceous and Lower Tertiary sedimentary rocks in the basin. The exposed rocks are slightly folded; local structural relief is imperceptible in the Tertiary strata that dip to the southwest at about 100 feet per mile (Wyoming Geological Association 1971). Laramide deformation, Tertiary erosion, and continual sedimentation may have produced as much as 21,000 feet of total structural relief in the basin (McDonald 1972, pp. 243-256).

Major faults are not known to offset the rocks in the eastern part of the basin, but faults of small displacement may be present, such as those described by Osterwald and Dean (U.S. Geological Survey 1961, pl. 28). Regionally, two prominent sets of joints are developed in the Great Plains and the Powder River Basin; one set striking northwest and the other northeast (U.S. Geological Survey 1971, pl. 28). Detailed studies of the attitude and spacing of the joint planes or other fractures have not been made.

The general structural development of the Powder River Basin may be summarized as follows: During gentle downwarping in Paleozoic time, sandstone, shale, and limestone were deposited in shallow seas and broad Carboniferous seaways. Thin, transgressive marine deposits, interbedded shaly marine and coarse nonmarine beds characterize Mesozoic deposition. Uplift on the mountain

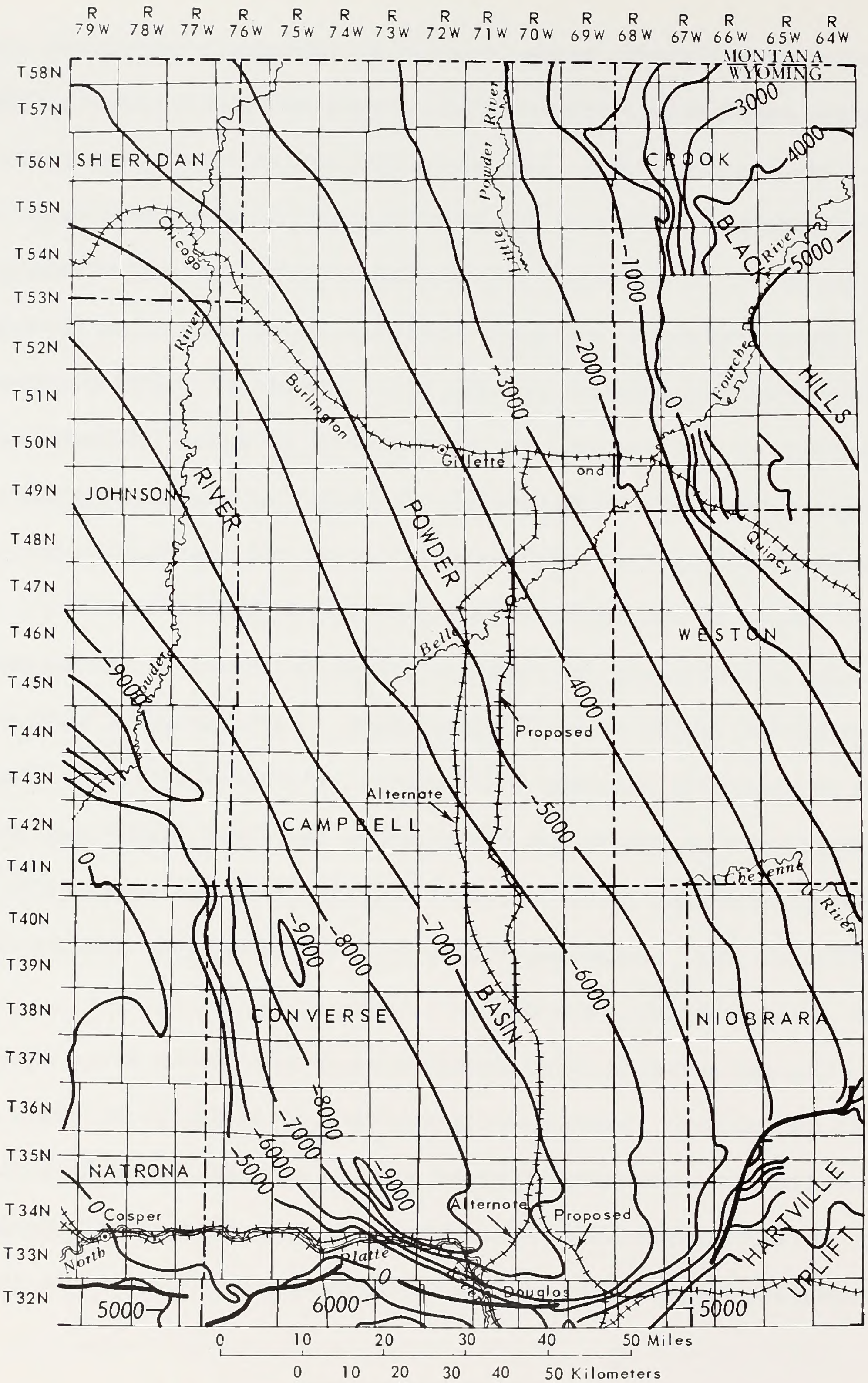


Figure 12

Structure Contour Map of the Eastern Powder River Basin. Contours Drawn on Top of Dakota Sandstone or Equivalent. Datum is Mean Sea Level.

ranges and subsidence of the enclosed area during the Laramide Orogeny blocked out this regional structural basin. Thick accumulations of Paleocene and Eocene rock accompanied the subsidence of the basin. During Paleocene time, the Northern Great Plains was a vast swampy region in which extensive coalbeds developed (Howard, Williams and Raisz 1972). Rock types in the coal-bearing Fort Union Formation that were derived from the Laramie Range indicate erosion at about the same rate as uplift of the range. The Tullock Member of the Fort Union marks the first evidence of downwarping in the basin (Curry 1971), whereas deposition of the thick sequence of mudstone of the Lebo Shale Member, which defines the margins of the basin, clearly indicates typical Laramide structure. The Laramide Orogeny was near its peak activity in Tongue River time as indicated by marked thickening of the sandstone and coalbeds (Curry 1969). A period of deformation and erosion preceded a final Laramide surge, which gave rise to elastic rocks of the Wasatch Formation. With the renewed uplift, the moisture-bearing winds were blocked off and the swamps gave way to grasslands. Unstable heavy mineral suites and sub-angular shape of grains indicate that at least the Wasatch in the southern part of the basin had a nearby source, probably in the northern part of the Laramie Range. The downwarping of the Powder River Basin was completed in early Tertiary time. Subsidence of the enclosing mountain ranges after deposition of the Oligocene White River strata caused local tilting of these beds toward the mountains (Curry 1969). Extensive erosion took place in late Tertiary time and most of White River Formation and probably much of the Wasatch Formation were removed. Upper Tertiary and Quanternary gravels were deposited on terraces, flood plains, and valley floors, and Holocene alluvium filled eroded channels in the older rocks.

<u>Coal</u>

Coalbeds are present in the Lance, Fort Union, and Wasatch Formations in Campbell and Converse Counties. Beds of coal amenable to strip mining by present day methods occur in the Fort Union and Wasatch Formations and generally near the contact between the two formations (Figure 13).

Coalbeds are found in the Lance Formation in the Glenrock coal field in the extreme south end of the basin and in the Sussex coal field along the southwest flank of the basin. These beds are lenticular, discontinuous, and less than five feet thick (U.S. Geological Survey 1909, pp. 151-164; 1912, pp. 441-471). Production from coalbeds in the Lance Formation probably has not been more than a few hundred tons for local consumption; future production probably will not be any greater.

Numerous coalbeds occur in the Fort Union Formation throughout the eastern and southern parts of the basin. Individual beds vary in thickness and character but many may persist over large areas. In general, coalbeds in the Tullock Member throughout the basin and in the Lebo Shale Member in Converse County are thin and abundantly parted. Multiple beds, individually 1 to 10 feet thick, may cumulatively total 15 to 25 feet of coal interbedded with other rocks in intervals ranging from 30 to 40 feet in thickness. These beds have provided coal for local, domestic use. Because of the thinness of the beds and the many partings, mining of the coal for any other use is not anticipated in the immediate future.

Thick, persistent strippable coalbeds occur at or near the top of the Fort Union Formation in the eastern part of the Powder River Basin. The beds crop out in Campbell County from the Montana-Wyoming boundary south to Converse County (Figure 13) and are continuous for many miles westward into the subsurface of the basin. The beds have been variously called the Wyodak, Roland, Smith, Anderson, D, and E (Figures 14 & 15). Coal is presently being produced

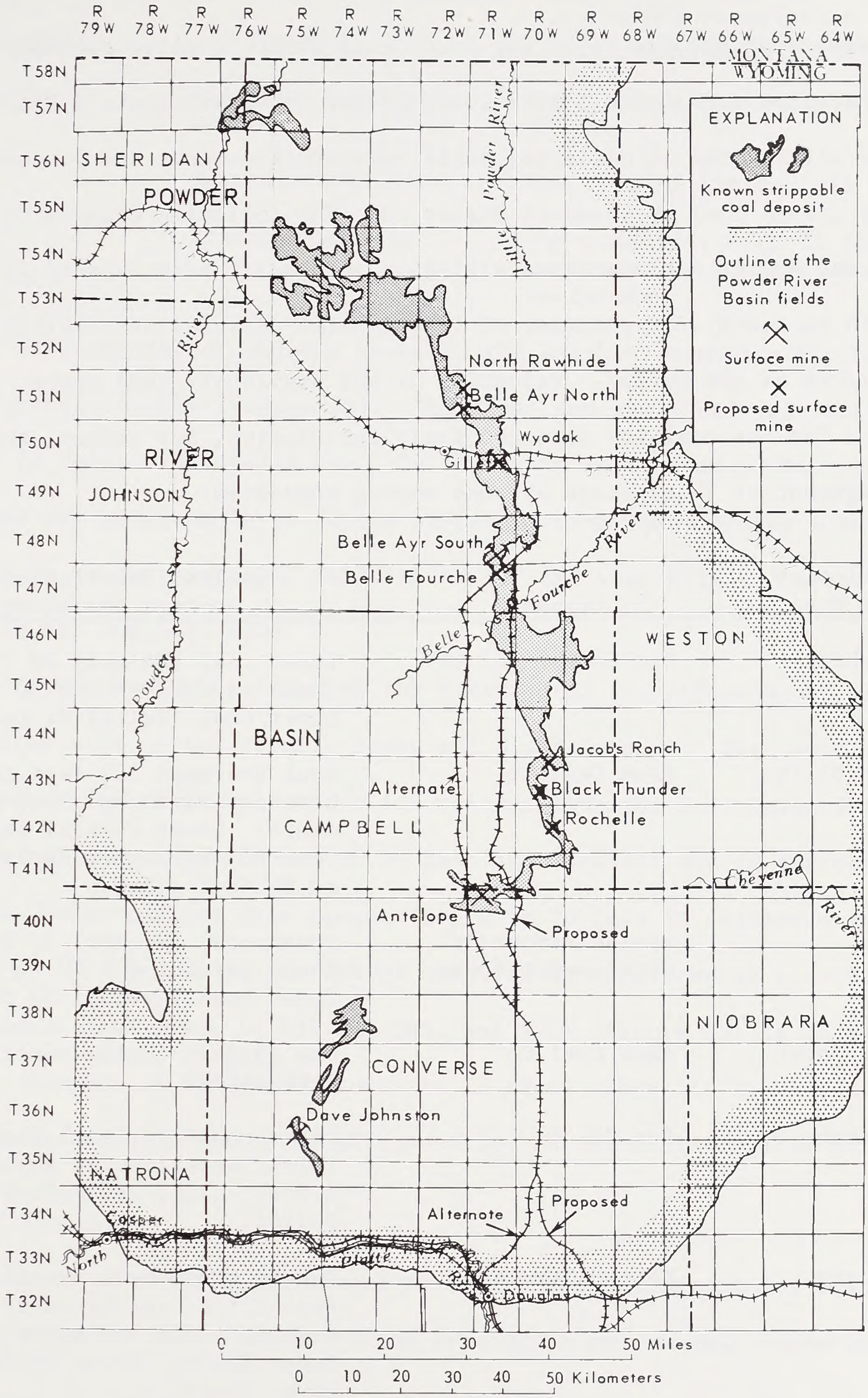


Figure 13
Strippable Coal Deposits of the Eastern Powder River Basin, Wyoming

from these beds on federal coal leases at three sites--the Wyodak mine just east of Gillette, Wyoming; the Belle Ayr South mine about 12 miles south of Gillette; and the Antelope mine about 1 mile south of the Converse-Campbell County line almost 60 miles south of Gillette; additional surface mines are proposed in federally leased coal as shown on Figure 13. The following summary of coal descriptions at the various sites will give an overall relationship of the beds from north to south; for purposes of this general regional discussion, the coal is correlated as the Wyodak. Retention of the previously used names, Roland and Smith, for the coalbeds does not imply correlation, but rather, the acknowledgement of local usage by some mining companies.

Name of Mine or Proposed Mine	Company	Coalbed Description and Average Thickness
North Rawhide	The Carter Oil Co.	Upper coal (Roland) 25 feet thick Shale parting - 2 to 10 feet thick Lower coal (Smith) 82 feet thick.
Belle Ayr North	Amax Coal Co.	Coal averages 111 feet thick. Two beds separated by about 6 feet of shale. Lower (Smith) is 50 to 120 feet thick. Upper (Roland) is 15 to 80 feet thick.
Wyodak	Wyodak Resources Development Corp.	Upper coal (Wyodak) 32 feet thick Shale parting $<$ 1 to 25 feet thick Lower coal (Wyodak) 52 feet thick.
Belle Ayr South	Amax Coal Co.	One coalbed (Roland-Smith) 70 feet thick.
Belle Fourche	Sun Oil Co.	Three coalbeds, each about 20 feet thick, separated by shale about 2 feet thick; collectively called Roland.
Jacobs Ranch	Kerr-McGee Coal	One to three beds totalling 64 feet thick, separated by $<$ 1 to 70 feet of shale and sandstone. Called Upper Wyodak, Lower Wyodak 1 and Lower Wyodak 2.

Name of Mine or Proposed Mine	Company	Coalbed Description and Average Thickness
Black Thunder	Atlantic Richfield Company	One coalbed (Roland) 60 to 73 feet thick.
Rochelle	Rochelle Coal Co.	One coalbed (Roland) 53 feet thick.
Antelope	Brannon Coal Co.	Two coalbeds, each 35 feet thick, separated by 72 feet of shale and sandstone.

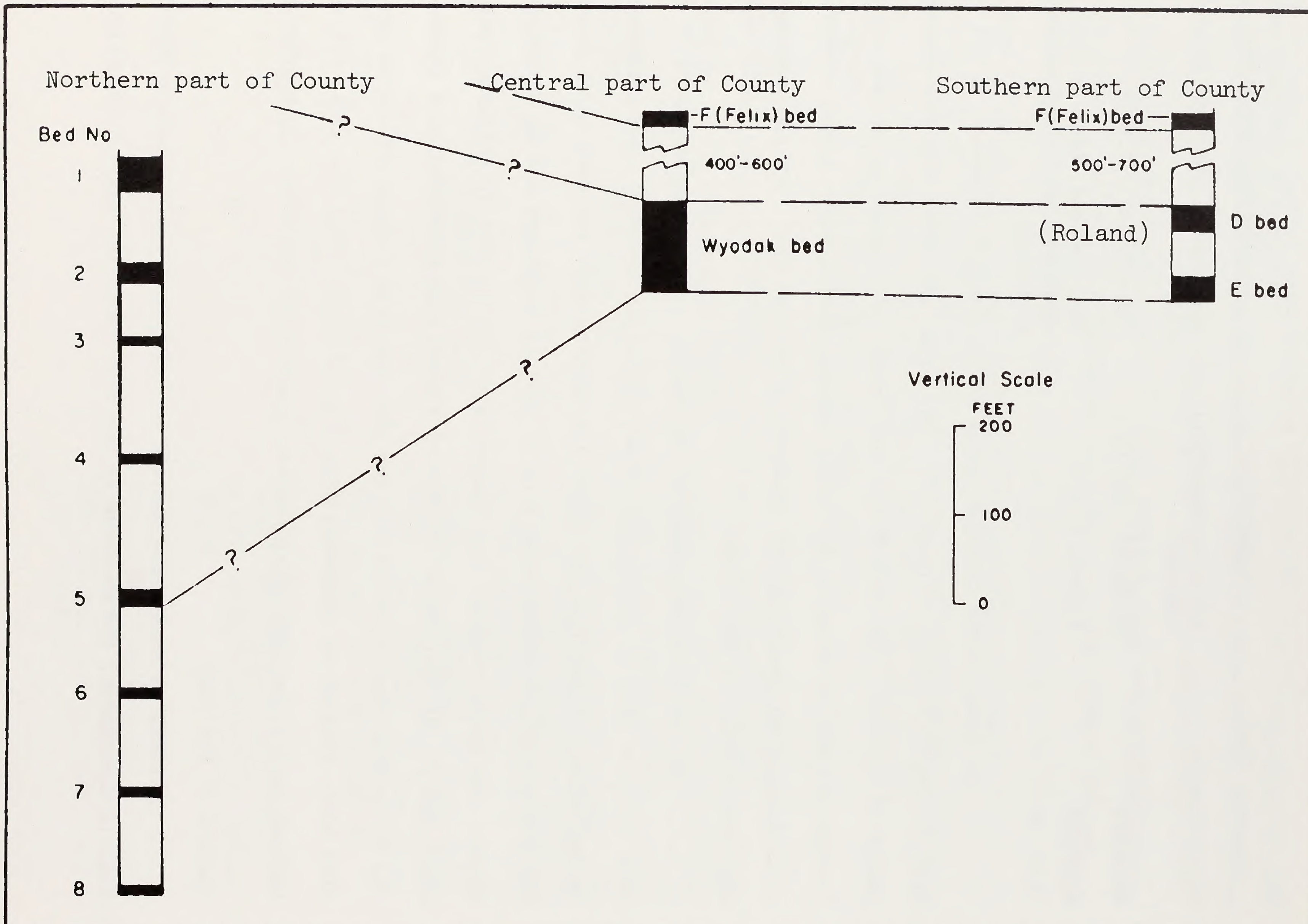
At least three coalbeds occur in the Wasatch Formation in the eastern part of Campbell County (Figure 15). The upper and lower beds may attain thicknesses of 12 feet. The middle bed, the Felix, is as much as 20 feet thick locally and may be amenable to future surface mining under proper economic conditions in an area south of Gillette in T47 and 48N, R72W and near Reno Junction in T43 and 44N, R72W.

On the southwest flank of the basin, coal is surface mined at the Dave Johnston mine of the Pacific Power and Light Company. The coalbeds are in the Wasatch Formation just above its contact with the Fort Union Formation. The School coalbed ranges from 5 to 39 feet in thickness and is currently being mined. The Badger coalbed that ranges from 2 to 20 feet in thickness and occurs about 110 to 150 feet above the School bed will be recovered at a future time. The strippable coal shown in T37 and 38N, and R74W (Figure 13) is in one or two thin beds, ranging in thickness from 2 to 12 feet. They lie above the Badger bed and may be near the stratigraphic position of the Felix coalbed to the east.

Quality of the coal

Based on analyses submitted by individual coal companies and from the Federal Government, the coalbeds in the Fort Union and Wasatch Formations in

Figure 14
Generalized Diagram of Principal Coalbeds in Campbell County, Eastern Powder River Basin; Showing Suggested Correlation of Beds



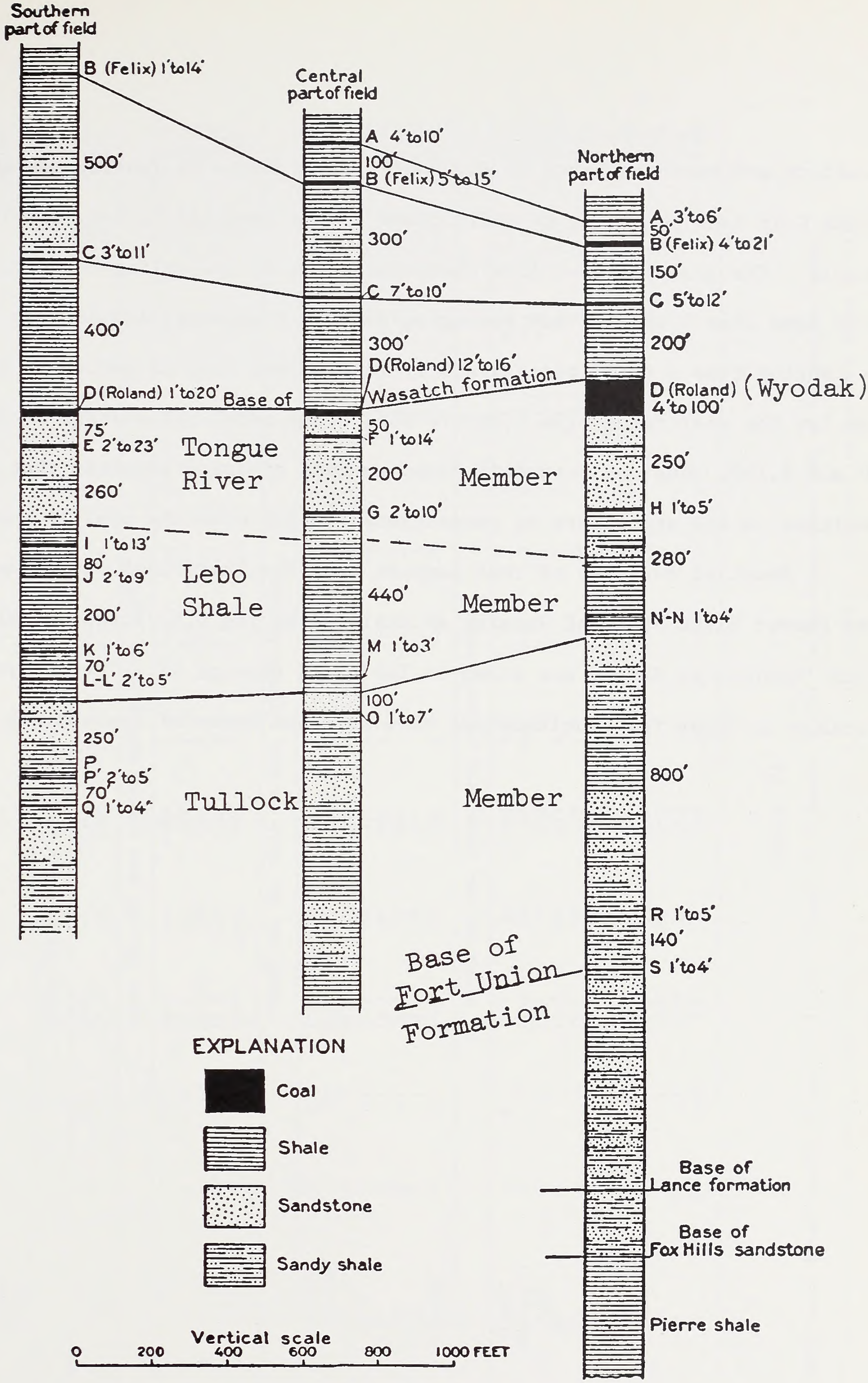


Figure 15
Stratigraphic Sections in the Gillette Coal Field,
Wyoming, Showing Position of Coalbeds

the eastern and southern parts of the Powder River Basin in Wyoming are subbituminous C in rank according to definitions of the American Society for Testing Materials. The coal has favorable characteristics of low sulfur content, usually less than 1 percent and averaging about 0.5 percent, and low ash contents ranging from 3 to 15 percent and averaging less than 10 percent. Btu values for the coal range from 7,800 to 10,300 per pound but average between 8,300 and 8,700. The coals contain minor amounts of trace elements that may be transmitted to the atmosphere or concentrated in ash when the coal is burned.

Detailed analyses of coal samples from the individual producing mines in the Powder River Basin of Wyoming as analyzed by the U.S. Bureau of Mines and the U.S. Geological Survey are shown in Tables 10 through 13. The analyses are comparable to those for subbituminous coal in other areas of the western U.S.

Sample No.	Thickness of sample interval (feet)	As	Cd	Cu	F	Hg	Li	Pb	Sb	Se	Th	U	Zn	Ash (percent)
BADGER COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING														
D161315	5.(T)	4	<0.1	15.8	---	0.140	10.7	10.0	---	2.3	5.0	2.4	12.6	15.8
D161316	5.5	3	.1	16.9	70	.128	11.6	8.4	0.6	1.6	6.6	2.2	4.0	12.5
SCHOOL COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING														
D161314	6.(T)	2	<0.1	6.2	---	0.088	1.5	5.1	---	0.9	<1.5	0.3	2.6	8.20
D161313	5.	1	< .1	5.7	---	.070	1.0	5.1	---	.7	<1.5	.4	3.4	7.36
D161312	5.	6	.15	18.5	50	.350	4.1	5.9	0.2	3.5	<1.5	< .3	4.1	8.62
D161311	5.	2	< .1	19.0	---	.095	5.8	6.1	---	.6	<1.5	.8	4.5	9.76
D161310	5.(B)	1	< .1	13.4	---	.059	3.5	7.1	---	.8	<1.5	1.1	2.9	10.3
WYODAK COAL BED, BELLE AYR MINE, GILLETTE, WYOMING														
D160988	(Tipple)	2	0.1	13.3	30	0.13	1.9	5.5	0.2	1.8	<1.5	0.6	6.8	6.64
D163516	2.1(T)	4	.1	12.0	90	.28	1.2	2.2	.4	2.2	<1.5	2.9	6.8	8.69
D163517	4.2	3	.2	45.	80	.13	4.4	5.3	.7	2.0	7.7	1.7	5.9	11.7
D163518	5.	2	.1	8.6	40	.13	2.0	<1.5	.3	.6	4.8	.4	7.6	7.06
D163519	5.	2	<.1	10.7	90	.10	1.2	1.9	.2	.3	<1.5	.4	4.6	6.42
D163520	5.	2	<.1	4.2	65	.08	<.5	<1.5	.2	.4	<1.5	<.3	2.7	4.83
D163521	5.	2	<.1	5.3	60	.06	.5	1.5	.1	.5	<1.5	.6	2.1	4.38
D163522	(Tipple)	2	<.1	12.3	50	.09	1.4	2.2	.2	.9	<1.5	.9	4.4	6.32
WYODAK COAL BED, WYODAK MINE, GILLETTE, WYOMING														
D160987	(Tipple	1	<0.1	7.7	30	0.081	1.6	5.6	0.1	0.6	<1.5	0.6	4.2	6.42
D160986	(Shot-pile)	2	.15	22.0	40	.108	4.1	5.7	.3	1.4	<1.5	1.5	12.5	8.82
D160985	3.(T)	2	< .1	3.3	30	.055	.7	3.9	<.1	.4	<1.5	<.2	5.5	4.90
D160984	10.	3	.16	10.0	40	.214	2.2	5.7	.2	1.4	<1.5	.6	7.1	7.54
D160983	10.	2	< .1	20.4	50	.176	4.0	7.1	.3	.8	3.1	.9	15.4	10.6
D160982	10.	1	< .1	8.3	40	.048	2.0	5.7	.1	.6	<1.5	.6	5.6	6.80
D160981	.5	2	< .1	51.	200	.150	49.	<40.	.5	.6	7.9	3.2	25.	84.9
D160980	3.5	1	< .1	9.8	50	.104	4.2	8.1	.3	1.0	<1.5	.5	7.5	9.78
D160979	5.	1	< .1	12.4	40	.068	3.6	8.2	.3	.9	<1.5	.9	8.0	10.0
D160978	5.	1	< .1	7.6	40	.064	1.1	6.2	.3	.4	<1.5	.5	3.3	6.78
D160977	5.	<1	< .1	5.6	30	.063	1.3	7.2	.2	.3	<1.5	.5	4.4	7.34
D160976	5.	<1	< .1	3.8	30	.050	1.9	6.0	.1	1.9	<1.5	.5	3.5	6.20

Table 10

Quantitative Determinations (in ppm) for 12 Trace Elements in 27 Samples of Coal from the Powder River Basin of Northeastern Wyoming

(T and B indicate top and bottom of bed, respectively. Values for Cd, Cu, Li, Pb, and Zn are calculated from analyses on ash of coal.)

Table 11

Semiquantitative Spectrographic Analyses (in ppm) for 19 Trace Elements in 27 Samples of Coal from the Powder River Basin of Northeastern Wyoming

(T and B indicate top and bottom of bed, respectively. All values have been calculated from analyses on ash of coal.)

Sample No.	Sample Interval (feet)	B	Ba	Be	Co	Cr	Ga	La	Mn	Mo	Nb	Ni	Sc	Sn	Sr	Ti	V	Y	Yb	Zr
BADGER COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYO.																				
D161315	5. (T)	100	50	0.5	2	15	7	10	100	2	3	5	5	< 0.5	70	500	50	5	0.5	20
D161316	5.5	100	100	.5	1	10	7	10	200	2	2	7	2	< .5	150	500	20	5	.5	10
SCHOOL COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYO.																				
D161314	6. (T)	50	50	0.15	1	5	1	5	100	0.5	< 1.5	3	1	< 0.5	150	300	10	3	0.15	10
D161313	5.	50	70	< .15	1	5	1	< 5	150	< .5	< 1.5	1.5	1	< .5	150	200	10	2	.2	7
D161312	5.	70	150	.15	1.5	7	3	< 5	150	.5	< 1.5	7	1.5	< .5	150	700	15	3	.3	15
D161311	5.	50	200	.2	1.5	7	3	7	70	1	2	3	3	< .5	300	700	15	3	.3	20
D161310	5. (B)	70	150	.3	1.5	15	7	7	70	1	3	3	3	< .5	150	700	30	5	.3	15
WYODAK COAL BED, BELLE AYR (AMAX) MINE, GILLETTE, WYO.																				
D160988	(Tipple)	20	200	0.2	2	5	2	10	20	0.5	1.5	5	2	< 0.5	30	300	15	3	0.3	10
D163516	2.1(T)	30	300	.7	3	7	3	15	200	1.5	2	10	5	< .5	200	300	30	7	.7	15
D163517	4.2	20	300	.7	2	10	3	20	30	1	2	3	7	< .5	200	700	30	5	.5	20
D163518	5.	30	200	.3	1.5	5	2	10	20	.5	< 1.5	3	2	< .5	70	300	10	5	.5	15
D163519	5.	30	200	.2	1	5	1	5	30	.5	1.5	3	2	< .5	70	200	10	2	.3	20
D163520	5.	30	200	< .15	1	1.5	1	< 5	30	.3	< 1.5	3	1.5	< .5	70	150	7	2	.2	7
D163521	5.	30	200	< .15	1.5	3	1	< 5	20	.7	< 1.5	3	1.5	< .5	70	150	7	1.5	.15	10
D163522	(Tipple)	20	200	.2	1	5	1.5	< 5	20	.7	1.5	3	3	< .5	70	200	10	2	.3	10
WYODAK COAL BED, WYODAK MINE, GILLETTE, WYO.																				
D160987	(Tipple)	30	200	< 0.15	1	5	2	< 5	10	0.5	1	2	1	< 0.5	50	200	10	2	0.2	10
D160986	(Shot-pile)	50	200	.3	3	7	3	< 5	200	1	2	7	3	< .5	50	500	30	5	.7	20
D160985	3. (T)	30	150	< .15	1.5	2	1	< 5	50	.3	< 1	3	0.7	< .5	20	100	7	2	.2	5
D160984	10.	50	150	.2	2	5	2	7	50	.5	1.5	5	1	< .5	20	200	15	1	.1	10
D160983	10.	30	200	.3	2	7	3	10	30	.7	2	7	2	< .5	30	500	20	5	.5	15
D160982	10.	30	200	< .15	1	5	2	< 5	20	.5	< 1	5	1	< .5	30	200	10	2	.2	10
D160981	.5	50	500	< .15	< 0.5	50	20	< 5	50	< .5	20	15	15	< .5	150	5,000	150	< 1	2	150
D160980	3.5	20	300	< .15	2	7	3	< 5	15	.7	< 1	3	1.5	< .5	50	300	15	2	.3	15
D160979	5.	20	200	< .15	1.5	10	3	< 5	15	.7	< 1	3	1.5	< .5	30	300	20	3	.3	15
D160978	5.	20	300	< .15	.7	2	1.5	< 5	10	.5	< 1	2	1	< .5	50	200	7	2	.2	10
D160977	5.	20	300	< .15	.7	2	2	< 5	20	.5	2	2	.7	< .5	50	200	5	1.5	.2	10
D160976	5.	30	300	< .15	1	2	2	< 5	10	.7	3	2	1	< .5	70	200	5	2	.2	10

Table 12

Major-Oxide Composition (in percent) of the Laboratory Ash of 27 Coal Samples for the Powder River Basin, Northeastern Wyoming

(T and B indicate top and bottom of bed, respectively.)

Sample No.	Sample interval (feet)	Ash	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	Fe_2O_3	SO_3
BADGER COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING											
D161315	5.(T)	15.8	48.	16.	0.08	0.9	13.	2.00	0.17	3.0	10.
D161316	5.5	12.5	36.	18.	.07	.7	18.	2.30	.91	2.8	12.
SCHOOL COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING											
D161314	6.(T)	8.20	22.	9.3	0.11	0.2	30.	4.00	0.51	3.8	16.
D161313	5.	7.36	13.	9.6	.12	.2	35.	4.70	.11	3.5	15.
D161312	5.	8.62	22.	12.	.10	.2	27.	3.40	.73	5.4	19.
D161311	5.	9.76	24.	18.	.08	.3	25.	3.10	3.4	2.8	11.
D161310	5.(B)	12.3	32.	16.	.11	.8	22.	2.95	1.5	4.0	9.2
WYODAK COAL BED, BELLE AYR MINE, GILLETTE, WYOMING											
D160988	(Tipple)	6.64	26.	13.	1.19	0.3	21.	3.55	0.1	4.6	22.
D163516	2.1 (T)	8.69	27.	12.	.98	.4	14.	2.60	1.4	14.	25.
D163517	4.2	11.7	41.	19.	.65	.9	12.	1.80	1.7	2.8	15.
D163518	5.	7.06	31.	16.	1.23	< .1	21.	3.40	.67	3.3	20.
D163519	5.	6.42	31.	9.6	1.28	< .1	24.	3.80	< .05	3.8	17.
D163520	5.	4.83	16.	11.	1.78	.7	29.	4.60	< .05	5.5	22.
D163521	5.	4.38	15.	11.	1.83	.2	29.	4.80	< .05	4.3	25.
D163522	(Tipple)	6.32	25.	12.	1.23	.3	22.	3.60	.40	4.1	23.
WYODAK COAL BED, WYODAK MINE, GILLETTE, WYOMING											
D160987	(Tipple)	6.42	30.	13.	1.55	0.5	21.	5.05	1.7	3.3	13.
D160986	(Shot-pile)	8.82	28.	18.	.46	.5	16.	4.15	1.5	2.8	19.
D160985	3. (T)	4.90	17.	12.	.87	.7	24.	6.15	< .05	7.3	21.
D160984	10.	7.54	28.	17.	.60	1.1	16.	4.25	.5	5.2	20
D160983	10.	10.6	33.	15.	.44	.8	14.	3.25	1.2	4.0	18.
D160982	10.	6.80	21.	13.	1.00	.6	23.	5.80	.7	3.8	21.
D160981	.5	84.9	63.	26.	.13	1.7	.5	.80	.07	1.7	.3
D160980	3.5	9.78	33.	14.	.83	.7	19.	4.90	1.2	3.1	13.
D160979	5.	10.0	41.	15.	.71	1.1	15.	3.80	.6	2.5	10.
D160978	5.	6.78	20.	10.	1.42	.5	27.	8.00	1.1	3.2	15.
D160977	5.	7.34	24.	10.	.88	.7	25.	6.20	.6	4.6	14.
D160976	5.	6.20	26.	11.	1.31	.5	24.	6.85	2.1	3.7	10.

Table 13

Proximate, Ultimate, BTU, and Sulfur Analyses of Samples of Coal from the Powder River Basin of Northeastern Wyoming

(All analyses except BTU, in percent; AR, as received; MAF, moisture and ash free)

Coal bed name Mine name	Badger Dave Johnston		School Dave Johnston		Wyodak Belle Ayr South		Wyodak Wyodak		Wyodak Wyodak		Wyodak Wyodak	
Sample No.	D161316		D161312		D160988		D160987		D160983		D160978	
USBM Lab. No.	K-19970		K-19969		K-12883		K-12882		K-12881		K-12880	
Sampled interval (feet)	5.5		5.0		Tipple		Tipple		10.0		5.0	
	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF
Moisture	15.0	...	14.8	...	26.2	...	27.1	...	10.4	...	25.9	...
Volatile matter	35.4	50.5	38.6	50.2	33.6	49.1	31.5	46.7	40.9	50.7	32.2	46.9
Fixed carbon	34.6	49.5	38.4	49.8	34.9	50.9	35.9	53.3	39.7	49.3	36.3	53.1
Ash	15.0	...	8.2	...	5.3	...	5.5	...	9.0	...	5.6	...
Hydrogen	5.6	5.6	5.7	5.3	6.8	5.7	6.6	5.3	5.6	5.6	6.4	5.1
Carbon	50.9	72.8	55.8	72.5	50.7	74.0	49.5	73.4	58.8	73.0	50.2	73.2
Nitrogen	.7	1.0	.7	.9	.7	1.1	.7	1.1	.8	1.0	.7	1.1
Oxygen	27.1	19.6	28.9	20.4	35.9	18.3	37.4	19.7	24.9	19.3	36.6	20.1
Sulfur	.71	1.0	.7	.9	.6	.9	.3	.5	.9	1.1	.5	.5
Sulfate	.01	.01	.01	.01	.02	.04	.01	.01	.09	.11	.08	.11
Pyritic	.26	.36	.17	.22	.17	.25	.07	.11	.09	.11	.09	.14
Organic	.44	.63	.55	.71	.44	.64	.22	.33	.70	.87	.20	.30
BTU	8,540	12,200	9,520	12,370	8,820	12,880	8,530	12,650	10,280	12,760	8,570	12,500

Source: U. S. Bureau of Mines

Trace element content of coal and overburden

Investigations of minor and trace elements in coal have been ongoing since coming into prominence in the early 1930's. Zubovic and others (USGS 1961, p. A4-A5) have listed publications of work in 18 countries and the U.S.A. through 1956; O'Gorman and Walker (Office of Coal Research, 1972) have summarized information on trace elements in selected U.S. coals. Swanson (USGS Open File Report, 1972), in addition to giving results of analyses for trace elements for coals to be used for power generation in the southwestern U.S., has described the coal sampling procedure, sample preparation, analytical methods, and limits of detection used by the U.S. Geological Survey in determining trace element contents of coal. The work of O'Gorman and Walker contains average trace element contents of coal. The work of O'Gorman and Walker contains average trace element contents for subbituminous coal and lignite, as does more recent soon-to-be-released work by Swanson on trace element contents of coal analyzed for the Northern Great Plains Resource Study.

Analyses show that coal in the study area of the impact statement in the Powder River Basin contain about the same, or less, amounts of trace metal elements as shown by analyses of coal beds in other areas of the U.S. and throughout the world. Many of these coal beds, as analyzed in the U.S. and other countries, have been used as a source of fuel and power generation for hundred of years. The scientific literature lacks documentation of high levels of pollution by toxic elements from the burning of these coals, except for contribution of oxides of sulfur to smog during air inversion. The trace element contents of the Powder River Basin coals do not show unusual concentrations when compared to trace element contents of coals that have been used for years. Less trace element research has been done on contents of overburden than has been done on coal; fewer samples have been analyzed and even fewer oxidation and leaching tests have been conducted.

Twenty-four samples, believed to be representative of the sedimentary rocks overlying mineable coalbeds in Campbell County, Eastern Powder River Basin, Wyoming, have been analyzed in detail by the U.S. Geological Survey (Tables 13a-13d). These rocks, which are dominantly siltstone, interbedded with lesser amounts of poorly sorted sandstone and carbonaceous shale, are in the Fort Union and Wasatch Formations of early Tertiary age. The compositions of these rocks are not significantly different in any important environmental aspects from compositions of similar sedimentary rocks in other parts of the United States.

Based on the chemical analyses, silica and alumina comprise three-fourths of these overburden rocks, with potassium, magnesium, calcium, and iron oxides comprising most of the remainder (Table 13b). Organic matter, generally as microscopic disseminated material or less commonly as thin coaly layers or particles visible to the naked eye, makes up from less than one to more than ten percent of the rock samples. The sulfur content is low, generally less than 0.5 percent; only one sample (coaly shale, sample No. D168822) contained more than one percent sulfur, and pyrite was visible in this sample.

The trace elements that are generally of environmental concern are listed in Table 13c. Analyses of the 24 overburden samples show that none of these elements are present in abnormally greater amounts than are present in similar rock types throughout the United States. Some of the apparently higher values for arsenic, copper, and zinc are for samples of carbonaceous sediment, which commonly contains greater amounts of these and other metals than non-carbonaceous rocks. A few samples contain slightly more than average amounts of

Table 13 a

Drill-core Information, and Lithologic Description, Carbon and Sulfur Analysis (in percent) of 24 Samples of Rock Overburden Above Coal Beds to be Mined in the Eastern Powder River Basin, Campbell County, Wyoming.

Sample No.	Depth from surface (ft)	Description of lithology	Total carbon percent	Mineral carbon percent	Organic carbon percent	Total sulfur percent
		PEABODY COAL COMPANY, CORE P8-C[1/]				
D168820	20-30	Carbonaceous shale, medium gray	1.81	0.10	1.7	0.18
D168821	40-50	Slightly carbonaceous siltstone, light gray	1.38	1.16	.2	.06
D168822	60-70	Slightly carbonaceous shale to coaly shale, light gray to dark gray	1.85	.49	1.4	1.98
D168823	90-100	Carbonaceous claystone, medium gray	3.38	<.01	3.4	.19
D168824	161.0-165.7	Slightly carbonaceous silty shale, medium gray	1.70	<.01	1.7	.09
		ATLANTIC-RICHFIELD COMPANY, CORE BT-81[2/]				
D168825	15.5-30.3	Corbonaceous siltstone and shale, medium gray	5.97	.07	5.9	.16
D168826	39.6-43.6	Slightly carbonaceous siltstone and carbonaceous shale, medium gray	.99	.28	.7	.14
D168827	50.5-61.7	Fine-grained sandstone and siltstone, light gray	2.22	1.70	1.5	.07
D168828	66.2-84.5	Carbonaceous silty claystone and shale, medium gray	2.78	1.15	1.6	.49
D168829	159.5-165.5	Carbonaceous shale, medium to dark gray	2.44	<.01	2.4	.11
		KERR-McCEE CORPORATION, CORE 3C-15[3/]				
D168830	12.0-42.5	Ferruginous poorly sorted coarse-grained sandstone	1.92	<.01	1.9	.05
D168831	42.5-64.5	Slightly ferruginous siltstone and claystone, tannish gray	.28	.06	.2	.05
D168832	64.5-73.0	Silty claystone, light gray	.73	.28	.4	.09
D168833	73.0-89.0	Slightly carbonaceous clayey siltstone, light gray	1.85	.89	1.0	.22
D168834	93.0-111.5	Slightly carbonaceous cloystone and silty claystone, medium gray	.89	.29	.6	.06
D168835	112.5-119.0	Slightly carbonaceous claystone, medium gray	.97	<.01	1.0	.14
		CARTER OIL COMPANY, CORE 97-C[4/]				
D168836	10.0-10.4	Ferruginous fine-grained sandstone and silty sandstone	.93	.60	.3	.78
D168837	36.0-36.4	Ferruginous silty claystone, carbonized rootlets, tannish gray	1.32	.90	.4	.76
D168838	52.0-52.4	Slightly carbonaceous clayey siltstone, greenish gray	1.16	<.87	.3	.09
D168839	69.6-70.0	Mottled very carbonaceous mudstone, medium to dark gray	7.18	.01	7.2	.42
D168840	99.0-99.4	Slightly carbonaceous clayey siltstone, medium gray	2.28	.78	1.5	.23
D168841	122.0-122.4	Carbonaceous silty claystone, medium gray	2.87	.20	2.7	.17
		CARTER OIL COMPANY, CORE 123-C[5/]				
D168842	260.0-260.4	Carbonacous silty claystone, medium gray	1.86	<.01	1.9	.23
D168843	269.0-269.4	Fine-grained to silty sandstone, very light gray	.28	.16	.1	.36

1/ SE 1/4 sec. 2, T. 41 N., R. 70 W.; collected by W. L. Rohrer, USGS.
2/ NW 1/4 sec. 34, T. 43 N., R. 70 W.; collected by D. B. Tait, ARCO.
3/ NE 1/4 sec. 15, T. 43 N., R. 70 W.; collected by D. A. Jobin, USGS.
4/ SW 1/4 sec. 10, T. 51 N., R. 72 W.; collected by R. J. Waldram, Carter Oil Company.
5/ SW 1/4 sec. 10, T. 51 N., R. 72 W. (about 430 ft NE of core-hole 97-C); collected by R. J. Waldram, Carter Oil Company.

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Table 13b

Major Oxide Composition (in percent) of 24 Samples of Rock Overburden Above Coal Beds to be Mined in the Eastern Powder River Basin, Campbell County, Wyoming. See table 13a for further description of samples.

Sample No.	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	MnO	TiO_2	Fe_2O_3	Cl
PEABODY COAL COMPANY, CORE P8-C											
D168820	65.	17.	0.18	2.0	0.49	1.04	<0.10	0.02	0.75	3.1	<0.10
D168821	66.	13.	.13	1.8	.33	.76	< .10	.09	.63	9.0	< .10
D168822	63.	14.	.16	1.9	.48	.92	< .10	.04	.63	7.8	< .10
D168823	69.	15.	.12	1.6	.29	.61	< .10	<.02	.64	1.5	< .10
D168824	69.	17.	.11	1.9	.17	.59	< .10	<.02	.78	1.3	< .10
ATLANTIC-RICHFIELD COMPANY, CORE BT-81											
D168825	60.	17.	.11	1.8	.50	.84	<.10	<.02	.65	2.6	<.10
D168826	69.	16.	.13	2.0	.37	.80	<.10	.04	.71	3.7	<.10
D168827	67.	11.	.10	1.6	4.0	.85	<.10	.07	.59	6.3	<.10
D168828	56.	18.	.12	1.7	.63	1.20	<.10	.07	.69	9.4	<.10
D168829	63.	21.	.11	1.8	.27	.73	<.10	<.02	.77	1.6	<.10
KERR-McGEE CORPORATION CORE 3C-15											
D168830	78.	8.2	1.08	2.9	.34	.37	<.10	<.02	.23	1.5	<.10
D168831	64.	17.	.13	1.9	.66	.98	.15	.10	.72	6.8	<.10
D168832	68.	15.	.12	2.0	.72	.94	.27	.03	.71	3.7	<.10
D168833	72.	11.	.10	1.6	<.02	.67	.23	.06	.53	4.5	<.10
D168834	64.	19.	.13	1.9	.45	.90	<.10	<.02	.76	3.8	<.10
D168835	62.	23.	.15	1.8	.37	.84	<.10	<.02	.79	2.0	<.10
CARTER OIL COMPANY, CORE 97-C											
D168836	73.	9.5	.35	2.2	3.5	1.43	.17	.02	.42	2.8	<.10
D168837	64.	12.	.13	2.3	3.4	1.98	.11	.04	.59	5.1	<.10
D168838	75.	9.7	.12	2.2	2.8	1.58	.20	.03	.54	2.2	<.10
D168839	55.	16.	.18	2.5	.79	1.23	<.10	<.02	.60	3.1	<.10
D168840	66.	13.	.12	2.3	2.9	1.60	<.10	.03	.63	2.3	<.10
D168841	63.	17.	.13	2.6	1.0	1.33	<.10	.02	.69	2.6	<.10
CARTER OIL COMPANY, CORE 123-C											
D168842	61.	22.	.12	1.6	.36	.84	<.10	<.02	.87	2.2	<.10
D168843	90.	6.8	.07	1.3	.16	.33	<.10	<.02	.31	1.8	<.10

Table 13c

Quantitative Determinations (in parts per million) for 12 Trace Elements in 24 Samples of Rock Overburden Above Coal Beds to be Mined in the Eastern Powder River Basin, Campbell County, Wyoming. See Table 13a for further description of samples.

Sample No.	As	Cd	Cu	F	Hg	Li	Pb	Sb	Se	Th	U	Zn
PEABODY COAL COMPANY, CORE P8-C												
D168820	5	<1	29	790	0.10	35	<25	1.9	<0.1	13.5	4.3	104
D168821	4	<1	20	490	.04	25	<25	---	< .1	10.3	3.8	84
D168822	70	<1	24	620	.11	25	<25	---	< .1	13.2	4.2	70
D168823	4	<1	25	470	.07	26	<25	---	< .1	11.7	4.3	178
D168824	8	<1	20	520	.16	26	<25	---	1.4	13.2	4.2	73
ATLANTIC-RICHFIELD COMPANY, CORE BT-81												
D168825	5	<1	45	640	.13	35	<25	---	.3	15.0	5.0	120
D168826	12	<1	29	690	.15	31	<25	---	2.7	14.0	4.3	128
D168827	5	<1	22	460	.04	22	<25	---	<.1	11.0	3.8	74
D168828	30	<1	30	690	.68	34	<25	---	2.3	12.1	5.1	100
D168829	5	2.5	60	630	.42	32	<25	2.0	1.0	16.7	4.9	375
KERR-McGEE CORPORATION, CORE 3C-15												
D168830	4	<1	10	260	.02	11	<25	---	<.1	7.3	2.3	30
D168831	5	<1	20	740	.09	41	<25	---	1.0	13.2	5.1	100
D168832	10	<1	28	840	.09	34	<25	1.6	<.1	16.0	6.8	126
D168833	15	<1	25	580	.06	23	<25	1.8	<.1	9.2	4.5	100
D168834	5	<1	33	660	.09	39	<25	---	.9	13.3	5.4	100
D168835	5	<1	50	720	.07	50	25	---	.5	14.3	6.9	56
CARTER OIL COMPANY, CORE 97-C												
D168836	8	<1	20	440	.04	21	30	---	<.1	8.5	3.3	52
D168837	20	<1	32	650	.10	28	<25	---	.3	11.8	3.8	94
D168838	3	<1	24	510	.03	21	<25	---	<.1	12.4	4.9	47
D168839	10	<1	38	640	.08	41	30	2.9	.2	15.9	6.1	140
D168840	10	<1	29	660	.05	29	25	---	.3	16.0	5.6	91
D168841	10	<1	40	780	.08	35	25	---	<.1	18.3	5.5	104
CARTER OIL COMPANY, CORE 123-C												
D168842	25	<1	46	780	.50	33	30	1.8	1.3	12.1	4.5	54
D168843	8	<1	<10	250	.03	12	<25	---	<.1	4.3	2.5	23

selenium, but when the values for these samples are averaged with those of the other samples in the same core, their significance is seen to be minimal.

The analyses for an additional 17 trace elements are listed in Table 13d. Almost without exception, these values are about the same or less than the values for comparable sedimentary rocks elsewhere in the United States. None of the slightly higher analyses have significance when averaged with analyses of other samples from the same core.

The conclusion based on the chemical analyses of overburden rock samples is that no elements are present in amounts deserving special attention beyond that given to them in overburden rocks elsewhere. Based on the data, however, some of the carbonaceous shale and claystone units might be worth considering as sediment to be set aside during mining and then returned as topsoil; the slightly greater amounts of desirable micronutrient metals, phosphate, organic matter, and water retentivity may actually be preferable to those of the original soil. In examining trace element contents in any tables the reader is cautioned that samples from core hole, not outcrop, can be contaminated by drilling fluids and drill pipe. New equipment can result in anomalously high values for antimony, zinc, copper and lead. The presence or amount of toxic trace element in coal or overburden serves as a warning of a potential pollutant or contaminant upon the combustion of the coal or the disturbance, oxidation, and leaching of the overburden but does not necessarily indicate a level or degree of resultant toxicity. The form of the element and its interrelation with other elements, both before and after disturbance, oxidation or combustion, and leaching are important. During combustion of the coal trace elements may be emitted to the atmosphere in gas or particulate matter or may be concentrated in the ash. Trace elements may be emitted in

Table 13d

Semiquantitative Spectrographic Analyses (in parts per million) for 17 Additional Trace Elements[1]/ in 24 Samples of Rock Overburden Above Coal Beds to be Mined in the Eastern Powder River Basin, Campbell County, Wyoming. See Table 13a for further description of samples.

Sample No.	B	Ba	Be	Co	Cr	Ga	La	Mo	Nb	Ni	Sc	Sn	Sr	V	Y	Yb	Zr
PEABODY COAL COMPANY, CORE P8-C																	
D168820	30	500	<2	<5	50	30	<50	<5	15	7	10	<15	200	70	15	<2	100
D168821	30	500	<2	5	70	20	50	<5	15	10	10	<15	150	70	20	3	150
D168822	<30	500	<2	20	70	20	50	7	15	100	15	<15	100	100	20	2	100
D168823	50	500	<2	5	70	20	<50	<5	<10	10	10	<15	70	100	15	2	150
D168824	70	500	<2	5	70	30	<50	<5	15	15	10	<15	70	150	20	2	150
ATLANTIC-RICHFIELD COMPANY, CORE BT-81																	
D168825	50	700	<2	10	70	20	<50	<5	<10	20	10	<15	150	150	20	2	100
D168826	50	500	<2	10	70	20	<50	<5	<10	20	10	<15	150	100	20	2	100
D168827	30	500	<2	10	50	15	50	<5	<10	20	10	20	150	70	20	3	100
D168828	<30	1,000	<2	15	100	30	70	<5	<10	30	15	<15	150	150	20	2	70
D168829	50	500	<2	<5	100	30	<50	<5	15	10	15	<15	70	150	20	2	100
KERR-McGEE CORPORATION, CORE 3C-15																	
D168830	30	1,000	<2	<5	30	10	<50	<5	15	7	<5	<15	150	30	15	<2	100
D168831	50	700	<2	10	70	30	<50	<5	15	15	15	<15	200	150	20	2	100
D168832	50	700	<2	5	70	30	70	<5	15	15	15	<15	200	150	30	3	150
D168833	50	500	<2	5	50	15	70	<5	15	15	10	<15	150	70	20	2	150
D168834	50	500	<2	5	70	30	70	<5	15	15	15	<15	150	150	20	2	150
D168835	50	300	<2	5	100	30	50	<5	15	15	15	<15	150	150	20	2	100
CARTER OIL COMPANY, CORE 97-C																	
D168836	50	500	<2	5	30	15	<50	<5	<10	10	<5	<15	100	50	20	2	150
D168837	50	500	<2	10	50	20	70	<5	15	20	10	<15	150	70	30	3	150
D168838	50	700	<2	5	30	15	70	<5	15	15	7	<15	100	50	30	3	500
D168839	50	500	3	10	70	20	70	7	15	30	10	<15	150	150	20	2	100
D168840	50	300	<2	5	50	15	<50	7	15	20	10	<15	100	70	20	3	150
D168841	50	500	<2	10	70	20	70	<5	15	30	15	<15	100	150	20	3	100
CARTER OIL COMPANY, CORE 123-C																	
D168842	50	300	<2	<5	70	30	50	7	15	10	10	<15	70	150	15	<2	100
D168843	50	200	<2	<5	15	<10	70	<5	<10	<5	<5	<15	20	20	15	<2	300

1/ Some 20 additional trace elements were looked for, but were below the limit of detection using this analytical method; for example, it is thus known that all samples contain <2 ppm Ag, Au, and Pd, and <20 ppm Bi, Ge, and In.

dust from the overburden or concentrated in the disturbed rocks by oxidation or leaching. The emitted or concentrated element may be in an invert form or may be as free ions in solution. The amount of a toxic element in solution form is important, because in this form it may be easily ingested by plants and animals. The effects of long-term ingestion of low levels of these elements are poorly understood; most work on toxicity is based on high level exposure of short duration on small animals; extrapolation to humans, therefore, is uncertain.

Standards for acceptable levels of toxic trace elements pertaining to drinking water have been established by the World Health Organization, the U.S. Public Health Service, and the Federal Water Pollution Control Administration (Table 13e). Several water criteria reports containing discussions of trace elements are also listed in the selected references. Standards for acceptable levels or tolerance limits of toxicity for stack emissions or ash accumulations from coal-fired power generating plants and coal gasification and liquification plants have not been established for toxic trace metals.

Recently an exploratory study was set up to answer a specific geochemical question: do element levels in the sampled soils and plants decrease in a uniform way with increasing distance from a power generating plant?

Samples were collected from six localities parallel to, but away from, Interstate 25 at approximate distances of 0.8, 2.6, 6.6, 13.5, 26.4, and 53.8 kilometres from the Dave Johnston power plant. In each locality, two samples of surface soil (0-2.5 cm depth), subsurface soil (15-20 cm depth) and terminal leaves and stems of sagebrush were collected and analyzed by the U.S. Geological Survey for over 30 elements. Sufficient information was

Table 13e

Comparison of Chemical Constituents in the Drinking Water Standards of the World Health Organization and the U.S. Public Health Service

	Concentrations in Milligrams Per Liter						
	WHO International (1971)***			WHO European (1961)		U.S.P.H.S. (1962)	
Chemical Constituent	Permissible Limit(1958)	Highest Desirable Level	Maximum## Allowable	Recommended Limit	Tolerance Limit	Recommended Limit	Maximum Allowable
Alkyl benzene sulfonate	--	--	--	--	--	0.5	--
Ammonia (NIL)	--	--	--	0.5	--	--	--
Arsenic	--	--	0.05	--	0.2	0.01	0.05
Berium	--	--	--	--	--	--	1.0
Cadium	--	--	0.01	--	0.05	--	0.01
Calcium	75	200	--	--	--	--	--
Carbon chloroform extract	--	--	--	--	--	0.2	--
Chloride	200	600	--	350	--	250	--
Chromium (hexavalent)	--	--	0.05	--	0.05	--	0.05
Copper	0.05	1.5	--	3.0*	--	1.0	--
Cyanide	--	--	0.05	--	0.01	0.01	0.2
Fluoride	--	--	0.8-1.7###	1.5	--	0.8-1.7#	1.6-3.4#
Iron	0.1	1.0	--	0.1	--	0.3	--
Lead	--	--	0.10	--	0.1	--	0.05
Magnesium	150	150	--	125**	--	--	--
Magnesium + Sodium sulfate	30	1000	--	--	--	--	--
Manganese	0.05	0.5	--	0.1	--	0.05	--
Mercury	--	--	0.001	--	--	--	--
Nitrate (as NO_3)	--	--	--	50	--	45	--
Oxygen, dissolved (minimum)	--	--	--	5.0	--	--	--
Phenolic compounds (as phenols)	0.001	0.002	--	0.001	--	0.001	--
Selenium	--	--	0.01	--	0.05	--	0.01
Silver	--	--	--	--	--	--	0.05
Sulfate (SO_4)	200	400	--	250	--	250	--
Total Solids	500	1500	--	--	--	500	--
Zinc	5.0	15	--	5.0	--	5.0	--

*After 16 hours contact with new pipes; but water entering a distribution system should have less than 0.05 mg/1 of copper.

**If there are 250 mb/1 of sulfate present, magnesium should not exceed 30 mg/1.

***Based on average consumption of 2.5 liters by an individual weighing 70 kg.

#Recommended limits and maximum allowable concentrations vary inversely with mean annual temperature.

##Tentative upper limit or maximum permissible level.

###Depending on air temperature.

obtained to perform a standard regression, or trend, analysis on the following elements:

> <u>Surface and subsurface soil</u>: Fe, Mg, Ca, Ti, Mn, Ba, Co, Cr, Cu, La, Nb (surface soil only, Ni, Pb, Sc, Sr, V, Y, Zr, Al, K, Ga, Yb, Th, and U.
>
> <u>Sagebrush ash</u>: Fe, Mg, Ti, Mn, B, Ba, Cr, Cu, Mo, Ni, Pb, Sr, V, Zr, Al, P, Se (on dry weight), Li, Cd, Zn, and Co.

For each element in each material, a trend was computed in which the concentration of an element is predicted as a simple function of distance in kilometers from the power plant. The 95 percent standard statistical testing level indicates that Se, Sr, and V are most suspect as metal pollutants, particularly Se. Reductions in Co, Li, Ti, and Zn, while not as statistically significant as the previous three metals, should still be considered suspect.

This evaluation is a simple one, based on limited sampling, and further work is planned. The decrease away from the power plant is compelling, and the most likely source for the observed effects is stack emissions. The amounts of elements concentrated in sagebrush decrease rapidly from the power plant to about background level at 15 kilometers. Although a trend has been established the amounts of metals are not abnormal to contents in sagebrush in the entire Powder River Basin.

Considerable research has been done on certain trace elements such as selenium, cadmium, germanium, sulfur, uranium, vanadium, and flourine. A rare and useful trace element, germanium, is collected from power plant flue dust in England. Small amounts of selenium are actually required by enzymes in human metabolism. A trace amount of fluorine is commonly added to drinking water in many towns and cities to retard tooth decay of children. The National

Academy of Sciences are publishing a series of reports on the toxic trace metals (Vanadium, 1974; Selenium, 1971). In addition, the U.S. Geological Survey has a number of related trace element studies currently in progress in the major coal regions of western U.S. including the Powder River Basin: (1) coal; (2) coal-bearing rocks; (3) coal-related soils; (4) coal-related vegetation; (5) coal-related surface and ground waters. Reconnaissance trace metals surveys are being conducted by the U.S. Geological Survey in order to establish valid geochemical baselines for the major coal regions of the West. These studies encompass geochemical variations in rocks, soils, plants, and waters on a basinwide scale, presently centered on the Powder River Basin. Selenium converter plants and potential selenium problems are being studied on two projects. Problems related to element cycling, both natural and man-caused are being examined.

Some mining companies plan to replace overburden at the proposed surface mines in the same stratigraphic sequence as it is removed. It is recommended that all surface mines in the area be developed by this method. Overburden and coal at the mining face should be periodically sampled and analyzed for content of toxic trace elements.

Quantity of the coal

The Powder River Basin in Wyoming contains an estimated remaining resource of 610 billion tons of coal under less than 3,000 feet of overburden (Table 14). Of that total, 110 billion tons are identified resources (estimates based on known continuity of beds from geologic evidence with observation points generally no more than 1-1/2 miles apart); about 500 billion tons are hypothetical resources (estimates in unmapped and unexplored areas). About 73 billion of the 110 billion tons of the identified resources are estimated to be in Campbell (69 billion) and Converse (4 billion) Counties. About 25 billion tons of coal are under less than 1,000 feet of overburden in Campbell County and about 1.5 billion tons in Converse County. The coal potentially recoverable by present surface mining methods is about 13.5 billion tons in Campbell County and about 0.7 billion tons in Converse County, assuming 80 percent recoverability of coal in the ground (Table 15). Economically recoverable coal by present day surface mining standards is about 12.1 billion tons in Campbell County and 0.25 billion tons in Converse County.

These 12.4 billion tons of economically recoverable reserves are contained essentially in the Wyodak bed in the Eastern Powder River Basin (U.S. Bureau of Mines 1971a). The reserve has been calculated with the following parameters:

1. Minimum coalbed thickness of 5 feet,
2. Overburden-to-coal ratio of less than 10 cubic yards of overburden per ton of coal, and
3. An arbitrary overburden removal limit of 200 feet.

Projected annual coal production for the study area is summarized in Chapter II. Based on those projections, the economically recoverable reserves can be mined by surface methods for about 70 to 80 years.

An additional 24.6 billion tons of coal, mostly contained in the Wyodak bed, may be considered as hypothetically recoverable in the distant future when surface mining technology advances sufficiently to allow economical removal of overburden to a depth of about 400 feet.

Table 14

Estimated Remaining Coal Resources of the Powder River Basin in Wyoming, Jan 1, 1972. (In millions of short tons) Recoverability of tonnage in column 1 is discussed in Table 15

County	Remaining reserves in the ground, 0-1,000 ft. overburden, 1/1/72*	Inferred resources and resources in thin beds, 0-1,000 ft. overburden, plus identified resources in all beds, 1,000-3,000 feet overburden	Total remaining identified resources, 0-3,000 ft. overburden	Additional hypothetical resources in unmapped and unexplored areas, 0 - 3,000 ft. overburden#	Total remaining resources, 0-3,000 ft. overburden
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=(3)+(4)
Subbituminous coal					
Campbell	25,000	44,018	69,018##		
Converse	1,636	2,497	4,133		
Crook	Neg.	8	8		
Johnson	3,000	9,235	12,235##		
Natrona	35	158	193		
Niobrara	Neg.	14	14		
Sheridan	5,000	19,390	24,390##		
Weston	36	244	280		
Total	34,707	75,564	110,271	500,000	610,271
Bituminous coal					
Crook	1	1	2	0	2
Weston	14	18	32	0	32
Total	15	19	34	0	34
Grand Total	34,722	75,583	110,305	500,000	610,305

*Measured and indicated identified resources in thick and intermediate beds, 0-1,000 ft. overburden. Includes subbituminous coal and lignite in beds 5 feet or more thick, and bituminous coal in beds 28 inches or more thick.
#Based on data in Wold and Woodward (1968). Not classified by county.
##From Geological Survey of Wyoming (1972a)

Source: Compiled by Paul Averitt (1973).

Table 15

Method of Recovery of Remaining Coal Reserves of the Powder River Basin, Wyoming, Jan 1, 1972. (In millions of short tons)

County	Remaining reserves in the ground, 0-1,000 ft over-burden, Jan. 1, 1972	Method of recovery				
		Surface Mining			Underground Mining	
		Reserves in the ground	Potentially recoverable	Economically recoverable	Reserves in the ground	Potentially recover-able
	(1)*	(2)**	(3)#	(4)	(5)**	(6)##
		Subbituminous coal				
Campbell	25,000	16,900	13,520	12,100	8,100	4,050
Converse	1,636	810	648	250	826	413
Crook	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Johnson	3,000	2,000	1,600	800	1,000	500
Natrona	35	Neg.	Neg.	Neg.	35	17
Niobrara	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Sheridan	5,000	140	112	112	4,860	2,430
Weston	36	Neg.	Neg.	Neg.	36	18
Total	34,707	19,850	15,880	13,262	14,857	7,428
		Bituminous coal				
Crook	1	0	0	0	1	Neg.
Weston	14	0	0	0	14	7
Total	15	0	0	0	15	7
Grand Total	34,722	19,850	15,880	13,262	14,872	7,435

*From Col. 1, Table 4.
**Col. 2 plus col. 5 equals col. 1.
#80% of figures in col. 2.
##50% of figures in col. 5.
SOURCE: Compiled by Paul Averitt (1973).

The estimates for identified resources in Tables 14 and 15 are based on information collected prior to 1953. More recent information suggests that these identified resource estimates are conservative (U.S. Geological Survey 1973d). No hypothetical resources are included for Campbell and Converse Counties because data were not reported on a county basis. Estimates in the reserve category are also conservative because the inferred resource category as set up in rules governing resource estimates must include thick beds of coal remote from outcrops and points of measurement. The inferred resource category is not included as reserves. In future resource estimates using more recent data, the reserve and identified resource tonnages will be increased by a transfer of tonnages from the inferred and hypothetical resource estimates.

Oil and gas

The earliest oil and gas activity in the Eastern Powder River Basin occurred in the 1890's, and the first production of oil and gas is recorded in the early 1900's. Serious oil and gas exploration of the Powder River Basin began during the closing days of World War I and lasted through the 1920's. Exploration has been intense and steady since 1948 when both independent and major oil companies found that exploration drilling in the Powder River Basin is less expensive and less risky than drilling wells of equal depths in other petroleum provinces. A fact of prime importance to oil and gas investors in this area is that the discovery rate is about one out of nine exploratory wells while the national average is about one out of eleven. Intensive oil and gas exploration of the area is expected to continue for at least ten more years. The area may then have been adequately explored for those zones currently producing within the basin. Following this exploration cycle, exploration is expected to decline rapidly.

Rock subdivision and unit names as used by oil and gas specialists and drilling contractors do not always correspond to those used by mining or groundwater specialists; therefore, the generalized rock sequence that may be reported in exploratory wells in the Eastern Powder River Basin follows:

Formation	Era	Thickness	Productive oil or gas zones
White River Formation	Oligocene	0 - 500'	x
Wasatch and Fort Union Formations	Lower Eocene & Paleocene	3,000 - 5,000'	x
Lance Formation including Fox Hills Sandstone	Upper Cretaceous	0 - 3,500'	x
Lewis Formation or Upper Pierre Shale	Upper Cretaceous	400 - 800'	x
Mesaverde Formation	Upper Cretaceous	? ?	x
Lower Pierre Shale or Steele Shale	Upper Cretaceous	1,300 - 1,800'	x
Niobrara Formation (sometimes part of lower Pierre Shale)	Upper Cretaceous	500'	x
Frontier Formation including Carlile Shale	Upper Cretaceous	200'±	x
Graneros Group	Upper & Lower Cretaceous	600 - 900'	x
Dakota Group	Lower Cretaceous	250'±	x
Morrison Formation	Jurassic	100'±	x
Sundance Formation	Jurassic	300' ±	x
Spearfish Formation	Triassic	300 - 500'±	
Goose Egg Formation	Permian	200'±	
Minnelusa Formation	Pennsylvania	400 - 1,000'	x
Madison (Pahasapa) Limestone	Mississippian	200 - 800'	x
Devonian	Devonian	(0) none known	
Silurian	Silurian	(0) none known	
Ordovician	Ordovician	50 - 300'	
Cambrian (Deadwood Formation)	Cambrian	50 - 800'	

Oil and/or gas have been discovered in about 210 fields within the Eastern Powder River Basin study area (Figure 16). About 90 percent of the fields produce from either or both of two main zones, the Muddy sandstone of Early Cretaceous age and the Minnelusa Formation of Pennsylvanian age. A very active oil and gas exploration program is continuously adding many new fields and zones to the discovery lists. In fact, exploration activity for new fields in 1974 is again at an all-time peak due to the energy crisis and the unprecedented prices being paid for oil and gas. The remaining recoverable reserves of the 210 existing fields within the eastern part of the basin study area are conservatively estimated at 221 million barrels of oil and 508 billion cubic feet of natural gas.

The known geologic structures of the discovered fields within the eastern basin study area contain some 516,000 acres considered economically valuable for production of oil or gas. This acreage includes approximately 2,000 presently producing wells and 2,300 formerly productive wells. Of the known fields 166 are actively producing and 44 fields are classified as temporarily nonproductive. A majority of the nonproductive fields are shut-in, waiting for secondary or tertiary recovery procedures to be implemented, are being considered for reactivation, or are in the process of activation.

Regardless of the overlap of producing fields with surface coal mines, the area required by oil and gas facilities is less than one percent. The average area used by oil well facilities, including pumper, separator, ponds, pipelines, and access roads, does not exceed 15 acres per square mile. Where several wells share land facilities or are developed on wide spacing, the area required is less than five acres.

One shut-in and about 20 producing oil or gas fields overlap the area of strippable coal and may conflict with operations in future proposed mines.

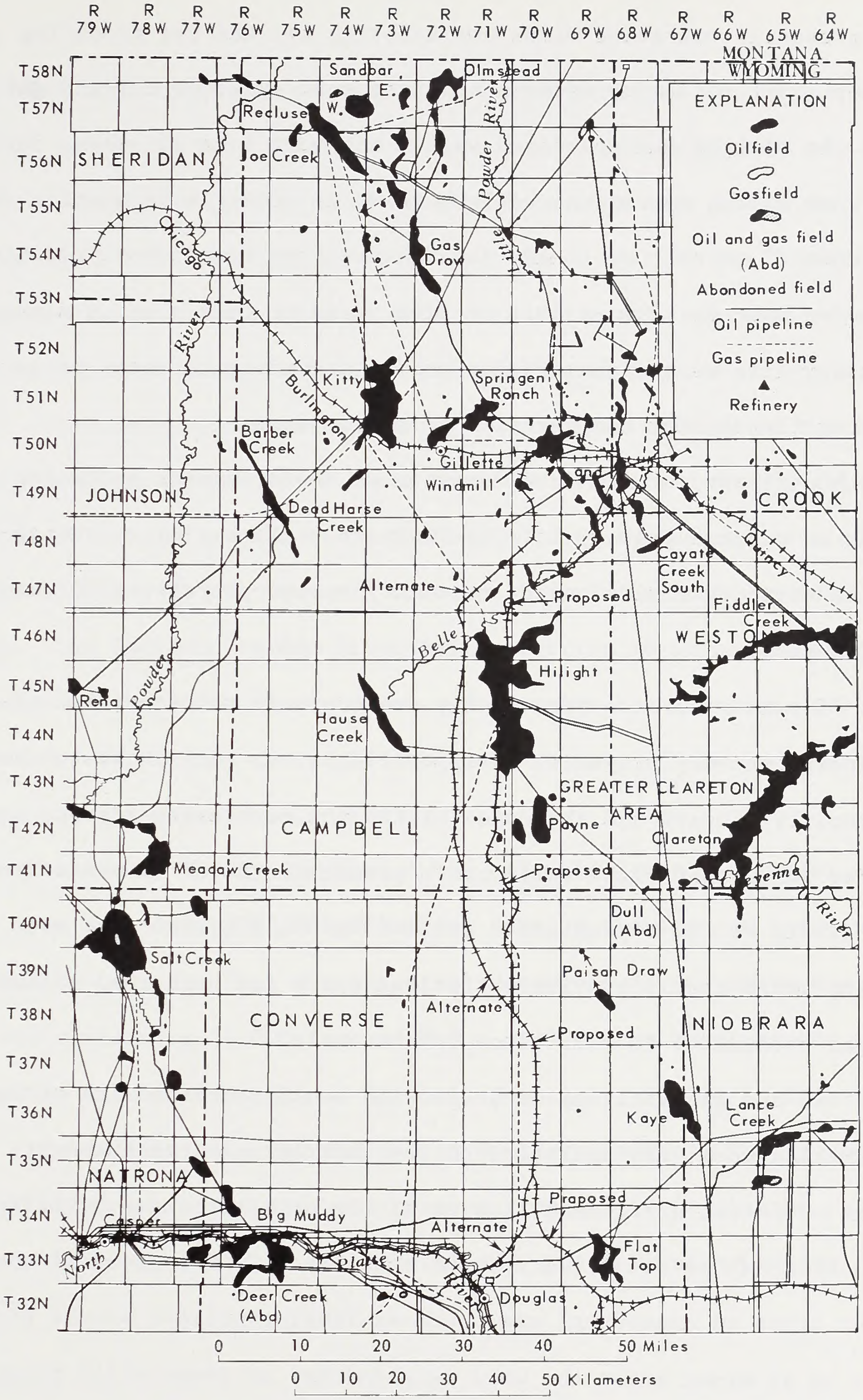


Figure 16

Oil and Gas Fields Associated With the Eastern Powder River Basin, Wyoming

However, presently operating mines and existing oil and gas producing areas do not overlap. The following factors indicate most existing oil and gas producing areas will be plugged and abandoned within the next 5 to 15 years, before most proposed coal mining operations will be ready to commence in overlap areas:

1. More than 75 percent of fields in 1974 are from Cretaceous producing zones having an average primary life of five years or less plus an average secondary life as stripper fields and/or secondary recovery projects, such as water floods, for another five to seven years.
2. Less than 25 percent are from Jurassic or Pennsylvanian producing zones having an average primary life of 10 years or less plus an average secondary life as stripper fields and/or secondary recovery projects for another three to five years.
3. About 75 percent of the present day producers in all zones are already in secondary recovery projects, stripper fields, or shut-in status and should be properly plugged and abandoned within the next seven years.
4. The few wells that might still be in production 10 or 15 years from 1974 will likely be the recent wells drilled on 40-, 80-, 160-, or even 320-acre spacing which should provide sufficient space for both coal mining and oil and gas production to take place concurrently.
5. Where oil and gas drilling or production would conflict with mining or reclamation work, the Secretary of the Interior has the authority to suspend either operation until such time as mining or oil and gas drilling or production can be conducted without conflict. This is done if the lessees cannot agree on concurrent use, such as leaving pillars around producing wells to be mined after the well is abandoned or temporarily plugging the well below the coal and reestablishing production after mining. All plans are subject to approval by the U.S. Geological Survey.

Uranium

The host rocks for uranium ores and minerals in the Powder River Basin are fluvial sandstone beds distributed from top to bottom of both the Fort Union and Wasatch Formations. A few radio-active anomalies have also been found near the top of the Lance Formation of Cretaceous age. Most of the deposits are located east of the basin's axis in beds that dip gently westward toward the axis. Some deposits occur in beds that dip 10 to 15 degrees on the west side of the axis. Uranium exploration and mining is confined chiefly to the Pumpkin Buttes and Southern Powder River Basin uranium districts. The Pumpkin Buttes district is in extreme southwestern Campbell County extending about six miles into Johnson County to the west and three or four miles into Converse County to the south. The Southern Powder River Basin district is in northwestern Converse County north of the North Platte River. No uranium ore deposits have been found north of T46N, and, except in the southern part of the basin south of T37N, none have been found east of R72W.

The Atomic Energy Commission has estimated that the Powder River Basin of Wyoming contains 25,400,000 short tons of uranium ore containing 40,000 tons of U_3O_8 and that the potential resources of the basin are 14,000,000 tons of ore containing 26,000 tons of U_3O_8. All of the reserves and most of the resources lie within Converse and Campbell Counties, chiefly in Converse County.

Mineralized material and ore in southern Campbell County and northern Converse County occur in areas well removed from active or planned coal mining activity with an exception of one mineralized zone. Uranium-bearing rock of less than ore grade was detected on parts of coal lease No. W-0244167 of the Pacific Power and Light Company and parts of lease Nos. W-0136195 and W-0136196 of the Humac Company, just north of the Pacific Power and Light Company lease.

On the Pacific Power and Light Company lease, low-grade uranium-bearing rock and thin spotty concentrations of ore-grade rock occur in an area 1 mile long and 1,000 feet wide in parts of sections 3 and 10, T36N, R75W. The top of the mineralized zone is at an elevation of about 5,450 feet, 25 to 50 feet below the base of a coalbed. Thin, mineralized beds alternating with barren rock are distributed through a vertical distance of about 50 feet. The grade and distribution of uranium here is such that no attempt has been made to exploit the deposit; but it is possible that, after the coal has been stripped, the uranium could be mined at a profit.

Numerous weak radioactive anomalies in the subsurface define a sinuous mineralized trend extending through sections 17, 18, 19, 20, 29 and 30, T37N, R74W on the Humac Company lease. The trend is probably an extension of the mineralized material on the Pacific Power and Light Company lease. No mineable accumulation of uranium has been found along the trend on the Humac Company lease.

Land use for exploration, development and mining of uranium is mostly in the mining districts. The Pumpkin Buttes district is west of most strippable coal. Strippable coal deposits extend into the Southern Powder River Basin district and here uranium deposits could exist in overburden materials or beneath mineable coalbeds. No mineable uranium deposits are known that conflict with coal mining operations, either active or planned. Extensive drilling for seismic shot lines, water wells, oil testing and coal exploration has not discovered workable uranium deposits or significant mineralization in proximity to strippable coalbeds in areas leased for coal in Campbell County. Uranium mineralization in overburden occurs in Converse County.

Early mining activity took place in the Pumpkin Buttes and other localities such as Turnercrest, Monument Hill, and Box Creek. Mining was conducted for deposits at or near the surface which were extracted from open pits. All of these mined-out pits are less than 100 feet deep and most are less than 5 acres in area. In the late 1960's exploratory activity for uranium was accelerated in the Powder River Basin resulting in discovery of significant ore bodies in the Southern Powder River Basin district.

Operation of the Exxon Corporation mine in section 28, T36N, R72W, and mill in section 29 in the same township will result in the disturbance of about 600 acres during the open-pit phase of production. The mill will occupy about 30 acres and tailings and mill waste about 250 acres. About 120 million cubic yards of earth will be moved. Upon completion of open pit mining, ore will be removed by underground methods starting in the wall face of the pit. Production from the underground phase is expected in early 1977. The Exxon ore deposit extends from section 28, northward through sections 20 and 21 into section 17, T36N, R72W. Overburden and waste from each pit is scheduled for use as fill in mined-out pits as the open-pit phase progresses.

The operation of the Teton Exploration Drilling Company is in section 1, T35N, R72W. Ore is trucked to the mill of the Exxon Corporation about 6 miles away and sold as custom ore. The uranium ore is extracted from a small open pit by conventional mining methods. Further operational data are not available.

The Kerr-McGee Corporation is sinking a shaft in section 36, T36N, R74W a few miles southwest of Exxon's operation. The underground mine is scheduled for production in 1975. When complete, the Kerr-McGee Corporation project will include one or more additional underground (shaft) mines and one or more open pits as well as a mill.

Other minerals

Clinker, also called baked shale, natural slag, scoria and red dog, is abundantly widespread throughout eastern Campbell and Converse Counties. Clinker is a reddish natural slag formed by the fusion and baking of strata overlying coalbeds when the coal burned. The clinker is a resource for road surface material, railroad ballast and construction and ornamental stone. Clinker is unsually readily accessible for quarry operations because it caps hills and ridges. Thicknesses of clinker as much as 50 feet have been reported. According to Dobbin and Barnett (U.S. Geological Survey 1927), several billion cubic yards of clinker underlie parts of T49 and 50N, R70 and 71W. This is only a small area of the total occurrences in the basin. The rock is quarried by conventional methods and crushed, primarily for railroad ballast and road surfacing. No data are available on actual reserves, but they are counted in hundreds of billions of cubic yards. The supply of clinker is almost inexhaustible. Thus, projected or actual increases in production will have little effect on the total clinker resource.

Sand and gravel suitable for construction purposes is scarce in the Powder River Basin in Campbell and Converse Counties except along the flood plain of the North Platte River. Scattered local deposits, as much as 10 feet thick with pebbles as much as 2 inches in diameter, are found along the major tributaries to streams draining the basin area. Several areas of active and inactive windblown sand deposits occur in the study area. The most prominent are in T34N, R74W, north of Glenrock and along the Belle Fourche River in T47N, R70W. Deposits of sand and gravel tested or used occur along the North Platte River and in the upper reaches of the Belle Fourche River. Most deposits along the Belle Fourche River are in T46N, R71 and 72W and T48N, R69W. The Wyoming Highway Department has identified several deposits containing not less than 25,000 cubic yards of sand and gravel along the North Platte River in Converse County.

There are three small companies in Casper, Wyoming, that mine or consume sand and gravel. The flood plain of the North Platte River contains most sand and gravel deposts and is the chief source.

Shale for local use as road surface material is quarried from the Potter shale pit about 3 miles from Gillette. Crushed and pit run material is sold to consumers. The Wyoming Highway Department quarries a sand and gravel deposit in T45N, R72W, about 2 miles west of Wyoming Route 59 on the Belle Fourche River. This operation is about 150 acres in area.

Water Resources

Most of the data used in compiling the following discussion of ground water and surface water were collected under the cooperative program of the U.S. Geological Survey and the Wyoming State Engineer.

Ground Water

The rocks considered in this discussion of ground water in the Eastern Powder River Coal Basin have been divided into two groups. The uppermost rocks include important aquifers within the sand, shale and coalbeds of Tertiary and Late Cretaceous age. These aquifers have potential for the development of water resources and are within economic drilling depths for most purposes. The lowermost formation considered in this group is the Fox Hills Sandstone which exceeds 7,000 feet in depth in the western part of the Eastern Powder River Coal Basin.

Underlying the Fox Hills Sandstone are 4,500 to 5,000 feet of rocks, predominately shale, that are not considered potential aquifers. Beneath this thick shale section, however, are several sandstone and limestone formations that, although deeply buried in the Eastern Powder River Coal Basin, are important aquifers in nearby areas where they are nearer the land surface. Because of the potential economic importance of these deeper aquifers, they are also considered. Figure 17 is a generalized geologic section across the Powder River Basin and shows the position of these rocks in the subsurface. Figure 18 shows the stratigraphic relation of the rocks in the basin.

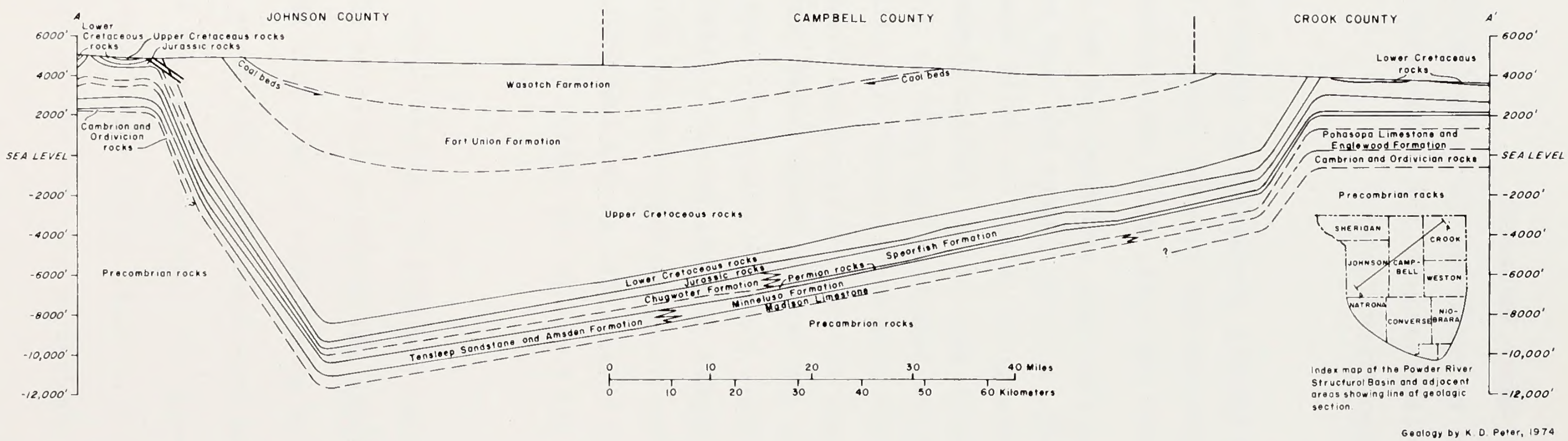
Upper aquifers

Alluvium. The alluvium consists of unconsolidated silt, sand and gravel underlying the flood plains and bordering terraces of the stream valleys. The thickness of the alluvium at most places is less than 60 feet.

Depth to water ranges from about three feet to as much as 20 feet below land surface. Water levels fluctuate seasonally and with precipitation amounts (see Figure 19). Yields of water to individual wells range from a few gallons per minute to several hundred gallons per minute depending on permeability

Figure 17

Generalized Geologic Section of the Powder River Structural Basin and Adjacent Areas, Northeastern Wyoming.



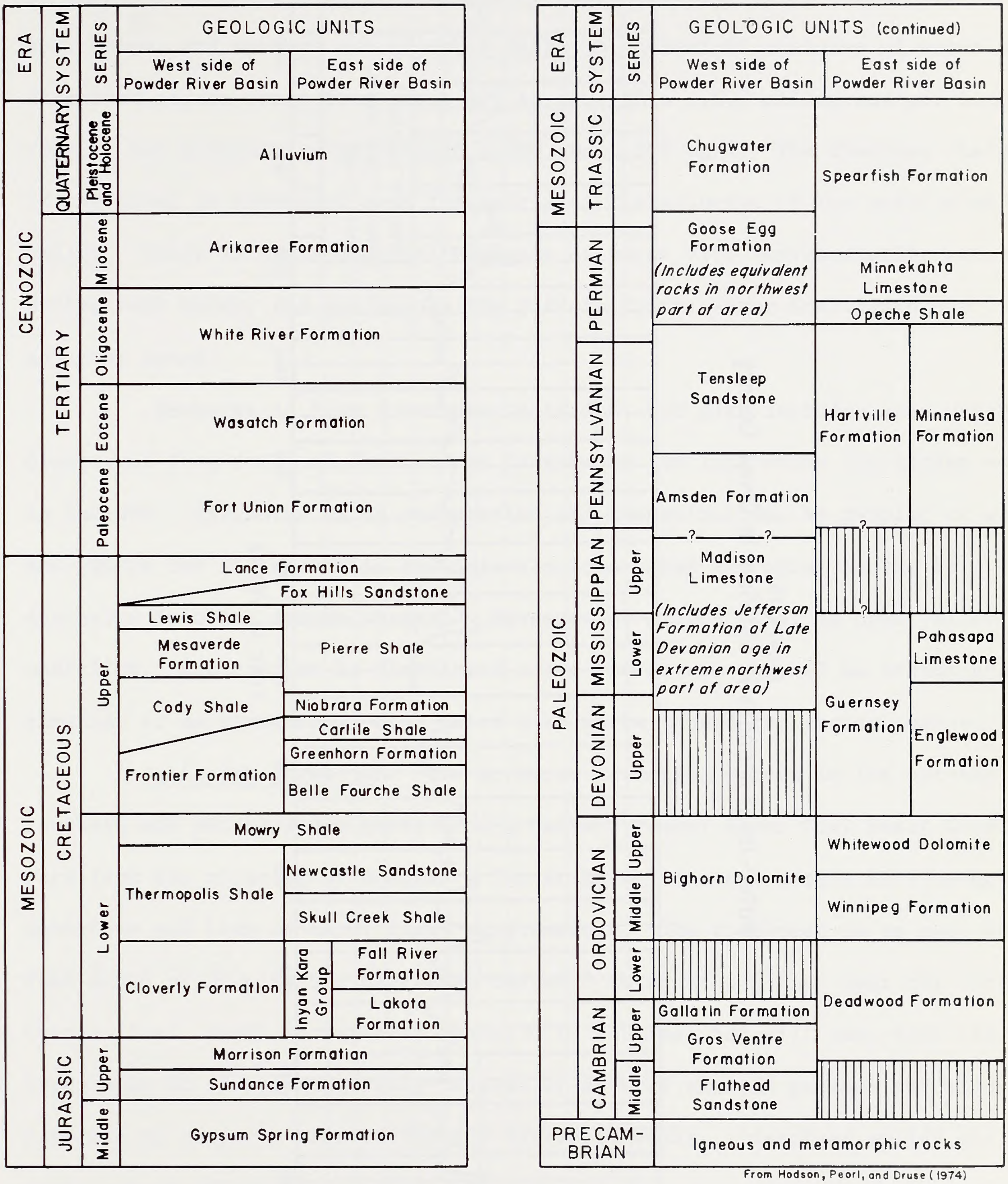
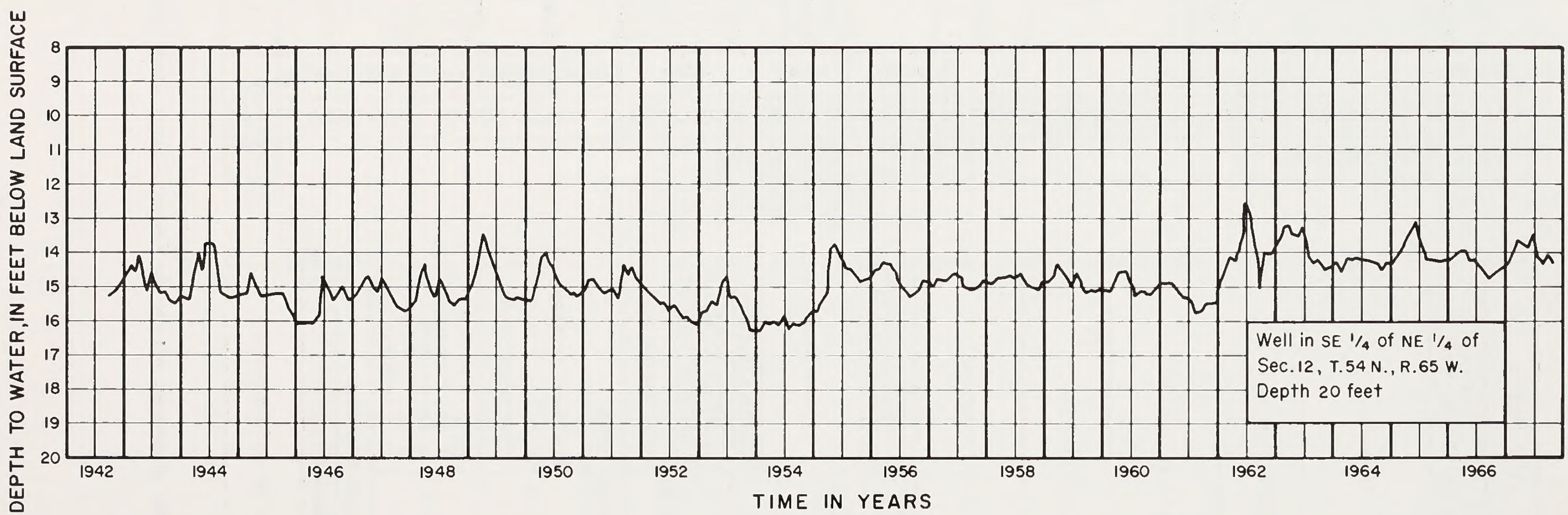


Figure 18
Stratigraphic relation of geologic units in the Eastern Powder River Coal Basin and adjacent areas

Figure 19

Water-level changes in alluvium in Crook County



of the deposits, saturated thickness, well construction and development, and on quantity of water needed. Records of representative water wells, deep oil-test holes, and springs are given in Table 16. Chemical analyses of water show dissolved solids range from about 500 to more than 2,000 milligrams per liter (mg/l), but commonly range between 1,000 and 1,500 mg/l. The chemical character of the water is dependent upon the matrix of the alluvium of the particular valley. Table 17 lists chemical analyses of water from representative water wells, test holes, and springs in the Eastern Powder River Coal Basin and adjacent areas.

Recharge is from local precipitation, but also includes some water discharged from rocks of Tertiary or Cretaceous age into which the stream valley is incised. Discharge is by evaporation and transpiration, by pumping of wells, and, where the stream bed is sufficiently lower than the water table, by discharge into the stream channel. Movement of ground water is down valley as underflow. Where water is discharged along the stream channel as evapotranspiration or as streamflow, some water also moves toward the stream channel.

Arikaree Formation. The Arikaree Formation occurs in the extreme southern and southeastern parts of the Eastern Powder River Coal Basin southward from the vicinity of Douglas. The Arikaree consists mostly of fine-grained sandstone and beds of hard, limey conglomerate. The thickness is as much as 700 feet south of Douglas but decreases eastward to about 300 feet near the Converse County line. Depth to water is about 50 to 100 feet but will vary with the topography of the land surface. Yields of several hundred gallons per minute are possible to properly constructed and developed wells. Dissolved solids are mostly about 300 mg/l.

Table 16

Records of Selected Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Coal Basin and Adjacent Areas, Northeastern Wyoming

See footnotes for abbreviations.

Location twp(n) rng(w) sec ¼ of ¼	County	Owner or tenant	Year drilled	Altitude of land surface above mean sea level (ft)	Depth of well below land surface (ft)	Distance to water below land surface (ft) 1/	Diam of well (in)	Use of water 2/	Geologic source	Discharge or flow (gallons per minute) 1/	Drawdown (ft below non-pumping water level) 1/	Date of measurement mo - yr	Remarks
33 72 7NWSE	Converse	Fred Marberger	1943	4880	12	8	2	D	Alluvium	-----	------	7-31	
33 73 25NWNW	"	Henry Slichter	----	5060	Spring	Flowing	0	S	White River Formation	5	------	7-50	
27SENW	"	I.O. Carlson	----	5100	92	9M	10	D	" " "	-----	------	7-50	
27SWSE 1	"	H.A. Blackburn	----	5100	30	12M	8	S	" " "	6	------	7-50	
27SWSE 2	"	" " "	----	5100	160	15	6	S	" " "	-----	------	7-50	
34SWNW	"	Unknown	----	5140	8	6M	60	N	" " "	-----	------	7-50	
33 75 4NENW	"	Phillips Petroleum Co.	1951	4992	9337			In	Madison Limestone	-----	------	7-51	
33 76 16NESW	"	Continental Oil Co	1964	5234	6954	Flowing	13	In	Madison Limestone	195	------	1-64	DST 9,162-9270 Ft. Cored 9,293-9337 Ft
33 77 3SENW	Natrona	John E. Peirce	1958	5025	20	6M	27	I	Alluvium	252	6	8-66	
15SWNW	"	Amax Petroleum Corp.	1966	5165	7615	Flowing	8 5/8	In	Madison Limestone	65M	------	7-66	
33 79 24SWNE	"	Casper Country Club	1959	5340	5101	Flowing	7	I	Cloverly Formation	40M	------	----	
33NWNW	"	Dempsey Stables	1958	5760	100	40	6 5/8	S	Cody Shale	-----	40	10-58	Date estimated
33 80 6NWSW	"	T.J. Lang	1961	5375	204	Flowing	5	S,D	Frontier Formation	1	------	12-66	Discharge estimated
8NENE	"	Bill Dye	1946	5271	147	29M	6	D	" " "	-----	------	7-50	Not used for drinking
33 81 33SESE	"	Tom Rennard	1948	5278	42	17M	6	S,D	Alluvium	-----	------	7-50	
34 61 6SESW	Niobrara	M.W. Jensen	----	4340	9	2M	30	S	White River Formation	6	2.0	11-59	
17NESW	"	P. Percival	----	4504	50	16M	6	D	" " "	5	------	9-58	Discharge estimated
34 62 29SESW	"	R. Roberts	1950	4589	80	30M	12	I	Arikaree Formation	195M	30M	10-58	
34 65 1SWNW	"	Continental & Ohio Oil Co	1946	4740	265	140	8	In	Inyan Kara Group	220	50	10-59	
4NWSW	"	" " " "	1955	----	300	Flowing	8	S	White River Formation	-----	------	10-59	
34 76 8SWNW	Converse	Phillips Petroleum Co.	----	----	3576	200	9	W	Mesaverde Formation	140	------	-----	
34 77 9SWNW	Natrona	Cole Creek Sheep Co.	----	5384	90	12	6 5/8	S	Lance Formation	-----	------	11-65	
34 79 17NWSE	"	R.M. Nunn	1955	5275	405	30	6	S	Cody Shale	15	0	-----	Discharges, drawdown estimated
34 80 21NESW	"	Casper Air Terminal	1963	5305	3100	Flowing	7 5/8	I	Cloverly Formation	30	------	-----	
30SENE	"	R.W. Noland	----	5305	11	6M	48	D	Alluvium	-----	------	6-67	
32NWSW	"	Wyatt Bros.	1961	5265	735	Flowing	8 7/8	S	Frontier Formation	-----	------	5-67	
35 60 27NENW	Niobrara	D.E. Jordan	1945	----	15	13M	48	S,D	Alluvium	5	4.4	11-59	
35 62 15SWNE	"	E.H. Himes	----	----	105	59M	6	D	White River Formation	5	30	9-59	
35 64 26NWSW	"	W.L. Magoon	1941	----	126	54M	--	S	" " "	5	------	11-59	
35 65 3SWSW	"	Lance Creek Village	----	----	11	6M	--	P	Alluvium	16	2	11-59	12 Ft by 24 Ft casing
35 65 15SENE	"	" " "	1952	----	80	45	5	D	Pierre Shale	5	45	11-59	
35 70 4NENW	Converse	Thomas Meisner	1946	----	415	Flowing	4	S	Fort Union Formation	.6M	------	6-69	
36 65 14NWSE	Niobrara	L.A. Penfield	1940	----	73	45	6	S,D	Lance Formation	5	------	11-59	
36 75 9SWSW	Converse	Resource Exploration	----	----	360	210	4	In	Fort Union Formation	-----	------	-----	
37 78 7SWSE	Natrona	Atlantic Refining Co.	1962	5498	1796	200	10 3/4	In	Mesaverde Formation	116	------	3-62	
37 79 19SESE	Natrona	Burke Sheep Co.	----	----	210	90	6	S	Mesaverde Formation	-----	------	-----	
30SWSE	"	" " "	----	----	510	79M	7	S	" "	-----	------	8-66	
37 82 36NWNW	"	M.F. Gowin	----	----	925	Flowing	[illegible]	[illegible]	Frontier Formation	-----	------	2-67	
36SESE	"	" " "	1929	5560	1275	Flowing	10 3/4	D	Cloverly Formation	-----	------	2-67	
38 62 17NENE	Niobrara	C.R. Brewster	----	----	110	1M	6	D	Fox Hills Sandstone	-----	------	10-59	
38 63 23SWSE	"	J. Wasserberger	----	----	105	45	6	SD	" " "	5	------	3-60	
38 79 34SENW	Natrona	Teapot Ranch	----	----	100	70M	6 5/8	S	Mesaverde Formation	-----	------	4-66	
39 61 2NESE	Niobrara	Coronado Oil Co.	1962	3832	3425	-------	---	In	Madison Limestone	-----	------	-----	
39 65 21SWSW	"	Spring Creek Ranch, Inc	1951	----	280	70	5	S	Lance Formation	5	------	-----	
39 66 10NENE	"	Unknown	----	----	132	109	---		Fort Union Formation	-----	------	-----	
39 72 6SENW	Converse	John Dilts	1968	----	1104	Flowing	2	S	Fort Union Formation	24	------	6-68	
39 79 11SESE	Natrona	Amax Petroleum Corp.	1939	----	2069	-------	6 5/8	D,I	Frontier Formation	7	------	-----	
39 82 9NWSW	"	Lone Bear Ranch	1964	----	1030	Flowing	2 3/8	S	" "	5	------	-----	
39 83 13SENW	"	James Kidd	----	----	117	Flowing	---	S,D	Mowry Shale	-----	------	10-65	
40 73 8SESW	Converse	Fred Taylor	1937	4836	310	Flowing	[illegible]	S	Wasatch Formation	5.5M	------	7-69	
40 78 11SWNE	Natrona	Town of Edgerton	1961	5120	950	62	8 5/8	N	Fox Hills Sandstone	22	249	6-63	
26NWSW	"	Bob Parsons	----	5030	90	60	7 ½	D	" " "	-----	------	-----	
40 80 27NENW	"	John J. Tobin	1966	----	1150	Flowing	2 3/8	S	Frontier Formation	2	------	-----	
40 81 20NESW	"	Lone Bear Ranch	1962	----	1029	Flowing	2 3/8	S	" "	2	------	9-65	
41 60 7NWSE	Weston	Francis Carr Ranch	1939	----	530	Flowing	6	N	Inyan Kara Group	150	------	5-69	
17NENE	"	G. Darrow	----	----	415	Flowing	4	S,D	" " "	4	------	5-69	
41 61 1SWNE	"	Morrisey Pipeline Co.	1968	----	665	Flowing	6	S	" " "	3	------	5-69	
41 63 15NENE	"	Mick James	----	----	180	140	6	D	Lance Formation	-----	------	-----	
41 80 22SWNE	Johnson	Wm. G. Irvine	1955	4810	1150	Flowing	2	S	Frontier Formation	10	------	-----	
30SENW	"	A.R. Gierse	1960	----	1292	275	2	S	Cloverly Formation	2	125	10-60	
41 81 25SENE	"	" "	1966	----	1016	250	5	S	" "	18	120	-----	
42 60 7NWSW	Weston	D and G Baldwin	1965	----	1469	10	4½	S	Inyan Kara Group	2	120	8-65	
42 65 6NESW	"	True Oil Co.	1960	----	2259	150	13	In,W	Fox Hills Sandstone	47	200	8-60	
30SWNW	"	Willis Bruce	1968	----	114	50	7	S	Lance Formation	30	.5	10-68	
42 67 14SWNE	"	Field Ranch	1965	----	161	60	6	S	Fort Union Formation	30	40	8-65	
42 70 5SESE	Campbell	Burton K. Reno	1966	----	233	110	6	S	Wasatch Formation	10	30	-----	
42 77 24NESW	Johnson	Robert Moore	1960	----	530	Flowing	2	S	" "	6	------	12-60	
42 78 15NESW	"	Continental Oil	----	5280	630	184	6 7/8	S	Lance Formation	3.5M	------	8-69	
42 81 25NWSW	"	" "	1963	5038	4246	Flowing	12	In	Madison Limestone	1000	------	-----	
42 82 14NESW	"	Gulf Res Dev Co.	----	----	640	Flowing	4	S	Cloverly Formation	.1M	------	[illegible]-69	
42 84 25SWSW	Johnson	Blue Creek Ranch	1930	----	800	Flowing	4	S	Tensleep Sandstone	-----	------	-----	
43 80 20SWSW	"	Joe Kos	----	----	140	17	4	D	Fox Hills Sandstone	-----	------	-----	
20SWSW	"	" "	----	4498	16	8M	24	S	Alluvium	-----	------	9-50	
43 81 5NW	"	----------------	----	----	285	-------	--	---	Cody Shale	-----	------	-----	
10NESW	"	Walter Elm	----	4579	400	9M	4	S	Mesaverde Formation	-----	------	7-50	
43 82 12SWNE	"	City of Kaycee	1950	4647	17	6M	60	P	Alluvium	-----	------	8-50	

Location twp(n) rng(w) sec ¼ of ¼	County	Owner or tenant	Year drilled	Altitude of land surface above mean sea level (ft)	Depth of well below land surface (ft)	Distance to water below land surface (ft) 1/	Diam. of well (in)	Use of water 2/	Geologic source	Discharge or flow (gallons per minute) 1/	Drawdown (ft below non-pumping water level) 1/	Date of measurement mo - yr	Remarks
43 82 15SWNW	"	Elmer F. Gosney	1911	----	1925	Flowing	16	S	Tensleep Formation	467	------	-----	
21SWSE	"	Author Malnas	1929	----	329	Flowing	4	S,D	Frontier Formation	2	------	8-69	
43 83 5SWSW	"	Robert Brock	----	----	Spring	Flowing	--	D	Tensleep Sandstone	30	------	-----	
43 84 4SENE	"	Nall Walcott	1946	----	750	Flowing	4	S,D	" "	22	------	8-69	
26NWSW	"	Dean Graves	1947	5200	761	Flowing	4	S,D	" "	45	------	-----	
44 62 2SWSE	Weston	Dave True	1955	----	6227	Flowing	8	---	Deadwood Formation	5M	------	---63	
22SWSW	"	McAlester Fuel	1965	----	3832	5	13	W	Lakota Sandstone	146	------	---67	30 ft static water level reported
44 64 27SWNE	"	Western Plains Petroleum	1964	----	5331	175	10 3/4	W	Inyan Kara Formation	18	------	2-66	
44 82 17SESE	Johnson	J.T. Spratt	----	----	12	7M	60	D	Alluvium	-----	------	8-69	
44 83 8NWNW	"	Brock Livestock	----	----	400	-------	6	S	Tensleep Sandstone	-----	------	-----	
45 61 2SWNW	Weston	C. Fred Martens	1933	4700	720	Flowing	6	S	Minnelusa Formation	8M	------	9-62	
20SWSE	"	City of Newcastle	1949	4360	2638	Flowing	10 3/4	P	Pahasapa Formation	1450	------	2-49	200 p.s.i.(460 Ft above LSD) in 1949
28NWNE	"	Louis W. Carlson	1962	4715	1950	Flowing	10	In	Minnelusa Formation	300	------	-----	
28NWNE	"	" " "	1962	4440	2738	Flowing	7	S	Pahasapa Formation	1200M	------	-----	
29NWSW	"	Grayco Refinery Co	1941	----	830	-------	10	--	Lakota Formation	-----	------	-----	
29NWSW	"	Sioux Oil Co	1960	4240	3073	Flowing	--	In	Pahasapa Formation	117M	------	5-60	
30SENE	"	City of Newcastle	1961	4280	3028	Flowing	10	P	" "	650M	------	7-60	
33NWNE	"	Coronado Co	1964	4378	3596	Flowing	6	W	" "	290	------	-----	
45 62 22SWSW	"	Engle Ranch	----	----	3450	Flowing	--	S	Inyan Kara Group	5	------	5-69	
45 63 4NESW	"	Sherrill Slagle	1925	4052	1800	Flowing	8	S	" " "	30M	------	3-66	
45 79 20SENW	Johnson	Shell Oil	1966	4679	4760	2156	--	W	Lance Formation	124	1008	3-69	
45 81 18NWSE	"	John Myhre	1956	5060	200	128	4	S	" "	-----	------	-----	
45 83 7NWNE	"	Mat Ranch	----	----	Spring	-------	--	D	Tensleep Formation	-----	------	-----	
18SWSE	"	Leroy Smith Jr	1962	----	260	18M	6	S	" "	50	0	8-69	
46 60 31NENW	Weston	C. Fred Martens	1942	4760	1178	Flowing	2	S,I	Pahasapa Formation	35	------	-----	
46 62 18SENW	"	David Seeley	1957	4505	2677	Flowing	5	S	" "	30M	------	-----	
27SWSE	"	V.E. Lissolo	1950	----	300	20	6	S	Lakota Formation	-----	------	-----	
46 63 5SESE	"	Lydia Roy	1920	4250	----	Flowing	--	S	" "	1.2M	------	5-64	
10SWSE	"	Black Hills Pwr & Lgt Co	1941	4350	2592	Flowing	10	In	Pahasapa Formation	580	------	8-60	Osage Plant well #1
18SENE	Weston	Coronado Oil	1925	----	1030	Flowing	--	D	Lakota Formation	25	------	2-46	
19SENW	"	Martens	1920	4075	1645	Flowing	--	O	Inyan Kara Group	6.7M	------	9-60	
21NENE	"	Julius	----	4225	1500	Flowing	--	S,D	Lakota Formation	1.3M	------	5-64	
31NW	"	Bock Estate	----	----	1900	-------	--	---	Fall River Formation	-----	------	-----	
46 64 11NWSE	"	E.J. Thompson	1942	----	1800	Flowing	--	D	Lakota Formation	6M	------	9-60	
13SWSW	"	The Coronado Co.	1959	----	1927	Flowing	6	---	" "	210M	------	-----	Govt.-McCullough
13SWSW	"	" " "	1960	4068	4522	Flowing	8	W	Pahasapa Formation	30	------	-----	" " "
20NWNW	"	Leroy Griffin	1964	----	200	159	4	S,D	Fox Hills Sandstone	-----	------	-----	
24SENE	"	W.D. Townsend	1920	----	1852	Flowing	10	S,O	Lakota Formation	42	------	1-46	
46 72 1SWNW	Campbell	Harold Tanner	1954	----	90	30M	4	S	Wasatch Formation	-----	------	7-68	
46 73 34SWSW	"	Lea Wright	1965	----	200	19M	6	D	" "	20M	30M	7-68	
46 82 9SENE	Johnson	L. Ramsbottom	1953	----	150	5	4	S	Mesaverde Formation	6	27	1-61	
46 83 3SENW	"	Adrian Bros	----	----	Spring	Flowing	--	S,D	Tensleep Sandstone	30	------	-----	
13NESW	"	David Hammond	----	----	70	9M	4	D	Frontier Formation	10	------	10-60	
22SESE	"	L. Ramsbottom	1954	----	258	55M	10	S,I	Tensleep Sandstone	600	------	4-61	
46 84 6SESE	"	-------------	----	7100	Spring	Flowing	--	---	Madison Limestone	------	------	7-71	
47 60 4SENE	Weston	Weston Co. (Mallo Camp)	1965	----	380	194M	6	P	Pahasapa Formation	8	------	-----	Water level 9-12-72
47 61 1NWSW	"	Weston Co. (School Dist)	----	----	400	-------	6	P	Minnelusa Formation	-----	------	-----	
11NWSW	"	Alvin Fowler	1965	----	410	330	6	S,O	" "	20	10	11-65	
47 62 11NENE	"	Mary Perino	1961	----	140	50	6	D	Spearfish Formation	-----	------	-----	
47 63 31SESW	"	Willis Martens	1931	----	800	Flowing	6	O,I	Inyan Kara Group	4.1M	------	5-64	
47 67 2NENW	"	Emil Driskell	1947	----	160	60	6 5/8	S,D	Lance Formation	3	------	-----	
48 61 30NENE	"	Albert Perino	1964	----	400	350	6	S,D	Minnelusa Formation	20	5	-----	
48 62 19SWSE	"	Sammy Sewell	----	4920	30	12	6	S	Sundance Formation	-----	------	-----	
20SESE	"	Bill Lambert	1963	----	98	50	6	S	" "	25	48	-----	
48 63 30SENW	"	Albert Douglass	----	----	700	Flowing	5	S	Inyan Kara Group	1	------	9-69	
48 65 25SWSW	"	Upton City	1949	4332	3161	160	12½	O	Madison Limestone	-----	200	6-72	
48 66 1SWSW	"	Bill Barton	1952	----	822	126	6	S,D	Fall River Formation	10	------	-----	
48 68 26NENW	"	Tenneco Oil	1967	4490	2250	325	6	W	Fox Hills Sandstone	105	------	-----	
48 69 28SWSE	**Campbell**	**Bob Dillinger**	**1954**	**----**	**40**	**15M**	**7**	**S**	**Alluvium**	**-----**	**------**	**7-68**	
49 62 22SWSE	Crook	Rachel Necklason	----	----	150	110	6	D	Minnekahta Formation	-----	------	-----	
49 63 5NESE	"	Allen Edwards	1952	----	1450	Flowing	6	S	Minnelusa Formation	30	------	-----	
49 72 5NENE	Campbell	L. Christmick	----	----	120	55M	6	S	Wasatch Formation	-----	------	5-49	
49 77 20NENW	Johnson	Industrial Pipeline Co.	1960	3935	31	7M	16	In	Alluvium	6nM	------	4-61	
49 83 27SENW	"	" " "	----	5950±	Spring	Flowing	--	---	Madison Formation	200	------	6-73	
27SWSE	Johnson	A. Dressler	1956	-----	245	-------	7	S	Tensleep Formation	33	------	11-59	
50 68 14SESW	Crook	L. McCullough	1955	-----	97	14M	8	S	Lance Formation	4.4M	2.6	6-56	
50 72 8NWNW	Campbell	Jim W. Cole	----	-----	380	160	6	S,D	Wasatch Formation	-----	------	5-49	
20NESW	"	E.E. Littleton	1909	4607	160	-------	6	S,D	" "	-----	------	-----	
21SWNE	"	City of Gillette	1948	-----	210	-------	8		" "	40	------	-----	
50 83 36NENE	Johnson	R. Stokey	1957	-----	270	19M	4	---	Cody Shale	5	50	4-61	
51 63 9NWSE	Crook	U.S.A. Corps of Engineers	1959	-----	400	24	6	P	Minnelusa Formation	28	------	-----	Schloredt #7, formerly #5
51 66 27SENW	"	Bureau of Reclamation	1946	-----	690	175	6	O	Sundance Formation	19.6M	311.9M	4-48	
51 69 20SENW	Campbell	Bob Hamm	1957	-----	206	-------	4	S,D	Fort Union Formation	-----	------	-----	
20NWSE	"	" "	1966	4147	2250	Flowing	8	S	Fox Hills Formation	.5	------	7-68	
51 72 22NWSW	"	Kenneth Reveland	1957	-----	100	32M	8	S	Wasatch Formation	-----	------	8-68	
52 60 5NESW	Crook	E.M. Reinecke	----	-----	65	37M	6	D	Opeche Shale	-----	------	9-69	
52 61 24NENE	"	U.S. Fish Genetics Lab	----	3845	Spring	Flowing	--	---	Pahasapa Limestone	300	------	9-69	Majack Spring
52 63 25SWSE	"	City of Sundance	1965	4745	530	483M	10	P	Minnelusa Formation	300	15	6-68	
52 70 2SWSE	Campbell	Atlantic Richfield	1969	3926	2164	-------	10 3/4	In	Fox Hills Formation	168	345	-----	
52 77 3NWNE	Johnson	J. Otaegui	1947	----	828	Flowing	4	S	Fort Union Formation	17.0	------	11-59	

Table 16 (Cont'd.)

Records of Selected Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Coal Basin and Adjacent Areas, Northeastern Wyoming

Table 16 (Cont'd)

Table 16 (Cont'd)

Records of Selected Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Coal Basin and Adjacent Areas, Northeastern Wyoming

Location twp(n) rng(w) sec ¼ of ¼	County	Owner or tenant	Year Drilled	Altitude of land surface above mean sea level (ft)	Depth of well below land surface (ft)	Distance to water below land surface (ft) 1/	Diam. of well (in)	Use of water 2/	Geologic source	Discharge or flow (gallons per minute) 1/	Drawdown (ft below non-pumping water level) 1/	Date of measurement mo - yr	Remarks
53 61 26NESE	Crook	Robert E. Vore	1952	----	852	34M	6	D	Minnelusa Formation	-----	------	9-69	
53 65 7SESE	"	National Park Service	1958	----	52	-------	--	P	Spearfish Formation	-----	------	-----	Devil's Tower
17NENW	"	Merle R. Bandy	1959	3940	675	75M	4	D	Minnelusa Formation	-----	30	4-60	
18NWNW	"	National Park Service	----	----	63	13M	--	P	Spearfish Formation	50	------	9-62	Devil's Tower
18NWNW	"	" " "	1962	3865	1341	21M	8	P	Pahasapa Formation	55	18.7	9-62	" "
53 72 14SESW	Campbell	Texaco, Inc.	1951	4213	9714	-------	16	---	Madison Limestone	-----	------	-----	Oil-test well, plugged
53 73 24SWNE	"	Ralph E. Barbour	1957	----	173	50	4	S	Fort Union	18		5-57	
53 83 7SESE	Sheridan	Dan Evers	1959	----	42	7M	4	---	Wasatch Formation	30	10	5-61	
54 64 7SWNW	Crook	City of Hulett	1934	3756	663	Flowing	8	P	Minnelusa Formation	375	------	-34	
54 65 11NWNE	"	L. Davis	1946	----	52	20	6	S	Gypsum Spring Formation	-----	------	-----	
13NENW	"	D. Steiger	1953	----	38	8M	16	I	Alluvium	266M	18.3M	7-56	
54 79 21SENW	Sheridan	Clearmont	----	----	121	-------	8	P	Wasatch Formation	8	------	-----	
55 64 21SESW	Crook	W.T. Dirks	1950	----	150	104M	6	S	Spearfish Formation	3.7M	6.1M	8-56	
56 63 7SENW	"	I. Moore	1954	----	300	26M	4	0,S	Morrison Formation	3.5M	17.3M	8-56	
15SENE	"	Jim McClure	1951	----	60	16M	6	0,S	Sundance Formation	-----	------	7-56	
56 66 11NESW	"	R.S. Jolley	1953	3700	125	Flowed	--	S	Inyan Kara Group	2.7M	------	-----	
56½ 69 34SWSW	Campbell	Union Oil Co. of Calif	1948	----	6382	-------	--	---	Madison Limestone	-----	------	-----	Oil-test well
56 70 34SENW	"	Wm. Snyder	1959	----	580	Flowing	2	S	Fort Union Formation	16	------	7-68	
56 78 22SWNE	Sheridan	Buffalo Creek Land Co.	1954	-----	165	Flowing	4	S	Fort Union Formation	1M	------	8-60	
56 86 7SWSE	"	J. L. Graham	1952	-----	148	18M	6	---	Frontier Formation	2	126	7-61	
57 64 3NWSE	Crook	Roy Foster	1946	-----	390	153	4	S,D	Inyan Kara Group	4.5	------	-----	
57 69 25NENE	Campbell	Allen Dickey	1960	-----	100	-------	5	S,D	Pierre Shale	2	------	-----	
26SWNE	"	Calvin Sams	1967	-----	180	122M	6	S	" "	8	22	8-68	
57 71 14SENW	"	Richard Flint	1960	-----	615	Flowing	2	S	Fort Union Formation	.5	------	8-68	
57 74 18NESE	"	E.R. Wallis	1966	-----	400	240M	6	S	" " "	10M	10M	8-68	
57 86 30SWNE	Sheridan	George R. Mock	1952	-----	115	Flowing	4	0	Mesaverde Formation	4M	------	-----	
34NWNW	"	A.E. Adamson	1950	-----	315	Flowing	6	S,D	Lance Formation	.75M	------	9-60	
58 69 31SWSW	Campbell	Frank Parks	1954	-----	625	Flowing	4	S	Fox Hills Formation	2	------	10-68	
58 84 30NESW	Sheridan	G. Buszkiewic	1955	4033	10462	-------	--	---	------------	------	------	-----	Oil-test well
58 87 35NESW	"	Chicago, Burlington & Quincy R.R.	1949	-----	129	41M	6	In	Lewis Shale	------	------	7-60	

1/ Measured

2/ Use of water; D, domestic; S, stock; In, industrial, I, irrigation; W, water flood for secondary recovery in oil fields; P, public supply.

See footnotes at end of table.

Location twp(n) rng(w) sec ¼ of ¼	Well depth or interval sampled (ft)	Date of Sample	Temperature (deg c)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) [1]	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (CL)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum of constituents)	Hardness (Ca,Mg)	Specific conductance (micromhos)	Ph (units)	County
Alluvium																				
33 72 7NWSE	12	2-17-50	12.0	17	139	33	332	8.6	510	0	700	31	.6	2.3	420	1510	482	2120	7.6	Converse
33 77 3SENW	20	8-25-67	12.0	14	140	44	250	3.7	328	0	738	32	.7	.0	100	1380	530	1900	7.7	Natrona
33 81 33SESE	42	6-14-66	14.0	13	412	735	1140	13	563	0	5320	119	1.1	207	700	8240	4050	8280	7.8	"
34 80 30SENE	11	6-13-67	12.0	26	139	82	151	11	426	0	596	44	2.8	31	510	1290	682	1740	7.6	"
35 60 27NENW	15	11-12-59	----	29	94	22	176	17	429	0	340	14	.4	.5	230	915	326	1330	7.1	Niobrara
35 65 3SWSW	11	11-11-59	----	22	102	31	230	15	419	0	495	19	.5	.4	290	1120	382	1610	7.1	"
43 80 20SWSW	16	8-19-50	10.0	14	137	69	218	7.5	330	0	668	119	.4	2.6	100	1400	627	1880	7.4	Johnson
43 82 12SENE	17	9-22-50	14.0	12	171	58	149	6.4	274	0	608	106	.4	.9	100	1250	667	1670	7.4	"
44 82 17SESE	12	8-12-69	----	13	280	95	200	3.8	373	0	712	58	.3	.1	140	1550	1090	2330	8.1	"
48 69 28SWSE	40	7- 2-60	----	13	84	23	52	4.7	394	14	74	1.4	.4	.1	80	467	303	753	8.5	Campbell
49 77 20NENW	31	10-27-60	12.0	11	302	87	237	8.5	271	0	1220	194	.4	.8	210	2240	1110	2860	7.4	Johnson
54 65 13NENW	38	10-18-56	9.0	19	365	73	27	6.8	305	0	970	3.5	.5	.0	260	1620	1210	1940	7.2	Crook
Arikaree Formation																				
34 62 29SESW	80	11-14-57	11.0	60	51	10	8.9	7.5	218	0	10	4.0	.3	3.8	30	263	169	371	7.7	Niobrara
White River Formation																				
33 73 25NWNW	0	8-17-50	11.0	72	20	.5	216	9.4	478	0	105	29	.8	2.8	200	691	52	1030	7.8	Converse
33 73 27SENW	92	8-17-50	10.0	64	25	1.0	309	16	616	0	205	32	.7	18	450	974	67	1450	8.1	"
33 73 27SWSWSE	30	8-17-50	11.0	64	263	57	1060	42	464	0	2650	26	1.0	33	1200	4430	892	5450	7.8	"
33 73 27SESWSE	160	8-17-50	12.0	59	157	13	1130	46	343	0	2500	41	.6	83	820	4200	447	5200	7.2	"
33 73 34SWNW	8	8-17-50	13.0	43	305	49	995	37	388	0	2750	30	1.1	19	1300	4400	960	5350	7.8	"
34 61 6SESW	9	9-14-57	14.0	54	8.5	.2	121	9.6	307	0	25	12	1.2	3.9	120	387	22	553	8.0	Niobrara
34 61 17NESW	50	10- 2-57	----	60	73	2.9	62	26	268	0	44	57	.4	22	80	479	194	720	7.7	"
34 65 4NWSW	300	10-12-59	13.0	9.2	3.2	.0	131	3.4	318	0	2.0	9.8	5.0	.1	370	320	8	536	7.7	"
35 62 15SWNE	105	9-11-57	----	49	6.5	.2	167	10	360	0	40	33	1.9	10	280	495	17	746	8.0	"
35 64 26NWSW	126	12- 4-59	----	31	26	3.6	124	11	386	0	25	11	.6	.4	60	428	80	670	7.4	"
Wasatch Formation																				
40 73 8SESW	310	7- 3-69	13.0	12	30	4.1	165	2.1	189	0	277	3.5	.2	.2	40	587	92	901	7.8	Converse
42 70 5SESE	233	7- 9-68	12.0	37	414	919	720	6.8	254	0	5940	35	1.0	.2	60	8200	4810	7660	8.1	Campbell
42 77 24NESW	530	8-22-69	14.0	10	10	2.2	119	2.6	200	1	110	4.4	.6	.0	70	358	34	579	8.4	Johnson
46 72 1SWNW	90	7-15-68	11.0	12	594	218	167	14	296	0	2480	19	1.9	1.6	110	3660	2380	3600	8.2	Campbell
46 73 34SWSW	200	7-19-68	12.0	8.8	130	31	271	4.9	573	0	555	12	.3	1.2	50	1300	450	1820	8.1	"
49 72 5NENE	120	6-14-49	----	12	365	114	40	9.2	46	0	1370	4.0	.6	4.6	270	1940	1380	2210	7.0	"
50 72 8NWNW	380	5-20-49	11.0	12	25	14	254	5.6	823	0	2.4	8.0	.8	.2	80	734	120	1180	7.5	"
50 72 20NESW	160	5-21-49	----	17	85	32	9.1	5.6	249	0	149	4.0	.9	2.4	0	430	344	667	7.6	"
50 72 21SWNE	210	6- 7-67	11.0	19	248	127	34	9.9	323	0	911	9.6	.7	.2	110	1520	1140	1960	7.1	"
51 72 22NWSW	100	6- 6-68	12.0	12	79	38	306	10	1120	0	73	1.2	.7	.0	360	1070	354	1660	7.5	"
53 83 7SESE	42	8-28-61	14.0	13	34	11	2.3	1.0	156	0	1.3	.3	.1	.5	10	141	129	248	7.8	Sheridan
54 79 21SENW	121	10-26-60	11.0	8.8	20	5.1	317	1.9	728	0	145	2.8	.9	.1	110	860	71	1400	8.1	"
Fort Union Formation																				
35 70 4NENW	415	6-19-69	14.0	9.2	9.8	.4	161	2.0	307	0	100	8.0	1.5	2.7	40	446	26	708	8.1	Converse
36 75 9SWSW	360	9-29-69	11.0	27	40	11	5.7	3.6	94	0	75	1.6	.5	4.4	20	215	144	326	6.9	"
39 66 10NENE	132	12- 1-59	2.0	12	151	73	333	8.2	806	0	775	8.8	0	11	90	1770	676	2380	7.6	Niobrara
39 72 6SENW	1104	6-17-68	19.0	11	9.3	.5	94	1.4	167	4	81	2.8	.2	.1	50	286	25	458	8.4	Converse
42 67 14SWNE	161	9- 8-69	12.0	7.0	4.8	4.4	385	1.9	937	9	33	30	2.2	3.0	70	942	30	1510	8.3	Weston
51 69 20SENW	206	7- 1-68	----	6.9	28	3.9	450	4.9	576	22	530	1.5	2.8	9.0	100	1340	86	1980	8.7	Campbell
52 77 3NWNE	828	10-26-60	17.0	11	14	3.4	500	4.6	1350	0	1.5	23	.6	0	70	1220	49	1900	8.0	Johnson
53 73 24SWNE	173	5-14-68	12.0	7.6	379	102	431	17	1350	0	1120	9.3	.7	4.9	30	2740	1370	3430	7.5	Campbell
56 70 34SENW	580	7-18-68	14.0	8.7	2.9	.7	300	1.5	514	12	206	6.1	.7	.0	190	792	10	1230	8.5	"
56 78 22SWNE	165	8-30-61	15.0	9.2	7.3	2.9	400	3.5	1110	0	2.3	7.4	2.2	.0	150	981	30	1570	8.2	Sheridan
57 71 14SENW	615	8- 6-68	13.0	9.6	2.3	.9	254	1.1	468	26	129	5.0	2.3	.2	130	661	9	1060	8.8	Campbell
57 74 18NESE	400	8- 1-68	13.0	7.1	444	319	890	21	729	12	3560	10	.2	.2	330	5620	2420	5890	8.3	"

Table 17

Chemical Analysis of Water from Selected Water Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Basin and Adjacent Areas, Northeastern Wyoming. (Mineral Constituents and Hardness in Milligrams Per Liter; Boron in Micrograms Per Liter).

Table 17

Table 17 (Cont'd)

Chemical Analysis of Water from Selected Water Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Basin and Adjacent Areas, Northeastern Wyoming. (Mineral Constituents and Hardness in Milligrams Per Liter; Boron in Micrograms Per Liter).

Location twp(n) rng(w) sec ¼ of ¼	Well depth or inter-val sampl-ed (ft)	Date of sample	Tem-pera-ture (deg C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Car-bonate (CO_3)	Sulfate (SO_4)	Chloride (CL)	Fluo-ride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum of con-stituents)	Hard-ness (Ca,Mg)	Specific conduct-ance (micro-mhos)	Ph (units)	County
									Lance Formation											
34 77 9SWNW	90	11-10-65	10.0	15	174	97	78	9.2	305	0	712	37	0.7	0.0	40	1270	834	1710	7.8	Natrona
36 65 14NWSE	73	12- 2-59	----	15	89	30	221	12	384	0	393	80	.5	.4	230	1030	347	1540	7.5	Niobrara
39 65 21SWSW	280	12- 1-59	7.0	17	47	3.5	922	4.0	676	0	1500	15	.2	13	140	2850	132	3440	7.6	"
41 63 15NENE	180	9-12-69	----	12	11	.8	712	2.0	994	11	705	9.0	.6	3.2	210	1960	31	2800	8.4	Weston
42 65 30SWNW	114	9- 9-69	12.0	9.0	70	28	132	1.9	436	4	185	13	.4	13	70	670	292	1010	8.3	"
42 78 15NESW	630	8-12-69	20.0	4.4	12	9.5	480	3.8	314	10	770	5.0	.9	.2	280	1450	69	2110	8.7	Johnson
45 79 20SENW	4760	8-19-69	42.0	18	8.5	3.6	188	4.7	325	4	141	16	1.8	.0	210	546	36	854	8.4	Johnson
45 81 18NWSE	200	8-19-69	10.0	12	59	14	8.5	2.4	230	0	33	1.6	.5	6.8	70	251	205	412	8.1	"
47 67 2NENW	160	7-15-69	11.0	8.3	13	6.0	455	2.3	454	0	635	4.0	.1	.2	150	1340	57	2020	8.2	Weston
50 68 14SESW	97	8-16-56	10.0	6.7	11	6.2	315	3.6	550	0	275	10	.8	.1	230	900	53	1440	8.2	Crook
57 86 34NWNW	315	8-28-61	12.0	8.4	33	18	404	5.3	592	0	493	42	.3	.3	120	1300	155	1980	8.0	Sheridan
									Fox Hills Sandstone											
38 62 17NENE	110	12- 1-59	7.0	8.0	14	3.2	1040	2.9	380	0	1970	23	.6	.2	480	3250	48	4440	7.8	Niobrara
38 63 23SWSE	105	12- 1-59	6.0	9.8	37	13	598	4.5	380	0	1120	11	.3	2.6	310	1980	144	2780	7.7	"
40 78 11SWNE 2/	950	5-14-63	13.0	7.4	29	2.3	374	C	451	0	483	13	1.4	1.7	----	1130	82	1700	8.0	Natrona
40 78 26NWSW	90	7-13-67	16.0	7.9	20	1.0	655	2.0	466	0	1070	12	.8	.9	320	2000	54	2850	7.9	"
42 65 6NESW	2259	7-12-69	25.0	11	3.8	.6	350	1.0	559	0	288	11	2.5	.2	210	943	12	1490	8.1	Weston
43 80 20SWSW 2/	140	8-19-50	11.0	13	318	116	780	8.0	436	0	2320	157	.4	.2	100	3930	1270	4570	7.4	Johnson
46 64 20NWNW	200	10-23-68	----	12	67	36	82	4.2	371	0	182	8.5	.2	.0	110	579	316	875	8.0	Weston
48 68 26NENW	2250	7-17-69	25.0	12	1.5	.8	330	1.0	419	26	310	11	.9	.0	380	900	7	1400	9.0	"
51 69 20NWSE	2250	7- 1-68	10.0	8.0	18	1.2	390	3.8	557	20	384	3.5	1.8	4.9	120	1110	50	1660	8.7	Campbell
52 70 2SWSE	2164	8-17-72	----	----	0	0	345	C	522	38	197	33	3.1	.0	.1	837	----	----	8.6	"
58 69 31SWSW	625	10- 8-68	12.0	11	6.6	.4	231	1.2	306	0	272	2.1	.1	.1	30	676	18	1040	8.2	"
									Lewis Shale											
58 87 35NESW	129	10-25-60	9.0	38	16	2.9	236	.1	337	0	233	30	.2	1.0	60	723	52	1110	7.9	Sheridan
									Mesaverde Formation											
34 76 8SWNW	3576	9-30-69	33.5	22	1.0	1.8	670	2.2	1030	16	515	52	3.1	.1	1400	1790	10	2650	8.5	Converse
37 78 7SWSE	1796	8-24-67	22.0	10	15	1.2	712	2.3	419	3	1150	15	.9	.1	180	2120	44	3080	8.3	Natrona
37 79 19SESE	210	8-15-66	12.0	22	82	48	310	7.4	40	0	995	5.5	.2	.1	80	1510	400	1950	6.7	"
37 79 30SWSE	511	8-17-66	13.0	1.8	.2	2.3	141	.8	235	17	89	3.7	.3	.1	150	374	10	625	8.9	"
38 79 34SENW	100	4-26-66	12.0	10	146	46	1100	9.2	662	0	2040	73	2.5	153	400	3910	554	5000	7.5	"
43 81 10NESW	400	8-19-50	11.0	7.1	55	8.9	692	2.2	220	0	1430	36	.3	2.5	----	2340	174	3120	7.8	Johnson
46 82 9SENE	150	5-24-61	9.0	11	62	14	366	3.3	359	0	690	12	.3	4.3	480	1340	212	1930	8.1	"
57 86 30SWNE	115	10-25-60	9.0	13	97	40	29	2.0	330	0	186	1.6	.4	.0	120	531	407	823	7.8	Sheridan
									Pierre Shale											
35 65 15SENE	80	12- 3-59	----	29	61	18	123	11	344	0	203	15	.4	1.9	140	631	224	950	7.6	Niobrara
57 69 25NENE	100	8- 6-68	----	15	35	18	41	3.7	215	7	65	1.7	.5	.7	20	294	163	490	8.4	Campbell
57 69 26SWNE	180	8- 6-68	12.0	16	81	38	52	7.4	353	---	183	1.9	.2	.4	30	554	360	866	7.9	"
									Cody Shale											
33 79 33NWNW	100	9-19-67	11.0	11	145	80	600	3.3	481	0	1470	75	4.0	6.6	930	2630	690	3470	7.8	Natrona
34 79 17NWSE	405	6-12-67	13.0	8.1	14	3.8	1260	4.0	509	0	2130	46	1.0	.3	420	3720	50	4840	7.8	"
43 81 5NW	285	11-19-46	8.0	----	77	99	30	C	204	0	465	8.0	----	1.0	----	780	599	1130	---	Johnson
50 83 36NENE	270	4-25-61	9.0	----	298	573	2350	17	500	0	7830	227	----	1.6	2000	----	3100	12980	8.0	"
									Frontier Formation											
33 80 6NWSW	204	12- 6-66	23.0	8.8	42	21	963	2.4	688	8	1620	12	.7	.2	1100	3020	192	4110	8.3	Natrona
33 80 8NENE	147	6-13-67	18.0	9.0	4.4	1.0	984	2.8	1750	9	425	149	12	.0	3100	2460	15	3670	8.3	"
34 80 32NWSW	735	5-25-67	10.0	6.4	.4	.6	752	1.3	1440	28	64	208	7.3	.0	1900	1790	4	2830	8.5	"
37 82 36NWNW	925	2- 2-67	11.0	19	2.9	.7	461	1.2	442	12	487	73	2.0	1.2	1100	1280	10	2000	8.6	"
39 79 11SESE	2069	3-22-67	----	16	2.0	1.8	1040	2.4	2220	0	0	243	13	.6	1800	2410	12	3530	8.1	"
39 82 9NWSW	1030	2- 2-67	13.0	9.8	2.7	1.3	766	1.2	350	20	1280	12	.9	.2	370	2270	12	3230	8.7	"
40 80 27NENW	1150	7-13-67	22.0	19	1.2	0.0	352	0.6	391	90	286	4.6	1.0	3.3	270	950	3	1460	8.9	"
40 81 20NESW	1029	2- 2-67	13.0	11	14	11	703	1.7	728	19	884	21	3.5	.6	1500	2030	82	2930	8.6	"
41 80 22SWNE	1150	10- 2-65	17.0	9.7	.0	.0	550	5.4	1100	93	13	122	1.2	.0	620	1340	0	2170	8.9	Johnson
43 82 21SWSE	329	8-14-69	17.0	7.4	1.4	1.1	415	4.7	459	20	446	14	5.5	.1	1800	1140	8	1750	8.8	"
46 83 13NESW	70	10-24-60	13.0	29	177	70	299	6.2	175	0	1250	4.4	1.5	.4	580	1920	731	2430	7.1	"
56 86 7SWSE	148	7-27-61	----	10	47	14	74	1.0	277	0	104	1.7	.3	3.2	530	392	174	638	8.1	Sheridan

Table --Chemical analysis of water from selected water wells, springs, and oil- and gas-test holes in the Eastern Powder River Coal Basin and adjacent areas, northeastern Wyoming - continued
(Mineral constituents and hardness in milligrams per liter; boron in micrograms per liter.)

Location twp(n) rng(w) sec ¼ of ¼	Well depth or interval sampled (ft)	Date of Sample	Temperature (Deg c)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (CL)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (Sum of constituents)	Hardness (Ca,Mg)	Specific conductance (micromhos)	Ph (units)	County
Mowry Shale																				
39 83 13SENW	117	2- 2-67	9.0	22	36	9.7	196	1.7	141	0	424	1.9	1.3	0.5	370	763	130	1140	7.3	Natrona
Cloverly Formation																				
33 79 24SWNE	5101	3-23-67	31.0	27	1.0	.0	149	.3	278	0	74	6.7	.7	.0	70	396	2	538	8.0	Natrona
34 80 21NESW	3100	12-21-66	35.0	20	.0	.2	112	.2	253	8	12	3.2	2.5	.0	1400	284	1	453	8.5	"
37 82 36SESE	1275	2- 2-67	11.0	19	9.8	1.3	600	1.3	351	0	958	18	.7	.2	380	1780	30	2540	8.2	"
41 80 30SENW	1292	10-13-65	----	12	5.6	4.0	1180	12	1270	0	0	1080	2.2	.0	3600	2920	30	4850	8.2	Johnson
41 81 25SENE	1016	8-15-69	17.0	12	3.4	3.0	1260	3.9	2450	0	341	278	2.7	.0	3800	3110	21	4510	8.2	"
42 82 14NESW	640	8-20-69	15.5	12	1.7	1.9	615	2.0	654	12	565	117	3.2	.0	780	1650	12	2490	8.5	"
Inyan Kara Group																				
34 65 1SWNW	265	10-13-59	----	9.6	21	2.3	57	6.6	210	0	15	2.8	.5	.1	50	218	62	368	7.4	Niobrara
41 60 7NWSE	530	5-14-69	14.0	8.1	21	11	365	3.3	200	8	660	13	.3	.0	90	1190	98	1920	8.4	Weston
41 60 17NENE	415	5-14-69	15.0	8.1	22	7.5	330	4.1	183	12	570	10	.3	.7	60	1050	86	1630	8.6	"
41 61 1SWNE	665	5-14-69	9.0	8.6	3.1	2.8	330	2.1	251	10	454	22	.5	.0	70	956	19	1480	8.7	"
42 60 7NWSW	1469	5-14-69	26.0	11	234	66	150	9.4	153	0	985	18	.4	.0	70	1570	855	2540	8.1	"
44 64 27SWNE	5331	7-15-69	50.0	39	.8	1.2	405	2.1	472	0	382	58	2.8	.1	560	1120	7	1700	8.2	"
45 62 22SWSW	3450	5-19-69	32.0	20	243	77	83	19	144	0	970	3.6	.2	.0	10	1490	923	1780	7.7	"
45 63 4NESW	1800	5-22-69	24.0	12	2.5	1.5	304	1.4	197	0	456	8.8	.1	.2	30	884	12	1360	7.8	
47 63 31SESW	800	5-22-69	18.0	10	47	20	740	3.8	144	0	1610	11	.5	.2	170	2510	198	3360	7.7	"
48 63 30SENW	700	9-10-69	11.0	11	62	26	12	5.0	128	0	171	36	.6	.0	60	356	260	555	7.0	"
56 66 11NESW	125	10-28-56	----	9.6	58	21	486	10	339	0	1020	7.0	.4	.0	270	1780	231	2530	7.6	Crook
57 64 3NWSE	390	10-30-56	13.0	8.8	39	15	206	12	385	0	305	5.0	.4	.0	210	782	159	1200	7.7	"
Fall River Formation																				
46 63 31NW	1900	1-22-46	27.0	----	----	----	652	C	205	--	1160	29	---	---	---	1920	---	----	---	Weston
48 66 1SWSW	822	7-11-69	15.0	8.2	.4	.5	244	.4	262	0	279	16	.6	.1	60	678	3	1090	8.2	"
Lakota Formation																				
44 62 22SWSW	3832	7-14-69	11.5	26	77	19	270	14	162	0	690	13	.6	.1	60	1190	269	1660	8.0	Weston
45 61 29NWSW	820	8-15-41	----	-----	308	138	128	C	140	--	1410	21	---	---	---	----	1340	----	---	"
46 62 27SWSE	300	9- 9-69	11.0	9.8	424	248	172	18	376	0	2000	26	.3	.0	420	3090	2080	3350	7.8	"
46 63 5SESE	----	2-11-46	16.0	-----	----	----	415	C	255	--	631	26	---	---	----	1240	----	----	---	"
46 63 18SENE	1030	3-14-58	----	-----	5.0	1.0	486	C	194	--	861	13	---	---	---	----	----	----	7.9	"
46 63 18SENE	1030	6- 5-67	19.0	9.3	7.6	1.2	475	1.0	171	0	890	12	.8	.3	70	1480	24	2130	7.4	"
46 63 19SENW	1645	1-22-46	19.0	-----	----	----	810	C	185	--	1510	25	---	---	---	2380	----	----	---	"
46 63 21NENE	1500	2-11-46	14.0	-----	----	----	488	C	205	--	703	114	---	---	---	1210	----	----	---	"
46 64 11NWSE	1800	8-19-60	----	-----	8.0	----	688	C	183	--	1270	32	---	---	---	----	----	----	8.1	"
46 64 13SWSW	1927	8-19-60	----	-----	3.0	----	225	C	195	--	307	12	---	---	---	----	----	----	7.7	"
46 64 24SENE	1852	6- 5-67	23.0	11	.0	.0	250	.5	207	0	361	7.1	.6	.6	60	734	0	1130	7.7	"
Morrison Formation																				
56 63 7SENW	300	8-16-56	11.0	9.2	23	10	276	8.7	250	0	460	6.0	.8	.7	1800	920	100	1400	8.2	Crook
Sundance Formation																				
48 62 19SWSE	30	9-10-69	8.0	8.8	187	112	29	12	463	0	580	14	.3	12	310	1180	928	1560	7.7	Weston
48 62 20SESE	98	7- 9-69	11.0	8.8	393	87	19	7.7	296	0	1080	6.8	.2	.2	120	1750	1340	2040	7.5	"
51 66 27SENW	690	4---48	----	---	35	14	524	----	381	0	927	9.6	.3	----	---	----	145	2320	7.7	Crook
56 63 15SENE	60	10- 2-56	12.0	11	37	19	222	7.2	231	0	475	3.0	.3	.4	220	889	169	1330	8.0	"
Gypsum Springs Formation																				
54 65 11NWNE 3/	52	8-16-56	9.0	24	318	130	129	13	310	0	1310	7.0	1.3	1.0	310	2090	1330	2500	7.7	Crook

Table 17 (Cont'd)
Chemical Analysis of Water from Selected Water Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Basin and Adjacent Areas, Northeastern Wyoming. (Mineral Constituents and Hardness in Milligrams Per Liter; Boron in Micrograms Per Liter).

Table 17 (Cont'd)

Table 17 (Cont'd)

Chemical Analysis of Water from Selected Water Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Basin and Adjacent Areas, Northeastern Wyoming. (Mineral Constituents and Hardness in Milligrams Per Liter; Boron in Micrograms Per Liter).

Location twp(n) rng(w) sec ¼ of ¼	Well depth or inter-val sampl-er (ft)	Date of sample	Tem-pera-ture (deg C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Car-bonate (CO_3)	Sulfate (SO_4)	Chloride (CL)	Fluo-ride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum of con-stituents)	Hard-ness (Ca,Mg)	Specific conduct-ance (micro-mhos)	Ph (units)	County
									Spearfish Formation											
47 62 11NENE	140	9- 9-69	----	12	533	95	111	5.8	188	0	1680	9.0	0.9	6.2	400	2540	1720	2760	7.7	Weston
53 65 7SESE	52	6- 6-67	11.0	15	469	77	120	8.5	283	0	1400	22	1.0	.7	390	2250	1480	2540	7.2	Crook
53 65 18NWNW	63	10- -59	----	---	550	162	83	----	409	--	1800	11	---	----	---	----	1970	----	6.8	"
53 65 18NWNW	460	9- 9-61	----	13	558	116	261	24	281	0	2110	13	.5	.0	1100	3230	1870	3380	6.7	"
55 64 21SESW	150	8-16-56	11.0	36	518	94	59	7.0	304	0	1490	13	.9	3.7	470	2370	1680	2620	7.7	"
									Minnekahta Limestone											
49 62 22SWSE	150	9-15-69	----	13	148	37	4.0	2.4	295	0	261	3.2	.4	7.5	210	622	522	904	8.0	Crook
53 65 18NWNW 4/	545	9-15-61	----	9.0	289	120	52	12	247	0	1050	38	2.2	.0	150	1690	1210	2250	7.1	"
									Opeche Shale											
52 60 5NESW	65	9-16-69	14.0	17	136	35	4.9	2.0	296	0	235	2.2	.4	3.0	120	582	484	855	7.8	Crook
									Tensleep Sandstone											
40 79 25NESW	4400	11-18-66	71.0	42	315	67	561	41	125	0	1130	698	5.5	.1	460	2920	1060	4280	7.6	Natrona
42 84 25SWSW	800	8-19-69	10.0	8.8	44	26	4.6	1.5	241	0	21	3.3	.4	3.0	10	231	215	414	8.0	Johnson
43 82 15SWNW 5/	1925	8-14-69	28.0	14	456	161	2220	34	130	0	1560	3420	2.5	---	1200	7930	1700	12200	7.8	"
43 83 5SWSW	0	8-20-69	11.0	9.8	52	31	7.8	2.4	240	0	63	7.5	.4	3.3	40	295	257	493	8.1	"
43 84 4SENE	750	8-18-69	11.0	9.4	50	24	3.3	2.0	244	0	28	1.3	.3	.0	10	238	224	430	8.2	"
43 84 26NWSW	761	8-31-65	13.0	10	38	31	2.8	1.2	281	0	1.6	6.0	.2	2.5	20	231	225	407	8.0	"
44 83 8NWNW	400	8-13-69	10.0	8.7	40	42	2.4	1.2	319	6	5.6	1.2	.1	1.7	10	----	275	485	8.4	"
45 83 7NWNE	0	8-12-69	----	12	43	26	3.7	1.9	234	0	26	1.0	.1	1.1	10	230	213	419	8.2	"
45 83 18SWSE	260	8-12-69	10.0	13	38	37	3.5	1.5	274	0	12	13	.4	6.6	30	260	246	457	7.9	"
46 83 3SENW	0	10-24-60	8.0	7.8	43	30	1.1	.8	279	0	5.3	.2	.1	.9	20	226	231	411	7.7	"
46 83 22SESE 5/	258	4-21-61	----	----	135	60	70	2.8	343	0	415	13	---	.0	130	----	585	1260	7.5	"
49 83 27SWSE	245	7-31-62	8.0	9.5	35	41	3.0	1.5	302	0	13	3.0	.2	---	----	----	256	477	8.0	"
									Minnelusa Formation											
45 61 2SWNW	720	6-18-68	15.0	9.2	685	37	35.	4.8	141	0	1680	9.5	1.2	1.7	280	2530	1860	2700	8.0	Weston
45 61 28NWNE	1950	3-14-62	23.0	10	604	161	29	6.7	127	0	1980	19	.9	2.1	150	2870	2170	3010	7.4	"
47 61 1NWSW	400	6- 3-69	9.0	11	83	12	8.4	1.3	304	0	13	1.9	.2	16	0	297	257	495	7.8	"
47 61 11NWSW	410	6- 3-69	10.0	9.7	70	15	1.6	1.4	254	0	19	1.5	.2	6.9	0	250	235	432	8.0	"
48 61 30NENE	400	6- 5-69	12.0	10	150	45	2.8	2.0	233	0	335	1.8	.4	14	60	676	559	995	8.0	"
49 63 5NESE	1450	9-15-69	12.0	13	615	86	5.2	2.4	234	0	1600	.9	.9	1.9	70	2440	1890	2640	7.5	"
51 63 9NWSE	400	9-15-69	10.0	10	139	34	2.4	1.5	498	0	68	2.9	.2	.6	20	504	485	834	7.8	"
52 63 25SWSE	530	6- 8-67	----	12	66	14	2.4	.9	239	0	25	4.6	.3	1.4	90	245	220	424	7.5	"
53 61 26NESE	852	6- 8-67	----	10	112	45	3.1	1.6	214	0	276	6.0	.7	.9	50	560	466	834	7.5	"
53 65 17NENW	675	6- 6-67	----	6.0	237	105	38	9.6	211	0	877	27	2.9	.2	100	1420	1020	1820	7.3	"
53 65 18NWNW	900	10-27-61	----	12	440	156	119	17	268	--	1550	39	---	.6	---	----	1690	----	7.5	"
54 64 7SWNW	663	6- 4-68	13.0	11	107	36	3.2	2.3	286	0	180	1.7	2.0	.0	20	485	415	730	7.7	"
									Madison Limestone											
33 75 4NENW	9162-9270	7----51	----	----	500	37	1308	C	220	--	3229	500	---	----	----	5682	----	----	---	Converse
33 76 16NESW	6954	7----72	60.0	37	411	64	537	51	112	0	1560	623	4.4	.0	1200	3340	1290	4600	---	"
33 77 15SWNW	7615	4----67	60.0	40	338	55	452	58	124	0	1560	322	5.0	1.1	710	2900	1070	3660	---	Natrona
39 61 2NESE	2970-2975	12----34	----	----	91	7	58	C	185	--	131	67	---	----	----	445	----	----	---	Niobrara
42 81 25NWSW	4246	7----72	----	26	283	80	450	28	117	0	1080	583	4.3	0.0	560	2590	1040	3800	---	Johnson
46 84 6SESE	0	11----70	6.0	11	30	13	1.6	.8	163	3	1.0	.7	.1	2.3	0	140	128	258	---	"
48 65 25SWSW	3161	7----72	----	13	92	40	2.9	2.1	275	0	166	1.7	3.6	.7	20	457	394	713	---	Weston
53 72 14SESW	9664-9714	11----51	----	---	143	16	406	C	410	---	858	54	---	---	---	1679	----	----	---	Campbell
49 83 27SENW	0	10----73	5.5	13	11	4.1	2.1	.5	52	0	5.8	1.5	.2	.2	20	65	45	99	---	Johnson
56½ 69 34SWSW	6308-6382	5----48	----	---	270	66	826	C	245	24	2359	32	---	---	---	3698	----	----	---	Campbell
58 84 30NESW	9704-9760	2----58	----	---	323	69	24	----	161	---	962	16	---	---	---	1479	----	----	---	Sheridan

Location twp(n) rng(w) sec ¼ of ¼	Well depth or inter-val sampl-er (ft)	Date of sample	Tem-pera-ture (deg C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Car-bonate (CO_3)	Sulfate (SO_4)	Chloride (CL)	Fluo-ride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum of con-stituents	Hard-ness (Ca,Mg)	Specific conduct-ance (micro-mhos)	Ph (units)	County
									Pahasapa Limestone											
45 61 20SWSE	2638	3-15-62	26.0	13	63	28	2.5	1.6	291	0	38	1.2	0.3	0.9	30	292	274	507	7.7	Weston
45 61 28NWNE	2738	3-15-62	26.0	13	62	29	2.9	1.8	289	0	37	1.4	.3	.9	10	290	273	504	7.4	"
45 61 29NWSW	3073	3-15-62	27.0	14	76	33	6.1	2.6	257	0	117	2.5	.4	1.0	20	379	327	642	7.4	"
45 61 30SENE	3028	6-18-68	31.0	13	75	33	5.2	2.3	266	2	108	1.6	.5	.8	10	372	324	603	8.3	"
45 61 33NWNE	3596	6- 4-69	22.0	13	76	26	2.9	2.3	276	0	74	1.2	.6	.2	0	332	298	534	7.9	"
46 60 31NENW	1178	10-24-68	16.0	13	65	24	2.8	1.5	318	0	12	.4	.3	.7	0	276	260	473	8.2	"
46 62 18SENW	2677	6- 5-69	16.0	12	62	28	1.9	1.4	296	0	27	.8	.3	.0	---	279	270	480	7.8	"
46 63 10SWSE	2592	4- 8-58	23.0	15	80	26	2.6	.6	298	0	69	1.0	.2	.6	---	342	306	560	7.5	"
46 64 13SWSW	4522	5-22-69	37.0	14	61	26	1.8	1.4	273	0	29	.7	.4	.5	10	269	258	484	7.8	"
47 60 4SENE	380	6- 3-69	10.0	12	62	23	1.0	.8	291	0	5.2	1.0	.5	.1	0	249	250	435	7.9	"
52 61 24NENE	0	12-20-63	----	13	140	29	2.0	1.9	274	0	228	3.1	.0	1.9	0	588	468	911	7.7	Crook
53 65 18NWNW	1341	7-11-62	----	12	112	43	4.0	1.0	264	--	275	1.5	.5	.0	---	---	460	----	7.2	"
									Deadwood Formation											
44 62 2SWSE	6227	5-19-69	32.0	25	603	138	150	36	160	0	2100	58	1.6	.0	1200	3200	2070	3290	8.1	Weston

1/ C - Potassium (K) and sodium (Na) were calculated together and recorded in sodium column.
2/ Some water also from Lance Formation.
3/ Some water also from Sundance Formation.
4/ Some water also from Opeche Shale.
5/ Some water also from Goose Egg Formation.

Table 17 (Cont'd)
Chemical Analysis of Water from Selected Water Wells, Springs, and Oil- and Gas-Test Holes in the Eastern Powder River Basin and Adjacent Areas, Northeastern Wyoming. (Mineral Constituents and Hardness in Milligrams Per Liter; Boron in Micrograms Per Liter).

Table 17 (Cont'd)

Table 17a

Significance of Chemical and Physical Properties of Natural Waters

Constituent or physical property	Source or cause	Significance
Arsenic (As)	In wastes from some industry and mining activity, and in residues from certain insecticides and herbicides. In natural water, trace quantities may be fairly common.	Arsenic is toxic to humans and animals. It can accumulate in tissue and result in serious physiological effects. See text for maximum limit recommended for drinking water.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium cause carbonate hardness.
Boron (B)	Dissolved from soil and rock, particularly those of igneous origin. Waters from hot springs and especially waters from areas of recent volcanic activity may be rather high in boron. May be added to water through disposal of waste materials, especially from cleaning operations where borates are used as detergents.	Small amounts in irrigation water and soil are damaging to certain crops. It is essential in trace quantities in plant nutrition, but becomes toxic to some plants in concentrations as small as 1.0 mg/l in irrigating water.
Calcium (Ca)	Dissolved from most soils and rocks but especially from limestone, dolomite, and gypsum. Some brines contain large concentrations of calcium.	Calcium and magnesium cause most of the hardness and scale-forming properties of water; soap consuming. (See Hardness.) Calcium products may deposit on pipe walls and in well-screen openings and reduce the water-transmitting efficiency.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large concentrations in ancient brines, sea water, and industrial brines.	High concentrations increase the corrosiveness of water and, in combination with sodium, give a salty taste.
Dissolved solids	Mineral constituents dissolved from rocks and soils, or added as a result of man-made conditions, May include dissolved organic constituents and some water of crystallization.	Dissolved solids values are a measure of the collective concentration of constituents in the water; the higher the value the higher the concentration. Tons per acre-foot and tons per day are calculated values that are measures of the total dissolved salt load in an acre-foot of the water and in the total volume of the water passing the sampling site in a 24-hour period.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, the amount of drinking water consumed, and the susceptibility of the individual.
Hardness ($CaCO_3$)	In most waters nearly all the hardness is due to calcium and magnesium. Metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form, and deposits soap curds on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. See adjective rating of hardness in the text.
Iron (Fe)	Dissolved from most rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 mg/l of soluble iron in surface waters generally indicates mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 0.3 mg/l stains laundry and utensils reddish-brown. Objectional for food processing, beverages, dyeing, bleaching, ice manufacture, and other purposes. Large concentrations cause unpleasant taste and favor growth of iron bacteria.
Magnesium (Mg)	Dissolved from most soils and rocks but especially from dolomitic limestone. Some brines contain large concentrations of magnesium.	Magnesium and calcium cause most of the hardness and scale-forming properties of water; soap consuming.
Nitrogen Ammonia (NH_3) Nitrate (NO_2) Nitrate (NO_3)	May occur in water in these forms, depending on the level of oxidation. Dissolved from igneous rocks; soils enriched by legumes and commercial fertilizers; barnyard and stock corrals; and sewage effluent.	Concentrations much above average for any form of nitrogen probably indicate pollution. Nitrate encourages growth of algae and other organisms that produce undesirable tastes and odors. Concentrations of nitrate greater than 45 mg/l may cause methemoglobinemia in infants, the so-called "blue-baby" disease.
pH (Hydrogen-ion concentration)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Higher values denote increasing alkalinity; lower values, increasing acidity. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals. pH is a measure of the activity of the hydrogen ions.
Phosphate (PO_4)	Weathering of igneous rocks, leaching of soils containing organic wastes from plants and animals, phosphates added by fertilizers, and domestic and industrial sewage. Phosphate in detergents is important source of sewage effluent.	Phosphate concentrations much above average probably indicate pollution.
Potassium (K)	Dissolved from most rocks and soils. Found also in ancient brines, sea water, some industrial brines, and sewage.	Large concentrations, in combination with chloride, give a salty taste. Potassium is essential in plant nutrition and will be taken into the plant. The potassium will return to the soil when the plant dies, unless the plant is removed. The soil must be replenished with potassium to remain productive.
Selenium (Se)	Principal source of selenium-bearing rocks are volcanic emanations and sulfide deposits which have been redistributed by erosion and weathering. Found in rocks of Cretaceous age, especially shales, and soils derived from them.	Selenium is toxic in small quantities, and in some areas its presence in vegetation and water constitutes a problem in livestock management. Selenium is hazardous because it can accumulate in animal tissue and result in serious physiological effects. See text for concentration limits with respect to drinking water.
Silica (SiO_2)	Dissolved from most rocks and soils, generally in small amounts from 1 to 30 mg/l. Higher concentrations, as much as 100 mg/l, may occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried in steam of high pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Sodium (Na)	Dissolved from most rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage.	Large concentrations, in combination with chloride, give a salty taste. High sodium content commonly limits use of water for irrigation.
Specific conductance (micrombos at 25°C)	Specific conductance is dependent upon dissolved mineral content of the water. Numerically equal in moderately mineralized water to approximately 1.1 to 1.8 times the dissolved solids.	Specific conductance is a measure of the capacity of water to conduct an electric current. This property varies with concentration and degree of ionization of the constituents, and with temperature (therefore reported at 25°C). Can be used to estimate the total mineralization of the water.
Strontium (Sr)	Dissolved from rocks and soils, especially carbonate sediments and rocks of igneous origin.	Concentrations generally are too low to be of concern to most water users.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	High concentrations may have a laxative effect and, in combination with other ions, give a bitter taste. Sulfate in water containing calcium forms a hard scale in boilers.
Temperature		Affects usefulness of water for many purposes. In general, temperature of shallow ground water shows some seasonal fluctuation, whereas temperature of ground water from moderate depths remains near the mean annual air temperature of the area. In very deep wells, water temperature generally increases about 1°F for each 60-foot increment of depth.

Table 17a (Continued)

Constituents and Properties in Water Analyses

The constituents in water analyses are the substances that are in solution in the water. The substances commonly determined by analytical methods and expressed as ions are the cations calcium, magnesium, sodium, and potassium, and the anions are sulfate, chloride, fluoride, nitrate, and those contributing to alkalinity, which are usually expressed in terms of an equivalent amount of carbonate and bicarbonate. Other substances determined, but not as routinely, are boron, phosphate, selenium, and other trace elements.

Certain chemical and physical properties of the water also are reported in water analyses. Some of these properties include dissolved solids, hardness expressed as equivalent quantities of calcium carbonate, and specific conductance.

The units used in reporting the concentration of constituents are milligrams per liter. One milligram per liter represents one milligram of solute for each liter of solution.

Chemical Constituents in Relation to Use

The quality of a water is judged according to the use for which it is needed. Generally, the lower the dissolved solids, the better the water. For some uses, however, the concentration of particular constituents in a water may be more important than the total concentration of dissolved solids. General criteria for evaluating water for common uses are discussed below.

Domestic and municipal use

Chemical-quality standards for water used for public carriers and by others subject to federal quarantine regulations have been established by the U.S. Public Health Service (1962). These regulations concern bacteria, radioactivity, and chemical constituents that may be objectionable in a water supply. Recommended maximum concentrations of some constituents are:

Concentration, in mg/l	Constituent
0.05	Arsenic (As)
250	Chloride (Cl)
500	Dissolved solids
1.3*	Fluoride (F)
.3	Iron (Fe)
125	Magnesium (Mg)
.05	Manganese (Mn)
45	Nitrate (NO_3)
.01	Selenium (Se)
250	Sulfate (SO_4)

*Based on the annual average of maximum daily air temperature at Gillette, Wyoming.

Hardness is important in evaluating the suitability of water for domestic, municipal, and industrial uses. An adjective rating has been established by the U.S. Geological Survey as follows:

Hardness as $CaCO_3$ (mg/l)	Adjective rating
0 - 60	soft
61 - 120	moderately hard
121 - 180	hard
More than 180	very hard

Industrial use

Water-quality criteria for industrial use vary considerably depending on the use. Some industries have strict quality requirements. Requirements for cooling and waste disposal are more lenient, although certain waters may require treatment to prevent corrosion and scale.

Stock use

The tolerance of animals to dissolved solids in water depends on the species, age, and physiological condition of the animal; on the quantity and type of salts in the water; and on the amount of water consumption. Standards for most of these factors have not been determined; however, the general standards based on the concentration of dissolved solids are used. Beath and others (1953, p. 86) suggest the following classification as a guide for evaluating stock water in Wyoming:

Dissolved solids (mg/l)	Classification
Less than 1,000	good
1,000 to 3,000	fair (usable)
3,000 to 5,000	poor (usable)
5,000 to 7,000	very poor (questionable)
More than 7,000	not advisable

Recharge to the Arikaree Formation in the Douglas area south of the North Platte River is by infiltration of precipitation. Movement of ground water is mostly eastward with a component at places toward the North Platte Valley.

White River Formation. The White River Formation occurs in the extreme southern and southeastern parts of the Eastern Powder River Coal Basin southward from the vicinity of Douglas. The White River also caps a few high buttes in the Pumpkin Buttes area in southwestern Campbell County. The White River consists mostly of claystone and siltstone but also contains local lenses of conglomerate. The thickness increases eastward from about 200 feet south of Douglas to about 500 feet near the Converse County line. Depth to water is about 50 to 100 feet but will vary with the topography of the land surface. Yields of water to individual wells are generally less than 20 gpm but well yields of several hundred gallons per minute are possible where secondary permeability has increased the yield. Dissolved solids range from about 300 to more than 4,000 mg/l but most water contains less than 1,000 mg/l.

Recharge to the White River Formation in the Douglas area south of the North Platte River is by infiltration of precipitation. Movement of ground water is mostly eastward with a component at places toward the North Platte Valley.

Wasatch Formation. The Wasatch Formation forms the surface of most of the central and western parts of the Eastern Powder River Coal Basin. The Wasatch consists of fine- to coarse-grained lenticular beds of sandstone and interbedded shale and coal. Coarse-grained deposits are proportionately greater toward the west and south. Thickness ranges from 1,500 feet in the Pumpkin Buttes area to zero at the outcrop of the Wasatch and underlying Fort Union contact. Because minor subsidence continued in the basin into middle Tertiary time, the beds dip very gently westward toward the center of the basin, but local reversals of dip are not uncommon. Dips average as much as 75 feet per mile in northern Campbell County and as much as 100 feet per mile (approximately one degree) in southern Campbell County. In Converse County, the beds dip mostly toward the center of the basin.

Clinker beds crop out along the coal horizons in many places. Because the clinker is more resistant to erosion, clinker beds usually are found capping hills and buttes. The clinker was formed mainly from clays which have been baked by natural combustion of coal. Locally, the burning has been sufficiently intense to fuse some of the contiguous rock into vitreous masses. The clinker is typically a reddish, porous rock.

Multiple water levels are present in the Wasatch because of the lenticular nature of the sandstone beds. Some wells flow at land surface in topographically low valley reaches, but wells cannot be expected to flow in interstream areas. Wells in deeper aquifers are more likely to flow than are wells in more shallow aquifers.

The formation yields water from lenticular sandstone beds and, to a lesser extent, from jointed coal and clinker beds. Yields of at least 500 gpm are possible from properly constructed and adequately developed wells where a sufficient thickness of the aquifer is open to the well.

Chemical analyses of water from the Wasatch show dissolved solids range from less than 500 to more than 2,000 mg/l but commonly range between 500 and 1,500 mg/l. Sodium bicarbonate and sodium sulfate are the dominant water types.

Recharge to the Wasatch is from local precipitation. Areas underlain by clinker beds are especially favorable for infiltration of precipitation because of the porous nature of the rock. Discharge of water is by small springs and seeps along stream drainages, by evaporation and transpiration, and by pumping of wells. Principal natural discharge of water is along the Powder River and Little Powder River valleys and their tributaries and probably is the controlling factor in the regional movement of water in the Wasatch. This movement is northward toward these drainageways, but locally, especially in the nearsurface aquifers, movement of water is controlled by other drainages such as Donkey Creek and the Belle Fourche River. Some water from the Wasatch also moves downward into the underlying formations.

Fort Union Formation. This formation consists of about 2,500 feet of fine-grained sandstone and interbedded shale and coalbeds. The lower member, Tullock, is predominately sandstone whereas the overlying member, Lebo Shale, is mostly shale. The beds dip gently basinward on the east side of the basin and dip rather steeply basinward at the southern end of the basin.

Flowing water wells are common in the Fort Union along major stream drainageways, but water will not rise to land surface in higher interstream areas. Yields of at least 500 gpm are possible from properly constructed and adequately developed wells in the Fort Union. Some wells flow because of the lifting action of gas derived from coal within the formation. There is sufficient gas from some water wells that it is collected and used for domestic purposes.

Chemical analyses of water from the Fort Union show dissolved solids range from about 300 to more than 1,500 mg/l but commonly range between 500 and 1,000 mg/l. The quality of water in the Fort Union is, in general, better and is more consistently similar than water from the overlying Wasatch where the water quality tends to be more erratic. The better quality water in the Fort Union is believed to result from (1) ion exchange of calcium and magnesium in the water for sodium in the clay and shale beds and (2) sulfate reduction which results in a higher biocarbonate concentration with corresponding decrease of dissolved solids in the water. Water type in the Fort Union is mostly sodium bicarbonate and, to a letter extent, sodium sulfate.

Recharge is from precipitation and consequent downward percolation of water from the overlying Wasatch Formation. At the south end of the basin, some recharge may occur on the outcrop and move basinward, but the relation of the potentiometric surface to the outcrop of the Fort Union in this part of the basin is not known. Principal natural discharge of water is along the Powder River and Little Powder River drainages and the general movement of water in the Fort Union is northward toward these drainages. Other discharge includes evapotranspiration along stream drainages and by pumping of wells. Some water moves downward through the Fort Union into the underlying sands of the Lance Formation.

Lance Formation. The Lance Formation consists of fine- to medium-grained sandstone and interbedded shale and sandy shale. Thickness ranges from about 500 feet in northern Campbell County to about 3,000 feet near Douglas. The beds dip basinward, gently on the east side of the basin and steeply at the south end of the basin.

The depth to water increases basinward from only a few feet or tens of feet in the outcrop area to nearly 500 feet below land surface near Gillette. The depth to water in the Hilight oil field in southeastern Campbell County is about 300 feet. The depth to water in the deeper parts of the basin is not known. Hydrographs showing depth to water in Tertiary and Upper Cretaceous rocks are shown in Figure 20.

Yields of as much as 1,000 gpm are believed possible from properly constructed and adequately developed wells in the Lance, but well spacing could be critical because of pumping interference between wells. Recharge is

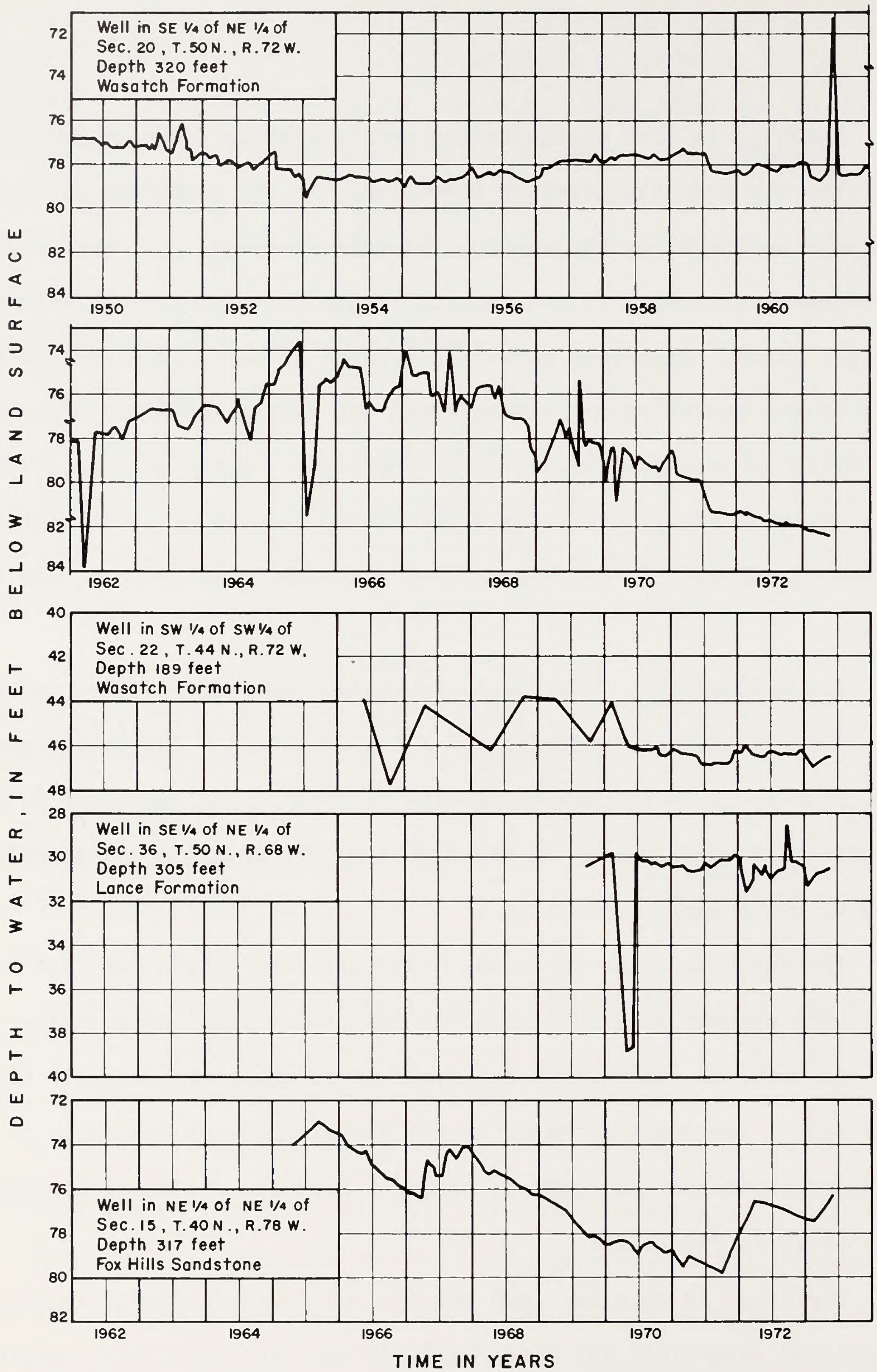


Figure 20

Water-level changes in the Wasatch and Lance Formations, and the Fox Hills Sandstone in the Eastern Powder River Coal Basin.

from downward movement of water from the overlying rocks. Movement of water in the Lance is mostly northward.

Dissolved solids of water from wells in the Lance range from about 500 to more than 2,000 mg/l, but commonly range between 500 and 1,500 mg/l. No dominant water type is prevalent. The quality of the water in the Lance is not known in the deeper parts of the basin, but a water analysis from a drill-stem test in sec. 32, T49N, R75W in the Lance at a depth of about 5,300 feet showed a dissolved-solids content of 2,630 mg/l.

Fox Hills Sandstone. This formation consists predominantly of fine- to medium-grained sandstone. The thickness ranges from about 150 feet in northern Campbell County to about 500 feet near Douglas. Dips are gently basinward on the east side of the basin but dip steeply at the south end of the basin.

Depth to water increases basinward from only a few feet or tens of feet in the outcrop area to about 200 feet near Rozet. Depth to water in deeper parts of the basin is not known. Wells near Rozet yield about 200 gpm for oil-field waterflood. Dissolved solids of water from wells in the Fox Hills in the eastern part of the coal basin range from about 500 to more than 1,500 mg/l but are mostly less than 1,000 mg/l. Water from a drill-stem test in the western part of the coal basin in sec. 32, T49N, R75W in the Fox Hills at a depth of about 6,000 feet had a dissolved-solids content of 3,200 mg/l.

Recharge is from downward percolation of water from the overlying rocks. Movement of water is northward. Discharge points, other than water wells, are not known.

Deep aquifers

Inyan Kara Group. The Inyan Kara Group is composed of the Fall River and Lakota Formations and is the lateral equivalent of the Cloverly Formation in the western and southern parts of the Powder River Basin.

The Fall River Formation consists of fine- to medium-grained sandstone with interbedded shale and siltstone. The thickness ranges from 120 to 150 feet. The Lakota Formation consists of sandstone, conglomeratic sandstone and shale. Individual beds are lenticular with rapid changes in composition both laterally and vertically. The thickness ranges between 100 and 300 feet. The lateral equivalent, Cloverly Formation, consists of similar rocks, however, the thickness is only about 150 feet.

Hydrographs showing depth to water level in some of the deep aquifers are shown in Figure 21.

Yields of most water wells tapping the Inyan Kara Group, and equivalent Cloverly Formation, range from 5 to 20 gpm, but yields of 100 gpm or more are possible from the complete section of rocks. Several hundred gallons per minute are possible from zones of secondary permeability. A well in sec. 24, T33N, R72W, Natrona County, flows about 40 gpm from the Cloverly and is pumped at about 250 gpm. A well in sec. 1, T56N, R62W, Crook County, flows 70gpm from the Lakota, and a well in sec. 22, T54N, R67W, had a reported flow of more than 150 gpm from both the Lakota and Fall River. A well in sec. 35, T35N, R65W, Niobrara County, flowed 140 gpm from the Lakota and Fall River when drilled. Dissolved solids generally range between 300 and 3,000 mg/l; most water is sodium sulfate type.

Sundance Formation. This formation consists of greenish-grey shale interbedded with yellowish-grey, fine-grained sandstone. The thickness is about 400 feet. The formation is divided into five members in the Black Hills, which

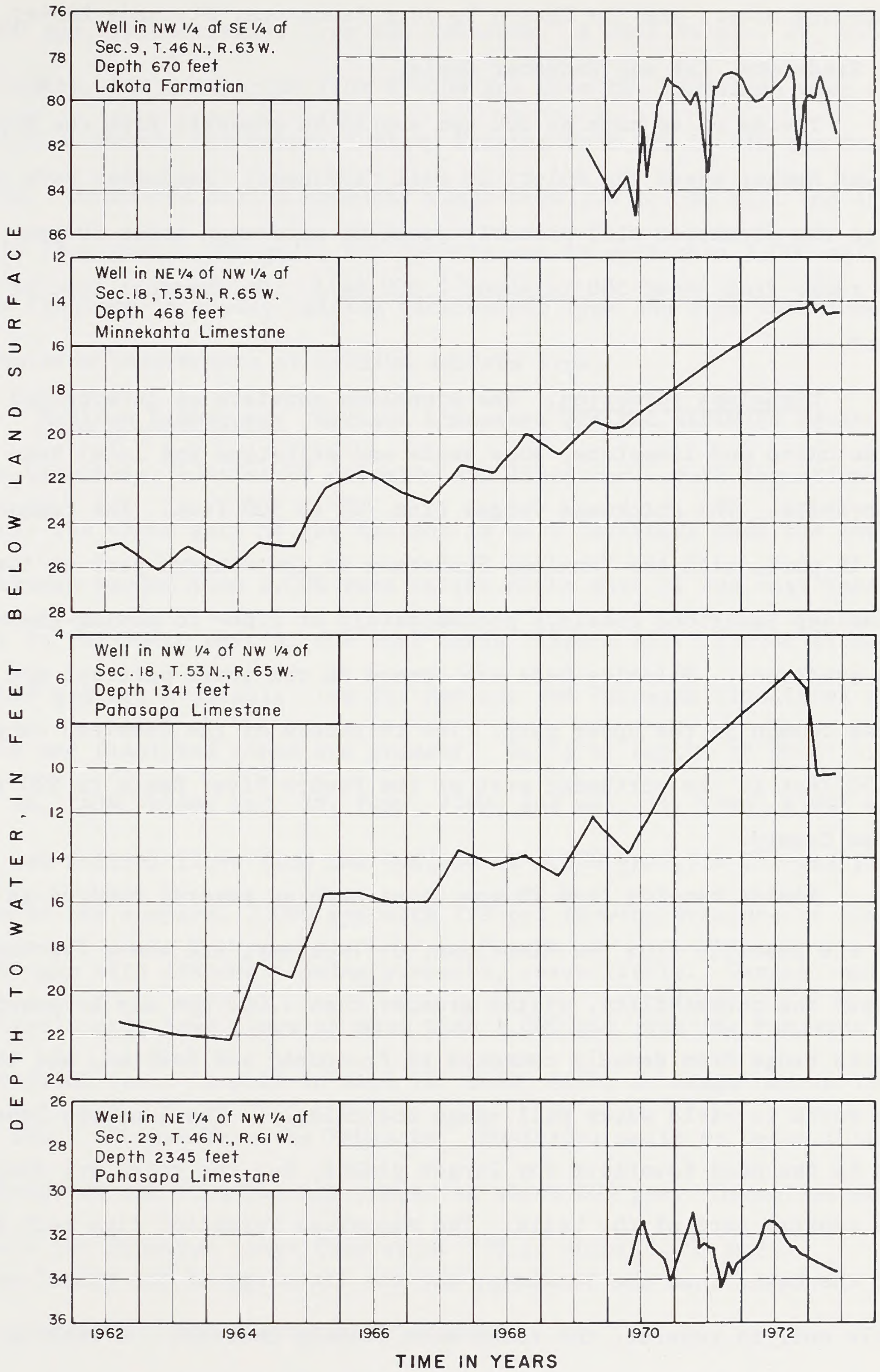


Figure 21

Water-level changes in the Lakota Formation, Minnekahta Limestone and the Pahasapa Limestone in the Eastern Powder River Coal Basin.

in ascending order, are the Canyon Springs Sandstone, Stockade Beaver Shale, Hulett Sandstone, Lak and Redwater Shale.

Yields of as much as 100 gpm should be possible from the Hulett Sandstone Member where the Hulett is well developed. Sandstone beds in other parts of the formation will probably yield no more than about 20 gpm. Dissolved solids range from about 500 to about 2,000 mg/l. No chemical type of water is dominant.

Minnelusa Formation. The Minnelusa consists of interbedded sandstone, sandy dolomite and limestone, some shale and siltstone and local beds of gypsum and anhydrite. The thickness ranges from 700 to 900 feet. The formation correlates, in part, with the Tensleep Sandstone in the western part of the basin. The Tensleep Sandstone consists predominately of fine- to medium-grained cross-bedded sandstone. Dolomite beds are common in the lower part but are thinner and less common in the upper part. The thickness of the Tensleep ranges from about 50 feet in the northwest part of the Powder River Basin to 500 feet in Converse County.

Yields ranging from 20 gpm to as much as several hundred gallons per minute are possible from the Minnelusa, or Tensleep, and where fracturing has increased the permeability, yields greater than 1,000 gpm may be possible. The rocks range from densely cemented to fractured and faulted, and the ability of the rocks to yield water will range accordingly. The Tensleep Sandstone should be the most favorable for larger yields, but the rocks are deeply buried in the central part of the basin. The Minnelusa Formation dips much more gently toward the basin than the Tensleep, but the lithology of the Minnelusa is more variable and, in general, the rocks more densely cemented. A well in sec. 22, T46N, R83W, Johnson County, yields 600 gpm from the Tensleep. Wells in sec. 25, T40N, R79W, and sec. 9, T40N, R84W, Natrona County, have flows of about 500 gpm and 1,200 gpm, respectively, from the Tensleep. A well in sec. 28, T45N, R61W, Weston County, had a reported flow of 300 gpm from the Minnelusa when drilled. City wells at Hulett had reported flows ranging from 250 to 480 gpm from the Minnelusa. Dissolved solids commonly range from 200 to 500 mg/l and are generally less than 1,000 mg/l, but locally may be more than 2,000 mg/l. Water from the Tensleep is mostly calcium bicarbonate type and from the Minnelusa mostly calcium bicarbonate or calcium sulfate type.

Madison Limestone. Madison Limestone and the eastward equivalent, Pahasapa Limestone, consist of dolomite and limestone. Both formations are cavernous; the upper part of the Madison is more cavernous than the lower part. The thickness ranges from 1,000 feet in the north part of the coal basin to 100 feet in the south part of the coal basin (Figure 22). Yields of more than 1,000 gpm are available from the Madison and Pahasapa Limestones where cavernous and fractured zones are present. Wells at depths of about 5,000 feet in sec. 26, T40N, R79W; sec. 35, T40N, R79W; and sec. 11, T39N, R79W; Natrona County, had initial flows from the Madison of 3,900 gpm with 150 psi flowing pressure at the surface, 7,000 gpm with 179 psi flowing pressure at the surface, and 4,750 gpm with unknown flowing pressure, respectively. Several wells in the Newcastle area have flows of more than 1,000 gpm from the Pahasapa at depths of about 3,000 feet. A well in sec. 10, T46N, R63W, at Osage had an initial flow of about 800 gpm from the Pahasapa. Municipal wells at Upton that tap the Pahasapa do not flow but are pumped at about 200 gpm. Dissolved solids in water from the Pahasapa range from about 250 to about 3,000 mg/l.

Recharge, movement, and discharge relations

Alluvium. Recharge to the alluvium occurs by infiltration of precipitation, runoff and by discharge of water from rocks of Tertiary or Cretaceous

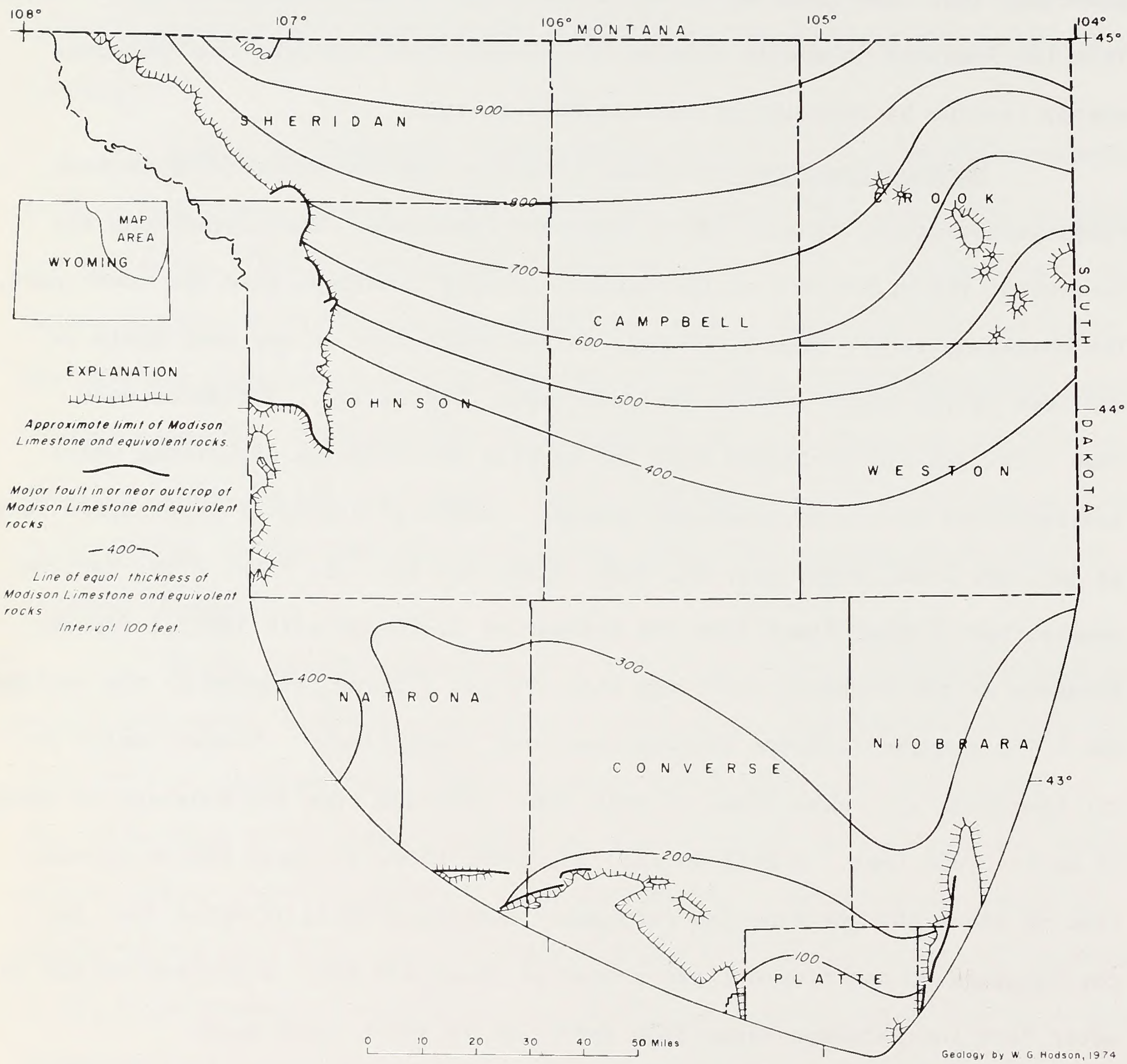


Figure 22
Thickness of the Madison Limestone and equivalent rocks in the Powder River Basin and adjacent areas.

age into which the stream valley is incised. The direction of water movement is in the direction of stream gradient with a component towards the stream. In many valleys, permeability is so low that the deposits may not be recharged to capacity even during fairly long periods of sustained runoff. Figure 23 shows the recession of flow in the Belle Fourche River below Moorcroft. The lowest discharge in the preceding period beginning January 25, 1970, was 1.8 cubic feet per second on April 5, 1970. With more than four months of sustained flow to recharge the alluvium, the deposits were not saturated to the point that sufficient additional water went into bank storage during peak storms in June and July to alter the recession by contributing release from bank storage to the streamflow.

Discharge is by underflow and evapotranspiration. That evapotranspiration may be a dominant factor is shown by water-level fluctuations in a well in sec. 35, T58N, R87W, during an unusually dry period (Figure 24). The well taps alluvium in a small drainage basin in the extreme northwest part of the Powder River Basin, north of Ranchester, Wyoming. The well is within one half mile of a drainage divide and the adjacent bedrock consists of shale beds of Cretaceous age. Therefore, ground water moving into the immediate vicinity of the well by underflow from upstream or from adjacent formations is minimal. A qualitative scale of discharge from the alluvium by evaporation, transpiration and underflow is shown by the graph (Figure 24). The decline during the non-growing season, which is minor, represents only discharge by underflow, whereas, during the growing season when evaporation, transpiration and underflow occur, there is a comparatively large decline. Evaporation and transpiration are the types of discharge at this location. This relation may be true in much of the alluvium in the basin because of the low permeability of the deposits. A well in sec. 24, T58N, R85W, which is in alluvium along a stream

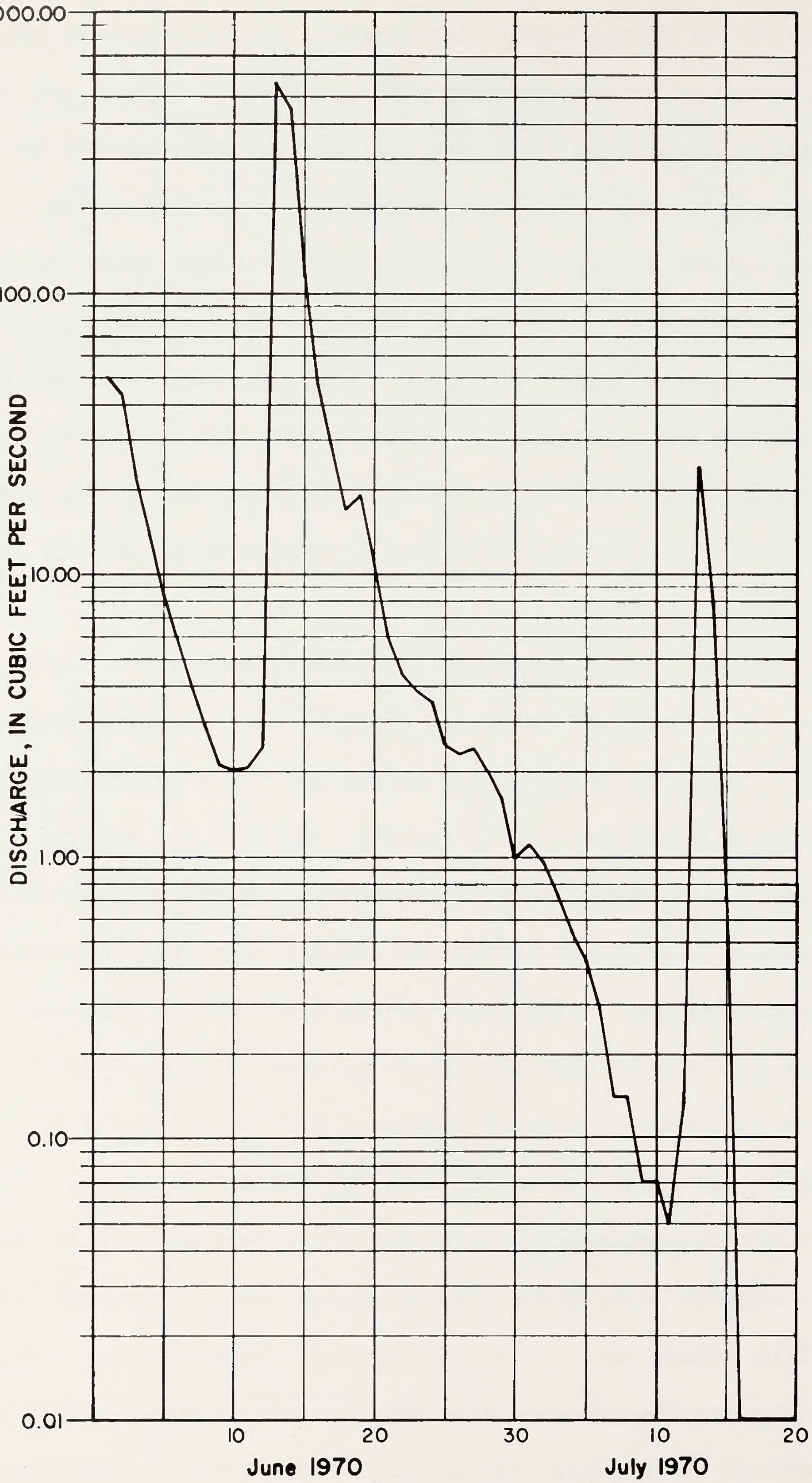


Fig. 23

Flow recession of the Belle Fourche River below Moorcroft, Wyoming

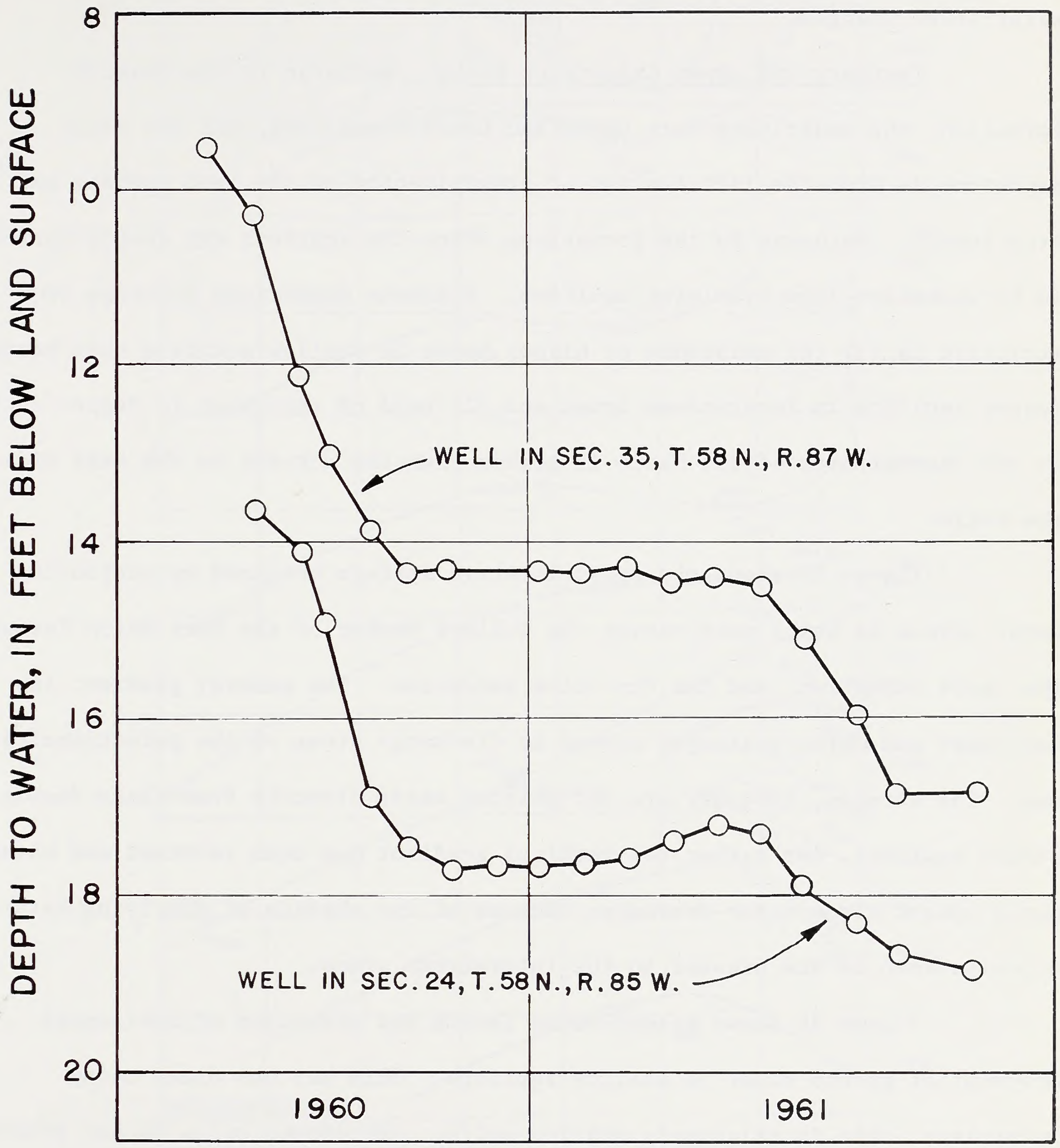


Figure 24
Hydrographs of two wells that penetrate the alluvium.

incised in the Fort Union Formation, shows essentially the same pattern of water-level changes.

Tertiary and Upper Cretaceous Rocks. Recharge to the Wasatch Formation, the underlying Fort Union and Lance Formations, and Fox Hills Sandstone is from the infiltration of precipitation on the land surface and from runoff. Recharge to the formations where the aquifers are deeply buried is by accretion from overlying aquifers. Evidence supporting recharge from accretion is (1) the existence of higher heads in shallow aquifers than heads in deeper aquifers in interstream areas and (2) head of the water in deeper aquifers in the central part of the basin is higher than the outcrop on the east side of the basin.

Figure 25 shows the potentiometric surface obtained by contouring water levels in wells penetrating the Tullock Member of the Fort Union Formation, the Lance Formation, and the Fox Hills Sandstone. The general gradient is northward and major drainages appear as discharge areas on the potentiometric map. The streams, however, are not gaining water directly from these deeply buried aquifers, but rather the vertical gradient has been reversed and water moves upward along major drainages because of the absence of overlying saturated deposits such as are present in the interstream areas.

Figure 26 shows ground-water levels and direction of horizontal movement of ground water in shallow aquifers. This map was drawn using water-level data in relatively shallow wells. All of the wells do not penetrate the same aquifer and, hence, the contours do not represent a potentiometric surface. The actual gradient would not be as steep as inferred if the contours were of a single potentiometric surface because the streams have essentially no base flow. The discharge of the Belle Fourche River near Moorcroft was less than 0.01 cubic foot per second for 45 percent of the time during the period of

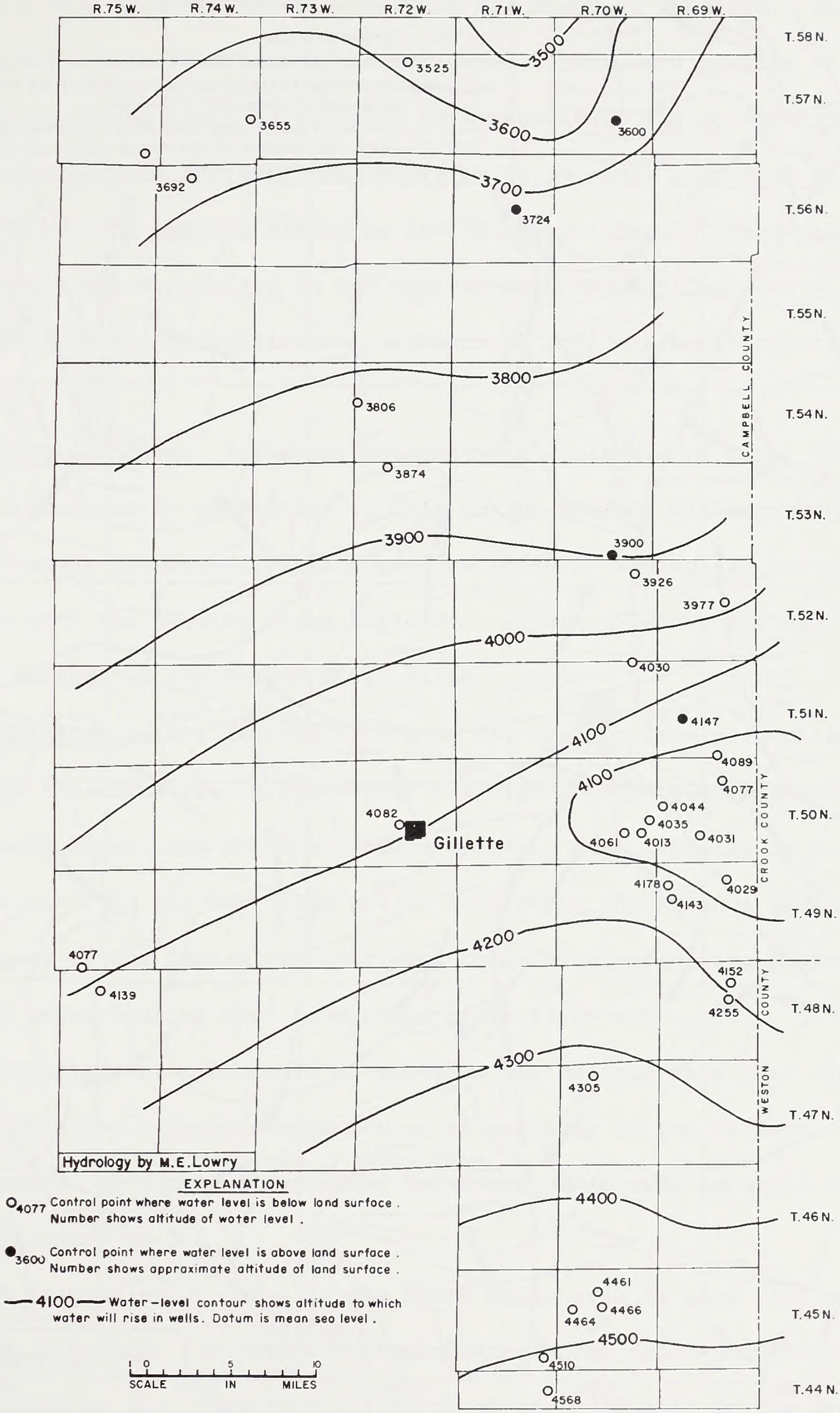


Figure 25

Generalized map of water levels in wells completed in the Fox Hills Sandstone, Lance Formation, and lower Fort Union Formation in the Gillette area.

Figure 26 Water levels and direction of horizontal movement of ground water in shallow aquifers in the Gillette Area , Campbell County , Wyoming .

record. However, from the relation between the slope of the water level shown on the map and a conservative estimate of permeability, a discharge of tens of cubic feet per second would be expected as streamflow. The gradient of the potentiometric surface in individual aquifers is not only less than that shown in Figure 26 but the natural discharge is also proportionally less than would be if a potentiometric surface in one aquifer were shown. The natural discharge is principally by evapotranspiration and much of this discharge occurs above stream level.

Deep aquifers. Recharge, movement and discharge of water in deep aquifers is believed to be similar to that in the Madison Limestone where a preliminary study is presently being made by the U.S. Geological Survey in cooperation with the Wyoming State Engineer. Figure 27 shows the depth to the top of the Madison in the Powder River Basin.

Recharge to the Madison occurs on the outcrop from precipitation and runoff where the formation is exposed in the Bighorn Mountains, the north end of the Laramie Range, and the Black Hills uplift. Some recharge is also believed to occur in the Hartville uplift area where the Madison is exposed and where, because of the removal of overlying rocks by erosion, the Madison is overlain by water-bearing sand formations of Tertiary age.

Potentiometric contours of water in the Madison show that the Black Hills area supplies a considerable source of recharge to the Madison (Figure 28). Shut-in pressure of water wells in the Newcastle-Osage area is about 180 psi (pounds per square inch).

A freshening of water in the Black Hills area is also very apparent (Figure 29). Chemical analyses of water obtained from drill-stem tests by the petroleum industry show dissolved solids of about 3,000 mg/l in the deeper part

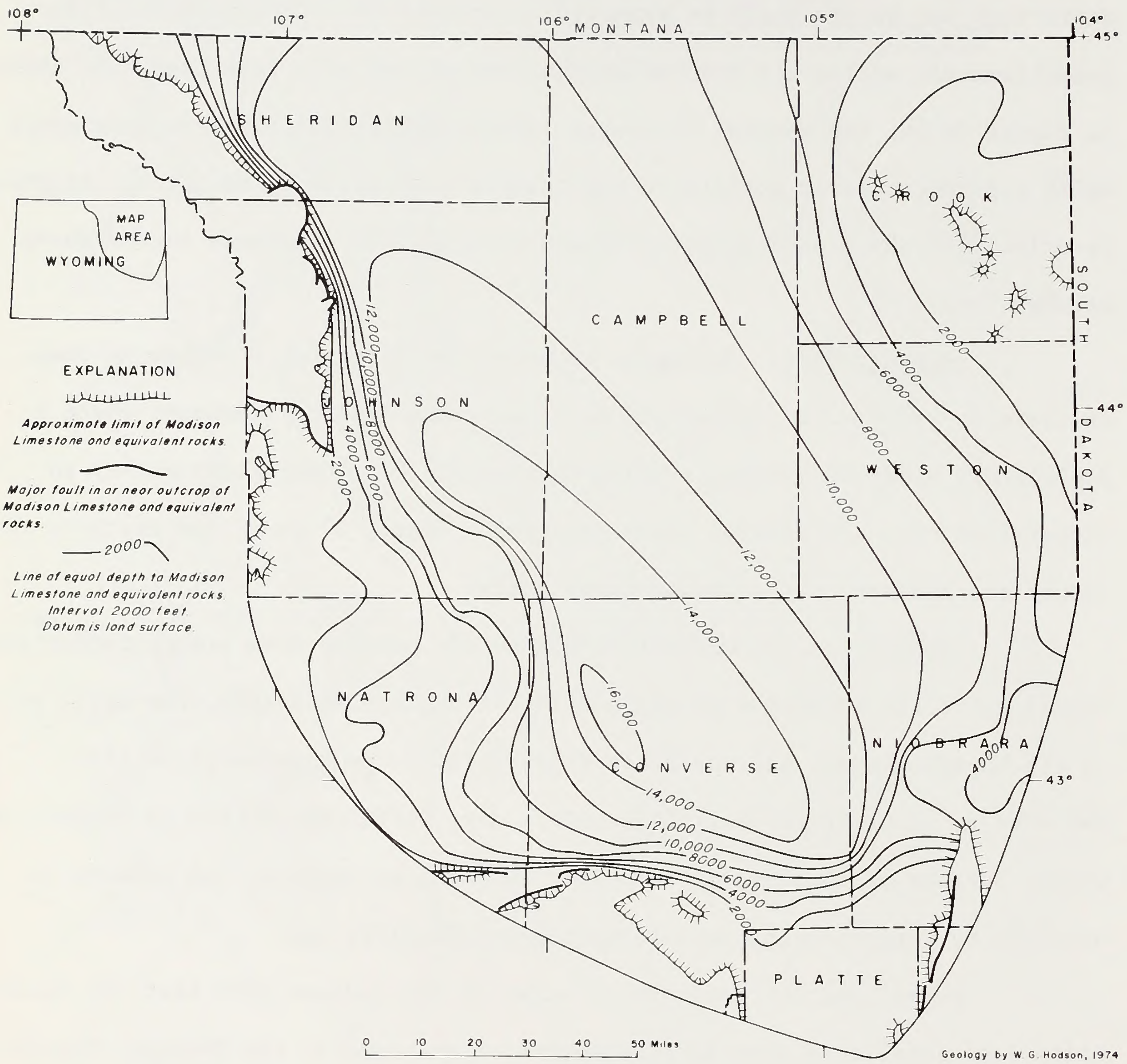


Figure 27
Depth to the Madison Limestone and equivalent rocks in the Powder River Basin and adjacent areas.

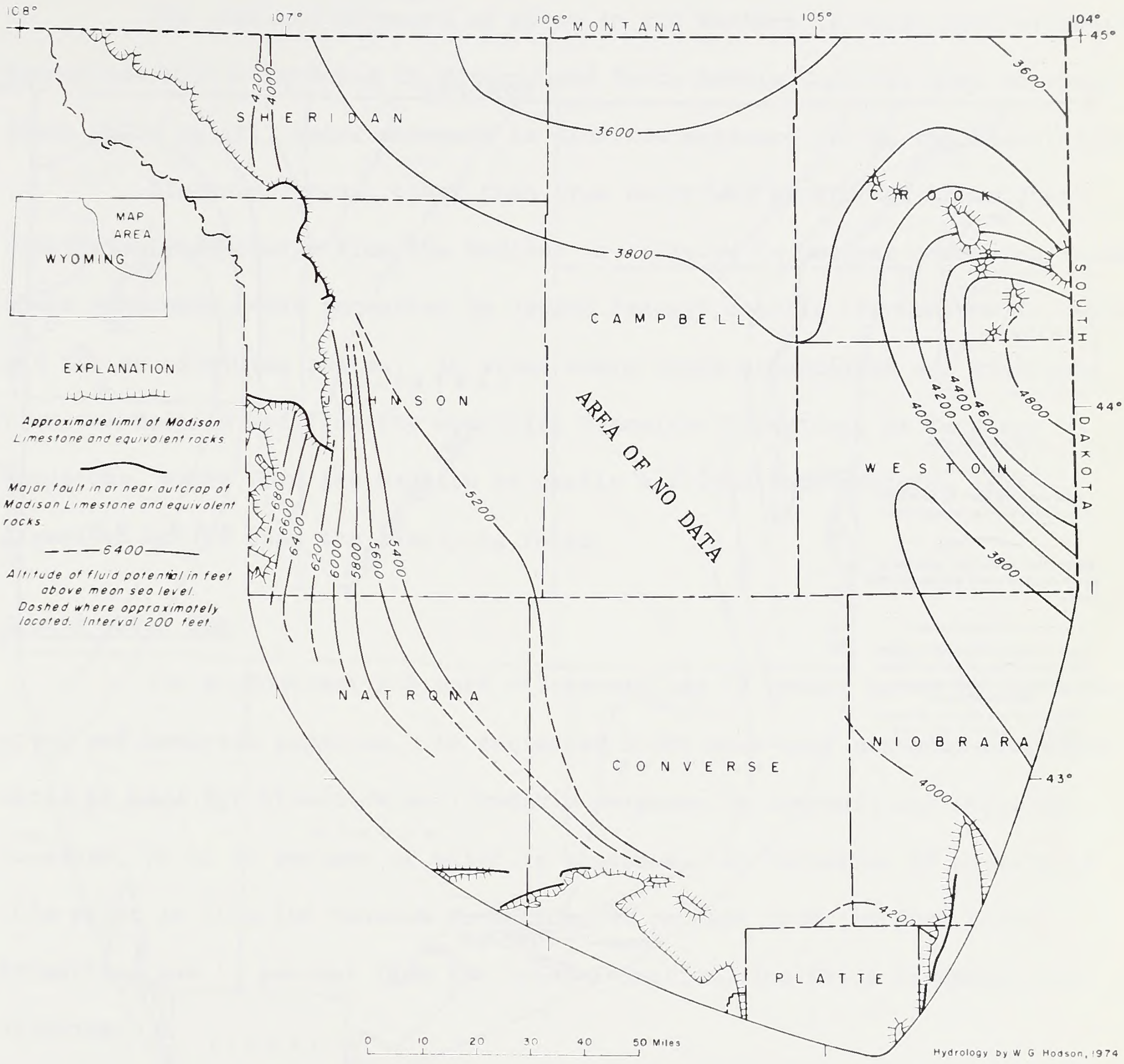


Figure 28

Preliminary map showing potentiometric surface of water in the Madison Limestone and equivalent rocks in the Powder River Basin and adjacent areas.

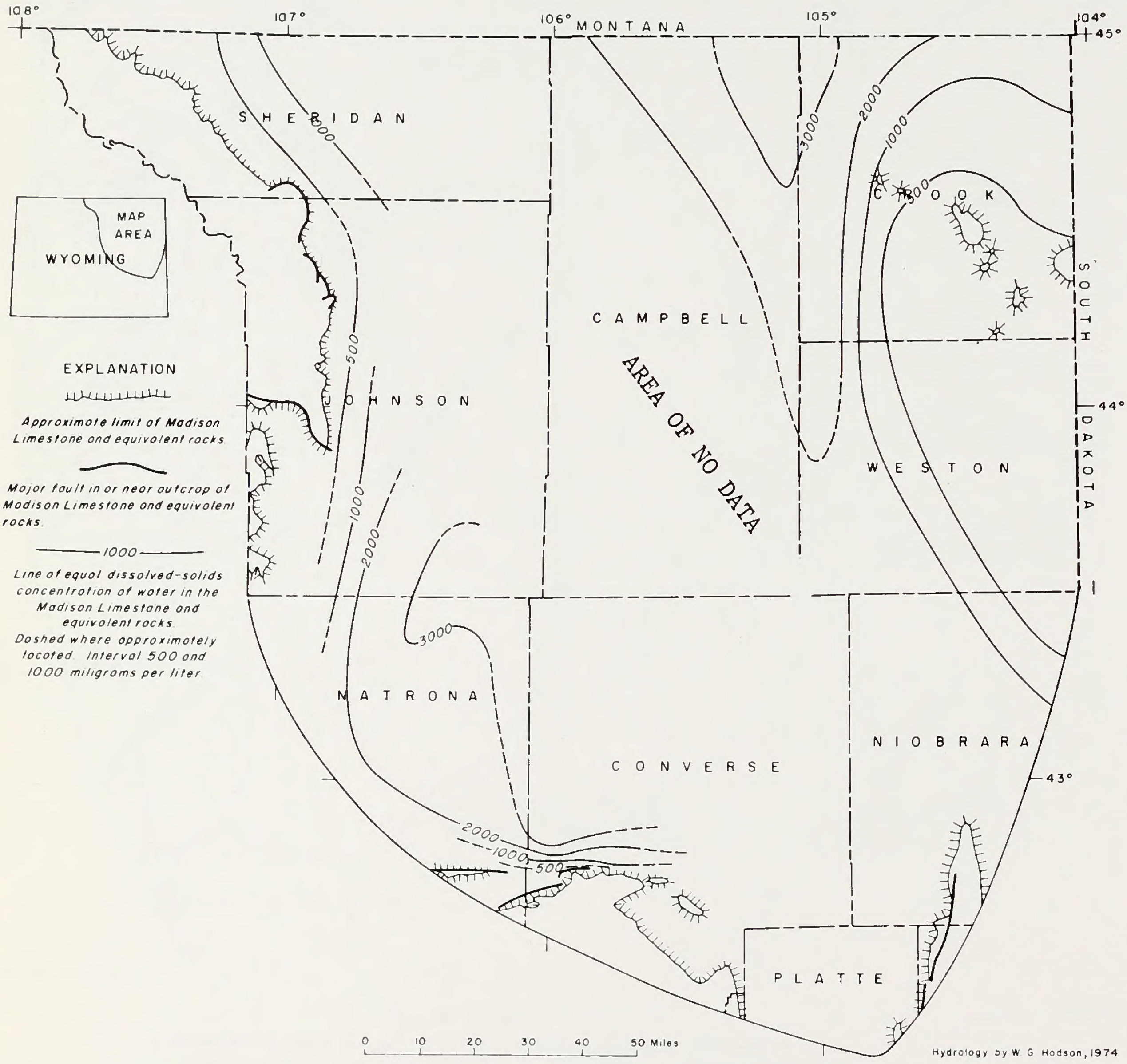


Figure 29
Preliminary map showing dissolved solids in water in the Madison Limestone and equivalent rocks in the Powder River Basin and adjacent areas.

of the basin west of the Black Hills. Dissolved solids in the Newcastle-Osage area, however, are only about 300 mg/l.

The regional movement of water in the Madison is north northeastward toward the Williston Basin in Montana and North Dakota. In the area south of the Black Hills uplift, water movement is diverted eastward around the Black Hills.

Discharge areas, other than from water wells, are not known, but considerable discharge from the Madison is believed to be into overlying rocks where permeable rocks receptive to upward leakage overlie the Madison in Wyoming and in the adjoining states. In areas where chemical analyses are available from the Madison and from the overlying Minnelusa Formation, or Tensleep Sandstone, water from the Madison at nearly all locations contains less dissolved solids than the overlying rocks.

Ground-water Use

The predominant and most widespread use of ground water is for livestock and domestic purposes. An estimated 2,000 acre-feet per year of ground water is used for livestock and domestic purposes in Campbell and Converse Counties, 90 to 95 percent of which is consumed. An estimated 60 percent of this water is from the Wasatch Formation, 30 percent from the Fort Union Formation, and 10 percent from the Lance Formation, Fox Hills Sandstone and alluvium.

Very little ground water is used for irrigation and most of this is from alluvium along the Cheyenne River Valley. Water in the Wasatch is too mineralized for most irrigation, and sodium in Wasatch water would be especially troublesome.

The City of Gillette used approximately 1,000 acre-feet of ground water during the 1973 calendar year, about 50 percent of which was from the Wasatch, 45 percent from the Fort Union and 5 percent from the Lance and Fox Hills.

Wyodak Resources Development Corp. used an estimated 180 acre-feet of ground water from the Fort Union during 1973. Additional wells were developed in the Fox Hills Sandstone during the summer of 1973 to supply anticipated expansion.

Estimated amount of ground water used for waterflood (exclusive of oil-produced water) in secondary recovery of oil fields in 1973 was 8,500 acre-feet in Campbell County and 3,500 acre-feet in Converse County. Water for waterflood in northeastern Campbell County is obtained mostly from the Inyan Kara rocks and the Minnelusa Formation. In the southeastern and western part of Campbell County, the water is mostly from the Fort Union Formation, Lance Formation, and Fox Hills Sandstone. Water for waterflood in Converse County is obtained chiefly from the Minnelusa Formation and the Madison Limestone.

Surface water

Streamflow characteristics

Streams outside the coal development area are included in this discussion as it is evident that the water resources of all of northeastern Wyoming could be affected by the proposed developments.

Northeastern Wyoming is part of the Missouri River Basin. Drainage is principally by tributaries of the Yellowstone River, the Little Missouri River, and the Cheyenne River system. Several small tributaries of the North Platte River drain the southern part of the area. Figure 30 shows the major streams and drainage pattern of the area. Table 18 lists the major streams

Table 18

Major Streams of Northeastern Wyoming by Tributary Rank and Downstream Order

- MISSOURI RIVER BASIN
  - YELLOWSTONE RIVER BASIN
    - Tongue River
      - Goose Creek
    - Powder River
      - North Fork
      - Middle Fork
      - South Fork
      - Salt Creek
      - Pumpkin Creek
      - Crazy Woman Creek
      - Wild Horse Creek
      - Clear Creek
      - Little Powder River

- LITTLE MISSOURI RIVER BASIN
  - Little Missouri River
- CHEYENNE RIVER BASIN
  - Cheyenne River
    - Dry Fork
    - Thunder Creek
    - Lodgepole Creek
    - Lance Creek
      - Lightning Creek
    - Beaver Creek
    - Belle Fourche River
      - Caballo Creek
      - Buffalo Creek
      - Donkey Creek
      - Redwater Creek
- PLATTE RIVER BASIN
  - North Platte River

by tributary rank in upstream to downstream order. Tributaries that originate in the coal development area are underlined in the table.

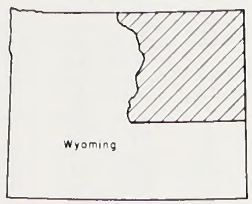
Drainage patterns of the area are mainly of a dendritic nature, in which the smaller tributaries show no predominant direction orientation or control. The courses of the smaller tributaries have developed as a result of minor inequalities in rock and soil resistance. Wind erosion has affected the development of some tributaries in the plains area.

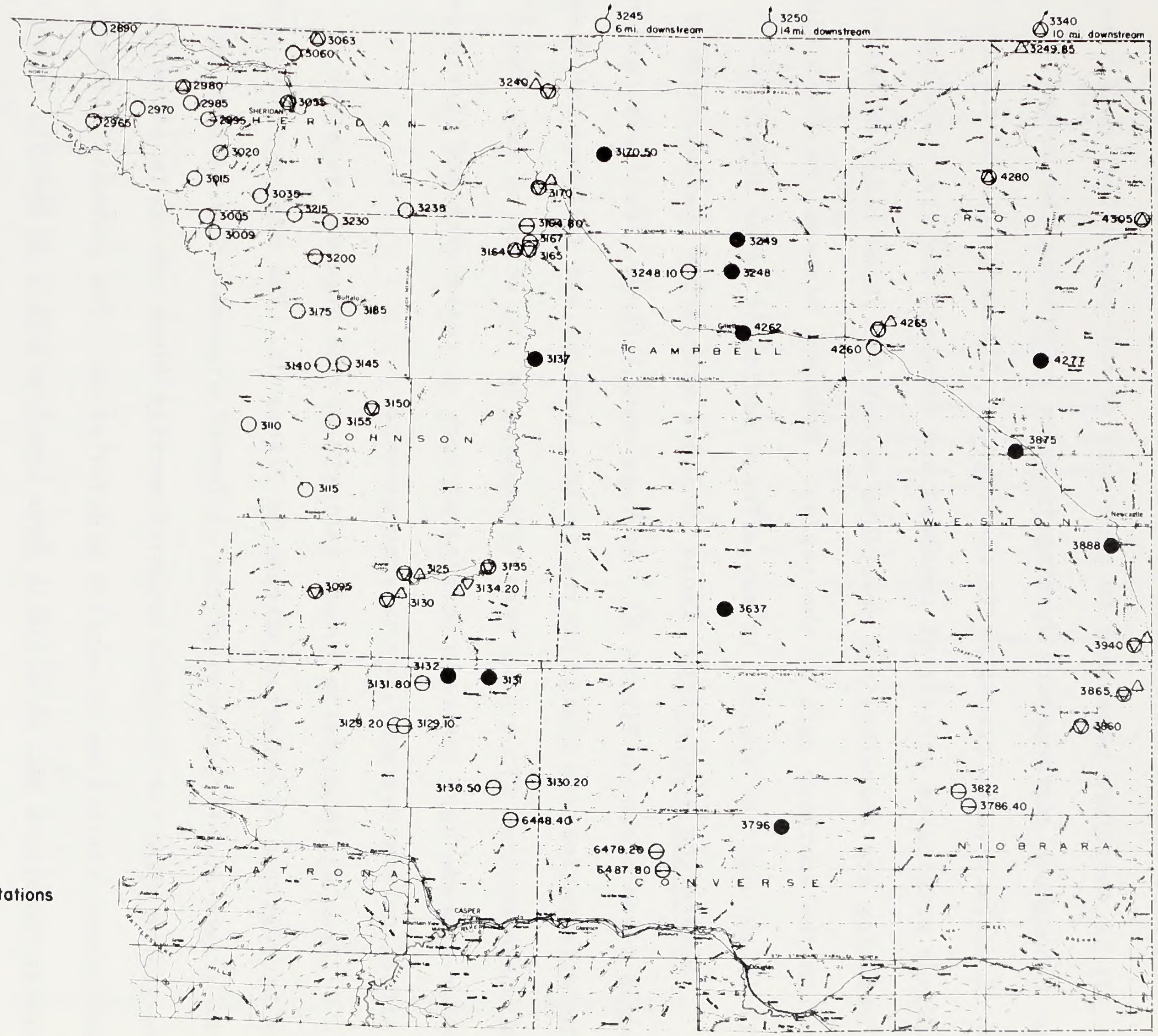
Stream types. The Eastern Powder River Coal Basin is located in the plains area between the Bighorn Mountains and the Black Hills. Streams originating in these plains are mainly ephemeral, flowing only as a result of direct runoff from snowmelt or rainfall. Some main channel reaches of the Little Powder, Little Missouri and Cheyenne River drainages are intermittent, with low flows occurring as a result of discharge from alluvial aquifers associated with the streams.

Streams originating in the Bighorn Mountains and Black Hills are mainly perennial, with sustained base flows occurring from ground-water inflow. The major portion of their runoff occurs as a result of snowmelt.

Some major streams, such as the Powder River, drain both mountain and plains areas. The resulting streamflows are therefore a combination of perennial and ephemeral types.

Data available. Streamflows of the area have been monitored by various types of gauges operated by the U.S. Geological Survey in cooperation with the Office of the Wyoming State Engineer, the Wyoming Department of Economic Planning and Development, the Wyoming Highway Department, the U.S. Bureau of Reclamation and others. The locations and types of the gauges are shown on Figure 30.





EXPLANATION

- ○ Continuous – record gaging station.
- ⊖ Partial – record gage for determining rainfall – runoff relation.
- ● Partial – record gage for determining of peak flows.
- ▽ Suspended – sediment sampling site.
- △ Chemical – quality and temperature sampling site.

4277 — Abbreviated identification number, refers to 8 – digit station number 06427700.

Scale in miles: 10 0 10 20 30 40

Scale in kilometers: 10 0 10 20 30 40 50

Base from U.S. Geological Survey 1:500,000, edition of 1967.

Figure 30
Locations of surface water gaging stations and sampling sites.

Surface waters can be transported from areas of supply to areas of demand. It is therefore necessary to show most of the gauges that have been operated throughout northeastern Wyoming in order to present the overall picture of surface-water resources in the region. The main stem of the North Platte River originates outside of northeastern Wyoming, and its hydrologic characteristics are therefore not described except for those minor tributaries which drain the southern part of the region. However, because the North Platte River flows through the region, it may offer a source of water supply.

Streamflow statistics. Table 19 lists streamflow characteristics for the gauged sites shown on Figure 30. Average annual flows, low flows, and peak-flow characteristics are listed in the table. Remarks are included for those streams whose natural flows have been influenced by the works of man. Most of the larger streams have man-made structures such as reservoirs and diversions which affect natural streamflows to some extent.

Areal differences in runoff patterns of the streams are shown by monthly hydrographs of selected streams in Figure 31. The mean monthly graphs show the season runoff patterns of the different streams. The maximum and minimum graphs show the recorded range of monthly flows, which is primarily due to year-to-year variations in monthly precipitation. The perennial streams of the Bighorn Mountains and Black Hills have less variation in monthly flows than the ephemeral streams of the plains.

Figures 32 and 33 show yearly hydrographs for selected streams of northeastern Wyoming. These hydrographs show the fluctuations of annual flows, which are primarily due to differences in annual precipitation. Average annual yields of the different streams are indicated by their unit runoffs. The largest and most dependable flows are contributed by mountain streams. Relatively small amounts of water are contributed by plains streams.

Station number and type (see footnotes)	Station name	Drainage area (sq mi)	Records available (years)	Annual mean discharge (cfs)		Range of annual minimum daily discharge (cfs)	Peak flows								Factors affecting natural flow
							Average recurrence interval (years)					Maximum observed			
				average	range		2	5	10	25	50	Date	Discharge (cfs)	Unit discharge (cfs/sq mi)	
06289000 C	Little Bighorn River at State line, near Wyola, Mont.------	193	1939-	150	90.3-220	23 - 67	1,000	1,420	1,730	2,150	2,480	6- 3-44	2,730	14.1	Diversions for irrigation of 163 acres above station.
06296500 C	North Tongue River near Dayton-----------------	32.4	1945-57	32.3	29.2-44.3	9 - 14	250	372	470	------	------	5-21-48	560	17.3	
06297000 C	South Tongue River near Dayton-----------------	85.0	1945-	78.8	43.2-108	7.0 - 12	886	1,190	1,380	1,610	1,780	6- 4-68	1,910	22.4	
06298000 C	Tongue River near Dayton----------------------	204	1918-29, 1940-	187	108-316	18 - 56	1,670	2,220	2,550	2,930	3,180	6- 3-44	3,400	16.7	Highline ditch and Dayton municipal supply diversions.
06298500 C	Little Tongue River near Dayton-----------------	25.1	1951-53, 1955-	12.8	3.74-22.4	.8 - 1.7	120	236	342	514	------	6- 9-64	850	34.0	
06299500 C	Wolf Creek at Wolf------------------------	37.8	1945-	29.3	13.8-45.0	1.8 - 4.5	297	494	670	960	1,230	6-15-63	1,130	29.9	
06300500 C	East Fork Big Goose Creek near Big Horn----------------	20.3	1953-	32.4	21.4-41.8	1.0 - 3	470	649	802	1,040	------	6-15-63	1,230	60.6	
06300900 C	Cross Creek above Bighorn Reservoir, near Big Horn------	9.29	1960-71	13.2	8.67-15.7	0 - 1.3	164	204	231	------	------	6-15-63	285	30.7	One reservoir (capacity, 796 acre-ft).
06301500 C	West Fork Big Goose Creek near Big Horn-----------------	24.4	1953-	34.4	21.7-45.7	.8 - 3.8	431	549	654	819	------	6-15-63	1,030	42.2	Two reservoirs (capacity, 3,000 acre-ft).
06302000 C	Big Goose Creek near Sheridan---------------	120	1929-	79.6	26.6-137	1.6 - 14	1,050	1,490	1,770	2,100	2,320	6-15-63	3,160	26.3	Transbasin and irrigation diversions, storage reservoirs.
06303500 C	Little Goose Creek in canyon, near Big Horn----------------	55	1941-	63.4	40.6-83.9	3.0 - 9.8	557	765	900	1,070	1,190	6-15-63	1,350	24.5	Two small diversions, three reservoirs (capacity, 860 acre-ft).
06305500 C	Goose Creek below Sheridan--------------------	392	1941-	181	58.7-311	4.0 - 55	1,650	2,710	3,510	4,590	5,450	6-16-63	5,450	13.9	Irrigation diversions, several small reservoirs (capacity, about 15,000 acre-ft).
06306000 C	Tongue River near Acme-------------------	894	1938-57	403	191-704	3.4 - 110	3,260	4,870	6,070	7,730	------	6- 4-44	9,110	10.2	Do.
06306300 C	Tongue River at State line, near Decker, Mont.-----------	1,477	1960-	493	187-664	5.4 - 126	4,060	5,830	6,880	------	------	6-15-67	7,480	5.06	Do.
06309500 C	Middle Fork Powder River above Kaycee----------------	450	1949-70	71.7	46.8-112	12 - 30	642	978	1,250	1,650	------	6- 8-68	1,750	3.89	Irrigation diversions.
06311000 C	North Fork Powder River near Hazelton----------------	24.5	1946-	14.4	6.91-26.7	.6 - 2.2	314	453	560	714	843	6-15-53	886	36.2	
06311500 C	North Fork Powder River near Mayoworth---------------	106	1940-	32.8	17.9-47.1	5.6 - 18	433	690	874	1,120	1,310	8-11-41	1,270	12.0	Two small irrigation diversions, one reservoir (capacity, 4,200 acre-ft).
06312500 C	Powder River near Kaycee------------------	980	1938-39, 1940-71	129	57.7-217	0 - 11	1,390	2,320	3,040	4,050	4,880	8-11-41	5,230	5.34	Irrigation diversions.
06312910 S-R	Dead Horse Creek tributary near Midwest----------------	1.53	1965-72	-----	-----	0 - 0	388	1,130	2,170	------	------	6-20-69	3,020	2,000	
06312920 S-R	Dead Horse Creek tributary No. 2 near Midwest----------	1.34	1965-72	-----	-----	0 - 0	226	550	922	------	------	6- 4-72	1,470	1,100	
06313000 C	South Fork Powder River near Kaycee-----------------	1,150	1938-40, 1950-69	36.2	10.5-109	0 - 4.6	2,630	8,150	14,900	28,600	43,800	5-22-62	35,500	30.9	
06313020 S-R	Bobcat Creek near Edgerton----------------	8.29	1965-73	-----	-----	0 - 0	24	260	850	------	------	9-11-73	1,070	129	
06313050 S-R	East Teapot Creek near Edgerton----------------	5.44	1965-72	-----	-----	0 - 0	320	1,300	2,700	------	------	6-10-65	4,450	818	

Table 19

Streamflow Characteristics at Gauging Stations

Table 19 (Cont'd)

Streamflow Characteristics at Gauging Stations

Station number and type (see footnotes)	Station name	Drainage area (sq mi)	Records available (years)	Annual mean discharge (cfs)		Range of annual minimum daily discharge (cfs)	Peak flows								Factors affecting natural flow
							Average recurrence interval (years)					Maximum observed			
				average	range		2	5	10	25	50	Date	Discharge (cfs)	Unit discharge (cfs/sq mi)	
06313100 C-S	Coal Draw near Midwest	11.4	1961-	-----	-----	0 - 0	696	1,900	2,730	------	------	6-22-64	2,620	230	
06313180 S-R	Dugout Creek tributary near Midwest	.71	1965-73	-----	-----	0 - 0	251	635	1,050	------	------	7-15-67	1,590	2,239	
06313200 C-S	Hay Draw near Midwest	1.60	1958-70	-----	-----	0 - 0	300	634	920	1,350	------	7-15-67	900	562	
06313500 C	Powder River at Sussex	3,090	1938-40, 1950-57	151	115-217	1.5 - 9.8	4,070	10,400	18,200	------	------	5-23-52	32,500	10.5	
06313700 C-S,C	Dead Horse Creek near Buffalo	155	C-S 1958-71, C 1971-	-----	-----	0 - 0	822	1,560	2,040	2,600	------	5-26-62	2,300	14.8	
06314000 C	North Fork Crazy Woman Creek near Buffalo	44.9	1942-49	25.2	19.3-38.7	3.1 - 3.8	261	417	552	------	------	6- 6-49	611	13.6	
06314500 C	North Fork Crazy Woman Creek below Spring Draw, near Buffalo	51.7	1949-	18.5	7.61-30.9	1.0 - 4.3	260	582	915	1,520	------	6- 9-68	1,290	25.0	Irrigation diversions.
06315000 C	North Fork Crazy Woman Creek near Craub	174	1950-68	17.3	3.60-40.7	0 - 2.7	301	600	889	1,380	------	6- 8-68	1,640	9.42	Do.
06315500 C	Middle Fork Crazy Woman Creek near Creub	82.7	1942-	22.3	10.0-44.3	1.7 - 7.0	277	614	1,020	1,870	2,890	5- 2-47	4,520	54.6	
06316400 C	Crazy Woman Creek at upper station, near Arvada	945	1963-70	44.7	14.5-102	0 - 2.0	1,000	2,100	3,400	------	------	6-15-65	15,800	16.7	Irrigation diversions for irrigation of over 30,000 acres.
06316480 S-R	Headgate Draw at upper station, near Buffalo	3.32	1965-73	-----	-----	0 - 0	200	1,900	4,600	------	------	6-15-65	5,490	1,650	
06316500 C	Crazy Woman Creek at Arvada	956	1939-43, 1950-64	40.0	3.66-96.3	0 - 3.5	1,040	2,140	3,420	6,090	9,210	7-14-62	2,900	3.03	Irrigation diversions for irrigation of over 30,000 acres.
06316700 S-R	Powder River tributary near Buffalo	1.64	1965-73	-----	-----	0 - 0	258	1,100	2,250	------	------	6-16-65	2,290	1,400	
06317000 C	Powder River at Arvada	6,050	1930-33, 1934-	272	70.3-668	0 - 24	7,330	14,700	22,200	36,000	50,500	9-29-23	100,000	16.5	Irrigation diversions, numerous reservoirs.
06317050 C-S	Spotted Horse Creek tributary near Spotted Horse	4.28	1961-	-----	-----	0 - 0	91	412	985	2,660	------	6-13-62	3,120	729	
06317500 C	North Fork Clear Creek near Buffalo	29.0	1949-68	13.9	9.53-23.0	1.0 - 4.2	196	347	465	631	------	6-15-63	675	23.3	Irrigation and transbasin diversions.
06318500 C	Clear Creek near Buffalo	120	1897-99, 1917-27, 1938-	62.7	18.1-148	0 - 11	673	1,072	1,390	1,850	2,230	6-15-63	3,420	28.5	Diversion above station for irrigation of 330 acres.
06320000 C	Rock Creek near Buffalo	60.0	1943-44, 1945-	36.4	16.1-82.4	.5 - 5.0	535	1,040	1,470	2,140	2,720	6-15-63	1,860	31.0	Irrigation and transbasin importation.
06321000 C	South Piney Creek near Story	69.4	1951-	75.3	52.4-103	.4 - 14	719	1,130	1,410	1,790	------	6-15-63	2,090	30.1	Irrigation diversion, three reservoirs (capacity, 9,702 acre-ft).
06321500 C	North Piney Creek near Story	36.8	1951-	37.2	21.4-50.4	3.0 - 9	465	788	1,080	1,580	------	6-15-63	1,820	49.4	
06323000 C	Piney Creek at Kearney	118	1940-	85.3	31.8-167	2 - 12	1,110	1,640	1,970	2,350	2,620	6-15-63	3,410	28.9	Irrigation diversions, three reservoirs (capacity, 9,702 acre-ft).
06323500 C	Piney Creek at Ucross	267	1917-23, 1950-	81.2	24.7-133	.6 - 16	960	1,690	2,210	2,880	3,370	6-16-63	3,570	13.4	Irrigation diversions, four reservoirs (capacity, about 42,000 acre-ft).

Station number and type (see footnotes)	Station name	Drainage area (sq mi)	Records available (years)	Annual mean discharge (cfs): average	Annual mean discharge (cfs): range	Range of annual minimum daily discharge (cfs)	Peak flows: Average recurrence interval (years): 2	5	10	25	50	Maximum observed: Date	Discharge (cfs)	Unit discharge (cfs/sq mi)	Factors affecting natural flow
06324000 C	Clear Creek near Arvada----------------------	1,110	1939-	179	47.7-408	0 - 22	2,860	5,040	6,680	8,930	10,700	8- 5-54	9,600	8.65	Irrigation diversions, four reservoirs (capacity, about 42,000 acre-ft).
06324500 C	Powder River at Moorhead--------------------	8,088	1929-72	453	109-868	0 - 83	9,800	19,000	26,000	43,000	60,000	6-17-62	23,000	2.84	Irrigation diversions, numerous reservoirs.
06324800 C-S	Little Powder River tributary near Gillette----------------	.81	1960-	-----	-----	0 - 0	-----	------	------	------	------	6-22-64	176	218	
06324810 S-R	Box Draw tributary near Gillette----------------	.5	1965-72	-----	-----	0 - 0	10	60	150	------	------	5-22-68	84	168	
06324900 C-S	Little Powder River tributary No. 2 near Gillette----------	3.95	1959-	-----	-----	0 - 0	168	350	502	725	------	6-22-64	758	192	
06325000 C	Little Powder River at Biddle, Mont.-------------	1,541	1938-43	-----	20.5-30.2	0 - 0	-----	------	------	------	------	8-17-40	5,700	3.70	Small diversions for irrigation of hay meadows above station.
06334000 C	Little Missouri River near Alzada-----------------	904	1911-25, 1928-32, 1935-69	77.2	1.92-324	0 - .1	1,940	3,350	4,220	5,210	5,860	4- 4-44	6,000	6.64	Do.
06363700 C-S	Porcupine Creek near Turnercrest------------	31.5	1959-	-----	-----	0 - 0	-----	------	------	------	------	6-15-62	1,230	39.0	
06378640 C-S	Lance Creek tributary near Lance Creek------------	1.2	1965-	-----	-----	0 - 0	60	331	744	------	------	9- 3-68	1,060	883	
06379600 C,C-S	Box Creek near Bill------------------------	112	C 1956-58, C-S 1959-	-----	-----	0 - 0	145	692	1,560	3,660	------	5- 5-71	1,720	15.4	
06382200 S-R	Pritchard Draw near Lance Creek-----------------	5.1	1965-	-----	-----	0 - 0	763	2,140	3,420	------	------	9- 3-68	4,050	794	
06386000 C	Lance Creek at Spencer---------------------	2,070	1948-54, 1956-	26.3	2.74-73.9	0 - 0	1,970	3,600	4,790	6,340	7,500	5-24-71	7,410	3.58	Numerous small reservoirs, diversions for irrigation of 3,500 acres.
06386500 C	Cheyenne River near Spencer----------------	5,270	1948-	59.4	5.95-283	0 - 0	3,160	6,620	9,820	15,000	19,900	5-27-62	16,000	3.04	Numerous small reservoirs, diversions for irrigation of 6,860 acres.
06387500 C-S	Turner Creek near Osage-----------------------	47.8	1959-	-----	-----	0 - 0	1,270	2,120	2,710	3,470	------	6-15-62	3,000	62.8	
06388800 C-S	Blacktail Creek tributary near Newcastle---------------	.25	1960-	-----	-----	0 - 0	66	92	98	101	------	6-17-65	102	408	
06394000 C	Beaver Creek near Newcastle-------------------	1,320	1944-72	33.2	5.13-130	0 - 1.5	1,030	2,070	3,270	5,730	8,590	6-16-62	11,900	9.02	Numerous small reservoirs, diversions for irrigation of 4,900 acres.
06426000 C	Belle Fourche River near Moorcroft--------------	1,380	1923-33	67.8	3.0-244	0 - .3	2,000	7,000	11,000	------	------	4- 7-24	12,500	9.06	Numerous small reservoirs, diversions for irrigation.
06426200 C-S	Donkey Creek tributary near Gillette---------------	.28	1960-	-----	-----	0 - 0	34	57	84	137	-----	7-22-66	165	589	
06426500 C	Belle Fourche River below Moorcroft-------------	1,670	1924-70	21.0	1.14-104	0 - 0	898	2,040	3,050	4,600	5,950	4- 7-24	12,500	7.49	Numerous small reservoirs, diversions for irrigation.
06427700 C-S	Inyan Kara Creek near Upton------------------	96.5	1959-	-----	-----	------------	215	616	1,220	2,830	------	7- 1-59	4,660	48.3	
06428000 C	Belle Fourche River at Hulett-------------------	2,800	1929-32, 1938-51	68.6	17.0-134	0 - 3.2	2,400	8,000	13,000	21,000	------	3-26-43	6,320	2.26	Reflects streamflow prior to construction of Keyhole Reservoir.
06430500 C	Redwater Creek at Wyoming-S. Dakota State line-	471	1929-31, 1954-	34.8	17.9-59.1	0 - 18	258	712	1,220	2,190	------	6-16-62	2,340	4.97	Murray Ditch, large irrigation diversion.

Table 19 (Cont'd)

Streamflow Characteristics at Gauging Stations

Table 19 (Cont'd)

Table 19 (Cont'd)

Streamflow Characteristics at Gauging Stations

Station number and type (see footnotes)	Station name	Drainage area (sq mi)	Records available (years)	Annual mean discharge (cfs)		Range of annual minimum daily discharge (cfs)	Peak flows								Factors affecting natural flow
							Average recurrence interval (years)					Maximum observed			
				average	range		2	5	10	25	50	Date	Discharge (cfs)	Unit discharge (cfs/sq mi)	
06644840 S-R	McKenzie Draw tributary near Casper------------------	2.02	1965-73	-----	-----	0 - 0	32	212	540	------	------	9- -73	970	480	
06648720 S-R	Frank Draw tributary near Orpha------------------	.79	1965-73	-----	-----	0 - 0	50	212	408	------	------	8-19-66	342	433	
06648780 S-R	Sage Creek tributary near Orpha------------------	1.38	1965-73	-----	-----	0 - 0	22	94	181	------	------	7-25-65	229	166	

Footnotes:

C, continuous record gaging station.
C-S, partial-record gage for determining peak flows.
S-R, partial-record gage for determining rainfall-runoff relations.

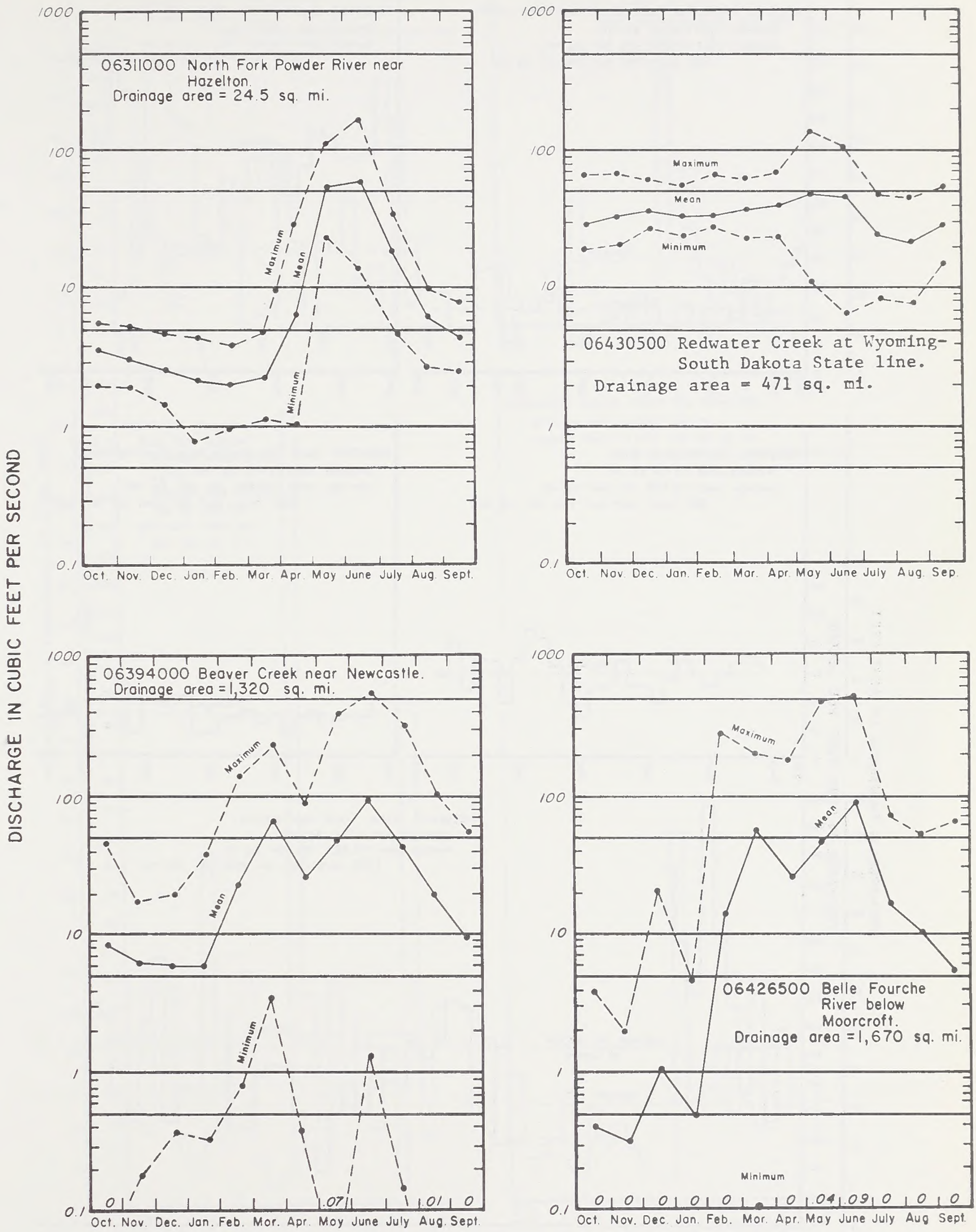


Figure 31 —— Monthly hydrographs of selected streams.

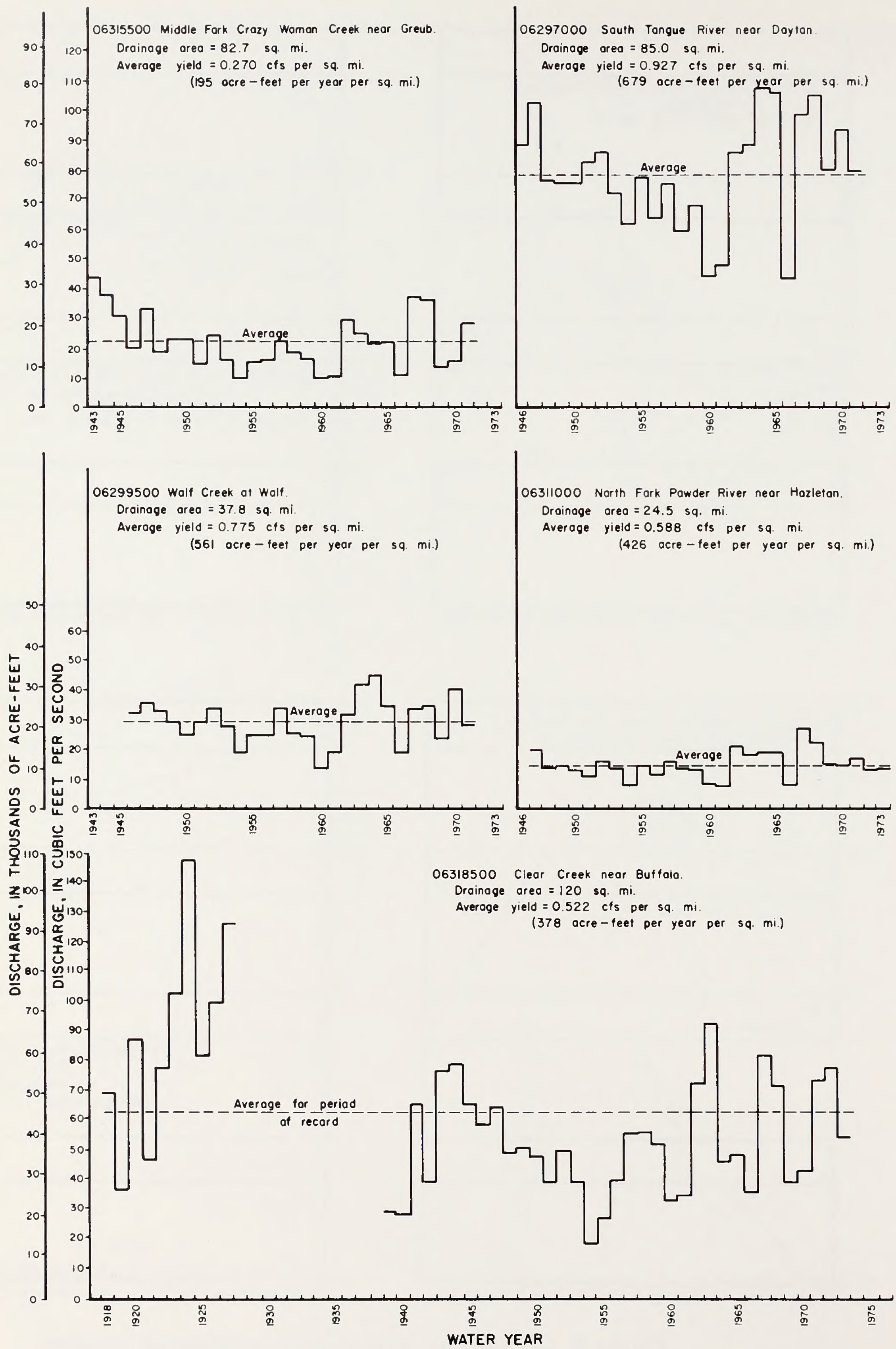


Figure 32--Yearly hydrographs of selected mountain streams.

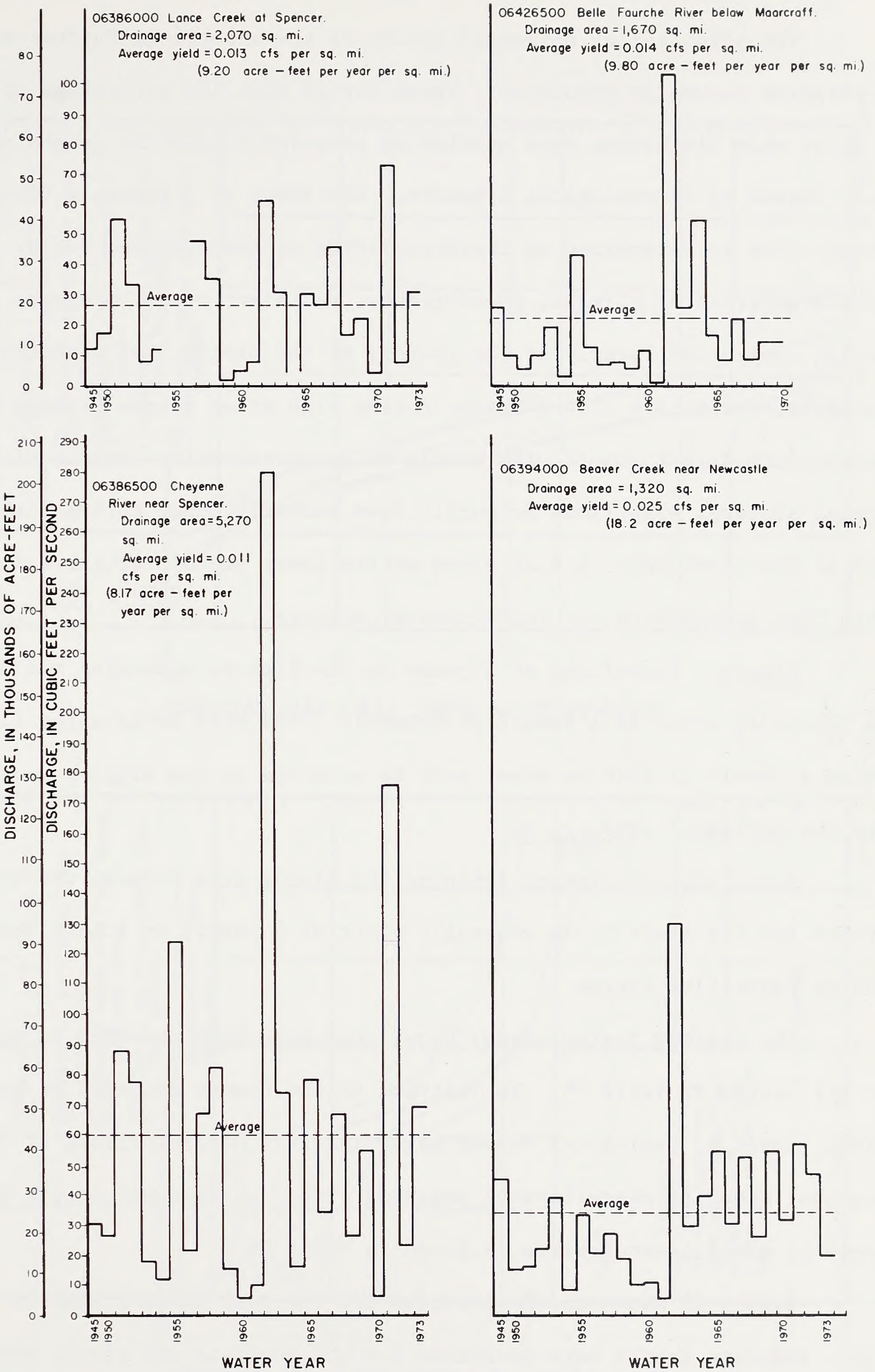


Figure 33--Yearly hydrographs of selected plains streams.

The perennial or ephemeral nature of the streams is further shown by flow-duration curves in Figure 34. These curves show the percentage of time that daily mean discharges were equaled or exceeded during the gauged period without regard to chronological sequence. The shape of a stream's flow-duration curve is determined by characteristics of the drainage basin. The high flows are governed by climate, physiography, and plant cover; whereas, the low flows are controlled largely by the geology of the basin. The ephemeral streams characteristically have flow-duration curves with steep slopes because their flows are from direct runoff with little or no ground-water contribution. The perennial streams, with flows primarily from snowmelt, have curves with flat slopes at the upper end. A flat slope at the lower end of the curve indicates release from ground-water or surface-water storage.

Floods. Floodflows of streams in the Bighorn Mountains and Black Hills generally occur as a result of snowmelt. The most devastating floods occur as a result of rain on snow, such as occurred in the Bighorn Mountains during the spring of 1963.

Floodflows of streams draining the plains area between the Bighorn Mountains and the Black Hills generally occur as a result of runoff from high-intensity convective storms.

The maximum instantaneous flows that have been recorded at gauged sites are listed in Table 19. In addition to the floods recorded at gauging stations, the U.S. Geological Survey makes indirect determinations of outstanding floods that occur at miscellaneous ungauged sites. A listing of peak flows measured at miscellaneous sites is given in Table 20.

Figure 35 shows envelope curves for the peak flows listed in Tables 19 and 20. Separate graphs were developed for the mountain and plains streams due to inherent differences in their flood characteristics. The curves show

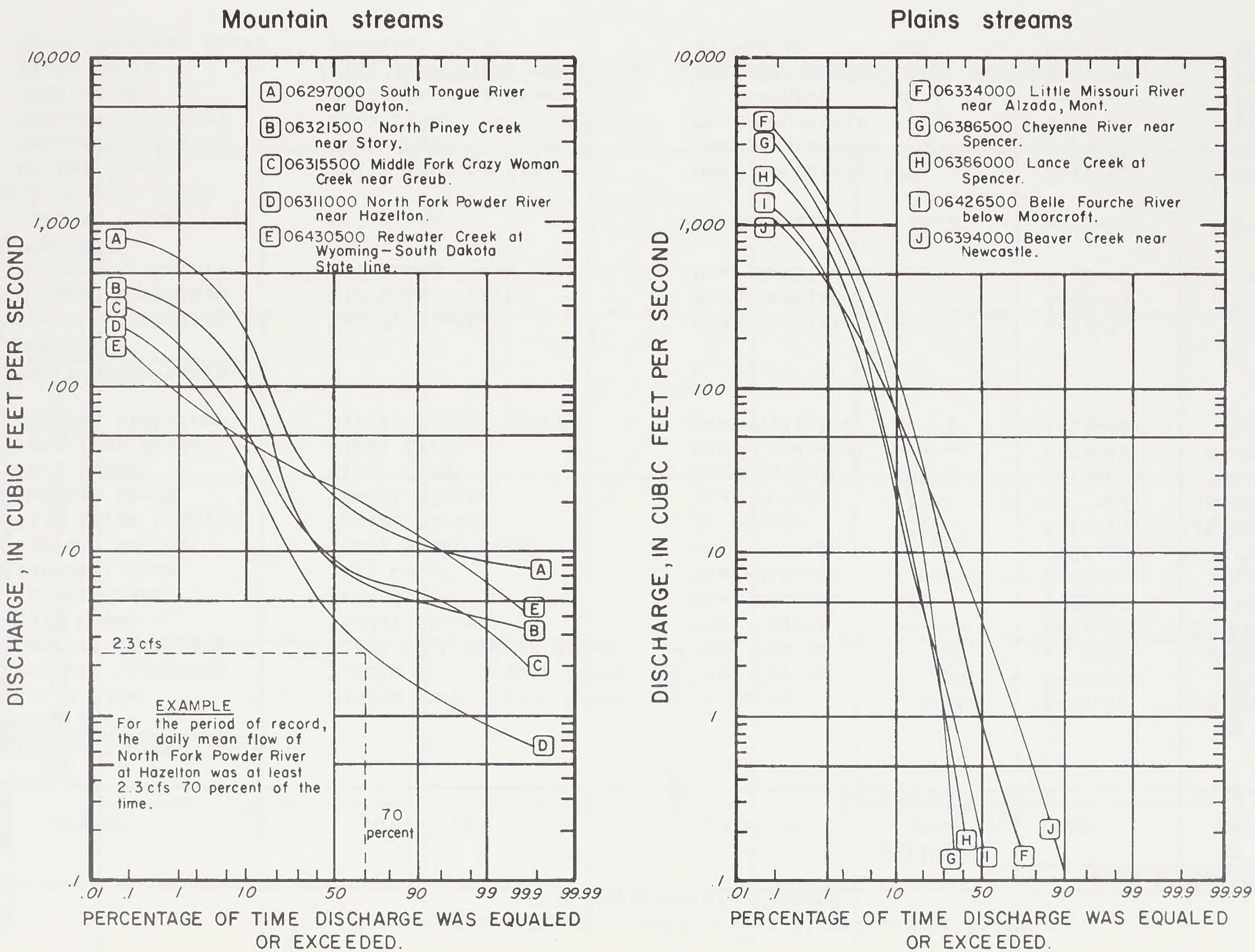


Figure 34 -- Duration curves of daily flow for selected streams.

Table 20

Measurements of Peak Discharges at Miscellaneous Sites
In Northeastern Wyoming

STREAM	TRIBUTARY TO	LOCATION	DRAINAGE AREA (SQ MI)	PEAK DISCHARGE DATE	PEAK DISCHARGE CFS	PEAK DISCHARGE CFS PER SQ MI
YELLOWSTONE RIVER BASIN						
POWDER RIVER						
Keyes Draw	Middle Fork Powder River	At Kaycee	3.14	6-16-72	3,900	1,240
Unnamed tributary	Middle Fork Powder River	Near Kaycee	.50	6-16-72	154	308
Unnamed tributary	North Fork Powder River	Near Kaycee	.60	6-16-72	1,320	2,160
Salt Creek	Powder River	Near Sussex	------	5-23-52	21,600	-----
Teapot Creek	Salt Creek	Near Midwest	383	5-21-62	2,360	6.2
Bothwell Draw	Salt Creek	Near Midwest	------	8-02-53	5,820	-----
Buffalo Wallow	Crazy Woman Creek	Near Buffalo	.8	7-20-66	755	944
Wild Horse Creek	Powder River	At Arvada	322	6-16-25	10,000	31.0
Deadman Creek	Powder River	Near Arvada	12	6- -62	16,600	1,380
Rock Creek	Clear Creek	Near Buffalo	109	6-15-63	1,410	12.9
Lone Tree Creek	Clear Creek	Near Clearmont	------	6-25-42	6,800	-----
Unnamed tributary	Little Powder River	Near Gillette	.5	7-15-69	223	446
CHEYENNE RIVER BASIN						
LANCE CREEK						
Unnamed tributary	Wyatte Creek	Near Manville	-----	6-27-52	181	-----
Unnamed tributary	Old Woman Creek	Near Redbird	-----	6-28-52	156	-----
Unnamed tributary	Old Woman Creek	Near Redbird	-----	6-28-52	1,140	-----
BEAVER CREEK						
Cambria Creek	Oil Creek	At Newcastle	16.2	6-15-62	1,020	63.0
BELLE FOURCHE RIVER						
Donkey Creek	Belle Fourche River	Near Moorcroft	520	5-27-62	2,280	4.4
Unnamed tributary	Rush Creek	Near Moorcroft	.47	5-24-60	336	715
Unnamed tributary	Rush Creek	Near Moorcroft	.16	5-24-60	136	850
Wind Creek	Belle Fourche River	At Thornton	16.3	5- -62	531	32.6
Freda Creek	West Fork Wind Creek	Near Moorcroft	5.6	5- -62	232	41.4
South Redwater Creek	Redwater Creek	At Beulah	200	8-21-73	2,600	13.0

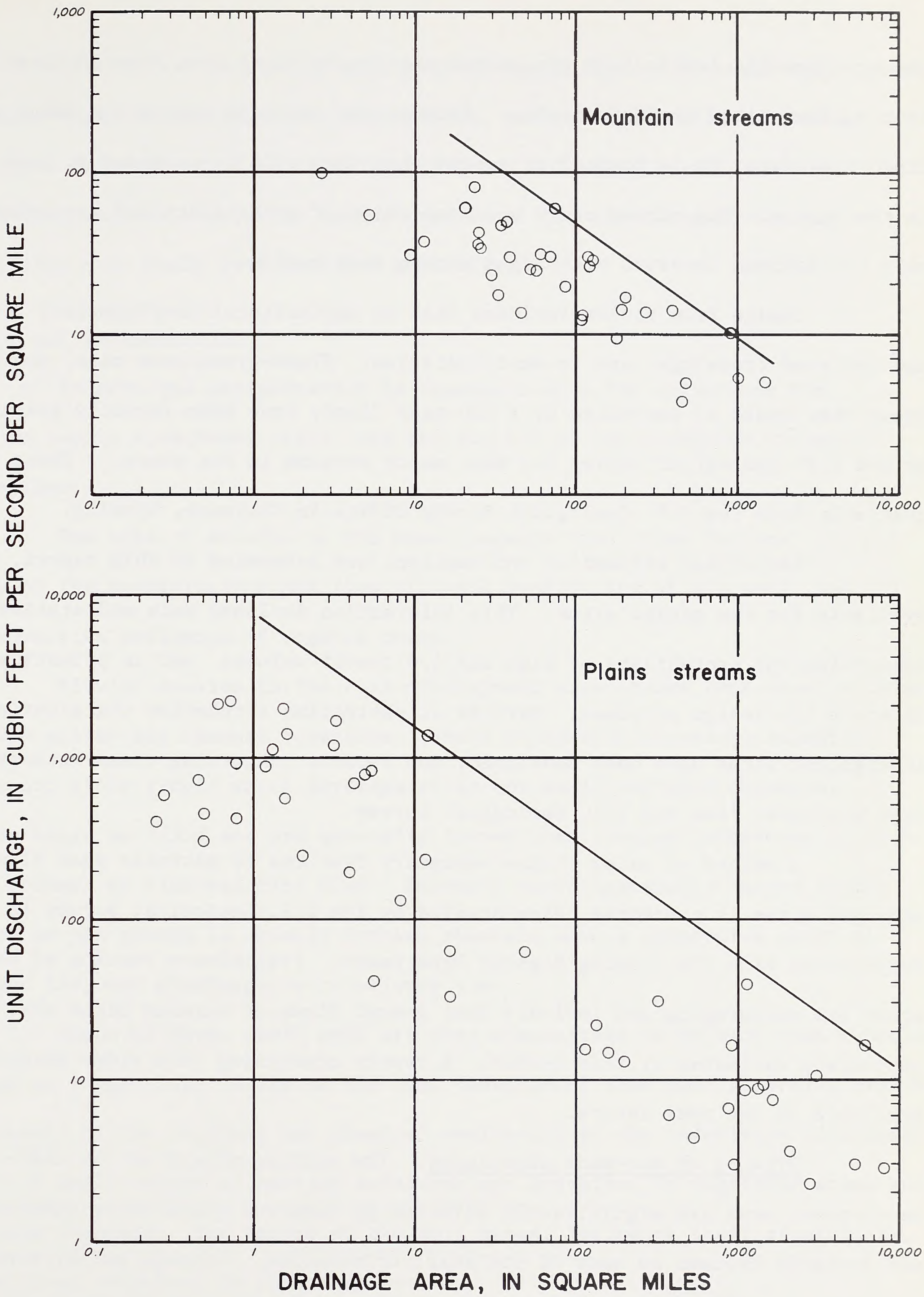


Figure 35--Maximum observed unit discharges and envelope curves.

the unit runoffs (cubic feet per second per square mile) that have occurred from various-sized drainage basins. Because the envelope curves are based upon historical data, it is logical to assume that they will be exceeded at some time in the future. The curves carry no connotation of probability and represent only the maximum observed discharges within each region.

Damage from floods includes that to agricultural developments, road and railroad crossings, and to municipalities. Flood-prone area maps, showing areas that would be inundated by a 100-year flood, have been recently prepared by the U.S. Geological Survey for most major streams in the state. These maps are available from the U.S. Geological Survey Office in Cheyenne, Wyoming.

Additional streamflow information, not presented in this report, is available for the gauged sites. This information includes data and statistics concerning the probability of high and low runoff volumes and is primarily of interest for design purposes. Methods of estimating streamflow characteristics at ungauged sites have been developed, and reports concerning these methods are also available from the U.S. Geological Survey.

A method of using channel-geometry features to estimate peak flows at ungauged sites is currently being studied by the U.S. Geological Survey in cooperation with the Wyoming Highway Department. Preliminary results of the study are encouraging and indicate that annual flows of streams might also be accurately estimated by this method. A report concerning this study should be available in the near future.

Effects of man-made structures. The surface waters of the coal-development area are significantly affected by numerous stock-water reservoirs and spreader systems on many of the small tributaries. Storage and diversion by these structures results in appreciable depletion of water through evaporation and seepage. The natural runoff from the area is thus reduced by the structures.

These structures also reduce the magnitude of small floods; however, experience has shown that the magnitude of large floods, such as those with an average recurrence interval of 50 years or greater, are not significantly reduced. In some cases, such as when a dam washes out, resulting flood magnitudes may be higher than what would have occurred naturally.

Erosion and sedimentation

Erosion and sedimentation is dependent upon the ability of the basin to supply a sediment yield and the ability of the stream to transport the sediment.

The rate of erosion in the basin depends upon three factors: (1) the energy of the precipitation and flow, (2) the erodibility of the soil, and (3) the protective influence of vegetal cover.

Fluvial erosion in the coal development area occurs from sheet erosion and from gulley and channel formation. Sheet erosion is caused by raindrop impact and storm runoff which develops rills and small unstable channels. Gullies begin as rills and are generally formed when intense rainstorms provide large volumes of high-velocity flow. Snowmelt runoff generally causes little erosion as the ground is usually frozen, channels have a protective cover of snow and ice, and discharge is relatively low.

Areas of fine, sandy soil are more susceptible to erosion than cemented hardpan or tough clay. Soils of the coal development area have generally evolved as a result of the physical and chemical weathering of the underlying lithologic units. A small amount of aeolian sediments are deposited in vegetated areas and in stream channels. The nature of the soil types, including their erodibility, is described elsewhere in this chapter.

Vegetation dissipates much of the energy of falling raindrops and also tends to bind the soil and increase its resistance to erosion. Vegetal cover also restricts the velocity of flow, thus decreasing its erosive ability. Erosion in the coal-development area is at a minimum where vegetation is most dense. A more detailed description of the existing vegetation is found in the following section of this chapter.

Streams of the coal development area are alluvial; that is, their channels are formed in cohesive or non-cohesive materials that have been or can be transported by the streams. The non-cohesive material consists of silt, sand and gravel. Cohesive material consists of clays forming a binder with silts and sand.

The variables affecting alluvial streams are numerous and interrelated, and include stream discharge, longitudinal slope, sediment load, bank resistance to flow, vegetation, temperature, geology, and works of man. Alluvial streams are dynamic and are in a continual state of changing their positions and shapes as a consequence of hydraulic forces on their beds and banks.

The numerous small reservoirs in the coal development area act as sediment traps, and a large part of the sediment runoff is deposited in them. The reservoirs also tend to decrease flood peaks, thus the energy of the flow and its sediment-transport ability is also reduced. The lifespan of the reservoirs is dependent upon the entering sediment load, their trap efficiency, and storage capacity.

Water quality

Chemical quality. Chemical quality in a stream continually changes as a result of varying amounts and sources of water. Water in shallow aquifers of the eastern coal region in Wyoming normally have higher dissolved solids concentration than the runoff from precipitation. Lower dissolved solids concentrations occur in periods of higher streamflow when a larger portion of the water is runoff. At lower streamflow when a larger portion of the water is from shallow aquifers, higher dissolved solids concentrations occur and often exceed that of the source due to evaporative concentration in the stream channels and many stock ponds. Salts are deposited by evaporation of water in stream channels and by evaporation of ground water discharge that never reaches the stream.

Concentrations of individual constituents in the water vary widely, but sodium and sulfate are normally the major ions. Calcium and magnesium concentrations increase in comparison to the sodium concentration during high runoff periods. Solution of salt deposits by localized precipitation results in higher sodium concentrations during high flow periods than would be normally expected from direct ground water contribution.

Surface water quality data have been collected on the Powder River at Arvada, Little Powder River near the Wyoming-Montana state line, Belle Fourche River below Moorcroft, and the Cheyenne River near Spencer. Although some of these sites are not within the eastern coal region of the Powder River Basin, they are downstream from the region, and in most cases the data collected is indicative of upstream water quality. Greater definition in the upper reaches of these basins would require more localized upstream data collection.

Water quality data has been collected on the Powder River at Arvada intermittently from 1946 to 1967 and continuously from 1967 through 1974. In samples collected, dissolved solids concentrations ranged from about 700 to 4,500 milligrams per liter with a corresponding range in streamflow of 725 to 3 cubic feet per second (cfs). Water temperature ranges from freezing to a maximum observed 32^{o}C with a yearly mean temperature of 7^{o}C in 1970 and 1971.

Due to discharge of oil field waters and irrigation return flow upstream from Arvada, water quality on the Powder River at Arvada is not representative of the tributaries originating in the eastern coal region.

Five chemical water quality samples were collected from the Little Powder River near the Wyoming-Montana state line between October 1969 and May 1970. The dissolved solids concentration ranged from 791 to 4,050 mg/l with a corresponding range in streamflow of 17 to 0.55 cfs. Sodium and sulfate were the major ions with lesser concentrations of calcium, magnesium, and bicarbonate. One water sample taken upstream on the Little Powder River near Weston in May 1969 had a dissolved solids concentration of 2150 mg/l at 11.4 cfs. Sodium and sulfate concentrations were 315 and 1,280 mg/l respectively as compared with corresponding concentrations of calcium, magnesium, and bicarbonate of 180, 140 and 410 mg/l, respectively. The similarity in chemical character of water sampled at the two points indicates that samples taken near the state line are representative of water upstream within the coal region.

Forty samples were collected from the Belle Fourche River below Moorcroft from 1954 to 1957. Dissolved solids concentration during this period ranged from 162 mg/l at 132 cfs to 2,910 mg/l at 0.3 cfs. Sodium and sulfate were the major ions at low flows but decrease in concentration in relation to calcium, magnesium, and bicarbonate concentrations at high flow. Keyhole Reservoir, downstream from the sampling site, reflects a mixture of high and low flows naturally weighted toward the high flow chemical characteristics. A sample taken from Keyhole Reservoir in October 1956 had 437 mg/l dissolved solids, 61 mg/l sodium, 45 mg/l calcium, 148 mg/l bicarbonate, and 190 mg/l sulfate. Although data collected below Moorcroft is representative of upstream water quality during the data collection period, more recent sampling is necessary to define existing water quality and to measure possible future impact.

In monthly water samples taken from the Cheyenne River near Spencer from May 1969 to June 1970, dissolved solids concentration ranged from 1,000 mg/l at 175 cfs to 4,000 mg/l at less than 1 cfs. Sodium and sulfate ions become increasingly predominant at low flow. Because a major portion of the drainage basin upstream from this site falls within the eastern coal region, chemical quality sampled at this site is representative of the general chemical quality of streams within the eastern coal region. More localized definition requires additional sampling on upstream tributaries.

Sediment. Sediment is defined as fragmented material that is transported by, suspended in, or deposited by water or air. Only fluvial sediment, which is related to water, is discussed in this section of the report. Sediment quality of streamflow is a result of erosion and sedimentation processes.

The highest sediment yields occur from those areas of badland topography. Most of the badlands are found in those areas underlain by the White River Formation. The higher relief of the badland areas appears to exert an orographic barrier on precipitation. The combination of heavier storm rainfall and higher erodibility of soils probably has significant effects on the formation of the badlands (U.S. Geological Survey, 1961C.)

The highest sediment concentrations occur during flood periods as the flow has a high amount of energy available to pick up and transport sediment.

Sites where suspended sediment data have been collected are shown on Figure 30. Table 21 lists the maximum concentrations and loads observed at the sites.

Increase of sediment concentrations in water decreases its ability to transmit light. Turbidity is mainly due to fine materials (nominal diameters

Table 21

Suspended-Sediment Data

			Observed Daily Values					
Station Number	Station Name	Period of Record	Date	Flow (cfs)	Maximum Concentration (mg/l)	Date	Flow (cfs)	Maximum Load (tons/day)
06309500	Middle Fork Powder River above Kaycee	1949-53, 1965-68, 1970	7/29/53	55	25,900	6/8/68	877	69,000
06312500	Middle Fork Powder River near Kaycee	1950-53	9/7/51	728	37,300	9/7/51	728	82,700
06313100	South Fork Powder River near Kaycee	1950-53	9/7/51	852	94,800	5/22/52	4,260	1,270,000
06313500	Powder River at Sussex	1950-53	8/3/53	1,090	87,500	5/23/52	14,100	2,850,000
06315000	North Fork Crazy Woman Creek near Greub	1965-68	9/3/66	35	30,600	6/9/68	950	34,900
06316500	Crazy Woman Creek near Arvada	1950-53	6/15/53	822	48,200	6/15/63	1,170	127,000
06317000	Powder River at Arvada	1947-57 1968	7/19/54	792	113,000	5/24/52	12,500	2,340,000
06324000	Clear Creek near Arvada	1950-53	5/28/53	498	17,800	7/30/53	475	25,800
06334000	Little Missouri River near Alzada, Mont.	1949-52	5/21/49	57	20,300	5/10/50	1,180	17,600
06386000	Lance Creek near Spencer	1950-54, 1957-59	7/19/54	74	57,700	6/27/52	3,620	281,000
06394000	Beaver Creek near Newcastle	1949-57	5/22/57	134	36,000	5/25/57	780	90,800
06426500	Belle Fourche River below Moorcroft	1947-52	-------	---	------	9/5/51	710	12,400

of less than four microns) which are slow to settle out of water even when it is impounded.

Surface-water uses

The main use of water in the coal development area is for consumption by domestic and wild animals. Actual amounts of water consumed by the animals are minor, but the associated depletions of stored flows in the numerous stock-ponds from evaporation and seepage are significant.

Dry farming is generally practiced in the coal development area, although some water spreader systems are used for supplemental irrigation of hay meadows and pastures.

The main use of surface waters in the rest of northeastern Wyoming is for agricultural purposes, including irrigation and livestock water. Most of the irrigation occurs along the base of the Bighorn Mountains where numerous ranch operations rely on hay production for a winter feed base. The limited and variable precipitation of the area requires irrigation for dependable crop production. Table 22 lists the irrigated acres of each stream system.

Extensive irrigation is also being done in the North Platte River drainage. Over 500,000 acres of land in Wyoming are irrigated in the Platte River system. Most of this irrigation is downstream from Casper.

Another major use of surface waters of the area is for recreation purposes, including fishing, boating, and hunting. Most of these water-related activities take place in the Bighorn Mountains, the Black Hills, along the North Platte River, and on Keyhole Reservoir.

The municipalities of Buffalo, Dayton, Ranchester, Sheridan, Casper, Glendo, and Douglas presently have water supply systems using surface waters.

Table 22

Tablulation of Irrigated Acres in Northeastern Wyoming*

Stream	Total Acres Irrigated	Idle	Average Acres Irrigated
Tongue River	64,320	6,175	58,145
Clear Creek	35,320	5,350	29,970
Crazy Woman Creek	12,090	1,880	10,210
Powder River	18,900	2,705	16,195
Little Powder River	3,230	990	2,240
Little Missouri River	7,760	2,380	5,380
Belle Fourche River	6,540	1,945	4,595
Cheyenne River	12,425	2,435	9,990
Total	160,585	23,860	136,725

*Wyoming Water Planning Program, Water and Related Land Uses of Northeastern Wyoming, Wyoming Water Planning Program Report No. 10, (April 1972).

Industrial companies are presently using relatively minor quantities of surface water as most of their needs are being met by ground-water supplies.

A number of reservoirs have been constructed to provide a more dependable water supply for the above uses. Table 23 is a listing of the principal reservoirs in northeastern Wyoming. Reservoirs of the North Platte River are not listed; however, the North Platte is almost completely regulated by large reservoirs on its main stem.

Ground water and surface water relationship

The streams heading in the nonmountain parts of the Powder River Basin are ephemeral at most of their reaches. The discharge of the Belle Fourche River near Moorcroft was less than 0.01 (cfs) 45 percent of the time for the period of record indicating, for all practical purposes, no ground water pickup by the river. However, the elevation to which water in the shallow wells will rise is higher than stream level and, therefore, the streams cannot lose water to the underlying aquifers during periods of flow. Head relations show the streams must be gaining in the lower reaches but the amount of pickup is too small to appear as significant stream discharge.

Water supplies and potential development

Ground water

Ground water is the principal source of domestic and livestock supplies throughout the area. The City of Gillette is supplied by ground water, some of which is treated at a desalting plant because of the high mineralization of the water. Very little ground water is used for irrigation, most of which is for lawns and gardens. The largest use of ground water at present is for waterflooding in the secondary recovery of oil in oil fields.

Table 23

Principal Reservoirs in Northeastern Wyoming
(Reservoirs of over 1,000 acre-foot capacity)

Reservoir	Capacity Acre-feet	Use*	Water Source
Betty	1,345	I,S	South Fork Cheyenne River; Beaver Creek
Big Goose Park	11,200	I,D,S,P,Mun	East Fork Big Goose Creek
Big Horn	4,960	I	Cross Creek
Clark and Metzger	1,525	I,D	Alum Creek
Cloud Peak	2,720	I	South Fork of South Piney Creek
Dome Lake	1,318	I,S,D	West Fork Big Goose Creek
Dull Knife	4,345	I	North Fork of Powder River
Gillette	2,900	RR,Mun	Stonepile Creek
Kearney Lake	6,131	I,S,D	North Fork of South Piney Creek
Keyhole	190,000	P,Mun,I,S,Ind,FC	Belle Fourche River
Lake DeSmet	239,243	I,D,S	Piney Creek
Lower Salt	2,708	D,Oil	Salt Creek
M.W.	1,810	I	Stockade Beaver Creek
Robbers Roost	1,250	I,S	Robbers Roost Creek
Spencer	2,160	I	Stockade Beaver Creek
Stone #2	1,556	I,D	Bonepile Creek
Twin Lakes #1	1,180	Mun	West Fork Big Goose Creek
Wallows Creek	1,194	I,S	Buffalo Wallows Creek
Willow Park	4,457	I,S,D,Fish	South Fork South Piney Creek

* Includes uses listed on permits: I = Irrigation; D = Domestic; S = Stock; P = Power; Mun = Municipal; RR = Railroad; Ind = Industrial; FC = Flood Control; Oil - Oil Production; Fish = Fishery.

Source: Wyoming Water Planning Program, Water and Related Land Uses in Northeastern Wyoming, Wyoming Water Planning Report No. 10, (April 1972).

Much of the ground water available to wells is in the near-surface Tertiary and Upper Cretaceous formations. Lesser amounts are available from sandstone formations of Mesozoic age. Depth to the Fox Hills Sandstone at Gillette is about 3,500 feet and to the Inyan Kara rocks about 8,500 feet. The Madison Limestone lies at a depth of about 11,000 feet at Gillette and might yield quantities of water for municipal or industrial use if the well penetrated zones of secondary permeability. The water level in a well drilled near Gillette to the Madison would rise to within 700 to 800 feet of the land surface. Dissolved solids in the water would be about 2,000 mg/l. The Madison Limestone yields large supplies of water to wells at depths of 3,000 to 5,000 feet at distances of 30 to 40 miles from the outcrop along the front of the Bighorn Mountains and in the Black Hills area. The water yielding capacity of the Madison in Campbell County and northern Converse County, however, is not known.

A considerable amount of water is available in the near-surface formations of Tertiary age. Assuming that one percent of the water in the Wasatch and Fort Union Formations is available for pumping, an estimated 18 million acre-feet of water would be available in Campbell County. Similarly, assuming that one percent of the water in the Lance Formation would be available for pumping, 10 million acre-feet of water would be available. Numerous livestock and domestic wells produce water from these aquifers; withdrawals of ground water for industrial use would be in competition with existing wells according to the extent and amount that water in the aquifers was pumped.

Surface water

The coal development area has very limited surface water supplies within its boundary. The nearest and most logical sources of additional supplies are from streams draining the Bighorn Mountains and Black Hills, and from the Platte River system. Studies and suggestions have also been made of importing water from areas outside northeastern Wyoming. The potential supplies of northeastern Wyoming, and of these other areas, are therefore included in this discussion.

In determining the water supplies of northeastern Wyoming, consideration must be given to several factors, including the actual physical availability and dependability of streamflows, state and federal water rights, and interstate compacts.

Physical availability. The natural streamflow which originates in northeastern Wyoming is determined by adding flow depletions caused by man's activities to the gauged streamflows. These depletions include those caused by reservoir and stock-pond evaporation, and consumptive uses of irrigation, industry, and municipalities. Estimates of the amounts of these depletions, and the estimated water yield for northeastern Wyoming are shown in Table 24.

Water rights. The Wyoming Constitution declares that surface waters within the boundaries of the state are property of the state. The supervision and distribution of these waters for beneficial uses is under control of the Office of the State Engineer and the Board of Control. Wyoming water laws establish the priority of adjudicated water rights on the basis of "first in time is first in right." A tabulation of the irrigation water rights in northeastern Wyoming is shown in Table 25. These rights date from the 1870's, and during most years only those rights with a priority dating before 1900 have a dependable water supply during late summer months. Irrigation water rights provide for one cubic foot per second of water for each 70 acres of irrigated land during the irrigation season.

Stream	Flow Leaving Northeastern Wyoming	Estimated Depletions of Streamflow					Water Yield from north-eastern Wyoming
		Irrigation	Municipal Domestic & Stock	Industrial	Reservoir Evaporation	Total	
Tongue River	302,700	77,100	2,400	1,000	3,100	83,600	386,300
Powder River	322,600	66,100	2,100	700	27,600	96,500	419,100
Little Missouri River	31,400	1,800	100	-----	2,100	4,000	35,400
Belle Fourche River	76,400	1,500	1,000	1,000	16,800	20,300	96,700
Cheyenne River	64,800	4,500	600	1,700	14,100	20,900	85,700
Total	797,900	151,000	6,200	4,400	63,700	225,300	1,023,200

Table 24

Average Annual Streamflows, Water Depletions and Natural Water Yields in Northeastern Wyoming
(Figures in acre-feet)

Table 25

Tabulation of Adjudicated Acres and Permits in Good Standing in Northeastern Wyoming from State Engineer's Records

Stream (1)	Adjudicated acres (2)	Permits in Good Standing (3)	Total (2) & (3) (4)
Tongue River	92,436.35	1,695.87	94,132.22
Clear Creek	80,598.41	2,334.66	82,933.07
Crazy Woman Creek	35,788.02	382.04	36,170.06
Powder River	37,296.40	1,978.14	39,274.54
Little Powder River	6,535.57	1,396.77	7,932.34
Total Powder River Basin	160,218.40	6,091.61	166,310.01
Little Missouri River	3,377.38	766.21	4,143.59
Belle Fourche River	25,232.46	5,469.04	30,701.50
Cheyenne River	41,909.98	7,960.13	49,870.11
Total northeastern Wyoming	323,174.57	21,982.86	345,157.43

In addition to water rights for irrigation, there are rights for other uses such as municipal, domestic, livestock, industrial, and fish and wildlife purposes. These rights presently involve relatively minor quantities of water. There are also water rights for storage which involves considerable quantities of water.

The United States Government claims water rights for federal reservations, including national forests and grasslands, national parks, and Indian reservations. Although federal reservations have not significantly affected other water users to date, the potential for a conflict does exist between state and federal water rights.

Interstate compacts. The division of available streamflows between Wyoming and bordering states has been agreed upon for the Yellowstone and the Belle Fourche Rivers. No agreements presently exist for the Little Missouri or the Cheyenne Rivers.

The Yellowstone River Compact provides for division of the streamflow of the Yellowstone River between Wyoming, Montana, and North Dakota. State water rights existing as of January 1, 1950, are recognized, and each state is allocated sufficient water to provide supplemental supplies to all rights existing as of that date. The remaining unused and unappropriated water of the streams is allocated as is shown below.

Stream	Wyoming	Montana
Clarks Fork of the Yellowstone River	60%	40%
Bighorn River (Excluding the Little Bighorn)	80%	20%
Tongue River	40%	60%
Powder River (Including the Little Powder)	42%	58%

An important provision of the Yellowstone River Compact provides that "no water shall be diverted from the Yellowstone River Basin without the unanimous consent of all the signatory states." This provision must be considered in the event of proposed transbasin diversion.

Waters of the Belle Fourche River are divided between Wyoming and South Dakota on the basis of the Belle Fourche River Compact. Waters unappropriated as of February 1944 are allocated 10 percent to Wyoming and 90 percent to South Dakota.

Interstate compacts also exist for other streams leaving the state, such as the Green River and the Snake River. Because these rivers originate from areas outside of northeastern Wyoming, their compact agreements are beyond the scope of this report.

Development of unused and unappropriated water. Since time of the earliest water development projects, the need for storage to improve and regulate water supplies has prompted investigations of surface water developments. Although past investigations of reservoir sites were primarily concerned with irrigation potentials, many of these reservoir sites are now being considered for industrial purposes. Unused and unappropriated water supplies exist in northeastern Wyoming, and there are potential reservoir sites which could be used to develop these supplies. Table 26 lists potential reservoirs as indicated by applications to the State Engineer.

It is estimated that the Tongue River drainage in Wyoming has an average unused and unappropriated water supply of 241,000 acre-feet per year. Compact agreements allocate Wyoming 40 percent or 96,400 acre-feet per year and Montana 60 percent or 144,700 acre-feet per year. Carryover storage would be necessary to develop these shares into a firm water supply.

The Powder River drainage has an average unused and unappropriated water supply of about 287,300 acre-feet per year. Wyoming's allocation is 42 percent or 120,700 acre-feet per year, and Montana's allocation is 58 percent

Reservoir	Priority Month-Day-Year	Capacity Acre-Feet	Source	Use [a]
Tongue River Basin				
North Fork	5-12-58	39,718	North Fork Tongue River	I,F
South Fork #1	3-8-60	27,301	South Fork Tongue River	I
Rockwood	3-8-60	29,231	Tongue River	I
Prairie Dog	2-17-66	80,860	Prairie Dog Creek	P,Ind
Tongue River (Upper State Line)	2-28-69	185,000	Tongue River	P,Ind
Graves	1-16-74	1,883	Graves Creek	I,S,Ind
Clear Creek				
Little Sour Dough	10-18-33	1,642	Little Sour Dough Creek	I
Camp Comfort	8-16-39	11,640	Clear Creek	I,S,D
Reynolds Box Elder[b]	2-4-55	8,902	Box Elder Creek	I,S,Ind
Reynolds Shell Creek	3-8-55	1,369	Shell Creek	Ind
Healy[c]	4-15-67	41,974	Clear Creek	I,Ind,P,D
Enlargement Healy[b]	10-14-57	13,725	Clear Creek	I,Ind,P,S,D,R
Reynolds High Dam[b]	11-13-63	44,442	Piney Creek	I,Ind,Pwr,S
4th Enlargement Lake DeSmet[d]	1-26-70	23,513	Piney, Rock, Clear Creeks	I,Ind,Pwr,R
Reynolds Piney Creek	1-26-70	12,660	Piney Creek	I,Ind,Pwr,R
Lower Clear Creek Reservoir Co. Boxelder Reservoir	2-21-68	20,000	Piney Creek	I,Ind,R
B.C.L. Company	3-16-71	19,126	Clear Creek	I,Ind,R
Tex Ellis	8-21-72	46,519	Buffalo Creek	I,Ind,D
Mill Creek	11-16-73	15,653	Mill Creek	I,Ind,D,S,Pwr

Table 26

Potential Reservoirs Indicated by State Engineer Records
(as of March 1, 1974)

Table 26 (Cont'd)

Reservoir	Priority Month-Day-Year	Capacity Acre-Feet	Source	Use[a]
Crazy Woman Creek				
Enl. Negro Creek	9-19-56	13,911	Clear Creek and Negro Creek	I,S,Pwr,Ind
Crazy Woman	7-5-67	64,300	Crazy Woman Creek	I,D,Ind
Beaver Creek	10-22-70	1,523	Beaver, South Fork, Crazy Woman Creeks	I,S
Prospector	3-24-72	9,957	Bull, Taylor, Doyle, Middle Fork Crazy Woman Creeks	I,S,F
Hazelton	8-1-72	1,946	Middle Fork Crazy Woman Creek	I
Powder River				
Middle Fork (Hole-in-the-wall)	3-7-40	41,075	Middle Fork Powder River	I,S,D,Pwr,M
Pumpkin	2-13-62	206,985	Powder River	M,Ind,Mfg,R,I Pwr,S,F,Mech
Bass Industrial	5-1-68	123,380	Powder River	Ind,I,R
Enl. Pumpkin	7-24-70	71,938	Powder River	same as Pumpkin
Enl. Middle Fork of Powder River (Hole-in-the-wall)	12-29-70	8,474	Middle Fork Powder River	I,Ind
UII Montana Project	11-20-73	106,730	Powder River and Fence Creek	Ind,I,R,F,M,W
Little Missouri River				
Little Missouri	12-13-73	34,924	Little Missouri River	M,Ind
Tract 37	1-2-74	2,454	North Fork Little Missouri	S,I
Platte River				
Deer Creek	2-9-73	65,915	Deer Creek	I,M,Ind
LaBonte Creek	4-12-73	36,760	LaBonte Creek	M,Ind,R
Wagonhound Creek	9-20-73	34,511	Wagonhound Creek	M,Ind
Philbrick	1-21-74	107,006	Box Elder Creek	I,M,Ind
Cena	2-6-74	11,904	Horseshoe Creek	Ind,M
Panhandle No. 1	2-14-74	24,190	North Platte River	Ind

[a] Abbreviations refer to the following uses: I-Irrigation; F-Fish; P-Steam Power; Ind-Industrial; S-Stock; D-Domestic; R-Recreation; Pwr-Power; M-Municipal; Mfg-Manufacturing; Mech-Mechanical; W-Wildlife

[b] Storage transferred by petition to Lake DeSmet.

[c] 36,834 acre-feet of storage transferred by petition to Lake DeSmet.

[d] Brings total permit capacity of Lake DeSmet to 239,243 acre-feet with transfers and present capacity.

or 166,600 acre-feet per year. Reynolds Mining Corporation developed a water supply using about 55,000 acre-feet of Wyoming's allocation; thus about 65,000 acre-feet per year remains available for other uses in Wyoming. (Reynolds recently sold part of these interests to Texaco, Inc.) Due to the high variability of annual flows, large carry-over storage would be necessary to develop the remaining allocation into a dependable water supply. Potential dam sites exist on the Powder River which could provide storage for both Wyoming's and Montana's allocations.

The Belle Fourche River Compact enables Wyoming users to purchase 10 percent of the Keyhole Reservoir capacity, or about 13,000 acre-feet; however, due to the variability of flows, a firm supply is not guaranteed. A potential reservoir site on Beaver Creek, tributary of the Cheyenne River, could provide a water supply of about 15,000 acre-feet per year.

Surface-water supplies available for development from the Platte River drainage are limited due to existing and projected needs within that basin; however, investigations and negotiations are being made in an attempt by companies to obtain Platte River water. The possibilities of obtaining these supplies are complicated because of operation of the river under terms of a United States Supreme Court Decree and by current water uses. Potential storage sites on tributaries of the North Platte River and expansion of Seminoe Reservoir could be utilized to firm up the river's unused and unappropriated supplies.

Change in water use. Wyoming statutes provide for a change of use of water rights to higher, preferred uses. The order of preferred uses is:

(1) domestic and livestock water
(2) water for municipal purposes
(3) water for use of steam engines and general railway use, water for culinary, laundry, bathing, refrigerating uses, water for steam and hot-water heating plants and steam power plants
(4) industrial purposes
(5) irrigation, and
(6) hydropower.

Provision is made for the condemnation of irrigation rights for the first three preferred uses (except steam power plant use). Irrigation water rights may be purchased by industrial users. Changes of use of adjudicated water rights to new uses have to be approved by the Board of Control which can approve the change only if other appropriators will not be adversely affected by it.

Possibilities of imported water. Analyses of available water under interstate compacts and foreseeable local water needs reveal that water is available from Wyoming's Green River, Snake River, Clarks Fork, and Bighorn River and could be diverted for development of coal in the Powder River Basin. The Bureau of Reclamation has entered into option agreements to supply water for several companies to be made available from regulation of Boysen and Yellowtail Dams on the Bighorn River. Three possible routes of diversion have been considered.

One possible route would be a diversion from the Yellowstone River at Miles City, Montana, below the confluence of the Tongue River, which would divert 694,000 acre-feet per year through a 173-mile pipeline to Gillette.

Another possible route considered would be a diversion from the Bighorn River at Hardin, Montana, and a 180-mile pipeline to the Gillette area. A diversion of 694,000 acre-feet per year would be delivered to various points in Montana and Wyoming with 312,000 acre-feet at Gillette.

The third route considered was a 182-mile pipeline from Boysen Reservoir to Gillette carrying 135,000 acre-feet per year.

An alternative considered by the Wyoming Water Planning Program is a diversion from the Nowood River via a 40-mile tunnel through the Bighorn Mountains and a 77-mile pipeline to Gillette.

Another source of water for importation is the Green River in southwestern Wyoming. It is estimated that between 93,000 and 272,000 acre-feet per year could be used outside the Green River Basin in Wyoming. The larger figure assumes Wyoming's full allocation of water will be available for use in the state.

Vegetation

Campbell County and northern Converse County are rangeland, in the truest definition of the word. While both coniferous and deciduous woodland occur locally, the vegetation is characterized by communities of low-growing shrubs and herbaceous plants adapted to the semiarid condition of the region.

Throughout its developmental history, large herbivores (grazing animals) have had an important influence on composition of the vegetation. The area was within the range of northern bison herds until the middle-to-late 19th Century, and these animals doubtless had profound effect on the vegetation. During the latter part of the 19th Century, bison were replaced by domestic livestock, and ranching has continued to the present as a major industry of the two counties. Vegetation has been held in a seral stage of succession for a long period of time by animal grazing, although conditions prior to the introduction of domestic livestock may be designated a "zootic climax."

Figure 35A
Big Sagebrush

Big sagebrush (Artemisia tridentata) is the shrub most characteristic of better drained uplands throughout Campbell and northern Converse Counties. The successional status (relation to ecological climax) of big sagebrush in this part of northeastern Wyoming has not been fully defined. Because the herbaceous understory of big sagebrush stands is composed of species common to the Northern

Great Plains grassland, probability is high that big sagebrush is an invader into what should be grasslands. The theory generally held for this invasion is that heavy grazing of desirable grasses by domestic livestock has resulted in changing the competitive position of sagebrush and permitted its establishment. However, since it appears the area was grazed, perhaps quite heavily, by large herds of bison prior to the introduction of domestic livestock, the over-grazing theory may be of questionable value in explaining the presence of big sagebrush.

Another view is that big sagebrush should not be considered an invader but rather a natural component of a vegetation type which represents a transition from a Northern Great Plains grassland (short-grass/mid-grass prairie) environment to the sagebrush environment which is predominant at this latitude over much of the rangelands of the West. This theory is compatible with current thinking in ecology which equates abrupt changes in vegetation only with equally abrupt changes in environment.

In the basic study area, a gradual decrease in elevation occurs from west to east, accompanied by an increase in annual precipitation and presumably an increase in length of the growing season. The vegetational expression of this complex environmental gradient is a big sagebrush/shortgrass community, which represents the ecotone (transition) between two major vegetational zones--the sagebrush zone to the west and the Northern Great Plains grassland zone to the east. The composition and structure of this standard vegetative association may vary from place to place, as controlled by broad environmental transitions, by site-specific factors and by use-history, including grazing and fire. The vegetation types and subtypes occurring on the area are shown on Map 8, Appendix A, and are briefly described below:

Dry meadow grassland, Type 1

On sites which occur adjacent to non-saline and non-alkaline live streams, lakes, ponds, or springs, but are not inundated, a "dry meadow" grassland-type is present. The more extreme hydrophytes are absent, and grasses such as prairie cordgrass (Spartina pectinata), tufted hairgrass (Deschampsia caespatesia), basin and canada wildrye (Elymus cineias and E. canadensis), slender wheatgrass (Agropyron trachycaulum), bearded wheatgrass (A. canium), western wheatgrass (Agropyron smithii), inland sedge (Carex interior), and mat muhly (Muhlenbergia richardsens) will be present along with a variety of mesophytic forbs, including licorice (Glycyrrhiza spp.), aster (Aster spp.), golden pea (Thermopsis spp.), meadowrue (Thalictrum spp.), starwort (Stellaria spp.), virginsbower (Clematis spp.), and yarrow (Archillea spp.). Willows (Salix spp.) may grow immediately adjacent to the water's edge on some sites. These meadows are very productive and are often mowed for wild hay. Many of the areas which would support "dry meadow" grassland have been, or are being, used for agriculture. About 148,400 acres are included in this type.

Figure 35B
Playa

Playa grassland, Type 1A

Scattered through the level to gently sloping upland regions of southern Campbell and northern Converse Counties are numerous playas (dry lakes) of varying size. These playas are seasonally inundated with runoff water from adjacent uplands and have a deep, poorly drained, very clayey soil. A very distinctive grassland-type with western wheatgrass as the dominant species occurs on the playa sites. Subordinate species appear to be dependent on length and degree of inundation. On playas where surface water evaporates rather rapidly and the subsurface water table lowers, foxtail barley (*Hordeum jubatum*) is second most important grass and almost the only other plant species present. On wetter playas, slender spike rush (*Eleocharis acicularis*) becomes codominate with western wheatgrass. This type covers only 250 acres in the region.

Figure 35C
Scoria Grassland Type

Scoria grassland, Type 1B

A distinctive grassland-type is found on "scoria" hills and ridges that are a prominent landscape feature in Campbell and northern Converse Counties. Scoria is a reddish colored, slaglike, clinker material produced by heating and partial fusing of shale where coalbeds adjoining shale have burned. The scoria areas have a relatively rough, steep topography and sandy to gravelly loam soils with low water holding capacity. Bluebunch wheatgrass (Agropyron spicatum) is the most characteristic species, although blue grama (Bouteloua gracilis) is often the most productive grass. Several psammoplytic grasses grow in these dry, well drained areas. The most distinctive of these is little bluestem (Andropogon scoparius). Others are prairie sandreed (Calamovilfa longifolia), sand dropseed (Sporobolus cryptandrus), red threeawn (Aristida longiseta), and Indian ricegrass (Oryzopsis hymenoides). Needleandthread (Stipa comata), stoney hills muhly (Muhlenbergia cuspidata), hairy grama (Bouteloua hirsuta), sideoats grama (B. curtipendula), prairie junegrass (Koelaria cristata), and Sandberg bluegrass (Poa secunda) are minor species. Forbs include globemallow (Sphaeralcea spp.), lupine (Lupinus spp.), licorice (Glycyrrhiza spp.), and small soapweed (Yucca glauca). Scattered big sagebrush, skunkbush sumac (Rhus trilobata), shrubs and stunted Rocky Mountain juniper (Juniperus scopulorum) may be present in draws where moisture conditions are somewhat better. About 27,300 acres are included within this type.

Figure 35D
Sandhills Grassland Type

Sandhills grassland, Type 1C

In southwestern Converse County, just north of the North Platte River, is a region of sand dunes. Both active and stablized dunes are present. The vegetation on these dunes is a rather open grassland with prairie sandreed the most comspicuous grass. Needleandthread, Indian ricegrass, blue and hairy grama, sand dropseed and Sandberg bluegrass are common. Scattered sand bluestem (Andropogon hallii) may be present. Silver sagebrush (Artemisia cana) may occur, and in some areas rather dense stands have developed. Small soapweed, fringed sage (Artemisia frigida) and cudweed sagewort (A. graphaloides) may be locally abundant. This type occupies 90,100 acres.

Wet meadow, Type 2

A wet meadow grassland-type is present on level to nearly level, poorly-drained lands near springs, seeps, or sloughs where the land is inundated for most of the growing season. Soils on these sites have a high organic matter content. The plant community is dominated by species which can withstand long periods of submersion. In good conditions, Nebraska sedge (Carex nebraskensis), northern needlegrass (Calamagrostis koeleriodes), bluejoint reedgrass (C. canadensis), and tufted hairgrass are the most important species. Species which may increase as range condition declines but which are also present on good condition areas are inland sedge (Carex interior) and baltic rush (Juncus balticus). Forbs such as arrowgrass (Triglochin spp.), blue-eyed grass (Sisyrinchium spp.), iris (Iris spp.), horsetails (Equisetum spp.), and water-hemlock (Cicuta spp.) are also present. This type occupies 14,400 acres.

Figure 35E
Big Sagebrush Type

Big sagebrush, Type 4

The shrub layer of the sagebrush/grass community is composed almost exclusively of big sagebrush. The density (plants/unit area) of the big sagebrush layer varies from a few scattered plants, with a predominatly grass understory, to closely spaced or clumped shrub stands with little or no herbaceous understory. In the later instance, crowns of individual plants normally do not touch. The height of the shrub layer rarely exceeds 18-24 inches.

The major understory species is blue grama which is found almost everywhere. Taller growing grasses (midgrasses) such as needleandthread and western wheatgrass are also abundant. These latter two species will vary in abundance from year to year, and it is thought this variation is, to some extent, controlled by variations in the moisture regime. Needleandthread seems better adapted to soils which tend to be sandy and may dry out rapidly, while western wheatgrass is better adapted to clayey soils which hold available water into the growing season.

Secondary grasses and sedges include Sandberg bluegrass, prairie junegrass, and threadleaf sedge (Carex filifolia). All of the above species are usually present on moderately used range but rare or absent from areas continuously subjected to heavy grazing. On such sites, blue grama will be the most abundant species. Lesser grasses include Indian ricegrass, green needlegrass (Stipa viriduala), bluebunch wheatgrass, and cheatgrass (Bromus tectorum). Plains pricklypear (Opuntia polycantha) is widely distributed in the big sagebrush type and may be abundant on ranges in any condition. The abundance and distribution of this species is related more to a succession of drought years rather than to excessive grazing as ungrazed ranges often support denser stands of plains pricklypear than moderately used ranges.

The big sagebrush/grass vegetation-type is by far the most widespread shrub community in the area. However, other shrub communities are present. These occupy rather specific habitats. Big sagebrush may be present in some of these other shrub communities and can occur with some abundance, but other shrub species will be more characteristic. The big sagebrush type occupies 4,188,000 acres.

Figure 35F
Silver Sagebrush Type

Silver sagebrush, Type 4A

A silver sagebrush shrub community is found on level to gently sloping flood plains of streams which run water during at least part of the growing season or on land which receives additional water from overflow. Soils of these sites are deep, well drained and permeable, somewhat sandy or loamy, and usually not extremely saline or alkaline. Silver sagebrush may form rather dense stands and grows two to three feet tall. The predominant grass is western wheatgrass. Needleandthread, Sandberg bluegrass, matmuhly, blue grama, prairie junegrass, and threadleaf sedge are present to a lesser extent, especially on areas subject to moderate to heavy grazing pressure. On lightly grazed areas, basin wildrye, green needlegrass, and several species of bluegrass (Poa spp.) are present. Forbs are scarce. Occasionally, snowberry (Symphoricarpos spp.) shrubs are present. About 36,900 acres are included in this type.

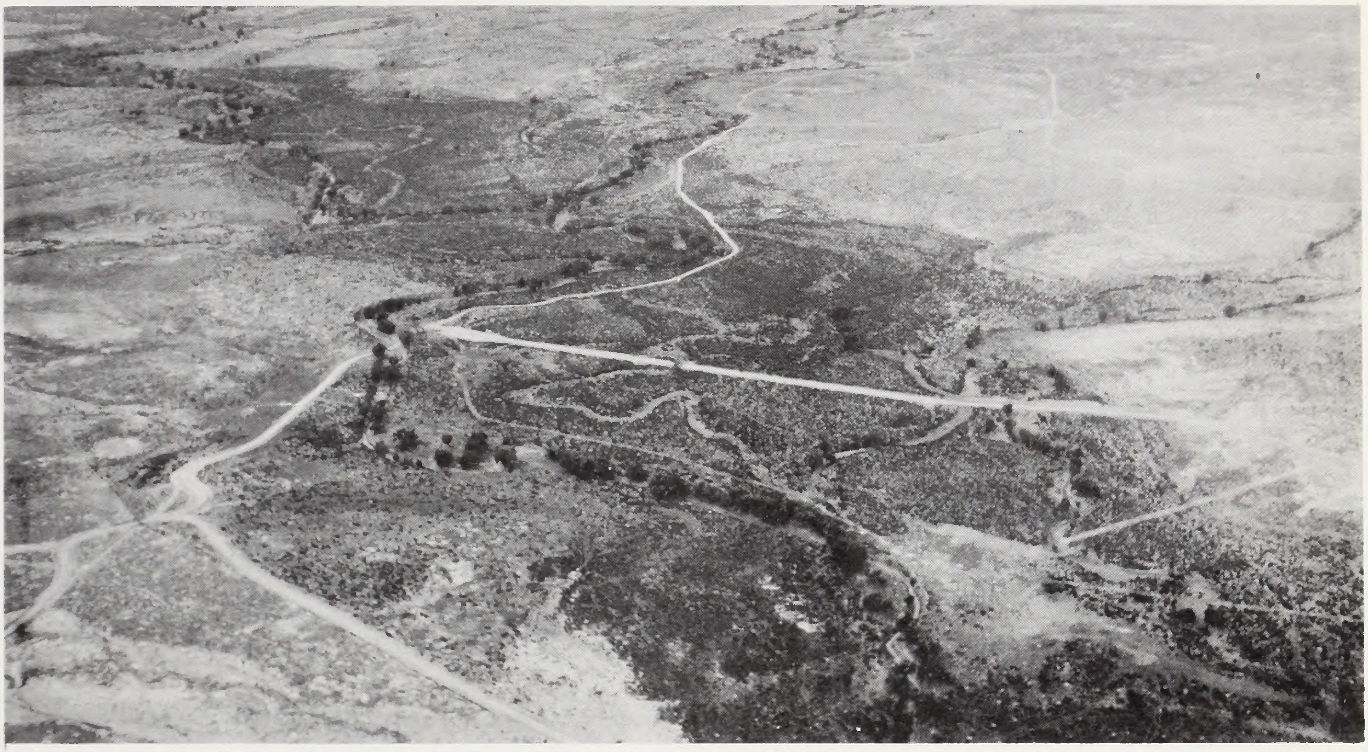


Figure 35G
Greasewood Type

Greasewood, Type 5

Another shrub community is present along stream channels and on flood plains which receive additional water from overflow or runoff and where soils are moderately to strongly saline or alkaline. The shrub layer of this plant community is characterized by a moderate to heavy stand of black greasewood (Sarcobatus vermiculatus) with some scattered rubber rabbitbrush (Chrysothamnus nauseousus). Fourwing saltbush (Atriplex canescens), Gardner saltbush (A. gardneri) and winterfat (Eurotia lanata) also may be present on good condition sites. The herbaceous understory is dominated by inland saltgrass (Distichilis spicata spp. stricta), squirreltail (Sitanion hystrix), and alkali bluegrass (Poa juncifolia) in grazed areas. Alkali sacaton (Sporobolus airoides) and Nutall alkaligrass (Puccinellia airoides) occur where high soil moisture conditions exist well into the growing season and where grazing is light. This type includes 80,700 acres.

Saltbush-greasewood, Type 5A

A shrub community, where Gardner saltbush and black greasewood are the shrub-layer dominates, also occurs on upland areas where the soils are moderately to strongly saline and/or alkaline. Gardner saltbush is more characteristic of these sites than black greasewood when they are in good condition. The production of vegetation on this "saline upland" is less than on the "saline lowland" described above, because no additional moisture is received from runoff. The composition of the herbaceous layer is much the same as that of the lowland site except that species requiring high soil moisture, e.g., Nutall alkaligrass, are absent. About 2,260 acres of this type are found in the basin.

The four shrub communities (big sagebrush, silver sagebrush, black greasewood, Gardner saltbush) form a vegetational mosaic with several grassland communities. The uncertainty of the ecological status of big sagebrush and the preponderance of herbaceous species characteristic of the Northern Great Plains grasslands in big sagebrush shrubland has been discussed. Areas of big sagebrush with low density will have the appearance of grasslands and might be classified as such. Thus, a needleandthread-blue grama grassland type could be distinguished on loamy to sandy uplands and a western wheatgrass-blue grama grassland type on clayey uplands. The separation of shrubland from grassland, in this instance, is made on the density of big sagebrush. Whether certain areas exist where big sagebrush density is limited by specific factors and which, therefore, could be considered "true grassland," remains to be determined for the Campbell-northern Converse region.

An analogous problem may also be present with regard to the black greasewood shrub community, since stream channels and swales where an inland-saltgrass-western wheatgrass grassland type occurs are also present. These are very similar to the black greasewood/inland saltgrass-western wheatgrass shrubland type, except for the complete absence of the shrub layer.

Nevertheless, plant communities where grasses and sedges are dominant do occur in the area under consideration. In general, these communities have rather distinctive site attributes, most important of which are high soil moisture conditions, or shallow, stoney soils, or very sandy soils (sand dunes).

Figure 35H
Ponderosa Pine Forest Type

Ponderosa pine forest, Type 6

Areas where trees are dominant are present in the Campbell-northern Converse Counties area. The most widely distributed type is ponderosa pine (Pinus ponderosa) forest. This vegetation type is well distributed over the badlands-scoria land region north and east of Gillette in Campbell County. It extends southward in a long, narrow band to the vicinity of Lusk where it swings west toward Douglas. A distinct area of ponderosa pine is present on the western edge of Converse County, east of Midwest. The distribution of ponderosa pine forest appears to be controlled by outcrops of sandstone, shale, and clinker. It is located primarily on the crests of these surfaces.

Ponderosa pine is the principal tree species. It grows in stands which range from a closed-canopy forest to a savannh-like open woodland. The closed-canopy forest may have a secondary overstory of Rocky Mountain juniper. Shrub species in the understory of the denser forest stand include skunkbush sumac (Rhus trilobata), creeping juniper (Juniperus horizentalis), and western snowberry (Symphoricarpos occidentalis). The herbaceous layer is composed mostly of grasses. Major species are green needlegrass, Sandberg bluegrass, prairie junegrass, and stoneyhills muhly. More open stands of ponderosa pine will have silver sagebrush, green needlegrass, and sideoats grama as the major understory species. On sites with coarser soils, bluebunch wheatgrass, little bluestem, and porcupine needlegrass (Stipa spartea) may be present. There are 328,400 acres of ponderosa pine forest in the region.

Broadleaf forest, Type 10

Broadleaf trees are present on some of the perennial stream flood-plains (Cheyenne River, Belle Fourche River, Powder River, Little Powder River) and intermittent streams which flow eastward and northward from Campbell and northern Converse Counties. The density of the trees will range from a scattering of single trees, to a fringing row, to a riparian woodland extending several miles along the stream channel and two to three miles on either side of it. The latter type of forest is most prevalent on the eastern edge of the two counties. Plains cottonwood (Populus sargentii) is the characteristic tree for this vegetation type, although lanceleaf cottonwoods (P. acminata) may also be present. Other less common trees are sandbar willow (Salix interior), coyote willow (S. exigua), peach-leafed willow (S. amygdaloises), and boxelder (Acer negundo). The understory of the riparian forest is quite complex and diverse. Shrubs such as snowberry, wild rose (Rosa spp.) silver sagebrush, rubber rabbitbrush (Chrysothamnus nauseousus), and silverberry (Elaeagnus argentea) may be present under the woodland canopy. Tall stands of wildrye grow in sloughs and other semi-inundated sites. Several of the more mesophyllyic species of wheatgrass, needlegrass, and bluegrass are found in the herbaceous layer along with a wide variety of forbs. The region includes about 61,700 acres of this type.

Archeological and Paleontological Values

Archeological values

It is impossible to say exactly how many, or where, archeological sites exist in the Powder River Basin. The accompanying map (Figure 36) shows 26 sites which have been archeologically investigated and reported within the greater Powder River Basin. Many other sites are known within the area, and their frequency of occurrence fits the same pattern of geographic distribution (Figure 37). These other sites have been reported but not investigated.

It is important to note that the distribution of archeological sites is evidently related to present day population distribution. This is because presently known sites, as shown on the map, became known when development of the more populated areas created a need for these sites to be salvaged.

The Ruby Site (Figure 36, #12) further bears on the reason of why archeological sites are recorded in this apparent geographic disproportion. The interior of the Powder River Basin is more deeply filled with sediments than the periphery as seen in the Ruby Site photographs (Figures 38 & 39). Many older sites are covered with many feet of fill. Because the overlying mantle of soil hides the sites from surface searches, they remain undiscovered and unreported. Topography is more broken, the surface generally more eroded, and overlying soil layers are thinner along the western and eastern edges of the Powder River Basin. These factors plus the fact that early settlement occurred near the edges should result in higher probability of archeological discovery and reporting.

Archeological sites do exist in the interior Powder River Basin as illustrated by the Ruby Site example and the Glenrock Buffalo Jump (Figure 40). Dr. George Frison (1973, p. 172), State Archeologist, who is most familiar with the area recently stated "... a person can stand on the Wyoming-Colorado border

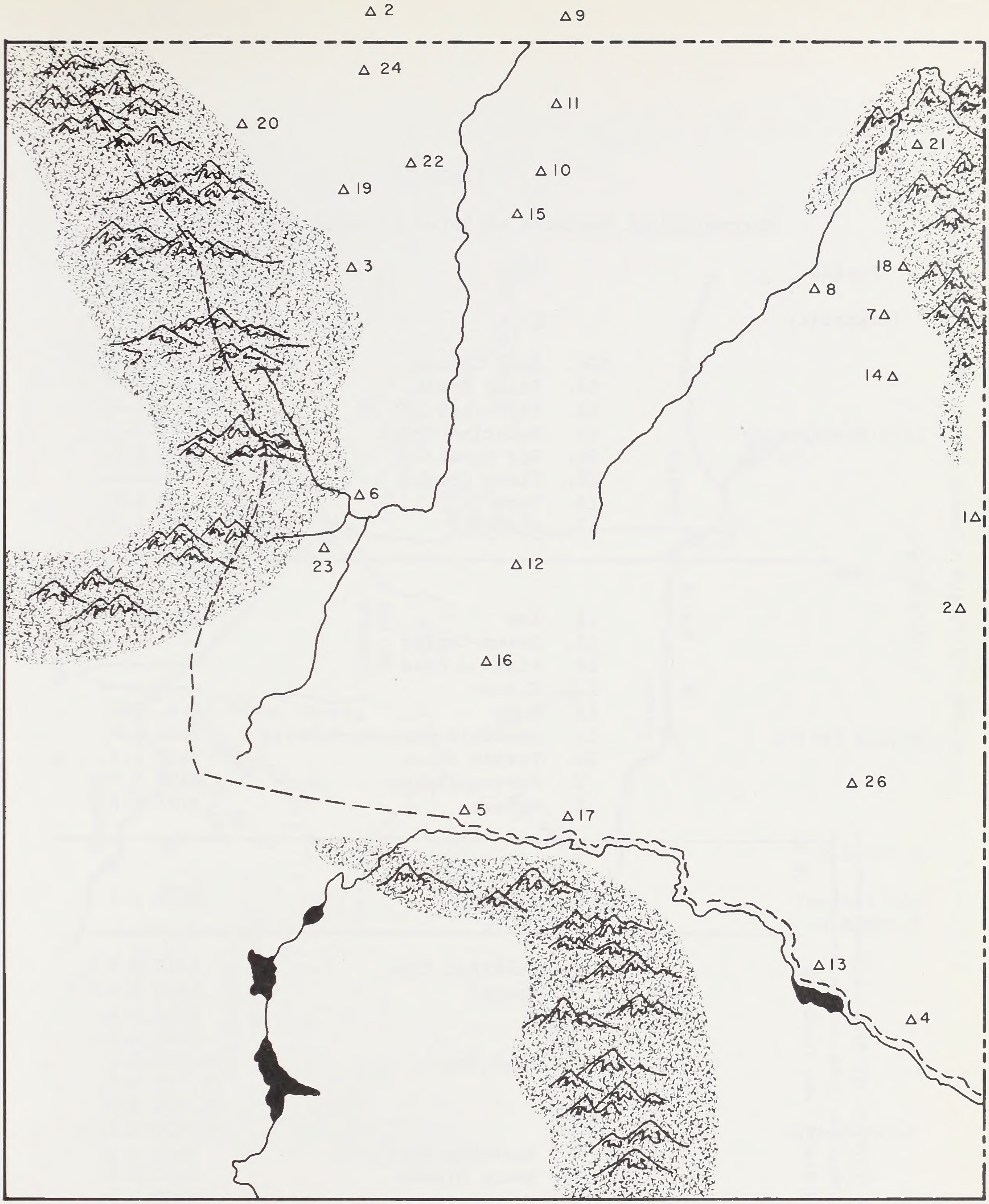


Figure 36
Excavated Archeological Sites in the Powder River Basin.

Table 27

Chronological Sequence of Dated Sites in the Study Area

Period		Site	Radiocarbon Date
(Historic)			
	*24.	Foss Thomas	500 B.P.
	23.	Billy Creek	--------
	22.	PK Burial	--------
Late Prehistoric	21.	Medicine Creek	--------
	20.	Big Goose	450 B.P.
	19.	Piney Creek	--------
	18.	Vore	200 B.P.
	17.	Glenrock	250 B.P.
A.D. 500			
	16.	Lee	1500 B.P.
	15.	Sweem-Taylor	---------
	14.	Lissolo Cave	---------
	13.	Glendo	---------
	12.	Ruby	A.D. 300
Middle Period	11.	Mavrakis-Bentzen-Roberts	2600 B.P.
	10.	Powder River	3220 B.P.
	9.	Powers-Yankee	4450 B.P.
	8.	McKean	3287 B.P.
2,500 B.C.			
Altithermal	7.	Hawken	6440 B.P.
5,000 B.C.			
	6.	Schiffer Cave	8450 B.P.
	5.	Casper	9800 B.P.
			8600 B.P.
			8600 B.P.
	4.	Hell Gap	10,000 B.P.
			10,150 B.P.
			10,600 B.P.
Paleo-Indian			10,850 B.P.
	3.	Sister's Hill	9650 B.P.
	2.	Betty Greene	7870 B.P.
			9350 B.P.
	1.	Agate Basin	9970 B.P.
			10,375 B.P.

*Numbers refer to sites located on Figure 36.

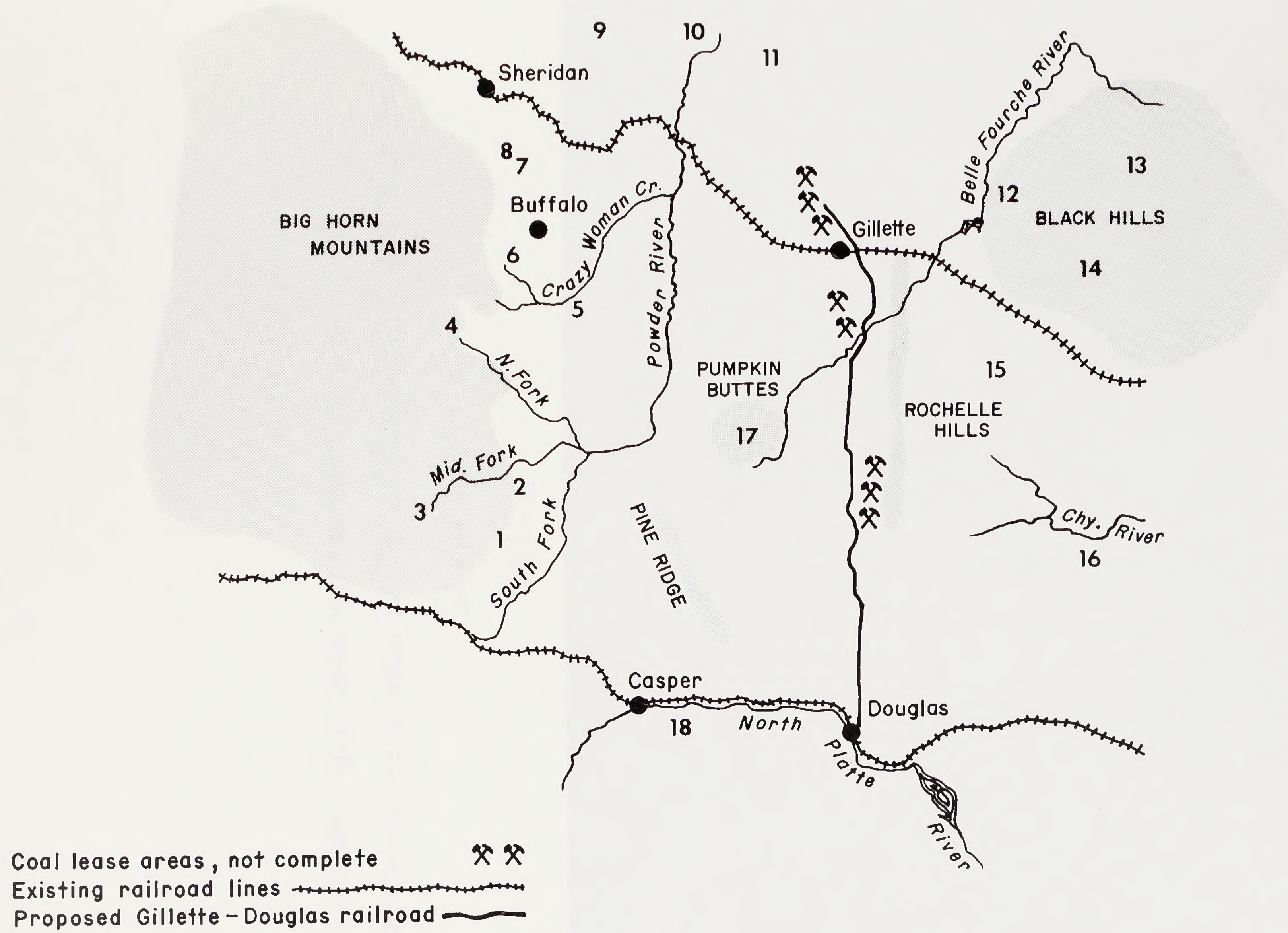


Figure 37

Archeological resources within the Powder River Basin, Wyoming

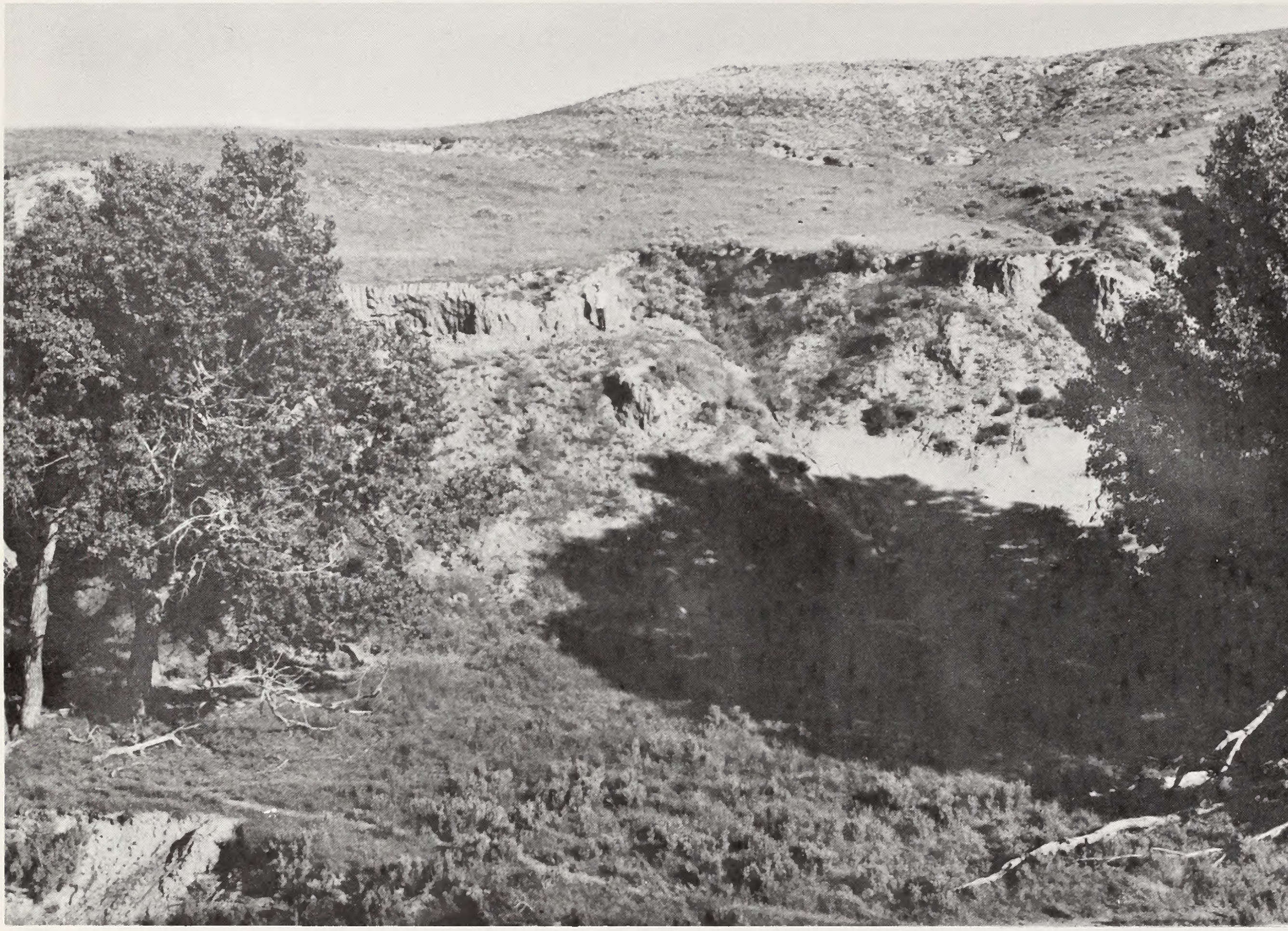


Figure 38

The Ruby Site

A deeply buried Arroyo Bison Trap in the Pumpkin Buttes Area, used about 2000 years ago. Photo shows site prior to excavation.

Figure 39

The Ruby Site

Photo exposes prehistoric use level, about 20 feet of fill overlies the butchering area. Holes are the post molds of the palisade erected to guide Bison to the kill area.

Figure 40

Glenrock Buffalo Jump

Above Bison were driven over cliff (at arrow) and animals butchered below. Bone profile at left shows different periods of use. Bison butchering area below. Glenrock Buffalo Jump is on the National Register of Historic Places; located near Casper, Wyoming.

and look from one buffalo jump, trap, or pound to another continuously to the forests of Canada." Illustrations of man's method of hunting and trapping in the basin are shown in Figures 41 and 42.

Because of recent development activities in the Powder River Basin, archeological site surveys have been initiated in the area. George Zeimens, Assistant State Archeologist, has identified six sites on the Black Thunder lease area, two of which are being considered for salvage (Wyoming Environmental Institute Report, July 1974, Enclosure 1). Some evidence of archeological value has been sited along the Burlington Northern railroad proposed right-of-way during preliminary examinations prior to archeological survey. While surveying the Sun Oil Company lease, he uncovered many more, including a potentially high value, deeply buried, multicomponent site.

Olaf Doud, Kerr-McGee archeologist, reported archeological sites and lithic scatters on the Kerr-McGee lease area which he surveyed. In addition, 19 sites were reported in the archeological survey report prepared by the University of Montana for the Amax Company to cover its Belle Ayr North and South units. Morton May (1974) mentioned seven archeological sites on the Carter Oil Company lease and ten more in the Gillette area. The Kerr-McGee and Carter Oil Company reports were not intensive archeological surveys, and more sites which were not seen or recognized probably exist in these areas.

"The Powder River Basin remains largely uninvestigated with no real systematic program ever having been undertaken. Present investigations reflect mostly attempts to salvage endangered sites that were brought to someone's attention. The entire spectrum of the different known periods of high plains pre-history is to be found there but details of the cultural systems involved is well in the future." (Emphasis added) (Frison 1974b).

Though a great probability for finding sites exists (Frison, et al 1974) no large- scale formal archeological surveys have been conducted, and ". . . most of the activity has been by collectors. . . . The writer has seen only a small number of the local surface collections from east of the Bighorns,

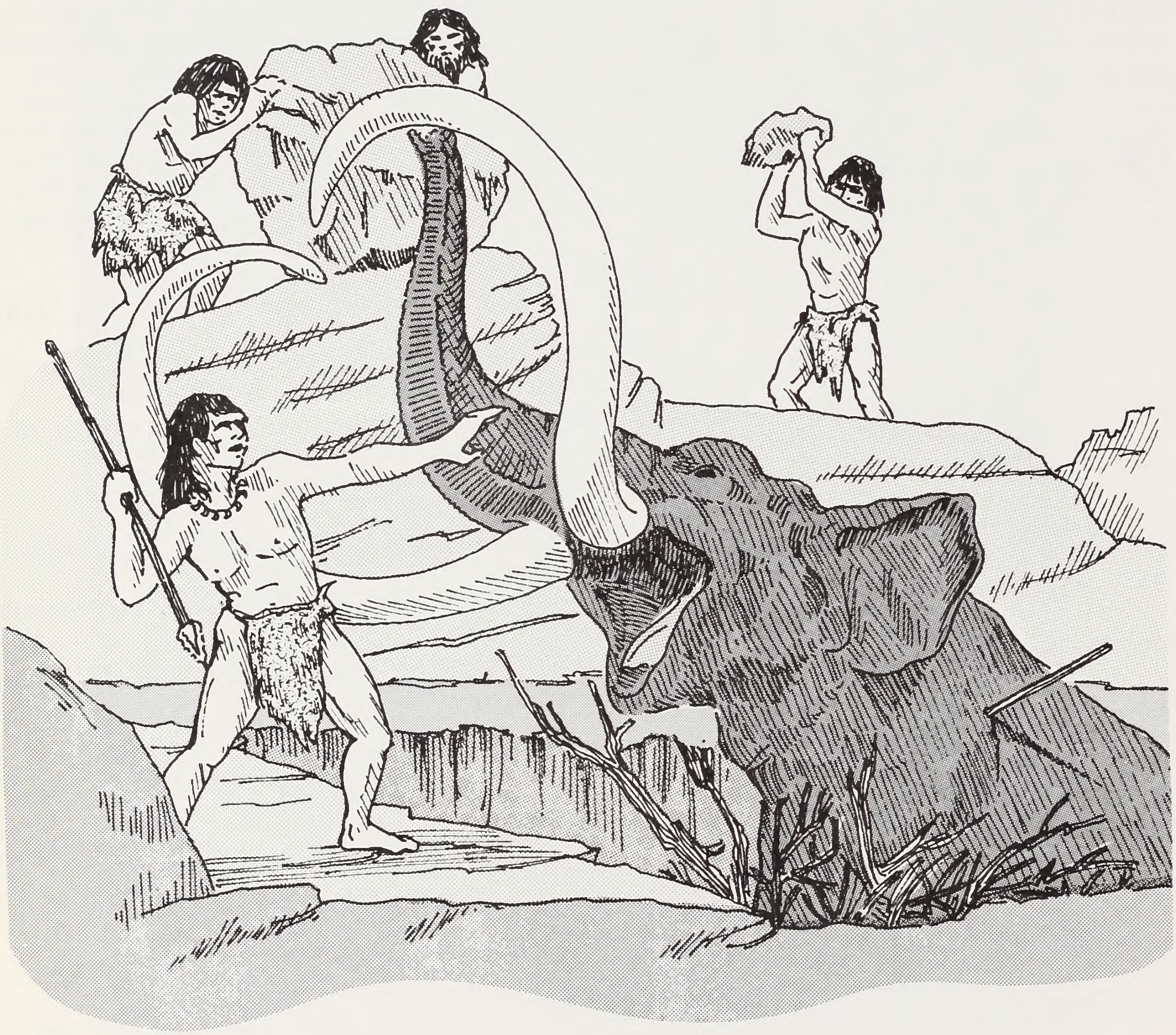


Figure 41
A Mammoth Hunt in Post Pleistocene Wyoming

Figure 42
Buffalo Jump by Historic Plains Indians

but nearly all contain a small amount of fluted materials (Frison 1974b). The fluted materials are of the Llano culture, about ten to twelve thousand years old. So little is known that the entire basin can be considered a data gap, an informational void. Examples of certain periods of human existence have been discovered; very few, but they do exist. Of these, the Altithermal period is least known. However, one site, the Hawkin Site, has been examined which dated to this period (No. 7, Figure 36).

Paleontological values

The paleontological values of the Powder River Basin are known to be extensive and valuable but they have never been systematically studied (McGrew 1974). It is not possible to say where, how many, and what kind of paleontological values exist in the Powder River Basin. What little work that has been done is mostly related to geological mapping and uranium exploration. Wortman's (1896, pp. 81-110) Hyracotherium discovery from Wasatch beds in the Bighorn Basin and the work of Osborn and Wortman (1892, pp.80-147) in Wasatch fossil mammals are important to our understanding of paleontological potentials. Wegemann (Geological Survey 1917, pp. 57-60) published on Wasatch fossils in 1917. Delson's (1971) work is our most recent reference. Delson writes, "Several invertebrates, numerous lower vertebrates, and at least 41 species of mammals have been studied in detail." He also states that these specimens were recovered from 122 localities and that the methods of collection were entirely surface pickup from "ant hills, flats, and dissected badlands." (See Figure 43) Field methods used by Delson would not necessarily have uncovered evidence of larger mammals, and his work is an incomplete inventory of paleontological values of the Powder River Basin. It is the best available, however. Hager (1971)

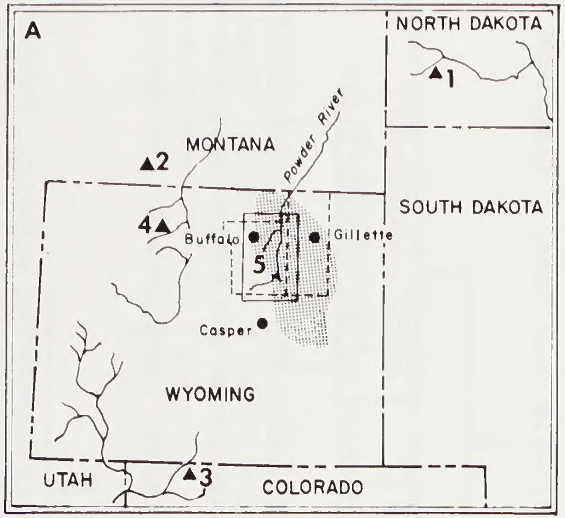


Fig. A. Index map of Wyoming and neighboring states, with locations of major fossil faunas discussed in the text. 1) Golden Valley local fauna. 2) Bear Creek local fauna. 3) Four Mile local fauna. 4) Big Horn Basin local faunas (Gray Bull, Clark Fork, Sand Coulee). 5) Powder River local fauna. Shaded area (A) indicates approximate extent of the Powder River Basin, solid rectangle outlines area enlarged in B, and dotted lines are the borders of Johnson and Campbell counties, Wyoming. B. Major collecting areas in the Powder River Basin. 6) Reculusa Blowout. 7) Dry Well locality (and neighboring localities 51-11, 51-20, 51-62). 8) Bozeman locality. 9) Monument Blowout. 10) Locality 51-3. 11) Locality 51-25. 12) Locality 52-12. 13) Locality 52-36.

Source: Delson, Eric, Mammal fossils of the early Wasatchian Powder River local fauna Eocene of Northwest Wyoming. Bulletin American Museum of Natural History Vol. 146, Article 4, 1971.

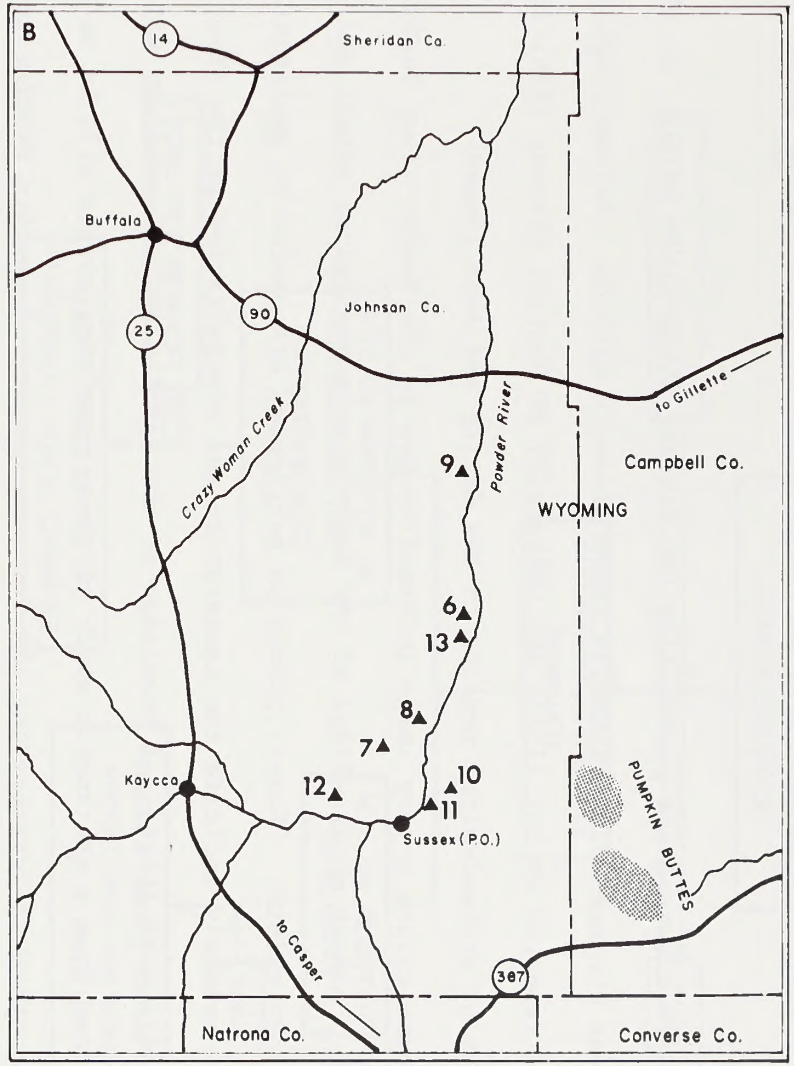


Figure 43

Collecting Area in the Powder River Basin and Major Fossil Fauna of Wyoming and Neighboring States.

doesn't mention the Powder River Basin though occasional paleontological salvage in the area clearly indicates that significant paleontological values exist (McGrew 1974).

There exists great probability for finding sites since Delson, et al met with great success using extensive reconnaissance methods. Paleontological remains were reported by May (1974) and University of Montana (Keyser 1974) in their reports of archeological remains on the Carter and Amax leases.

There exists a very large information gap in the Powder River Basin's paleontology. Almost no knowledge of the basin's paleontological animal and plant inventory exists. "Fossil plants in particular are useful to geologists because they reliably indicate the temperature and precipitation at the time that the plants were living. A knowledge of the species and paleoecology which could be gained from a systematic study of these overlying strata will be especially important in interpreting the Tertiary history of eastern Wyoming in addition to an understanding of the geologic processes which resulted in the deposition and formation of these currently valuable coal beds." (Harrison 1973.)

Information on the archeological surveys conducted by the applicant companies and approving agencies have been forwarded to the Wyoming State Historic Preservation Officer, the State Archeologist and the National Advisory Council on Historic Preservation. These organizations and individuals also have been asked for comments. The procedures for review compliance by the Advisory Council are graphically illustrated in Figure 44.

According to information contained in the Federal Register (February 19, 1974) and all succeeding monthly supplements listing sites on the National Register of Historic Places, the following four sites have been entered in the National Register and therefore qualify for federal protection under terms of the National Historic Preservation Act of 1966: Glenrock Buffalo Jump, Casper Buffalo Trap, Vore Buffalo Jump and Big Goose Creek Buffalo Jump.

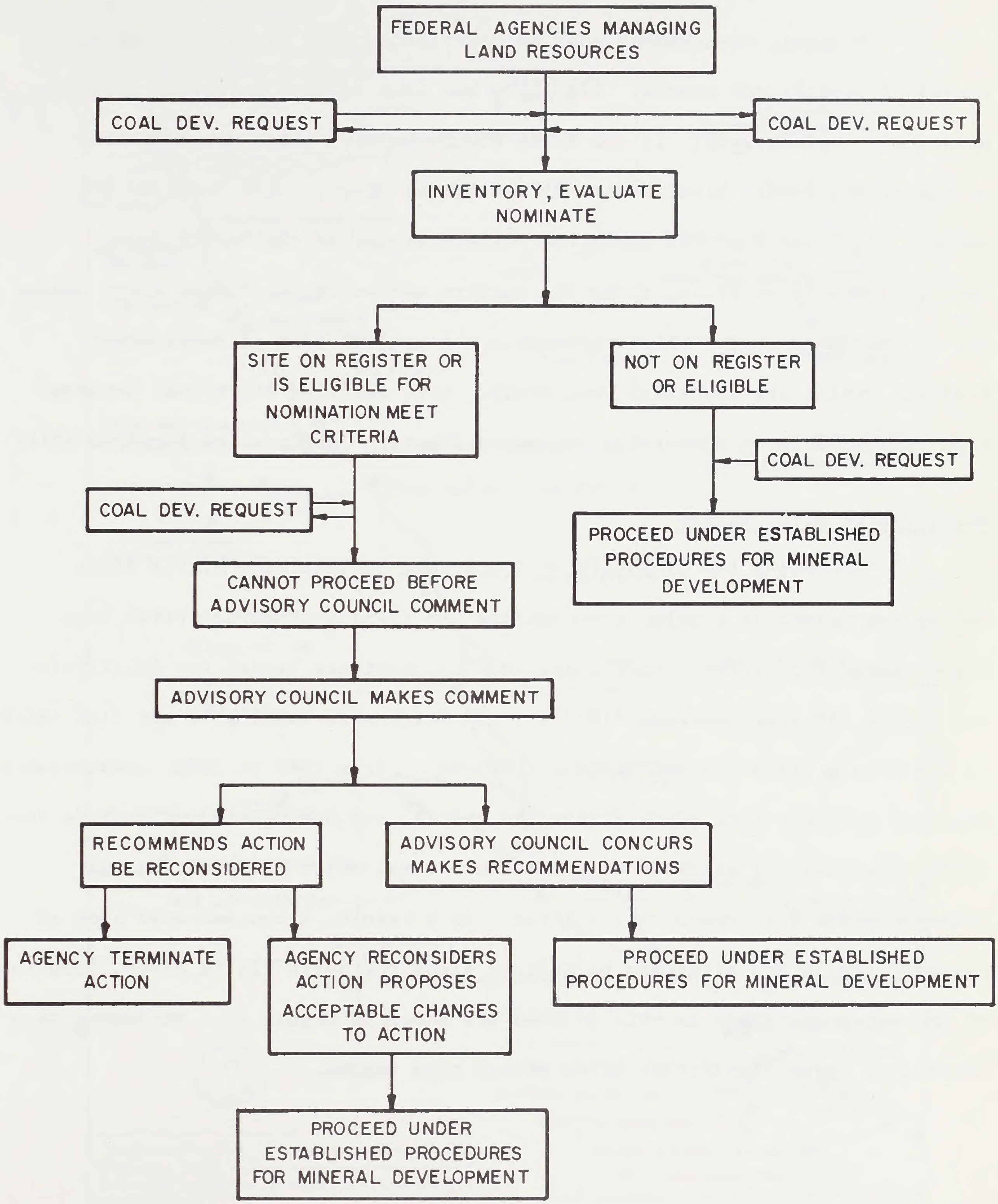


Figure 44

Agency Procedures to be Followed for Consideration of Historic Properties in Powder River Coal Development.

Historical Values

Historic environment must be described on the basis of a regional survey of significant events. The study has been divided into four separate geographic regions, viz: 1) the North Platte Valley, along the southern sector of the Powder River Basin; 2) the Powder River, which includes the Bozeman Trail and Bighorns along the western sector of the Powder River Basin; 3) the Black Hills, along the eastern sector of the Powder River Basin, and 4) the Inner Basin, which represents the central core of development. Historic trails are described separately. More detailed historical information is available in supporting documents (Western Interpretive Services 1974).

North Platte River Valley

Following the discovery of South Pass in 1812, the Platte River Valley was opened as a major thoroughfare for transcontinental travel over which passed fur traders (1820's and 1830's), settlers headed for California and Oregon (1840's), Mormons (1840's), and emigrants, rushing to get rich quick in California (1849-70) and Montana (1865-68). From 1849 to 1890, considerable military activity took place within the valley, and during various periods the valley corridor was utilized as a link in several major transcontinental transportation and communication lines. As a result, a concentrated band of historic trails and sites can be defined along the North Platte River. Locations of the sites described in this section are shown on Figure 45. Following is a listing of seven significant sites within this region.

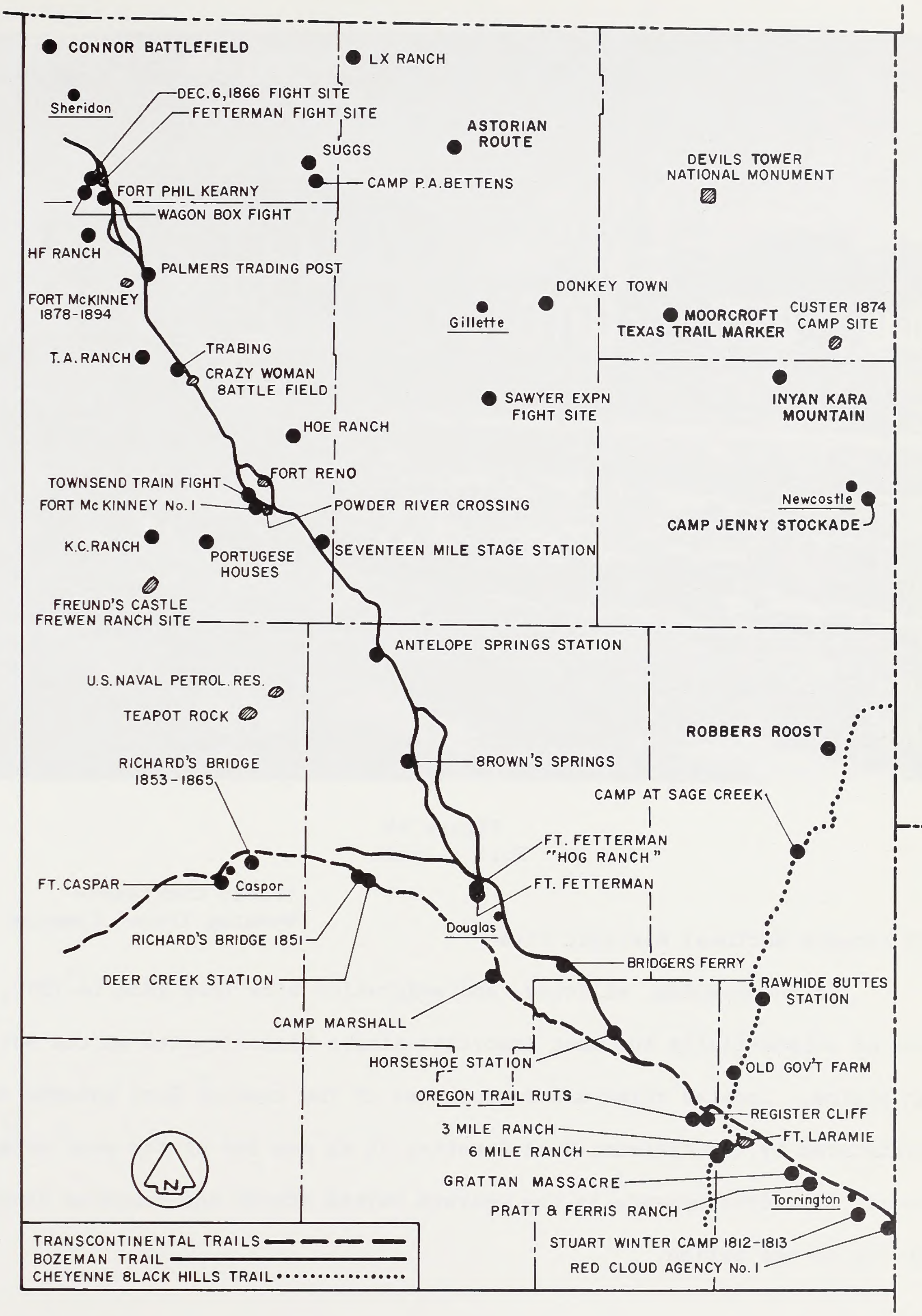


Figure 45
Historic sites and trails.

Figure 46
Fort Laramie

(Photo Courtesy--
Wyoming Travel Commission)

Fort Laramie National Historic Site

A fur-trading, military, and emigration site from 1834 to 1890, this ranks as substantially the most important single historic site on the entire high plains. Located three miles southwest of the town of Fort Laramie and administered by the National Park Service, it is now one of the most extensive historic site developments in the western United States and compares favorably with any in the nation.

Grattan Fight Site

This is the site of the first major engagement between U.S. troops under Lt. John Grattan and the Sioux Indians. It occurred August 19, 1854, and marked 37 years of intermittent plains warfare. Located some eight miles east of Fort Laramie National Historic Site, it is privately owned and a pair of historical markers are its only developments.

Red Cloud Agency No.1

From 1869-1872 buildings and operations of the Red Cloud Agency marked the major point of government contact with Oglala Sioux. Located near the Nebraska line on the north bank of the Platte River and privately owned, its cellars and foundations remain undisturbed and undeveloped.

Figure 47
Oregon Trail Ruts

(Photo Courtesy of
Wyoming Travel Commission)

Oregon Trail Ruts and Register Cliff

These are important and nicely preserved landmarks along the route of trancontinental travel from the 1830's through the 1870's. Located just south of Guernsey, Wyoming, both sites are owned by the State of Wyoming and both have received a measure of interpretation and development in recent years.

Deer Creek Site group

This group includes Bissonette's Trading Post, a fur trade operation from 1850-65; Deer Creek Station, a stage coach, Pony Express, telegraph and garrison station from 1858-67; Richard's 1851 Bridge, operated in conjunction with Bissonette's Trading Post; and the Mormon Farm/Upper Platte Agency/Deer Mission which existed from 1949-57. Located at Glenrock and nearby, it is privately owned and has not been developed.

Richard's Bridge Site group

Richard's Trading Post and Bridge, which served the emigrants from 1853-1865; the military establishments of Camp Davis, Fort Clay, Camp at Platte Bridge 1855-56, Camp Payne 1858-59; and Richard's Coal Mine which operated from 1853-65 are all included in this group. All are State of Wyoming owned and located just east of Casper on the south bank of the Platte River. Little or no development or preservation has yet occurred here.

Fort Caspar Site group

This group includes Guinard's Toll Bridge and Trading Post built in 1859 and operated until 1865 as a stage, Pony Express, and telegraph station; and Fort Caspar, garrisoned by the military 1865-67. Located on the northwest edge of Casper, it is owned and maintained by the City of Casper. On the National Register of Historic Places, this property and its buildings are one of the oldest historic site developments in Wyoming.

A number of minor sites on the transcontinental trails exist in varying degrees of magnitude, integrity, significance, and convenient locations. A complete listing and explanation of these may be found in the support document.

Powder River Basin

Although the region north of the Platte River Valley has been known since the first traveler pased through in 1802, it was too far north of established emigrant trails to attract visitors other than trappers, traders, and explorers until 1863 when the Bozeman Trail was established along the western border of the study area. During the five years of heavy use that followed, military activity accelerated in response to the inevitable Indian conflicts. After the Indian Wars, the region was settled by ranchers and farmers who continued hostilities among themselves for a short period of time. The current era of mineral development began in 1910. Eighteen significant historic sites have been identified within this portion of the study area.

Portuguese Houses

A fur trading post established in 1834 and operated until 1841 on the Powder River, it is a significant contemporary operation with Fort Laramie. Located a few miles east of Kaycee and privately owned, its undisturbed remains constitute a valuable resource which presently is noted only by a single stone marker.

Fort Reno

Built on the Bozeman Trail as Fort Conner in 1865, then renamed Reno, it was garrisoned by various units from 1865-68. It was a central post in the prevailing Indian hostilities. Located on the north bank of the Powder River several miles east of Kaycee, it is State of Wyoming owned and on the National Register of Historic Places. Development presently consists of protection, and a single stone marker near the stockade outline remains.

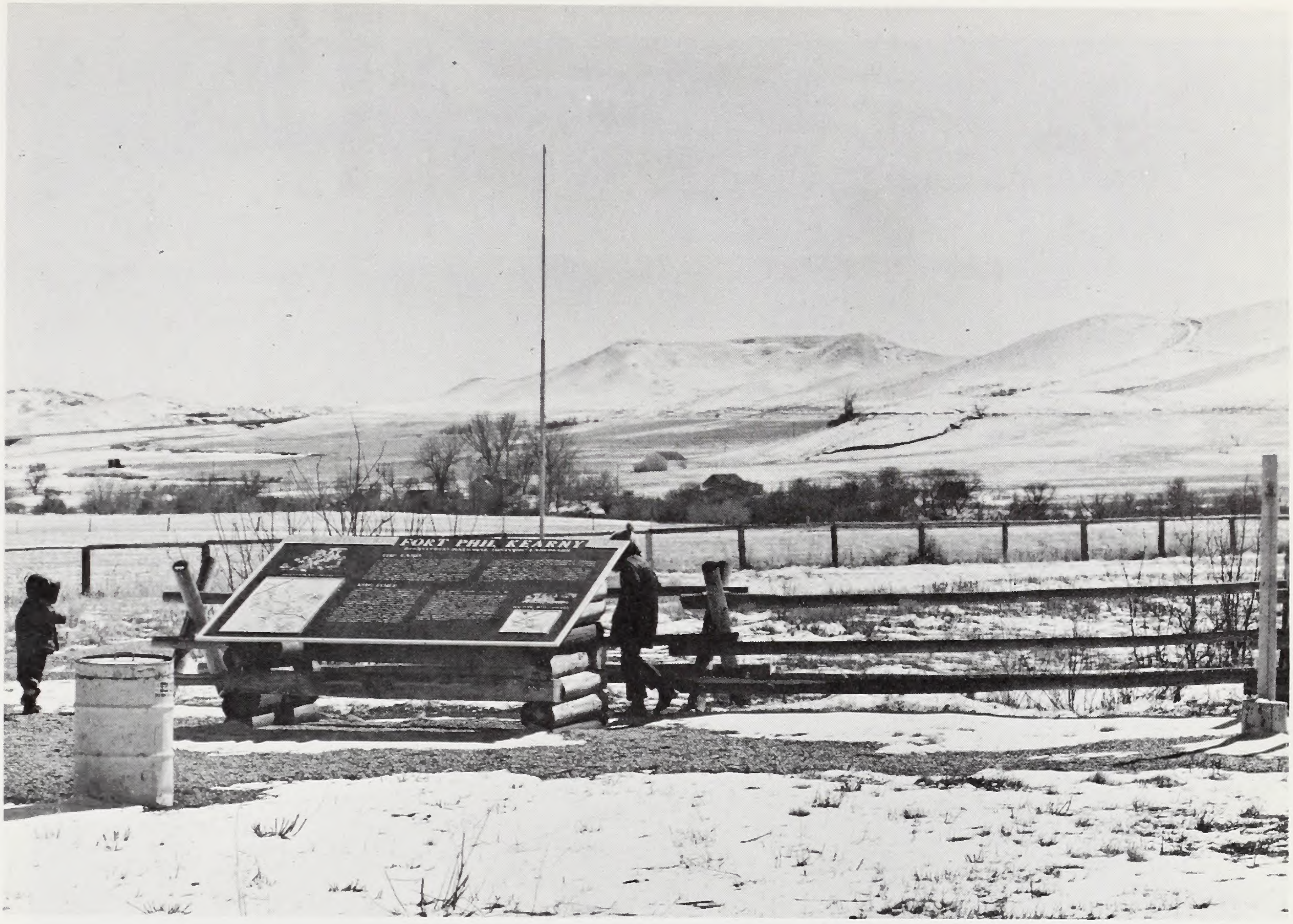


Figure 48
Fort Phil Kearny

Fort Phil Kearny Site group

This group includes the highly significant Bozeman Trail military sites of Fort Phil Kearny 1866-1868, the Wagon Box Fight 1867, and the Fetterman Fight 1868. All are located south and west of Story and have multiple State of Wyoming and private ownerships. Fort Phil Kearny is on the National Register of Historic Places and has received some interpretive development in recent times.

Figure 49
Fort Fetterman

Fort Fetterman

Established on the Platte River near the starting point of the Bozeman Trail, Fort Fetterman served as a major support base for military operations in the region from 1867-78, and particularly in 1876. Located about nine miles northwest of Douglas, it is owned by the State of Wyoming, is on the National Register of Historic Places, and its two surviving structures, parade field, and other remains are being preserved and interpreted.

Cantonment Reno (Fort McKinney #1)

This served as General Crook's main field supply base in the 1876-77 campaigns and as supply base until the summer of 1878. Administered by BLM and located on the north (left) bank of the Powder River east of Kaycee, its remains have yet to be marked or developed.

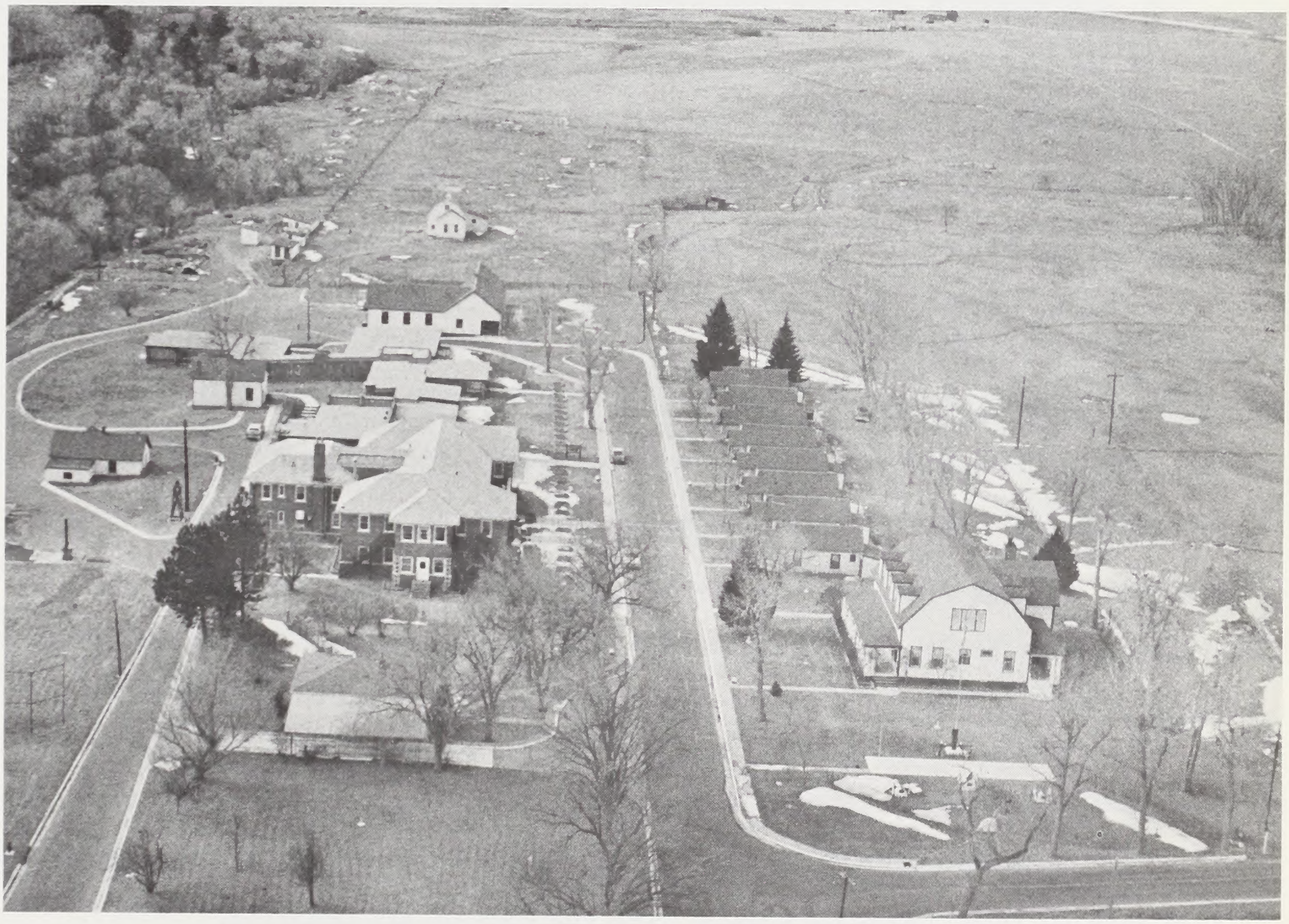


Figure 50
Fort McKinney

Fort McKinney (#2)

This was the Army's main base of operations in northeastern Wyoming for the period 1878-1894. It served during the closing days of the Indian Wars, and its troops played a significant role in the Johnson County War. State of Wyoming owned, its several buildings one mile west of Buffalo now house the Wyoming State Soldiers' and Sailors' Home.

South Bozeman Trail Site group

This group includes Sage Creek, first stop out of Fort Fetterman; Brown's Springs, second stop out of Fort Fetterman and site of an 1865 Indian fight and stage station 1878-92; and Antelope Springs, a garrison, stage station and road house 1877-87. Located adjacent and near Ross road, all are privately owned and few identifiable remains have been discovered at this time.

Crazy Woman Crossing

A major landmark on the Bozeman Trail between Fort Reno and Fort Phil Kearny, it was a camping site where a number of engagements with the Indians occurred 1866-68. It also became the site of the later Trabing Brothers' trading post, 1880's. Located southeast of Buffalo within a mile of the present county bridge over Crazy Woman Creek, it has multiple BLM and private ownership.

Seventeen-Mile Stage Station

Seventeen-mile Stage Station was a Rock Creek Stage Company Station from 1878 to 1892. Privately owned, its few remains are unmarked.

Powder River Crossing

This was a major crossing on the Bozeman Trail, a stage station site 1878-92, and location of Moreton Frewen's "76 Ranch." Although publically owned, its inaccessibility has left it unmarked and undeveloped.

TA Ranch Barn

At the TA Ranch in May 1892, a body of armed citizens surrounded the force of cattlemen that had assembled to raid the small ranchers of Johnson County and beseiged them until federal troops arrived from Fort McKinney and took the "invaders" into protective custody. Located 12 miles south of Buffalo, it is privately owned and the barn is still in use. Present owner tolerates visitors but is hostile to suggestions of possible development.

Figure 51
TA Ranch

Suggs

Suggs was an end-of-tracks town on the Burlington railroad as it came into northeastern Wyoming, and the scene of a very interesting conflict in 1892 between soldiers from nearby Camp Bettens and civilians in the town. Privately owned and located on the right bank of the Powder River opposite Arvada, few remains and no development or interpretation are to be found.

Figure 52
Hoe Ranch Ruins

Hoe Ranch

This was a ranch headquarters in the open range days that came into prominence when its foreman, George Wellman, was "dry gulched" during the Johnson County War activities. Located about three miles downstream from Fort Reno and privately owned, a massive stone chimney and other ruins remain.

Camp P. A. Bettens

Camp Bettens was a "summer camp" established in 1892 in response to the political currents prevailing after the Johnson County War. Troops from this camp had one very interesting battle with the citizenry of Suggs that summer. Located about four miles southeast of Arvada on the east bank of the Powder River, and privately owned, few remains and no development or interpretation may be found.

Teapot Rock and Naval Petroleum Reserve #3

Teapot Rock is a distinctive regional landmark and the adjacent government oil field became the focus of national attention in the early 1920's. Located south and east of Midwest, it is still government owned and administered by the Bureau of Land Management.

Freund's Castle and Frewen's 76 Ranch

Freund's Castle is a prominent local landmark and Frewen's 76 Ranch is a historic open range cattle operation that was well known during the 1880's. Located on the South Fork of the Powder River, about ten miles off I-25, both are privately owned. The landmark is unchanged but little remains of the ranch buildings.

LX Ranch

The LX Ranch was the main headquarters for John B. Kendrick's cattle operation along the Powder River in Wyoming. Extensively developed from 1909-1915 by the construction of native stone buildings, it remains as fine an example of a cattle baron's property as is to be found anywhere. Located on the left (north) bank of the Powder River a few miles south of the Montana line, it is still owned by the Kendrick Family. All buildings remain intact although deteriorating gradually.

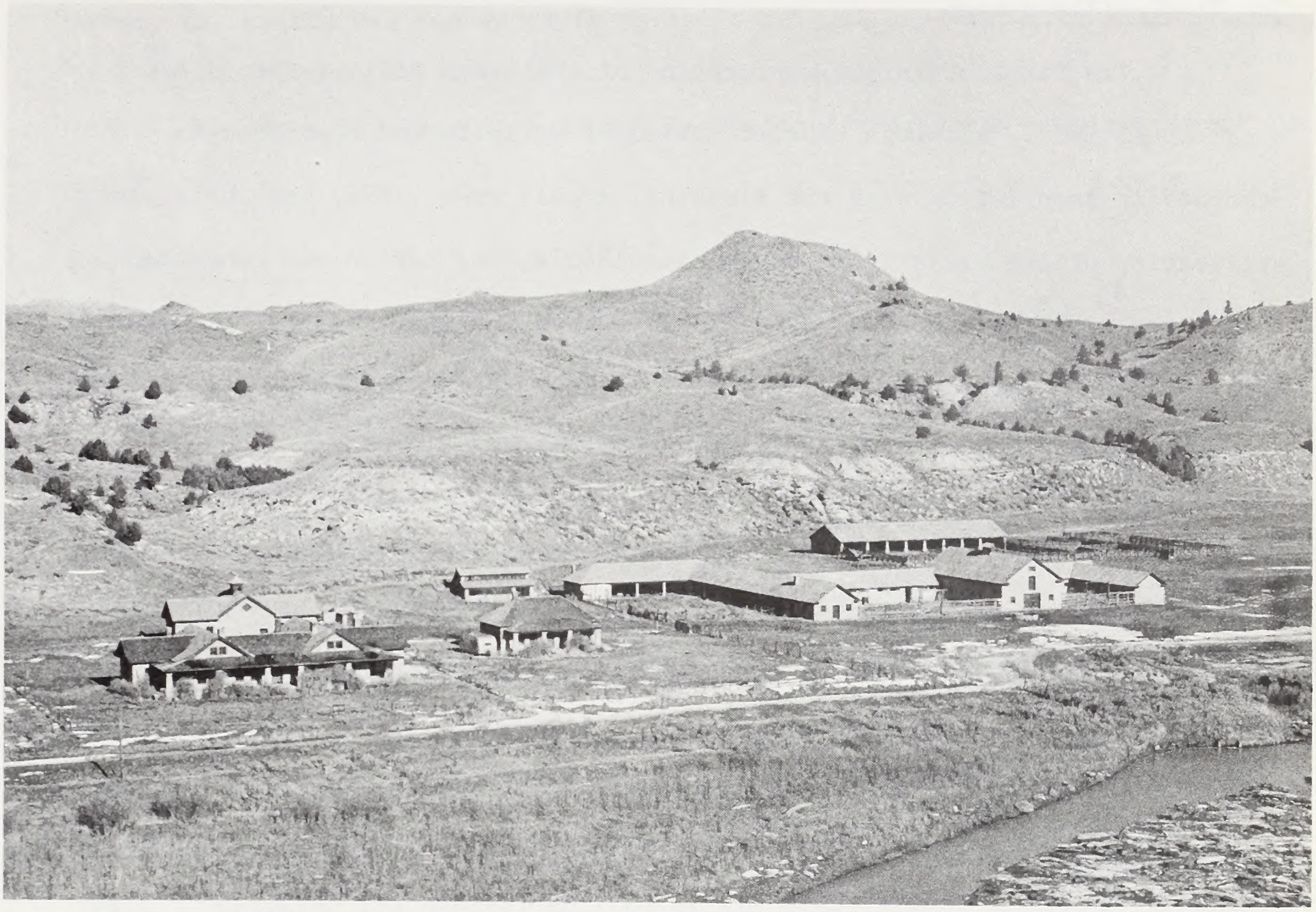


Figure 53
LX Ranch

Trail End and Sheridan Inn

Trail End is the townhouse of Senator John Kendrick completed in 1915. Located in Sheridan, it has been restored and refurnished and is owned by the Sheridan County Chapter, Wyoming Historical Society. Sheridan Inn was built by Buffalo Bill in 1893 and was a prestige accommodation in the West for many years thereafter. Acquired and saved in 1964 by Mrs. N. D. Kings, it has been extensively restored and is still operating. Both of these properties are on the National Register of Historic Places.

The Black Hills region

The first organized exploration of the Black Hills region did not occur until 1857. Although a brief period of activity and migration is recorded in association with the Black Hills gold rush (1876) and subsequent utilization of the Texas Trail during the 1880's, the region was converted to less colorful agricultural use. In later years some recreation and mineral development has occurred. Only three significant sites have been identified within this region of the study area.

Floral Valley/Inyan Kara Mountain

Inyan Kara Mountain, situated in the Floral Valley, is a prominent Indian landmark and was visited by the Warren Expedition in 1857, Raynold's Expedition 1859, and Custer's "Black Hills" Expedition 1874. Located near Sundance, it is under multiple private and U.S. Forest Service ownership and administration. The site is enrolled in the National Register of Historic Places.

Cambria

Cambria was a major coal mining company town of the Burlington railroad 1892-1916. Located north of Newcastle, and privately owned, few building and cemetery remains may be found and no development or interpretation has occurred.

Devils Tower National Monument

This is a distinctive regional landmark and was the first National Monument created in 1908. Located 12 miles off U.S. 14-16 northwest of Sundance, it is administered by the National Park Service and is intensively developed.

The Inner Powder River Basin

Although this area was first traversed in 1811 by a party of Astorians, it was not until the Burlington railroad came into the basin during the years 1890-92 that any sustained activity is recorded. Following this event, the region was converted to agricultural use and very little of its history can be considered to be of state or national significance. As a result, no sites of significance have been identified within this region of the study area.

Historic trails

The study region is fringed on the south by the classic main route of westward migration, the "Oregon Trail," which in this area generally follows the course of the North Platte River; however, keeping on ground easy for wagons to traverse, it departed some miles from either side of the river where conditions dictated. The Oregon and Mormon Trails (parallelling this segment of the Oregon Trail) are currently being studied by federal, state, and local participants as potential additions to the National System of Historic Trails.

Branching off from the transcontinental "Oregon Trail" in the region between present Orin Juntion and Fort Fetterman State Park is the "Bozeman Trail." Crossing the central portion of the study region diagonally, this trail passes on out of the state northwest of Dayton.

Connecting with the Bozeman Trail at Fort Reno is the "Sawyer Wagon Road," a little used route that entered the state from the Niobrara River Country.

The Cheyenne/Black Hills Stage Route followed the old route from the railroad at Cheyenne northward to Fort Laramie. Established in 1876, the route passed two stage stations southwest and south of Fort Laramie and, within the study region, the notable stations of Rawhide, Silver Cliff, Hat Creek, Cheyenne River, and Beaver Stockade.

From 1877 to the mid-1880's, range cattle moved into Wyoming in some quantity. These cattle followed routes that depended from season to season on availability of water and forage. Generally, there appears little justification

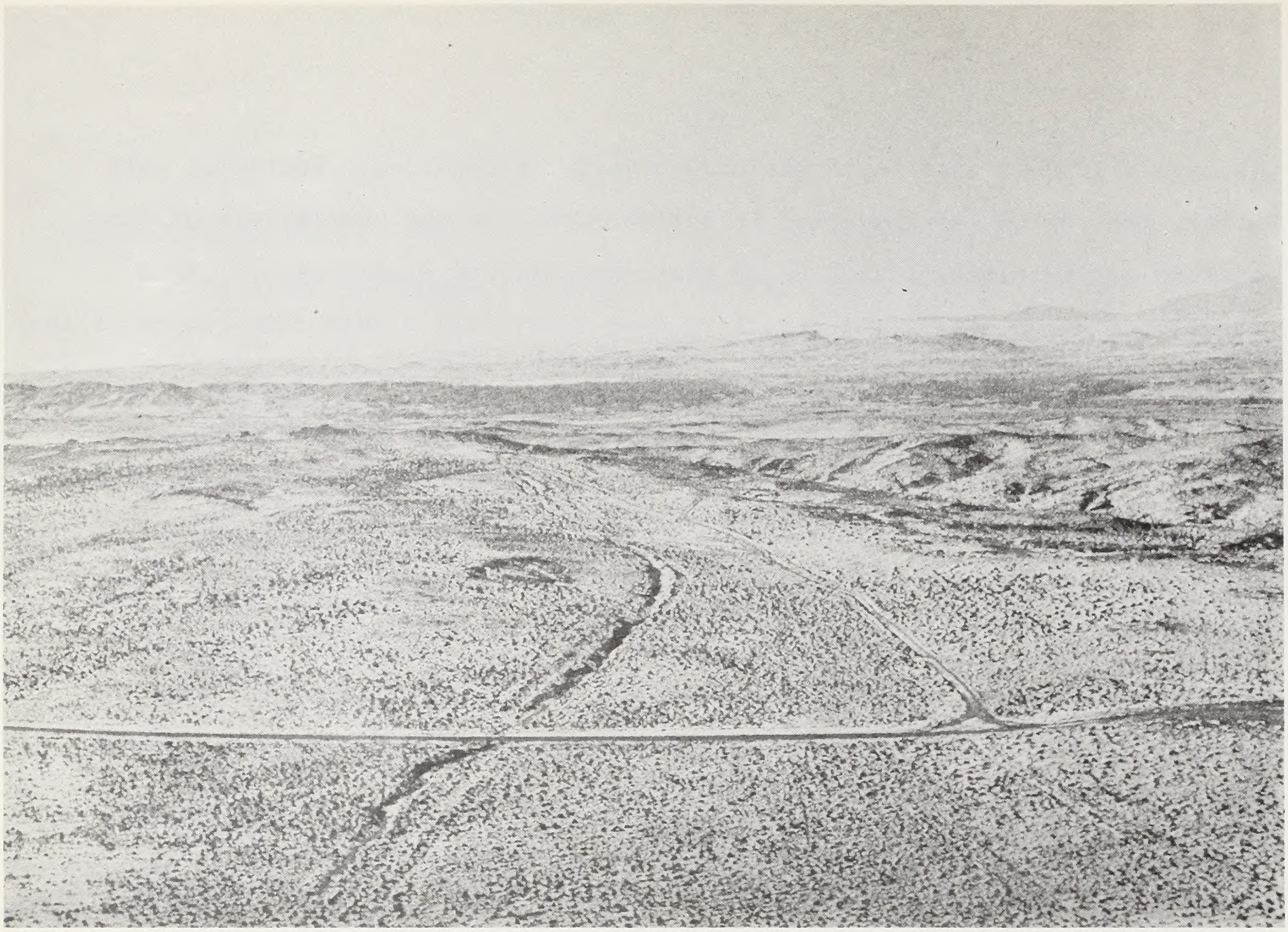


Figure 54
Bozeman Trail

for the notion of a "Texas Trail" as a well-defined geographic entity in this region, and yet Texas herds did move north across the general area and their passing has been commemorated by markers. More detailed information is available in the Regional History Study (Western Interpretive Services 1974).

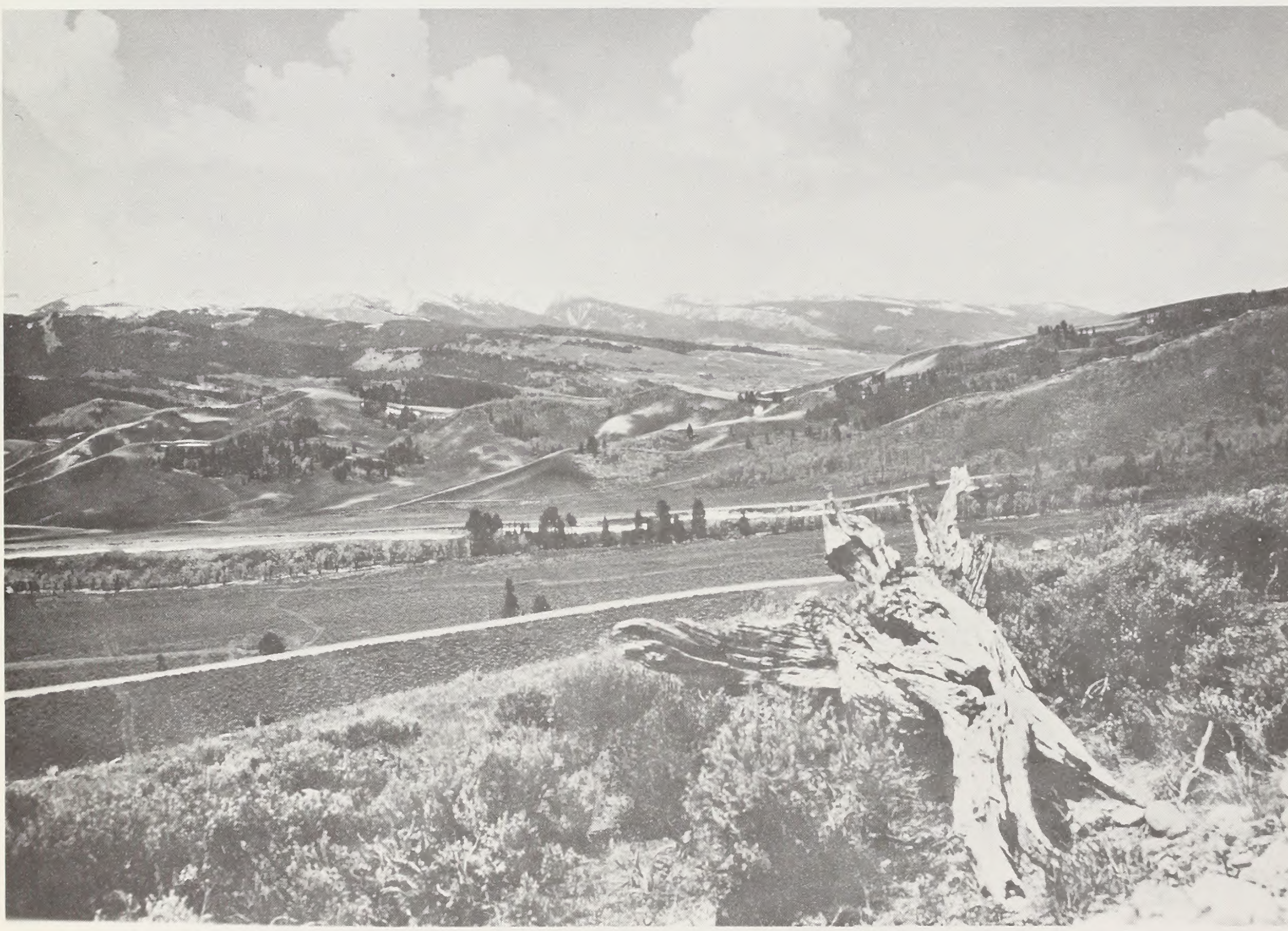
According to information contained in the Federal Register (February 19, 1974) and all succeeding monthly supplements listing sites on the National Register of Historic Places and from the Wyoming State Preservation Office, the following eleven historic sites have been entered in the National Register and therefore quality for federal protection under terms of the National Historic Preservation Act of 1966: Fort Caspar, Fort Fetterman, Fort Phil Kearny, Fort Laramie, Fort Reno, Register Cliff, Sheridan Inn, Trail End, Oregon Trail Ruts, Inya Kara Mountain, Cheyenne Black Hills Stage Route--Rawhide to Silvercliff, and Jenny Stockade.

Additionally, at the present time, National Register nominations are being prepared by the State Preservation Office for the following four properties: Teapot Rock and Naval Petroleum Reserve #3, Cantonment Reno, Crazy Woman Crossing, and the Hog Ranch.

Information on the historical surveys conducted by the applicant companies and approving agencies have been forwarded to the Wyoming State Historic Preservation Officer and the National Advisory Council on Historic Preservation. These organizations and individuals also have been asked for comments.

Aesthetics

The aesthetic region includes the interior Eastern Powder River Basin as well as peripheral areas of the Laramie Range (south), Bighorn Mountain (west), and Black Hills (northeast) which relate to any industrial and population growth of the basin. Some landforms of the region are best illustrated and described by photographs.



(Photo Courtesy of Wyoming Travel Commission)

Figure 55
Bighorn Mountains

The Bighorn Mountains have some of the highest quality scenery and exhibit the greatest relief in the region. Vegetative contrast of trees and open parks of grass and shrubs provides assorted seasonal colors, textures, and patterns.

These are highlighted by deeply cut drainages with rock formations of mixed red, yellow and gray colors. Elevations range from 5,200 feet near the western edge of the basin to 13,175 feet on Cloud Peak.

Intrusions in and near the Bighorns are few and highways and power lines blend with the forest. Some exceptions exist where timber clear cuts in unnatural shapes have been made. These are mostly visible from the air and on lightly traveled dirt roads. Irrigated meadows and tree-lined water courses along the foothills and streams and abundant wildlife add to the visual qualities of the mountains. Numerous small alpine lakes and streams near the central Bighorns are clustered around the Cloud Peak Primitive Area.

(Photo Courtesy of Wyoming Travel Commission)

Figure 56
Black Hills

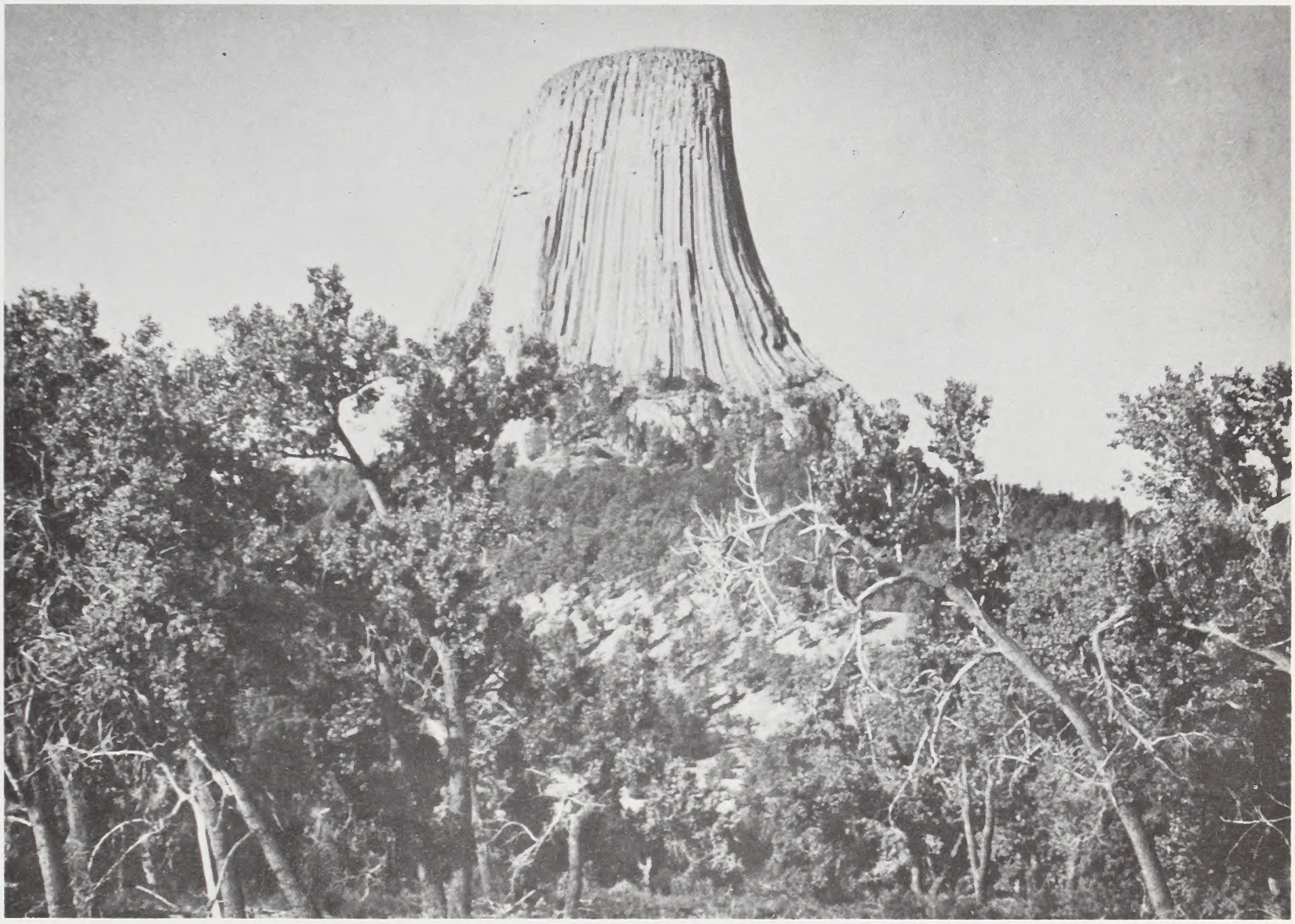
Another mountainous landform, the Laramie Mountain Range, is made seemingly more forbidding by its sharply rugged nature. The mountains at the north end are 5,500 feet elevation at the base and rise to 10,200 feet on Laramie Peak. The dense, wooded cover on very steep slopes, narrow grassy draws, and some open meadows at higher elevations typify the more rugged inaccessibility of the region.

(Photo Courtesy of Wyoming Travel Commission)

Figure 57
Laramie Range

The Black Hills of Wyoming, shown above, are located along the east side of the basin. The Wyoming Black Hills have a landform of rolling hills, open timber and grasslands. The park-like stands of ponderosa pine, rolling grasslands and rushing streams provide a variety of colors and textures throughout the day or season. Elevations from the edge of the basin to the South Dakota line range from 4,200 to 6,600 feet.

The Black Hills consist of blended small farms, ranches, sawmills, and mines. The mines represent many early gold propects long since abandoned and lend a sense of cultural color to the area.



(Photo Courtesy of Wyoming Travel Commission)

Figure 58
Devils Tower

Standing as a prominent landmark and visible from the inner basin is Devils Tower, an imposing formation appearing as a stump-shaped cluster of rock columns. The national monument is 1,000 feet across at the bottom and 275 feet across at the top. It rises 865 feet above its wooded base (5,117 feet above sea level) and 1,280 feet above the Belle Fourche River near the base. Other peaks as high as 6,300 feet are located in the Inyan Kara Mountains.

Figure 59
Rolling Plains of the Powder River Basin

Within the basin, the landforms, textures, and colors become more muted and less spectacular. However, some periods of day or season do provide various combinations of color and shadow from hills, vegetation, and soil.

Figure 60
Typical River Banks in the Basin

This land is more the characteristic theme of open rangeland as the relative relief of river breaks and surrounding lands is less than 100 feet with gentle side slopes and rolling open country. In river bottoms of the North Platte, Belle Fourche, Little Powder, and Little Missouri Rivers, cottonwood along banks contributes to some natural interest during the winter, glossy green leaves during the spring and summer, and brief gold colors in the autumn. Some views of the rolling Black Hills and other scenic ponderosa pine ridges can be seen from most northern drainages.

Along the Powder River, terrain is more broken and a true sample of the badlands. Here, the Bighorn Mountains can also be seen. Running water contributes scenic variation year around.

Land patterns of irrigated farmlands are more prevalent along the North Platte where the river still provides a stop to rest and view wildlife and remnant signs of the emigrants who traveled on the Oregon Trail.

(Photo Courtesy of Wyoming Travel Commission)

Figure 61
Buttes and Rolling Plains

In the open country characteristic of the mining region of the basin, topography is variable with rolling plains, broad level river courses, low hills and buttes. These buttes often stand isolated in the basin like

Pumpkin Buttes (central basin), Teapot Rock, (western) or Chimney Rock (southeast). The Rawhide Buttes (southeast) and Rochelle Hills (central) with scattered pine provide relief from the more level plains, a principal characteristic of the Thunderbasin National Grasslands.

Figure 62
Artificial Intrusion

Land patterns in the basin change from the more distinct natural features of the mountains to man-made features and patterns, i.e., strip mining, coal storing silos, oil and gas equipment, dry farming, power plants, transmission lines and Interstate Highways 25 and 90.

Many small reservoirs scattered over the plains break the solid patterns of native grasslands.

Wildlife and Fish

The wild fauna of the Eastern Powder River Coal Basin is a composite of native terrestrial and aquatic animal communities representative of several biomes and major plant communities. In a broad sense, the basin is a transition zone or ecotone with plant and animal species representative of the short grass prairie, the northern desert shrub community, the montane coniferous forest, and the deciduous forest edge (riparian woodland). While some animals may be tied closely to a particular plant community or vegetative type within the basin, others are more wide ranging. Some introduced species are also present. Vertebrate animals which are found in the basin are listed in Tables 29, 30, 31, 32, Appendix C.

To analyze the impacts on wildlife from coal development in the basin, the ecology of each species involved must be known. Information with respect to food, breeding habits, migration routes, seasonal and key habitats, life cycles, predators, population trends, carrying capacities of given habitats, etc., is limited in scope. Further, since action which may be beneficial to one species may prove detrimental to another, an understanding of how individual species relate to others in local ecosystems is necessary. To the extent information is available, the wildlife portion of the existing environment will be described more or less categorically and quantified where possible. More information is available for species of higher recreational and economic value to man. The following information was abstracted from draft material in the Northern Great Plains Resource Program and augmented by new or more detailed information where pertinent.

Big game

Mule deer

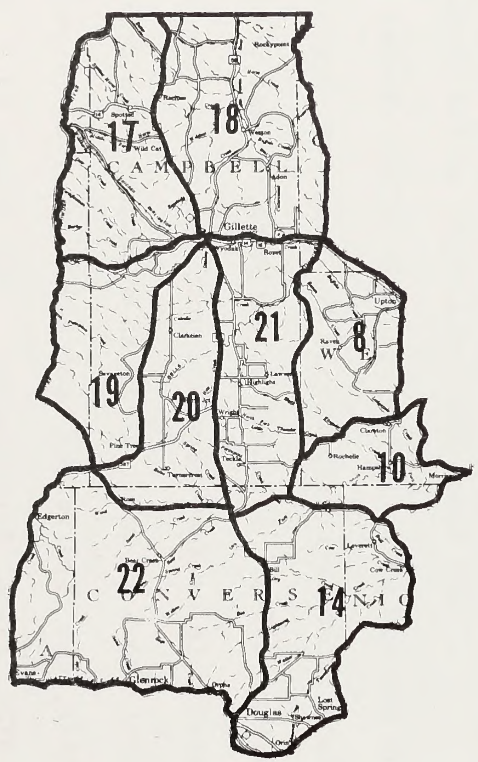
Mule deer are found throughout most of the study area. Highest populations are in moderately timbered areas, rough breaks and along the drainage courses as opposed to the large unbroken prairie lands. (See Map 10, Appendix A)

Some seasonal migration takes place, especially during severe winter periods. In most instances, this is characterized by winter concentrations in year-round resident areas wherein numbers increase during periods of winter stress (Map 10.) Available winter browse and suitable protective cover during severe winter storms are the most critical habitat elements presently limiting mule deer herds. Oilfield and other mineral development have eliminated some habitat in recent years. Mule deer populations are considered to be stable and in balance with the carrying capacity. Liberal hunting regulations keep most herds in check.

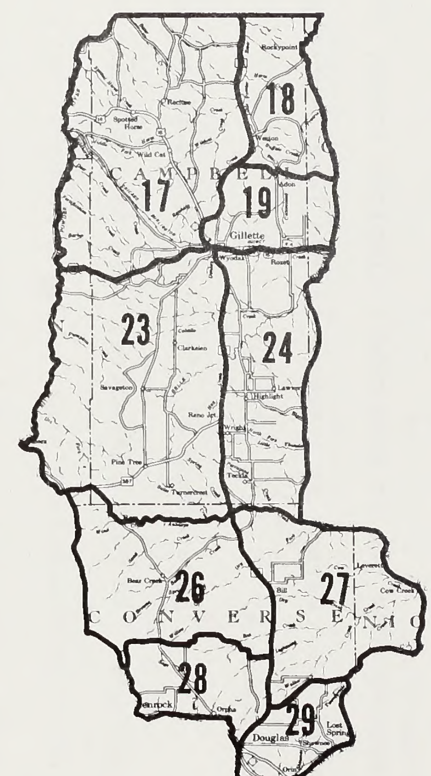
The total deer population of the study area, (16,800, see Table 28) is the sum of estimates provided by the Wyoming Game and Fish Department Big Game Biologists responsible for each deer hunting area (Pate 1974, Roby 1974, Wilson 1974). Although an estimate, it was derived from the best information available to knowledgeable professionals. The annual harvest figure of 6,200 deer shown in Table 28 is an average of the deer harvested during the years 1971, 1972, and 1973 in the hunt areas involved (Wyoming Game and Fish Department 1972a, 1973a, forthcoming). (See Figure 63.) Predators, primarily coyotes, take some deer but are not considered an important influence upon populations. Big sagebrush is probably the most important winter browse species with other sagebrushes, rabbitbrush, rose, skunkbush sumac and serviceberry having local importance.

Figure 63
Wyoming Game and Fish Department 1973 Deer and Antelope Hunt
Area Pertinent to the Study Area.

1973 DEER AREAS



1973 ANTELOPE AREAS



Pronghorn Antelope

Hunt Area		1973-74 Estimated Winter Pop.	1971 No. of Hunters	1971 Average Days Hunted	1971 Harvest	1972 No. of Hunters	1972 Average Days Hunted	1972 Harvest	1973 No. of Hunters	1973 Average Days Hunted	1973 Harvest	Three Year Average of Harvest
17	Gillette	4,600	958	2.09	911	1,043	2.40	943	1,439	1.77	1,414	1,090
18	Rockypoint	1,000	279	2.66	263	378	3.01	345	423	2.30	400	340
19	Rozet	2,700	750	2.23	713	852	2.39	759	961	1.89	914	800
23	Pumpkin Buttes	5,700	952	2.51	925	1,253	2.31	1,160	1,779	1.79	1,747	1,280
24	Thunder Basin	3,700	691	2.29	646	716	2.54	661	886	1.79	880	730
26	Bear Creek	5,500	1,455	1.74	1,404	1,902	2.32	1,735	1,910	1.67	1,861	1,670
27	Bill	4,300	1,160	2.39	1,077	1,719	2.70	1,632	1,700	1.99	1,627	1,450
28	Sage Creek	1,800	472	2.06	455	481	2.08	443	480	1.66	466	450
29	Shawnee	1,000	181	2.16	172	281	2.19	255	301	1.70	289	240
	Totals (or average):	30,300	6,898	2.24	6,566	8,625	2.44	7,933	9,879	1.84	9,598	8,050

Deer*

Hunt Area		1973-74 Estimated Winter Pop.	1971 No. of Hunters	1971 Average Days Hunted	1971 Harvest	1972 No. of Hunters	1972 Average Days Hunted	1972 Harvest	1973 No. of Hunters	1973 Average Days Hunted	1973 Harvest	Three Year Average of Harvest
8	Upton Four Horse	3,200	651	1.90	611	588	2.41	335	762	2.83	654	530
10	Hampshire Resident	2,500	381	2.75	277	207	3.89	155	371	3.11	309	250
14	Twenty Mile	3,400	1,207	2.76	956	496	2.82	2[illegible]8	1,298	2.25	1,070	770
17	NW Gillette	2,500	2,574	2.29	1,405	1,028	2.30	59[illegible]	1,757	2.50	1,529	1,180
18	Campbell	6,200	2,574	2.29	2,266	1,589	2.75	1,078	3,343	2.49	3,042	2,130
19	Pumpkin Buttes	1,200	642	2.80	400	821	1.97	263	614	2.62	485	380
20	Clarkelen	900	349	2.37	289	314	2.25	149	430	2.92	313	250
21	Thunder Basin	1,800	778	2.86	657	648	2.64	397	1,122	2.61	817	620
22	Douglas	800	873	2.70	594	1,067	2.00	427	2,052	1.82	1,590	870
	Totals (or average):	16,800	8,997	2.58	6,567	5,963	2.39	3,192	10,616	2.46	8,846	6,200

*The harvest information presented for deer for 1972 is incorrect. In the "Northeast Region", an additional 8,252 non-resident hunters were projected to have harvested an additional 5,826 deer above that which was published in the annual harvest report. The majority of these hunters and deer were projected in the Gillette area and Weston County. (Received in comments from the Wyoming Game and Fish Department.)

Table 28

Deer and Antelope Populations, Hunter Activity and Harvest

White-tailed deer

Small whitetail populations are scattered over various parts of the study area. Concentrations are found in the stream bottoms. They are found in good numbers along the Powder and Little Powder Rivers within the study area. Although distribution appears to be increasing, the major whitetail concentrations are found outside the study area along the east face of the Bighorn Mountains and in the Black Hills. Whitetail populations and harvest information are included in the figures given for deer in Table 28.

Pronghorn antelope

In 1970, approximately 46 percent of the estimated world population of 435,000 pronghorn antelope inhabited Wyoming, a large proportion of these occurring in the study area. Most of Wyoming's antelope inhabit the sagebrush steppe, saltbush-greasewood ranges or grama-needlegrass-wheatgrass ranges (Sandstrom, Hepworth, Diem 1973, p. 61). The major forage species utilized by antelope are sagebrush, rabbit brush, and sagewort which are of utmost importance as winter browse. Use of forbs is high in spring, declining in fall and winter; grass use is minimal. Sagebrush stands are important as protective cover during winter storms and for concealment of newborn fawns. Populations decreased slightly for a time in the late 1960's in Campbell and eastern Sheridan Counties due to loss of habitat and increased illegal killing during fuel exploration and production. Antelope populations have since increased significantly in most of eastern Wyoming.

Migration is minimal and takes the form of concentration of dispersed populations into a local area of more favorable winter browse and climatic conditions. Areas used heavily during the winter are abandoned during the summer if water is not available. Map 9, Appendix A, illustrates seasonal pronghorn distribution patterns. Amount and quality of winter browse available determines antelope carrying capacity of the area. Sheeptight fencing is widespread in the study area and effectively segregates and confines some populations to certain parcels of land. The availability of surface water can be crucial to populations confined in sheeptight pastures during dry seasons. Coyotes and eagles take some antelope, especially fawns, but at present they are thought to have minimal influence on the overall population of the study area. Antelope are more vulnerable to coyote predation in the more heavily sheeptight fenced areas.

As with the deer, antelope populations are managed on the basis of hunt areas and those all or partly within the study area are shown in Figure 63. The total winter pronghorn population of these areas (30,300), shown in Table 28, are total population estimates by Wyoming Game and Fish Department Biologists (Pate 1974, Roby 1974, Wilson 1974). The annual harvest figure of over 8,000 antelope for the study area is the combined three-year averages (1971, 1972 and 1973) for each hunt area involved (Table 28 and Figure 63) (Wyoming Game and Fish Department 1972a; 1973a; Forthcoming).

Elk

Several small herds of Rocky Mountain elk are found in the study area. The only herd now hunted is increasing and has a winter population of about 230 animals. It is located in the Fortification Creek area of the Powder River Breaks (see Map 9). In 1973, elk were harvested here (Wilson 1974). Other small herds are found in the Rochelle Hills at the head of the Belle Fourche and Cheyenne River drainages. The ranges of three separate bunches totaling about 90 elk are shown on Map 9 (Roby 1974).

Grass is the prime constituent of the elk's diet, but forbs and shrubs are important seasonally. To some extent, elk compete with domestic livestock for forage. The scattered timber and rough topography areas offer only marginal cover for elk in the study area. Relative isolation and lack of human activity in the ranges of these small herds have allowed them to establish and maintain their numbers.

Other mammals

Predators and furbearers

The coyote, red fox, and bobcat range over most of the study area. Both sheep predation and high fur prices have placed heavy pressure recently on these animals and many hundreds are taken annually. However, accurate data on population, harvest, and density figures do not exist.

Coyotes predation is one of the many agents acting to "check" rabbit and rodent populations. They also take some sheep. Fluctuation in numbers can be correlated with rabbit and rodent populations despite heavy mortality inflicted by humans. Generally, coyotes have little effect on deer and antelope populations. Some increased antelope predation takes place in localized areas of heavy sheeptight fencing.

Bobcats prefer rough areas such as the Powder River breaks, Rochelle Hills, and Pine Ridge. Drainage bottoms and drywashes such as tributaries of the Little Powder, Belle Fourche, and Cheyenne Rivers are also typical habitat. The bobcat hunts mostly by stalking small mammals; rabbits and small rodents are the diet mainstay (Thomas 1971, pp. 80-81).

Red fox numbers are increasing. Although not a threatening factor, the red fox is an important predator on sage grouse and other birds in the area. They are highly dependent upon rabbits, mice and ground squirrels and, at times, large numbers of insects. The badger is widespread and feeds primarily on burrowing rodents such as ground squirrels, prairie dogs, and pocket gophers. The gray fox probably occurs in the study area in small numbers, but no detailed population information is available. Other predators include the long tailed weasel, widely distributed through the study area, and the mink, found primarily along the stream courses. Striped and spotted skunks and raccoons are also common along the stream bottom areas and lowlands. Mink, skunks, and raccoons have a more varied diet, preferring more aquatic and semiaquatic animals.

The black-footed ferret, another predator, is discussed in the "Threatened species" section.

Muskrat and beaver inhabit the ponds, streams, lakes, and marshes of the study area. Beaver occur only in scattered populations. These species must have riparian vegetation and water bodies to survive. There is some harvest but it is generally light in this part of Wyoming.

Rabbits and hares

The cottontail rabbit is classified as small game in Wyoming, and hunting is becoming increasingly popular. Two species of cottontail inhabit the study area. The mountain cottontail is found in forested areas, and the desert cottontail inhabits open desert and prairie. More than 17,000 cottontails were harvested in or near the study area in 1972 (Table 29) (Wyoming Game and Fish Department 1973b). Broken topography, rocks, and dry washes along with sagebrush, yucca, and other shrubs provide the cottontail with important protection from predators and harsh winter conditions. Sagebrush, rabbitbrush, snakeweed, and saltbush provide the bulk of winter feed while a wide variety of other species are used throughout the balance of the year. Recent limited surveys indicate cottontail population densities ranging from 41 to 254 per square mile (Ecology Consultants Incorporated 1974, p. 115).

The white-tailed jackrabbit is cyclicly abundant throughout the area, while the black-tailed jackrabbit occurs primarily in the southeast part of the

Table 29

Upland Game and Waterfowl Harvest Data (1972)

Harvest Location	Sage Grouse	Chukar & Hungarian Partridge	Sharptail Grouse	Wild Turkey	Cottontail Rabbits	Waterfowl*
Campbell County	235	--	21	--	5,051	812
Converse County	656	15	--	--	4,557	3,075
Johnson County**	424	215	171	--	3,682	1,111
Niobrara County**	--	--	--	--	1,026	--
Sheridan County**	417	902	1,409	--	1,167	1,566
Weston County**	172	--	197	--	2,274	252
Carlisle (Turkey area)	--	--	--	78	--	--
Converse-Niobrara (Turkey Area)	--	--	--	16	--	--
TOTAL	1,904	1,132	1,798	94	17,757	6,816

*Includes ducks and geese.
** Only portions of these counties fall within the area influenced by the subject coal development.

Source:
George J. Wrakestraw, Richard Saul and Leonard Serdiuk, Migratory Bird Survey, Game Division Spot Report (Cheyenne: Wyoming Game and Fish Department, June 1973).

Joe J. Nemick, Wild Turkey Population Studies, Game Division Spot Report, District VII, (Cheyenne: Wyoming Game and Fish Department, June 1973), pp. 7, 50.

study area. The jackrabbit is widely hunted in Wyoming for its hide, used in glove manufacture, and its meat, fed to captive carnivorous furbearers. Food preferences are similar to those of cottontail. Density calculations for jackrabbits from the studies referred to in the preceding paragraph range from 61 to 144 per square mile.

Rodents, bats, and shrews

Richardson's and thirteen-lined ground squirrels are common throughout most of the study area. They feed heavily on weedy, green vegetation, forb seeds and insects. They are among the first and most numerous animals found in disturbed areas where forbs become established.

Black-tailed prairie dog colonies are widespread in grassland areas having suitable soils. Some colonies are large and provide potential black-footed ferret habitat. While prairie dogs eat a wide variety of plants in the vicinity of their burrows, the bulk of their diet is grasses such as western wheatgrass and blue grama. White-tailed prairie dogs may be found in the south-west corner of the study area in smaller, less close-knit colonies.

In areas of rougher topography, rocky ledges and deeply cut washes, the bushy-tailed wood rat, deer mouse and least chipmunk are common. Porcupines are found in pinyon-juniper areas. The deer mouse and least chipmunk are most abundant in the sagebrush type. Other small mammals of the sagebrush grasslands include the Ord kangaroo rat, sagebrush vole, Wyoming pocket mouse, northern grasshopper mouse, western harvest mouse, and prairie vole. More widely distributed are the northern pocket gopher, meadow vole, meadow jumping mouse, and wherever people are, the house mouse. Bats in the study area include the little brown bat, small-footed and long legged myotis, little longeared bat, big brown bat, hoary bat, and the silver-haired bat. The vagrant shrew, wandering shrew and Merriam shrew probably occur in the study area.

The abundance and variety of small mammals is very important to resident mammalian predators and to resident and wintering raptorial birds. The results of limited live trapping studies on three sites within the study area, described as scattered sagebrush, are shown as examples of population densities of these species at various times (Ecology Consultants Incorporated 1974, pp. 84-87).

Species	Densities	Period	Area
Thirteen-lined ground squirrel	13.3 per 10 acres	6/73	Rochelle Mine Area
	.47 per 10 acres	8/74	" " "
Deer Mouse	17.8 per 10 acres	6/73	" " "
	22.3 per 10 acres	8/73	" " "
Ords Kangaroo Rat	19.0 per 10 acres	9/73	Northern Plant Site
Deer Mouse	28.0 per 10 acres	9/73	" " "
Deer Mouse	49.0 per 10 acres	9/73	Southern Plant Site

Upland game birds

Sage grouse

Sage grouse are generally distributed throughout the study area wherever sagebrush types occur. This bird is extremely dependent upon sagebrush for food and cover. Critical to their needs are strutting grounds, nesting and brooding areas and winter concentration areas. Specific water sources and wet-meadow sites are crucial habitat elements. Much habitat has been lost through sagebrush eradication, intensified farming, oil field development and livestock grazing. Hunting pressure and harvest has been light owing to closure of the large amount of private land, limited local hunting, sparse human population and remoteness from larger population centers. Detailed population, distribution and critical data are scarce since this area has received less intensive "area wide" average inventory attention for the above reasons. The sage grouse habitat supports populations estimated at five to eight birds per square mile (Nemick 1974, Williams 1974). This density is considered "medium."

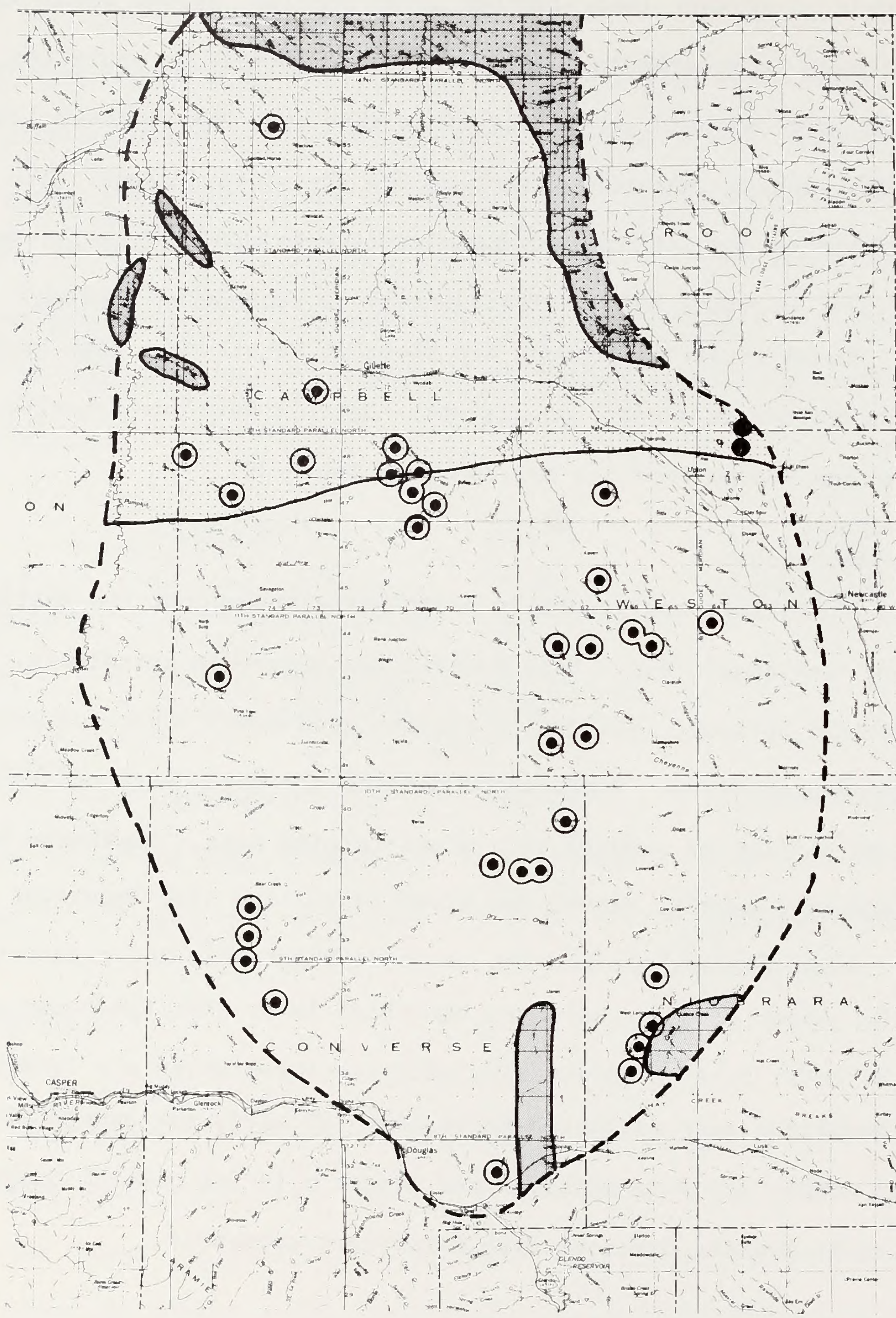
Known strutting grounds are shown in Figure 64. Sage grouse winter range information is almost nonexistent. Harvest data for Converse, Campbell, Niobrara, and Weston Counties are shown in Table 29.

Sharp-tailed grouse

Sharptails are generally distributed throughout the northern half of the basin (see Figure 64). They inhabit the sagebrush grasslands, often near brushy stream bottoms. Sharptails require good brush cover for nesting and early brood protection. Wheat seeds make up the major part of the sharptail diet based on limited studies on a wheat farming area. Hawthorne berries, willow buds, dandelion leaves, clover and grass leaves are also important (Nemick 1972, p. 17). Known dancing grounds are shown in Figure 64, and recent harvest in Table 29. About 1,800 grouse were harvested in or near the study area in 1972. Although "total area" comprehensive detailed inventories are lacking, sharptail grouse densities were estimated to be 14 to 20 birds per square mile in northern Campbell County and 8 to 12 birds per square mile for central Campbell County (received in Wyoming Game and Fish Department comments).

Hungarian and chukar partridge

Chukar populations are limited to rough arid lands, and only a few select habitat areas are considered more than marginal for this species. Since 1940, thousands of chukars have been released within the study area, but only a few huntable populations persist. Detailed inventories have not been warranted. Hungarian partridge occupy widely diversified habitat types. These



Legend

Turkey

Sharptail Grouse

● Sharptail Dancing Ground

⊙ Sage Grouse Strutting Ground

Source: Map Compiled with Information Provided by the Wyoming Game and Fish Department

Figure 64
Wild Turkey and Sharptail Grouse Distribution and Known Sharptail Dancing Grounds and Sage Grouse Strutting Grounds in the Vicinity of the Study Area.

birds have been observed in sagebrush-grassland, but the greatest populations exist in areas of interspersed agricultural lands, grasslands, weeds and brushy patches (Wyoming Game and Fish Department 1972b, p. 19). The "hun" feeds mostly on wheat and various weed seeds. The Hungarian and chukar partridge harvest which totals over 1,100 birds taken is shown combined in Table 29. Population or density estimates for these birds are not available.

Wild turkey

Wild turkey populations are established in several locations around the edge of the study area (Figure 64). Off-shoots of the Black Hills turkey populations are found in northern Campbell County and Western Crook County. Turkeys are also found in the Powder River breaks and in the Cheyenne River drainage of Converse and Niobrara Counties. Birds are hunted in or along the edges of the study area in the Carlile hunting area and in the Converse-Niobrara hunting area. The 1971 spring harvest in the Converse-Niobrara Area and spring and fall harvests in the Carlile Area are shown in Table 29. Hunters took 94 turkeys in 1972. Turkeys require trees, usually ponderosa pine, for roosting. Food habitat studies (over 100 birds) in the Black Hills indicats fall diets were made up predominately of cultivated grains. Acorns, fruits, pine nuts and various berries comprise almost one-third of the diet, and grass leaves and grasshoppers were present in significant quantities (Nemick 1973, p. 79). Certain populations are not hunted. The total turkey population of the portion of Converse County in the study area is estimated to be 300 birds. Low moisture is a major habitat limiting factor.

Mourning dove

Mourning doves nest in most of eastern Wyoming with the exception of heavily timbered areas. Highest densities occur in areas with interspersed trees and open lands such as along the wooded stream bottoms. Doves nest most successfully in trees although they also nest on the ground in clumps of brush in otherwise open areas. Nesting cover is enhanced by open perches in the area. Several studies indicate that doves are seed eaters taking about 70 percent weed and forb seeds and 30 percent grass seeds and grain when available (Bureau of Land Management 1970, p. 6). Doves occupy all but the most arid areas of the basin. Good habitat depends on water being within the daily cruising radius. The majority migrate south for the winter. Doves were recently classified as game birds in Wyoming, and the legal hunting season reopened in 1973. No detailed information on doves is available for the study area.

Waterfowl

The study area is part of the Central Flyway. In spring and fall, hundreds of thousands of ducks and thousands of geese and sandhill cranes migrate through the area. In addition, some ducks and geese winter at open waters in the area. Large numbers of mallards and green-winged teal, goldeneye, and mergansers winter on the ice-free waters of the North Platte River downstream from Glenrock. In 1972 hunters harvested almost 7,000 ducks in the counties of the study area. This is only a small portion of those produced annually (Table 29). Keyhole Reservoir in the southwest corner of Crook County is an important spring and fall migration stop for large numbers of waterfowl. Almost all water areas in the basin are attractive to various species of waterfowl.

The thousands of stock ponds and small reservoirs throughout the study area are most significant in providing waterfowl production habitat. Over half of the breeding ducks are mallards and American widgeon. Other duck species nesting in large numbers include gadwall, green-winged teal, bluewinged teal, pintail, and shoveler. Other nesting ducks include redhead, lesser scaup, ring-necked duck, goldeneye, bufflehead, ruddy duck, and common mergansers. Scaup, canvasback, cinnamon teal, American Merganser, and, occasionally, wood ducks migrate through the area. Ducks nest on almost all small water bodies and large streams and rivers, but the best breeding habitat is supplied by ponds and marshes that hold water throughout the year. Temporary shallow ponds are used for feeding, courting, and breeding and nesting areas in the spring. The best brood ponds are more than an acre in size and contain scattered emergent plants such as cattails and bullrushes. Puddle ducks nest on dry land where sufficient vegetation exists to provide cover requirements. Most nests are within 100 yards of water but some may be a mile or more away. Diving ducks nest along the shore or over the water among emergent plants. Mallards usually comprise more than half of the study area harvest.

Canada geese breed and winter in the study area. Small numbers of snow geese migrate through in spring and fall. Some wintering geese concentrate on the North Platte River downstream from Glenrock where the river does not freeze over. Few geese are harvested annually; they are included with ducks under "waterfowl" in Table 29. Goose hunting in northeastern Wyoming is currently regulated with the objective of building up the population of resident birds. Small numbers of geese nest on the many stock ponds and small reservoirs now, and these are largely progeny of transplanted goslings.

From 80,000 to 100,000 sandhill cranes migrate south through the eastern half of the study area annually. Keyhole Reservoir serves as a resting area for those large birds. Whooping cranes, an endangered species, are not known to overfly northeastern Wyoming.

Small numbers of whistling swans fly south each fall through the center of the study area.

<u>Other birds</u>

Raptors

In 1973 an estimated 600 bald, 9,000 golden, and 900 unidentified eagles were wintering in the state. Almost the entire study area is excellent eagle wintering habitat (Wrakestraw 1972, pp. 1-7). Usually, golden eagles are widespread, while bald eagles are more concentrated along rivers. Abundance of prey species such as small mammals which do not hibernate largely determine eagle concentration. Nesting densities of both eagle species is low. Golden eagles nest in many areas, while only a few bald eagles nest along the North Platte River. Other birds of prey inhabiting the study area include the marsh hawk, red-tailed hawk, Swainson's hawk, rough-legged hawk, sharp-shinned hawk, kestrel, great horned owl, and short-eared owl. Less common are the Cooper's hawk, prairie pigeon hawk, western burrowing owl and long-eared owl. Occasionally observed are the peregrine falcon and prairie falcon. The turkey vulture is a common summer resident.

The falcons, hawks, owls, and eagles make almost no direct use of plants in their diets. Yet, plants are vitally important to local and regional distributions of these birds because the flora controls prey habitat. Trees provide nesting sites for the majority of birds of prey. Shrubs often provide cover and nesting sites for Swainson's hawk and marsh hawk. In open country, utility poles, fence posts and other more or less isolated structures provide important perches for nesting and hunting raptors. These are often well used along transportation routes where traffic-killed small animals make an attractive ready-made food source. The abandoned burrows of badgers and prairie dogs are used as nesting sites and escape cover for burrowing owls. Raptors, like other predatious animals, play their part in the overall predator-prey-relationships, acting as one of the regulating influences on prey populations.

Shore birds and song birds

The many stock ponds, reservoirs, and rivers provide acres of shoreline and riverbank nesting and feeding habitat necessary for continued existence of shore birds. Great blue herons, gulls, grebes, coots, snipe, lesser yellow-legs, willets, avocets, terns, upland sandpipers, killdeer, and northern long-billed curlews all nest in the study area. These species migrate through the area in spring and fall. The various vegetative types provide habitat for a surprising variety of song birds. Most are migratory, leaving during the winter. Seed-eating birds such as the horned lark, vesper sparrow, lark bunting, Savannah sparrow, and McCowns longspur are common, as are largely insectivorous birds such as the western meadowlark, loggerhead shrike, and mountain bluebird. Aerial insectivores such as bank swallows and common nighthawks are often abundant, soaring above the open lands. Western kingbirds, various warblers, goldfinches and robins are usually found in the riparian vegetation, but sage thrashers, Brewer's sparrows, and green-tailed towhees prefer the shrub types. There is little information concerning the densities, distribution, and limiting factors of these species in the study area. (Results of a recent plot census are given in Table 30.) (Ecology Consultants Incorporated 1974, p.143.)

Table 30

Numbers and Relative Abundance of Birds in Three Habitats, June 1973

	Species	Number Observed On 22 June	23 June	24 June	Total	Relative Abundance	Mean Number Per Day
Plot 1 (scattered sagebrush)	Brewer's sparrow	22	9	27	58	39.5	19.3
	Lark bunting	12	11	15	38	25.8	12.7
	Horned lark	13	13	10	36	24.5	12.0
	Vesper sparrow	1	6	2	9	6.1	3.0
	Western meadowlark	1	2	3	6	4.1	2.0
	Total	49	41	57	147	100.0	
Plot 4 (heavy sage-brush)	Brewer's sparrow	27	20	23	70	38.2	23.3
	Lark bunting	23	4	17	44	24.1	14.6
	Western meadowlark	17	9	12	38	20.8	12.6
	Horned lark	6	5	6	17	9.3	5.6
	Vesper sparrow	4	5	5	14	7.6	4.6
	Total	77	43	63	183	100.0	
Plot 3 (grassland)	Horned lark	19	10	17	46	36.8	15.3
	Lark bunting	12	8	14	34	27.2	11.3
	Western meadowlark	11	5	13	29	23.2	9.7
	Brewer's sparrow	4	1	3	8	6.4	2.6
	Vesper sparrow	1	1	1	3	2.4	1.0
	Mallard	1	1	1	3	2.4	1.0
	Grasshopper sparrow	--	1	1	2	1.6	0.3
	Total	48	27	50	125	100.0	

Source: Ecology Consultants Incorporated, "Sampling Locations, Methods, and Tabular Results of a Biological Inventory on the Proposed Rochelle Mine and Coal Gasification Plant Sites," March 1974, p. 143.

Fish

The Powder River Basin encompasses a variety of fish habitats, many of which are small flowing streams and intermittent small tributaries. In addition, a large number of stock-watering ponds and reservoirs scattered throughout the study area contain several fish species.

Major drainages deserving consideration are the Belle Fourche, Cheyenne, Little Missouri, Little Powder and the Powder River proper. The lack of suitable aquatic habitat is the major factor limiting fish populations. For this reason, any impounded waters ranging upwards from one acre to the almost 9,000-acre Keyhole Reservoir, are important fish habitats (Wyoming Game and Fish Department 1966, p. 43).

Irrigation demands and return flows often cause fluctuations, increased siltation, and elevated water temperatures in streams, making them unsuitable for trout habitat. A large percentage of existing aquatic habitat is classed as warm-water. Numerous tributaries, streams, and reservoirs do provide cold water environments.

Fishing pressure is light throughout most of the study area. Although numerous small stock ponds and reservoirs in the basin are lightly fished, collectively they are significant by supporting many days of fishing annually. The exact number of producing ponds is not known.

A list of known or suspected fish species residing in the study area is found in Table 32, Appendix C. It should be noted that no threatened or endangered species of fish (as listed in the 1973 edition "Threatened Wildlife of the United States," U.S.D.I., B.S.F. & W.) are thought to occur in the study area. Several species presently found in the "Wyoming List of Rare & Endangered Wildlife" do occur. Refer to page I-345. The following descriptions are primarily adapted from Fisheries Technical Report No. 15, Wyoming Game and Fish Department, March 1966).

Belle Fourche River drainage

A majority of the drainage area of 3,700 square miles is used for grazing of livestock. Crops below Keyhole Reservoir are usually irrigated with water from the Belle Fourche River. Most streams in the Belle Fourche River drainage are not suitable for trout; many are intermittent or flow very little water, and high water temperatures and insufficient habitat become controlling factors. Approximately 54 farm ponds have been stocked with trout, and about 108 ponds have been planted with largemouth bass. Many contain green sunfish or bullheads through illegal transplants. Walleye pike and channel catfish are found in the Belle Fourche River and Keyhole Reservoir.

Cheyenne River drainage

Two streams in this drainage support reproducing trout populations, and two others provide habitat for planted trout on a small scale. Black bullheads and green sunfish are present in some streams which are unsuitable for trout. Numerous stock ponds and stock-water reservoirs support fish populations.

Little Missouri River drainage

Small reservoirs to impound stock water and water for irrigation are abundant in this drainage and, along with the Little Missouri proper, provide the bulk of fish habitat.

Little Powder River drainage

Flowing water in the drainage is restricted to the Little Powder River proper with no permanent flowing water in tributary streams. Fish habitat is present throughout the length of Little Powder River and in some of the many small stock-water reservoirs in the area.

Powder River drainage

The main Powder River does not contain a significant fishery. Flow variations are extreme, ranging from high, turbid runoff in the spring to practically a drystream bed in late summer months.

Nongame species include the flathead chub; carp; goldeye; northern redhorse; white, longnose and mountain suckers; fathead minnow; longnose dace; sturgeon chub; river carpsucker; plains minnow and silvery minnow. Stonecats, black bullheads and channel catfish are present where habitat is adequate and the shovelnose sturgeon, classified as rare in the State of Wyoming, has been found in the Powder River proper.

Selected individual habitats

The following better known individual habitats are representative of those which may be directly affected by industry proposals. Numbers assigned correspond to locations plotted on Map No. 11, Appendix A.

Belle Fourche drainage

Belle Fourche River (1). Habitat below Keyhole Reservoir varies from holes over six feet deep to shallow riffle areas. Presence of beaver dams is not reliable; shelter ranges from poor to good and food conditions are classified as poor. Nongame fish dominate fish populations in the Belle Fourche River above and below Keyhole Reservoir. The most important game fish is the channel catfish. Others include walleye pike, bullheads, green sunfish, stonecats and smallmouth bass.

Variations of flow are extreme above Keyhole Reservoir. Waters directly below the reservoir contain populations of walleye pike and channel catfish as well as bullheads, green sunfish, and smallmouth bass.

Keyhole Reservoir (2). Game fish include rainbow trout, walleye pike, channel catfish, smallmouth bass, yellow perch, green sunfish, bullheads, and northern pike. Nongame species are carp, river carp sucker, northern redhorse sucker, white sucker, fathead chub, flathead minnow, sand shiner and possibly, the silvery minnow. With the exception of walleye pike, rainbow trout, northern pike, and smallmouth bass, all of the above mentioned species were present in the drainage at the time of impoundment.

Many feel that this reservoir, with about 9,000 surface acres, represents the major singular aquatic habitat in the Powder River Basin.

Gillette Fishing Lake (3). The Wyoming Game and Fish Department purchased this site in 1957, and the 25-surface-acre reservoir is designated as a public fishing area. This deed was turned over to the City of Gillette in 1968. About 90 percent of the lake is in shoal area less than 15 feet deep. Aquatic vegetation is abundant and algal blooms are frequent.

About 6,500 catchable rainbow trout are planted annually to maintain the heavily used fishery.

Cheyenne River drainage

South Fork Cheyenne River (4). This stream is intermittent throughout its course in Wyoming. Black bullheads and green sunfish inhabit isolated holes and some flowing tributaries but are considered to be unimportant as a sport fishery.

Old Woman Creek (5). Several large spring holes at the extreme headwaters provide limited habitat for trout. Flowing water between spring holes is too small to allow natural reproduction.

Little Missouri River drainage

North Fork Little Missouri River (6). This is a small stream providing limited habitat for fish. Summer flows are small, but deep holes hold water and provide limited year-round habitat. Game fish present may include channel catfish, black bullheads, and green sunfish.

Little Powder River drainage

Little Powder River (7). Planted brook and rainbow trout survive in the upper headwaters. The headwaters of this stream have not been planted since 1960. Since flows are small and habitat is limited, game fish populations are generally restricted. Sections of the stream are periodically dewatered with fish habitat being confined to large holes along the streambed. Summer water temperatures restrict trout in all but a short section influenced by headwater springs. The lower section of the Little Powder, particularly near the state line, contains channel catfish, black bullheads, and green sunfish.

Although natural reproduction does not occur, numerous plants of brook and rainbow trout have allowed the maintenance of short-term salmonoid fisheries. While no tributary of the Little Powder provides a particularly significant fishery, permanent water is available in several of the draws. Game fish species present are generally limited to green sunfish and black bullheads.

Other ponds in the drainage contain populations of large mouth bass, green sunfish, and black bullheads.

Reptiles and amphibians

Quantitative information relating to these animals in the study area appears nonexistent, but resident species include the prairie rattlesnake, the bull (gopher) snake, milk snake, plains garter snake, eastern short-horned lizard, and others. Amphibians are, of course, tied to aquatic environments for at least part of their lives. The plains spadefoot toad, Great Plains toad, leopard frog, and tiger salamander are fairly common in good habitat. Other reptiles and amphibians of the study area are listed in Table 30, Appendix C.

Invertebrates

Invertebrates, especially insects, are present in variety and abundance during the warm months and are greatly reduced during winter. They are important because of their impacts on ecosystems, especially in food chains, and as primary consumers of vegetation. Insects rank as one of the three major groups of herbivores. Certain species prey on others and some feed on dead organic matter. Some mollusks, snails, aquatic insects, and worms are major food sources for fish, shore birds, amphibians, and mammals. Many animals such as the shrews, nighthawks, eastern short-horned lizard, little brown bat, grasshopper mouse, and mountain bluebird are almost wholly insectivorous. Others, such as skunks and burrowing owls make insects a major part of their diets. Sometimes insect populations such as grasshoppers can rise to plague proportions. Wyoming Game and Fish Department (1966, pp. 64,65) studies recorded the major groups of invertebrates valuable as fish foods in the Belle Fourche and Little Powder Rivers. These were mayflies, stoneflies, caddisflies, two-winged flies (Diptera), and beetles. Invertebrate studies on one of the coal lease areas in northern Campbell County indicated that total individual insect numbers sampled by sweep net and pit trap were about 20 percent less in heavy sagebrush as compared to grasslands, but most of this difference was made up by the large numbers of springtails (Collembola) found in the grassland (Ecology Consultants Incorporated 1974, pp. 159-165). There were wide differences in the families of insects represented and, in some cases, in the relative abundance within families between the two vegetative types. Grasshoppers were more abundant in the grassland samples, while plant bugs, leaf hoppers, and aphids were more abundant in the sagebrush type.

Threatened Species

Those wildlife species determined by the Secretary of the Interior to be threatened with extinction and named on a list published in the Federal Register are officially "endangered species." The species categorized as "threatened" in the Bureau of Sport Fisheries and Wildlife's 1973 publication, Threatened Wildlife of the United States (1973, p. 289), include all vertebrate species whose existence is considered threatened whether they are officially listed as "endangered" or not. The following species, threatened with extinction, inhabit the study area.

The black-footed ferret was observed once in Crook County in 1969, once in Weston County in 1971, and once in Campbell County in 1974. Exact locations were not reported by the observers. Other sightings of the black-footed ferret have been verified. Ferrets are closely associated with prairie dogs and prairie dog towns since the prairie dog is their major food source.

The spotted bat may occur in the study area, but little is known of this rare species.

The prairie falcon frequents the area. The American peregrine falcon is commonly observed to the north in Montana and probably frequents the study area.

Status-undetermined species include the northern swift fox, which may occur in the area, and the ferruginous hawk, prairie pigeon hawk, mountain plover, northern long-billed curlew, and western burrowing owl which are uncommon but regular inhabitants of the area.

Some species, while not endangered throughout their range, have remnant populations in danger of being eliminated in local areas. This has prompted state development of "rare and endangered" species lists (Wyoming Game and Fish Department (no date), pp. 1-28). Wyoming's list includes such species as the shovelnose sturgeon, goldeye, sturgeon chub, kit fox, western burrowing owl, upland sandpiper, and western smooth green snake which may occur within the study area.

Recreation Resources

Zoological

Hunting

The Powder River Basin and its peripheral mountain ranges and hills provide some of the best variety of big game and upland game in Wyoming. The big game hunting resource also ranks with national significance. In 1973 over 29,000 hunters hunted deer within the basin (74 percent nonresident), representing 78,000 hunter days. Nearly 67 percent of the antelope hunters (13,612) were nonresidents (Wyoming Game and Fish Department), representing 30,000 hunter days (Table 31).

Mule deer, elk, and antelope are the most plentiful and sought after big game in the region. These animals can be hunted within a few hours of any community in the basin. Ranges of these species are shown on Maps 9 and 10, Appendix A.

In 1973, more than half (19,504) of the antelope harvested in Wyoming were taken within the basin. Antelope hunter success rates averaged 95 percent. Wyoming's antelope represent over 50 percent of the world's population.

The principal upland game species of northeastern Wyoming are sage grouse, wild turkey, sharp-tail grouse, ring-necked pheasant, and cottontail rabbit. However, the number of upland game hunters is low in the portions of Campbell and Converse Counties within the study area, primarily because of poor public access to private lands where these species are frequently found.

In 1972, Wyoming hunters (8,111) harvested 85,000 ducks which is only a small portion of those produced in the state annually. Twenty-one percent of the harvest occurred in the region (Wyoming Game and Fish Department 1973b). Some of the larger streams such as the North Platte, Tongue River, and portions of Sand Creek in Crook County provide some fine waterfowl hunting in the late season. Many stock ponds, small reservoirs and small mountain lakes, dispersed throughout the region provide excellent spring and summer waterfowl production.

Table 31
Hunter Use - 1973

Principal Management Units
Study Area

Antelope Unit	Hunters	Deer Unit	Hunters
(17) NW of Gillette	1,439	(17) NW of Gillette	1,757
(19) NE of Gillette	961	(18) NE of Gillette	3,343
(23) SW of Gillette	1,779	(20) West of State 59	430
(24) SE of Gillette	886	(21) East of State 59 (Coal leases)	1,122
(26) West of Bill	1,910	(22) West of State 59 NW of Douglas	2,052
(27) East of Bill	1,700	(14) East of State 59 Between Bill and Douglas	1,298
(28) West of Douglas	480		
(29) East of Douglas	301		
Total	9,456		10,002

Source: Wyo
Source: Wyoming Game and Fish Department, Annual Report of Big Game Harvest,

Fishing

Sport fishing in the region, representing 1.3 million visitor days, occurs mostly on larger reservoirs (see recreation regional map, Figure 66). The attraction of good warm and cold water fisheries, good public access and the opportunity to combine fishing with other recreation such as boating and picnicking account for this use. The shortage of trout streams in the basin and poorer public access to streams makes the larger reservoirs more attractive. Low land reservoirs account for up to three-fourths of the fishing pressure in the basin, with Keyhole Reservoir, Lake DeSmet and North Platte River impoundments the centers of use. Fishermen from Colorado and Utah bring added pressure to the North Platte River Reservoir system. Good reservoir fishing also will be found on the Bighorn and Tongue River Reservoirs near Sheridan. Fishing in 1970 within the region described here represents approximately 870,000 fisherman days of which 175,000 nonresidents participated (Wyoming Recreation Commission 1973).

(Photo Courtesy of Wyoming Travel Commission)

Figure 65
Fishing on the North Platte River

Many small mountain streams and reservoirs can be fished in the Black Hills, Bighorn and Laramie Mountains. Two proposals for new reservoirs are presently being analyzed near the Laramie and Bighorn mountain ranges; however, no recreation reserves have been planned for those reservoirs at this time. For an inventory of fishing waters in the region refer to Table 32. Regions 2 and 3 are state recreation planning regions which encompass the region described in the statement.

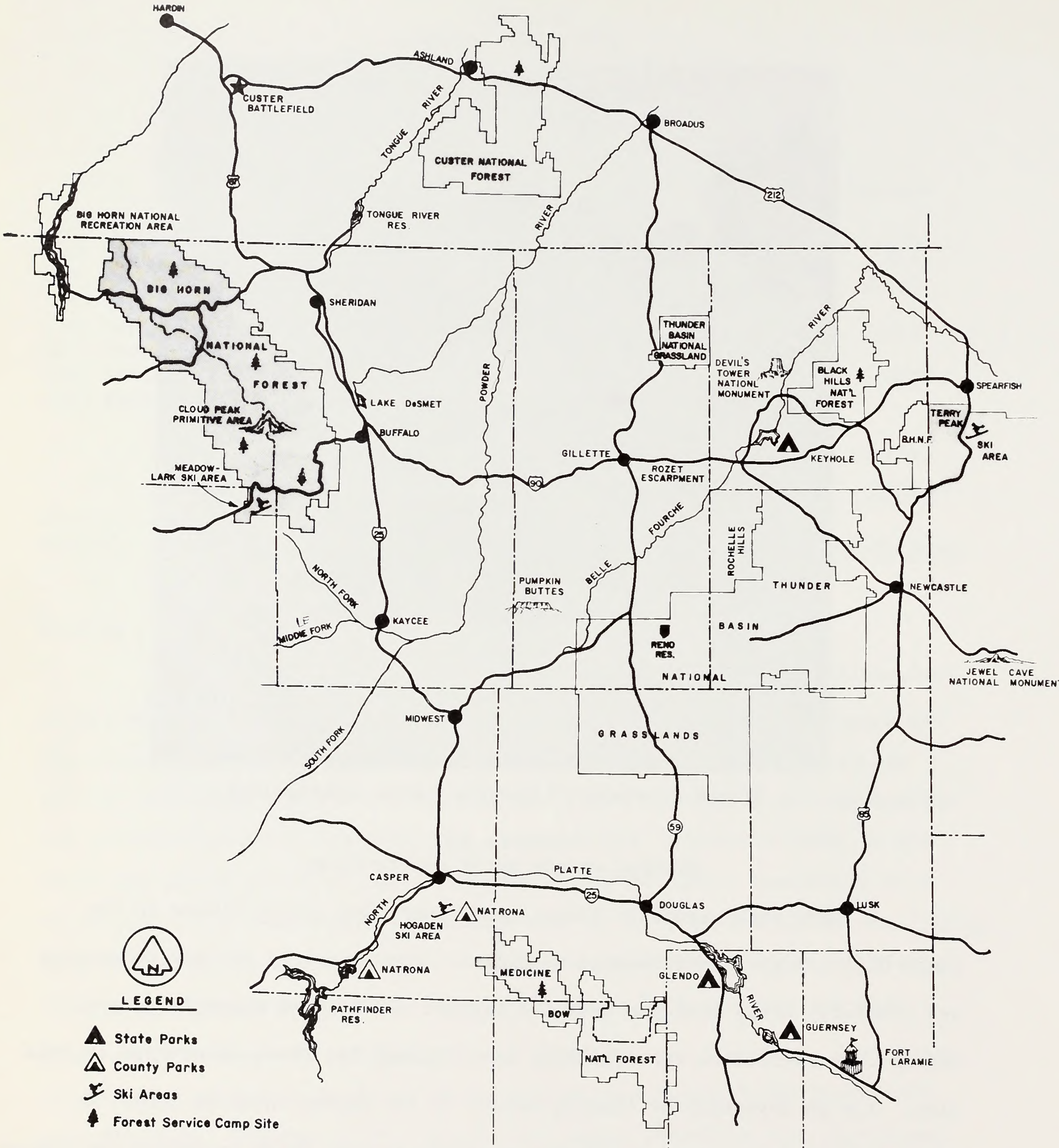


Figure 66
Recreation Regional Map

Region	Cold Water Fish Total maximum acres or total minimum miles	Warm Water Fish Total maximum acres or total minimum miles	Mixed Fish* Total maximum acres or total minimum miles	Region	Cold Water Fish Total maximum acres or total minimum miles	Warm Water Fish Total maximum acres or total minimum miles	Mixed Fish Total maximum acres or total minimum miles
Region 2				Region 3			
Lakes				Lakes			
Alpine	00	00	00	Alpine	853.80	00	00
Lowland	00	00	00	Lowland	00	00	00
Reservoirs				Reservoirs			
Alpine	00	00	00	Alpine	1,305.00	00	352.70
Lowland	10,375.10	51.00	20.00	Lowland	513.50	309.10	9,822.40
Ponds	75.20	17.70	2.00	Ponds	274.20	123.20	14.00
Total Acres	10,450.30	68.70	22.00	Total Acres	2,946.50	432.30	10,189.10
Streams				Streams			
Class 1	00	00	00	Class 1	00	00	5.80
Class 2	30.50	00	00	Class 2	82.00	00	5.20
Class 3	201.20	00	65.20	Class 3	454.50	00	145.80
Class 4	290.10	00	00	Class 4	153.00	00	340.60
Class 5	55.70	00	00	Class 5	71.70	159.00	280.30
Total Miles	577.50	00	65.20	Total Miles	761.20	159.00	777.70

*Contains both a cold and warm water fisherv.

Source: Wyoming Recreation Commission, Wyoming Statewide Comprehensive Outdoor Recreation Plan, (1973).

Table 32

Inventory of Lakes, Reservoirs, Ponds and Streams in Which Fishing is Available, by Region

Sightseeing

State Highway 59 and U.S. Highway 14-16 along with county roads in the basin provide good antelope and small upland game viewing for the traveler.

Mountain areas of the National Forests provide the most exotic opportunities during the summer along off-highway truck trails and footpaths. Large open parks in the timber, the most outstanding characteristics of the Bighorn Mountains and Black Hills, provide the sightseer more chance of viewing deer, elk, and an occasional moose.

A prairie dog town has been protected for the enjoyment of the many visitors of Devils Tower National Monument. Interpretive displays and naturalist presentations aid the visitor's enjoyment.

The Wyoming Game and Fish Department has trout and walleye fish trapping facilites at Lake DeSmet and Keyhole Reservoir and elk wintering pastures in the Bighorn Mountains that collectively provide opportunities to view game and fish management programs.

Grazing buffalo can frequently be observed on a private ranch south of Gillette on State Highway 59.

Wintering eagles frequent the area between Casper and Douglas. In 1973, 600 bald, 9,000 golden and 900 unidentified eagles were estimated wintering in the state. These great birds together with migrating and nesting waterfowl seen on farm ponds provide local birdwatchers good viewing. Resident sightseeing in the region represents 7.6 million visitor days annually (Wyoming Recreation Commission 1973).

Geological

Sightseeing

The Powder River Basin and the region surrounding it possess considerable geological resources of recreational value. In the Black Hills, 100 miles from Gillette, the Jewel and Wind Caves (National Park Service) under-

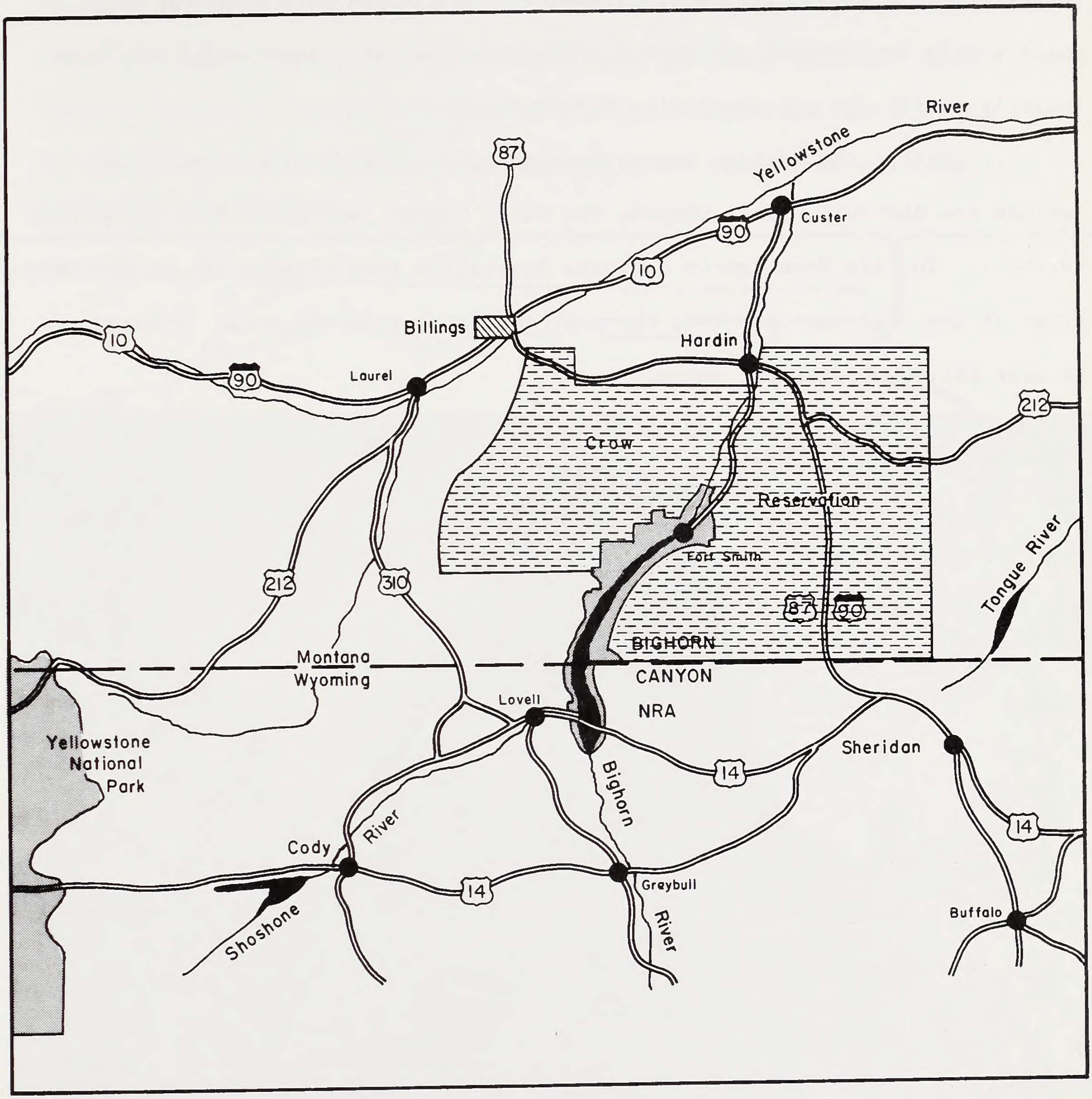
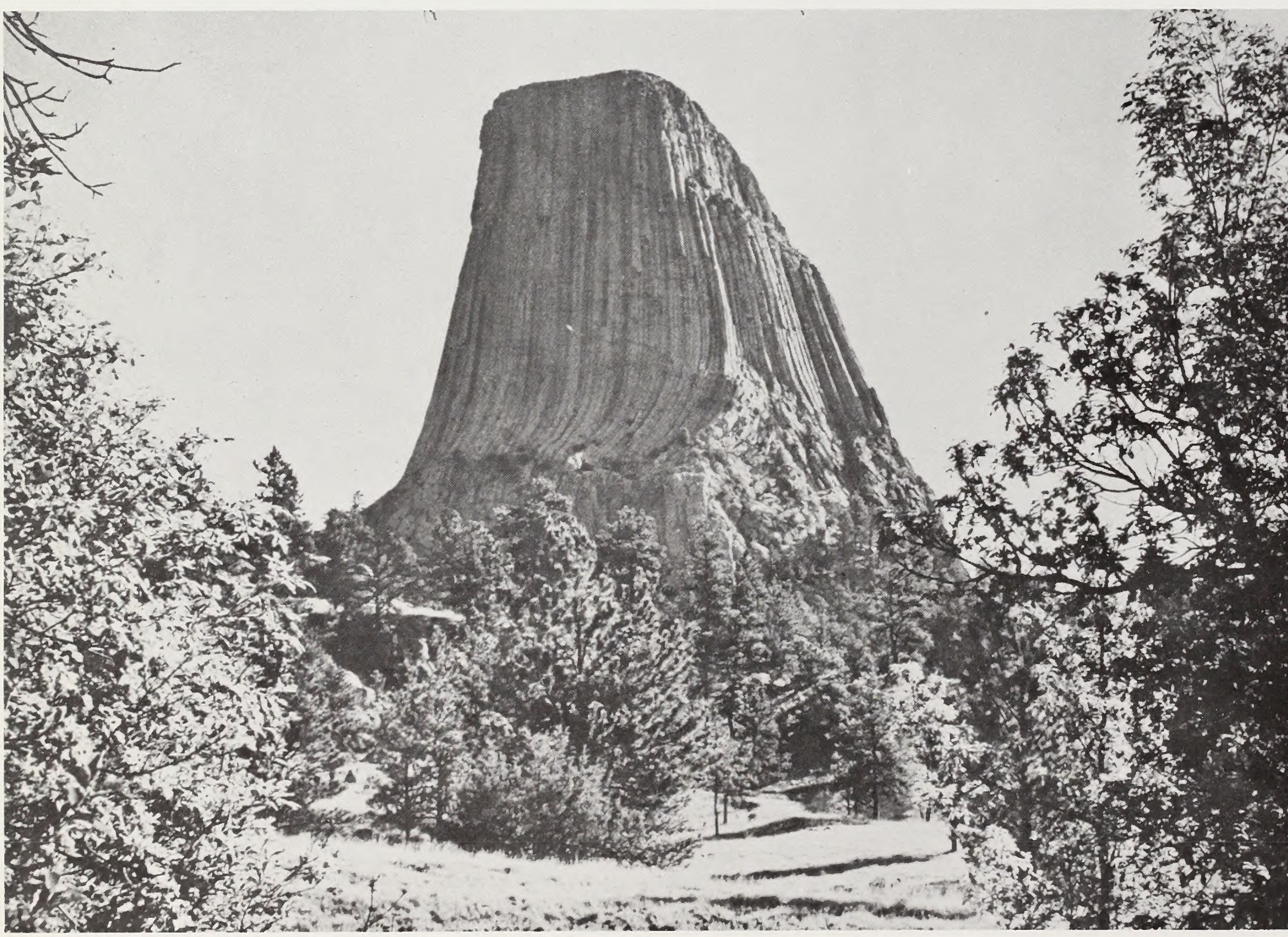


Figure 68

Bighorn Canyon National Recreation Area.

ground caverns of calcite crystals and dripstone stalagtites; erosional formations in Custer State Park; Harney Peak; and Inyan Kara Mountain are collectively outstanding geological sightseeing values. Jewel and Wind Caves register nearly one million visits per annum.

Within the Bighorn Mountains, geological sightseeing attractions include the Red Wall, Shell Canyon, Ten Sleep Canyon, and Cloud Peak (elevation 13,165'). The Big Horn Canyon National Recreation Area (Figure 68) on the west slope of the Bighorns is one of the most spectacular in the area. Present use is near 161,800 visits per annum.



(Photo Courtesy of Wyoming Travel Commission)

Figure 69
Devils Tower

On the periphery of Powder River Basin are Devils Tower National Monument (Figures 69 & 70) and six potential natural landmarks, Pumpkin Buttes, Rozet Escarpment, Missouri Buttes, Inyan Kara Mountain, Hat Creek Breaks and Sundance Mountain. These features and the red cinder cones and coalbeds near Gillette provide spectacular evidence of alluvial deposition and erosional history of the region.

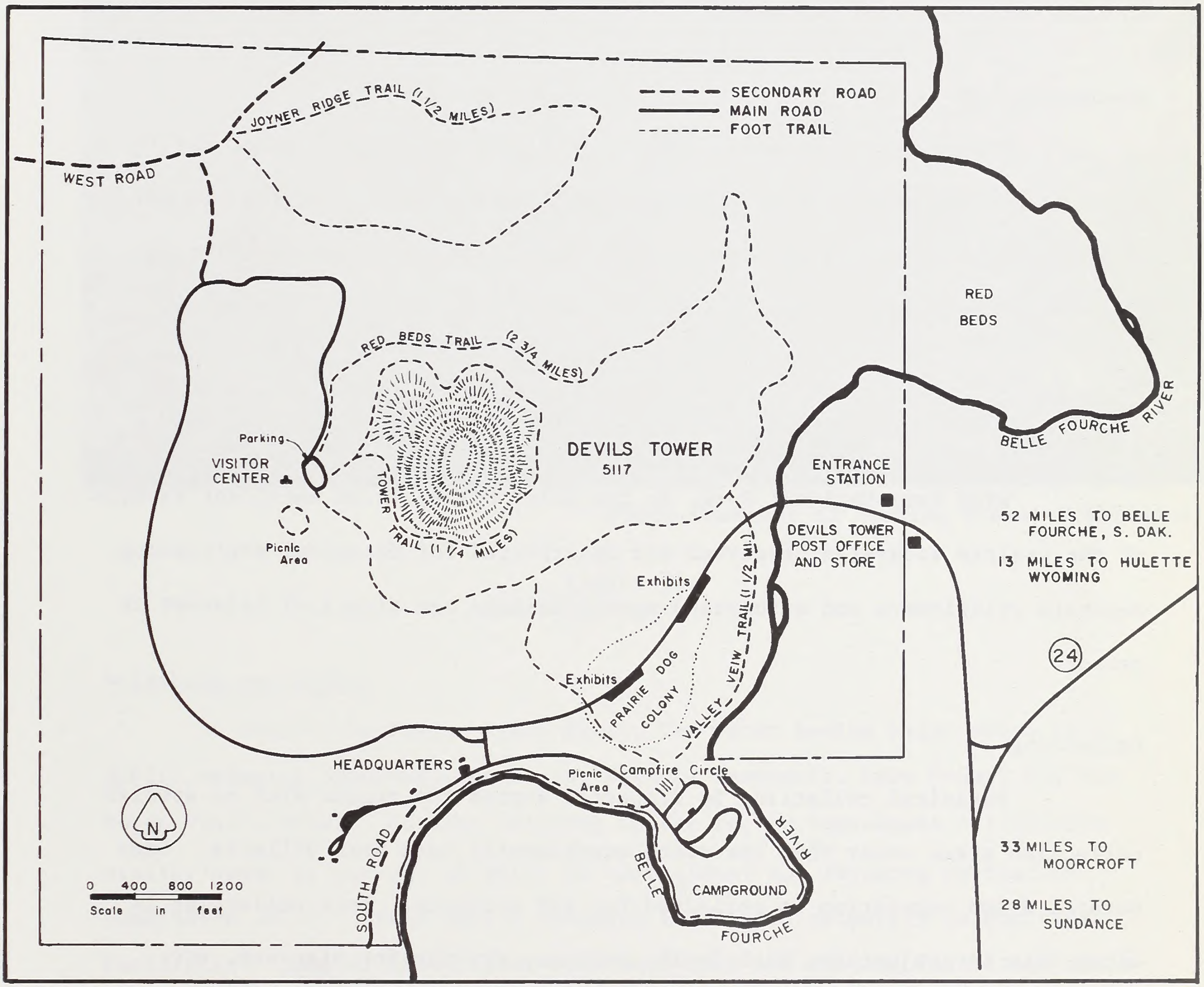


Figure 70
Devils Tower National Monument

Collecting

Gem and mineral collecting is popular all across the basin, Black Hills and Bighorn Mountains; however, few areas possess significant value. One exception is Tepee Canyon, 21 miles east of Newcastle on U.S. Highway 16. Tepee Canyon agate is a much sought after gem of nationwide renown. Other valuables include petrified wood and quartz.

Mountaineering

The central portions of the Black Hills, the Laramie Range and the Bighorns provide some mountain climbing challenges. Devils Tower possesses mountaineering values of nationwide significance and receives comparatively heavy use. Total use of Devils Tower is nearly 173,700 visits per annum.

Botanical

Sightseeing

Wind Cave National Park, in the Black Hills, is an excellent example of the prairie ecosystem preserved and interpreted for botanical sightseeing. Mountain wildflowers and autumn and spring foliage are always of interest in season.

Collecting

Botanical collecting is dispersed across the region with no special collection areas other than the state experimental farm near Gillette. Some natural dried vegetation is collected for art projects. This collecting is often done in conjunction with family outings, driving for pleasure, etc.

(Photo Courtesy of Wyoming Travel Commission)

Figure 71
Keyhole Reservoir

Waterbase recreation

Within the Powder River Basin, few water bodies exist which offer public swimming opportunities except Keyhole Reservoir, Lake DeSmet and the North Platte River. Outdoor swimming in the region represents 4.3 million visitor days, 16 percent of which is nonresident use (Wyoming Recreation Commission 1973). Other public swimming is limited primarily to municipal facilities. Some of these reservoirs have boat and camping facilities administered by the Wyoming Recreation Commission. Keyhole, Glendo, Alcova and Guernsey Reservoirs offer good water skiing when the water levels are kept to a compatible level.

(Photo Courtesy of Wyoming Travel Commission)

Figure 72
Cook Lake

(Photo Courtesy of Wyoming Travel Commission)

Figure 73
Floating Alcova Reservoir

These areas are also popular boating reservoirs, but more important in boating for pleasure (sightseeing) is the Bighorn Canyon National Recreation Area near Sheridan with its 71 mile lake. Good float boating exists along portions of the North Platte and Tongue Rivers and Cook Lake.

Tongue River is being considered as a possible addition to the National Wild and Scenic Rivers system.

Figure 74
Skiing Bighorn Mountains

Winter recreation

Downhill skiing at developed commercial facilities within the region is confined to Meadowlark Ski Area west of Buffalo and Antelope Buttes west of Sheridan in the Bighorn Mountains, Hogadon Ski Area near Casper on Casper Mountain, and Terry Peak northeast of Newcastle in the Black Hills. Cross-country skiing in the Bighorn Mountains, Laramie Mountains, and Black Hills provides many good opportunities accessible from all-weather highways. Downhill skiing by residents in the basin represents 708,000 visitor days (Wyoming Recreation Commission 1973).

(Photo Courtsey of Wyoming Travel Commission)

Figure 75
Snowmobiling Bighorn Mountains

Primary areas of enjoyment for snowmobiling are the Bighorn Mountains, Black Hills and Laramie Range in that order. All-weather highways, land ownership, snow conditions and terrain influence the quality of the snowmobiler's experience in these areas. Resident snowmobiling represents 481,370 visitor days. In 1970, 13.8 percent of the population participated in the sport (Wyoming Recreation Commission 1973).

Most winter sports areas for basin residents (Douglas and Gillette) are within 100 miles.

(Photo Courtesy of Wyoming Travel Commission)

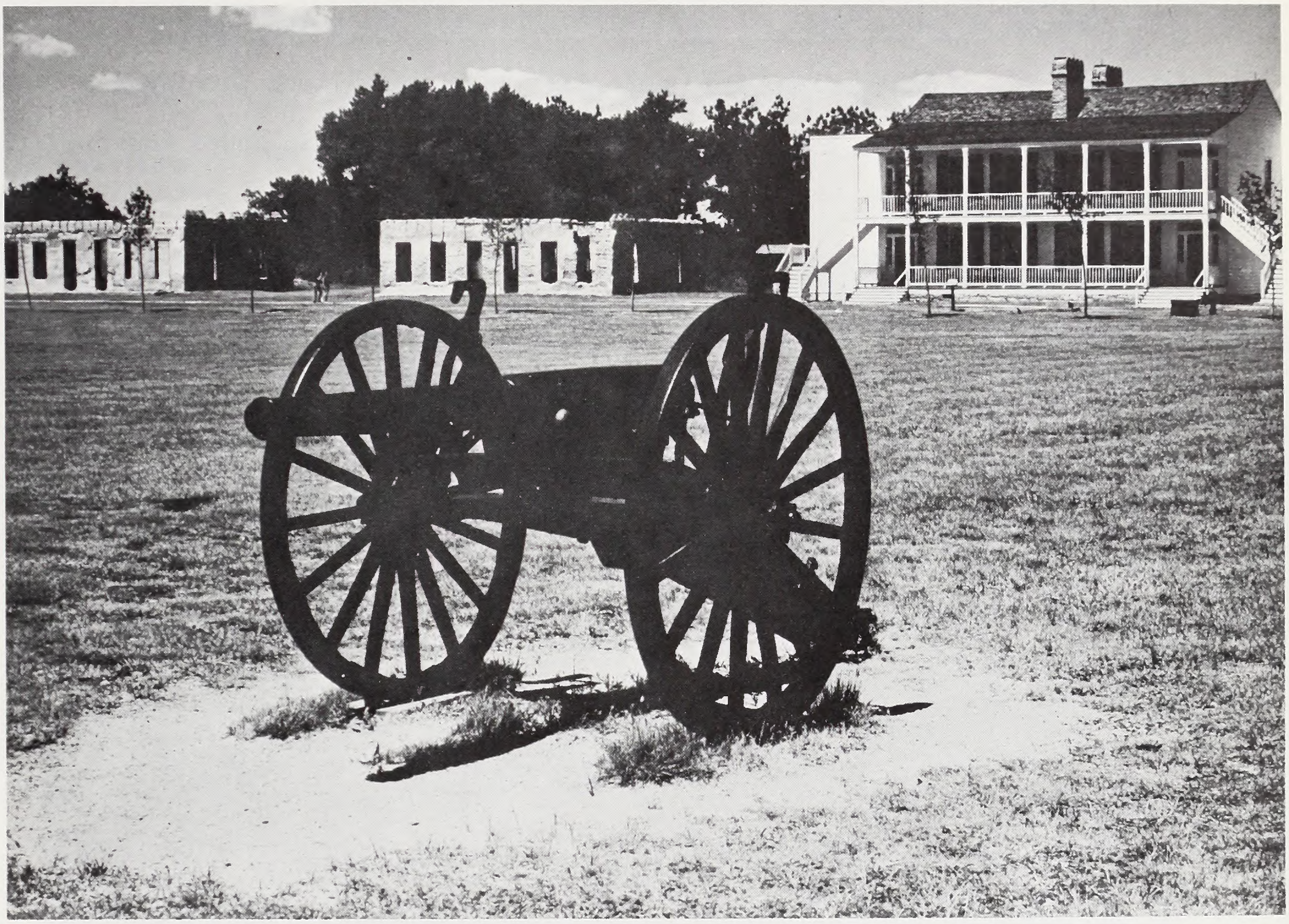
Figure 76
Cloud Peak Primitive Area

Primitive

The Cloud Peak Primitive Area, the only designated wild area in the region, is now being considered for wilderness designation (137,000 acres). It is located along the hydrographic divide of the Bighorn Mountains west of Buffalo and Sheridan. Some of the principal uses of the area are hiking, horseback riding, fishing, and tent camping. Total annual use for the area has been near 57,000 visitor days. Congress will consider a 150,490- and 282,000-acre proposal for enlarging the Cloud Peak Wilderness Area.

An area of 10,420 acres (Laramie Peak) has been chosen for study as a wilderness candidate area. Citizen groups have recommended 26,800 acres. Approximately 17 roadless areas have been inventoried in the Medicine Bow and Bighorn National Forests.

The North Fork of the Powder River Canyon is being studied for possible designation as a primitive area. This area lies northwest of Kaycee on the east slope of the Bighorn Mountains.



(Photo Courtesy of Wyoming Travel Commission)

Figure 77
Fort Laramie

History

Visitor interpretive sites have been developed by federal, state and local agencies and groups, providing good opportunities within the region for understanding a period of rich history along the Oregon and Bozeman Trails. More detail on these sites is included in the Historical Values section of this chapter.

Some of the interpretive sites, each listed on the National Register of Historic Places are Fort Laramie, Fort Fetterman, Fort Caspar, Register Cliff, Fort Phil Kearny, Trail End, Sheridan Inn, Custer Battlefield.

Because of the many historical sites, largely along the southern and western boundaries of the region, more interpretive sites will be developed. Figure 45 of the section on historical values in this chapter includes locations of other historic sites.

Figure 78
Petroglyphs, Powder River Basin

Archeological

Some significant archeological sites like the "Medicine Wheel" in the Bighorn Mountains and other areas under study provide unusual opportunities for cultural sightseeing. However, most sites are either inaccessible or unprotected from vandalism. Some like the Glenrock Buffalo Jump (National Register of Historic Places) are generally known but not interpreted for the visitor.

(Photo Courtesy of Wyoming Travel Commission)

Figure 79
Camping, North Platte River

Other cultural

Camping - picnicking

Picnic use in the region is estimated at 3.8 million visitor days. Camping, with 8.6 million visitor days, is greater because 50 percent of this use is made by nonresidents staying in the region for longer periods (Wyoming Recreation Commission 1973). Except for municipal facilities, recreation developments within the basin are minimal. Keyhole Reservoir, a state park, 35 miles from Gillette has day-use and camping. Devils Tower National Monument approximately 61 miles from Gillette has similar facilities. Glendo and Guernsey State Parks approximately 35-70 miles from Douglas have camping and picnicking units.

Most camping and picnicking are confined to the cooler mountain areas of the National Forests (Bighorn, Black Hills, Custer and Medicine Bow).

Urban

Table 33 summarizes an inventory of municipal parks and playgrounds which includes 14 swimming pools.

An active program of community recreation is being provided for youth and adults of Gillette and Douglas. Outdoor parks, golf courses, swimming pools and camp-picnic areas are well supplied in both communities for summer enjoyment. There are modern facilities in both cities currently under construction for year-round use. The facilities include a new high school pool, handball court and auditorium in Douglas and a community recreation complex with indoor pool in Gillette.

Adult and youth development programs are provided year-round in both cities. These community programs include, for example, trade and crafts, swimming, wrestling, basketball, cross-country skiing in Gillette under the direction of a full-time county recreation director. Both counties have a recreation board.

From reports in Douglas, facilities are adequately planned to support expected population growth to approximately 1985. In Gillette the present recreation program is up to standard in almost every aspect and exceeds the standards (National Recreation and Park Association) in many areas. The future holds the need for rapid and costly expansion. The needs will double by 1980 and quadruple by 1990. These figures are based on the Comprehensive Plan and DEPAD (Campbell County Recreation Study 1974).

Private

Table 34 summarizes an inventory of privately managed recreation land and water in the region. Most of the private enterprises are involved in guiding, leasing, or dude ranching for hunting, fishing, and camping.

County	Number of Parks and Playgrounds	Acres	Open Grass play Areas	Trees and/or Shrubs	Rest Rooms	Playground Equipment	Baseball or Softball	Tennis Courts	Ice Skating
Converse	5	63	4	5	5	5	4		1
Natrona	50	378	37	42	31	37	6	4	
Niobrara	5	18	4	4	4	2		1	1
Campbell	11	130	4	4	9	8	7	4	1
Crook	3	5	1	1	2	2	1		1
Johnson	4	55	4	4	4	2	2	1	1
Sheridan	12	26	2	2	10	10	2	2	
Weston	5	70	4	4	4	4	1	1	1
Total	95	745	60	67	69	70	23	13	6

Source: Wyoming Recreation Commission, Wyoming Statewide Comprehensive Outdoor Recreation Plan (1973).

Table 33

Inventory of Municipal Parks and Playgrounds
by Planning Regions and Counties

Table 34

Private Lands Managed for Recreation in Northeast Wyoming Counties

	Land Acres	Water Acres
Campbell	1,131,737	
Converse	230,361	389
Crook	99,621	
Johnson	1,430,533	2,130
Natrona	78,800	124
Niobrara	1,505	
Sheridan	45,971	100
Weston	390,255	41
Total	3,408,783	2,784

Other recreation

In Appendix C are listed present (1970) and estimated use (1990) of other recreational interests within the region. These tables provided by the the Wyoming Recreation Commission (1973) combine both resident and out-of-state visits. Also in Appendix C can be found a comprehensive recreation inventory for each county in the recreation region and the planned future development within the two recreation planning regions in Wyoming.

Agriculture

Livestock grazing

Production of range beef cattle and sheep is the predominant agriculture land use within the study area. An estimated 94 percent of the land within Campbell and Converse Counties is used as pastureland. The 1969 Census of Agriculture indicates that 793 ranch operations are present within the two county area. The average ranch is 7,276 acres and carries approximately 262 animal units.[1] Most ranch units are reasonably well contained in a contiguous ownership pattern. A few ranches in western Campbell County move sheep and cattle from winter range to summer range ranch holdings located in the southern Bighorn Mountains. Based on federal grazing lease statistics, 59 percent are cattle operations, 14 percent are sheep operations, 25 percent both sheep and cattle and the remaining 2 percent are ranches and farms with dairy cattle, horse or buffalo operations.

Other average statistics of ranches in Campbell and Converse Counties are contained in Table 35.

[1] Animal Unit - Year round support for one cow and calf or five sheep.

Table 35

Average Statistics of Ranches in Campbell and Converse Counties

Statistical Item	Campbell County	Converse County
Total land area (acres)	3,034,614	2,653,284
Total land in ranches (acres)	3,069,561	2,557,645
% Ranch land to total land*	100.9	93.3
Number of ranches	479	314
Avg. size of ranches (acres)	6,408	8,145
Cropland (acres)	65,073	41,307
Irrigated lands (acres)	2,480	40,920
Woodland (acres)	7,633	40,477

*Percentage may exceed 100 percent because of acreage assignment problems where individual ranch units cross county boundaries.

Source: University of Wyoming, College of Commerce and Industry, Division of Business and Economic Research, Wyoming Data Book 1972, (Laramie: University of Wyoming).

As of January 1972, statistics indicated the following livestock numbers within Campbell and Converse Counties.

Table 36

Livestock Numbers
Campbell and Converse Counties, January 1973

	Campbell County	Converse County	Total
Cattle & Calves	84,600	82,600	167,200
Sheep & Lambs	121,100	119,100	240,200

Source: Wyoming Crop and Livestock Reporting Service.

The number of livestock on the area in any one year is dependent on market and/or forage conditions. Cattle and calf numbers were as low as 61,200 in 1950 for Campbell County and 48,600 in 1961 and 1962 in Converse

County (Olson, Morgan, Marquardt 1971, Vol. 2). Sheep numbers have been on the decline in recent years. Numbers recorded were 303,700 head of sheep in 1964 for the two county area (Olson, Morgan, Marquardt 1971, Vol. 2). Many livestock operations have been shifting from sheep to cattle in recent years for economic reasons. Other classes of livestock contribute little to total production within the study area.

Native vegetation provides the majority of the livestock forage. Major forage species are blue grama grass, western wheatgrass, needle grasses, blue grasses, June grass and numerous forbs. Sagebrush, by far the most common shrubby forage species, is utilized primarily by sheep. Crested wheatgrass, the principal introduced forage plant, is planted extensively on abandoned farmland sites. Detailed information on plant association is located in the Vegetation section of this chapter.

Most of the hay is produced on irrigated meadows along the North Platte River and, to a lesser extent, on dryland farms in Campbell County. Both alfalfa and grass hay are grown, but alfalfa is predominant on the irrigated meadows. Hay production is not sufficient to provide the total winter forage requirements. For this reason Campbell and Converse Counties are classified as a feed deficit area wherein feed must be imported annually. According to the 1969 Census of Agriculture, ranches in Campbell and Converse Counties purchased approximately $2,110,000 worth of livestock feed. Most operations rely on native range to winter livestock. Imported protein and vitamins are used to supplement the locally grown hay and native forage. In many cases, hay is saved and used only during critical winter periods as prices in the market reach premium levels. Winter forage is therefore a critical limiting factor to the livestock industry within the study area.

The principal range improvements are fences and watering facilities. Other facilities include ranch headquarters, corrals, access roads, trails, feeders, etc. Livestock water improvements are important because little natural water exists in the basin. Use of existing streams is limited and most are intermittent. Water improvements are mainly reservoirs, wells, and to a lesser extent, scattered springs.

The average range conditions and average recommended stocking rates for Campbell and Converse Counties are shown in the following tables.

Table 37

Estimated Range Conditions
Range Site Categories for Campbell and Converse Counties

County	Range Site Categories	Approx. Land Area (acres)	Range Conditions Percent of Area Excellent	Good	Fair	Poor
Campbell	Shallow Sites	913,200	25%	40%	33%	2%
	Sandy, loamy, clayey	1,674,100	20%	35%	40%	5%
	Overflow and lowlands	152,200	25%	35%	35%	5%
	Other	304,400	---	---	---	---
Converse	Shallow sites	822,300	25%	35%	38%	2%
	Sandy, loamy, clayey	1,507,600	20%	30%	45%	5%
	Overflow and lowlands	137,100	25%	35%	35%	5%
	Other	274,100	---	---	---	---

Source: USDA, Soil Conservation Service, unpublished data.

Table 38

Average Stocking Rates for Campbell and Converse Counties by Precipitation Zone, Range Site Categories, and Range Condition Class

15" - 17" precipitation zone Northern Campbell County	Recommended Stocking rates Acres/Animal Unit Month* by Range Condition Class			
	Excellent	Good	Fair	Poor
Shallow sites	3.5	4.3	10.0	14.3
Sandy, loamy, clayey	2.2	2.7	4.3	10.0
Overflow and lowlands	.8	.9	1.6	1.7
10" - 14" precipitation zone Southern Campbell County and Converse County				
Shallow sites	5.5	6.7	12.5	25.0
Sandy, loamy, clayey	2.8	3.4	5.6	11.1
Overflow and lowlands	.8	1.0	1.7	2.9

*Animal Unit Month - forage requirements to sustain one cow and calf or five sheep for one month.

Source: USDA, Soil Conservation Service, "Technician Guide to Range Site and Range Condition with Initial Stocking Rate: Northern Plains."

The area north of Gillette receives greater amounts of annual precipitation than the southern portions of the study area. Livestock forage production in this area is, therefore, generally greater. Based on the range condition classes and range site categories an average stocking rate can be estimated. The estimated average stocking rate for Northern Campbell County in the 15" - 17" precipitation zone is 4.3 acres/AUM. The southern portions of the study area in the 10" - 14" precipitation zone average 6.5 acres/AUM.

From this basis a total of 831,923 AUM's of average annual livestock forage is assumed available. Regional difference in vegetation production and climate influence the type and class of livestock operations. Cattle operations predominate in the northern part of the study area while sheep are more common in the south.

Federal land used for grazing within the study area is managed by either the BLM or Forest Service. The following table gives the Federal ownership for Converse and Campbell Counties by federal agency.

Table 39

Acres of Federal Grazing Lands
by County and Agency

	Campbell County	Converse County	Total
Bureau of Land Management	223,318	127,905	351,223
U.S. Forest Service (Thunder Basin Grasslands)	158,005	185,708	343,713
Total	381,323	313,613	694,936

The federal lands under BLM grazing management are under ten-year renewable leases to contiguous ranches. These lands are located in a fragmented ownership pattern and are usually fenced and used in conjunction with the adjoining private lands. (See Map 1, Appendix A for major ownership status.) A total of 309 leases on approximately 351,000 acres are currently held within Campbell and Converse Counties.

The Forest Service managed grazing lands are located within the Thunder Basin National Grasslands. Grazing use on the grasslands is authorized through Thunder Basin, Spring Creek and Inyan Kara grazing associations which issue 219 annual grazing permits for use of 343,713 acres.

Farming

The Powder River Basin is not noted for extensive farming activities. Hay and forage are the major crops raised within the study area because of livestock industry needs and prevailing climatic conditions. Most farming is conducted by livestock operations, and hay is used locally to provide yearlong livestock feed requirements.

The primary farming practice in Campbell County is dryland farming due to lack of irrigation water. The annual precipitation rate allows reasonable success. Irrigated farmlands are primarily limited to Converse County. The number of acres under irrigated crop production has been rising gradually over the years but is limited by water. Dryland farming acreages change from year to year, reflecting market fluctuations, adverse weather conditions, and governmental programs.

The last four decades have shown a wide variability in amount of dryland farming, crop yields and failures. During Wyoming's early homesteading era from 1920 to 1930, large acreages of semiarid lands were being tilled. The final chapter of homestead development was written in dust storms and ruined land when droughts descended on the area. Many of these lands were reaquired by the Federal Government under the National Industrial Recovery Act of 1933, Emergency Relief Act of 1935, and Bankhead Jones Act of 1937. Most of these lands are currently included in the Thunder Basin National Grasslands.

Total dryland cropland has decreased over the years as submarginal lands were retired from cultivation where the land proved to be more valuable and suitable for livestock grazing. During the past two years, some of these lands have again been placed into crop production in response to recent changes of government farm programs and rises in grain prices.

Methods of increasing yields or insuring the success of dryland crops are a function of soil management. Summer fallowing is practiced to reduce the probability of crop failure. Strip farming is practiced or entire fields are fallowed every other year to increase and conserve soil moisture.

Table 40

Average Nonirrigated Crop
Production 1950-1968
For Campbell and Converse Counties

	Campbell County	Converse County
Wheat		
Avg. Acres Harvested Annually	24,708	4,553
Avg. Yield Per Acre (Bushels)	18.6*	15.3*
Avg. Annual Total Production (Bushels)	459,089	69,563
Barley		
Avg. Acres Harvested Annually	3,014	960
Avg. Yield Per Acre (Bushels)	10.4	16.9
Avg. Annual Total Production (Bushels)	31,184	16,221
Oats		
Avg. Acres Harvested Annually	5,631	1,176
Avg. Yield Per Acre (Bushels)	21.7	18.5
Avg. Annual Total Production (Bushels)	122,289	21,784
Corn		
Avg. Acres Harvested Annually	44	225
Avg. Yield Per Acre (Bushels)	12.9	11.9
Avg. Annual Total Production	567	2,677
Hay**		
Avg. Acres Harvested Annually	41,720	7,135
Avg. Yield Per Acre (Tons)	0.78	0.76
Avg. Annual Total Production (Tons)	33,225	5,400

* Average acres harvested annually and average annual total production does not necessarily correspond to average yield per acre as these averages were derived independently. Chart does not reflect the variance between years of high or low total production due to the number of acres being farmed.

** Data available 1959-1968.

Source: Olson, et al, Wyoming Agriculture: Past, Present and Future, an Economic Sector Study.

Table 41

Average Irrigated Crop Production 1950-1968
For Campbell and Converse Counties

	Campbell County	Converse County
Wheat		
Avg. Acres Harvested Annually		407
Avg. Yield Per Acre (Bushels)	Negligible	21.2*
Avg. Annual Total Production (Bushels)		8,631
Barley		
Avg. Acres Harvested Annually		1,423
Avg. Yield Per Acre (Bushels)	Negligible	35.8
Avg. Annual Total Production (Bushels)		50,894
Oats		
Avg. Acres Harvested Annually		1,671
Avg. Yield Per Acre (Bushels)	Negligible	38.3
Avg. Annual Total Production (Bushels)		64,015
Corn		
Avg. Acres Harvested Annually	---	161
Avg. Yield Per Acre (Bushels)	---	34.8
Avg. Annual Total Production (Bushels)	---	5,600
Beans		
Avg. Acres Harvested Annually	---	507
Avg. Yield Per Acre (100 wt.)	---	13.0
Avg. Annual Total Production (100 wt.)	---	6,564
Sugar Beets		
Avg. Acres Harvested Annually	---	488
Avg. Yield Per Acre (Tons)	---	11.4
Avg. Annual Total Production (Tons)	---	5,568
Hay**		
Avg. Acres Harvested Annually	1,075	28,490
Avg. Yield Per Acre (Tons)	2.15*	1.62
Avg. Annual Total Production (Tons)	2,295	46,581

* Average acres harvested annually and average total production do not necessarily correspond to average yield per acre as these averages were derived independently and do not reflect the variance between years of high or low total production due to the number of acres being farmed.

** Data available 1959-1968.

Source: Olson, et al, Wyoming Agriculture: Past, Present and Future, an Economic Sector Study.

The most successful dryland farm areas are located in northern Campbell County, generally from Gillette and vicinity northward, where 14 to 17 inches of annual precipitation are received. Dryland farming southward through the study area has proven to be marginal to submarginal over an extended time period.

Campbell and Converse County average cropland acreages and production for a 19-year period from 1950 through 1968 are shown in Tables 40 and 41.

An average of 2,480 acres of cropland is annually irrigated Campbell County compared to 65,073 acres devoted to dryland farming. Cropland represents only 2.2 percent of the county land area of 3,043,840 acres. The major dryland crops have been hay, with a past average annual yield of approximately 33,225 tons from 41,700 acres, and wheat, which has been harvested on approximately 24,700 acres yielding 459,000 bushels. Minor acreages of oats, barley, and corn are harvested some years.

In Converse County, irrigated lands along the North Platte River amount to 41,370 acres, or 1.5 percent, of the county land area. Hay is the principal crop raised under irrigation and in the past has yielded an approximate average of 46,600 tons per year from 28,500 acres. A greater variety of crops is grown along the North Platte, and minor acreages of barley, oats, corn, beans, and sugar beets are harvested annually as cash crops or livestock feed. Average annual yields for these crops are contained in Table 41.

In addition to production of harvested crops, an unknown amount of irrigated pastureland is harvested by grazing and additional livestock forage is obtained by grazing hay meadows after harvest. Irrigated pastureland apparently accounts for a significant amount of the total irrigated acreage which is not accounted for in crop harvest statistics.

The main water supplies readily available within the Powder River Basin are the North Platte River and several streams that originate in the Bighorn Mountains and flow through the northwest corner of the basin. A comparatively limited supply is available from the Little Missouri, Belle Fourche, and Cheyenne Rivers located to the east of the basin.

The present major consumptive use of water within the Powder River Basin and adjoining areas is for cropland irrigation. Irrigated area and consumptive use data by stream system for northeastern Wyoming are contained in Table 42. The North Platte River system provides approximately 580,100 acre-feet to irrigate 527,900* acres of cropland (State Engineer's Office 1973). Based on this information, the average consumptive use of water per acre of irrigated cropland varies from 1.0 to 1.1 acre-feet/acre.

Demand for irrigation water exceeds the supply. It is estimated that water shortages are 72,480 acre-feet (State Engineer's Office 1973). Shortages for northeastern Wyoming are contained in the before mentioned Table 42.

*Includes irrigated lands in Carbon, Natrona, Converse, Laramie, Niobrara, Albany, Platte, and Goshen Counties.

Table 42

Irrigated Acreage, Estimated Consumptive Use of Irrigation Water, and Indicated Shortage to Consumptive Use in Northeastern Wyoming

Drainage System	Irrigated Acres		Acre-Feet of Consumptive Use		
	Total	With Short Supply	Ideal	Actual	Indicated Shortage
1. Tongue River	64,320	24,140	93,320	77,380	15,940
2. Clear Creek	35,320	20,980	55,220	37,110	15,110
3. Crazy Woman Creek	12,090	8,700	17,820	9,190	8,630
4. Powder River	18,900	9,950	28,860	21,240	7,620
5. Little Powder River	12,425	8,380	4,090	850	3,240
6. Little Missouri River	6,540	3,890	9,400	2,270	7,130
7. Belle Fourche River	7,760	5,190	7,200	2,920	4,280
8. Cheyenne River	3,230	2,070	17,920	7,390	10,530
Total	160,585	83,300	230,830	158,350	72,480

Source: Wyoming Water Planning Program, Water and Related Land Uses of Northeastern Wyoming, Wyoming Water Planning Report No. 10 (April 1972).

Transportation Networks

Existing transportation networks and facilities are described by modes; viz. highways, railroads, pipe and electric transmission lines, water transportation, airports, and commuting. To aid the description three maps are included which portray location of facilities plus a traffic flow chart of daily highway use.

Highways

The major federal, state and county highway transportation routes of the eight northeastern counties of Wyoming are shown on Figure 80. Two major interstate routes traverse this section. Interstate 25 runs in a north to south direction between Sheridan and Cheyenne, and Interstate 90 travels east/west between Sheridan and the South Dakota border. A portion of Interstate 25 remains uncompleted between Casper and Buffalo, and a portion of Interstate 90 remains uncompleted between Gillette and Moorcroft. This latter portion is scheduled for completion and opening for traffic during the later half of 1975. Figure 81, a traffic flow chart prepared by the Wyoming State Highway Department, illustrates the volume of traffic over major roads in this eight-county region. Traffic over State Highway 59 between Douglas and Reno Junction is presently a very light 380 to 400 vehicles per day as compared with 1,120 per day from Gillette to Reno Junction.

Railroads

The Burlington Northern railroad presently operates and maintains two east/west routes through this eight-county region. One passes through Sheridan, Gillette and Newcastle in the north and the other passes through Casper and Douglas. The latter is jointly operated by Burlington Northern

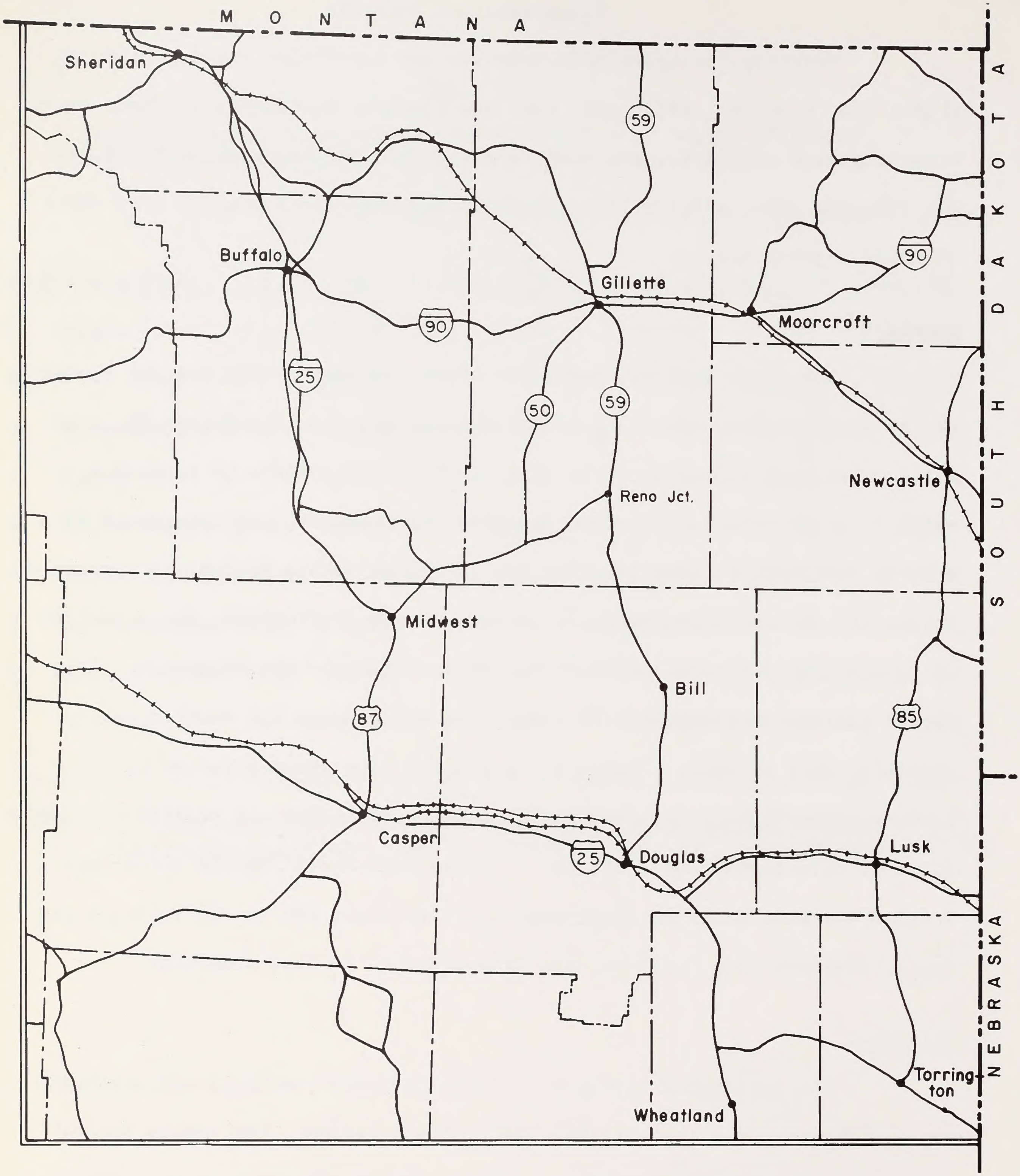


Figure 80
Eastern Powder River Coal Basin Area

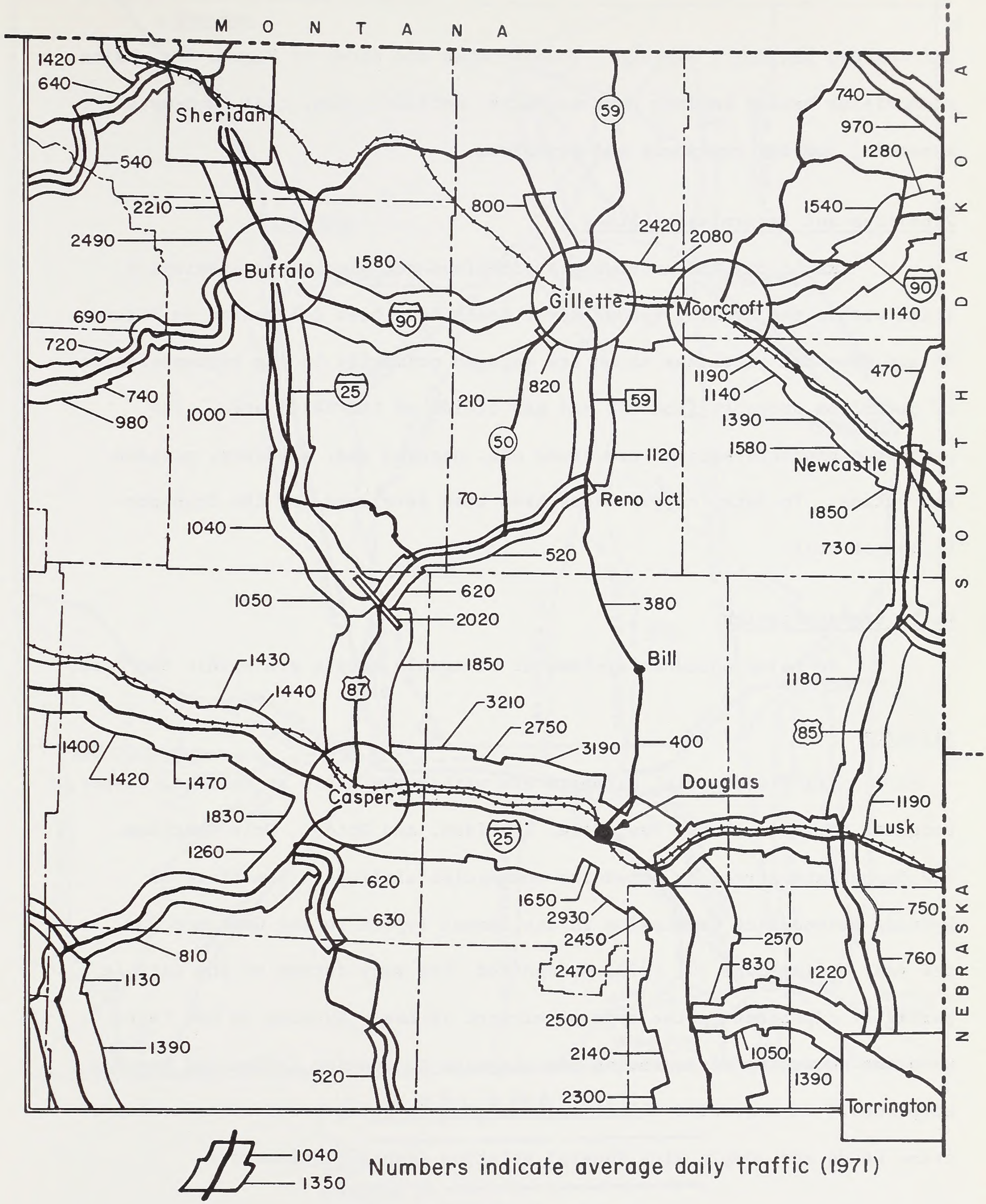


Figure 81
Traffic flow map.

and Chicago and North Western. These routes are shown on Figure 80. Major commodities hauled include farm products, metallic ores, coal, non-metallic minerals, lumber, chemicals and petroleum.

Pipelines and transmission lines

Major oil and natural gas pipelines and electric transmission lines within the Wyoming Powder River Basin have been delineated on Figures 82 and 83. The pipelines shown are engaged primarily in the transportation of petroleum products from oil and gas fields of the basin area. The petroleum products shipped are crude oil, natural gas, gasoline, propane and butane. To date, no pipelines have been developed for the transportation of coal.

Water transportation

No major aqueduct systems or navigable waters are within the area.

Airports

Eight commercial airports are within the basin at Buffalo, Casper, Douglas, Gillette, Lusk, Newcastle, Sheridan, and Upton. Only Sheridan and Casper are served by scheduled commercial airlines. The State of Wyoming Aeronautics Commission in its annual report to the Governor for the year ending June 30, 1973, recognized "The very future of any city is partially dependent on the type of airport it has. Wyoming is now faced with the necessity of improving its airports to receive faster and heavier airplanes." A statewide airport system plan is being prepared to evaluate these needs and comply with Federal Aviation Agency requirements.

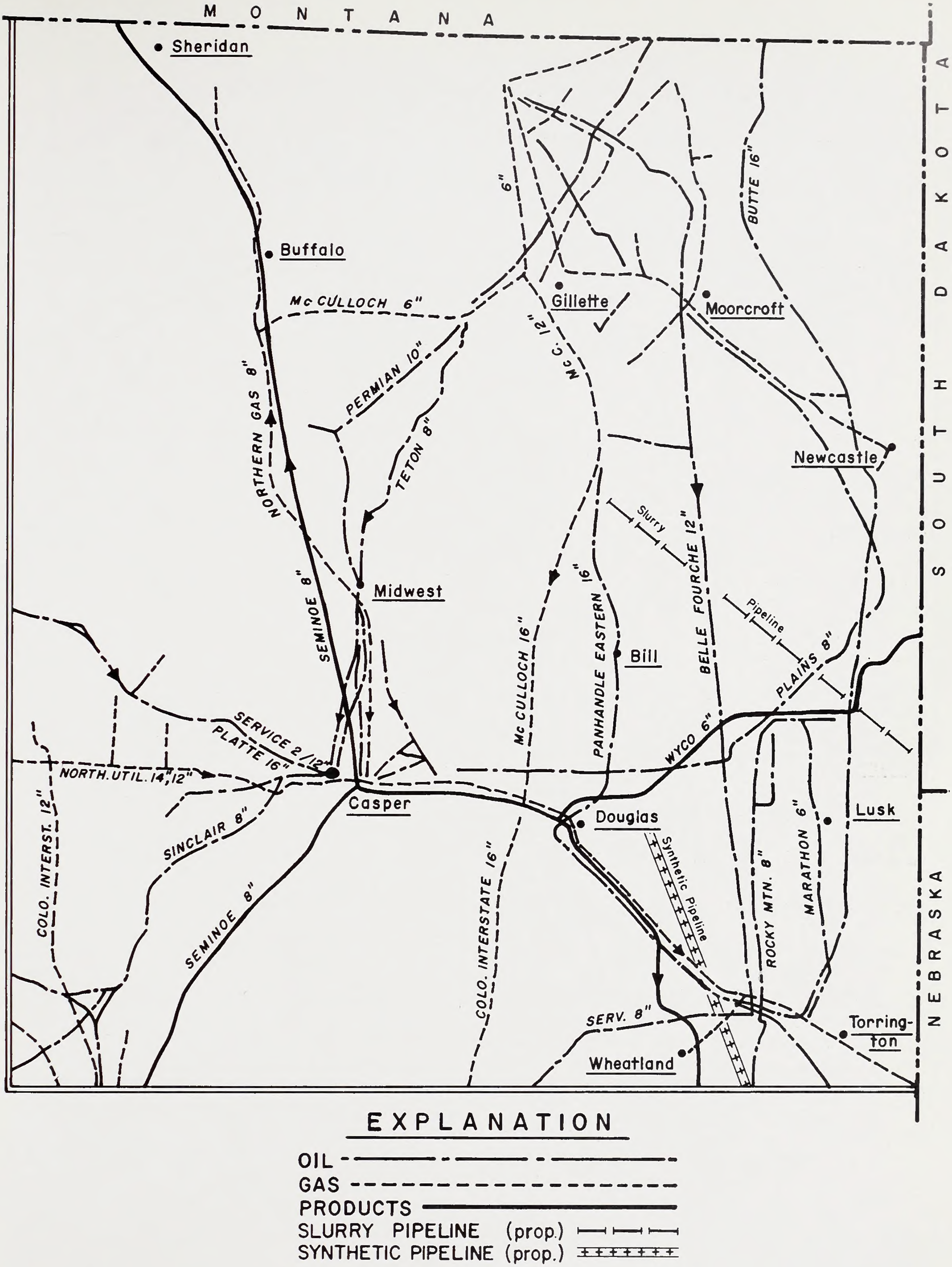
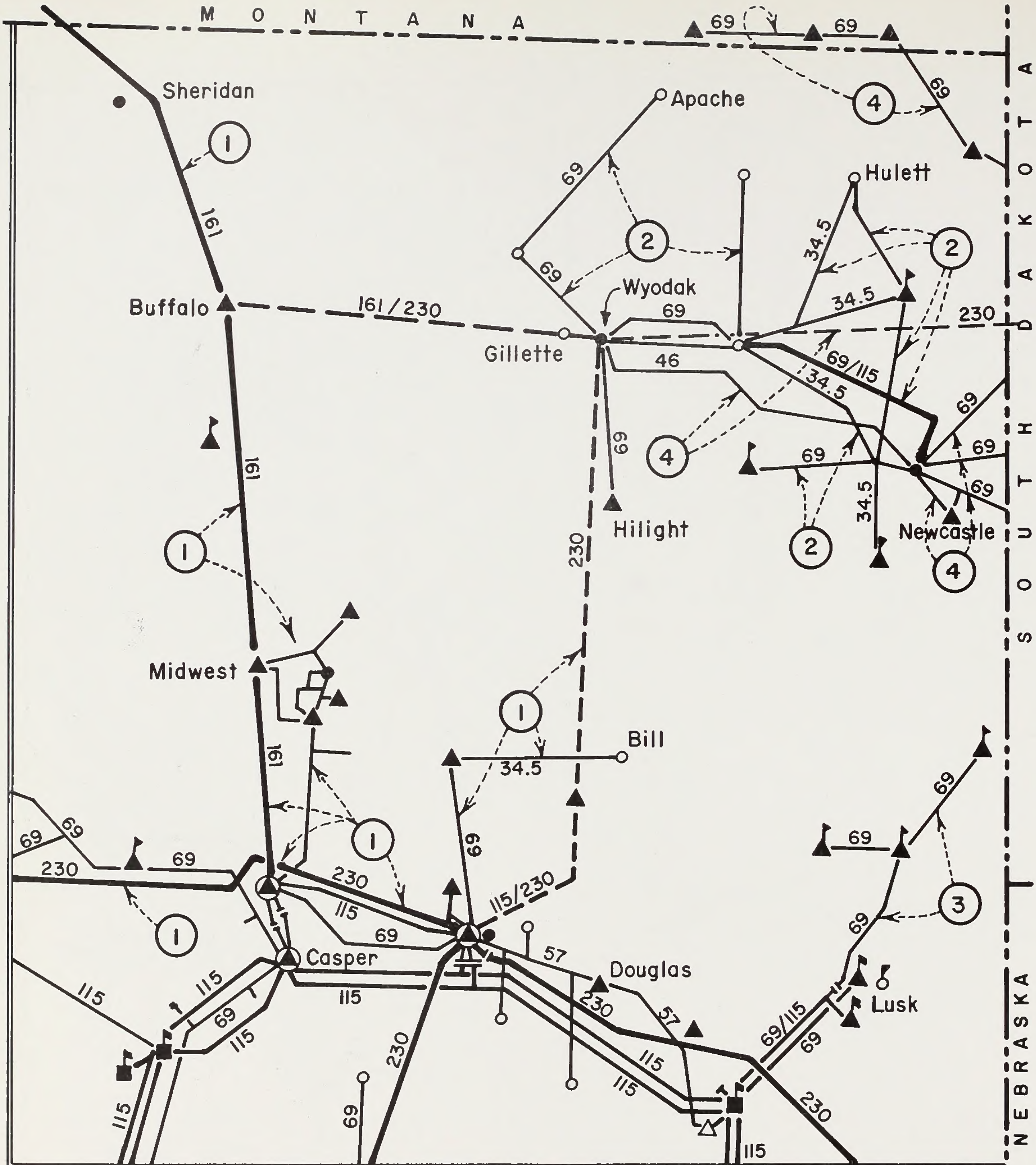


Figure 82
Pipelines (showing owner, size, flow direction).



EXPLANATION

(1) PACIFIC POWER & LIGHT CO.

(2) TRI-COUNTY ELEC. ASSN.

(3) NIOBRARA ELEC. ASSN.

(4) BLACK HILLS POWER & LIGHT CO.

PROPOSED TRANSMISSION LINES --------

Figure 83
Major electric transmission lines

Commuting

Information relative to commuting and public transportation is sketchy. Very few workers use public transportation (less than ½ of 1% in any of the eight counties utilize any form of public transportation). Converse, Crook and Natrona Counties have 9.9 percent to 12.3 percent of their residing work force commuting to other counties for work (Bureau of Census 1970). Crook and Weston County residents are probably traveling west into Campbell County where employment opportunities are better. Campbell County has the lowest percentage of residents in the basin traveling outside its county borders for employment (3%). This is chiefly attributable to the oil boom of the 1960's which created a great number of employment opportunities.

Land Use Controls and Constraints

In the study area, a large number of separate jurisdictional entities exercise certain types of land and resources use controls. The Federal sector includes the National Park Service (Devils Tower National Monument), Bureau of Reclamation (withdrawn lands in Natrona County), Forest Service (Big Horn, Medicine Bow, Black Hills National Forests and Thunder Basin National Grasslands), Bureau of Land Management (national resource lands and mineral estate under certain private lands).

Development, management, use and control of use on federal lands has been delegated to these agencies. With certain exceptions, uses and controls come under the discretionary authority of the agency head. Controls are effected through issuance or nonissuance of a variety of leases, permits, licenses, etc. Each authorization to use federal lands contain provisions to control that use. Agencies have monitoring, compliance and enforcement authority. Controls exercised by the Federal Government for the subsurface estate are governed by the statutes authorizing the disposition and use of that estate. Foremost among these statutes would be authority for leasing coal deposits and authority to require, as a condition of such leases, an operation-management plan and a reclamation-restoration plan. Management policy has been extended in greater detail by the National Environmental Policy Act of 1969. In certain situations, there is a joint or multiagency sharing of particular management and control functions and responsibilities. The subsurface estate vested in private or state ownership would normally be governed by applicable State of Wyoming statutes.

A number of state agencies have development and administrative authority over State of Wyoming owned lands. Additionally, under State of Wyoming statutes the state is authorized to perform and administer certain surface land use, planning, and development activities on state, county, municipal, and privately-owned properties. Control does not apply to federal properties except as provided by law.

Except where controls have specifically been delegated by statute to counties or municipalities, Wyoming retains total jurisdiction over public (nonfederal) and privately owned lands. Certain of these lands were conveyed to the state as part of the act admitting Wyoming to the Union. This legislation granted sections 16 and 36 of every township to the state for educational purposes. Use and control of these lands (including mineral leasing, rights-of-way, etc.) is governed by Wyoming law.

Under Wyoming statutes counties have authority to effect a wide variety of controls in matters not specifically reserved to the state. The authority applies only to those portions of the county that are unincorporated. A county may regulate and restrict location and use of buildings and structures and use, condition of use or occupancy of lands for residency, recreation, agriculture, industry, commerce, public use and other purposes. The authority does not apply to any planning or zoning controls over lands used or occupied for the extraction or production of minerals.

Less than 1 percent of the lands in the study area are owned by county governments. Use and control of these lands would be governed by state law and county ordinances. The county cannot effect planning or zoning control over any lands used in the extraction or production of mineral resources. Control over mineral uses is vested in the State of Wyoming under the Wyoming

Environmental Quality Act of 1973. This act also authorizes the state to control air quality, water quality and solid waste management.

Where a county or city lacks a specific authority, provisions of the Wyoming Joint Powers Act are available to enable joint exercise of power, privilege or authority. This legislation enables two or more agencies to jointly plan, create, finance and operate (control) water, sewage, or solid waste facilities; fire protection agency facilities; transportation systems facilities; and public school facilities.

In the eight-county regional area only Natrona County and Campbell County have developed and adopted comprehensive plans. Johnson County has been working on the development of a comprehensive plan for the past two years. Only Natrona County has passed a zoning ordinance for a portion of the county. However, Natrona, Johnson, Campbell, and Sheridan counties have passed or are working on subdivision regulations, mobile home park codes and other land use control measures. Campbell, Natrona, and Johnson counties have active joint city/county comprehensive planning programs with resident planners and staffs on board. Glenrock, Douglas, and Converse County have acknowledged their potential for a joint city/county planning office.

Nineteen incorporated towns or cities are in the basin. Of these the largest in terms of population are Gillette (Campbell County), Douglas (Converse County), Buffalo (Johnson County), Casper (Natrona County), Sheridan (Sheridan County), and Newcastle (Weston County). As in the case for Wyoming counties, the statutory authority available for cities to control land uses is quite restrictive. Cities have authority to effect a master plan, zoning, and other regulatory controls. Cities do not have statutory authority to effect controls over minerals extraction or production within their corporate limits. Furthermore, the Wyoming Environmental Quality Act of 1973 would preempt cities' authority to regulate and control air, water, solid waste, and land quality standards except where specifically delegated to a municipality.

Nearly all of the larger cities in the study area have developed a master plan and a zoning ordinance.

In summary, all of the respective jurisdictions (federal, state, and counties) have sufficient authority to impose effective land and resource use controls.

Socio-Economic Conditions

Demography

Population distribution: State of Wyoming

In 1970, Wyoming had a total population of 332,416 persons, ranking 49th in the United States. The population density of 3.4 persons per square mile is substantially below the 57.3 national average (Appendix C, Table 37), and the state realized a population increase of only 0.7 percent in the 1960-1970 decade.

During the past 70 years, Wyoming has realized an increasing urban population (Appendix C, Table 38). In 1970, approximately 60.5 percent of the population resided in urban places of 2,500 people or more. Cheyenne, the state capital, is the largest city, with a population of 40,914. Casper is second with 39,361 persons, and Laramie ranks third with a population of 23,143. Wyoming had no Standard Metropolitan Statistical Areas in 1970.

Population distribution: Powder River Basin

In 1970, approximately one-third (or 107,364 persons) of the state's population resided in the Powder River Basin. Converse and Campbell Counties had 17.6 percent (or 18,895 persons) of the regional population (Table 43). As indicated in Table 44 the regional population increased 23.3 percent versus 13.6 percent for the state in the 1950-1960 decade and 4.5 percent versus 0.7 percent for the state in the 1960-1970 decade.

Campbell County. The most substantial population growth in the Powder River Basin has occurred in Campbell County. Since 1950, the county population has more than doubled to 12,957 people in 1970, and the population of Gillette, the county seat, has more than tripled to 7,194 (Table 44). In the 1960-1970 decade, the population in Campbell County and Gillette grew 121.1 percent and 100.9 percent, respectively, due primarily to the oil boom in the region.

	1950	Percent of Region Total	1960	Percent of Region Total	1970	Percent of Region Total
Campbell	4,839	5.8	5,861	5.7	12,957	12.1
Converse	5,933	7.1	6,366	6.2	5,938	5.5
Crook	4,738	5.7	4,691	4.6	4,535	4.2
Johnson	4,707	5.7	5,475	5.3	5,587	5.2
Natrona	31,437	37.8	49,623	48.3	51,264	47.8
Niobrara	4,701	5.6	3,750	3.7	2,924	2.7
Sheridan	20,185	24.2	18,989	18.5	17,852	16.6
Weston	6,733	8.1	7,929	7.7	6,307	5.9
Regional Total	83,273	100.0	102,684	100.0	107,364	100.0
State Total	290,529	-----	330,066	-----	332,416	-----

Source: U.S. Department of Commerce, Bureau of the Census, Census of Population, 1950 through 1970.

Table 43

Population Distribution of Wyoming Counties
Powder River Basin
1950 - 1970

Table 44

Population Changes of Powder River
Basin Counties & Places Within Counties
1950 - 1970

	1950	1960	% Changes 1950-1960	1970	% Changes 1960-1970
Campbell County	4,839	5,861	21.1	12,957	121.1
Gillette	2,191	3,580	63.4	7,194	100.9
Converse County	5,933	6,366	7.3	5,938	-6.7
Douglas	2,544	2,822	10.9	2,677	-5.1
Glenrock	1,110	1,584	42.7	1,515	-4.4
Crook County	4,738	4,691	-1.0	4,535	-3.3
Sundance	893	908	1.7	1,056	16.3
Moorcroft	517	826	59.8	981	18.8
Johnson County	4,707	5,475	16.3	5,587	2.0
Buffalo	2,674	2,907	8.7	3,394	16.8
Natrona County	31,437	49,623	57.8	51,264	3.3
Casper	23,673	38,930	64.4	39,361	1.1
Mills	866	1,477	70.6	1,724	16.7
Mountain View	-----	1,721	----	1,641	-4.6
Paradise Valley	-----	-----	----	1,764	----
Evansville	393	678	72.5	832	22.7
Edgerton	203	512	152.2	350	-31.6
Niobrara County	4,701	3,750	-20.2	2,924	-22.0
Lusk	2,089	1,890	-9.5	1,495	-20.9
Sheridan County	20,185	18,989	-5.9	17,852	-6.0
Sheridan	11,500	11,651	1.3	10,856	-6.0
Dayton	316	333	5.4	396	18.9
Ranchester	251	235	-6.3	208	-11.5
Clearmont	225	154	-31.6	141	-8.4
Weston County	6,733	7,929	17.8	6,307	-20.5
Newcastle	3,395	4,345	28.0	3,432	-21.0
Upton	951	1,224	28.7	987	-19.4
8 County Region	83,273	102,684	23.3	107,364	4.5
State	290,529	330,066	13.6	332,416	0.7

Source: U. S. Department of Commerce, Bureau of the Census, Census of Population, 1950 through 1970.

In 1970 approximately 55.5 percent of the county population resided in Gillette, the only urban place in the county (Table 45). The county population density is only 2.7 people per square mile, below the 3.4 state average (Appendix C, Table 39).

Converse County. In contrast to Campbell County, the population of Converse County increased only 7.3 percent to 6,366 persons in the 1950-1960 decade, but then declined significantly 6.7 percent to 5,938 persons by the year 1970 (Table 44). This decline can be directly attributed to a declining agricultural employment trend in the county, even though agriculture remains the primary or basic employment sector. In the 1950-1960 decade, the population of Douglas increased 10.9 percent to 2,822 persons but then declined 5.1 percent to 2,677 people in the following decade. In 1970, the rural population included the majority (54.9%) of the county residents; the urban population (or remaining 45.1%) resided in Douglas (Table 45). The county population density is only 1.4 people per square mile, substantially below the 3.4 state average (Appendix C, Table 39).

Other six counties. Tables 43 through 45 provide information concerning population distribution, trends, and percentage urban for the remaining six counties.

Social characteristics of regional population

Tables 40 through 42 in Appendix C indicate population distribution by age, sex, ethnicity, and the educational level of persons 25 years old and over. The majority of the regional population is between 18 and 64 years of age (54.1%) and racially white (96.9%). The population distribution by sex is approximately even throughout the region. People 25 years old and over in the region had a 12.4 median number of school years completed, slightly above the

Table 45

Urban & Rural Population by County
Powder River Basin Region
1970

	Urban* Population	%	Rural Population	%
Campbell	7,194	55.5	5,763	44.5
Converse	2,677	45.1	3,261	54.9
Crook	0	----	4,535	100.0
Johnson	3,394	60.7	2,193	39.3
Natrona	39,361	76.8	11,903	23.2
Niobrara	0	----	2,924	100.0
Sheridan	10,856	60.8	6,996	39.2
Weston	3,432	54.4	2,875	45.6
Region	66,914	62.3	40,450	37.7
State	201,111	60.5	131,305	39.5

*Places with 2,500 people or more.

Source: U.S. Bureau of the Census, Census of Population, 1970.

12.1 national average. The region's high percentage (63.6%) of persons (25 years old and over) with four years of high school or more greatly surpasses the 52.3 percent national average.

The majority of the counties have lower percentages of persons with four or more years of college than the 11.8 percent state average and 10.7 percent national average. Because of the lack of business opportunities and reduced needs of a small population for professional services, it is likely that people with four or more years of college education would find work in larger urban centers, both in and out of state. Natrona County, which includes Casper (the state's second largest city), had 13.3 percent of its populace over 25 years old with four or more years of college.

Employment

This sector analyzes employment trends that have developed during the decade 1960 to 1970. An overall view of predominant employment within the region as is discussed within the first part. Only significant employment sectors are discussed and conspicuous trends are noted. Part two analyzes employment characteristics in Campbell and Converse Counties.

For purposes of analysis, employment is divided into ten sectors on a format identical to that used by the Water Resources Research Institute at the University of Wyoming. A component breakdown of the sectors appears in Appendix C.

In 1970 the eight counties of the Wyoming Powder River Basin employed 41,253 persons, up 7.1 percent from 1960 (University of Wyoming 1974). The unemployment rate in 1970 was 4.1 percent as compared with a statewide rate of 4.8 percent (Bureau of Census 1971a, Table 121). Within the eight county region, the petrochemicals (petroleum and natural gas), agriculture, and construction industries were the principal employers with 12.4 percent, 9.2 percent, and 7.7 percent of employment (Table 46). The most immediately noticeable trend throughout the region is a consistent loss in agricultural employment. Each county posted losses varying from 10.3 percent to 41 percent (Tables 46 through 53, Appendix C). Regionally, Sheridan County remains the major agricultural employer. Petrochemical employment remained fairly static regionally due to a shift from Natrona to Campbell County. Natrona County still remains the major petrochemical employer with 56.6 percent of regional petrochemical employment. At present, employment in sythetic gas production (coal gasification), coal mining, and power generation sectors is an insignificant one percent. Sheridan County retained the bulk of this employment (Table 54, Appendix C).

Table 46

Employment Summary for the Eight-County Region

	1960	1970
Population	102,700	107,364
Employment		
Agriculture	4,861	3,784 (9.2%)*
Petrochemicals		
Petroleum and Natural gas	4,964	5,135 (12.4)
Synthetic Gas	-------	-------
Coal Mining	95	224 (0.5)
Uranium Mining and Milling	136	572 (1.4)
Power Generation	193	221 (0.5)
Other Mining	126	269 (0.7)
Other Manufacturing	1,150	931 (2.3)
Railroads	518	305 (0.7)
Construction	3,677	3,196 (7.7)
Other Residentiaries	22,799	26,616 (64.5)
Total Employment	38,519	41,253 (99.9)

*Percentage of employment by sector in parentheses for 1970.

Source: University of Wyoming, Water Resources Research Institute, (1974).

Campbell and Converse Counties

Total employment within Campbell County increased by 111 percent during the ten-year period 1960 to 1970 (Table 47). This increase resulted from significant employment increases to the sectors of petrochemicals and other residentiaries (509% and 110%, respectively). This is a direct result of the oil boom which occurred within Campbell County in the 1960's. Petrochemicals

Table 47

Employment Summary, Campbell and Converse Counties

	Campbell County			Converse County		
	1960	1970 *		1960	1970*	
Population	5,861	12,957		6,366	5,938	
Employment						
Agriculture	670	601	(12.5%)	580	486	(22.4%)
Petrochemicals Petroleum and Natural gas	224	1,364	(28.4)	177	204	(9.4)
Synthetic Gas	-----	------		-----	-----	
Coal Mining	32	32	(0.7)	17	39	(1.8)
Uranium Mining and Milling	2	------		30	71	(3.3)
Power Generation	-----	40	(0.8)	25	-----	
Other Mining	-----	------		-----	-----	
Other Manufacturing	18	131	(2.7)	16	16	(0.7)
Railroads	22	11	(0.3)	25	6	(0.3)
Construction	189	268	(5.6)	192	225	(10.4)
Other Residentiaries	1,120	2,356	(49.1)	1,345	1,121	(51.7)
Total Employment	2,277	4,803	(100.1)	2,407	2,168	(100.0)

*Percentage of employment by sector in parentheses for 1970.

Source: University of Wyoming, Water Resources Research Institute (1974).

and agriculture are the top two employment sectors (excluding other residentiaries) within the county. Coal mining, power generation, and railroad sectors combined comprise only 1.8 percent of total employment. Presumably as a secondary result of the 1960's oil boom, the other manufacturing sectors (manufacturing not related to energy mining or fuels) experience a large growth of 628 percent but still remained a moderately low numerical employer in the county. The rate of unemployment is a low 2.6 percent.

In contrast to Campbell County, Converse County experienced a 9.9 percent decline in total employment and has a higher unemployment rate than Campbell at 4.3 percent. This decline is principally attributable to a loss of nearly 100 employees in the agricultural sector, a 16.2 percent drop (Table 47). Other residentiaries, which includes service-oriented employment, concurrently showed a drop of 9.9 percent. Agriculture, nevertheless, remains the principal employment sector (excluding other residentiaries) in the county. Coal mining, power generation, and railroad sectors combined employ a mere 2.1 percent of the labor force, but the remaining energy sectors (petrochemical and uranium mining and milling) employ a significant 12.7 percent of the labor force.

Employment summaries for the counties of Crook, Johnson, Natrona, Niobrara, Sheridan and Weston are found in Appendix C, Tables 46 thru 54.

1970 unemployment rates for these counties are shown below:

Crook	3.0%	Niobrara	2.7%
Johnson	1.7%	Sheridan	4.2%
Natrona	4.8%	Weston	4.1%

Income

This section describes 1970 income levels and distribution for the eight-county study area as a whole and Campbell and Converse Counties specifically, and the remaining six counties generally. (Table 48)

The eight counties of the Powder River Basin

The mean family income for the study region is $10,878 which exceeds the state mean of $10,127 by 7.4 percent. The mean family income ranges from a high of $12,949 in Campbell County to a low of $8,153 in Crook County. Likewise median income ranges from a high of $11,303 in Campbell County to a low of $7,474 in Crook County. Generally, those counties which experienced a population increase from 1960 to 1970 have the higher median family and mean family incomes.

Campbell County

The median ($11,303) and mean ($12,949) incomes of Campbell County are the highest in the eight-county region. The introduction of oil and coal development with associated high incomes has contributed to the generally high income levels. While 60.6 percent of the 3,085 families have incomes which exceeded $10,000 in 1970, 26.2 percent of the families have incomes greater than $15,000. The 10.2 percent of total families having incomes less than $5,000 is nearly 50 percent less than study area and state averages.

Converse County

The median and mean incomes for Converse County are $8,947 and $9,191, respectively. Of the 1,582 families, 43.3 percent had 1970 incomes greater than $10,000. This is slightly below the average of 47.4 percent for the eight county region but greater than the statewide average of 42.6 percent. The 10.1

Group	Family Income	Campbell County % By Group	Campbell County # Families	Converse County % By Group	Converse County # Families	Crook County % By Group	Crook County # Families	Johnson County % By Group	Johnson County # Families	Natrona County % By Group	Natrona County # Families
	Less than $1,000		53		47		41		17		236
	$1,000 to $1,999		33		62		54		67		272
I	$2,000 to $2,999		61		87		47		109		442
	$3,000 to $3,999		84		119		87		100		496
	$4,000 to $4,999	10.2%	83	23.6%	58	25.3%	81	24.8%	81	15.2%	544
	$5,000 to $5,999		132		91		141		122		612
II	$6,000 to $6,999		181		83		115		136		761
	$7,000 to $7,999	14.0%	119	19.6%	136	28.8%	97	23.6%	98	17.6%	932
III	$8,000 to $8,999		221		114		120		93		893
	$9,000 to $9,999	15.2%	249	13.5%	99	13.6%	46	10.9%	72	14.0%	952
IV	$10,000 to $11,999	16.2%	501	18.3%	290	13.2%	161	10.9%	165	14.8%	1937
V	$12,000 to $14,999	18.2%	560	14.9%	236	9.9%	121	10.7%	162	16.2%	2131
	$15,000 to $24,999		610		132		108		211		2415
VI	$25,000 to $49,999		150		28		55		40		395
	$50,000 or more	26.2%	48	10.1%	---	9.2%	---	19.0%	36	22.3%	114
	Total Families		3085		1582		1224		1509		13132
	Median Income		$11,303		$8,947		$7,474		$8,263		$10,440
	Mean Income		$12,949		$9,191		$8,153		$11,389		$11,388
	Per Capita Income		$ 3,534		$2,709		$2,415		$ 3,421		$ 3,244

Source: U.S. Department of Commerce, Bureau of Census, Census of Population: 1970 (1971a).

Table 48

Income Data by County
1970

Table 48 (Cont'd)

Group	Family Income	Niobrara County % By Group	Niobrara County # Families	Sheridan County % By Group	Sheridan County # Families	Weston County % By Group	Weston County # Families	8 County Area % By Group	8 County Area # Families	State Wide % By Group	State Wide # Families
	Less Than $1,000		---		94		50		538		1797
	$1,000 to $1,999		27		174		43		732		2362
	$2,000 to $2,999		68		259		51		1124		3844
I	$3,000 to $3,999		60		377		109		1432		4325
	$4,000 to $4,999	25.4%	46	24.3%	256	19.8%	66	18.2%	1215	20.3%	4826
	$5,000 to $5,999		67		390		72		1627		5570
II	$6,000 to $6,999		78		397		143		1894		6080
	$7,000 to $7,999	28.2%	78	24.9%	398	24.3%	177	20.0%	2035	21.6%	6612
III	$8,000 to $8,999		58		395		145		2039		7351
	$9,000 to $9,999	14.7%	58	15.0%	320	18.2%	149	14.4%	1945	15.9%	6115
IV	$10,000 to $11,999	7.2%	57	11.4%	542	10.6%	170	13.8%	3823	13.5%	11448
V	$12,000 to $14,999	10.1%	80	11.0%	523	10.3%	166	14.4%	3979	13.1%	11115
	$15,000 to $24,999		96		458		194		4224		10505
VI	$25,000 to $49,999		15		167		56		856		2292
	$50,000 or more	14.4%	3	13.4%	16	17.0%	24	19.2%	241	15.6%	461
	Total Families		791		4766		1615		27704		84703
	Median Income		$7,635		$8,096		$8,666				$8,943
	Mean Income		$9,071		$9,499		$10,967		$10,878		$10,127
	Per Capita Income		$2,807		$2,896		$ 3,063				$ 2,910

Source: U.S. Department of Commerce, Census of Population: 1970 (1971a).

percent of Converse County families with incomes greater than $15,000 is relatively low in comparison to the region and state averages of 19.2 percent and 15.6 percent, respectively. Finally, 23.6 percent of Converse County families have incomes below $5,000, while the proportions for the region and state are 18.2 percent and 20.3 percent, respectively.

Housing

This section describes the 1970 housing conditions within the Powder River Basin. An assessment is made of housing trends specific to the region with more detailed descriptions of housing conditions in Campbell and Converse Counties, respectively. Occupancy, structure type and age, plumbing facilities, crowding, value of owner occupied housing and contract rent for rental housing are discussed in turn.

Regional

Six tables (49-54) illustrate various housing conditions using 1970 census data as the primary data source.

Occupancy characteristic. Household size (the number of persons per occupied housing unit) and occupancy characteristics differ only slightly from state averages. Household size is generally greater in rural than urban areas. Those counties and cities which experienced a population gain during the 1960's tended to have lower vacancy rates than those areas which lost population. Finally, within the study area more housing units are likely to be owner occupied than the state average and within rural as opposed to urban areas (Table 49).

Structure and age characteristics. While single family structures constitute the greatest percentage of housing units within the study area, the mobile home is beginning to assume a greater proportion of the housing stock. This phenomenon is especially true in the rural areas and places which have

Table 49

1970 Occupancy and Vacancy Characteristics of Housing by County of the Powder River Basin, Wyoming

County	Total Population in Year-Round Housing Units	Total Year-Round Housing Units*	Population Per Occupied Housing Unit**	Owner Occupied Units	Percent Owner Occupied Units	Rental Occupied Units	Percent Rental Occupied Units	Total Vacant	Percent Vacant
Campbell	12,665	3,937	3.4	2,607	66.2	1,122	28.5	208	5.3
Urban	6,982	2,228	3.3	1,385	62.2	735	33.0	108	4.8
Rural	5,683	1,709	3.5	1,222	71.5	387	22.6	100	5.9
Converse	5,932	2,247	3.0	1,369	60.9	589	26.2	289	12.9
Urban	2,388	1,029	2.7	620	60.3	262	25.5	146	14.2
Rural	3,544	1,218	3.3	748	61.4	327	26.8	143	11.7
Crook	4,524	1,576	3.2	1,055	66.9	355	22.5	166	10.5
Urban	---	---	---	---	---	---	---	---	---
Rural	4,524	1,576	3.2	1,055	66.9	355	22.5	166	10.5
Johnson	5,516	2,158	2.9	1,268	58.8	614	28.5	276	12.8
Urban	3,491	1,319	2.9	857	65.0	364	27.6	98	7.4
Rural	2,025	839	3.1	411	49.0	250	29.8	178	21.2
Natrona	50,624	17,228	3.1	11,341	65.8	4,852	28.2	1,035	6.0
Urban	38,971	13,426	3.1	8,636	64.3	4,077	30.4	713	5.3
Rural	11,653	3,802	3.3	2,705	71.1	775	20.4	322	8.5
Niobrara	2,940	1,330	2.7	752	56.5	323	24.3	255	19.2
Urban	---	---	---	---	---	---	---	---	---
Rural	2,940	1,330	2.7	752	56.5	323	24.3	255	19.2
Sheridan	17,178	6,799	2.8	4,196	61.7	1,993	29.3	610	9.0
Urban	10,698	4,434	2.6	2,714	61.2	1,397	31.5	323	7.3
Rural	6,480	2,365	3.1	1,482	62.7	596	25.2	287	12.1
Weston	6,232	2,188	3.2	1,387	63.4	573	26.2	228	10.4
Urban	3,273	1,268	2.9	721	56.9	395	31.2	152	12.0
Rural	2,959	920	3.5	666	72.4	178	19.3	76	8.3
Study Area	105,611	37,463	3.1	23,975	64.0	10,421	27.8	3,067	8.2
State	322,949	114,572	3.1	69,440	60.6	35,160	30.7	9,972	8.7

*Year-round units exclude vacant units intended for seasonal occupancy and vacant units held for migratory labor.

**Computed by division of total population in year-round housing units by sum of owner and renter occupied units.

Source: U.S. Department of Commerce, Bureau of Census, Detailed Characteristics, Wyoming, 1970 Census of Housing, (1971b), Tables 32,60.

experienced rapid and substantial population growth. Of the housing within the eight-county study area, 43.3 percent was built prior to 1939. This age characteristic is similar to that noted for the state as a whole. Housing in centers of recent population growth is of more recent construction (Tables 50 and 51).

Plumbing and crowding characteristics. Differences in the percentage of housing which lacks some or all plumbing facilities are most pronounced between urban and rural areas. In rural areas of every county, the proportion of housing deficient in plumbing facilities exceeds the statewide average. Crowding conditions were generally less than state averages except within Campbell County where crowding was most extreme (Table 52).

Value of owner occupied housing and contract rent of renter occupied housing. The median value of an owner occupied home ranges greatly within the area from $8,400 in Niobrara County to $20,700 in Campbell County. Median contract rent was $78 which slightly exceeded the state median of $73. Naturally, newer construction commanded higher rents. Median contract rents paralleled changes in median value of owner occupied housing units (Tables 53 and 54).

Campbell County

Occupancy characteristics. There are 3,937 year-round[1] housing units in Campbell County. The City of Gillette, including the entire urban population within the county, contains 2,228 year-round housing units or 55.1 percent of the housing in the county. The remaining 1,709 housing units are located in rural areas. There are 3.4 people per household in Campbell County.

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[1] Year-round housing excludes vacant units intended for seasonal occupancy and vacant units held for migratory labor.

Table 50

1970 Structural Characteristics of Housing by County in the Powder River Basin, Wyoming

County	Total Year-Round Units	Single Family	Percent Single Family	Multi-Family	Percent Multi-Family	Mobile Homes	Percent Mobile Homes
Campbell	3,937	1,782	45.3	491	12.5	1,664	42.3
Urban	2,228	1,074	48.2	441	19.8	713	32.0
Rural	1,709	708	41.4	50	2.9	951	55.6
Converse	2,247	1,741	77.5	254	11.3	252	11.2
Urban	1,029	754	73.3	170	16.5	105	10.2
Rural	1,218	987	81.0	84	6.9	147	12.1
Crook	1,576	1,143	72.5	112	7.1	321	20.4
Urban	---	---	---	---	---	---	---
Rural	1,576	1,143	72.5	112	7.1	321	20.4
Johnson	2,158	1,684	78.0	277	12.8	197	9.1
Urban	1,319	1,009	76.5	254	19.3	56	4.2
Rural	839	675	80.5	23	2.7	141	16.8
Natrona	17,228	12,801	74.3	3,206	18.6	1,221	7.1
Urban	13,426	10,222	76.1	2,999	22.3	205	1.5
Rural	3,802	2,579	67.8	207	5.4	1,016	26.7
Niobrara	1,330	1,153	86.7	109	8.2	68	5.1
Urban	---	---	---	---	---	---	---
Rural	1,330	1,153	86.7	109	8.2	68	5.1
Sheridan	6,799	5,528	81.3	1,023	15.0	248	3.6
Urban	4,434	3,446	77.7	929	21.0	59	1.3
Rural	2,365	2,082	88.0	94	4.0	189	8.0
Weston	2,188	1,698	77.6	200	9.1	290	13.3
Urban	1,268	998	78.7	159	12.5	111	8.8
Rural	920	700	76.1	41	4.5	179	19.5
Study Area	37,463	27,530	73.5	5,672	15.1	4,261	11.4
State	114,572	84,457	73.7	19,859	17.3	10,256	9.0

Source: Detailed Housing Characteristics, Wyoming, 1970 Census of Housing, Tables 35, 62.

County	Total Year-Round Units	1939 or Earlier	Percent 1939	1940-49	Percent 1940-49	1950-59	Percent 1950-59	1960-March 1970	Percent 1960-March 1970
Campbell	3,937	1,096	27.8	306	7.8	501	12.7	2,034	51.7
Urban	2,228	613	27.5	210	9.4	271	12.2	1,134	50.9
Rural	1,709	483	28.3	96	5.6	230	13.5	900	52.7
Converse	2,247	1,355	60.3	140	6.2	420	18.7	332	14.8
Urban	1, 029	569	55.3	83	8.1	226	22.0	151	14.7
Rural	1,218	786	64.5	57	4.7	194	15.9	181	14.9
Crook	1,576	614	39.0	154	9.8	303	19.2	505	32.0
Urban	---	---	----	---	---	---	----	---	----
Rural	1,576	614	39.0	154	9.8	303	19.2	505	32.0
Johnson	2,158	1,118	51.8	348	16.1	314	14.6	378	17.5
Urban	1,319	728	55.2	249	18.9	146	11.1	196	14.9
Rural	839	390	46.5	99	11.8	168	20.0	182	21.7
Natrona	17,228	5,726	33.2	2,192	12.7	5,665	32.9	3,645	21.2
Urban	13,426	4,840	36.0	1,703	12.7	4,642	34.6	2,241	16.7
Rural	3,802	886	23.3	489	12.9	1,023	26.9	1,404	36.9
Niobrara	1,330	939	70.6	178	13.4	111	8.3	102	7.7
Urban	---	---	----	---	----	---	----	---	----
Rural	1,330	939	70.6	178	13.4	111	8.3	102	7.7
Sheridan	6,799	4,388	64.5	660	9.7	859	12.6	892	13.1
Urban	4,434	3,055	68.9	398	9.0	547	12.3	434	9.8
Rural	2,365	1,333	56.4	262	11.1	312	13.2	458	19.4
Weston	2,188	987	45.1	315	14.4	565	25.8	321	14.7
Urban	1,268	605	47.7	179	14.1	384	30.3	100	7.9
Rural	920	382	41.5	136	14.8	181	19.7	221	24.0
Study Area	37,463	16,223	43.3	4,293	11.5	8,738	23.3	8,209	21.9
State	114,572	49.055	42.8	15,550	13.6	24,960	21.8	25,007	21.8

Source: Detailed Housing Characteristics, Wyoming, 1970 Census of Housing, Tables 35, 62

Table 51

Year of Construction of Present Housing Stock by County in the Powder River Basin, Wyoming

Table 52

1970 Plumbing and Crowding Characteristics of Housing
by County in the Powder River Basin, Wyoming

County	Total Units	Lacking Some or All Plumbing Facilities	Percentage Lacking Some or All Plumbing Facilities	Persons/Room Greater Than 1.01	Percentage Persons/Room Greater Than 1.01
Campbell	3,937	175	4.4	518	13.2
Urban	2,228	24	1.1	269	12.1
Rural	1,709	151	8.8	249	14.6
Converse	2,247	145	6.5	174	7.7
Urban	1,029	18	1.7	63	6.1
Rural	1,218	127	10.4	111	9.1
Crook	1,576	177	11.2	169	10.7
Urban	---	---	---	---	---
Rural	1,576	177	11.2	169	10.7
Johnson	2,158	243	11.3	161	7.5
Urban	1,319	36	2.7	104	7.9
Rural	839	207	24.7	57	6.8
Natrona	17,228	511	3.0	1,128	6.5
Urban	13,426	276	2.1	689	5.1
Rural	3,802	235	6.2	439	11.5
Niobrara	1,330	107	8.0	55	4.1
Urban	---	---	---	---	---
Rural	1,330	107	8.0	55	4.1
Sheridan	6,799	367	5.4	362	5.3
Urban	4,434	153	3.5	184	4.1
Rural	2,365	214	9.0	178	7.5
Weston	2,188	123	5.6	217	9.9
Urban	1,268	68	5.4	99	7.8
Rural	920	55	6.0	118	12.8
Study Area	37,463	1,848	4.9	2,784	7.4
State	114,572	5,758	5.0	8,843	7.7

Source: Detailed Housing Characteristics, Wyoming, 1970 Census of Housing, Tables 33, 60.

County	Total Year-Round Housing Units	Median*	Less Than $5,000	$5,000-9,999	$10,000-14,999	$15,000-19,999	$20,000-24,999	$25,000-34,999	$35,000-or More
Campbell	713	$20,700	14	60	117	140	190	92	100
Urban	678	20,819	8	55	117	122	190	92	94
Rural	35	18,400	6	5	-	18	-	-	6
Converse	815	15,100	58	176	165	247	81	69	19
Urban	460	15,332	34	82	104	131	34	60	15
Rural	355	14,800	24	94	61	116	47	9	4
Crook	390	11,300	20	144	71	110	22	9	14
Urban	---	---	---	---	---	---	---	---	---
Rural	390	11,300	20	144	71	110	22	9	14
Johnson	808	15,800	35	166	166	182	96	97	66
Urban	693	15,949	28	138	143	177	74	77	56
Rural	115	14,900	7	28	23	5	22	20	10
Natrona	9,387	17,000	271	1,038	2,284	2,651	1,470	1,076	597
Urban	7,926	17,869	107	652	1,960	2,385	1,328	955	541
Rural	1,459	12,300	164	386	324	266	142	121	56
Niobrara	465	8,400	132	148	114	39	3	29	---
Urban	---	---	---	---	---	---	---	---	---
Rural	465	8,400	132	148	114	39	3	29	---
Sheridan	3,112	13,700	250	723	720	592	409	289	129
Urban	2,385	13,365	149	592	584	461	299	227	73
Rural	727	14,800	101	131	136	131	110	62	56
Weston	865	10,000	136	298	206	113	40	40	32
Urban	577	11,248	59	172	162	82	30	30	32
Rural	288	7,500	77	126	44	21	10	10	-
Study Area	16,555	15,645**	916	2,753	3,843	4,074	2,311	1,701	957
State	48,200	15,400	2,856	8,171	11,861	12,166	6,273	4,620	2,253

*Median value for urban areas is computed value and represents the difference between the product of total county year-round units and its median value and the product of rural year-round housing units and its median value which is divided by the number of urban units.

**A computed value which is the summation of the products by county of total year-round housing units and respective median value which is divided by total year-round units in the study area.

Source: Detailed Housing Characteristics, Wyoming, 1970 Census of Housing, Tables 34, 61.

Table 53

1970 Value of Owner Occupied Housing by County in the Powder River Basin, Wyoming

Table 54

1970 Contract Rent of Rental Housing by County in the Powder River Basin, Wyoming

County	Total Rental Units	Median*	Less Than $30	$30-39	$40-59	$60-79	$80-99	$100-149	$150 or More	No Cash
Campbell	992	118	-	-	106	75	107	385	205	114
Urban	731	117	-	-	73	72	95	296	154	41
Rural	261	121	-	-	33	3	12	89	51	73
Converse	454	73	20	16	62	127	111	33	16	68
Urban	262	67	10	6	37	102	58	11	12	26
Rural	192	81	10	10	26	25	53	22	4	42
Crook	254	75	-	4	54	62	52	44	-	38
Urban	-	-	-	-	-	-	-	-	-	-
Rural	254	75	-	4	54	62	52	44	-	38
Johnson	491	69	4	33	97	141	49	76	11	80
Urban	364	69	-	27	89	123	49	49	11	16
Rural	127	68	4	6	8	18	-	27	-	64
Natrona	4,691	79	73	132	749	1,331	926	1,085	178	217
Urban	4,057	80	60	125	636	1,104	828	991	178	135
Rural	634	72	13	7	113	227	98	94	-	82
Niobrara	266	58	12	17	83	53	31	12	-	58
Urban	-	-	-	-	-	-	-	-	-	-
Rural	266	58	12	17	83	53	31	12	-	58
Sheridan	1,731	65	43	171	399	512	201	160	79	166
Urban	1,372	63	28	149	361	428	161	126	41	78
Rural	359	74	15	22	38	84	40	34	38	88
Weston	522	68	26	30	108	147	115	24	-	72
Urban	395	68	20	24	97	89	102	24	-	39
Rural	127	69	6	6	11	58	13	-	-	33
Study Area	9,401	78**	178	403	1,659	2,448	1,592	1,819	489	813
State	31,650	73	831	1,489	5,782	9,559	4,613	5,451	1,324	3,601

*Median value for urban areas is a computed value and represents the difference between the product of total county year-round units and its median value and the product of rural year-round units and its median value which is divided by the number of urban units.

**A computed value which is the summation of the products by county of total year-round housing units and respective median value which is divided by total year-round housing units in the study area.

Source: Detailed Housing Characteristics, Wyoming, 1970 Census of Housing, Tables 34, 61.

This county is the only one in the state to experience an increase in household size in the last decade. Predictably, household size in the rural areas (3.5) is greater than household size in Gillette (3.3). Owners occupied 66.2 percent of the housing units, a figure that exceeds state and study area percentages. As with most counties in the study area, the percentage of owner occupied housing is less in the urban than rural area. The vacancy rate is 5.3 percent in the county, 4.8 percent in Gillette, and 5.9 percent in the rural sectors of the county. (Table 49)

Structural and age characteristics. Of the 3,937 year-round housing units, 1,782 or 45.3 percent are single family, 491 or 12.5 percent are multi-family, and 1,664 or 42.3 percent are mobile homes. Normally, there are fewer multi-family units in rural areas, and Campbell County is no exception. The percentage of mobile homes greatly exceeds study area and state averages. Housing tends to be newer in Campbell County than in any county in the study area and the state regardless of urban or rural location. (Tables 50 and 51)

Plumbing and crowding characteristics. Of the 3,937 year-round housing units in Campbell County, 175 or 4.4 percent lack some or all plumbing facilities. This percentage is less than the study area and state averages of 4.9 percent and 5.0 percent, respectively. Only 1.1 percent of the housing units in Gillette lack some or all plumbing facilities, while the same percentage for the rural areas is 8.8 percent. The number of persons per room exceeds 1.01 in 13.2 percent of all housing in Campbell County. This is nearly twice the study area and state averages. The number of persons per room is slightly less in Gillette than in the rural areas of the county (Table 52).

Value of owner occupied housing and contract rent. The median value of a home in Campbell County is $20,700. This value exceeds by approximately one-third the median value of homes in the study area and the state. The value of urban homes tends to be higher than that of rural homes.

The median monthly contract rent is $118, a figure which greatly exceeds study area and state averages by $40 and $45, respectively. Contract rent tends to be slightly higher in rural areas than in the City of Gillette. (Tables 53 & 54).

Converse County

Occupancy characteristics. There are 2,247 year-round housing units in Converse County. The City of Douglas, the only urban area in the county, contains 1,029 year-round housing units or 40.3 percent of the housing in the county. The remaining 1,218 units are in rural areas. Household size is 3.0, a 9.1 percent decrease from 1960. This figure approximates study area and state averages. Household size in the rural areas (3.3) is greater than household size in Douglas (2.7), also corresponding to the trend observed in other counties of the study area. Owners occupy 60.9 percent of the housing, less than state and study area percentages. The rate of owner occupied housing units is slightly less in Douglas than in the rural areas. The vacancy rate of 12.9 percent for the county exceeds by roughly one-half study area and state rates. The vacancy rate in Douglas is 14.2 percent, greater than the 11.7 percent rate in rural areas (Table 49).

Structural and age characteristics. Of the 2,247 year-round housing units in the county, 1,741 or 77.5 percent are single family, 254 or 11.3 percent are multifamily, and 252 or 11.2 percent are mobile homes. Urban housing is characterized by a lower percentage of single family homes (73.3 %) than rural housing (81.0%); however, urban housing has a greater percentage of multifamily structures (16.5%) than rural housing (6.9%). Mobile homes comprise a slightly higher percentage of housing in the rural areas (12.1%) than in Douglas (10.2%). Housing in Converse County is generally older than in the study area and the state. Within the county, rural housing is slightly older than housing in Douglas (Tables 50 & 51).

Plumbing and crowding characteristics. Of the 1,029 year-round housing units in Converse County, 145 or 6.5 percent lack some or all plumbing facilities. This exceeds study area and state rates of 4.9 percent and 5.0 percent, respectively. Compared to 10.4 percent of rural housing, only 1.7 percent of urban housing lacks some or all plumbing facilities. The percentage of year-round units where the number of persons per room is greater than 1.01 is lower in Douglas (6.1) than the rural areas (9.1) of the county (Table 52).

Value of owner occupied housing and contract rent. The median value of a home in Converse County is $15,100, approximately the same as the study area and state. The value of urban homes tends to be higher than that of rural homes.

Median monthly contract rent is $73. This is slightly less than the study area median of $78 but identical to the statewide median. Median rent in Douglas is $67 and in the rural areas $81 (Tables 53 & 54).

Remaining 6 counties of the study area - Crook, Johnson
Natrona, Niobrara, Sheridan and Weston

Occupancy characteristics. The total number of year-round housing units in the six county area is 31,279. There are 20,447 housing units in urban areas or 65.4 percent of the total housing stock. The City of Buffalo, comprising the entire urban population of Johnson County, contains 1,319 or 61.1 percent of the 5,516 year-round housing units in that county. Casper accounts for 13,426 or 77.9 percent of the 17,228 year-round housing units of Natrona county. Sheridan contains 4,434 or 65.3 percent of the 6,799 year-round housing units of Sheridan county. The City of Newcastle represents the urban area in the county of Weston and has 1,268 or 58.0 percent of the year-round housing stock of that county. In the counties of Crook and Niobrara, the housing stock and population are classified as rural.

Household size ranges from 2.7 in Niobrara county to 3.2 in Crook and Weston Counties. This range closely parallels the study area and state average of 3.1. In every county household, size dropped from 1960 census levels. Additionally, for every county, household size is less in urban than rural areas.

The percentage of owner occupied housing units to total year-round housing units by county ranges from 66.9 percent and 65.8 percent in Crook and Natrona Counties, respectively, to 56.5 percent in Niobrara county. Generally, this percentage is higher than the corresponding state rate of 60.6 percent. For all six counties except Johnson, the percentage of owner occupied housing units tends to be higher in rural than urban areas. The percentage of renter occupied housing units by county is higher in urban than rural sectors except for Johnson County. Lastly, the vacancy rates by county exceed the state average of 8.7 percent except in Natrona County. Vacancy rates for urban housing are less than that for rural housing except in Weston County (Table 49).

Structure and age characteristics. For each of the six counties except Crook, single family dwellings as a percentage of the total stock exceeds the statewide average of 73.7 percent. For each of the six counties, except Natrona, multi-family structures as a percentage of total stock is less than the statewide average of 17.3 percent. Mobile homes constitute a larger proportion of the housing stock than the state average of 9.0 percent for the counties of Crook, Johnson, and Weston and a smaller proportion for the counties of Nartona, Niobrara, and Sheridan. Mobile homes are more common in rural than urban areas. Single family structures predominate in rural areas except in Natrona and Weston Counties.

The age of the housing stock fluctuates greatly by county. Johnson, Niobrara and Sheridan Counties have a housing stock which is older than housing in the state as a whole. Conversely the counties of Crook and Natrona have newer housing than the state generally. Finally urban housing tends to be older than rural housing (Tables 50 & 51).

Plumbing and crowding characteristics. Each of the six counties except Natrona has a greater percentage of homes lacking some or all plumbing facilities than the statewide average. Crook and Johnson Counties have rates which exceed 11 percent. The percentage of homes deficient in plumbing facilities is greater in rural than urban areas.

The proportion of year-round units where the number of persons per room is greater than 1.01 ranges from 5.2 percent in Sheridan County to 10.7 percent in Crook County. This measure of crowding is less than the statewide average in Johnson, Natrona, Niobrara, and Sheridan Counties. Rural housing is more crowded than urban housing for each county except Johnson (Table 52).

Value of owner occupied housing and contract rent. The median value of an owner occupied home ranges from $8,400 in Niobrara County to $17,000 in Natrona County. Of the six counties, only Johnson and Natrona Counties exceed the state median of $15,400. The median value is greater for an urban than a rural home except in Sheridan County.

The median monthly contract rent ranges from $58 in Niobrara County to $79 in Natrona County. Of the six counties only Crook and Natrona Counties exceed the state median of $73. While urban rental payments are higher than rural rents in Johnson and Natrona, the opposite is true in Sheridan and Weston Counties (Tables 53 & 54).

Education

In the Powder River Basin region, there are 12 unified school districts which had a combined fall 1973 enrollment of 26,754 students, accounting for 31.3 percent of the state's total (Table 55). The region has a total of 103 elementary schools, 16 junior high schools, 18 senior high schools and three special education schools. The average student to teacher ratio is 18.5 to 1, and no school is on double session.

On the average, the region had a higher assessed valuation and higher effective expenditure per pupil in average daily membership (ADM) than state averages for the 1972-73 school year (Appendix C, Table 61). Campbell County ranked number one in the state with the highest assessed valuation and effective expenditure per pupil in ADM. Converse County has the state's second highest assessed valuation per pupil in ADM.

In the 1972-73 school year, Powder River Basin school districts on the average derived more revenues from district and county sources and less from state and federal sources than the state on the whole (Appendix C, Table 62). School district revenues accounted for more than 50 percent of the total school revenue receipts in Campbell (58.5%), Converse (54.8% and 52.4% for two districts), and Johnson (53.0%) Counties. Natrona County and Sheridan County unified school districts required the most state and federal assistance.

Campbell County

The Campbell County Unified School District consists of 19 elementary schools, one junior high school, and one senior high school and had a total fall 1973 enrollment of 3,060 students and an average student to teacher ratio of 15 to 1 (Table 55). In the 1972-73 school year, the county had the state's highest assessed valuation ($48,288) per pupil and the state's highest effective

Table 55

Fall Enrollment, Pupils/Teacher Ratio, and Number of Public Schools in Powder River Basin Counties, Region, and State for Fall 1973

County or Area	Fall Enrollment	Pupils/ Teacher	Number of Schools Sr.High	Jr.High	Elementary	Special	Total
Campbell							
1 Gillette	3,060	15.0	1	1	19	-	21
Converse							
1 Douglas	1,104	15.5	1	1	9	-	11
2 Glenrock	679	21.4	1	1	4	-	6
Crook							
1 Sundance	1,187	14.1	3	3	10	-	16
Johnson							
1 Buffalo	1,209	16.3	2	-	7	-	9
Natrona							
1 Casper	13,181	21.5	3	3	28	2	36
Niobrara							
1 Lusk	616	14.4	1	1	8	-	10
Sheridan							
1 Ranchester	660	15.7	2	2	4	-	8
2 Sheridan	3,291	20.3	1	2	8	1	12
3 Clearmont	123	8.0	1	-	2	-	3
Weston							
1 Newcastle	1,266	16.1	1	1	3	-	5
7 Upton	378	13.5	1	1	1	-	3
Region	26,754	18.5	18	16	103	3	140
State Totals	85,391	18.7	71	42	268	5	386

Source: Wyoming State Department of Education, Division of Management Information Services (1974).

expenditure ($1,219) per pupil in average daily membership (Appendix C, Table 61). During the same school year, approximately 95.4 percent of the total 5.4 million dollar school revenue receipts came from district (58.5%) and county (36.9%) revenues with only 4.5 percent from the state and 0.09 percent from the Federal Government (Appendix C, Table 62).

Public schools in Gillette. The City of Gillette has five elementary schools, one junior high school, and one senior high school. Table 56 indicates the grade levels, current enrollment, maximum enrollment capacity, acreage and structural type of each city school. At present, student enrollments are under capacity in elementary schools and the senior high school by 13.8 percent and 45.4 percent, respectively, and are over capacity in the junior high school by 7.5 percent. The current student to teacher ratio averages 15 to 1 with a maximum acceptable limit of 20 pupils per teacher.

Three elementary schools--Hillcrest, Northside and Stocktrail--are relatively new (built in 1971) and use the open classroom teaching concept which allows for grade flexibility. Eastside Elementary School is currently located in temporary module unit trailers on land leased from the National Guard and will be replaced by fall 1975 with a new 350-pupil capacity elementary school on a three-acre site.

The Campbell County Junior High School has a current enrollment of 699 pupils located in seven scattered buildings, including the old junior high school facilities, three parts of the old senior high school, several wooden annex buildings, and an old, hazardous, wooden church building. With a maximum enrollment capacity of 650 students, the school may realize a projected fall 1974 enrollment of 750 which exceeds its maximum capacity by 15.4 percent. County residents recently approved a $2.5 million school district bond issue to build new junior high school facilities. This school will be completed by

Type & Name of Public School	Grade Levels	Current Enrollments	Maximum Enrollment Capacity	% of Max. Enrollment Capacity	School Site Acreage	Structural Type
ELEMENTARY						
1. Hillcrest	1-6	293	350	83.7	6-7	Permanent, built in 1971
2. Northside	K-6	307	350	87,7	3	Permanent, built in 1971
3. Stocktrail	4-6	242	350	69.1	9	Permanent, built in 1971
4. Westside	1-3	226	225	100.4	2	Octogon & mobile module units
5. Eastside*	K-6	332	350	94.7	-	Temporary, mobile trailers
SUBTOTAL		1,400	1,625	86.2		
JUNIOR HIGH						
1. Campbell County**	7-9	699	650	107.5	12	7 separate buildings
SENIOR HIGH						
1. Campbell County***	10-12	601	1,100	54.6	40	Permanent, built in 1972
TOTALS		2,700	3,375	80.0		

*Will be replaced by new 350 student capacity elementary school on 3-acre site in Fall 1975.

**New junior high facilities to be completed by Fall 1975 and with facilities at the old high school will accommodate a maximum enrollment of 1,100 pupils.

***Existing facility can be expanded to accommodate an additional 400 students.

Source: Mr. J.O. Reed, School Superintendent, Campbell County Unified School District, March 22, 1974.

Table 56

Public Schools in Gillette, Campbell County
1974

fall 1975 and, with use of three parts of the old high school, will accommodate a maximum enrollment of 1,100 students.

The Campbell County High School, built in 1972, has 601 enrolled students and a maximum capacity of 1,100 students. The existing school facility on a 40-acre site has been designed to incorporate building additions to accommodate an additional 400 students.

In addition to existing school sites, the school district owns property at two sites (south and northwest of Gillette) which will be utilized to meet future demands and when funding becomes available.

County rural schools. There are 14 rural schools with a total of 322 students in grades K through 8 and 33 teachers. Table 57 provides the current enrollment, maximum enrollment capacity, and structural type of each rural school. Enrollments at these schools range from 2 to 74 pupils and are presently under capacity in all but one school (Gap). Most Junior high and all senior high school students from rural areas are bussed to public schools in Gillette.

Converse County

The county has two unified school districts--Douglas and Glenrock--which together had a fall 1973 enrollment of 1,783 students. In comparison with all other Wyoming counties, the combined 1972-73 school year figures from both districts placed Converse County second in the state with a $38,679 assessed valuation per pupil in ADM and above the state average in effective expenditures ($1,067) per pupil in ADM (Appendix C, Table 61).

Douglas Unified School District #1. This school district is the largest in Converse County with a fall 1973 enrollment of 1,104 students, an average student-teacher ratio of 15.5 to 1, and a school inventory of nine elementary schools and one junior-senior high school (Table 55). In 1972-73,

Name of School	Grade Levels	Current Enrollment	Maximum Enrollment Capacity	% of Max. Enrollment Capacity	Structural Type
Alcott	K-8	43	55	78.2	2-room frame bldg; metal bldg; mobile trailer
Bates Creek	K-8	2	10	20.0	Mobile trailer unit
Bundy	K-8	15	24	62.5	Old, 2-room frame, permanent building
Cactus	K-8	5	11	45.5	Mobile home trailer
Gap	K-8	19	15	126.7	2-room, wood frame building
Highway	K-8	15	25	60.0	2-room, wood frame building
Little Powder	K-8	26	30	86.7	2-room, wood frame building
Rawhide	K-8	26	30	86.7	Mobile trailer unit
Rimrock	K-7	1	6	16.7	Mobile trailer unit
Recluse	K-8	65	80	81.3	Excellent 6-room, wood frame building
Rozet	K-8	74	80	92.5	Excellent, 6-room building, plus a gymnasium
Teckla	K-8	2	6	33.3	Mobile trailer unit
Savageton	K-8	13	22	59.1	Mobile trailer unit
Wyodak	K-4	16	22	72.7	Temporarily closed, remodeling 2-room building
TOTALS		322	416	77.4	

Source: Mr. J. O. Reed, School Superintendent, Campbell County Unified School District, March 22, 1974.

Table 57

Rural Public Schools of Campbell County
1974

the district had a highly favorable assessed valuation of $44,417 per pupil in ADM and expended $1,107 per pupil, more than the $948 state average (Appendix C, Table 61). The majority of the total $1.4 million school revenue receipts came from the district (54.8%) and county (38.7%) with only 6.4 percent from the state and 0.12 percent from the Federal Government (Appendix C, Table 62).

The City of Douglas (population of 2,677) has one elementary and one junior-senior high school. Table 58 indicates the grade levels, current enrollment, maximum enrollment capacity, acreage, and structural type of each city school. Student enrollments are presently under capacity in the elementary school and junior-senior high school by 9.5 and 10.8 percent, respectively. The maximum acceptable student-teacher ratio is 20 to 1.

The Douglas Elementary School (grades K-6) has a current enrollment of 543 pupils and consists of the South and North Grade school sites and temporary classrooms at the fairgrounds. This school will be replaced by a new elementary facility with a maximum student enrollment capacity of 600 students by fall 1975.

The Converse County Junior-Senior High School (grades 7-12) has 535 enrolled students with a maximum capacity for 600. Upon completion of the new elementary school, the junior-senior high school will acquire the North Grade elementary school facilities and increase its maximum capacity to 750 pupils. The district will have a recreation complex completed by mid-1975 to include a gymnasium, 25-meter AAU swimming pool, facilities for handball, weight lifting, wrestling, and a rifle range.

In addition to existing school sites, the district owns 25 acres across the river which will be available for future school construction.

There are eight rural public schools in the district with a total of 58 pupils in grades K through 8. Table 58 provides the grade levels, current

Type & Name of School	Grade Levels	Current Enrollment	Maximum Enrollment Capacity	% of Max. Enrollment Capacity	School Site Acreage	Structural Type
CITY OF DOUGLAS						
ELEMENTARY						
1. Douglas*	K-6	543	600	90.5		Buildings at three sites
JR.-SR. HIGH						
1. Converse	7-12	535	600**	89.2	12	Permanent bldgs., built in 1953 1961, 1965
RURAL SCHOOLS						
1. Drag Creek (Bill)***	K-8	11	25	44.0		Medium, 2-room frame building
2. Nachtman***	K-8	7	20	35.0		Permanent, metal building
3. Ranch School***	K-8	2	5	40.0		Mobile trailer unit
4. Ranch School***	K-8	1	5	20.0		Mobile trailer unit
5. Pleasant Valley	K-8	11	11	100.0		
6. Wagon Hound	K-8	5	6	83.3		
7. White	K-8	14	24	58.3		
8. Shawnee	K-8	7	24	29.2		Modern, 2-room frame building

*Will be replaced by a new 600-student capacity elementary school on a 65-acre site by Fall 1975.

**Capacity will be increased by 150 pupils when elementary school vacates North Grade elementary facilities.

***Schools located in northern section of county near mining and industrial activities.

Source: Mr. Millard Meredith, School Superintendent, Converse County Unified School District #1, March 22, 1974.

Table 58

Public Schools
Converse County (Douglas) Unified School District #1
1974

maximum enrollment capacity, and structural type of each school. Enrollments range from one to 14 students and are currently under capacity at all schools. Most junior-senior high school students from rural areas attend Converse County Junior-Senior High School in Douglas.

Glenrock Unified School District #2. The Glenrock School District consists of four elementary schools and one junior-senior high school and had a total fall 1973 enrollment of only 679 students and an average student-teacher ratio of 21.4 to 1. In the 1972-73 school year, the district had a higher assessed valuation ($29,876) and higher effective expenditure ($1,004) per pupil in ADM than the respective state averages. District (52.4%) and county (40.2%) revenues accounted for 92.6 percent of the total school revenue receipts ($812,977) with the small remainder coming from state and federal revenues. Since the district is currently at maximum debt, it cannot initiate any school bond issues.

The Town of Glenrock has one elementary and one junior-senior high school, both of which have enrollments under maximum capacity (Table 59). The Glenrock Grade School (K-6) has 385 pupils and occupies three buildings (built in 1918, 1954 and 1955) on a 3- to 4-acre site. The district intends to replace the 1918 building with an addition to existing facilities which will increase its maximum enrollment capacity from 425 to 600 students. The Glenrock Junior-Senior High school houses 315 pupils in a steel frame building (constructed in 1967) and is at 90.0 percent capacity in student enrollment. As soon as the district's debt is sufficiently reduced to allow issuance of school bonds, the junior-senior high school facilities will be expanded to include additional classrooms and a library, hopefully by spring 1975. This expansion will increase the school's maximum enrollment capacity from 350 to 500 pupils.

Type & Name of School	Grade Level	Current Enrollment	Maximum Enrollment Capacity	% of Max. Enrollment Capacity	School Site Acreage	Structural Type
GLENROCK						
ELEMENTARY						
1. Glenrock	K-6	385	425*	90.6	3-4	3 bldgs. built in 1918, 1954, 1958
JR.-SR. HIGH						
1. Glenrock	7-12	315	350**	90.0	3	Permanent, steel frame built in 1967
RURAL SCHOOLS						
1. Allerman	K-6	8	12	66.7	-	Permanent, wood frame building
2. Deer Creek	K-8	2	10	20.0	-	Permanent, wood frame building
3. Hasier	K-8	2	4	50.0	-	

*District intends to replace 1918 facility and increase enrollment capacity to 600 pupils.

**School facilities will be expanded to accommodate 500 pupils.

Source: Dr. Sheldon Henderson, School Superintendent, Converse County Unified School District #2, March 1974.

Table 59

Public Schools
Converse County (Glenrock) Unified School District #2
1972

The district has three rural schools with only 12 students in grades K through 8 (Table 59). Most junior high and senior high students in rural areas attend school in Glenrock.

Remaining six counties

Tables 63 through 69 in Appendix C indicate the grade levels, current enrollments and maximum enrollment capacities of public schools in Johnson, Sheridan, Natrona, Crook, Weston and Niobrara Counties.

Health and social services

Encompassing a broad range of medical and helping services, health and social services are a vital element in the socio-economic environment of a given area. Although often functioning in much the same manner, each incorporates a far different perspective. Best viewed as separate but complimentary service sectors, the following discussion deals with each as a distinct element in the socio-economic environment.

Health

With both preventive and curative functions ranging from diagnosis to treatment and supervision of physical, mental, emotional, and social problems, the health care services available to a community are both broad and diverse. The following discussion centers upon the three primary elements in the health care system--manpower, facilities, and services.

Manpower. The various categories of health manpower include physicians, dentists, nurses (R.N.'s and L.P.N.'s), optometrists, pharmacists, dental hygienists, and sanitarians. Due to the sparsely settled development pattern common to both the Powder River Basin and the State of Wyoming, the distribution of health manpower has developed into a general pattern of urban

	Campbell	Converse	Crook	Johnson	Natrona	Niobrara	Sheridan	Weston	Region	Wyoming
Physicians	7	4	1	4	67	1	25	3	112	363
Dentists	3	2	1	2	27	1	12	1	49	157
R.N.'s	30	24	15	17	298	10	118	20	532	1,559
L.P.N.'s	13	5	0	8	123	3	26	8	186	440
School Nurses	5	2	1	1	10	0	2	0	21	54
P.H.N.'s	2	0	0	0	5	0	2	0	9	40
Pharmacists	7	5	1	8	39	1	25	4	90	287
Optometrists	2	1	0	½	6	1	1½	1	13	41½
Dental Hygienists	2	0	0	0	7	0	5	0	14	25
Sanitarians	1 (1)*	*	*	*	1(2)	*	*	*	5	14

*Covered by District #3 (Gillette)
(-) Apprentices

Source: Wyoming Department of Health and Social Services, Comprehensive Health Planning, Wyoming Health Profiles 1972.

Table 60

Health Manpower
Powder River Basin

Table 61

Existing and Recommended Health Manpower - Population Ratios

	Campbell	Converse	Crook	Johnson	Natrona	Niobrara	Sheridan	Weston	Wyoming	Recommended Ratios
Population (1970)	12,957	5,938	4,535	5,587	51,264	2,924	17,852	6,307	332,416	
Population Ratios*	**									
Physicians	1,851	1,485	4,535	1,396	765	2,924	714	2,102	916	1,000
Dentists	4,319	2,969	4,535	2,794	1,899	2,924	1,488	6,307	2,117	1,600
R.N.'s	432	247	302	329	172	292	151	315	213	285
L.P.N.'s	997	1,188	---	698	417	975	687	788	755	614
Optometrists	6,479	5,939	---	11,174	8,544	---	11,901	6,307	8,010	7,000
Sanitarians***	13,518	---	---	---	---	---	5,951	---	23,744	12,000
Pharmacists	1,851	1,188	4,535	698	1,314	2,924	714	1,577	1,158	N.A.
School Nurses	2,591	2,969	4,535	5,587	5,126	---	8,926	---	6,156	N.A.
P.H.N.'s	6,479	---	---	---	10,252	---	8,926	---	8,310	N.A.
Dental Hygienists	6,479	---	---	---	7,323	---	3,570	---	13,297	N.A.

*Population Ratio = number of persons per physician, dentist, R.N., etc.
**Population for District #3, aggregated over 7 counties = 27,035.
***Ratio includes apprentice sanitarians.

Source: Wyoming Department of Health and Social Services, Comprehensive Health Planning, Wyoming Health Profiles 1972.

adequacy and rural scarcity. Tables 60 and 61 present the numbers and population ratios of physicians, dentists, etc., currently practicing in each of the eight counties in the Powder River Basin region.

As Table 61 indicates, Campbell and Converse Counties are now below the state average for ratios of population to physicians, dentists, R.N.'s, and L.P.N.'s. Ranging from 30 to 100 percent below state averages, this indicates a definite scarcity of health manpower which, when viewed in relation to recommended ratios, becomes still more severe. Recommended ratios require from 2 to 275 percent more manpower than currently exists in these counties. This substantial manpower gap is particularly serious with respect to dentists, physicians, and licensed practical nurses (L.P.N.'s). In Campbell County, dentists serve 170 percent more persons than the recommended ratio, physicians serve 85 percent more persons, L.P.N.'s serve 62 percent more persons, and R.N.'s serve 52 percent more than recommended. Converse County, although not so severely underserved, is nevertheless short of L.P.N.'s, dentists, and physicians. Gaps of 93 percent 86 percent and 48 percent, respectively, reveal shortages which when compared with state averages are still substantially below statewide ratios.

Table 61 also reveals a clear distinction between urban and rural counties in the Powder River Basin region. While Sheridan and Natrona Counties are below state averages for all but optometrists, the remaining four rural counties show much the same pattern as Campbell and Converse Counties.

Facilities. Table 62 presents estimates of hospital utilization and bed needs for each of the eight counties in the Powder River Basin region. Bed needs, an indicator of general facility requirements, provides a standard unit from which to measure present and projected facility needs. Based upon present utilization rates per 1,000 population, most of the Powder River Basin area has a sufficient number of acute and extended care (nursing home) beds.

Table 62

Health Facility Utilization and Need (1970)

General Hospitals	Campbell	Converse	Crook	Johnson	Natrona	Niobrara	Sheridan	Weston	Region	Wyoming
Number Beds	31	32	16	26	298	24	89	42	495	1,693
Patient Days (1971)	6,468	4,218	1,432	6,366	79,375	3,639	20,087	7,478	141,181	363,030
Utilization Rate*	779	1,029	477	1,273	1,407	2,022	1,225	971	1,148	1,092
Bed Need	31	24	15	31	267	22	75	35	500	1,413
Bed Shortage	--	--	--	5	--	--	--	--	--	--
Bed Excess	--	8	1	--	31	2	14	7	58	280
Extended Care Facilities										
Number Beds	125	59	0	40	195	0	96	42	557	1,412
Patient Days	35,980	19,911	--	10,277	63,139	--	29,971	10,125	169,403	439,146
Utilization Rate***	43,349	31,307		14,536	14,445		9,282	18,785	16,463	13,211
Bed Need	123	73	17**	42	208	24**	122	42	651	1,815
Bed Shortage	--	14	17	2	13	24	26	--	94	403
Bed Excess	2	--	--	--	--	--	--	--	--	--

*1971 Patient days per 1000 population
**Projected by Wyoming Department of Health and Social Services
***Patient days on population 65 or over
Source: Wyoming Department of Health and Social Services, Wyoming Medical Facilities Planning and Construction. Bed need estimates based on Hill-Burton and Hill-Harris formula.

With 31 acute beds and 125 extended care beds, Campbell County appears in a good position to provide an acceptable level of service to its present population. However, in this particular case the number of beds is a poor indicator of available service because it does not show that one hospital is closed due to an inadequate number of physicians. The utilization rates, 799 acute patient days per 1,000 population and 43,349 extended care patient days on population 65 and over are substantially different from the statewide rates. While extended care rates may be attributed to use by nonlocal persons, acute rates may be due to either actual lower use (reduced morbidity in a younger population) or the seeking of alternate, nonlocal sources of acute care.

Converse County, with 32 acute and 59 extended care beds, is able to provide adequate levels of acute and extended care. As with Campbell County, Converse County's acute utilization rate is below the state average, but its extended care rate is above the average.

For the most part, the remaining counties in the Powder River Basin area provide an adequate number of acute and extended care beds. The exceptions, Crook and Niobrara Counties, have no extended care facilities. Residents of these areas must go elsewhere for such care.

Services. Besides inpatient and outpatient medical services, the health care system in the Powder River Basin region offers a wide variety of mental health services including alcoholism counseling and treatment, individual, group and family counseling, psychotherapy, and parent-teacher effectiveness training. Functional types of services include inpatient, outpatient and partial hospitalization, emergency services and education-consultation. In the Powder River Basin region, services are coordinated by the Northern Wyoming Mental Health Center (Sheridan, Crook, Campbell, Johnson, and Weston Counties) and the Central Wyoming Counseling Center (Natrona, Niobrara, and Converse Counties.) Of the 18 professional personnel serving this eight-county area, 11 are employed by the Northern Wyoming Mental Health Center and seven are employed by the Central Wyoming Counseling Center.

Alcoholism counseling and treatment is provided through the mental health organizations. Three staff members, two in the five-county area and one in the three-county area, spend 100 percent of their time on alchohol and alcohol related problems. As with the state as a whole, the incidence of such problems is quite high in the Powder River Basin area where as many as 10 percent of the population may be considered to have a "drinking problem,"[1] and a considerable number of arrests are alcohol related. (See Law enforcement and arrests in this chapter.)

According to staff members of the Wyoming Department of Health and Social Services, the problem of alcohol and alcohol treatment is compounded by its high, cultural acceptance. Liquor is an ingrained part of the "code of the way"; it is often represented as the only available recreational activity. In many areas, the availability of recreational outlets has changed little since former days, and alcohol thus retains its former role.

With this high cultural acceptance, many people deny that they have a "drinking problem." Social sanctions, particularly among persons with weak or nonexistent community ties, are delayed. Treatment is frequently delayed to the point at which its need is no longer desired.

Most mental health services in the Powder River Basin are nonpsychiatric in nature. Counseling in such areas as family relations, adjustment, and child management constitutes the bulk of the caseload.

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[1]This is an informal estimate of one of the alcoholism program staff members.

In Campbell County, approximately 100 mental health and 75 alcohol related cases are handled at a given time.[1] Between the two-man local staff and the part-time services of the alcohol treatment group, 11 man-days per week of mental health services are currently available in Gillette. Of the approximately 600 cases treated in calendar year 1973, the majority reflected regional trends. Family relations, children's performance at school, depression, and general adjustment are the most regularly occurring problems. Stresses arise from moving into a new community, adapting to a possibly new and strange environment, and adjusting to the strains of overloaded public services and a temporary life-style (mobile homes, schools, medical services, etc.)[2]. Thus, although Campbell County's mental health problems are substantially the same as in other areas of the region, the underlying causes are more readily identified.

According to alcohol treatment staff members, alcohol is frequently an underlying element in such other problem areas as truancy, family relations, and child management. In addition, as many as 12 percent of the population of Campbell County may be characterized as having a "drinking problem." Since 1970, the alcohol case load has declined from high-boom-related levels. However, as growth is now beginning to again be felt, caseload is again increasing.

In Converse County, approximately 30 mental health and 40 alcohol related cases are handled at a given time. The local office manager assisted by the Casper-based alcohol counselor provides approximately six man-days per week of mental health services.

As a relatively stable ranching area, the caseload in Converse County reflects the general composition and incidence of mental health problems throughout the Powder River Basin ranching region.

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[1]Estimates of local staff members.

[2]This relatively qualitative assessment comes from the professional judgement and experience of local staff members.

Social services

Although usually conceptualized as public assistance or welfare, social services refers to a broader range of helping services. These include: adoption, homemaker and chore services, family planning, foster care, day care, home management, protective services, and family counseling. In the Powder River Basin region, the Division of Public Assistance and Social Services provides these as well as referral services in the areas of health, training, education, and housing.

With a 28-member staff, of which 6 are local directors and 22 are social workers, the Division of Public Assistance and Social Services maintains offices in each of the eight counties within the Powder River Basin area. Among the individual offices, the caseload varies from fewer than twenty per social worker in the more stable rural areas to upwards of 50 per worker in the rapidly developing areas.

Campbell County is perhaps the most overloaded of all the local offices. The Gillette office is manned by two full-time social workers who are assisted by the district director (2 days per week) and another part-time social worker (1½ days per week). Even so, the full time social workers report a current caseload of approximately 95. Based upon Wyoming standards for recommended maximum caseloads, the Gillette office is now handling approximately 15 cases above the maximum. The division is presently considering hiring an additional full time social worker to reduce this overload.

The Gillette office is almost exclusively limited to child protection cases. Although family counseling and assistance to unwed mothers are offered, the bulk of services is directed toward the investigation of foster homes and the placement of children in such homes.

Since the mid-60's, large numbers of persons without strong community ties have migrated to the Gillette area. This influx, compounded by cramped living conditions, lack of recreational outlets, and frequent lack of commitment to the community have produced a disproportionate incidence of dysfunctional families in which child abuse and family discord are far more likely to occur. Social services in the Gillette area reflect this situation.

The Douglas office consists of a director and two full time social workers. Although caseloads have been increasing, the present level is approximately one-half the recommended maximum. While caseloads are generally more varied than in Campbell County, the Division of Public Assistance and Social Service reports an increasing proportion of child protection cases.

Social services in the remaining six counties reflect the urban/rural nature of each county. While Natrona and Sheridan have fairly substantial staffs and a relatively heavy caseload, Johnson, Niobrara, Weston, and Crook each have only one or two social workers and a relatively light caseload.

Law enforcement

This section discusses law enforcement in two parts: an assessment of sheriff and police departments in the basic study area and the incidence of crime and number of arrests.

Sheriff and police departments

Every county in the Powder River Basin has a sheriff's department and at least one municipal police department. The jurisdictional area of each police department is within municipal boundaries, whereas the sheriff's jurisdiction covers the entire county, including municipalities.

In Table 63, the sheriff's department of each county is described in terms of staff size (full and part-time sworn officers and civilians),

Table 63

Sheriff's Department
Powder River Basin Region
1972-1973

County	Total Population*	Sworn Officials		Civilian Staff		Full-Time Sworn Officer Per 1,000 Population	Population Served Per Full-Time Officer	Land Coverage Per Full-Time Officer (Sq. Miles)
		Full-Time	Part-Time	Full-Time	Part-Time			
Campbell	12,957	5	-	3	1	0.38	2,591	951
Converse	5,938	4	-	2	-	0.67	1,484	1,070
Crook	4,535	4	2	1	-	0.88	1,134	720
Johnson	5,587	2	1	1	3	0.35	2,793	2,087
Natrona	51,264	30	-	7	-	0.58	1,708	178
Niobrara	2,924	2	-	-	-	0.68	1,462	1,307
Sheridan	17,852	4	-	-	-	0.22	4,463	633
Weston	6,307	2	2	2	-	0.31	3,153	1,203

*1970 Census of Population.

Source: State of Wyoming Governor's Planning Committee on Criminal Administration, (Criminal Justice System Data Book - 1972), State of Wyoming (January 1974). Cheyenne (January 1974).

full-time officer manpower per 1,000 population, number of persons served, and number of square miles covered per full-time sworn officer. Table 64 provides the same information for police departments, except for land coverage per policeman.

Campbell County Sheriff's Department. In fiscal year 1973, the sheriff's department staff included five full-time sworn officers and four civilians. The department has jail facilities for 38 persons (28 male and 10 female) and an 850 square foot, minimum security apartment for eight prisoners. The department's radio system allows radio contact with ambulance service, Gillette Police Department, city and county fire departments, Wyoming Highway Patrol, and the sheriff's department. The sheriff's department functions as the emergency operative center for Campbell County in the event of a crisis. In 1973, one full-time officer served approximately 2,600 persons and covered 950 square miles in the county.

Gillette Police Department. The department had 16 full-time sworn policemen, one part-time policeman, and six full-time civilians in fiscal year 1973. The city has one full-time policeman per 450 population, or 2.22 policemen per 1,000 population, which is considered adequate in comparison to state (1.64) and national (2.0) averages.

Converse County Sheriff's Department. The department is headquartered in Douglas and includes four full-time sworn officers and two full-time civilians. Each full-time officer serves approximately 1,484 population and covers 1,070 square miles in the county. The existing county jail in Douglas is considered inadequate in terms of holding capacity and facility condition. The new county courthouse in Douglas will include new correctional facilities for the sheriff's department.

Table 64

Municipal Police Departments
Powder River Basin Region
1972-1973

City/Town	County	City/Town Population*	Sworn Officials		Civilian Staff		Number of Full-Time Officers Per 1,000 Population	Number of People Served Per Full-Time Officer
			Full-Time	Part-Time	Full-Time	Part-Time		
Gillette	Campbell	7,194	16	1	6	-	2.22	450
Douglas	Converse	2,677	6	-	4	-	2.24	446
Glenrock	Converse	1,515	5	-	-	-	3.30	303
Sundance	Crook	1,056	1	6	-	-	0.94	1,056
Buffalo	Johnson	3,395	6	-	-	1	1.76	566
Casper	Natrona	39,361	56	-	17	-	1.42	703
Mills	Natrona	1,724	2	-	-	-	1.16	862
Lusk	Niobrara	1,495	4	-	-	-	2.67	374
Sheridan	Sheridan	10,856	17	1	6	-	1.56	638
Newcastle	Weston	3,432	9	-	4	1	2.62	381
Wyoming							1.64	610
United States							1.47	680

*1970 Census of Population

Source: Criminal Justice System Data Book - 1972, Governor's Planning Committee on Criminal Administration, State of Wyoming, January 1974.

Douglas Police Department. In fiscal year 1973, the department had six full-time policemen and four full-time civilians located in adequate facilities. The city jail has a capacity for eight men and six women or juveniles, and new facilities with increased capacity are planned with financing from Law Enforcement Assistance Act funds. The city is adequately served with one full-time policeman per 446 persons (or 2.24 police per 1,000 population).

Glenrock Police Department. The city has five full-time policemen. There is one full-time officer for every 303 citizens or approximately 3.3 full-time policemen per 1,000 population, which is very adequate coverage.

Johnson County Sheriff's Department. In fiscal year 1973, the department had only two full-time sworn officers and one part-time officer with a civilian staff of one permanent and three part-time workers. The main office in Buffalo is too small for efficient operations with only 124 square feet of office space. The jail serves both the county and the City of Buffalo and is inadequate since its capacity is for only eight men and females must be transported to Sheridan jail facilities. There is one full-time officer for every 2,793 persons and 2,087 square miles.

Buffalo Police Department. The department consists of six full-time policemen and one part-time civilian, providing the city with one full-time officer per 566 population or 1.8 policemen per 1,000 persons. At present, the department is overcrowded in 128-square feet of office space and is currently sharing county jail facilities with the sheriff's department. A city and county building complex is proposed for construction within the next few years and will include facilities for the City Police, County Sheriff, Highway Patrol, City Attorney, central communications and records office, holding facilities and a jail for 35 persons.

Sheridan County Sheriff's Department. The department had a staff of four full-time officers in fiscal year 1973, providing the county with one full-time officer per 4,463 population (highest in the 8-county region). The department plans to move from the Courthouse in Sheridan to large office spaces at the county jail, which has all facilities for 12 males, four females, and six juveniles.

Sheridan Police Department. The police staff includes 17 full-time policemen, one part-time officer, and six full-time civilians. The city has one full-time policeman per 638 population or 1.56 officers per 1,000 population which is below the state (1.64) average. The department has over 8,000 square feet of office space in the city hall with a detention facility for 12 persons. The department has applied for a federal matching grant to remodel its present facilities and may increase its staff size.

Crook, Natrona, Niobrara, and Weston Counties. Refer to Tables 63 and 64 for manpower and coverage information concerning law enforcement agencies in these remaining four counties. The number of full-time policemen per 1,000 population was below state (1.64 officers) and national (2.0 officers) averages in the municipalities of Sundance (0.9), Casper (1.42), and Mills (1.16).

Incidence of crime and arrests

Table 65 shows the incidence of major crimes occurring in the Powder River Basin counties during calendar year 1972. The incidence of crime per 1,000 population has been calculated to facilitate comparisons between counties and with regional and state averages. Table 66 provides the same information for other categories of crime and arrests.

Of the major crimes indicated in Table 65, the incidence of criminal homicide, forcible rape, and robbery is very low. The region, excluding Natrona

	Total Population	Criminal Homicide		Forcible Rape		Robbery		Aggravated Assault	
		Number of Incidence	Crime Per 1000 Popu.	Number of Incidence	Crime Per 1000 Popu.	Number of Incidence	Crime Per 1000 Popu.	Number of Incidence	Crime Per 1000 Popu.
Campbell	12,957	1	0.1	2	0.1	4	0.3	11	0.8
Converse	5,938	0	0.0	0	0.0	2	0.3	7	1.2
Crook	4,535	0	0.0	0	0.0	0	0.0	1	0.2
Johnson	5,587	0	0.0	0	0.0	0	0.0	6	1.1
Natrona	51,264	3	0.1	4	0.1	28	0.5	125	2.4
Niobrara	2,924	0	0.0	0	0.0	0	0.0	0	0.0
Sheridan	17,852	0	0.0	2	0.1	2	0.1	45	2.5
Weston	6,307	1	0.1	0	0.0	0	0.0	8	1.3
Region	107,364	5	0.05	8	0.07	36	0.3	203	1.9
Wyoming	332,416	20	0.06	57	0.17	109	0.3	743	2.2

Source: State of Wyoming, (January 1974), Governor's Planning Committee on Criminal Administration, Criminal Justice System Data Book - 1972.

Table 65

Major Crime Incidence in Powder River Basin Counties
1972

Table 65 (Cont'd)

Major Crime Incidence in Powder River Basin Counties
1972

	Total Population	Burglary		Larceny		Auto Theft		County/Area Totals	
		Number of Incidence	Crime Per 1000 Popu.	Number of Incidence	Crime Per 1000 Popu.	Number of Incidence	Crime Per 1000 Popu.	Total No. Incidence	Crime Per 1000 Popu.
Campbell	12,957	51	3.9	207	16.0	16	1.2	292	22.5
Converse	5,938	17	2.9	37	6.2	2	0.3	65	10.9
Crook	4,535	3	0.7	5	1.1	2	0.4	11	2.4
Johnson	5,587	20	3.6	47	8.4	10	1.8	83	14.8
Natrona	51,264	531	10.3	1,197	23.3	217	4.2	2,105	41.1
Niobrara	2,924	0	0.0	2	0.7	0	0.0	2	0.7
Sheridan	17,852	109	6.1	354	19.8	25	1.4	537	30.1
Weston	6,307	15	2.4	41	6.5	0	0.0	65	10.3
Region	107,364	746	6.9	1,890	17.6	272	2.5	3,160	29.4
Wyoming	332,416	1,986	6.0	6,700	20.1	624	1.9	10,239	30.8

Source: State of Wyoming (January 1974), Governor's Planning Committee on Criminal Administration, Criminal Justice System Data Book - 1972.

County, realized only two criminal homicides, four forcible rapes, and eight robberies. Larceny is the region's leading crime with the highest incidence in all but two counties, Johnson and Crook, where it ranks second.

In other crimes and arrests (Table 66), a high percentage of arrests stem from alcohol-related problems--public drunkenness, driving while intoxicated, and violation of liquor laws. Campbell County had the state's highest incidence of drunk driving per 1,000 population, Johnson County ranked second in liquor law violations per 1,000 population, and Sheridan County had the state's second highest occurrence of public drunkenness per 1,000 population. Incidence of other arrests--arson, forgery, embezzlement, gambling, vagrancy, offense against family and children, and prostitution--is very low in Powder River Basin counties.

Campbell County. The ten leading categories of crime or arrest occurring in Campbell County are provided in Table 67. The county exceeds state averages for crime incidence per 1,000 population in all but three categories--larceny, burglary, and auto theft. However, larceny is the county's leading crime problem. The county also has the state's highest incidence of drunk driving per 1,000 population and an extraordinarily high occurrence of vandalism.

Remaining six counties. Table 69 presents the most frequent types of crime or arrest in Johnson, Sheridan, Natrona, Niobrara, Crook, and Weston Counties. In 1972 Natrona, the state's second most populated county, realized a higher incidence of crimes than most other Wyoming counties, with the state's highest incidence of burglaries and auto theft and ranking fourth in the state for larceny, public drunkenness, drug law violations, and other assaults.

Table 66

Crime Incidence and Arrests in Powder River Basin Counties
1972

	Total Population	Public Drunkeness Number	Public Drunkeness Per 1000 Popu.	Liquor Law Violations Number	Liquor Law Violations Per 1000 Popu.	Disorderly Conduct Number	Disorderly Conduct Per 1000 Popu.	Driving Intoxicated Number	Driving Intoxicated Per 1000 Popu.	Drug Law Violation Number	Drug Law Violation Per 1000 Popu.	Other Assults Number	Other Assults Per 1000 Popu.
Campbell	12,957	133	10.3	81	6.2	73	5.6	111	8.6	43	3.3	7	0.5
Converse	5,938	0	0.0	4	0.7	0	0.0	6	1.0	20	3.4	0	0.0
Crook	4,535	0	0.0	1	0.2	3	0.7	10	2.2	0	0.0	0	0.0
Johnson	5,587	27	4.8	85	15.2	1	0.2	14	2.5	3	0.5	4	0.7
Natrona	51,264	541	10.5	210	4.1	107	2.1	160	3.1	204	4.0	113	2.2
Niobrara	2,924	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0
Sheridan	17,852	319	17.9	100	5.6	57	3.2	44	2.5	23	1.3	19	1.1
Weston	6,307	19	3.0	20	3.2	7	1.1	20	3.2	2	0.3	4	0.6
Region	107,364	1,039	9.7	501	4.7	248	2.3	365	3.4	296	2.7	147	1.4
Wyoming	332,416	2,815	8.5	1,520	4.6	1,217	3.7	1,064	3.2	779	2.3	425	1.3

Source: State of Wyoming, (January 1974), Governor's Planning Committee on Criminal Administration, Criminal Justice System Data Book - 1972.

	Total Population	Vandalism		Fraud		Vagrancy		Forgery		All Other*	Total Arrests
		Number	Per 1000 Popu.	Number	Per 1000 Popu.	Number	Per 1000 Popu.	Number	Per 1000 Popu.	Number	Number
Campbell	12,957	67	5.2	17	1.3	0	0.0	2	0.1	80	614
Converse	5,938	0	0.0	8	1.3	0	0.0	1	0.2	46	85
Crook	4,535	0	0.0	0	0.0	0	0.0	0	0.0	13	27
Johnson	5,587	2	0.3	4	0.7	2	0.3	0	0.0	19	161
Natrona	51,264	2	0.0	64	1.2	47	0.9	15	0.3	531	1,994
Niobrara	2,924	0	0.0	0	0.0	0	0.0	0	0.0	11	12
Sheridan	17,852	11	0.6	2	0.1	4	0.2	28	1.6	91	698
Weston	6,307	1	0.1	8	1.3	1	0.1	1	0.1	47	130
Region	107,364	83	0.8	103	0.9	54	0.5	47	0.4	838	3,721
Wyoming	332,416	246	0.7	244	0.7	244	0.7	107	0.3	2,945	11,606

*All other includes arson, embezzlement, stolen property, weapons (carrying, possessing), prostitution and commercialized vice, sex offense (except forcible rape and prostitution), offense against family and children, check offense, and gambling, but excludes traffic offenses.

Source: State of Wyoming, (January 1974), Governor's Planning Committee on Criminal Administration, Criminal Justice System Data Book - 1972.

Table 66 (Cont'd)

Crime Incidence and Arrests in Powder River Basin Counties
1972

Table 67

The Ten Leading Types of Crime Incidence and Arrest
Campbell County, 1972

Type of Crime or Arrest	Number of Incidence	Incidence Per 1,000 Population County	State	County Rank
1. Larceny	207	16.0	20.2	9
2. Public Drunkenness	133	10.3	8.5	5
3. Driving Intoxicated	111	8.6	3.2	1
4. Liquor Law Violations	81	6.2	4.6	6
5. Disorderly Conduct	73	5.6	3.7	3
6. Vandalism	67	5.2	0.7	1
7. Burglary	51	3.9	6.0	10
8. Drug Law Violation	43	3.3	2.3	6
9. Fraud	17	1.3	0.7	3
10. Auto Theft	16	1.2	1.9	11

Source: State of Wyoming, Criminal Justice System Data Book-1972, (January 1974).

Converse County. The five leading types of crime or arrest in Converse County are indicated in Table 68. Arrests or crime incidence per 1,000 population exceeded state averages in drug law violations and fraud cases.

Table 68

The Ten Leading Types of Crime Incidence and Arrest
Converse County, 1972

Type of Crime or Arrest	Number of Incidence	Incidence Per 1,000 Population County	State	County Rank
1. Larceny	30	6.2	20.2	16
2. Drug Law Violation	20	3.4	2.3	5
3. Burglary	17	2.9	6.0	13
4. Fraud	8	1.3	0.7	2
5. Aggravated Assault	7	1.2	2.2	6

Source: State of Wyoming, Criminal Justice System Data Book-1972, (January 1974).

Table 69

Leading Types of Crime Incidence and Arrest
Natrona, Johnson, Sheridan, Crook, Niobrara, and Weston Counties
1972

Type of Crime or Arrest	No. of Indidence	Incidence Per 1,000 Population		
		County	State	County Rank
Natrona County:				
1. Larceny	1,197	23.3	20.1	4
2. Public Drunkenness	541	10.5	8.5	4
3. Burglary	531	10.3	6.0	1
4. Auto Theft	217	4.2	1.9	1
5. Liquor Law	210	4.1	4.6	9
6. Drug Law	204	4.0	2.3	4
7. Driving Intoxicated	160	3.1	3.2	9
8. Aggravated Assault	125	2.4	2.2	7
9. Other Assaults	113	2.2	1.3	4
10. Disorderly Conduct	107	2.1	3.7	10
Johnson County:				
1. Liquor Law Violation	85	15.2	4.6	2
2. Larceny	47	8.4	20.1	14
3. Public Drunkenness	27	4.8	8.5	9
4. Burglary	20	3.6	6.0	12
5. Driving Intoxicated	14	2.5	3.2	12
Sheridan County:				
1. Larceny	354	19.8	20.2	5
2. Public Drunkenness	319	17.9	8.5	2
3. Burglary	109	6.1	6.0	6
4. Liquor Law Violation	100	5.6	4.6	7
5. Disorderly Conduct	57	3.2	3.7	8
Crook County:				
1. Driving Intoxicated	10	2.2	3.2	14
2. Larceny	5	1.1	20.1	21
3. Burglary	3	0.7	6.0	19
4. Disorderly Conduct	3	0.7	3.7	18
5. Auto Theft	2	0.4	1.9	17
Niobrara County:				
1. Larceny	2	0.7	20.1	22
2. Drug Law	1	0.3	2.3	21
Weston County:				
1. Larceny	41	6.5	20.1	15
2. Driving Intoxicated	20	3.2	3.2	8
3. Liquor Law Violation	20	3.2	4.6	12
4. Public Drunkenness	19	3.0	8.5	14
5. Burglary	15	2.4	6.0	15

Source: State of Wyoming, Criminal Justice System Data Book - 1972, (January 1974).

Fire Protection

This discussion of fire protection is based entirely on a recent study prepared for the Wyoming Department of Economic Planning and Development (Wirth-Berger Associates 1974). This study inventoried the fire department facilities for the Cities of Douglas and Gillette.

The Douglas fire department is comprised of 20 volunteers under the direction of a volunteer fire chief. The department has the following equipment: two 550 gpm pumping units, one 1,200 gallon tank unit with a sprayer, one rescue unit, and one ladder truck capable of reaching the third story of any building. Present ladder extensions reach a maximum height of three stories, while the tallest building in Douglas is five stories. However, hose capacity does exist to reach the fifth floor of the building. One pumping unit and the tank unit are provided by the county. There is adequate water pressure at all hydrants.

Douglas's volunteer fire department is probably adequate. It provides an average level of service for rural towns of its size. However, there should be more firemen since volunteer fire departments generally should have three times the number of firemen needed to man the equipment.

The fire department for Gillette is staffed by 30 volunteer firemen. It maintains two completely equipped trucks and one rescue van. One truck is nine years old with a 750 gpm pumper. The other is two years old with a 1,000 gpm pumper. All fire department vehicles, including the fire chief's car, are equipped with two-way radios which, through the police department switchboard, connect to all other emergency vehicles and offices in the Gillette area. The water supply is drawn from wells and kept in a storage tank above the city. In the past, the water supply has been occasionally low but, as yet, has not been inadequate. The only resource when the supply dwindles is to ask people to use less water in order to keep the reserves higher. This has not been necessary for several years. This spring the fire department will move to a new building which it will share with the county fire department.

The Gillette Fire Department is about average for a town of its size. However, the department is somewhat less than adequate because the available water flow is substantially below the town's assessed need, a ladder truck is needed, and the number of volunteer firemen, although adequate to man the equipment, is below the recommended number.

<u>Water and sewer</u>

As Campbell and Converse Counties are the principal areas impacted by coal and other industrial development, an inventory of present water and sewage systems is presented. This assessment is based largely on a recent study prepared for the Wyoming Department of Economic Planning and Development (Wirth-Berger Associates 1974).

Water

<u>Gillette</u>. The City of Gillette obtains its water supply of 2,000,000 gallons per day entirely from wells. A new well is planned which is expected to produce an additional half million gallons per day. In 1977, an influx of construction workers is expected to build a power plant and a coal gasification plant. Should this occur, Gillette has a contract with the company building the plants to supply the town with 3,500 acre-feet of water per year from the North Platte River.

Last year, 360 million gallons of water were produced, and 303 million gallons were sold. The water treatment plant is capable of producing 803 million gallons of treated water annually. This may be inadequate, however, because Gillette has little water storage capacity. The three water storage tanks have a total capacity of three million gallons. One of these tanks, having a 750,000 gallon capacity, is for emergency use; it is filled and drained once a year and is virtually never used. Thus, effective water storage capacity (2.25 million gallons) is approximately equal to one peak day's usage (2.4 million gallons). The water treatment plant can process 2.2 million gallons per day, and peak daily usage has already surpassed this. Therefore, the crucial need at this time is more storage capacity. The distribution system will handle three million gallons per day at capacity.

Gillette's treated water does not meet normal U.S. Public Health Service standards. Standards are somewhat less strict for areas with extremely poor quality water, such as Gillette, and the treated water does meet the less stringent standards. However, the area south of the town limits, which includes mobile homes, modular houses, and some conventional houses, relies upon wells for its water supply. Because this area is not within the Gillette water and sewer district, the water does not go through a treatment plant. This situation constitutes a health hazard to those residents. Consideration is being given to annexing this area so as to include it within the town's water and sewer systems. While this may be time consuming and difficult, it may represent the simplest and least expensive way to improve the situation.

Douglas. Douglas obtains its present water supply from a natural spring with a capacity of 1,150 gallons per minute. At present, the water is not treated although recent regulations require the addition of chlorine. While water quality meets state standards, the minimum spring flow during summer periods requires dependency on the North Platte River. Water from the river must be treated and capacity exists for 1,000 gallons per minute. Storage is supplied by two tanks with a combined capacity of three million gallons. The water delivery system is fully utilized at present with no excess capacity.

On a daily basis, average consumption is 200 gallons per capita or 650,000 gallons per day. Peak usage is 550 gallons per capita daily or 1,800,000 gallons per day. Peak demand occurs during June, July and August at around 12,000 gallons per minute.

Sewer

Gillette. A new sewer plant went into service in January 1974. This plant has a daily capacity of 1.4 million gallons compared to average daily demand of about 800,000 gallons. Presently, 2,000 sewers are connected, and the system can handle an additional 1,000 connections. The condition of the sewer collection lines is fairly good with only occasional seepage which can be corrected inexpensively. A new 21-inch discharge line has been constructed in the southern part of town.

Douglas. The present sewage treatment system is a lagoon, two-pond system. Sewage is delivered into the lagoon from which it passes to the ponds and eventually filters back into the river. Given the present levels of sewage, this system is considered adequate and is not a source of water pollution. The main sewer lines are operating at approximately 50 percent of capacity, which is 450,000 gallons per day.

Utilities

Urban communities within the Wyoming Powder River Basin receive utility service of natural gas, telephone, and electricity from Mountain Bell, Montana-Dakota Utilities, Petrolane Gas Service, Kansas-Nebraska Natural Gas, Black Hills Power and Light, and Pacific Power and Light. These companies were contacted to assess how they were currently meeting existing demand in Buffalo, Douglas, Gillette, Newcastle, and Sheridan.

All companies stated they were easily able to meet current consumer demands for utility use and installation without undue delay. However, a couple of caveats were given. One natural gas company stated that its supplier had advised it that any new customer hookups would be done at the consumers own risk due to a potential gas shortage. The reality of the potential shortage was not known to the distributor. Almost every utility company stated that acquisition of certain construction materials was subject to delays of up to 50 weeks. The companies have adapted to this by providing added lead time for material orders.

Community attitudes and lifestyles

Lifestyles

The Powder River Basin has traditionally been a ranching area. The dominance of ranching as both an economic activity and way of life has profoundly affected the economic and social structure, the value systems and attitudes - in short, the lifestyle of the entire area.

Given the limited grazing capacity of the land, rural population density tends to be low. Isolation, the perceptual outcome of low density, coupled with long and arduous labor, demands self-sufficiency and self-reliance. The ranching ethic is thus tied to the land and to a hard-living, hard-working lifestyle in which the close knit family is reflected in a close knit community which fends for itself and takes care of its own.

Ranching communities tend to be very stable and very internally oriented. Inmigration is rare and what little population growth occurs is almost exclusively dependent upon birth and death rates. Stability is reflected in social and economic structures, value systems, and the very nature of the land itself.

In Campbell County mineral development has recently been superimposed on the traditional ranching lifestyle. Unlike ranching, mineral development is far more labor intensive. As economic dominance shifted from ranching to mineral development, both population and social structure were profoundly affected. The magnitude of population increases shattered the traditionally stable population base and destroyed the close-knit community character. Collective self-sufficiency and self-reliance generated various adaptive mechanisms through which the community sought to assimilate the incoming population. As dominance shifted still further, accomodation shifted from an attempt to assimilate newcomers into the previous lifestyle to a process of amalgamation between the two opposing lifestyles.

The practical consequences of rapid development have seriously affected the residents of this area. A shortage of vital public services, including water, sanitation facilities, housing, schools, medical services and recreational outlets, has strained both public officials and citizens alike. This stress has been reflected in the increasing incidence of family discord, adjustment problems, truancy, and alcoholism.

The new lifestyle which has and is emerging is as yet undefined. Indications are that it will not be so strongly tied to the land and to the self-sufficiency and stability so characteristic of the ranching culture. The transient nature of much of the incoming population argues against the development of strong community ties and suggests that the ultimate lifestyle will be more impersonal and fluid, less close knit and stable than before.

While Campbell and Natrona Counties have been profoundly affected by mineral development, Converse and the remaining five counties in the basin area have remained relatively undisturbed. Ranching and its attendant lifestyle have retained economic and social dominance.

Community attitudes

Closely tied to and emanating from the prevailing lifestyle of an area, community attitudes provide an indication of the goals and objectives of a given community. While vital to the planning and decisionmaking process, information on community attitudes is exceedingly difficult to obtain. Fortunately, a recent study by the Denver Research Institute (1974) provides considerable insight into the attitudes of present residents of Campbell County. Although limited to only one of the eight counties under discussion, certain of the findings are presented as indicative of ranching versus nonranching attitudinal sets, regardless of county.

When questioned regarding the present situation in Campbell County, ranching respondents were far less inclined to report needed improvements. Only recreational activities (22%), medical facilities (19%), streets and roads (16%), and retail stores (14%) were desired by any number. In contrast, respondents engaged in mineral development wanted more recreational activities (38%), retail stores (34%), better streets and roads (30%), more medical facilities (19%), and more housing (15%). Table 70 presents these findings.

Ranching respondents were also more likely to oppose a large population influx. While 52 percent of the total sample favored and 21 percent opposed development, only 27 percent of the ranchers favored and 41 percent opposed development.

In addition to ranching versus nonranching comparisons, the survey results provide an insight into community attitudes with respect to changes necessary to accommodate new population growth. Table 71 presents the ten most frequently cited changes and the percent of respondents who cited them. As Table 71 indicates, housing, retail stores, water and sewage treatment, education and medical facilities are considered most necessary.

Table 70

Public Attitudes Regarding Improvements Needed in Campbell County, by Employment of Respondent

Improvements	Percent Responding	
	Mineral-Related Employment	Ranching
More entertainment, recreational activities	38%	22%
Retail stores	34%	14%
Better streets and roads	30%	16%
Medical facilities and services	19%	19%
More quality housing	15%	---
Updated local administration	11%	---
Fire, police, transportation and other public services	8%	---
Nothing	---	11%
No more new people; no new town	---	10%

Source: Denver Research Institute, Socio-Economic Impacts of Proposed Burlington Northern and Chicago North Western Rail Line in Campbell-Converse Counties, Wyoming, (March 1974).

Table 71

Public Attitudes Regarding Changes Necessary to Accommodate Rapid Population Growth Campbell County, Wyoming

Change Description	Percent Responding	Rank
More housing, lower cost housing, better quality housing.	60%	1
More retail stores, businesses and shopping centers to add variety and availability through competition.	32%	2
Better water and sewer treatment facilities.	22%	3
More schools and teachers.	19%	4
More and better medical facilities (including hospitals); more doctors (including specialists).	16%	5
Planned housing developments with open space and recreation facilities; more better planned mobile home parks with better public facilities, open space, and recreation.	15%	6
More attention to zoning by local government; better planning for housing, education, recreation, public services, and growth policy.	14%	7
More fire and police protection; better transportation systems (including within Gillette as well as for the rural population); better trash collection, snow removal, power, utilities (especially in rural Campbell County).	9%	8
More updated local elected officials; more democratic distribution of power at local level; more efficient administration --Gillette government cannot handle this magnitude of problem.	8%	9
More variety of amusement, entertainment, cultural and recreational activities; this included indoor activities such as bowling, movies, restaurants, and outdoor activities such as parks, tennis courts, swimming facilities, etc.). It was originally broken into activities for adults, activities for the elderly, and activities for young people.	8%	10

Sample size: n=474

Source: Denver Research Institute, Socio-Economic Impacts of Proposed Burlington Northern and Chicago North Western Rail Line in Campbell-Converse Counties, Wyoming, (March 1974).

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