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Energy Development vs Water Quality in the Upper Colorado and Upper Missouri River Basins

University of California

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ENERGY DEVELOPMENT VS WATER QUALITY IN THE UPPER COLORADO AND UPPER MISSOURI RIVER BASINS

by

A. Bruce Bishop, Stanley L. Klemetson, Michael F. Torpy, and Mac McKee

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ABSTRACT

This report examines the relationship between energy development and water quality in the Upper Colorado and Upper Missouri River Basins. In order to provide a background for problem assessment, the general physiographic, water resources, and water quality settings are described for each of the basins. The location and type of energy resources and present and possible future developments are also identified relative to the water resource systems. The water quality problems and impacts from energy developments are discussed in terms of the various pollutants generated by energy extraction and processing activities, and the pollution transport mechanisms and pathways by which they can enter surface and groundwater. Looking at the problem from another perspective, the report discusses the implications for energy development of the water quality aspects of legislative requirements and regulations. These include the Federal Water Pollution Control Act Amendments, the Safe Drinking Water Act, the Surface Mining Control and Reclamation Act, the Resource Conservation and Recovery Act, and the Toxic Substances Control Act.

The variety of pollutants, as well as their massive volume that will be generated by projected energy development in both basins, give rise to almost sure pollution problems. Many of the potential water pollution problems associated with energy development will not be results of direct discharges--for zero waste water discharge appears to be the standard for tomorrow--but rather will occur through the transport of pollutants from other processes and disposal activities. These processes and activities-- air pollution and solid waste disposal, for example--are less obvious contributors to water pollution problems, and are therefore less likely to be controlled than waste water streams themselves.

In response to water quality regulations and their ultimate objective to eliminate discharge, existing and proposed

conversion plants are planning for total containment of waste water with no discharge to the stream system. The consumptive use of all water withdrawn for energy processing as a pollution control measure raises three important issues--each of which represents a potential conflict between energy developers' compliance with the legislation and western water law: (1) junior rights and water transfer, (2) the "beneficial use" question, and (3) the "reasonable use" measure of certain water quality practices.

INTRODUCTION

The major part of the developable energy resources in the western US lies in the Upper Colorado and Upper Missouri River Basins. The most extensive of these resources is coal; other resources include oil shale, tar sands, oil, natural gas, uranium, and geothermal.

In assessing the potential for and the problems of development, the main concern to date has focused on the quantities of water required for energy extraction and processing versus the quantities of water available in energy development regions. A number of "water for energy" studies have addressed this problem. While water quality has been of concern in some of the assessments, usually for specific projects or areas, no comprehensive assessment of the potential effects of energy development on water quality has been done.

The purpose of this study is to identify and describe the interrelationship between energy development and water quality in the Upper Colorado and Upper Missouri River Basins. In order to provide a background and setting for the study, an overview of the river basins and their energy resources is first presented. The assessment of energy development and water quality problems and issues is approached from a dual perspective:

1. The effects of energy development on water quality in terms of general types of problems and the nature of consequences for the particular river basins under study and

2. The implications of water quality regulations (such as the Federal Water Pollution Control Act Amendments and the Safe Drinking Water Act) for energy developments in terms of requirements, technology options, and means of compliance.

PHYSICAL DESCRIPTION OF THE RIVER BASINS

Of the river basins in the West, the Upper Colorado and the Upper Missouri River Basins are the most richly endowed with energy resources. Because of the vast potential for energy development in these two areas, there is also a large potential for major impacts on water quality. As background for discussing the potential water quality problems of energy development, the following sections provide a brief overview of the basins' physical characteristics, water resources, and present water quality.

The Upper Colorado River Basin

Physiography and Water Resources. The 1440-mile-long Colorado River Basin, which contains 1/12 of the land area of the 48 continental states (excluding Alaska and Hawaii), has the most varied physical setting of any American river. High mountainous elevations (> 14 000 ft) ultimately are succeeded by high plateaus and low desert valleys.

The Upper Basin divides naturally into three major drainage systems (Fig. 1): The Upper Main Stem (UM), the Upper Green (UG), and the San Juan (US). A broad range of climatic and streamflow conditions exist within the Upper Colorado River region. Most of the streamflow is provided by snowmelt from the mountainous areas; the desert regions contribute very little (see Table I). The river produces the lowest outflow per unit area (60 acre•ft per square mile) of any river basin in the US.

When unaffected by the activities of man, surface runoff is referred to as "natural" or "virgin" flow. Due to man's interventions, however, few streams in the Upper Colorado Basin now carry only natural flows. Consequently, the average annual virgin flow of the river must be reconstructed from gauged flows and estimates of consumptive uses in the basin. The records (Upper Colorado River Commission, 1973; flows recorded at Lee Ferry, Arizona) of average annual virgin flow in Fig. 2 show that large variations occur from year to year due to fluctuations in precipitation, and over periods of years due to long-term climatic trends. Extremes in the flow have ranged from a high of 21.894 million acre•ft in 1917 to a low of 4.396 million acre•ft in 1934.

Most of the groundwater in the Upper Colorado River Basin is in consolidated rocks, is generally saline, and often occurs at great depths (Price and Arnow, 1974). Furthermore, the consolidated rock formations yield water to wells rather slowly. The better groundwater sources developable in river valley regions are closely tied to the surface water system as well. With no intervention by man, over a period of years the natural groundwater discharge balances the recharge. Consequently, the diversion and consumptive use of groundwater by wells cause the natural forms of groundwater discharge, such as seepage to streams, to decrease proportionately.

Water Use. Superimposed on the natural hydrologic system are land uses and other activities, which place demands on the water resources of the Basin (see Fig. 3). As noted in Table II, irrigation is by far the largest consumptive use of water in the Upper Colorado River Basin, accounting for approximately 60% of the total depletion. Water uses in the basin, for purposes other than irrigation, include municipal and industrial water supply, mining, livestock, recreation, fish and wildlife, and present energy development, mainly for coal-fired steam electric generation. The two largest sources of depletion other than irrigation are the exports to the large population centers on the east slopes of the Colorado Rockies and the Wasatch Front in Utah, and evaporation losses from main stem reservoirs of the

Colorado Storage Project System. Upstream depletions were approximating 1 800 000 acre•ft in 1914 and increasing to about 2 800 000 acre•ft in 1962. The level of current depletions established by the 1975 Water Resources Assessment (US Water Resources Council 1976, 1977) is 3 700 000 acre•ft.

Water Quality. The higher elevation mountain streams contain the highest quality water in the basin. As these streams move down into the valleys, man's influence and natural processes begin to affect the quality of the water. An identification of present water quality and pollution problems was accomplished by examining STORET data from the US Environmental Protection Agency (EPA) for all water quality parameters at every recorded station in the Upper Colorado River Basin. Current water quality data were compared with state and federal standards in order to develop a profile of various problem types throughout the basin. The encircled numbers 1-68 on Fig. 4 indicate geographical locations where measurements of one or more of the parameters are available. A detailed summary of data for these stations is presented in Table A-II of the Appendix.

Analysis of the water quality parameters that exceed standards yields the general list of problems presented in Table III. Energy and mineral developments have caused water quality problems that are serious in specific locales, including (1) acid mine drainage usually from abandoned mines and heavy metal pollution in tributaries of the west slope of the Rockies, (2) impacts on water temperature, (3) sedimentation problems, and (4) increasing downstream salinity through depletions.

At present, from the standpoint of the entire basin, the most critical water quality problem in the Colorado River is the salinity, or total dissolved solids (TDS) content of the water. It is also the problem that is most affected by the natural background conditions of the basin. Comparisons of salt loading and salinity concentrations at various points on the river system have been estimated in a number of different studies (Colorado River Basin Salinity Control Forum, 1975; Hyatt et al., 1970; Irons et al., 1964; US Department of Interior, 1975; US Environmental protection Agency, 1971). These studies have employed techniques to identify and separate the sources of salinity. While varying in their estimates, these studies suggest that in the river flow from the Upper Basin (measured at Lake Mead), approximately 2/3 of the salt load (tons/yr) and 50% of the salt concentration (tons/acre•ft) originates from natural point and diffuse sources.

The Upper Missouri River Basin

Physiography and Water Resources. There are two major physiographic divisions within the Upper Missouri River Basin--the Interior Plains and the Rocky Mountain System. The Rocky Mountain System contains the Rocky Mountain and Wyoming Basin provinces. The Interior Plains contain part of the Great Plains, and include such distinctive topographic features as the Black Hills in South Dakota and Wyoming.

The 2 315-mile-long Upper Missouri River drains a watershed of 233 000 square miles within the US and about 9 700 square miles north of the International Boundary. This river basin divides into three subbasins representing hydrologic areas drained by a combination of major and minor tributaries of the Missouri River (see Fig. 5). The Upper Missouri River tributaries (Upper Missouri) include the drainage basin above the confluence with the Yellowstone River. The Yellowstone River (Yellowstone) Basin includes the Yellowstone River and its tributaries. The Dakota tributaries (Dakotas) include the balance of the Upper Missouri River Basin (Missouri Basin), principally in North and South Dakota. In general, the Missouri Basin is well supplied in total surface and groundwater resources. However, there are areas with marginal water resource balances. The average annual precipitation varies from over 40 inches in parts of the Rocky Mountains to as low as 6 to 12 inches immediately east of the Rocky Mountains. Historic streamflows reflect the constantly changing effects of water resource developments and streamflow depletion. Hence, the streamflow data must be adjusted to reflect the current level of development and use of the water.

Water Use. Table IV shows the contribution to stream flow by subbasins under the 1970 level of water development and utilization. A practical limit of additional future depletions in the Upper Missouri Basin has been tentatively determined to be 9.9 million acre•ft/yr above the 1970 level. This 9.9 million acre•ft will supply more than all the projected depletions that have been made in any study undertaken to date. Even with the entire 9.9 million acre•ft consumed, there still could be partial service to navigation, a viable hydropower generating capability, and minimum flows of 6 000 ft^3s between and from all main-stem reservoirs throughout a decade-long drought period (Northern Great Plains Resources Program, 1974).

Within the basin, groundwater is used for various purposes. Detailed data are not available on groundwater; estimates have been made, however, indicating the groundwater resources of the Upper Missouri Basin (see Table V).

Water Quality. The principal water quality characteristics that have been monitored concern the suitability of water for uses within the basin. The total dissolved solids of the surface waters range from less than 200 mg/L to more than 2000 mg/L. In most cases, the sodium absorption ratio* is less than 3; however, in some areas the ratio exceeds 10. Representative surface water quality data from STORET for the basin are contained in Table A-I of the Appendix. A summary of water quality problems, identified by comparing STORET data with established standards, is presented in Table VI. The river reaches in the table are delineated in Fig. 6. As the table shows, potential energy development is spread throughout the Upper Missouri River Basin. Presently, the most widespread water quality problem in the basin is salinity. Likewise, the possibility of eutrophication of streams and reservoirs is extensive due to relatively high nutrient loadings. Dissolved oxygen deficits are apparent in a few reaches and, as yet, there are virtually no heavy metals problems.

ENERGY RESOURCES AND DEVELOPMENT

The potential for energy development impacting water quality is apparent, considering the vast energy reserves and the quantities of water required for

*The sodium absorption ratio gives one an indication of the toxicity of sodium in the soil.

their development. In the future, national priorities likely will exert tremendous pressure for energy development. The following summarizes the energy resources and development potential for the Upper Colorado and Upper Missouri River Basins.

The Upper Colorado River Basin

Energy Resources. Of the abundant energy reserves in the Upper Colorado River Basin, coal is by far the most widespread (see Fig. 7). The states of Arizona, Colorado, New Mexico, Utah, and Wyoming produced only about 8.6% of the nation's coal in 1975 (Kolstad, 1976), yet these states contain about 25% of the total US reserves. Quantitative summary data on the coal mining activities shown in Fig. 8 are presented in Table VII.

The Green River oil shale formation, which appears as the most likely place where oil shale development will be initiated in the US, is located in Utah, Wyoming, and Colorado (see Fig. 9). The formation contains 90% of the total identified oil shale resources in the US. Specific projects (listed in Table VIII) proposed for future development under the oil shale lease program are indicated in Fig. 10. Development is not rapid. With known technology, costs of production are expected to be in the range of $25 to $30 per barrel. Assurance of a price above costs likely would result in substantial development.

Important oil and gas production areas are shown in Fig. 11. It is presumed that these fields will continue to be pumped in the future. About 50 million bbls of oil were produced in the Upper Colorado River Basin in 1972 (Minerals Yearbook, 1972).

Tar sand deposits (see Fig. 9), principally in Utah, are also being examined as sources of oil production. It appears that production of oil from tar sands is less capital intensive (Gill, 1974) and uses far less water (Lowe, 1974) than production of syncrude from oil shale. It is not anticipated that production volume will be large, but there could be substantial water quality impact in local areas.

Energy Conversion Facilities and Development. Besides the extraction of energy resources deposits, a number of conversion facilities have been proposed for the basin. The bulk of these facilities are aimed at using coal as the raw energy input. Geothermal also has been indicated as having development potential. Other processes suggested for the basin include oil refineries, expanded hydropower development, and solar power. Energy conversion facilities that have been indicated by the FEA 1985 Scenario (Federal Energy Administration, 1976) and the Forecast 2 Scenario of the Energy Research and Development Administration (Goettle et al., 1977) for energy demand and fuel supply are summarized in Table IX. Locations of the proposed plants are shown in Fig. 12. As indicated by the scenarios, energy resource development in the Upper Colorado River Basin will be initially concentrated in coal and coalfired steam electric generation, together with some limited development of oil shale. By the year 2000, a considerable expansion of coal mining, coal-fired electric generation, and oil shale is expected with coal gasification and geothermal also being added to the total supply.

Water Requirements for Energy Processing. The impact of energy development on water quality is certainly related to the quantities withdrawn for process uses in a region. A number of recent studies have estimated the annual water consumption required for projected levels of energy production using generally accepted water consumption coefficients. The total annual water consumption for energy development is summarized by activity types in Table X. The largest user of water is coal-fired electric generation, with oil shale and coal gasification also indicated as prominent uses.

Summary. An overall summary of the water, energy, and other related characteristics is presented in Table XI. Using the table and the detailed basin map of Fig. 13, those regions where energy resources are present and development potential exists can be compared with the water quality and environmental characteristics of the area.

The Upper Missouri River Basin

The Upper Missouri River Basin is a region that is extremely rich in energy resources. The following discussion presents a geographical and quantitative overview of the "conventional" energy reserves found within the four states (Wyoming, Montana, North Dakota, South Dakota) of this basin area. The statistics are changing as new reserves are proved or as more resources are projected. Likewise, the information on possible levels of future development is highly subject to economic, technological, and environmental conditions.

Energy Resources. There are about 1.4 trillion tons of coal in the four states of the Upper Missouri River Basin, or 42% of the total national resources. Sulfur content of these coals is often less than 1%, although contents as high as 2.4% have been reported. Figure 14 shows the general locations of the coal reserves in the four-state region. Table XII presents the estimated annual coal production rates for these states.

There are very limited deposits of oil shale in Montana; there are no deposits in the other three states of the Upper Missouri River Basin. Presently, there are no plans to develop this resource until its feasibility has been proven with richer sources (Environmental Protection Agency, 1974).

Interest in geothermal energy is increasing rapidly. The Upper Missouri River Basin contains significant geothermal energy potential in connection with the relatively youthful age of its geologic processes. Figure 15 indicates the large area of this basin in which potential for geothermal energy resources is best (Environmental Protection Agency, 1974).

In 1972, production of crude oil from the Upper Missouri River Basin was in the order of 540 000 bbl/d (197 million bbl/yr), or just under 6% of the total US crude oil and condensate production. Figure 16 portrays those general areas of the basin in which oil and gas deposits may be expected (Environmental Protection Agency, 1974). Production of natural gas from the Upper Missouri River Basin was about 1082 million standard cubic feet (scf) per day in 1972 (395 billion scf/yr) or 1.7% of the total US production.

Energy Conversion and Development. Current production from coal-fired electric generating plants in the Northern Great Plains portion of the Upper Missouri River Basin is approximately 3 000 MW. There are 42 potential power plant sites in the region where coal and water resources are considered adequate for the generation of a cumulative total of 200 000 MW of power. An annual production rate of 8 billion tons of coal and an annual usage of up to 900 000 acre•ft of water are required to sustain an electrical production capacity of 50 000 MW.

It is likely that the first commercial coal gasification plant will be built in the Upper Missouri River Basin at Beulah, North Dakota. The typical plant unit producing 250 million cubic feet per day ($MMft^3/d$) of pipeline-quality synthetic natural gas would use 10 million tons/yr of coal (Harza Engineering Company, 1976).

The forecasting of energy needs and production is subject to wide ranges in estimates, or because of the uncertainty of economic and technological factors. The Project Independence Evaluation System (PIES) of the Federal Energy Administration, used to produce low-to-high estimates of development rates, provides the basis for indicating the general level of coal-fired electric and coal gasification plants in development of the Upper Missouri River Basin. Locations of these plants are identified in Fig. 17 and listed in Table XIII.

About 25% to 30% of the total US coal production is expected to occur in the western Northern Great Plains. One of the primary reasons for the concentration of production in this region is that there are substantial reserves of low sulfur coal. The Northern Great Plains area (PIES Supply Regions Nos. 7 and 8) is forecast to produce about 305 million tons of coal in 1985, which amounts to about 30% of the projected national production for that year (Harza Engineering Company, 1976).

Estimates of the coal-related energy development in the lignite fields of North Dakota and Montana, and the Powder River coal fields of Montana and Wyoming are presented in Table XIV. This table indicates that, under the most probable scenario, the capacity of coal-fired steam electric plants would be about 4 700 MW in 1985 and 11 000 MW by the year 2000. With this level of development, there would be 11 plants by 1985 and 23 plants by the year 2000. Also indicated in Table XIV is the use of coal for gasification plants. Four of these types of plants have been announced for the Upper Missouri River Basin area.

Beyond 1990, the financial incentives coupled with dwindling domestic reserves of natural gas and oil are expected to cause rapid expansion of coal gasification activity. A total of 15 coal gasification plants with a capacity equivalent to 3 814 $MMft^3/d$ of pipeline quality gas are projected to be constructed in the Upper Missouri River Basin by the year 2000 under the most probable scenario (Table XIV). Under the high scenario, a total of 21 units are anticipated with a capacity equivalent of 5 354 $MMft^3/d$.

Water Requirements for Energy Processing. The consumptive water requirements for these energy processing activities are also presented in Table XIV. Potential water use could range from 300 000 acre•ft to over 500 000 acre•ft by the year 2000.

ENERGY PROCESSES AND WASTE STREAMS

Energy processing activities have both product streams and waste streams. Handling of waste streams may include recycling and/or treatment, but ultimately residuals in solid, gas, or liquid forms must be disposed of. If deleterious substances from these residuals are transported into the air, land, or water, they become pollution problems.

Mining Operations

Usually, an industry uses water in its process and contaminates it during the operation. Most of the water used by the mining industry, however, is for dust control and fire protection. The major water quality problem is mine drainage. Water enters the mines via precipitation, groundwater infiltration, and surface runoff, where it becomes polluted by contact and reaction with materials in the coal, overburden material, and mine bottom. While acid mine drainage is a typical problem in the Eastern US, alkaline drainage is frequently found in the western coal fields.

Coal-Fired Steam Electric

The coal-fired steam turbine consists basically of the coal-fired boiler, the steam turbine, the condenser, and the cooling system, as shown in Fig. 18. A variety of methods can be used to remove waste heat from the turbine exhaust stream, including once-through cooling, evaporative cooling, and dry cooling. As a rule of thumb, about 95% of the total power plant water use is for the cooling system, when wet evaporative cooling is used.

Water is also used as the working fluid in the boiler-turbine-condenser cycle and must conform to precise chemical specifications. Usually, extensive treatment is required before it can be used. Ash produced from burning the coal is usually sluiced with water to a pond for disposal. Water is also used for equipment cleaning, for domestic use at the plant, and for air pollution control devices, such as scrubbers.

The waste waters discharged from a power plant cooling tower usually consist of large quantities of hot water, which can directly affect aquatic life and reduce the dissolved oxygen content. As a result of evaporation, chemicals tend to become concentrated in the cooling water. When the blowdown water is discharged, its concentration of total dissolved solids (TDS) may be significantly higher than the TDS concentration of the makeup water. The degree of TDS concentration depends primarily on influent water quality and the number of recyclings in cooling tower operations. Stratton and Lee (1975) have studied the quality of the makeup and blowdown waters from 11 cooling towers and found that lead and mercury levels were significantly increased in the blowdown water.

Another source of waste water is ash pile drainage, which occurs as a result of rainfall. The ash pile drainage contains material leached from the ash pile, and unless it is controlled, the water can contaminate groundwater supplied or surface water by overland flow.

Coal Gasification

The basic modules in the coal gasification process are summarized in Table XV. Several modules could directly affect water quality through rainfall runoff as a source of pollution. In the winter, poor housekeeping in some areas of the plant can result in very high concentrations in the runoff during the spring thaw. Improper storage of ash piles and feed coal can result in leachate and runoff problems during spring thaw and rainstorms. All of the waste water recovery and treatment processes produce some sludges, brines, or effluents that can contribute to water pollution if not properly handled (Klemetson, 1976).

The major waste water stream originates at the quenching cooling unit, and the principal minor stream comes from the final gas purification unit (rectisol wash). The characteristics of the major and minor waste water stream of a gasification plant burning North Dakota lignite coal are shown in Table XVI. The expected composition of the wastewater following biological treatment is shown in Table XVII. In addition to the chemical constituents listed in Tables XVI and XVII, there are many other organic and inorganic constituents. The unlisted chemical constituents are not of minor significance, however, and some may yet be determined carcinogenic.

Oil Shale

Environmentally, the oil shale industry has numerous problems. Explosive or toxic gases are not present in coal mines, but even the richest oil shales use more than 1.5 tons of shale to produce a barrel of oil. After the shale is crushed, it occupies a volume 12% to 30% greater than when mined. While most of the spent shale is returned to the mine, the excess volume of crushed rock has to be disposed of on the land. These areas have to be protected from spring runoff and rainfall to prevent water pollution. Water used in the production of shale oil contains dissolved organics and inorganics, which may contaminate the environment (May and Kube, 1974).

Geothermal

Producing electricity from dry steam wells may have only a limited impact on the environment. However, dangerous trace elements are found in condensate from the cooling towers. Tapping hot water fields may present a formidable brine disposal problem unless a closed loop system is used.

WATER QUALITY PROBLEMS OF ENERGY ACTIVITIES

Water Pollution Impacts from Energy Activities

Energy extraction and conversion processes can affect water quality in two ways: (1) the various plant processes and on-site activities generate and mobilize pollutants that can then be transported by various means into water supplies, and (2) energy processes and activities alter the natural physical and hydrologic processes leading to pollution loading and pollution concentrating in water supplies. The major energy-related activities contributing to pollution problems are: (1) surface disturbances, producing sediments and salts; (2) mine drainage, producing heavy metals and toxicants; (3) waste water discharges, containing organics and carcinogenic agents; (4) temperature increases from blowdown water; and (5) decrease flow below minimum instream flow required for desirable aquatic communities. Such problems will be accentuated by the energy industries' diversion and consumptive use of water, which correspondingly decreases the streams capacity for assimilating pollution discharges.

Figure 19 is a flow diagram indicating major paths of possible contamination to the surface and groundwater streams at an energy site, and the mechanisms of transporting pollutants to surface and groundwater. The figure depicts (1) the on-site activities that interdict normal surface and groundwater flow patterns, (2) the processes that mobilize pollutants for transport to receiving waters, and finally, (3) the solids disposal and air emissions that become sources of pollutants, which can find their way through various transport mechanisms to receiving waters. The following paragraphs describe the generic types of energy activities and disposal methods that could have water quality impacts.

Terrestrial Disturbances of Extraction Operations. As a result of surface and subsurface activities related to energy development, water quality conditions can be affected by interrupting normal flow paths, and by leaching and transporting contaminants to receiving waters.

Mining excavations. Surface and underground mining operations often intercept aquifers; these inflows then create mining drainage problems. As the water contacts exposed materials in the mines, it becomes contaminated by various pollutant constituents. This degraded water can enter the hydrologic system through various pathways--leaching, runoff, and spillway from cachement ponds.

Mining spoils and overburden. The removal and handling of overburden makes it highly subject to water erosion and infiltration, which can leach pollutants and transport them to receiving waters. A recent study of selected spoil sites (McWhorter et al., 1975) indicated that the most significant water pollution potential of the coal strip mine spoils results from the soluble salt content of the overburden materials. Almost all the surface mineable coal reserves reside in formations deposited in the marine environment during the Upper Cretaceous and early Tertiary periods. Disruption of these saline shales and sandstones exposes fresh surfaces for leaching, and, for a significant period of time, will influence the quality of surface and subsurface runoff. The major constituents in surface and subsurface runoff from the spoils are sodium, calcium, magnesium, sulfate, and bicarbonate. The leaching problem is of particular concern in the Upper Colorado River Basin because of the salinity problems that already exist in the basin's rivers.

Land subsidence. Land subsidence sometimes results from underground mining and from oil and gas extraction from wells. This differential surface settling can cause the retention of water in these depressions for prolonged periods, allowing percolation of the water into disturbed strata where pollutants are picked up and transported to underground water.

Waste Containment and Disposal from Energy Processing. On-site activities and plant processes generate polluted waste waters that must be controlled, treated, and disposed of. Plant sites have runoff and drainage water problems that must be handled. Normal plant operations require some waste streams to be concentrated and contained, while others may be treated and discharged to the environment.

On-site and materials handling problems. Rainfall contacting and percolating through coal storage piles can leach pollutants and carry fine sediments to both surface and groundwater systems. Runoff can also transport pollutants that accumulate at the plant site as a result of spills or fugitive materials from process operations.

Wastewater containment. Disposal of unwanted solid and liquid waste by ponding has been a common practice for disposal. The metals and other constituents in the sludge tend to leach from the solids into solution. Unless the pond is completely sealed, the water from the sludge and the dissolved solids will be transported from the pond area by infiltration through the soil. The dissolved solids may eventually reach depths where the groundwater table is located, with resulting contamination of the groundwater supply system and, in some cases, contamination of proximate surface waters fed by the contaminated groundwater.

Discharge to surface waters. Energy conversion plants are permitted to directly discharge wastewaters, if they are treated to meet effluent standards. However, discharge standards have not been set for all pollutants. Thus, while the effluent meets discharge standards for specified substances, the effluent may contain toxic concentrations of other constituents for which there are no standards, thereby degrading the receiving water quality.

Deep well injection. Rather than discharging wastes to surface waters, another possible disposal method is deep well injection. The obvious hazard here is contamination of groundwater with various pollutants including toxic substances and heavy metals contained in the waste streams. Sections of the Safe-Drinking Water Act (PL93-523) require permits for disposal by deep well injection.

Landfills. The large quantities of ash and spent shale, sludge from scrubbers, concentrated brine streams, and other essentially solid wastes may be disposed of by landfill. The landfill material contains comparatively large proportions of leachable ions, such as sodium. If located in areas exposed to rainfall, the runoff may carry salts into the ground and surface waters. The water quality impacts of landfills would be expected to be similar to those described for mining spoils.

Air emission effects on water quality. Effluents such as stack gases often contain large quantities of pollutants that can enter water sources after being transported from the atmosphere. The possible pollutant pathways from atmosphere to water are illustrated in Fig. 20. Particulates from the stack gases often contain heavy metals that can be removed from the atmosphere by rainfall washout and by natural fallout onto the land and into water bodies. If the natural levels of some heavy metals (e.g., mercury) in soils are relatively low compared to the particulate derived heavy metals, then the transport of the fallout during erosion can be significant to water quality (Jurinak et al., 1977).

Stream Flow Alterations. Energy developments will also impact on water quality through alteration of existing stream flows to provide water for development.

Impoundments. Construction of impoundments causes a reduction in the silt-carrying capacity of the rivers, a reduction in downstream flows, and an increase in salt concentrations (from increased evaporation). In addition, reservoirs have different effects on processes affecting water quality (e.g., eutrophication and dissolved oxygen reactions). Waters released in the operation of the reservoir tend to be extremely cold because they are drawn from bottom layers. The release of these waters causes changes in the types and quantities of biota residing in the river.

Flow reduction. Water quality problems caused by energy development will be accentuated by the energy industries' diversion and consumptive use of water. As a result of decreasing the flow rate, a stream's capacity for assimilating pollution discharges is reduced and pollutant concentrations increase. Increasing the pollution concentrations by consumptive use is a particular problem because of the salinity problems in the western streams. The reduction of instream flow also causes environmental impacts because decreased flow, on an average annual and peak annual basis, can disrupt desirable natural communities, recreational pursuits, and water quality (Stalnaker and Arnette, 1976; Orsborn, 1976).

Secondary Impacts--Increased Population. Another potential source of water quality degradation is the discharge of pollutants associated with increased population growth and commercial activities associated with energy development. A case study of a set of subbasins of the Green River was made to evaluate water quality impacts of energy development and population growth. The impact of the resulting waste discharges on river water quality was analyzed using a stream quality model (SSAM Model, USU). Results showed that population increase from energy development will violate State of Utah Stream Standards for Biological Oxygen Demand (BOD) and coliforms. However, problems "associated with stream flow, land uses, and nonpoint sources appear to be of more concern than the point loads that receive prescribed levels of treatment." (Grenney and Porcella, 1976; p. 603).

Summary. As the discussion in the previous section indicates, many of the potential pollution problems associated with energy development will not be results of direct discharges, but will occur through the transport of pollutants from other processes and disposal activities that are less obvious and, therefore, not controlled.

Water Pollutants from Energy Processes

The development of energy entails water pollution from extractive, materials processing, and energy production activities. All of these activities involve water resources (surface and groundwater) and result in the addition of chemicals that usually decrease the beneficial uses of the water. The most typical and significant pollutants include heavy metals, acids, salts, and organics. In addition, concentration increases occur because of the removal of dilution capacity by increased consumptive use or by permanent diversion of water from the stream, plus the cumulative effects of evaporation as a concentrating process.

Acids associated with energy are often a rainfall problem and result from SO_2 discharges in stack gases from the energy production step:

$$SO_2 + H_2O = H_2SO_3$$

$$H_2SO_3 + 1/2\ O_2 = H_2SO_4 \text{ (sulfuric acid)} .$$

Although acid rainfall is a serious problem in the highly populated Northeastern US, it has not been a problem in the West as yet. This is due partially to the considerable buffer capacity in western rivers and partially to the low energy production in the West. Most western coal is fairly low sulfur coal. As producing facilities increase, however, potential problems may develop. Acid production from mine spoils directly affects surface and groundwaters. This usually results from bacterial catalysis of the oxidation of sulfides: mineral extraction is associated with metallic pyrites, and energy derived acid runoff is associated with organic matter sulfides. In local areas and specific streams, the low pH causes severe disruption of the ecosystem: erosion, toxicity, acid streams, and loss of terrestrial vegetation.

Heavy metals can be produced from stack gases of energy producers (e.g., see Jurinak et al., 1977) and also can occur from acid solubilization of specific metals. Thus, heavy metals are often associated with acid mine runoff. Heavy metals are toxic and represent human health hazards as a result of bioaccumulation.

Toxic and carcinogenic organic compounds are often associated with fossil fuels because of the organic reactions that result from the different regimes of temperature and pressure that occur during fuel processing. Little assessment of ecological effects or bioaccumulation has been performed in this field. The impacts of energy development relative to natural background levels of these compounds are largely unknown. Organic compounds could have a more serious impact on aquatic ecosystems since they represent a demand for dissolved oxygen resources in water.

Other pollutants with less damaging effects include nutrients, suspended materials, nitrogenous compounds, and taste and odor compounds. In addition, secondary impacts on water resources from waste discharges and increased water use (consumptive withdrawal) compound the pollution problem.

Potential Water Quality Effects in the Upper Colorado River Basin

The impacts of pollutants on stream quality levels in the Upper Colorado River Basin are potentially significant in areas of intense energy development. Stream reaches typical of areas with high potential for energy development contain range or forest lands and low population densities (less than three persons per square mile). In such regions, projected stream flow diversion and concomitant waste loading will create the most serious impacts.

Pollution Problems and Impact Areas. To assess problem areas for the Upper Colorado River Basin, the energy activities in the basin have been indicated according to the hydrologic subbasins (see Fig. 13) specified in Table XVIII. A summary of possible pollution problems resulting from energy-related activities in the major drainages of the Upper Colorado River Basin is presented in Table XIX. As the table shows, the major energy-related activities contributing to pollution problems are (1) surface disturbances, producing sediments and salt; (2) mine drainage, producing heavy metals and other toxicants; (3) waste water discharges, containing organics and carcinogenic agents; and (4) temperature increases from blowdown water or flow reduction.

The potential for pollution from energy activities is made more tangible by the estimates (see Table XX) of the total weights and volumes of materials that could be produced by coal-fired steam electric, coal gasification, and oil shale operations in the Upper Colorado River Basin, under the Energy Research and Development Administration (ERDA) and Federal Energy Administration (FEA) forecast development levels.

As noted previously, the variety of pollutants in these extensively disturbed areas and massive volumes of exposed materials are much more susceptible to being transported to water bodies. Furthermore, the pollution processes are of a diffuse nature. Consequently, control and treatment are much more difficult.

Effects of Energy Development on Colorado River Salinity. The most pervasive and important water quality problem facing both the United States and Mexico is salinity. Since the US and Mexico have agreed on a salinity level for water delivered to Mexico (under Minute 242) the effect of energy development on future salinity levels in the river is an important water quality concern. It is generally recognized that the total containment technology for water use in energy development will lead to reduced salt load in the river. However, the reduction in stream flow from total containment will increase salinity concentrations in the downstream reaches of the river any time the diverted water is of higher quality than that downstream. Recent studies have attempted to assess the changes in Colorado River salinity as a consequence of future development, including energy.

The Colorado River Regional Assessment study. The purpose of the Colorado River Regional Assessment study, conducted for the National Commission on Water Quality (Utah Water Research Laboratory, 1975), was to evaluate the impacts of PL 92-500 in the Upper Colorado River Basin. Since future development and water use levels are highly uncertain, "alternative futures" representative of a range of possible combinations of energy and water resource developments were adopted as a basis for analyzing salinity impacts.

A water and salt mass balance flow model for the Upper Colorado River Basin was used to analyze the salinity impact of alternative future levels of agriculture irrigation, energy development, and water export out of the basin. Total containment of all water used in energy production was assumed. The two key comparisons are the salinity impacts (1) of high-energy development and (2) of water transfers from agriculture to energy development.

(1) Impact of High-Energy Development on Salinity. The effect of increased energy development when the river flow is assumed to be 14 million acre•ft is seen by comparing cases A and J in Fig. 21. The plot J indicates that, as energy development proceeds through time, the total salt load decreases relative to the base condition, A. This trend is expected under a total containment policy because both water and salt are removed from the river system. Naturally, the energy development potential is greatest in those subbasins where the greatest tonnages are removed. While salt tonnage is reduced, salt concentrations in the river rise with the accelerated energy development (Fig. 21). This increase is attributable to the reduced flow of water for dilution. The energy developments contain the water and the accompanying salt load, but this is more than offset by the reduction in dilution water, with the result that concentrations increase markedly.

(2) Effects of Water Shift from Agriculture to Energy. Comparing Case N with Case A in Fig. 21 illustrates the impact of shifting water from agriculture to sustain high rates of energy development. Under these transfers, the salt load for N is reduced from the base A as a result of some reduced salt leaching from irrigation and effluent containment by energy activities. The increases in salt concentration under Case N remain about the same as base Case A. In general, there is a decrease in salt load accompanying the energy increases over time. However, it appears that concentrations still will increase substantially due to consumptive use of water that would otherwise serve for dilution.

Salinity Forum Salt Routing study. This study was carried out using the salt routing computer model developed by the Bureau of Reclamation (Ribbens and Wilson, 1973). The study assumed no return flow from electrical generating cooling, coal gasification or other coal development, or from the oil shale industry. Under the conditions specified for the model for the 14 million base flow case, the salinity levels are shown to increase as future development proceeds. However, it is estimated that total containment of energy process waste water will result in a subtraction of about 27 mg/L of TDS from the total increase (see Fig. 22).

Summary. There is a broad range of potential water quality impacts from energy development in the Upper Colorado River Basin. While the problems of point source pollution may be effectively controlled by existing water quality legislation--PL 92-500 and state water quality standards--many energy-related activities such as land surface disturbance, mining operations, air emissions, and water withdrawals are not easily controllable and could affect water quality.

The water quality problem of most concern to both the US and Mexico is salinity. Water and salt mass balance model studies have been carried out to analyze the effect of future water development in the basin. For a range of alternative energy development futures, the total dissolved solids concentrations are shown to increase below Imperial Dam, which is used as a reference point for the quality of water delivered to Mexico, even though the total salt load in the river is reduced via water diversion for energy. Thus, salinity concentrations are affected more by taking water that serves for dilution out of the river than by the removal of some salt load with the water. Even so, the control strategy of zero salt return in the form of highly concentrated brines from cooling and other energy processes does reduce the salinity impact from energy development. This reduction is estimated on the order of 27 mg/L by the Colorado River Basin Salinity Control Forum (1975) and 34 mg/L based on data from the Colorado River Regional Assessment Study (Utah Water Research Laboratory, 1975). These effects of future development will need to be considered in the planning and implementation of programs to meet water quantity and quality commitments to Mexico.

Potential Water Quality Problems in the Upper Missouri River Basin

Degradation of a variety of water quality parameters are of concern in the Upper Missouri River Basin. Some of these are due to the natural leaching by water as a solvent, while others are due to man's influence on the environment. Planned and projected energy developments could intensify existing problems and create a number of new pollution problems throughout the basin.

In Montana the Yellowstone, Milk, and Marias Rivers plus Muddy Creek (Sun River) all experience long periods of high turbidity, particularly from nonpoint sources. Surface mining in these areas would compound this problem. Sand Coulee Creek, Dry Fork (Belt Creek), the Upper Stillwater drainage, and the upper Blackfoot River drainage all have poor overall stream quality due to mine drainage. In eastern Montana, coal field developments have heightened the potential for groundwater pollution and sediment pollution due to erosion. In North Dakota, the streams in the western part of the state contain high levels of dissolved solids. The primary cause of poor water quality in South Dakota is nonpoint sources, largely the result of poor soil conservation techniques and natural erosion. For the most part, all the waters in Wyoming now meet water quality standards.

The main problem associated with rapid energy resources development is the deterioration of some water qualities, but the extent has not been determined at this time (US Environmental Protection Agency, 1974).

A report of the Northern Great Plains Resources Program (1975) gives some indication of the probable impact of energy conversion in the Upper Missouri River Basin on the quality of the water resources. Figure 23 shows the locations where coal-fired steam electric power generation developments are most likely to occur. Each numbered dot represents a 1000-MW power plant with the assumption that 19 000 acre•ft would be used annually per 1000 MW. Figure 24 shows the most likely locations for coal gasification plants. Each numbered dot represents a 250 million ft^3/day gas production plant. The location of the numbered dot is placed with reference to both the point of water withdrawal and the point of discharge described in the study. The numbered dots are, then, close to where the plants would actually be located. For the plants indicated in Figs. 23 and 24, Table XXI summarizes the production plant capacities in each subbasin and indicates the amount of water diversion and the return flow.

The impacts on the water quality in the basin occurring as a result of the most probable developments were considered in reference to TDS changes. The study assumed that the blowdown water from the cooling towers would be returned to a water body after being concentrated about 3.8 times. The following conclusions on salinity changes occurring in the water bodies as a result of energy development would be, of course, significantly different from an analysis that assumed no discharge from the production plant:

- The Bighorn River water quality would not be significantly different, that is, a 3 mg/L increase in TDS based on an annual average.
- The Yellowstone River water quality (TDS) at Miles City would be slightly increased by about 4.9 mg/L TDS.
- The Tongue River water quality at Miles City would be affected adversely, estimated at a 24% increase in TDS concentrations in the average year. This potential TDS increase is due in part to the relatively low dilution capacity (flow) in the Tongue River compared with the Yellowstone and Missouri Rivers. Also, the Tongue River historically has low TDS concentrations compared to the other Yellowstone and Missouri River tributaries analyzed. Discharges with high TDS concentrations, therefore, will result in a greater change in the Tongue River than in the Powder, Knife, and Heart Rivers (Northern Great Plains Resources Program, 1975).
- The Powder River water quality at Moorhead, Montana, would remain relatively unchanged. During low flow periods, however, the TDS concentration changes could increase by 4% over nondevelopment conditions.
- The Yellowstone River water quality at Sidney, Montana, would remain practically the same in terms of TDS concentration changes.
- Missouri River water quality at Bismarck, North Dakota, would decrease slightly.

Estimates of the residuals that can be expected from the energy conversion plants are given in Table XXII. Again, these massive quantities of waste materials must be regarded as sources from which pollutants can be easily mobilized and transported to receiving waters. Perhaps the most critical problem of water pollution control from energy development in the Upper Missouri River Basin states will be the handling, stabilizing, and containing of these wastes.

EFFECTS OF WATER QUALITY CONTROLS ON ENERGY DEVELOPMENT

The major pieces of water quality control legislation that could apply to and affect energy developments are the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), the Safe Drinking Water Act (PL 93-523), the Surface Mining Control and Reclamation Act of 1977 (PL 95-87), the Resource Conservation and Recovery Act of 1976 (PL 94-580), the Toxic Substances Control Act (PL 94-469), and counterpart state laws and regulations. The following sections provide a brief summary of the major requirements of these laws that might apply to energy developments, and discuss their implications for energy activities and processes in terms of controls imposed and potential problems and conflicts.

Federal Water Pollution Control Act Amendments (PL 92-500)

The 1972 Amendments to the Federal Water Pollution Control Act (PL 92-500) establish as a national goal the elimination of the practice of discharging pollutants into the navigable waters of the US by 1985. To meet this goal, PL 92-500 is aimed at controlling or modifying waste water discharges from pollution sources through such provisions and requirements as discharge controls (permits and effluent limitations), treatment technology requirements, planning, and so on. PL 92-500 will affect energy development in terms of the energy industry's contribution to water quality problems and controls and regulations imposed by the law.

Effluent Limitations and Control Technologies (Sec. 301).

Requirement. The basic thrust of the Act is that maintenance of water quality can be achieved principally by effluent limitation. The Act stipulates that effluent limitations for point sources other than publicly owned treatment works shall require the application of the best practicable control technology (BPT) not later than July 1, 1977, and the best available technology (BAT) by July 1, 1983.

Implications. Regulations promulgating effluent limits to be achieved by control technologies (BPT and BAT) have been issued for steam electric power generation and coal mining. Although regulations for coal gasification have not been issued, their content can be inferred. In response to these regulations and the Act's ultimate objective to eliminate discharge, existing and proposed energy conversion plants are planning for total containment of waste water with no discharges to the stream system. At this time, there does not appear to be a single energy facility being planned that would have a direct discharge. The consumptive use of all water withdrawn for energy processing as a pollution control measure raises three important issues, each of which represents a potential conflict between energy developers' compliance with PL 92-500 and western water law. These three issues are documented in the following paragraphs.

(1) No discharge, junior rights, and water transfers. Under the "appropriation doctrine," the first person to divert the water from a stream and apply it to a beneficial use acquires the prior or senior right. When water is diverted for irrigation and other uses, a substantial amount of water returns to the stream, through either surface or underground flowpaths.

Many of the existing water rights depend upon return flow from upstream diversions for satisfaction of decrees. Energy pollution control through recycling, evaporation, or treatment could result in a decrease of return flows and adversely affect vested junior water rights. Such use may be enjoined by a junior appropriator who is thereby deprived of water. The alternatives are to acquire sufficient water of a senior status to make up the additional consumptive use or to reduce water use to the level of the historic consumptive use. Potential transfers of water rights to meet these needs may also cause serious dislocations of existing water uses or, alternatively, substantially reduce the initial, beneficial, nonevaporative uses. The resolution of these problems depends, in a large degree, upon whether PL 92-500 is a valid exercise of the police power, or if it constitutes a "taking" of the junior appropriator's water without just compensation.

(2) Water consumption for pollution control as a "beneficial use." If water were "unappropriated," the proposed use were "beneficial," and the method of applying the water were "reasonable," a right to use the water traditionally could be perfected and maintained. With perhaps some qualified exception, water quality control or abatement is not regarded expressly as a beneficial use in the water laws of the western states at present, although few people would argue that such a use is not beneficial. Water rights generally designate the amount of water authorized to be diverted and may limit the consumptive use. They also identify the nature of the use. To the extent that pollution control enlarges the water use under an existing right or constitutes a new use, it would appear that new or amended permits would be required. Further, if water were to be consumed expressly for pollution control, there is a legal question about whether a right can be obtained for such use.

(3) No discharge as a "reasonable use." The "reasonable use" strain of western water law traditionally has provided that only customary methods of using water need to be employed, i.e., methods "reasonably fit" for the purpose served. Case law in this area has held that an upstream appropriator is not obliged to adopt expensive available technology beyond normal practice to conserve water for an increase of supply downstream. It might also be argued that the appropriator is not required legally to employ costly methods of improving the quality of his return flows. However, effluent limitations on point-source discharges of pollution require the application of the "best practicable control technology currently available" (BPT) by mid-1977 and the application of the "best available technology economically available" (BAT) [Section 301(b)] by mid-1983. Even under a modernized "reasonable use" standard that incorporates the right of the public to clean water, there is the issue of whether water consumption by adopted methods of waste water control technology (BPT or BAT) is "reasonable."

Stream Standards (Sec. 303).

Requirement. In protecting the quality and biological integrity of streams, the Act continues to enforce the federally approved interstate water quality standards and the state-adopted water quality standards. It also authorizes establishment of new standards. One problem that particularly affects energy development in the Colorado River Basin is the establishment of numeric water quality criteria for salinity.

Implications. The "Colorado River System: Salinity Control Policy and Standards Procedure," issued by the Environmental Protection Agency (effective December 18, 1974) required the Colorado River Basin states, by October 18, 1975, to adopt, and submit to the EPA for approval, salinity standards (including numeric criteria) and an implementation plan. The program submitted by these states enunciated a nondegradation policy. It stated that basin-wide solutions are necessary to deal with the salinity problem. It proposed that the lower main stem salinity be maintained at or below 1972 levels while the basin states continue to develop their compact-apportioned waters. The issue posed is whether stream standards and the salinity nondegradation policy are compatible. With the energy industries' plans to contain waste water in response to the effluent limitations of the Act, it is possible that energy development still will contribute to quality degradation through flow reduction. This likely would violate the salinity nondegradation principle unless other adjustments were made elsewhere.

Areawide Waste Treatment Planning (Sec. 208).

Requirement. The Act requires that areawide waste treatment management plans must be developed for designated areas, taking into account all municipal and industrial point and nonpoint sources and future pollution sources, so as to devise a phased comprehensive program of water pollution control.

Implications. Areas with energy resources and development possibilities, by and large, are included within areawide or statewide planning regions, and therefore must be included within water quality management plans. This will subject energy developments to Sec. 208 plan requirements and to the authority of the implementing agency. Under such plans, areawide strategies to reduce diffuse pollution sources could affect mining, reclamation, and solid disposal operations either by prohibiting them or by making them more costly to operate.

Toxic Effluent Standards (Sec. 307).

Requirement. Under the Act, the Administrator of EPA is directed to publish a list of toxic pollutants and effluent limitations for such pollutants.

Implications. The proposed and existing energy development activities, including coal and oil shale conversion processes, produce chemicals that are on the list of toxic substances. While these may or may not be present in the discharge of any one plant, the potential compounding of these substances as additional industries are added in the basin could be hazardous. It is anticipated that the costs of treatment for such compounds would be extremely high if reliable technology becomes available, thus lessening the competitive position of high-technology conversion processes.

Thermal Discharges (Sec. 318).

Requirement. Of particular importance in energy development is the use of cooling water and the resulting discharge of heated water. Thermal discharges are subject to the same requirements of best practicable control technology and best available control technology, except where the discharger can demonstrate that a proposed effluent limitation based upon BPT and BAT is more stringent than necessary to protect fish and other aquatic life.

Implication. Thermal discharge requirements virtually preclude once-through cooling. The language of the Act places the burden of proof on energy industries to obtain EPA approval of a variance. However, with the water scarcity and salinity problems in the West, water will be recycled a number of times and blowdown water will be contained. There is some concern that the loss of the water may be more critical than some increases in temperature and salinity.

National Pollution Discharge Elimination Permit System (Sec. 402).

Requirement. The National Pollution Discharge Elimination System (NPDES) is targeted at point-source polluters. Under the system, the discharge of a pollutant is unlawful unless it is in compliance with an issued permit. Permits may be enforced by measuring pollutants discharged into the wastewater.

Implications. One noteworthy enforcement problem emerging in connection with the administration of the point-source discharge permit system mandated by PL 92-500 could directly affect energy development. In at least two situations in the Colorado River Basin, it is being contended that waste can be released into dry washes without the necessity of a permit. Such discharges could become even more common in the arid West. The issue in these cases is whether such discharges involve the addition of a pollutant from a point source to navigable waters within the meaning of PL 92-500 [Secs. 201(a) and 502(12)]. In one recent case involving Phelps-Dodge Corporation, a decision has been rendered in favor of the discharger.

Safe Drinking Water Act (PL 93-523)

The Safe Drinking Water Act (PL 93-523), with an effective date of June 24, 1977, has three main provisions that have potential impact on energy development: (1) the maximum allowable contaminant levels of substances in public water supplies, (2) the limitation of underground injection of waste water, and (3) the underground injection of fluids for oil and gas production.

Public Water Supply Standards.

Requirement. Maximum contaminant levels of various chemicals are set based upon the possible health effects.

Implication. Problems for energy development in relation to public water supply arise where discharges from energy activities may contribute to contamination of water supplies. Pollution of water supplies could result from disturbance of watersheds, leaching of pollutants into groundwater reservoirs, or by improper disposal. The Act specifically controls underground injections of waste water and also could be used to control other activities linked to degrading water supplies below standards.

Underground Wastewater Injection.

Requirement. Public Law 92-500 provides for abatement of pollution in streams and lakes, but offers almost no protection for underground water sources. This protection, however, is provided under PL 93-523, which requires that each state adopt regulations to control underground injections.

Implications. While most plans for energy processing plants are opting for surface containment of waste water streams, underground injection of wastes still remains a possibility. If such practices were to be considered, they could be controlled by the underground injection controls of PL 93-523. The key consideration is whether the underground injection will increase contaminants to levels violating drinking water standards. In cases where such injections might impair the quality of underground drinking water supplies, they would be prohibited. This provision also raises some question whether or not *in situ* processes for shale oil recovery and tar sands processing would be precluded.

Underground Injection for Oil and Gas Production.

Requirement. Underground injection of fluids is a common practice in secondary and tertiary recovery operations for oil and natural gas. This practice is regulated by PL 93-523, only if such regulation is necessary to ensure that underground sources of drinking water will not be endangered.

Implications. While underground injection for oil and gas recovery is allowed, the burden of proof in determining whether or not injections will endanger groundwater supplies lies with the oil and gas industry. In areas where water supply aquifers and oil fields are close, the industry may have difficulty showing that there will be no degradation. In such cases, guaranteeing the integrity of water supplies would lead to delays and to higher cost operations.

Uncontrolled Practices that May Endanger Groundwater. Regulations on injection practices will not cover many disposal practices common at energy development sites. Leaching from landfills can contaminate underground waters. Surface impoundments such as ponds and lagoons used for treatment and disposal of wastes also represent a potential danger to underground water by percolation through the sides and bottom. The "dug wells" that will be regulated are defined apparently as those with a depth greater than the largest surface dimension. If this were the case, provisions of the Safe Drinking Water Act would not be applicable to most of the lagoons and ponds that are likely to be adopted as final disposal sites for energy development activities. Furthermore, such facilities are also subject to occasional dike failures, spills, and overflows, which can result in widespread pollution.

The Surface Mining Control and Reclamation Act of 1977 (PL 95-87)

The purpose of this Act is to guard against adverse environmental impacts that might result from surface coal mining, while keeping in mind the fact that the coal supply is essential for national energy requirements and economic and social well-being.

Requirements. Specific water quality requirements under the Act cannot be enumerated until the interim regulations are published. However, the Act contains numerous references to water quality and hydrologic concerns. Among these general provisions are regulations on permanent water impoundments that might be created in the mining or reclamation process, and regulations on mining activities to minimize disturbance of the prevailing hydrologic balance and the quantity and quality of surface and groundwater systems.

Implications. The Act addresses itself to a number of particular water quality problems and proposed solutions to those problems, some of which presently may not be standard practice across the mining industry. These include measures to avoid acid or other toxic mine drainage; prevent additional contributions of suspended solids to streamflow; clean or remove temporary settling ponds or other siltation structures from natural drainages after the disturbed areas are revegetated; restore recharge capacity of the mined area to premining conditions; avoid channel enlargement from operations requiring water discharge; and preserve, throughout the mining and reclamation process, the essential hydrologic functions of alluvial valley floors in arid and semiarid areas of the country. In addition, the Act requires that surface wastes, tailings, and spoils be stabilized in waste piles constructed in compacted layers, using incombustible and impervious materials if necessary. Excess spoil materials are to be placed so as to prevent soil erosion and infiltration of water into spoil piles. These provisions are significant because neither PL 92-500 nor PL 93-523 deals directly with water quality problems that could result from mining practices. Their stringent application to energy operations could force the attention of energy developers to on-site activities that are indirectly polluting and could lead to delays and higher costs for energy development.

The Resource Conservation and Recovery Act of 1976 (PL 94-580)

The general objectives of this Act are to promote the protection of health and the environment and to conserve valuable material and energy resources. The rubric of "solid waste" as defined by the Act could apply to many energy wastes, including refuse, sludge from a waste water treatment plant or air pollution control device, and other discarded material such as solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, and mining operations. Similarly, "hazardous waste" is defined by the Act as a solid waste that poses a hazard to human health or the environment. This definition would also apply to many solid wastes produced by energy development activities.

Requirements. Some sections of the Act contain specific requirements that provide for protection of water quality from the handling of solid wastes. These include protection of the quality of ground and surface waters from leachates, and protection of the quality of surface waters from runoff through compliance with effluent limitations under the Federal Water Pollution Control Act.

Implications. The Resource Conservation and Recovery Act is particularly important in that it specifically addresses water quality problems that arise from disposal of solid wastes. The protection of ground and surface waters from leachates, solid waste disposal sites, and dumping areas will certainly apply to the disposal of spent shale, mining overburden, sludge, and other on-site materials. These requirements may pose difficulties in compliance because the areas and masses of materials involved are large. Stabilization and revegetation of these materials will take considerable amounts of water. The water for these purposes may itself cause leaching and transport of pollutants.

Toxic Substances Control Act (PL 94-469)

The Toxic Substances Control Act, effective January 1, 1977, could have a significant effect on energy operations that impact environmental systems through the production or discharge of water, soil, sludge, or air residuals containing toxic chemical substances. The stated policy thrusts of the Act are that manufacturers have the responsibility to develop data on the effect of substances on the environment and health; that adequate authority should exist to regulate substances presenting an unreasonable risk; and that authority should be exercised prudently, so as not to impede technological innovation or to create unnecessary economic barriers.

Requirements. The specific application of the law to activities that produce or introduce organic or inorganic chemical substances into the environment is somewhat vague. However, the Environmental Protection Agency has a great deal of latitude in developing approaches for dealing with toxic substances. The methods of control available for use at the discretion of the EPA Administrator are (1) seizure of any hazardous substance and/or (2) relief against persons who manufacture, use, or dispose of an imminently hazardous chemical substance.

Implications. Although the implications of the Act are still evolving, there is certainly potential for interaction with proposed and ongoing energy development. The Act stipulates that toxic chemical substances produced by the processing activities but unrelated to the purpose of the processing should be controlled. Such substances released from mining and processing of energy resources include heavy metals and organic compounds with known or suspected environmental and health effects. Although the Administrator is constrained by economic and social considerations, he is also required to prevent unreasonable risk to health and environment from such toxic chemicals.

State Standards

The water quality standards of the six principal energy-producing states vary considerably. The state standards have been promulgated for a variety of reasons. North Dakota, Montana, and Utah base their classification systems and standards on beneficial use. New Mexico does not classify streams, but sets standards on a stream-by-stream basis as to their beneficial use. Wyoming has used aquatic life as the major criterion for determining water quality standards. Colorado uses body contact as the basis for its standards. To a large degree, of course, all states have used multiple-use criteria for developing their standards.

None of the state water quality laws or standards contains explicit constraints aimed in particular at energy development activities or industries. This is true for all aspects of state water quality regulation including legislation, permit application requirements, standards, and enforcement. The only possible exception to this is in the state of New

Mexico, where a "Notice of Intent to Discharge" from facilities for the production, refinement, or pipeline transmission of oil and gas or products thereof must be filed with the Oil Conservation Commission.

SUMMARY

This study examines the relationship between energy development and water quality in the Upper Colorado and Upper Missouri River Basins from two perspectives: (1) the water quality problems that could arise from energy development, and (2) the implications for energy development from water quality aspects of legislation and regulations.

Effluents and residuals from energy activities and processes contain a number of inorganic and organic substances that are hazardous to human health and the environment. The most typical and significant pollutants include acids, heavy metals, and toxic and carcinogenic organic compounds and salts. Acid runoff associated with sulfides in mine spoils could be severe in local areas, with low pH causing disruption of ecosystems. Heavy metals that are toxic and a health hazard are produced from stack gases and from acid solubilization of metals. Toxic and carcinogenic organic compounds that are hazardous to human and ecosystem health are associated particularly with oil shale and coal gasification because of the temperature and pressure regimes that occur during processing. Salinity (total dissolved solids and conductivity) is the result of salts being leached from exposed materials and solid wastes from mining and processing. Salinity limits the beneficial use of water for domestic, industrial, and agricultural purposes.

Energy developers plan to prevent direct discharge of pollutants to water sources by containing waste streams. Nevertheless, the amounts of effluent materials to be managed are enormous and represent potential pollution hazards through indirect means. Energy processing and waste disposal activities that will contribute to pollution problems are (1) surface disturbances, producing sediments and salts; (2) disruption of aquifers by surface and underground mining, producing heavy metals and toxicants; (3) placement of mining spoils, wet and dry solids from coal conversion facilities, and spent oil shales, resulting in salts and other pollutants indirectly entering surface and groundwater systems through runoff, leaching, and seepage; (4) plant process waste water discharges, containing aromatic hydrocarbons and other carcinogenic agents; and (5) decreased stream flow from water withdrawals, with resulting increases in pollution concentrations and temperatures.

Additional pressure will be placed on ensuring stream water quality, with particular attention paid to waste water discharges associated with energy-development-related population growth.

While water quality problems from heavy metals, toxic substances, and organics are potentially serious in localized areas around energy developments, the most widespread pollution problem in the Upper Colorado and Upper Missouri River Basins is expected to be salinity. Various studies have indicated that total dissolved solids concentrations will increase downstream largely as a result of diverting higher quality waters upstream.

A number of legislative controls and regulations can be applied to water quality aspects of energy activities. For example, the Federal Water Pollution Control Act Amendments of 1972 control discharges to surface waters through permits, effluent limitations, and treatment technology requirements. The energy industries' response to these measures is to opt for total containment of waste waters so there will be no discharge. This policy, however, possibly could lead to water law conflicts by depriving downstream water users of return flow to which they have a right and by consuming water for pollution control, a practice that is not recognized generally as a beneficial and reasonable use of water. These problems will need resolution before acceptable pollution control strategies finally can be determined. Other requirements of the Act include setting of stream standards, toxic effluent standards, and thermal discharge standards, all of which pose additional restrictions on discharges from energy processes.

The major thrusts of the Safe Drinking Water Act (PL 93-523) are protecting underground sources of water, setting public water supply standards, and prohibiting injection of waste water where contaminants could reach water supplies. Many energy residual disposal practices could have potential impacts on underground water sources including leaching from spoil piles and seepage from containment ponds. Thus, these practices might be subject to control under the Act. In the case of solid residuals, the Resource Conservation and Recovery Act (PL 94-580) specifically requires protection of ground and surface water quality from leachates and runoff from solid waste disposal operations.

The Surface Mining Control and Reclamation Act (PL 95-87) specifies a number of measures intended to avoid or mitigate water quality impacts of mining operations, including preserving the essential hydrologic functions of the mined area and stabilizing all mining wastes. The Act is important in that it deals specifically with terrestrial disturbances that could affect water quality.

The Toxic Substances Control Act (PL 94-469) gives the Environmental Protection Agency the authority to regulate activities discharging toxic substances. This could have a significant effect on oil shale and gasification processes that discharge residuals containing toxic chemicals.

The combined application of these requirements for the purpose of maintaining water quality could result in a number of problems for energy industries. Compliance certainly will mean increased operation costs and possible time delays in bringing developments on line. Operations also would involve added requirements for reporting and trained personnel. Plants already operational may be forced to retrofit with pollution control devices or reduce their operations.

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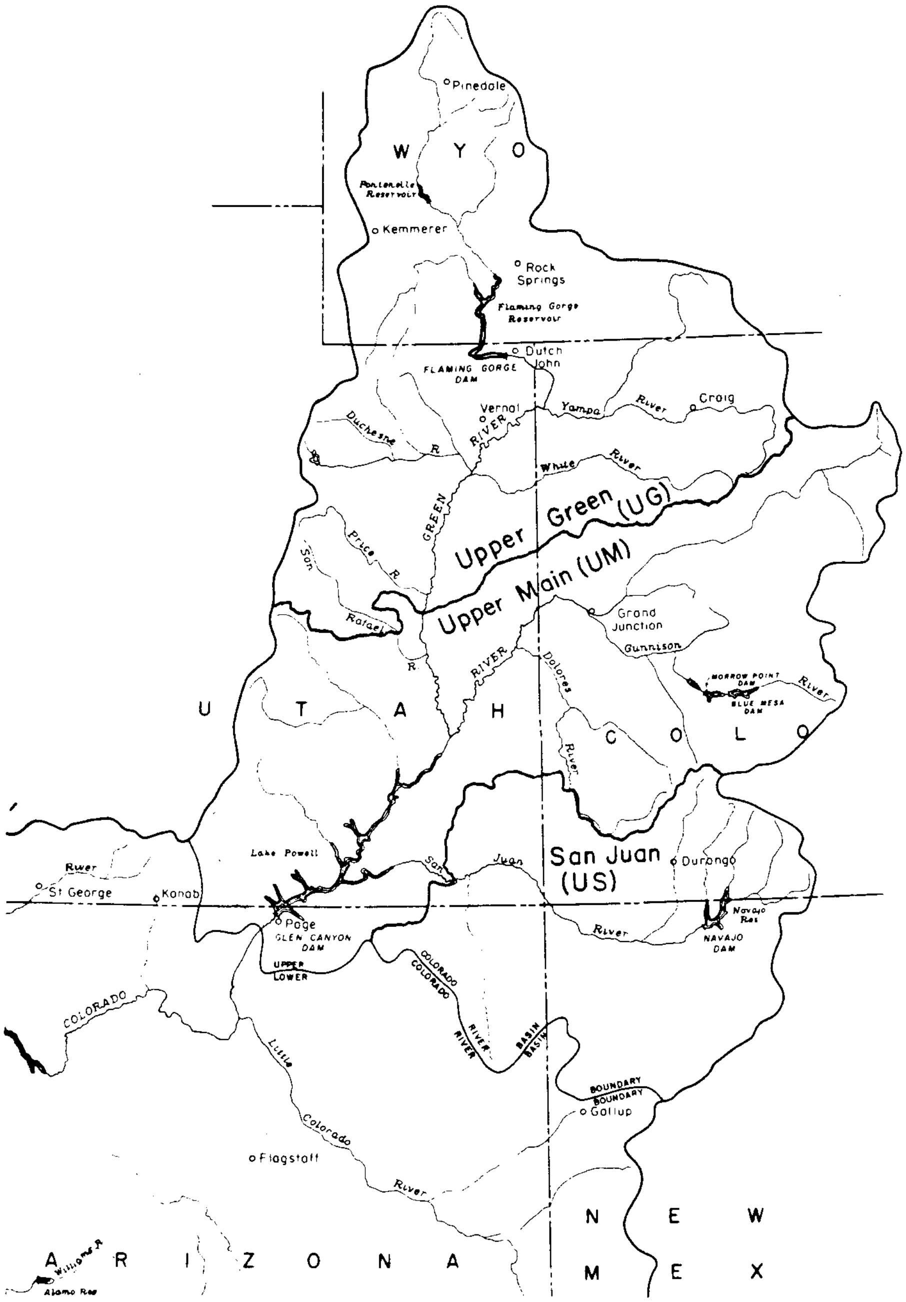


Fig. 1. Hydrologic regions of the Upper Colorado River. (Source: Utah Water Research Laboratory, 1975)

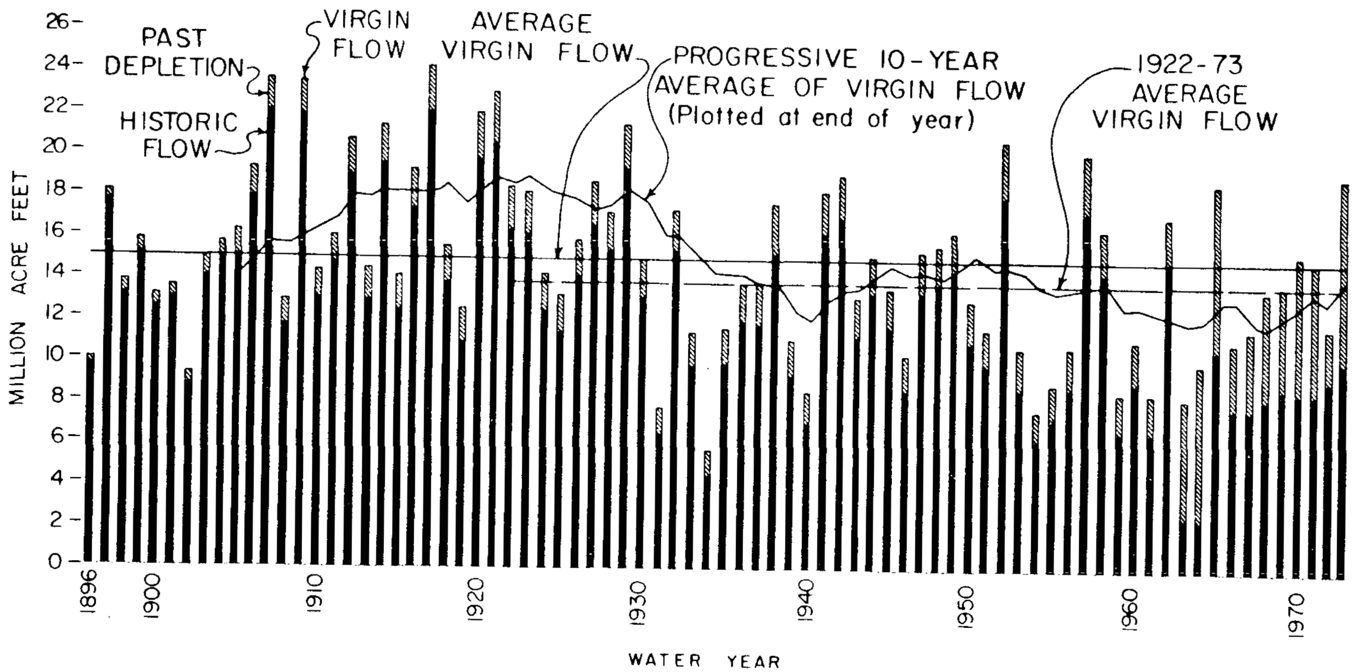


Fig. 2. Flow of the Colorado River, as recorded at Lee Ferry, Arizona. (Source: Upper Colorado River Commission, 1973)

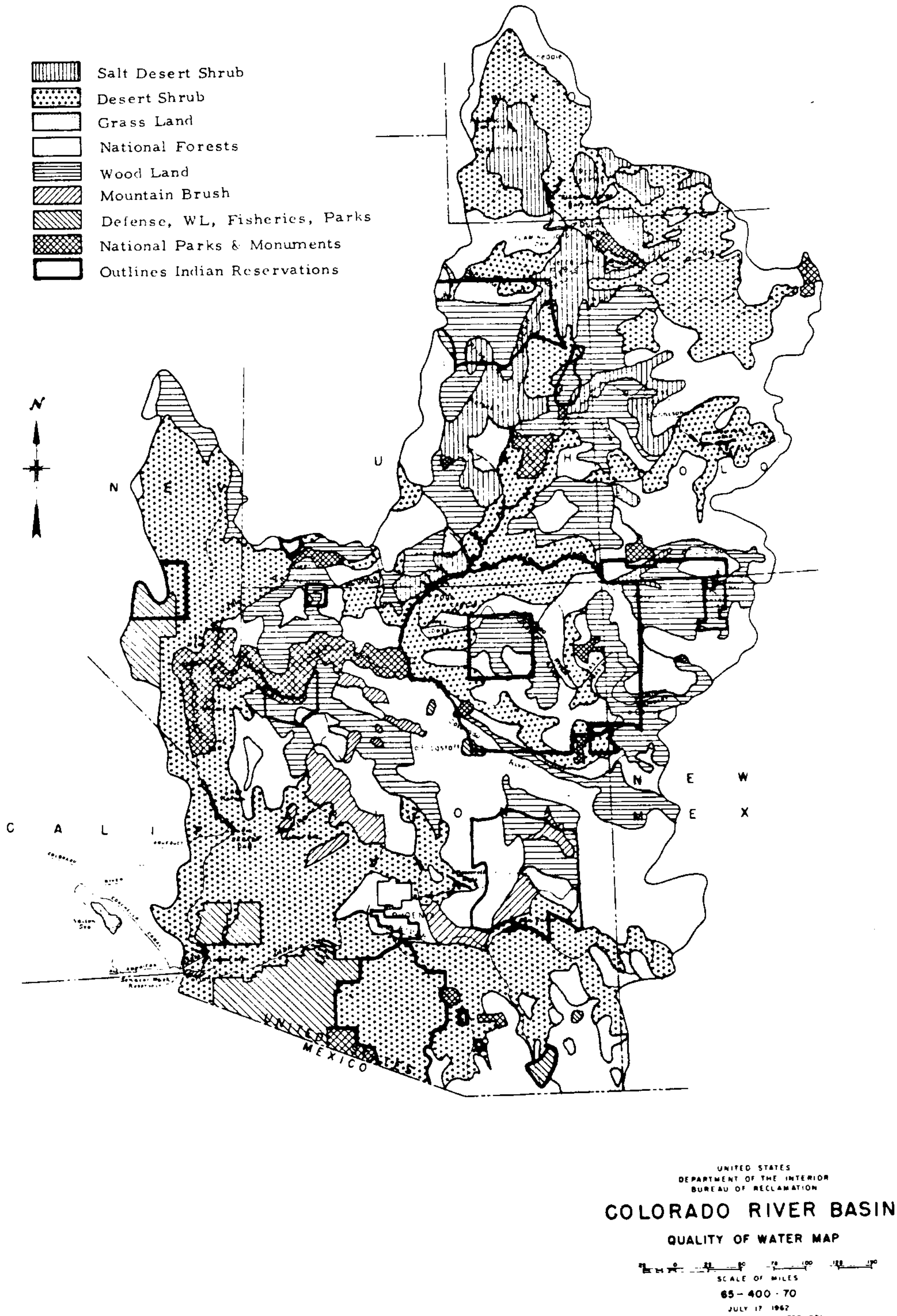


Fig. 3. Terrestrial ecosystems and land use in the Upper Colorado River Basin. (Source: US Department of Interior, 1975)

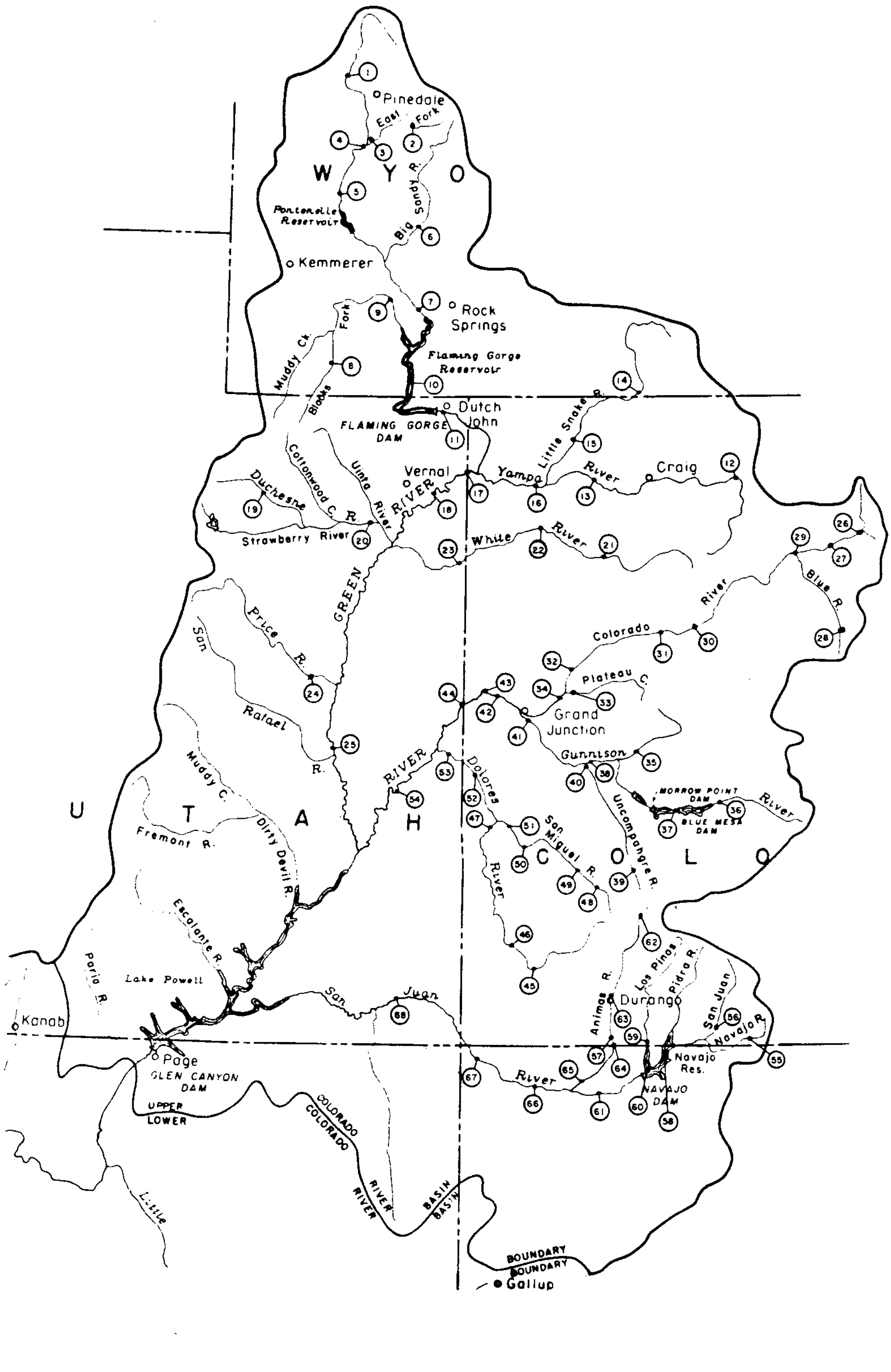


Fig. 4. Water quality STORET stations for Upper Colorado River Basin. (Source: Utah Water Research Laboratory, 1975)

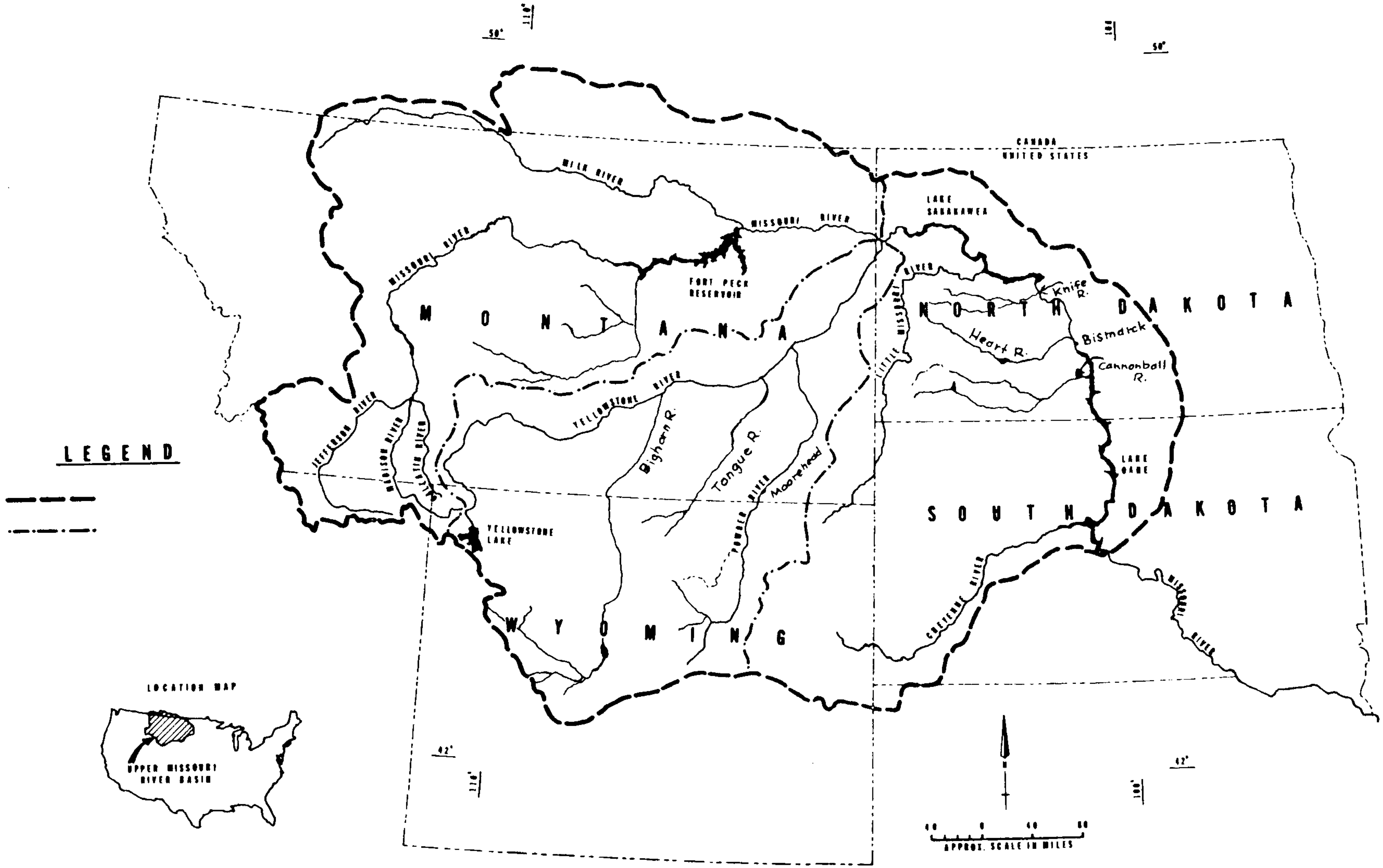


Fig. 5. Upper Missouri River Basin and subbasin boundaries. (Source: Missouri Basin Inter-Agency Committee, 1971)

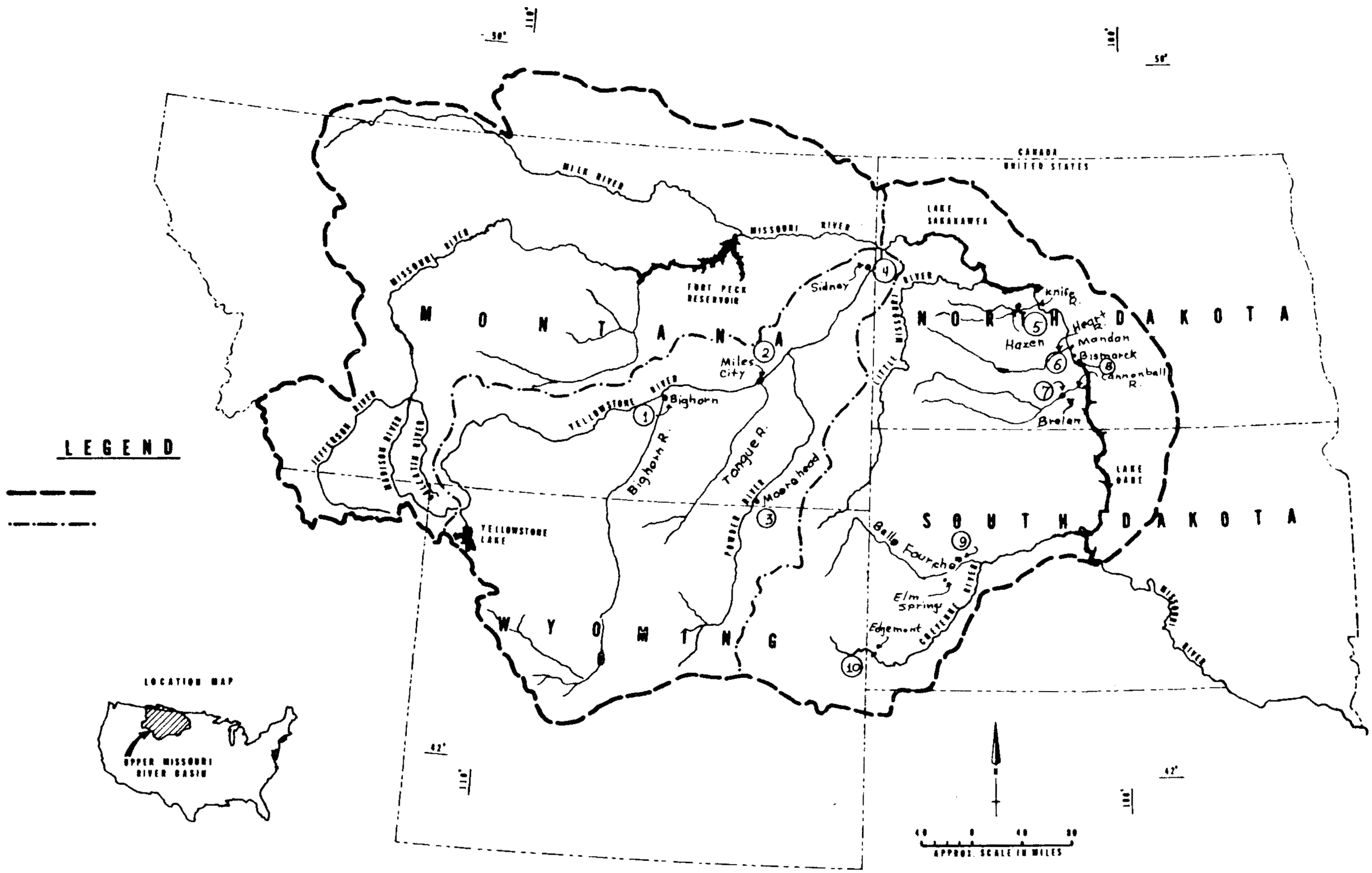


Fig. 6. River reaches for water quality assessment in the Upper Missouri River Basin. (Source: Missouri Basin Inter-Agency Committee, 1971)

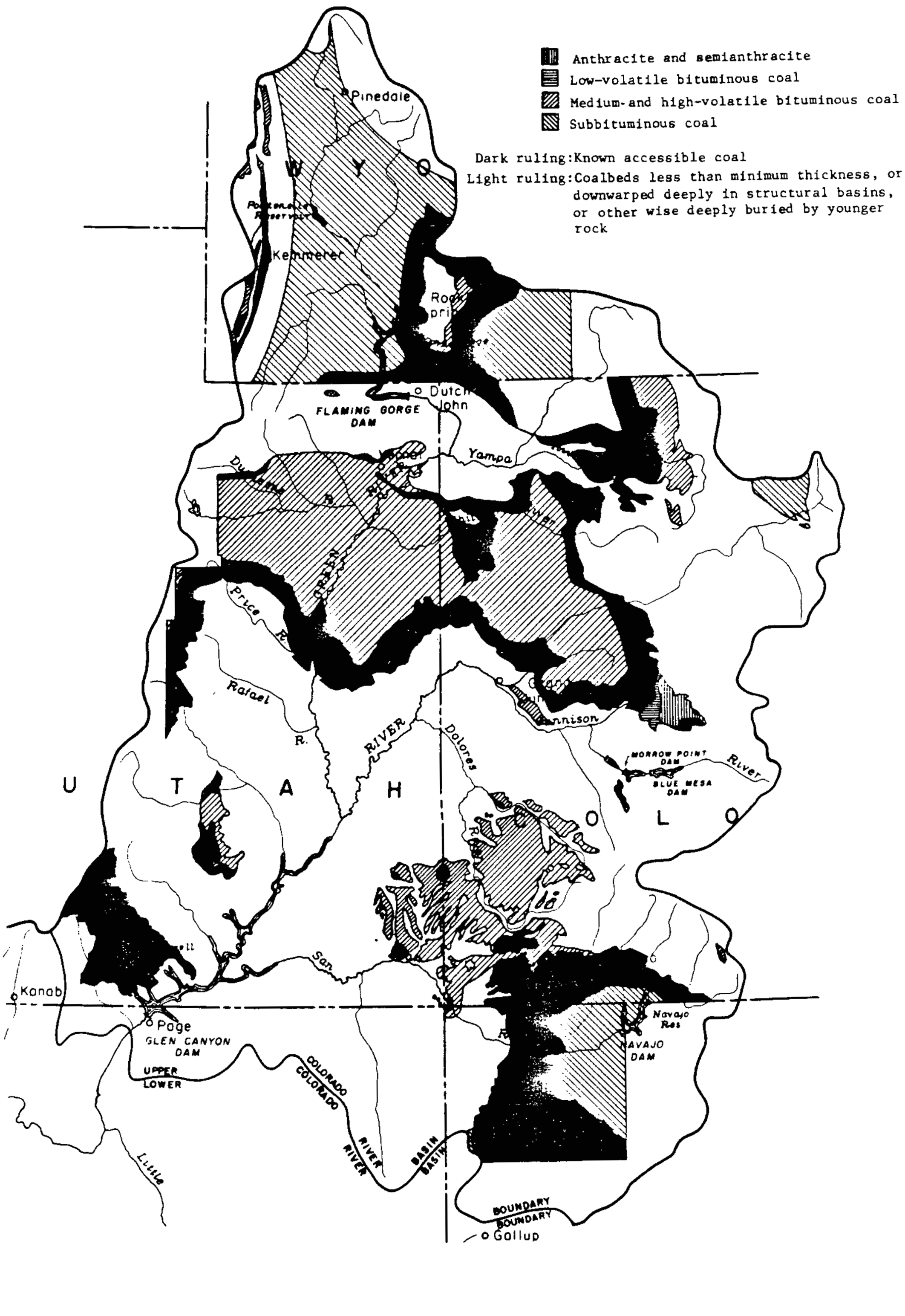


Fig. 7. Coal deposits in the Upper Colorado River Basin.
(Source: Utah Water Research Laboratory, 1975)

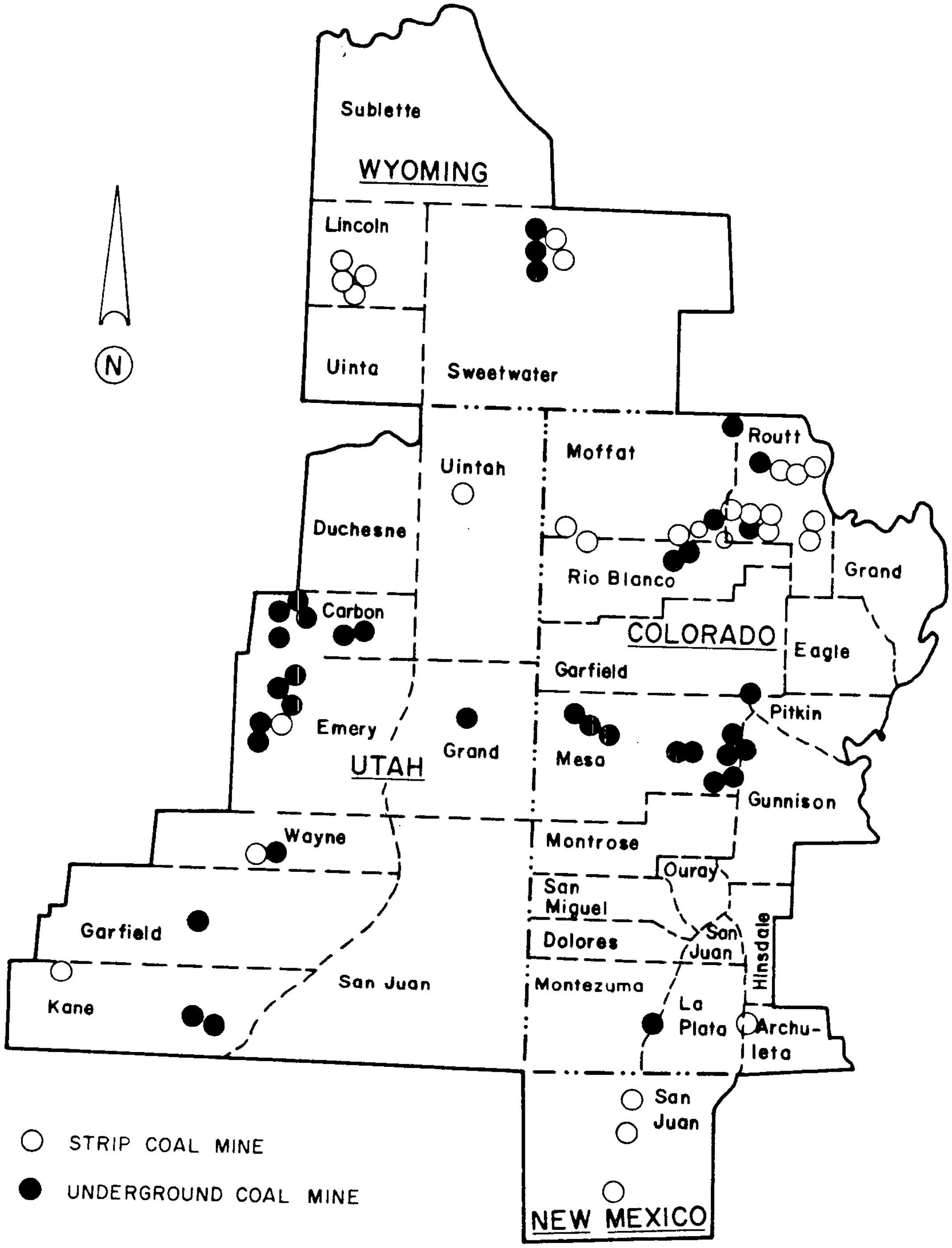


Fig. 8. Coal mining activities in the Upper Colorado River Basin. (Source: Utah Water Research Laboratory, 1975)

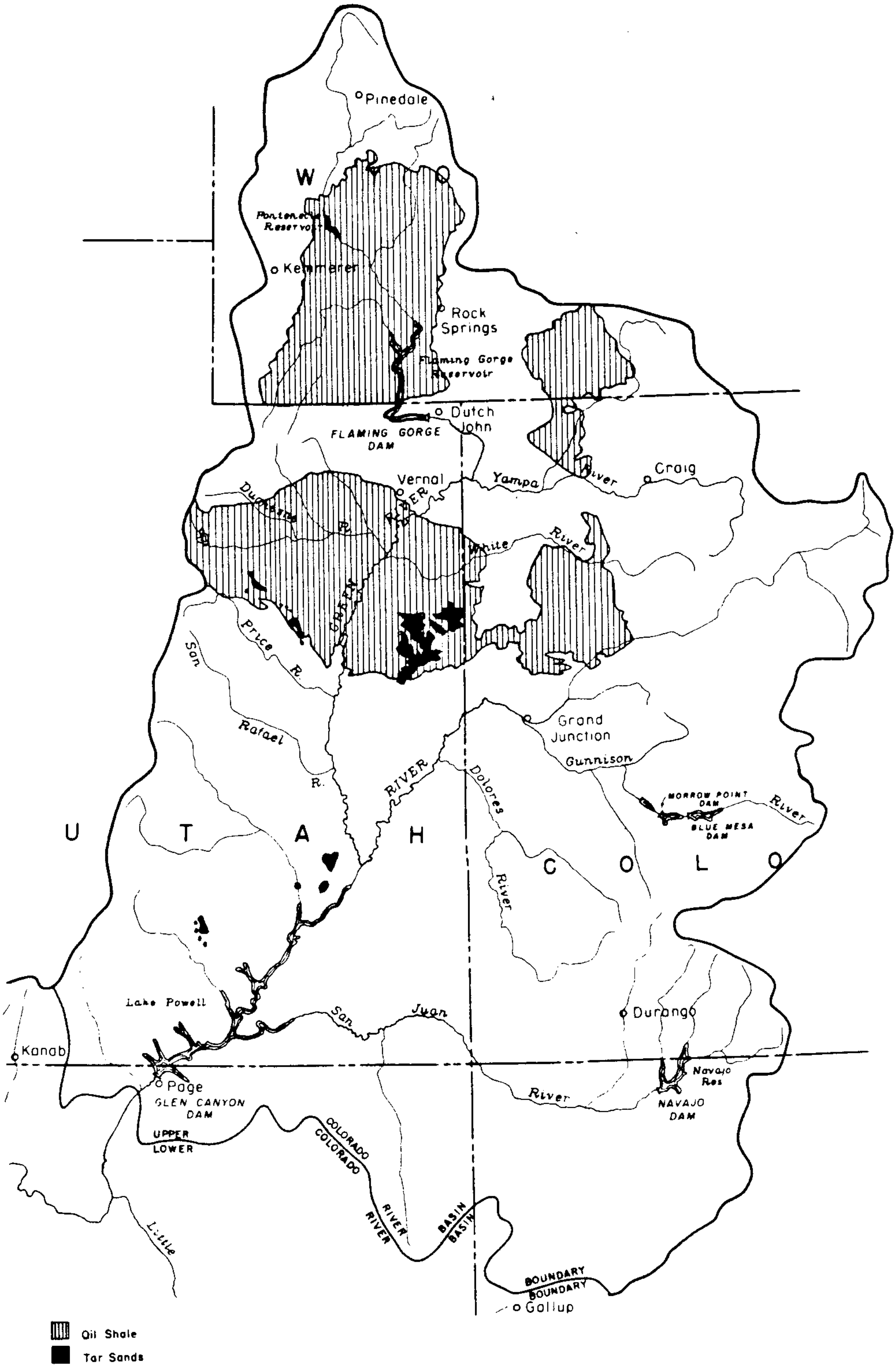


Fig. 9. Oil shale and tar sand deposits in the Upper Colorado River Basin. (Source: Utah Water Research Laboratory, 1975)

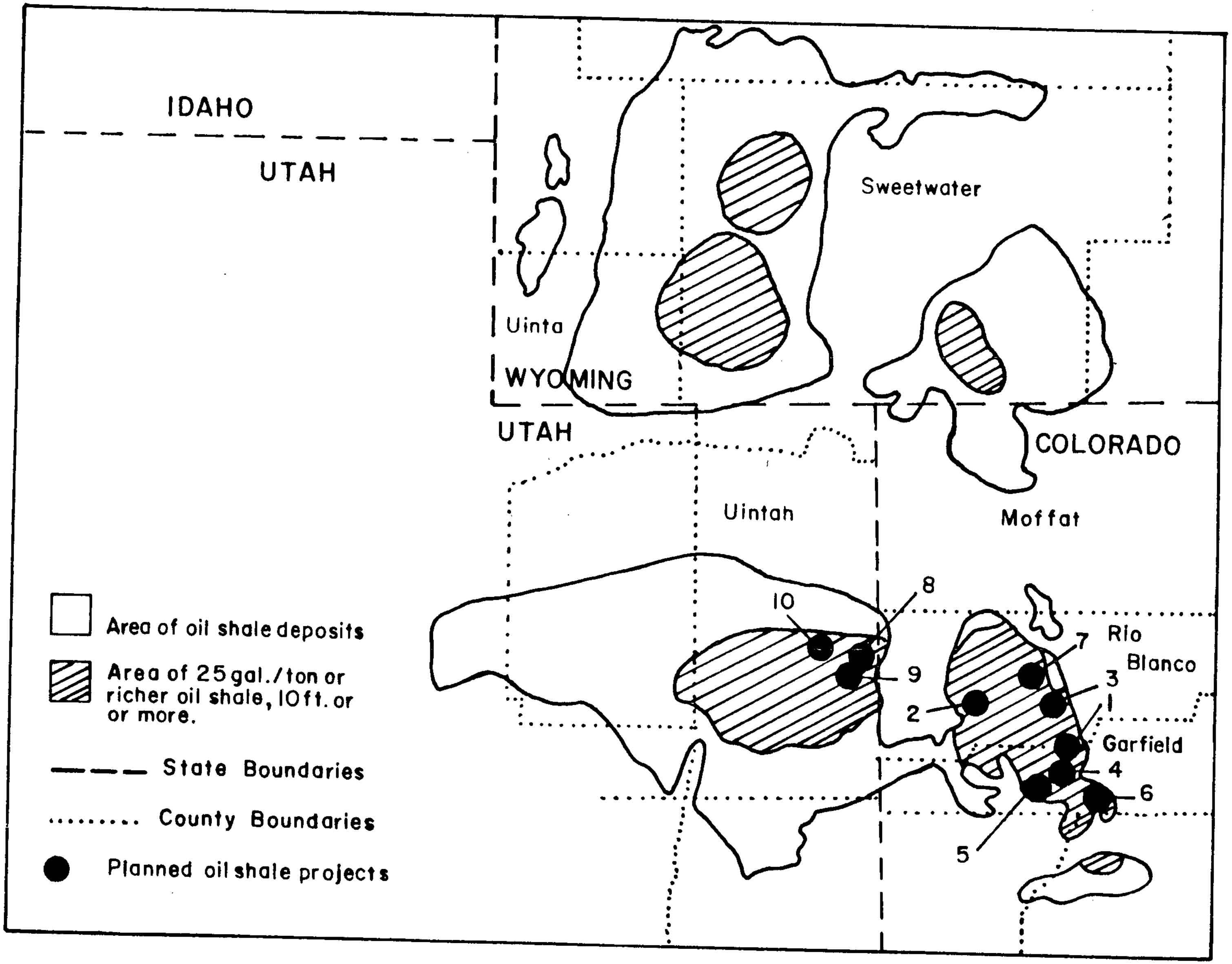


Fig. 10. Green River oil shales. (Source: Federal Energy Administration, 1976, and Goettle et al., 1977)

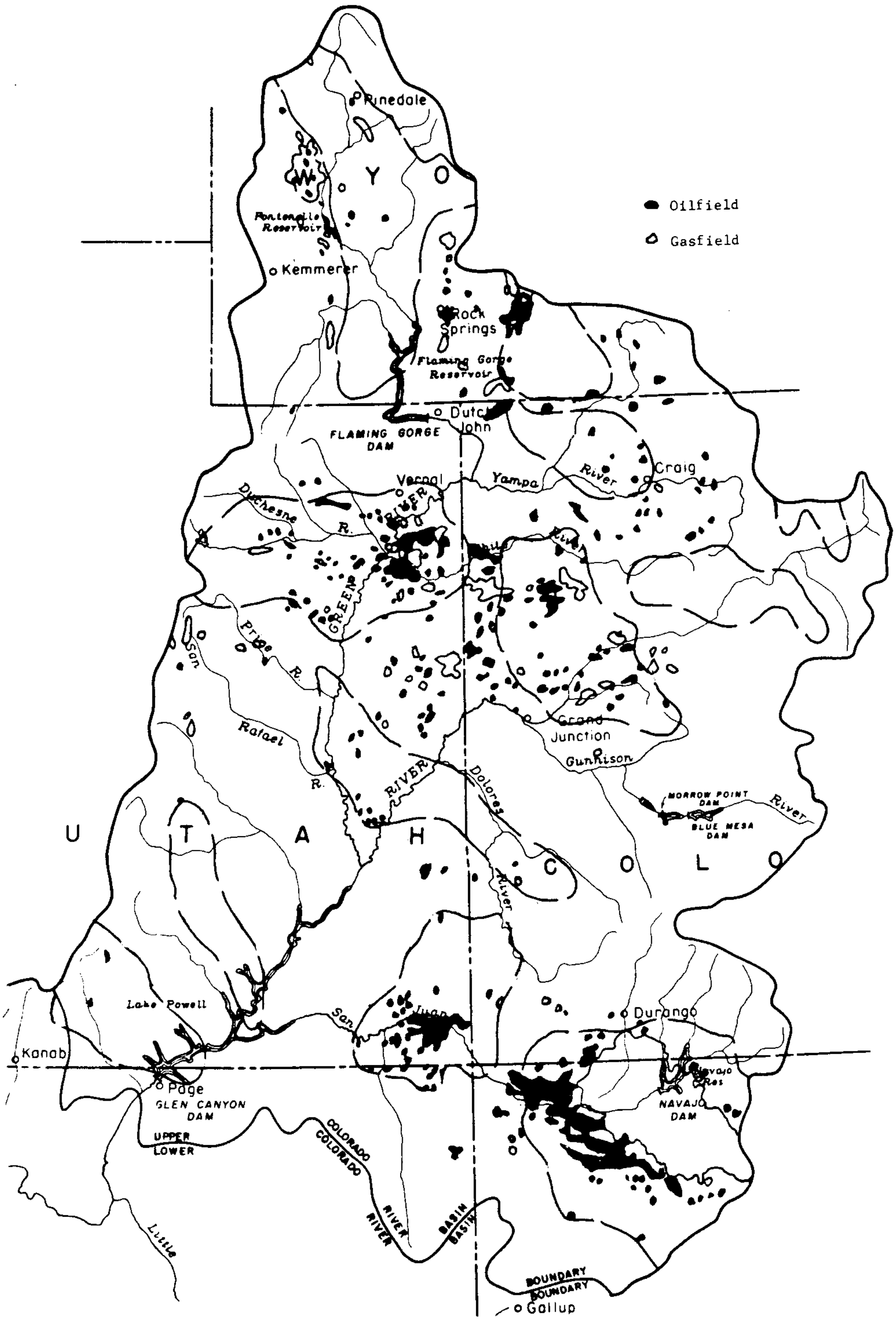


Fig. 11. Oil and gas fields in the Upper Colorado River Basin. (Source: Utah Water Research Laboratory, 1975)

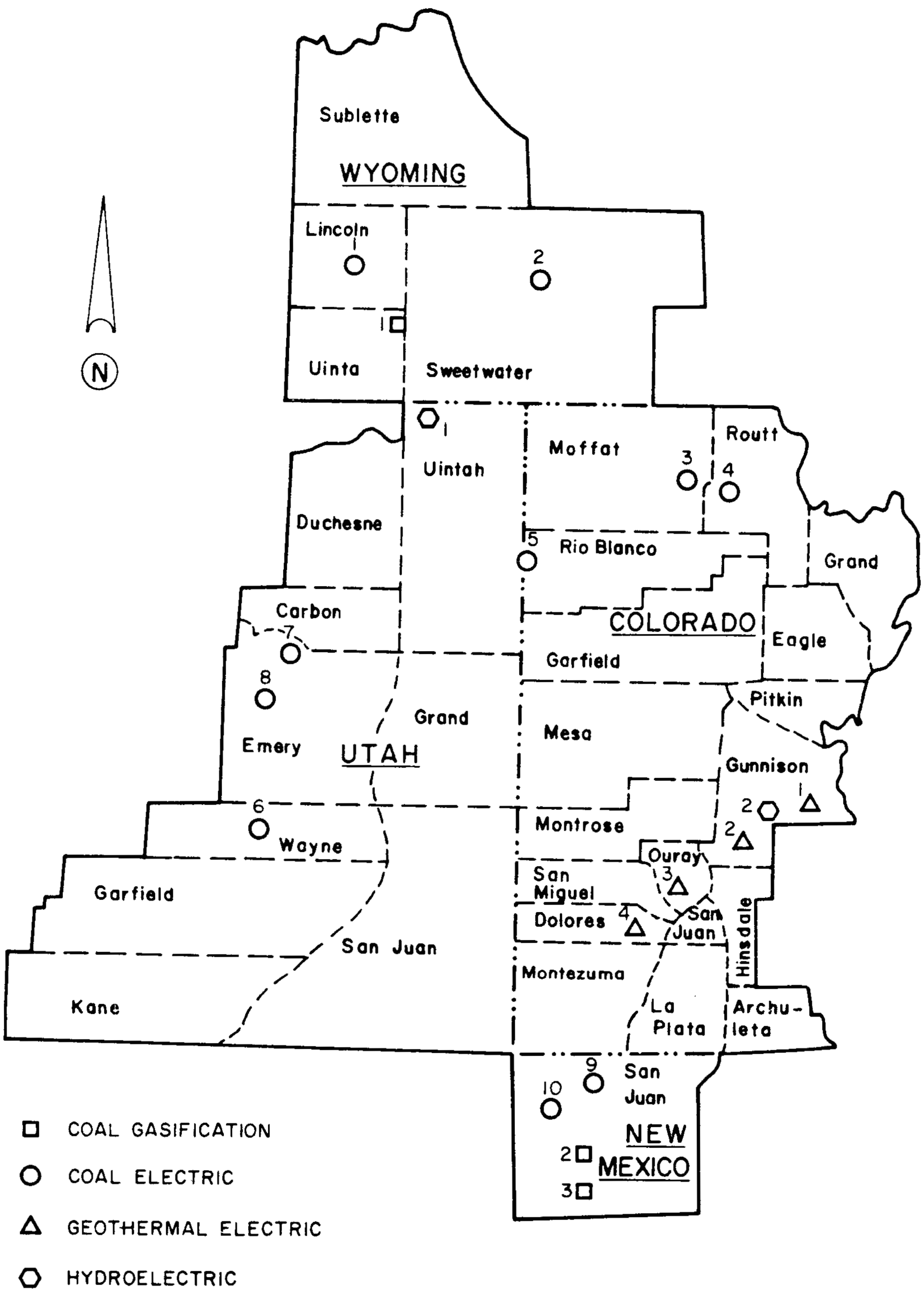


Fig. 12. Locations of proposed energy conversion facilities in the Upper Colorado River Basin. (Source: Federal Energy Administration, 1976, and Goettle et al., 1977)

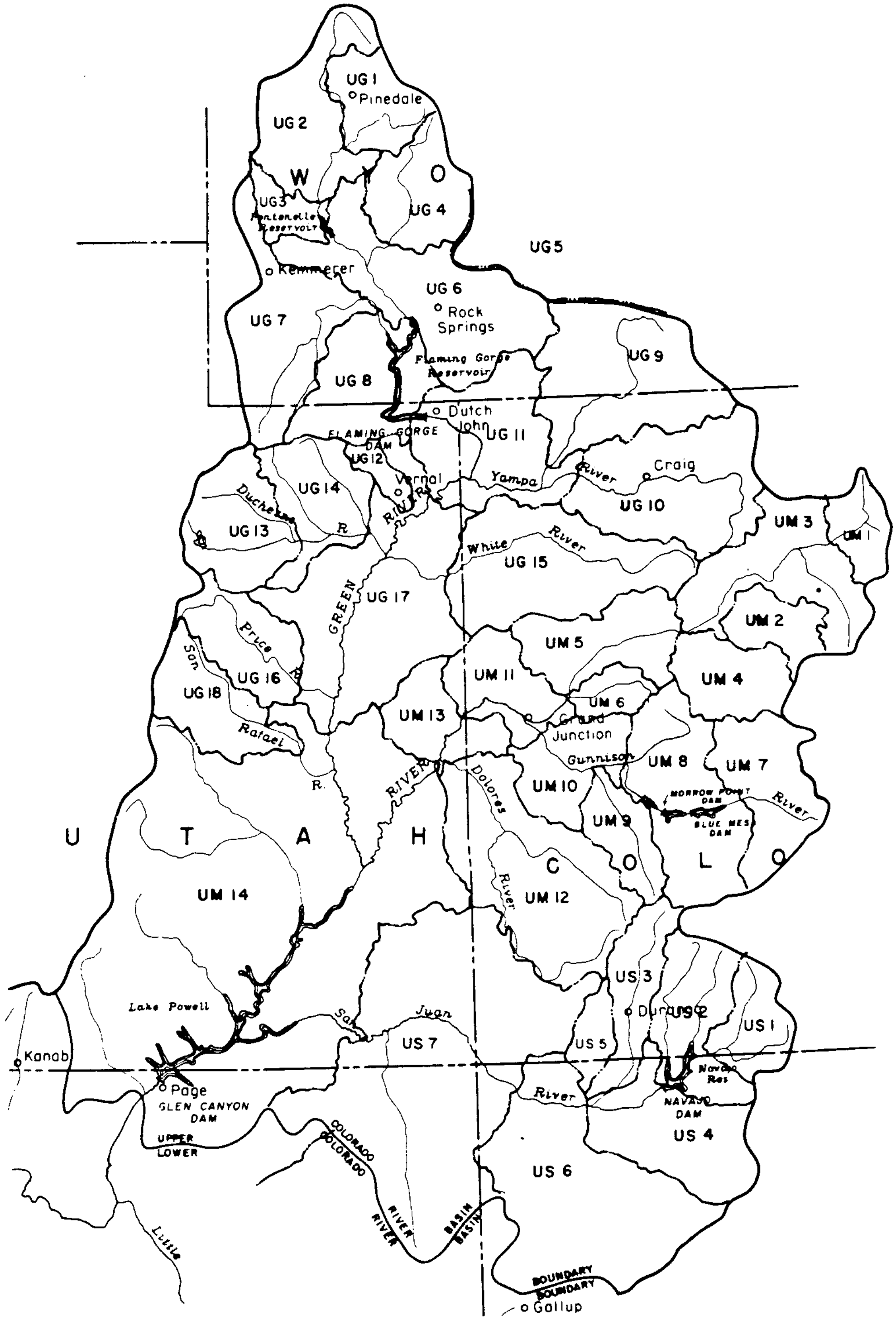


Fig. 13. Upper Colorado River Basin subarea map. (Source: Utah Water Research Laboratory, 1975)

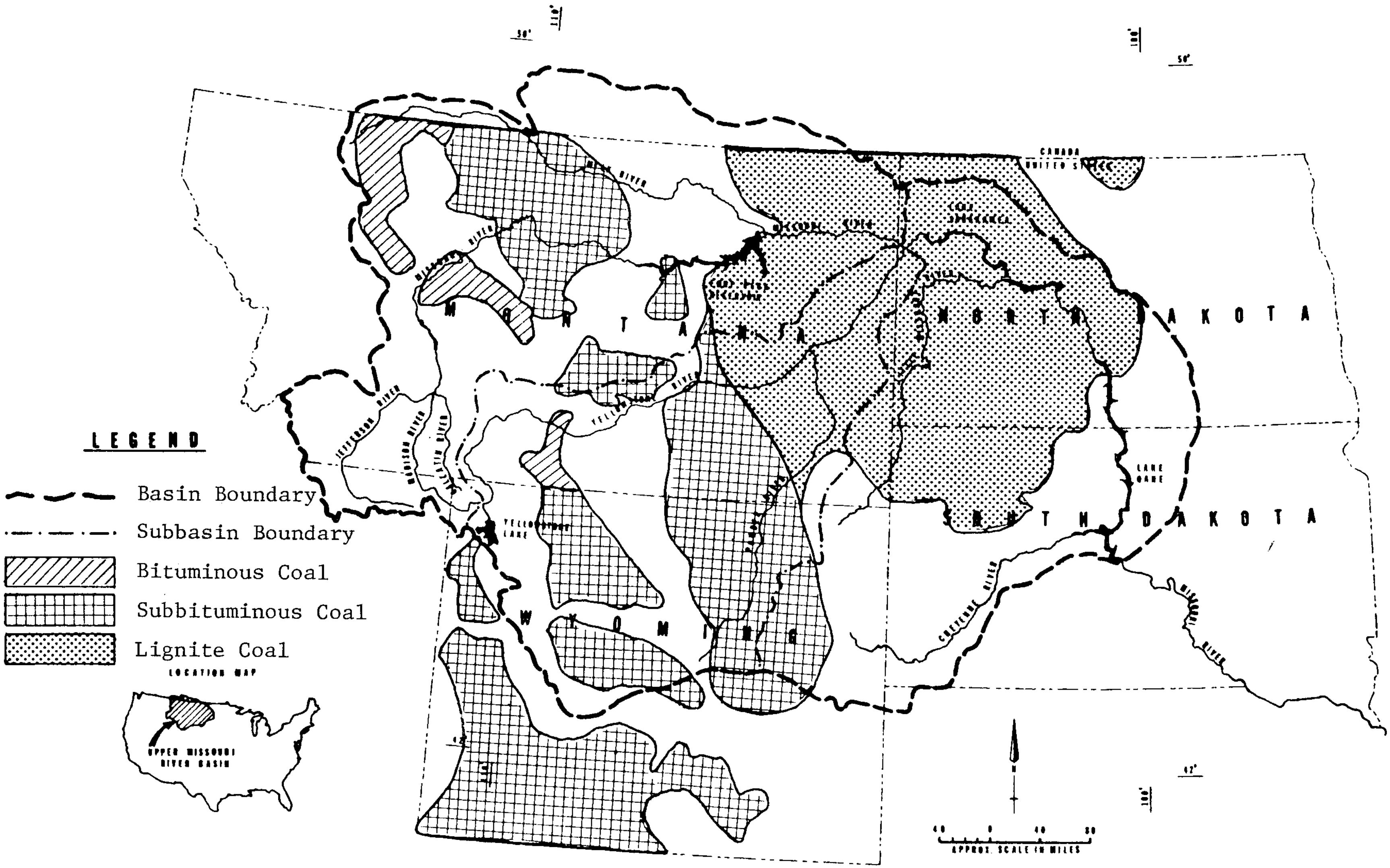


Fig. 14. General location of coal resources in the Upper Missouri River Basin. (Source: Environmental Protection Agency, 1974)

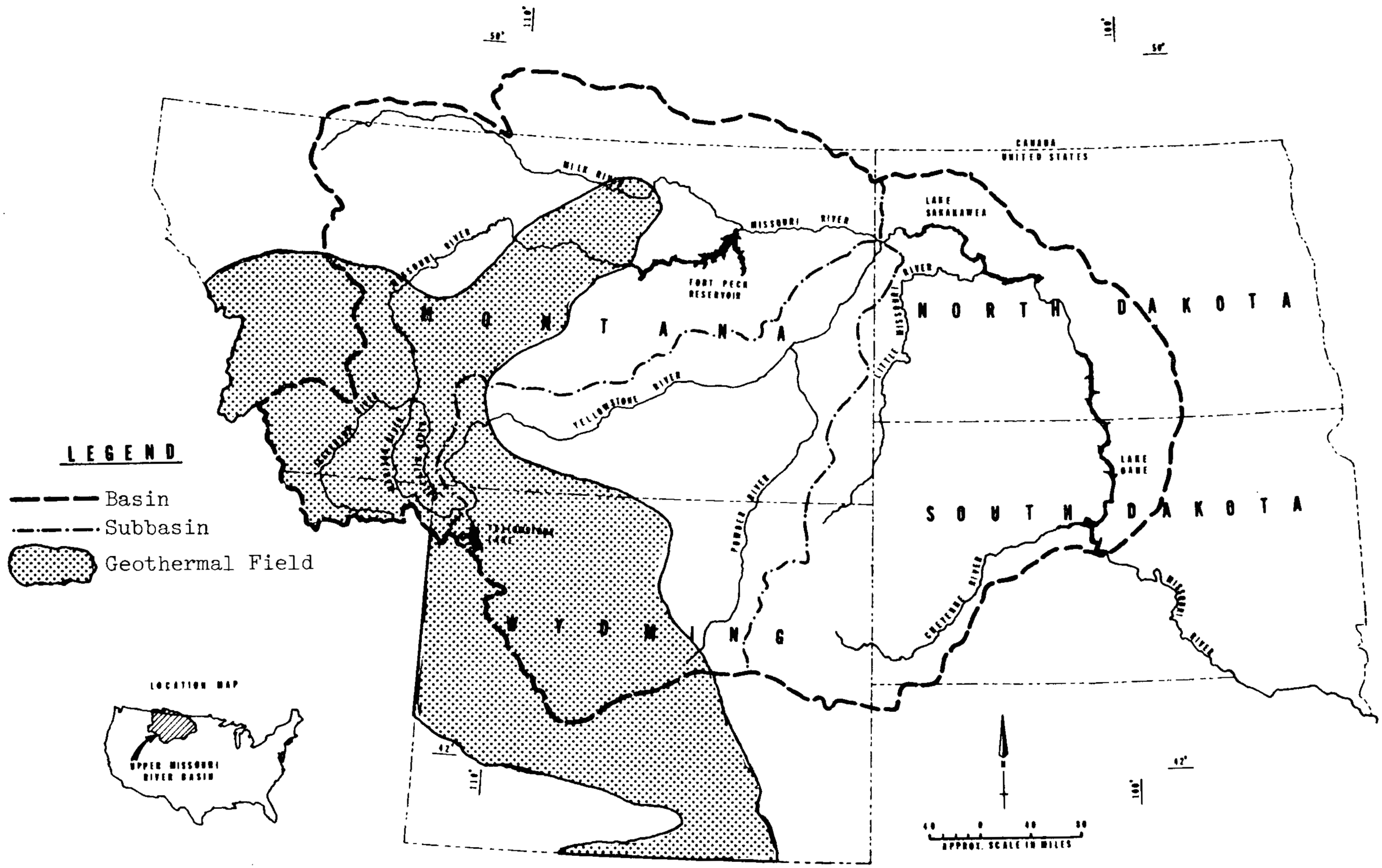


Fig. 15. Potential location of geothermal energy resources in the Upper Missouri River Basin. (Source: Environmental Protection Agency, 1974)

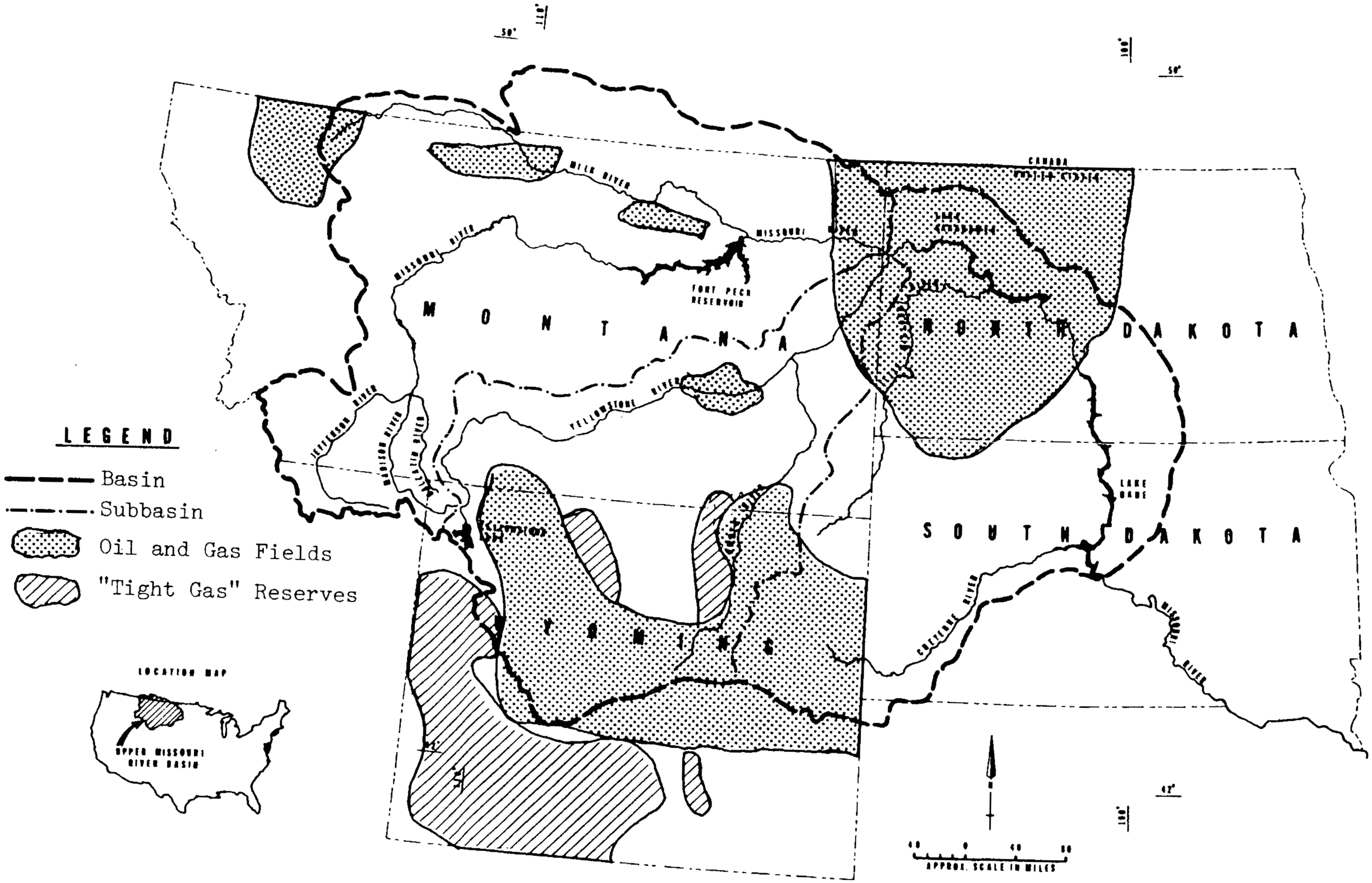


Fig. 16. General location of oil and gas reserves in the Upper Missouri River Basin. (Source: Environmental Protection Agency, 1974)

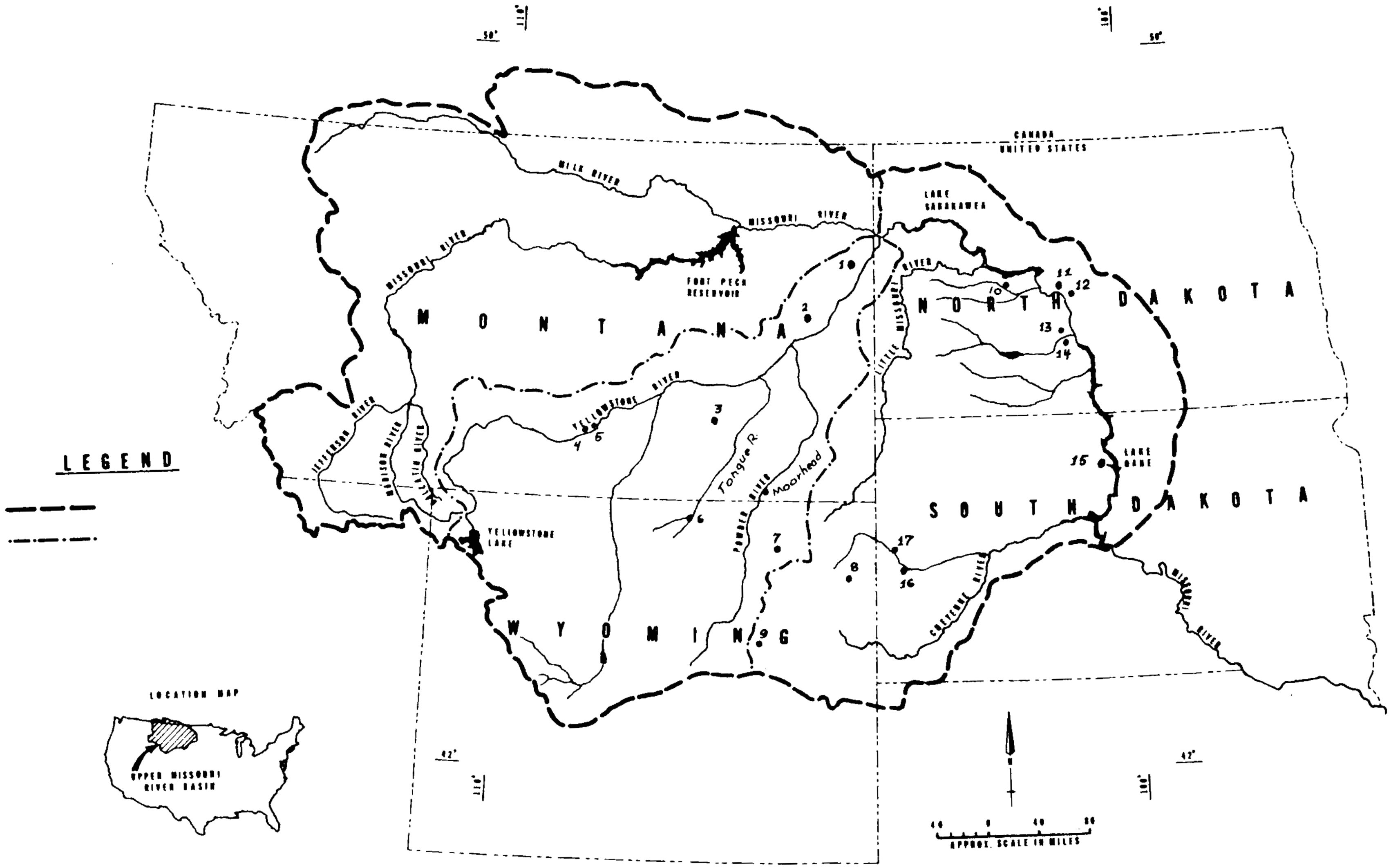


Fig. 17. Locations of coal-fired generating plants in the Upper Missouri River Basin. (Source: Harza Engineering Company, 1976)

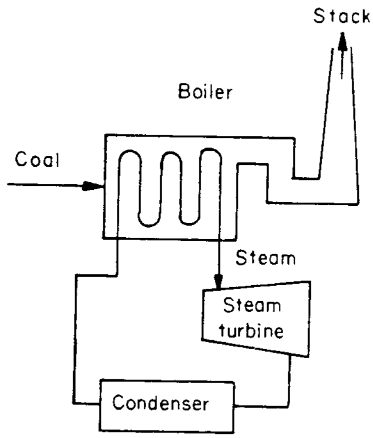


Fig. 18. Coal-fired steam electric generating plant. (Source: May and Kube, 1974)

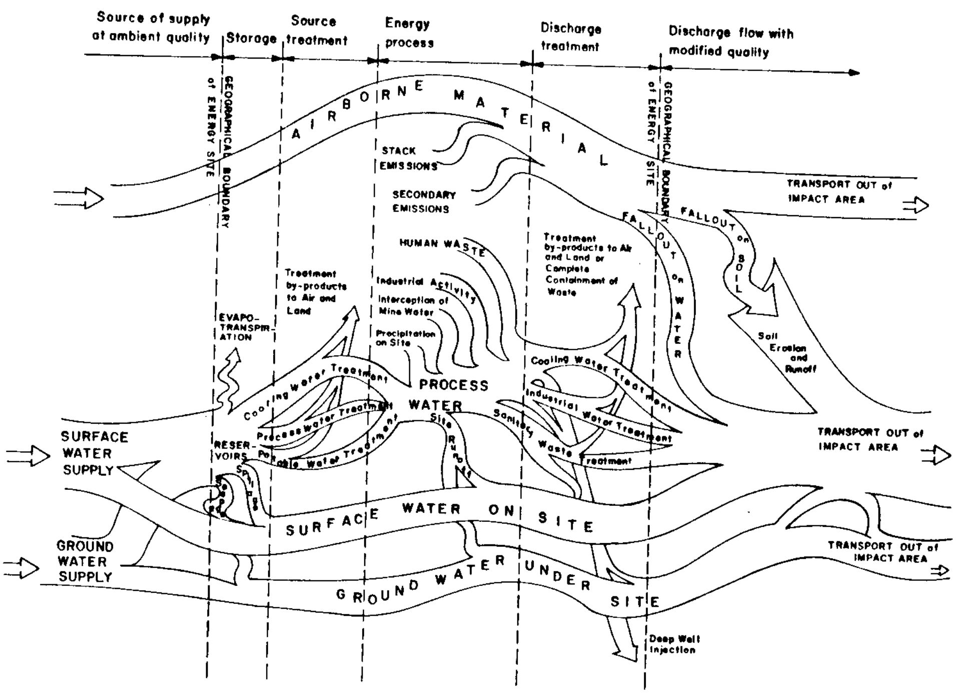


Fig. 19. Transport of contaminants to receiving water bodies.

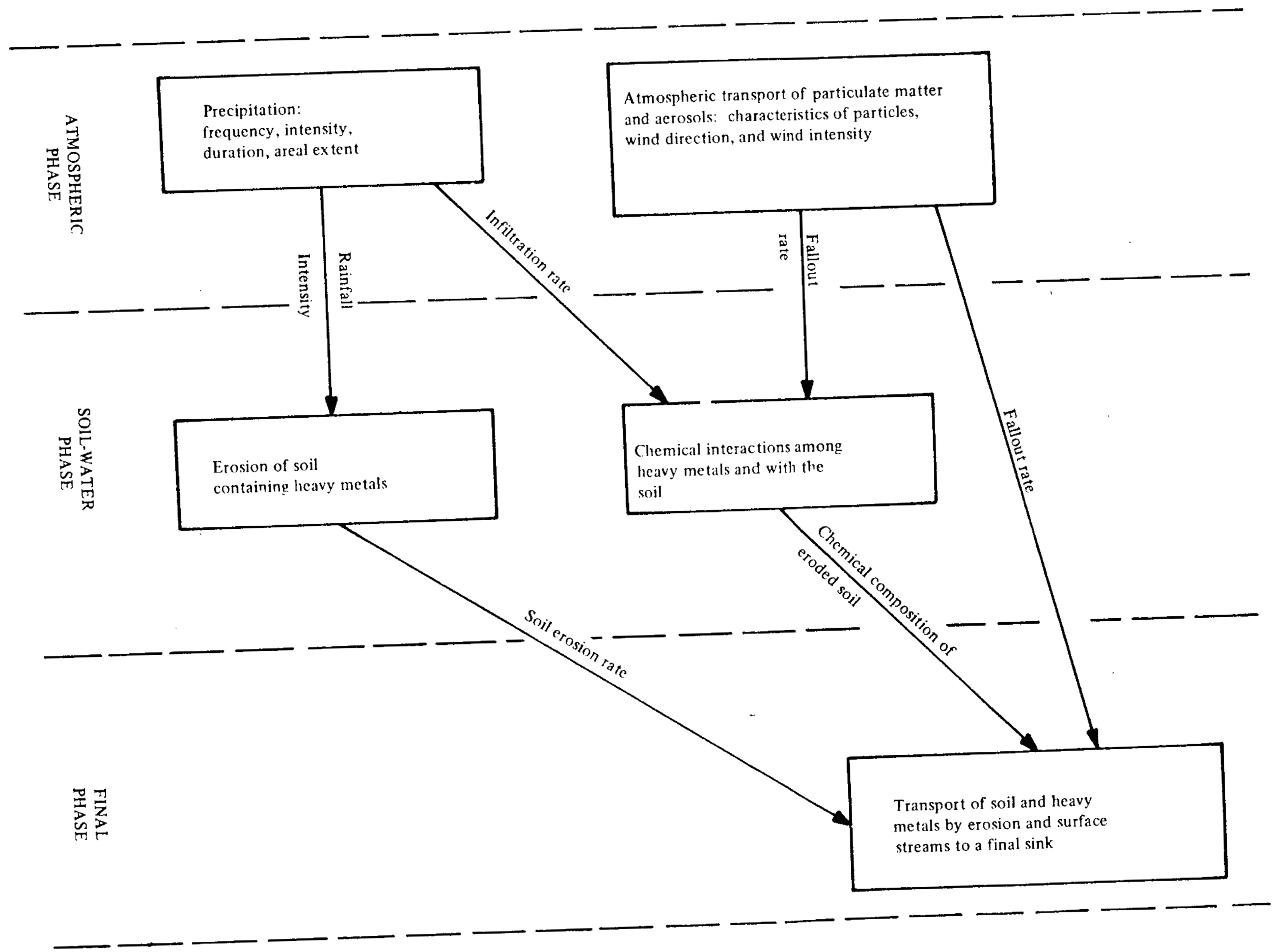
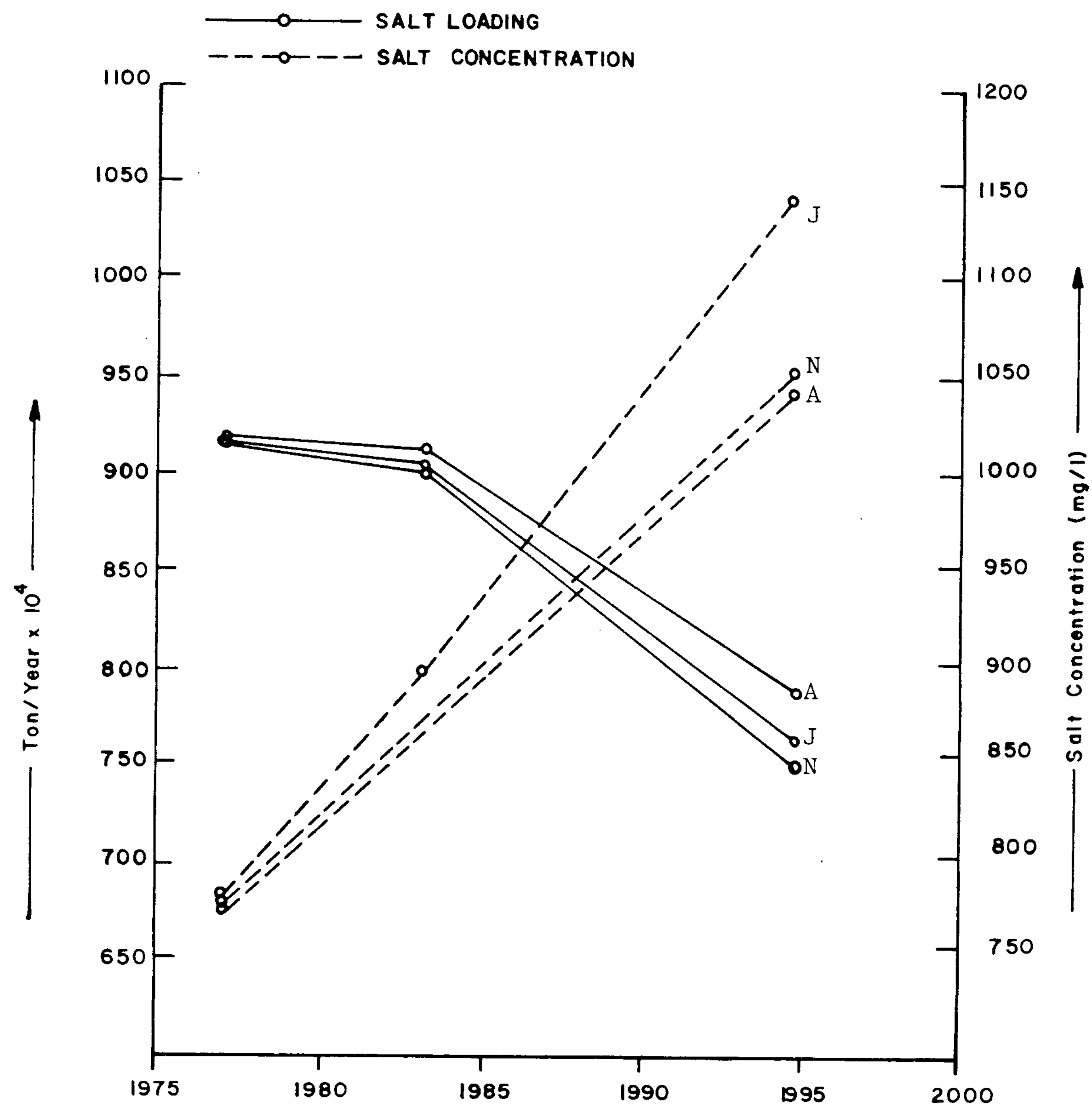
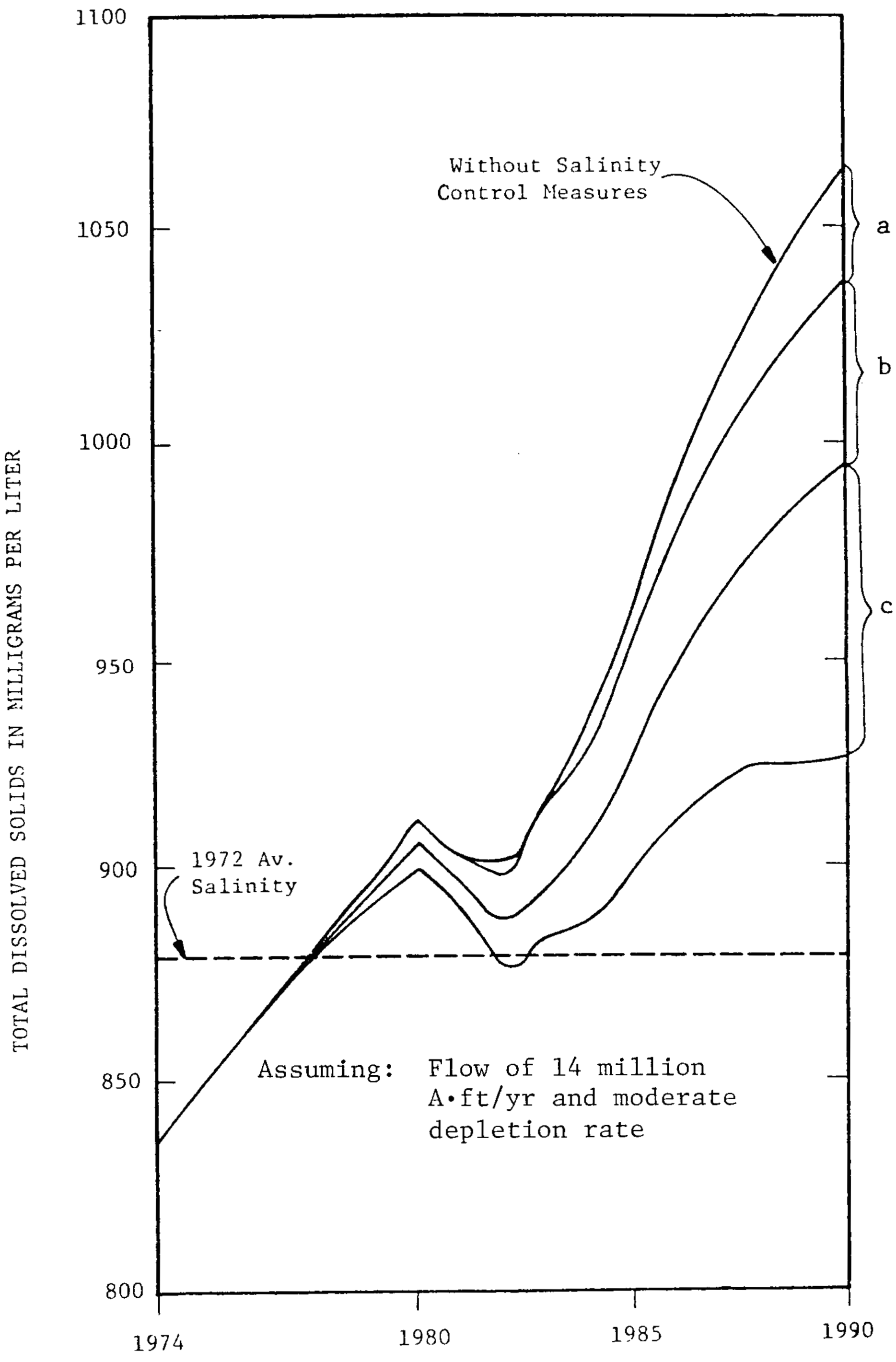


Fig. 20. Conceptual arrangements of the major components of heavy metal transport process. (Source: Jurinak et al., 1977)



J = High-energy development
N = Water shifts from agriculture to energy
A = Base case

Fig. 21. Predicted salinity effects at Imperial Dam for alternative energy development futures and stream flow conditions. (Source: Utah Water Research Laboratory, 1975)



a. Total waste water containment by industries and energy development
b. Four salinity control projects authorized by PL 93-320
c. Twelve additional salinity control projects

Fig. 22. Projected salinity at Imperial Dam. (Source: Ribbens and Wilson, 1973)

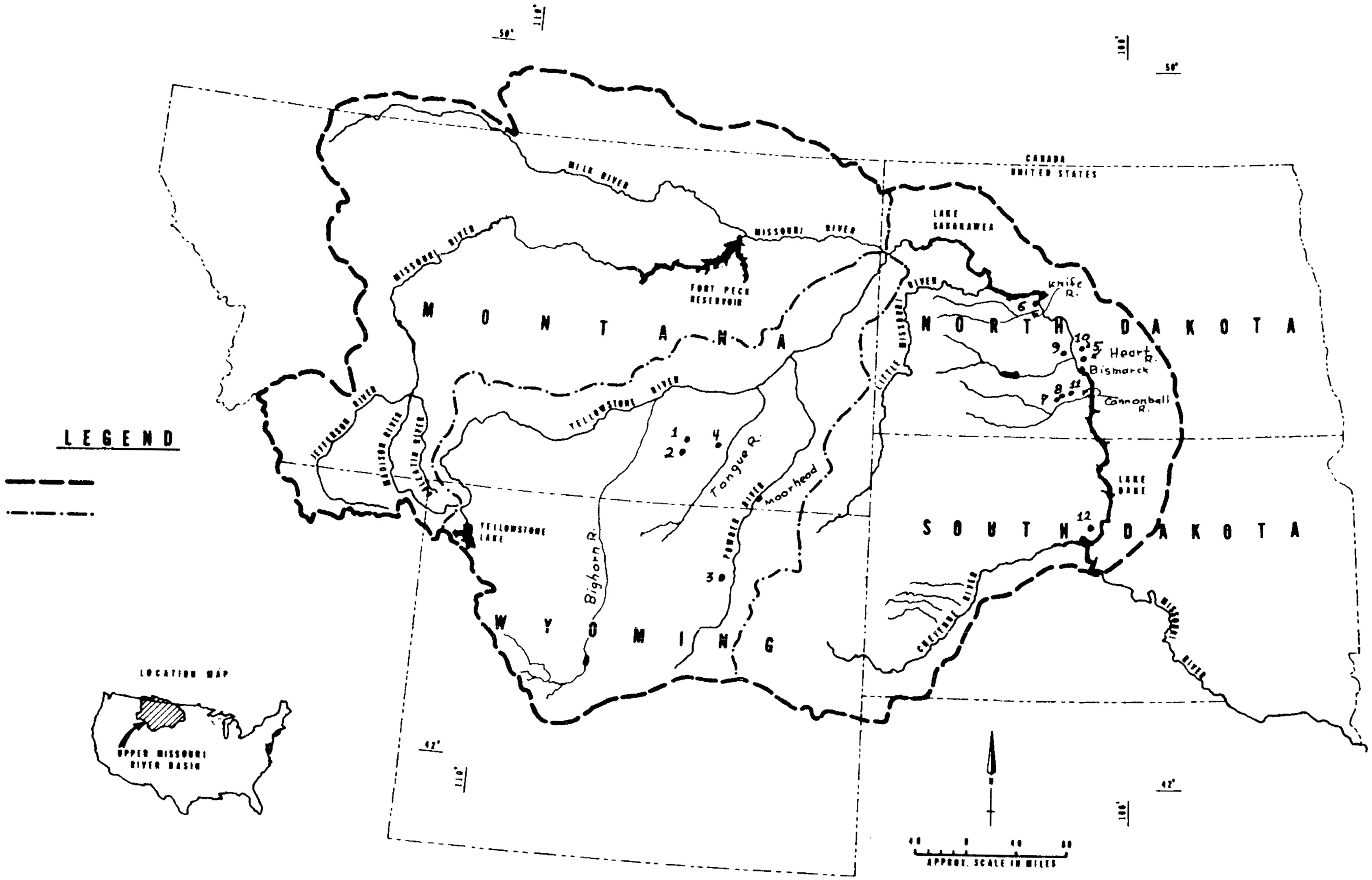


Fig. 23. Most probable locations for coal-fired electric plants in the Upper Missouri River Basin. (Source: Northern Great Plains Resources Program, 1975)

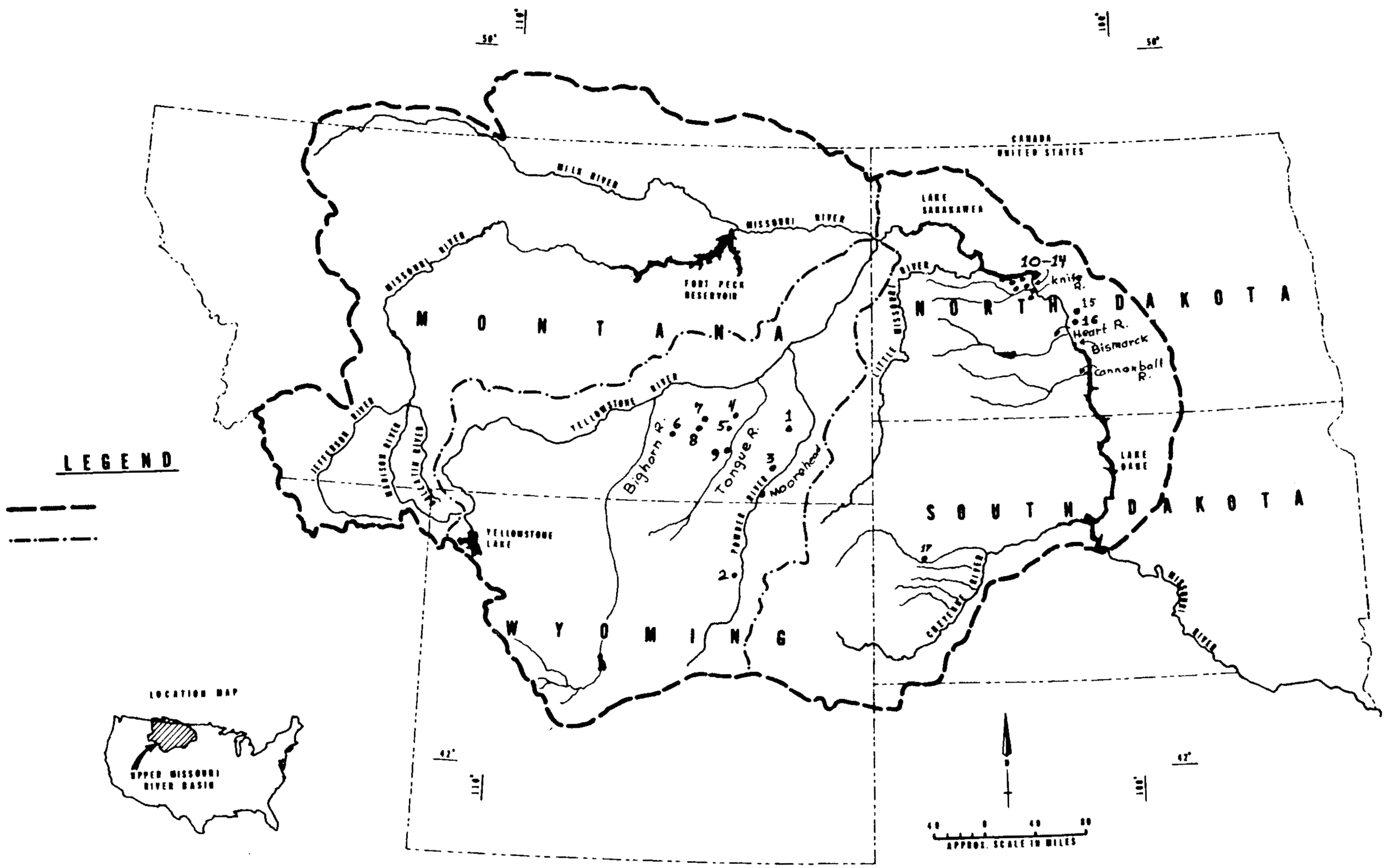


Fig. 24. Most probable locations for coal gasification plants in the Upper Missouri River Basin. (Source: Northern Great Plains Resources Program, 1975)

TABLE I

DRAINAGE AREA AND HISTORIC UNIT DISCHARGES
IN THE UPPER COLORADO RIVER BASIN

Gauging Station	Drainage Area	Record Prior to 1965	Unit Discharge
	Square miles	Years	ft^3s^b/sq. mi.
Colorado River near Grand Lake, Colorado	103	46	0.922
Colorado River at Glenwood Springs, Colorado	4 560	66	0.596
Colorado River near Cameo, Colorado	8 050	32	0.484
Colorado River near Cisco, Utah	24 100	54	0.327
Colorado River at Compact Point, Lee Ferry, Arizona	109 580[a]	52	0.155

[a]Drainage area as measured by Utah Water Research Laboratory, 1975; other area figures are from USGS Water Supply Papers.

[b]One cubic foot per second (ft^3s) = 724 acre•ft/yr

SOURCE: US Water Resources Council, 1976, and the Upper Colorado Region State-Federal Inter-Agency Group/Pacific Southwest Inter-Agency Committee, June 1971.

TABLE II

ESTIMATED LAND USE AND WATER DEPLETIONS IN THE UPPER
COLORADO RIVER BASIN, 1973

Land and/or Water Use	Land Use		Water Depletion[a]	
	Acres x 10^3	%	Acre•ft x 10^3	%
Irrigated Agriculture	1 622	2.0	2175	62.0
Dry Cropland	950	1.0	-[b]	-
Range Land	37 500	52.0	-[b]	-
Alpine and Forest	28 710	40.0	-[b]	-
Urban	368	1.0	91	3.0
Export	-	-	651	19.0
Energy Development	-	-	59	2.0
Barren or Other Land	3 084	4.0	-[b]	-
Water Surface Area	405	1.0	520[c]	14.0
Totals	72 639	100.0	3496	100.0

[a]From Colorado River Basin Salinity Control Forum, June 1975.

[b]On-site use of precipitation so that water does not reach streams.

[c]US Bureau of Reclamation estimate of Colorado River Storage Project reservoir evaporation. From US Department of Interior, April 1975.

TABLE III

OCCURRENCE OF SIGNIFICANT WATER QUALITY PROBLEMS IN THE UPPER COLORADO RIVER BASIN

STORET Data Stations	Basin/River Reach[a]	Subbasins		Salt									Potential Development of Energy Resources
		Hydrologic[b]	WRSA[c]	Sources	Damages	BOD-DO[d]	Eutrophication	Sediment Production	Heavy Metals	ΔTemp-Energy	Phenols + Petroleum Spills	NO_3-N	
2,3	New Fork	UG 1	1401						X				
1,4	GR above LaBarge	2	1401										Hydro
5	GR above Fontenelle	3	1401	X									
6	Big Sandy Creek	4	1401			X				X	X		Coal
7	GR above GRC	6	1401	X	X					X	X		Coal
8	Blacks Fork	7	1401			X				X			Hydro, coal
9	GR above FG Dam	8	1401			X				X			Coal
14,15	Little Snake	9	1402			X				X			Coal, oil, oil shale
12,13	Yampa River	10	1402			X				X			Coal, oil, oil shale
11,17	GR above Jensen	11	1402	X						X			Oil
16	Ashley Creek	12	1403										
19	Duchesne River above Duchesne	13	1403	X	X				X	X			Oil
20	Duchesne River above Randlett	14	1403	X					X	X			Oil, oil shale
21-23	White River	15	1402	X		X		X	X	X		X	Coal
24	Price River	16	1403							X			Coal
25	GR above Green River	17	1403	X				X		X			Coal
	San Raphael	18	1403			X			X				
26	CR above Hot Sulpher	UM 1	1405										
	Eagle River	2	1405			X			X	X			Coal
27-29	CR above Glenwood Springs	3	1405										
	Roaring Fork	4	1405			X							
30-32	CR above Plateau	5	1405			X			X				
33	Plateau Creek	6	1405			X			X				
36	Gunnison R above Gun.	7	1404			X			X				
37,38	CR above NFCR	8	1404	X	X	X			X				
39-40	Uncompahgre	9	1404,6	X									
34	CR above Grand Junction	10	1404-6	X	X	X			X	X			Coal
41-44	CR above CO-UT Line	11	1405	X		X			X			X	
45-53	San Miguel & Dolores	12	1406							X			Coal
54	CR above Cisco	13	1406			X	X	X	X	X	X		Hydro, coal
	CR above Lee Ferry	14	1406,8			X							
55,56	San Juan above Arboles	US 1	1407			X	X		X	X			Hydro, coal
58-60	SJ above Archuleta	2	1407			X	X		X	X			Coal
57,62-65	Animas	3	1407						X	X			Coal
61,65	SJ above Farmington	4	1407							X			Coal
	La Plata	5	1407										
66	SJ above Shiprock	6	1407			X		X	X		X	X	
67,68	SJ above Bluff	7	1408										

[a]GR = Green River, CR = Colorado River -- Main Stem, SJ = San Juan River.

[b]Hydrologic subbasins as defined by the USGS. (See Fig. 13 for geographic boundaries).

[c]Water Resources Subareas as designated by the Water Resources Council.

[d]BOD - Biological Oxygen Demand; DO - Dissolved Oxygen

SOURCE: Utah Water Research Laboratory, 1975.

TABLE IV

AVERAGE ANNUAL SURFACE WATER FLOW CONTRIBUTIONS TO THE UPPER MISSOURI RIVER BASIN

Subbasin and General Area Description	Average Depletions: Irrigation Farming	Large Reservoir Evap.	Forestry Practices	Watershed Treatment and Ponds	Other Uses	Total 1970
	(thousand acre•ft)					
Subtotal Fort Peck Dam	277.3	151.8	-16.9	53.2	0.0	465.4
Upper Missouri	326.8	152.8	-16.9	108.4	14.0	585.1
Yellowstone	213.1	82.3	-15.9	65.3	16.2	361.0
Subtotal Garrison Dam	602.1	780.1	-31.3	192.4	30.2	1573.5
Dakotas	229.6	1005.3	- 9.1	81.6	24.4	1331.8
Subtotal Oahe Dam	769.5	1240.4	-41.9	255.3	54.6	2277.9
Total Upper Missouri Basin	769.5	1240.4	-41.9	255.3	54.6	2277.9

Subbasin and General Area Description	Depletion Projections: 1970	1980	2000	2020	Average Annual Flow after 1970[a]	Percent of Basin Flow
Subtotal Fort Peck Dam	465.4	745.4	889.4	511.4		
Upper Missouri	585.1	953.3	1026.1	766.4	7 276	39
Yellowstone	361.0	934.1	784.5	857.4	8 800	48
Subtotal Garrison Dam	1573.5	3102.1	3339.5	3714.9		
Dakotas	1331.8	2379.2	3028.6	3893.7	2 449	13
Subtotal Oahe Dam	2277.9	4266.6	4839.2	5517.5		
Total Upper Missouri Basin	2277.9	4266.6	4839.2	5517.5	18 525	100

[a]Flow after 1970 depletion levels.

SOURCE: Missouri Basin Inter-Agency Committee, 1971.

TABLE V

ESTIMATED GROUNDWATER IN STORAGE
IN THE UPPER MISSOURI RIVER BASIN

Subbasins and Areas	Approximate Groundwater Volume (thousand acre•ft)	(%)
Upper Missouri	9 000	1
Yellowstone	15 000	2
North and South Dakota[a]	835 000	97
Totals	859 000	100

[a]Includes Eastern and Western Dakota subbasins of source document.
SOURCE: Missouri Basin Inter-Agency Committee, 1971.

TABLE VI

SUMMARY OF WATER QUALITY PROBLEMS
IN THE UPPER MISSOURI RIVER BASIN

	Location	DO[a]	BOD[b]	TDS	Eutrophi-cation	Heavy Metals	Potential Energy Development
1	Bighorn River at Bighorn, MT	--	--	X	--		X
2	Tongue River at Miles City, MT	--	--	X	--		X
3	Powder River at Moorhead, MT			X	X		X
4	Yellowstone River near Sidney, MT				X		X
5	Knife River at Hazen, ND	--		X	--		X
6	Heart River at Mandan, ND	X		X	X	--	X
7	Cannonball River at Brenen, ND			X	X		X
8	Missouri River at Bismarck, ND				X		X
9	Belle Fourche River near Elm Springs, SD	X		X	X		X
10	Cheyenne River at Edgemont, SD	X		X	X		--

NOTE:
X, when at minimum value
1. DO < 5 mg/L and when at average values
2. BOD > 5 mg/L
3. TDS > 500 mg/L
4. Heavy metals
   Pb >0.05   B > 1
   Cu > 1   Zn > 5
   F > 2
   Se >0.01
5. Eutrophication
   Total P >0.01
   N >0.3

--, when no data are available

[a]BOD - Biological Oxygen Demand.

[b]DO - Dissolved Oxygen.

TABLE VII

UPPER COLORADO RIVER BASIN COAL MINING ACTIVITIES
(MILLIONS OF TONS/YEAR)

State	County	1974 Production[a] Under-ground	1974 Production[a] Strip	1985 Production[a] Under-ground	1985 Production[a] Strip	Coal Reserves[b] (millions of tons) Under-ground	Coal Reserves[b] (millions of tons) Strip
Colorado	Moffat	0.243	0	2+	6.9	2571	270
	Montrose	0	0.107		+	806	60
	Pitkin	0.843	0.023	1.0			
	Rio Blanco	0.012	0	5.5	0.3	1067	0
	Routt	0.011	3.385	2.3	10.9+	3414	413
	La Plata	0.010	0	+		322	0
	Archuleta	0	0		0.25	66	0
	Delta	0.374	0	3.1+		205	0
	Gunnison	0.891	0	2.6		248	0
	Mesa	0.001	0	2.25		229	0
New Mexico	San Juan	0	7.873		76.3	442	2008
Wyoming	Lincoln	0	3.353		10.8	556	1000
	Sweetwater	0.103	0.735	0.2+	13.1	3625	1116
Utah	Carbon	2.958	0	11.4		767	0
	Emery	2.534	0	10.2	0.5	72	10
	Garfield	0	0	6.0		57	24
	Grand	0	0	0.2		0	0
	Kane	0	0	10.4		1715	200
	Wayne	0	0	10.0	1.0	23	18
	Uintah	0	0		+	40	0

[a]Data from BOM 1976 Circular 8719 and 1976 Keystone Coal Industry Manual. Production rate of some future mines not specified, indicated by +.

[b]Data from Bureau of Mines, Information Circular IC 8693, 1975.

TABLE VIII

FUTURE OIL SHALE PROJECTS IN UPPER COLORADO RIVER BASIN

	Project Name	Project Type	County	Production (thousand bbl/day) 1985	Production (thousand bbl/day) 2000
	Colorado				
1.	Parachute Creek	Underground Mine	Garfield	0	50
2.	Rio Blanco	Open Pit Mine	Rio Blanco	100	100
3.	C-B Project	Underground Mine	Rio Blanco	50	50
4.	Union Oil	Underground Mine	Garfield	50	50
5.	Roan Creek	Modified in Situ	Garfield	0	30
6.	Paramo Demonstration	Underground Mine	Garfield	0	7
7.	Superior Oil	Underground Mine	Rio Blanco	0	68.5
	Utah				
8.	Westco	In Situ	Uintah	Pilot	
9.	White River Shale	Underground Mine	Uintah	50	50
10.	Sand Wash	Underground Mine	Uintah	75	75

NOTE: The FEA 1985 Scenario calls for a production rate of 300,000 bbl/cd.[a] Apart from the pilot plant, the only other proposed plant for producing oil shale that has a stated initial operating date is the Sand Sash plant in Utah, set for 1985. All of the others have indefinite operating dates. We would suggest that, for the 1985 date, the 300,000 bbl/cd output be split as follows:

State	ASA	Oil Shale
Utah: 100,000 bbl/cd	1401	220×10^3
Colorado: 200,000 bbl/cd	1402	80×10^3 (Garfield)

In the year 2000, the ERDA 2 Scenario calls for a production of 1,300,000 bbl/cd, which far exceeds the 470.5×10^3 value from the sum of the proposed plant outputs. We suggest that the distribution for the year 2000 be as follows:

State	ASA	Oil Shale
Utah: 450,000 bbl/cd		
Colorado: 650,000 bbl/cd	1401	1.1×10^6
Wyoming: 200,000 bbl/cd	1402	200×10^3

[a]calendar day.

TABLE IX

UPPER COLORADO RIVER BASIN--ENERGY CONVERSION FACILITIES

			Production
A. Coal Steam-Electric Facilities			
1.	Naughton	Kemmerer, Wyoming, Lincoln County	1540 MWe
2.	Jim Bridger	Rock Springs, Wyoming, Sweetwater County	2000 MWe
3.	Craig	Craig Colorado, Moffat County	1520 MWe
4.	Hayden	Hayden, Colorado, Routt County	430 MWe
5.	Hatch Flats[a]	Rangely, Colorado, Rio Blanco County	300 MWe
6.	Intermountain[b]	Caineville, Utah, Wayne County	3000 MWe
7.	Huntington	Huntington, Utah, Emery County	1245 MWe
8.	Emery	Castle Dale, Utah, Emery County	830 MWe
9.	San Juan	San Juan, New Mexico, San Juan County	1590 MWe
10.	Four Corners	Farmington, New Mexico, San Juan County	2960 MWe
B. Hydroelectric Facilities			
1.	Flaming Gorge	Daggett County, Utah	129 MWe
2.	Morrow Point	Montrose, Colorado, Gunnison County	138 MWe
C. Geothermal Electric Facilities[c] (Low Temperature)			
1.	Mt. Waunita Hot Springs	Gunnison County, Colorado	25 MWe
2.	W. of Ponderhorn	Gunnison County, Colorado	25 MWe
3.	Oureay Area	Oureay County, Colorado	25 MWe
4.	Mt. Dunton	Dolores County, Colorado	25 MWe
D. Coal Conversion Facilities[c] (Gasification)			
1.	Green River	N.E. Uinta County, Wyoming	250 MMcfd[d]
2.	WESCO	30 m. S.W. of Farmington, New Mexico, San Juan County	1000 MMcfd
3.	Burnham	35 m. S.W. of Farmington, New Mexico, San Juan County	785 MMcfd
E. Oil Refineries			
	Gary Western Co. (currently operating)	W. of Grand Junction, Colorado	5400 bbl/cd[e]
F. Slurry Pipelines[f]			
	Proposed Route		
	Bald Knolls 8 miles south of Alton, Utah	Parallel lines to St. George, Utah, Washington County and Arrow Canyon, Nevada	Capacity 2.3×10^6 t/y St. George; 9.1×10^6 t/y Arrow Canyon
	Both pipelines are expected to be in operation before 1985.		

[a]Hatch Flats will not be operating before the 1980s and hence will not be part of the 1985 Scenario.

[b]Only 1500 MW of the Intermountain Project will be on line by 1985.

[c]For the year 2000 only.

[d]MMcfd - Million cubic feet per day.

[e]cd - Calendar day.

[f]BOM estimates that water consumption will be 8000 acre•ft/yr from underground wells.

SOURCE: Federal Energy Administration, 1976, and Goettle et al., 1977.

TABLE X

PROJECTED WATER NEEDS FOR ENERGY DEVELOPMENT BY 1990-2000

Study	Level[a] of Energy Development	Projected Energy Development Water Use in Thousands of Acre·ft: Coal-Fired Power	Coal Mining	Coal Gas	Other Energy Process	Oil Shale	Nuclear	Total
Western States Water Council		464	125	149	11	320	87	1156
Colorado River Salinity Forum	L		360[b]			105		465
	M		405[b]			130		535
	H		720[b]			225		945
Colorado River Regional Assessment Study	L	243	4	0	2	0	50	299
	M	303	10	63	20	73	90	599
	H	525	16	142	23	229	105	1040
Water for Energy Management Team		506[c]		273[c]		257		1036

[a]L = Low; M = Moderate; and H = High.

[b]Includes estimated requirements for coal-fired electric and coal gasification plants.

[c]Includes water required for coal mining operations.

TABLE XI

WATER, ENERGY, AND ENVIRONMENTAL CONDITIONS OF THE UPPER COLORADO RIVER BASIN

Upper Basin River Reach	Subbasin[a] Hydro (WRSA)	Usable Reservoir Storage (ac-ft)	Area of Irr. Ag. (%) (1000 acres)	Potential Energy Development	Population Centers (Number)	Salinity: 1000 tons per year	Salinity: TDS mg/l	Water Quality Problems: Sed. Production	Water Quality Problems: Temperature	Water Quality Problems: Eutrophication	Water Quality Problems: DO-BOD	Water Quality Problems: Coliform	Water Quality Problems: Toxic & Hazardous HM, Phn, Peat Spills	Significant Environmental Issues: Endangered Species	Significant Environmental Issues: Significant Habitats & Parks	Recreational Poten.: R-Running	Recreational Poten.: Reservoirs	Recreational Poten.: Fishing	Bash
New Fork	UG1(1401)	100 000	52.4 (6.5)			71	100								Wind R. Mtns			X	UG1
GR above LaBarge	UG2(1401)	8 500	116.0 (7.78)			310	200		X				H. Metals		Wind R. Mtns			X	UG2
GR above Fontenelle	UG3(1401)	345 000	4.3 (0.71)	Hydro		319	206										X	X	UG3
Big Sandy Creek Basin	UG4(1401)	58 000	21.4 (4.7)			87	1827		X										UG4
GR above GR, WY	UG6(1401)	-	1.8 (0.08)	Coal	Rock Springs 11657	494	323		X			X	Phenols		Wildlife				UG6
Blacks Fork R.	UG7(1401)	34 000	77.4 (3.9)	Coal		199	628						Phenols		Uintah			X	UG7
GR above FG Res.	UG8(1401)	3 500 000	28.0 (1.94)	Hydro, Coal		765	392										X	X	UG8
Little Snake	UG9(1402)	76 000	25.7 (1.1)	Coal		115	211		X		X				Medicine Bow			X	UG9
Yampa R.	UG10(1402)	7 400	79.4 (3.44)	Coal,oil,oil shale		333	220		X		X				Medicine Bow	X		X	UG10
GR above Jensen	UG11(1402)	4 000	5.4 (0.27)	Coal,oil,oil shale		1222	440				X					X			UG11
Ashley Creek	UG12(1403)	38 000	27.4 (11.1)	Oil		77	1316										X		UG12
Duchesne R. above Duch.	UG13(1403)	280 000	17.9 (1.64)			150	312								Uintah		X	X	UG13
D. R. above Randlett	UG14(1403)	58 000	141.0 (9.9)	Oil		422	707		X				H. Metals						UG14
White R.	UG15(1402)	-	34.8 (1.35)	Oil, oil shale		345	509		X		X		H. Metals	Bonytail	Wildlife				UG15
Price R.	UG16(1403)	78 000	19.6 (2.0)	Coal	Price,6 218	248	2532	X			X	X	H. Metals						UG16
GR above Green R., UT	UG17(1403)	7 6000	20.0 (0.58)	Coal		2405	473		X						Wildlife	X			UG17
San Raphael	UG18(1403)	68 000	39.3 (3.67)	Coal		243	1951	X							Natl. Forest				UG18
CR above Hot Sulphur	UM1(1405)	490 000	23.9 (4.45)			19	87		X		X		H. Metals		Rocky Mtns.		X	X	UM1
Eagle R.	UM2(1405)	2 500	22.0 (3.54)			203	338								Natl. Forest			X	UM2
CR above Glenwood Sp.	UM3(1405)	510 000	73.5 (4.15)	Coal		610	310				X		H. Metals		Natl. Forest		X	X	UM3
Roaring Fork	UM4(1405)	4 200	29.5 (3.17)			305	254								Natl. Forest			X	UM4
CR above Plateau Cr.	UM5(1405)	17 000	54.7 (4.14)			1540	443		X		X				Natl. Forest			X	UM5
Plateau Cr.	UM6(1405)	45 000	21.9 (5.66)			48	261				X		H. Metals		Natl. Forest			X	UM6
Gunnison R. ab. Gunnison	UM7(1404)	120 000	54.9 (4.22)			127	147				X		H. Metals		Natl. Forest			X	UM7
CR above NFGR	UM8(1404)	890 000	62.8 (4.27)			140	138				X		H. Metals		Natl. Forest		X	X	UM8
Uncompahgre	UM9 (1404) (1406)	-	104.2 (14.66)		Montrose 6496	580	1312				X	X	H. Metals		Natl. Forest			X	UM9
CR above Grand Jct.	UM10 (1404) (1406) (1405)	37 000	39.6 (2.48)			1647	639									X			UM10
CR ab. CO-UT Line	UM11(1405)	-	86.0 (11.6)	Coal	Grand Jct. 20 170	4202	680		X		X		H. Metals						UM11
San Miguel & Dolores	UM12(1406)	40 000	43.2 (1.47)			500	607									X			UM12
CR above Cisco, UT	UM13(1406)	-	2.7 (0.24)	Coal		4713	662								Arches,Canyonlands,Marshes				UM13
CR above Lee Ferry	UM14 (1406) (1408)	1 000 000	44.3 (0.37)	Hydro, coal		8570	609	X	X	X	X		H. Metals		Lake Powell, Bryce		X	X	UM14
San Juan ab. Arboles	US1(1407)	-	1.8 (1.49)			81	118				X				Natl.Forest	X	X	X	US1
S.J. above Archuleta	US2(1407)	1 200 000	11.8 (1.49)	Hydro, coal		197	165		X		X		H. Metals		Natl.Forest	X	X	X	US2
Animas R.	US3(1407)	61 000	33.3 (3.82)	Coal	Durango 10 460	246	288		X		X	X	H. Metals		Natl.Forest	X	X	X	US3
S.J. ab. Farmington	US4(1407)	-	12.3 (0.73)	Coal		530	241		X	b		X	H. Metals			X	X	X	US4
La Plata	US5(1407)	-	30.7 (8.2)	Coal		20	490									X	X	X	US5
S.J. above Shiprock	US6(1407)	6 700	14.5 (0.44)			680	300					X				X	X	X	US6
S.J. above Bluff	US7(1408)	63 000	79.7 (1.23)		Cortez 6032	1010	461	X			X	X	H. Metals			X	X	X	US7

[a] Hydrologic subbasins as defined by the U.S.G.S. See Fig. 13 for geographical boundaries. Water Resources.. Subareas as designated by the Water Resources Council.

[b] Phosphorus.

NOTE:

Blank areas indicate no data, the other data points (-) are incomplete because data are incomplete.

GR = Green River; CR = Colorado River; SJ = San Juan River; FG = Flaming Gorge; DR = Duchesne River.

TDS = Total Dissolved Solids.

SOURCE: Utah Water Research Laboratory, 1975.

TABLE XII

COAL PRODUCTION IN THE UPPER MISSOURI RIVER BASIN

	1972 Underground	1972 Strip	1972 Total	1973 Estimated	1980 Projected
	(thousand short tons)				
Montana				16 000	64 000
Bituminous	17	7 882	7 889		
Lignite		322	332		
North Dakota					
Lignite		6 632	6 632	7 500	42 000
Wyoming					
Subbituminous	442	10 487	10 928	15 000	54 000
Total	459	25,333	25 781	38 500	160,000

SOURCE: Environmental Protection Agency, 1974

TABLE XIII

COAL-FIRED ELECTRIC GENERATING FACILITIES
IN THE UPPER MISSOURI RIVER BASIN

Map Number[a]	Name	Location	Size (MWe)
1	Lewis and Clark	Sidney, Montana	50.1
2	Glendive	Glendive, Montana	7.0
3	Colstrip	Colstrip, Montana	660.0
4	Frank Bird	Billings, Montana	69.0
5	J. E. Covette	Billings, Montana	172.8
6	ACME	Sheridan, Wyoming	8.0
7	Neil Simpson	Gillette, Wyoming	27.6
8	Osage	Osage, Wyoming	34.5
9	Dave Johnston	Glenrock, Wyoming	750.0
10	Beulah	Beulah, North Dakota	12.5
11	Stanton	Stanton, North Dakota	172.0
12	Leland Olds	Stanton, North Dakota	240.0
13	Milton R. Young	Center, North Dakota	234.5
14	Hoskett	Mondan, North Dakota	105.0
15	Mobridge	Mobridge, South Dakota	8.5
16	Kirk	Lead, South Dakota	31.5
17	Ben French	Rapid City, South Dakota	22.0

[a]See Fig. 17 for map location.

SOURCE: Harza Engineering Company, 1976.

TABLE XIV

PROJECTIONS OF COAL-RELATED ENERGY DEVELOPMENTS IN THE UPPER MISSOURI RIVER[a] BASIN

		Energy Development Scenarios[b]					
		Low		Most Probable		High	
Activity	Units	1985	2000	1985	2000	1985	2000
Mines[c]	Total Number	25	25	32	103	59	159
Coal Production	10^6 tons/yr	111	111	162.82	513.1	293.9	791.8
Steam Electric Plants[d]	Total Number	14	14	11	23	21	21
Megawatt-capacity	MW	2 562	2 562	4 723	10 992	10 210	10 214
Generation	GW-h/yr	15 711	15 711	20 136	51 317	42 270	48 878
Coal Gasification[e]	Number of Units	0	0	1	15	1	21
Production	$MMft^3/d$	0	0	250	3 814	250	5 354
Water Requirements[f]	Acre•ft/yr	2 220	2 220	3 256	10 262	5 877	15 837
Mines	Acre•ft/yr	5 206	5 206	10 450	36 793	19 068	54 671
Reclamation	Acre•ft/yr	0	0	9 986	152 071	9 986	213 893
Coal Gasification	Acre•ft/yr	39 276	39 276	50 341	128 293	105 674	122 194
Electric Generation	Acre•ft/yr	0	0	0	0	58 724	149 437
Slurry Pipelines	Acre•ft/yr	46 702	46 702	74 033	327 419	199 329	556 032
Total	Acre•ft/yr						

[a]Yellowstone level B study of lignite fields in North Dakota and Montana, and Powder River coal fields in Montana and Wyoming.

[b]Assumes water delivery cost less than $450/acre•ft.

[c]Based on an average mine capacity of 5 million tons per year.

[d]Based on an average plant size of 500 MW.

[e]Based on an average unit capacity of 250 $MMft^3$/day.

[f]Consumptive use.

SOURCE: Harza Engineering Company, 1976.

TABLE XV

EFFLUENT SOURCE MODULES OF COAL GASIFICATION PLANTS

Module	Description	Effluent
1	Coal storage and preparation	Rainwater runoff
2	Oxygen blown gasification	Ash
3	Quenching and cooling	Tar-oil
4	Shift conversion	Catalyst
5	Gas cooling	Gas liquor
6	Gas purification (Rectisol wash)	Gas liquor
7	Methanation	Catalyst
8	Final gas purification (Rectisol wash)	Gas liquor
9	Compression and dehydration	Condensate
10	Ash handling	Wet ash
11	Tar-gas liquor separation	Tar & oil water
12	Phenol recovery (Phenosolvan process)	Wastewater
13	Ammonia recovery	Wastewater
14	Wastewater treatment	Sludge & Effluent
15	Cooling tower	Blowdown
16	Sulfur recovery (Stretford Process)	Wastewater
17	Stack gas cleaning	Wastewater
18	Ash ponds	Leachate & runoff
19	Raw water treatment	Sludge
20	Boiler feed preparation	Sludge & brine
21	Steam and power plants	Ash & blowdown
22	Oxygen plant	Condensate
23	Storage (product and byproduct)	Runoff
24	Washroom and work area	Sewage & runoff
25	Land surfaces	Runoff

SOURCE: Klemetson, 1976.

TABLE XVI

CHARACTERISTICS OF WASTE STREAMS FROM LIGNITE COAL GASIFICATION USING THE LURGI PROCESS

Constituents	Major Stream	Minor Stream
Flow rate	2510 gpm 3.6 mgd	259 gpm 0.38 mgd
Monophenols	31 ppm	31 ppm
Multivalent phenols	789 ppm	1699 ppm
NH_3 fixed (Cl)	108 ppm	3452 ppm
NH_3 fixed (fatty acids)	392 ppm	1297 ppm
Fatty acids	1390 ppm	4456 ppm
Cl	100 ppm	2158 ppm
F	46 ppm	1266 ppm
NaOH	377 ppm	--
CO_2	50 ppm	Tr-ppm
H_2S	20 ppm	Tr-ppm
NH_3 free	100 ppm	525 ppm
HCN	20 ppm	38 ppm
BOD	2840 ppm 85268 lb - BOD/Day	7100 ppm 22075 lb - BOD/Day

-- Not available.

SOURCE: Klemetson, 1976

TABLE XVII

ESTIMATED COMPOSITION OF WASTEWATER FOLLOWING BIOLOGICAL TREATMENT

Constituents	Waste Stream
pH	7.3
Total phenols	25-75 ppm
Phenol	1 ppm
Total ammonia	270 ppm
Fixed ammonia	212 ppm
TDS	435 ppm
Acetic acid	25 ppm
Thiocyanates	77 ppm
Chlorides	5 ppm

SOURCE: Klemetson, 1976.

TABLE XVIII

LOCATION OF PROPOSED ENERGY ACTIVITIES IN THE UPPER COLORADO RIVER BASIN

Basin[a]	County	Coal Undg	Mining Strip	Coal-Fired Electric	Coal Gas	Coal Slurry	Oil Shale	Oil Refinery	Geo-thermal	Drainage
UG 1	Sublette									New Fork
2										Green River above La Banc
3	Lincoln		X	X						Green River above Fountaine
4	Sweetwater						X			Big Sandy Creek
6		X	X	X						Green River
8										Green River above Flaming Gorge
7	Uinta				X					Blacks Fork
9	Moffat	X	X	X						Little Snake
11										Green River above Jensen
10	Routt	X	X	X						Yampa
15	Rio Blanco	X		X			X			White River
12	Uintah						X			Ashley (White River)
17										Green River above Green River
13	Duchesne									Duchesne River above Duchesne
14										Duchesne River above Rain
16	Carbon	X	X							Price River
18	Emery		X	X						San Raphael River
UM 7	Gunnison								X	Gunnison River above Gunnison
8	Hinsdale	X	X							Colorado River above NFC
9	Ouray								X	Uncompaghre
10	Delta	X	X							Colorado River above Grand
1	Grand									Colorado River above Hot Springs
3	Summit									Colorado River above Glen
2	Eagle									Eagle River
4	Pitkin	X	X							Roaring Fork
5	Garfield	X	X				X			Colorado River above Plates
6	Mesa	X	X					X		Plateau Creek
11		X	X							Colorado River above Cb-UT
12	Del/Sm/MT								X	San Miguel and Dolores
13	Grand, UT	X								Colorado River
US 1	Archuleta		X							San Juan above Archuleta
2										San Juan above Archuleta
3	San Juan, CO									Anurmas River
5	La Plata/Monte	X								La Plata
4	San Juan, NM		X	X	X					San Juan above Shiprock
6										San Juan above Shiprock
7	San Juan, UT									San Juan above Blanding
14	Wayne	X	X	X						Colorado River above Lee Ferry
	Garfield	X				X				
	Kane	X	X							

[a]USGS hydrologic definitions. See Fig. 13 for geographic boundaries.

SOURCE: Utah Water Research Laboratory, 1975.

TABLE XIX

POTENTIAL POLLUTION PROBLEMS FROM ENERGY DEVELOPMENT IN THE UPPER COLORADO RIVER BASIN

Geographical Areas	Activities	Pollutants
Upper Green River	Coal mining, coal-fired generation, urbanization, oil shale	Salts, organics
Yampa River	Two proposed dams, coal mining, coal-fired generation, oil shale, slurry	Salts, temperature, organics, sediment
Uintah-White River Basins	Oil shale, tar sands, oil and gas, urbanization	Salts, sediments, organics, nitrates, pesticides
Upper Colorado-Gunnison River (Denver, etc.)	Coal, oil and gas	Salts, sediments
Dolores River	Coal and other mining	Salts, metals (toxicity)
Lake Powell	Coal, coal-fired generation, gasification, slurry	Eutrophication, DO, temperature, sediments
San Juan River	Coal, coal-fired generation, gasification, uranium	Salts, radiation, toxicity, temperature

SOURCE: Utah Water Research Laboratory, 1975.

TABLE XX

SOLID RESIDUALS FROM ENERGY PRODUCTION[a] IN THE UPPER COLORADO RIVER BASIN

	To 1985 Production Levels						To 2000 Production Levels							
	Coal-Fired Electric		Oil Shale		Total 1976-85[b]		Coal-Fired Electric		Coal Gas		Oil Shale		Total 1976-2000[c]	
WRSA[d]/County	10^5 T/yr	A·ft	10^5 T/yr	A·ft	Tons	A·ft	10^5 T/yr	A·ft	10^5 T/yr	A·ft	10^5 T/yr	A·ft	Tons	A·ft
1401														
Lincoln	6.1	467			30.5	2335	6.1	467					122.0	9 340
Sweetwater	7.9	605			39.5	3025	7.9	605			5.3	300	198.0	16 600
Uinta									13.1	859			196.5	12 885
Moffat	6.0	459			30.0	2295	6.0	459					120.0	9 180
Routt	1.7	131			8.5	655	1.7	131					34.0	2 620
Rio Blanco			3.8	215	19.0	1075	1.2	92			11.9	673	215.5	12 550
Uintah			2.0	113	10.0	565					11.9	673	188.5	10 660
Carbon							8.2	627						
Emery	8.2	627			41.0	3135							164.0	12 540
1402														
Gunnison/Hinsdale														
Delta														
Pitkin														
Garfield			2.1	119	10.5	595					5.3	300	90.0	5 095
Mesa														
Dolores/San Miguel/Montezuma														
1403														
Archuleta														
San Juan, LA Plata, Montezuma														
San Juan, NM	18.0	1377			90.0	6885	18.0	1377	9.3	6113			499.5	119 235
San Juan, UT	5.9	451			29.5	2255	12.0	902					209.5	15 785
Wayne, Garfield, Kane														

[a]Does not include overburden and surface disturbance from mining operations.

[b]Assuming a linear increase from zero to the stated production.

[c]Assuming production is in place for full 1985-2000 period.

[d]Water Resource Subareas as designated by the Water Resources Council.

SOURCE: Utah Water Research Laboratory, 1975.

TABLE XXI

SUMMARY OF WATER DIVERSION AND RETURN FLOW FROM PRODUCTION PLANTS UNDER THE "MOST PROBABLE" SCENARIO IN THE UPPER MISSOURI RIVER BASIN (1000 A·FT UNITS)

	Plant No.	Diversions	RETURN FLOW										
			Bighorn at Bighorn	Sarpy Creek	Armells Creek	Tongue River	Powder River Above Moorhead	Powder River Below Moorhead	Missouri River above Bismarck	Knife River	Heart River	Cannonball River	Cheyenne River
Bighorn River													
Electric Plant	1	23 000						5 900					
	2	19 500				5 000							
	3	19 500				5 000							
Gasification	2	30 000						20 000					
	3	30 000					20 000						
	4	30 000				20 000							
	5	30 000				20 000							
Total Bighorn		182 000				50 000	20 000	25 900					
Yellowstone River													
Thermal Elect.	4	19 500				5 000							
Gasification	6	30 000		20 000									
	7	30 000			20 000								
	8	30 000			20 000								
	9	30 000				5 000							
Total Yellowstone		139 500		20 000	40 000	10 000							
Missouri River													
Thermal Elect.	5	19 500											
	6	23 000							5 000				
	7	23 000								5 900		5 900	
	8	23 000										5 900	
	9	23 000									5 900		
	10	23 000							5 900				
	11	23 000										5 900	
Gasification	10	30 000								20 000			
	11	30 000								20 000			
	12	30 000								20 000			
	13	30 000								20 000			
	14	30 000								20 000			
	15	30 000							20 000				
	16	30 000							20 000				
Total Missouri		367 500							45 900				
Powder River													
Reservoir Evap		42 600											
Gasification		30 000											20 000
Total Powder		72 600											20 000
Total		761 600		20 000	40 000	60 000	20 000	25 900	45 900	105 900	5 900	17 700	20 000

SOURCE: Northern Great Plains Resources Program, 1975.

TABLE XXII

SUMMARY OF THE DISCHARGES FROM PRODUCTION PLANTS UNDER THE "MOST PROBABLE" SCENARIO IN THE UPPER MISSOURI RIVER BASIN

River	Plant Number	Total Ash Weight (Tons/yr)	Volume (A·ft/yr)	Water Soluble Na_2O: 0.058% Assumed (Tons/yr)	Fly Ash Emitted @ 99.9% Removal and 70% Ash as Fly Ash for Electric Generation/Assumed Zero for Gasification (Tons/yr)
Bighorn					
Electric Generation	1	0.4×10^6	306	232	280
	2	0.4×10^6	306	232	280
	3	0.4×10^6	306	232	280
Gasification	2	1.31×10^6	859	760	
	3	1.31×10^6	859	760	
	4	1.31×10^6	859	760	
	5	1.31×10^6	859	760	
Yellowstone					
Electric Generation	4	0.4×10^6	306	232	280
Gasification	6	1.31×10^6	859	760	
	7	1.31×10^6	359	760	
	8	1.31×10^6	859	760	
	9	1.31×10^6	859	760	
Missouri					
Electric Generation	5	0.4×10^6	306	232	280
	6	0.4×10^6	306	232	280
	7	0.4×10^6	306	232	280
	8	0.4×10^6	306	232	280
	9	0.4×10^6	306	232	280
	10	0.4×10^6	306	232	280
	11	0.4×10^6	306	234	280
Gasification	10	1.31×10^6	859	760	
	11	1.31×10^6	859	760	
	12	1.31×10^6	859	760	
	13	1.31×10^6	859	760	
	14	1.31×10^6	859	760	
	15	1.31×10^6	859	760	
	16	1.31×10^6	859	760	
Powder					
Gasification	1	1.31×10^6	859	760	

SOURCE: Northern Great Plains Resources Program, 1975.

APPENDIX

WATER QUALITY DATA FOR THE UPPER MISSOURI AND

UPPER COLORADO RIVER BASINS

TABLE A-11

WATER QUALITY DATA FOR THE UPPER MISSOURI RIVER BASIN[a]

Storage location	Temp °C	DO mg/L	BOD mg/L	pH units	Flow cfs	TDS mg/L	SS mg/L	T-NO_3 as N mg/L	NH_3 mg/L	T-PO_4 as P mg/L	Po mg/L	Cu mg/L	Hg mg/L	F mg/L	Se mg/L	Al mg/L	B mg/L	Zn mg/L	Total hardness mg/L
								T-NO_3		T-PO_4	Trace elements								
Bighorn River at Bighorn, MT																			
Maximum value	27.2	-	-	8.5	23 000	836	21 100	0.50	-	-	-	-	-	700	-	-	270.0	-	643
Minimum value	0.0	-	-	7.0	612	471	42	0.01	-	-	-	-	-	200	-	-	30.0		169
Average value	12.8	-	-	7.7	4 249	608	4 088	0.18	-	-	-	-	-	400	-	-	133.5		338
Tongue River at Miles City, MT																			
Maximum value	29.4	-	-	8.8	4 139	816	-	0.10	-	-	-	-	-	800	-	-	1250.0	-	568
Minimum value	0.0	-	-	6.9	16	262	-	0.01	-	-	-	-	-	200	-	-	10.0	-	104
Average value	10.5	-	-	7.9	594	570	-	0.04	-	-	-	-	-	361	-	-	137.3	-	324
Powder River at Moorhead, MT																			
Maximum value	28.5	12.4	10.0	8.5	4 600	4 800	-	-	0.61	3.20	5.0	30.0	0.9	2 200	11.0	-	448.0	32.0	1 220
Minimum value	0.0	5.2	0.6	7.4	8	676	-	-	0.00	0.00	0.0	0.0	0.0	0	0.0	-	241.0	0.0	0
Average value	10.5	9.0	3.0	8.0	642	1 552	-	-	0.09	0.54	1.0	10.4	0.2	500	3.7	-	274.8	16.0	615
Yellowstone River near Sidney, MT																			
Maximum value	24.4	12.6	3.3	8.9	65 240	655	15 500	0.69	0.26	2.70	0.0	10.0	-	800	-	200.0	260.0	0.0	403
Minimum value	0.0	7.4	0.9	6.9	1 149	230	167	0.00	0.00	0.01	0.0	0.0	-	100	-	100.0	20.0	0.0	90
Average value	11.3	9.8	1.8	7.8	14 527	460	2 308	0.20	0.06	0.32	0.0	2.5	-	449	-	150.0	146.4	0.0	245
Knife River at Hazen, ND																			
Maximum value	24.0	-	-	8.3	5 930	1 510	-	2.40	-	-	-	-	-	900	-	-	1300.0	-	530
Minimum value	0.0	-	-	7.0	13	204	-	0.00	-	-	-	-	-	0	-	-	0.0	-	81
Average value	9.-	-	-	7.9	392	1 004	-	1.15	-	-	-	-	-	400	-	-	263.2	-	320
Heart River at Mandan, ND																			
Maximum value	25.0	16.2	8.9	9.0	-	2 280	-	-	-	0.76	-	-	-	-	-	-	-	-	515
Minimum value	0.0	3.7	0.8	7.0	-	175	-	-	-	0.01	-	-	-	-	-	-	-	-	110
Average value	10.3	9.6	2.9	8.0	-	844	-	-	-	0.11	-	-	-	-	-	-	-	-	290
Cannonball River at Breien, ND																			
Maximum value	24.0	-	-	8.3	2 770	1 960	-	4.80	-	0.21	-	-	-	1400	-	-	860.0	-	720
Minimum value	0.0	-	-	7.2	15	285	-	1.00	-	0.00	-	-	-	100	-	-	0.0	-	140
Average value	10.2	-	-	7.8	414	1 139	-	2.68	-	0.02	-	-	-	546	-	-	346.0	-	429
Missouri River at Bismarck, ND																			
Maximum value	22.0	14.3	6.0	8.6	36 400	653	-	-	0.90	0.07	60.0	50.0	-	700	0.1	59.0	360.0	42.0	706
Minimum value	0.0	6.1	0.0	7.7	1 040	268	-	-	0.00	0.01	4.0	10.0	-	450	0.01	9.0	91.0	2.0	4
Average value	8.3	10.6	1.1	8.3	18 239	425	-	-	0.24	0.04	33.6	22.0	-	519	0.2	37.3	217.0	20.4	212
Belle Fourche River near Elm Springs, SD																			
Maximum value	29.0	12.9	16.0	9.0	8 560	4 820	13 600	8.40	0.72	1.3	11.0	80.0	0.3	2700	-	179.0	710.0	40.0	2 440
Minimum value	0.0	4.8	0.2	6.5	2.8	512	7	0.11	0.01	0.0	0.0	5.0	0.0	300	-	0.0	80.0	0.0	300
Average value	9.7	9.2	3.3	7.7	361	2 071	1 537	3.25	0.24	0.53	0.9	34.2	0.1	608	0	114.5	342.2	18.9	1 110
Cheyenne River at Edgemont, SD																			
Maximum value	25.0	11.8	9.4	8.4	609	7 100	-	2.00	2.40	5.80	10.0	75.0	0.3	1100	20.0	100.0	770.0	490	3 100
Minimum value	0.0	0.2	0.5	4.2	0.3	695	-	0.00	0.00	0.00	0.0	3.0	0.1	200	0.0	0.0	10.0	20.0	260
Average value	10.4	8.6	2.9	7.7	61	3 551	-	0.44	0.35	0.49	2.1	25.5	0.2	600	5.1	50.0	346.9	132.1	1 476

Legend:
DO - Dissolved Oxygen
BOD - Biochemical Oxygen Demand
pH - Ionic Balance, 1.7 acid, 8.14 basic
Flow/cfs - Flow, cubic feet per second (ft^3/s)
TDS - Total Dissolved Solids
SS - Suspended Solids
T-NO_3 as N - Total Nitrate as Nitrogen
NH_3 - Ammonia
T-PO_4 as P - Total Phosphate as Phosphorus
Pb - Lead
Cu - Copper
Hg - Mercury
F - Fluorine
Se - Selenium
Al - Aluminum
B - Boron
Zn - Zinc
mg/L - Milligrams per liter
µg/L - Micrograms per liter
\- No Data Available

[a]Period of record is approximately 1965-1973.

SOURCE: EPA Data STORET (Storage and Retrieval System), Federal and state measurements, Water Quality Subgroup Report, and Northern Great Plains Resources Programs, 1975.

TABLE A-II

CHARACTERIZATION OF UPPER COLORADO RIVER BASIN WATER QUALITY BY STORET DATA

USU Station Map I.D.[a]	STORET Station	BOD 00310	DO 00300	Temp 00010	Salinity: DISS SOL SUM 70301	Salinity: RESIDUE 180C 70300	Salinity: RESIDUE 105C 00515	Salinity: CNC-UCTVY 00095	Sediment: SUSP SED 80154	Sediment: RESIDUE TOT NFLT 00530	Nitrogen: NH3-N TOTAL 00610	Nitrogen: NO2+NO3 N-TOTAL 00630	Phosphorus: SOL PO4-T 00653	Fecal Coli 31616/ 31615	Other
1	0918850 000224		(15) 8.85 10.8-6.7	(80) 6.8 19.0	(65) 249.7 426-74	(122) 239.4 426-78		(138) 375 636-129						(6) 16.7 43-1	Mn 2
2	09203600			(1) 14	(1) 49	(1) 52		(1) 76							
3	09203600		(11) 9.5 10.6-8.1	(68) 7.4 20-0	(89) 110.3 274-35	(125) 114 280-32		(137) 190.5 424-8.6							
4	09192600			(66) 7.7 23-0	(66) 259 408-130	(65) 264.4 430-134		(68) 418 658-.03							
5	09209400		(38) 9.4 13-7.2	(86) 8.2 21.5-0	(106) 209 356-91	(195) 222 368-102		(218) 373.8 2030-171						(5) 10.6 30-3	
6	09216000		(32) 9.6 11.3-7.4	(117) 8.9 26.5-0	(75) 1981 2880-237	(121) 218.25 4720-248		(149) 2670 5170-395							
7	5605A2 09217000		(45) 9.8 12.6-7.3	(135) 9.5 23.5-0	(113) 381.5 1040-61	(604) 411 984-156		(683) 6228 1660-257	(26) 1489.9 13400-14		(1) 0.02	(1) 0.016		(6) 294.7 850-40	Phenols 133 630,000- 1,000 ug
												(1) 0.016	(1) 60		
8	5600501 09222000		(8) 9 10.5-6.8	(64) 9.0 29.0	(131) 1205.5 3180-.009	(280) 1277-54 4000-260		(313) 1647 4520-.099			(1) 0.05	(14) 0.096 0.66-0		(6) 30.5 50-10	
												(1) 0.008			
9	09224700	(6) .95 1.4-0.1	(59) 9.6 12.4-9.8	(139) 12 26.0-0	(104) 1047 2110-112	(236) 935 2410-298		(327) 1396 3140-474	(35) 2566 16200-20	(7) 64.9 323-8	(10) 0.028 0.08-0	(10) 0.095 0.35-0.01		(18) 64.7 140-2.2	Phenols 140 3,110,000- 3,000ug
													(8) 0.1 0.3-0		
10	000281													(20) 27.2 348-2	
11	490121 09234500		(35) 9 11.9-5.5	(75) 6.13 10-3	(37) 481.8 621-430	(232) 4946 866-98	(97) 544 710-293	(318) 786.1 1240-112		(85) 54.2 240.3		(54) 2.0 3.2-0.1	(41) 0.04 0.25-0		

TABLE A-II. (Continued, 2 of 7).

USU Station Map I.D.[a]	STORET Station	BOD 00310	DO 00300	Temp 00010	Salinity: DISS SOL SUM 70301	Salinity: RESIDUE 180C 70300	Salinity: RESIDUE 105C 00515	Salinity: CNC-UCTVY 00095	Sediment: SUSP SED 80154	Sediment: RESIDUE TOT NFLT 00530	Nitrogen: NH3-N TOTAL 00610	Nitrogen: NO2+NO3 N-TOTAL 00630	Phos-Phorus: SOL PO4-T 00653	Fecal Coli 31616/31615	Other
12	000088 000088	(40) 2.6 5.1-0.5	(71) 8.55 12.5-4.4	(76) 7.2 22-0				(75) 299 210-54		(41) 60.6 313-3	(55) 0.1 0.41-0				
13	09251000		(31) 9.6 10.8-7.4	(82) 9.03 28-0		(616) 256.1 656-64		(675) 410.9 898-0.01				(21) 0.18 0.71-0.01	(103) 0.06 0.74-0		
14	092597000		(18) 9.5 11.9-7.3	(95) 8.5 26.6-0	(52) 284.8 825-83	(82) 327.6 2050-88		(100) 507.8 2960-120					(1) 300		
15	09260000 000041	(19) 1.7 5.5-0.3	(74) 8.1 11.8-0.4	(119) 8.3 29-0	(41) 364.8 699-.001	(19) 525.1 1600-103		(76) 586 1850-.01		(17) 1293 13350-5	(31) 0.05 0.25-0	(21) 0.19 0.9-0	(36) 0.08 0.4-0		
16	000040	(17) 1.7 4.9-0.7	(39) 7.98 11.5	(43) 9.4 26-0				(42) 448.6 728-135		(16) 554 5700-10	(30) 0.05 0.25-0				
17	000118	(6) 0.95 1.4-0.5	(11) 10.1 11.7-9.0	(12) 6.7 12-1				(12) 693.4 854-620		(7) 64.9 323-8	(10) 0.02 0.08-0				
18	09261000		(31) 9.4 13-5.9	(189) 10.8 38-0		(57) 407 578-0.01		(273) 623 2330-001				(20) 0.69 73-0.01	(58) 0.04 0.33-0		
19	190300501351	(16) 2.09 4.8-1.3						(17) 135 1796-103				NO3-N (18) 0.45 0.98-0.11		(16) 16.6 110-0	
20	09302000		(24) 9.4 12.6-6.6	(98) 11.0 28-0	(151) 1085.7 2880-0.01	(438) 1068 3330-209		(642) 1576 41400-291				(19) 0.26 0.9-0	(53) 0.06 0.34-0		
21	000117 000043	(26) 2.4 5.8-0	(53) 9.4 13-5.4	(60) 9.4 21-0				(59) 620 900-2		(26) 500 3100-11	(42) 0.03 0.16-0	(42) 0.20 2.0-0			AS 60
22	000044	(18) 1.7 3.0-0.8	(42) 8.2 13-4.7	(46) 9.9 25-0				(45) 630 970-71		(16) 400 2700-5	(30) 0.05 0.21-0	(30) 0.2 1.3-0			Fe 2 600 Mn 2 500
23	09306500		(37) 8.7 11.9-5.3	(95) 9.6 25-0			(3) 1300 1700-620	(454) 850 7200-0		(3) 200 480-48		(21) 0.14 0.52-0	(56) 0.06 0.35-0		B 17 800 Fe 1 100 Mn 71
24	09314500		(15) 10.5 15-7.8	(61) 11 ?-0	(49) 2900 5400-750	(494) 3200 7100-730		(551) 3600 7500-1000				(15) 2.6 11-0.01	(46) 0.13 1.0-0		F 1 400 Fe 2 300 Mn 71

TABLE A-II. (Continued, 3 of 7).

USU Station Map I.D.[a]	STORET Station	BOD 00310	DO 00300	Temp 00010	Salinity				Sediment		Nitrogen		Phos-Phorus	Fecal Coli 31616/ 31615	Other
					DISS SOL SUM 70301	RESIDUE 180C 70300	RESIDUE 105C 00515	CNC-UCTVY 00095	SUSP SED 80154	RESIDUE TOT NFLT 00530	NH3-N TOTAL 00610	NO2+NO3 N-TOTAL 00630	SOL PO4-T 00653		
25	09315000		(31) 9.6 14-0	(322) 15 ?-0			(23) 570 772-60	(478) 890 3600-93		(23) 490 2200-34	(3) 0.01 0.01-0.01	(8) 0.5 0.84-0.22	(46) 0.05 0.37-0		
26	09019000 091342		(42) 9.2 13-6.6	(151) 11.2 28-0	(175) 1100 2900-0	(455) 1100 3300-30		(684) 1600 41000-50		(26) 0.27 0.9-0			(61) 0.06 0.34-0	(10) 0 0-0	F 1 200 B 570 Fe 2 000 Mn 160
27	09034500 000045	(17) 2.2 9.2-0.6	(74) 8.4 15-3.1	(83) 6.6 19-0	(55) 86 179-49	(590) 88 170-8.3		(734) 150 1600-5.2		(17) 13 32-0	(32) 0.1 0.7-0	(23) 0.1 0.27-0	(86) 0.08 1.0-0		Fe 1 500 Se 11
28	000115 000098	(18) 1.0 1.4-0	(25) 9.5 12.2-6.9	(32) 7.2 14-0				(32) 155 2.6-110		(17) 12 51-0	(26) 0.02 0.08-0	(13) 0.01 0.3-0	(10) 0.08 0.1-0		
29	09057700		(3) 9.7 10-9.3	(10) 7.9 14-1.0	(8) 100 140-86	(5) 110 130-96		(11) 190 220-160				(4) 1.3 5-0.03	(4) 0.04 0.05-0.03		
30	09071100 000046 09070500	(48) 1.4 7.5-0	(110) 8.7 13.5-3.3	(76) 7.6 18.5-0	(149) 380 790-0	(910) 2380 2000-0.67		(1090) 630 1500-0.01		(51) 60 590-2	(65) 0.3 14-0	(21) 0.13 0.5-0.01	(78) 0.03 0.28-0		F 1 300 Mn 120
31	070022 000047	(48) 1.4 4.2-0.2	(80) 9.5 13.6-5.8	(103) 10 22-0			(103) 531.8 869-175	(188) 901.4 1520-250		(15) 61.5 379.3	(70) 0.06 0.49-0	NO_3-N (72) 0.2 1-0			
32	00098700 070023 09093700		(2) 10.2 11-9.3	(25) 7.9 20.5-0	(4) 411.7 615-206		(54) 537.5 897-180	(75) 902.9 1980-300		(9) 131.2 536-8			(4) 0.08 0.15-0.03		
33	09105000		(10) 10.3 12.4-7.2	(29) 8.8 22-0		(9) 439 546-179	(4) 422.4 510-200	(29) 661.7 950-2.3		(4) 168 280-105		(6) 1.2 5.3-0.1	(19) 0.37 5-0.02		
34	000048	(21) 2.2 5.1-0.5	(48) ? ?-3.8	(51) 10 22-0				(51) 894.9 1523-215		(19) 189 831-3	(34) 0.28 1.4-0	NO_3-N (35) 0.54 3.5-0			Mn 100
35	000100 231275 231274 231273	(84) 7.8 55.9-0.3	(80) 7.2 12.3-0.6	(20) 10 20-0				(20) 972 1343-200		(84) 729 473-0	(88) 1.1 11.6-0.01	NO_3-N (89) 1.8-0	(72) 0.71 1.78-0.01	(72) 1.41 22-0	Fe 3 000

TABLE A-II. (Continued, 4 of 7).

USU Station Map I.D.[a]	STORET Station	BOD 00310	DO 00300	Temp 00010	Salinity: DISS SOL SUM 70301	Salinity: RESIDUE 180C 70300	Salinity: RESIDUE 105C 00515	Salinity: CNC-UCTVY 00095	Sediment: SUSP SED 80154	Sediment: RESIDUE TOT NFLT 00530	Nitrogen: NH3-N TOTAL 00610	Nitrogen: NO2+NO3 N-TOTAL 00630	Phos-Phorus: SOL PO4-T 00653	Fecal Coli 31616/ 31615	Other
36	000057	(19) 1.5 3.4-0.6	(42) 8.8 15-1.6	(46) 6.1 18-0		(39) 140 181-72		(44) 232 320-153		(18) 17.5 98-2	(33) 0.08 0.62-0	NO_3-N (34) 0.12 1-0		(46) 1288 33000-2	Mn 70
37	0803A1											(1) 0.28			
38	000056	(21) 1.4 2.4-0.6	(47) 8.7 13-3.6	(51) 9.4 23-0				(51) 554 1346-250		(18) 131 739-8	(35) 0.07 1-0	NO_3-N (37) 0.3 2.5-0			
39	000079	(16) 0.85 1.6-0.3	(33) 8.4 11.2-5.5	(36) 9.2 19-0		(27) 409 684-154		(35) 588 912-280		(16) 69.7 303-0	(25) 0.05 0.7-0	NO_3-N (25) 0.18 0.8-0		(31) 74.7 330-0	
40	000055 09149500	(43) 1.8 3.2-0.4	(80) 8.7 12.4-1.0	(127) 12 24-0		(117) 1435 2360-99		(90) 1870 5250-159		(38) 319 1173-71	(55) 17.2 946-0	(5) 2.8 3.8-0.9		(71) 875 10900-1.1	F 23 000 As 200 Mn 100
41	00952500 000054 070002	(48) 16 4.0-0.7	(107) 8.5 12-5	(78) 10 24-0	(307) 1100 2800-0.01	(1118) 1100 3000-84		(1178) 1300 3000-0.01		(48) 260 1600-15	(62) 0.10 1.5-0	(19) 0.9 1.9-0.01	(114) 0.02 0.12-0		F 1 700 Mn 83
42	ASPN01	(20) 2.2 4.3-0.8	(43) 7.8 12-3.4	(51) 11 24.0				(52) 1000 1500-9.8		(20) 310 2600-12	(34) 0.2 1.2-0	(35) 1.1 4.5-0			Fe 3 600 Mn 700
43	070038 070006 000050	(370) 2.9 8.0	(321) 8.0 12.5-0	(249) 10 32-0			(217) 1000 2400-210	(89) 1100 1800-410		(275) 360 3900-0	(287) 1.4 9.5-0	(31) 1.5 3.6-0.1			As 300 Fe 5 600 Mn 70
44	09163530 09163500		(10) 8.9 12-7	(44) 10 22-0	(15) 800 1200-290	(104) 900 2600-225		(227) 1300 3200-68					(20) 0.1 0.31-0		
45	000080	(14) 1.3 2.5-0.3	(29) 8.7 11.5-5.1	(32) 7 23-0				(32) 340 590-5.8		(11) 23 91-2.0	(25) 0.05 0.33-0	(25) 0.06 0.5-0			Fe 1 600
46	DLOR05 DLOR06 DLOR05 DLOR02 DLOR01		(10) 4.1 9.1-0.00	(128) 7.2 21.1-0	(128) 513 1212-80			(109) 530.9 1160-104							Pb 2 700 Mn 9 500
47	000085 070041 09169500	(13) 1.5 4.1-0.3	(42) 9.2 12.8-5.4	(152) 13.3 29.4-0		(24) 10650 127190-228	(51) 532 1590-12.5	(202) 12868 100000-9.75		(16) 660.5 5189-22	(21) 0.45 4.5-0			(26) 1215.6 30000-2	

TABLE A-II. (Continued, 5 of 7).

USU Station Map I.D.[a]	STORET Station	BOD 00310	DO 00300	Temp 00010	Salinity: DISS SOL SUM 70301	Salinity: RESIDUE 180C 70300	Salinity: RESIDUE 105C 00515	Salinity: CNC-UCTVY 00095	Sediment: SUSP SED 80154	Sediment: RESIDUE TOT NFLT 00530	Nitrogen: NH3-N TOTAL 00610	Nitrogen: NO2+NO3 N-TOTAL 00630	Phos-Phorus: SOL PO4-T 00653	Fecal Coli 31616/ 31615	Other
48	SIVTNI SNIG04 SNIG02 SNIG03 SNIG01		(14) 8.8 10.4-6.8	(100) 11.1 15.6-0	(107) 260.6 552-56			(86) 458.3 110-83							Pb 2 000 Mn 7 100 Zn 5 100
49		(9) 0.9 1.6-0.4	(14) 10 11-6.6	(17) 9 21-0				(17) 350 470-200		(11) 46 160-3	(14) 0.04 0.2-0	(14) 0.44 5-0			Fe 1 300
50	09175500		(41) 10.0 12.2-7.5				(43) 440 800-170	(165) 630 1500-230							
51	09177000 ? 070045 09177100 ?		(50) 9.6 13.4-7.2	(107) 11 25-0			(263) 860 2530-180	(416) 1200 3000-257			(7) 1.0 2.9-0.06	(13) 2.6 11-0.13	(11) 0.02 0.08-0		As 100 Pb 300 Mn 120 Cd 30 Cr 64
52	070013	(28) 6.7 48-1.0	(42) 7.9 11.5-4	(4) 16 24-7				(46) 2700 8000-315		(25) 440 1900-14	(36) 5.6 20.5-0	(34) 2.2 6.2-0.2	(31) 0.12 0.5-0		Fe 7 800 Mn 150
53	09180000		(30) 10 13-6	(115) 12 27-0	(54) 1400 7100-0.01	(397) 1800 8200-200		(469) 2700 12800-.01				(25) 2.6 14-0.01	(53) 0.05 0.38-0		Fe 760 Mn 110
54	09183210 490009 490009						(42) 860 1420-228	(45) 1255 2030-384		(38) 421 3447-4					Cd 20 Mn 85
55	000102	(8) 1.3 2-0.8	(12) 8.6 11.5-4.5	(45) 10 20-0				(13) 211 281-135			(12) 0.01 0.12-0				Fe 900
56	000119	(9) 1.5 2.9-1	(12) 9.4 13-5.5	(14) 9.2 20-0				(14) 231 501-110		(9) 17 77-0	(12) 0.03 0.24-0	(12) 0.04 0.3-0			Fe 350
57	340000 000105	(8) 1.5 1.9-1.0	(11) 8.6 10.5-7	(13) 14 24-0				(13) 400 540-5		(9) 54 252-6	(11) 0.04 0.12-0	(11) 0.12 0.41-0			F 600
58	NS NG			(104) 12 22-6				(30) 222 260-195				(37) 0.44 1-0.165			
59	000067 0812E1	(17) 1.9 3-0.6	(40) 8.1 12-4.8	(44) 10 27-0				(45) 249 362-139		(18) 121 1301-0	(30) 0.07 0.4-0	(1) 0.012 .012-.012			F 600 Fe 2 200

TABLE A-II. (Continued, 6 of 7).

USU Station Map I.D.[a]	STORET Station	BOD 00310	DO 00300	Temp 00010	Salinity: DISS SOL SUM 70301	Salinity: RESIDUE 180C 70300	Salinity: RESIDUE 105C 00515	Salinity: CNC-UCTVY 00095	Sediment: SUSP SED 80154	Sediment: RESIDUE TOT NFLT 00530	Nitrogen: NH3-N TOTAL 00610	Nitrogen: NO2+NO3 N-TOTAL 00630	Phos-Phorus: SOL PO4-T 00653	Fecal Coli 31616/31615	Other
60	NO NA			(197) 14 19-6				(54) 227 259-182				(17) 0.4 1-0.22			
61	09357300 09365000 09355500	(126) 0.77 5.6-0.1	(190) 9.27 110-5.4	(463) 24.1 26.03-0	(373) 325 2011-135	(612) 379.96 1380-.0098	(4) 105 120-70	(1127) 545.5 2731-.0098	(44) 5586.8 33200-27	(120) 0.32 2.8-0	(32) 0.078 0.45-0	(120) 0.32 2.8-0	(73) 0.08 0.61-0	(159) 10020 120000-0	Mn 4 901
62	000082 ANIM01 ANIM10 SIVTN1	(7) 0.5 1-0.2	(24) 8.9 13-5	(49) 8.9 18.0	(24) 360 1548-104	(23) 184.5 297-29		(48) 428.7 640-130		(12) 11.5 31-0	(20) 0.05 0.72-0	(52) 0.25 0.8-0		(20) 146 2200-0	Pb 1 000 Mn 7 700
63	ANIM06 070004 000081	(131) 3 8-0	(25) 7.4 10-4.5	(151) 6.4 14-2	(161) 177.5 260-240			(70) 445.6 1100-112		(6) 22.5 48-5	(10) 0.15 0.58-0	(20) 0.07 0.8-0		(10) 79 240-0	Fe 2 000 Pb 800 Mn 2 250 Cu 1 500
64	340056 340000 000106	(165) 2.08 8.6-0	(182) 8.9 13.3-4.3	(198) 9.8 23.5-0		(13) 256.5 320-200	(127) 337.7 600-87	(19) 397.9 576-5		(257) 205.6 3316-6	(188) 0.14 2.4-0	(10) 0.27 1.5-0 (29) 0.20 1.5-0.1		(15) 1660.6 24000-2.2	
65	09364500	(29) 1.3 2.8-0.3	(47) 9.6 13.0-6.9	(177) 11.9 17.8-0	(90) 354.3 610-127	(400) 394.2 1050-130	(5) 460 560-260	(470) 586.8 1354-	(96) 3439.7 23000-18	(5) 292 1100-10	(16) 0.07 0.31-0.01	(11) 0.12 0.41-0 (30) 0.14 0.39-0.01	(32) 0.04 0.15-0	(20) 320 1520-10	B 12 000 Fe 600 Pb 100 Mn 75 Se 22
66	SJR105 SJR114 340002 SJR116 SJR118		(22) 9.1 9.7-6.7	(181) 10.9 26.5-0				(114) 512 837-200				(29) 0.7 1.4-0.07	(29) 0.15 1.0-0.01	(125) 3855 21000-266	

TABLE A-II. (Continued, 7 of 7).

USU Station Map I.D.[a]	STORET Station	BOD 00310	DO 00300	Temp 00010	Salinity: DISS SOL SUM 70301	Salinity: RESIDUE 180C 70300	Salinity: RESIDUE 105C 00515	Salinity: CNC-UCTVY 00095	Sediment: SUSP SED 80154	Sediment: RESIDUE TOT NFLT 00530	Nitrogen: NH3-N TOTAL 00610	Nitrogen: NO2+NO3 N-TOTAL 00630	Phos-Phorus: SOL PO4-T 00653	Fecal Coli 31616/ 31615	Other
67	SJR120 340003 09368000 000063	(107) 2.5 7-0	(157) 7.5 12.1-3.7	(162) 16.08 27-0	(378) 422.8 12090-86	(524) 533.7 1900-82	(113) 667 1920-144	(96) 1012 1309-206		(225) 1000.2 32600-0	(153) 0.287 0.25-0	(34) 15.8 40-0.1 (56) 0.71 1.55-0	(8) 0.08 0.3-0.01	(140) 4340 51000-2.2	Pb 600 B 7 364 As 100 Mn 6 500
68	09379500		(40) 9.2 14-1.3	(449) 15.5 34-0	(398) 650 1910-157	(921) 669 1800-7.0		(1021) 928 2680-237	(658) 11876 155000-42			(22) 0.75 1.7-0.07	(50) 0.08 0.46-0		F 6 700 Fe 1 500 Mn 150

[a]See Fig. 4 for map locations.

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