Water Availability for Synthetic Fuels: An Assessment of Current Studies

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INCREASED AUTOMOBILE FUEL EFFICIENCY AND SYNTHETIC FUELS

Alternatives For Reducing Oil Imports

Background Paper #5

Water Availability For Synthetic Fuels: An Assessment of Current Studies

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Preface

This volume contains papers written for OTA to assist in preparation of the report ***Increased Automobile Fuel Efficiency and Synthetic Fuels: Alternatives for Reducing Oil Imports.*** OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information than could be accommodated in the final assessment report, and are being made available for such purposes.

WATER AVAILABILITY FOR SYNTHETIC FUELS

An Assessment of Current Studies

Prepared for

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EXECUTIVE SUMMARY

The objective of this study is to describe and analyze the hydrologic, institutional, legal, and economic issues involved in assessing and interpreting estimates of water availability for synfuels development in four major river basins: (1) Upper Mississippi, (2) Ohio/Tennessee, (3) Upper Missouri, and (4) Upper Colorado. In addition, the study evaluates the adequacy of currently used estimates of water availability as a basis for energy planning in these four basins.

To meet the objectives of this study, assessments of water availability for the four basins were reviewed and analyzed. In addition, case studies of water availability for synfuel development in the Upper Colorado and Upper Missouri River Basins were completed. The general conclusions resulting from these analyses and case studies are detailed in the Discussions and Conclusions section herein.

Estimating water availability for synfuel development is a difficult and complex task involving incomplete and inadequate data, unforeseen and unpredictable future judicial decisions and legislation, imperfect demand forecasting methods, and political constraints on the entity responsible for assessing water availability. As a result, considerable variation exists in quality, detail, and scope of water availability assessments.

It is suggested that the primary use of these assessments will be to evaluate the availability of water for initial development of synfuel industries in the respective river basins. "Initial development" refers to that period of approximately 10-12 years in the future during which those synfuel plants which are presently in some stage of planning will be constructed. The considerable uncertainty that exists concerning almost all aspects of forecasting future water availability for synfuel development in, for example, 2000, severely limits the dependability of these forecasts and, consequently, their usefulness.

Therefore, it is suggested that rather than focus on predicting, the objective of water availability assessments should be to acknowledge this uncertainty and play out the consequences of some of the ways that unpredictable political, judicial, and administrative decisions may affect water availability.

WATER AVAILABILITY FOR SYNFUEL DEVELOPMENT

Upper Mississippi River Basin

From a regional perspective water supplies for synfuel development in the Upper Mississippi River Basin are adequate. Localized problems, however, may result depending on the specific site for a synfuel plant. Water supply Y shortages and negative impacts on water resources are most likely to occur for synfuel sites on tributaries. These shortages and negative impacts cal be eliminated or reduced by construction of reservoir storage on tributaries, conjunctive use of ground and surface water or other measures to reduce diversions from unregulated streams during low flow periods.

Ohio/Tennessee River Basin

The water availability situation for synfuel development in the Ohio and Tennessee Basins is comparable to that in the Upper Mississippi. From a regional perspective sufficient water is available for projected present and future synfuel development but localized problems or deficiencies may occur for synfuel plants sited on tributaries. The extent and nature of these deficiencies can only be predicted with site specific studies.

Upper Colorado River Basin

Water is available, and can be made available, in the Upper Colorado River Basin to meet presently proposed and future oil shale development. The question is not whether water is available, but rather what the impacts on agriculture and other sectors will be from allocating this water from its present and potential use to synfuel development. For, example, approximately 150,000 acre-feet of water storage presently exists in two Federal reservoirs on the western slope of Colorado which in part could be made available for synfuel production. Assuming the consumptive use requirements of a 50,000 bbl/d oil shale plant is approximately 5,700 acre-feet per year, the available stored water in these two Federal reservoirs alone could supply a number of unit-sized synfuel plants, more than the number of synfuel plants presently in some state of planning within Colorado. This available stored water could be more efficiently used and stretched further as a source of synfuel water supply when combined with the existing junior water rights of energy companies. If, however, the projected plants were to rely on water transferred from agricultural use rather than on existing available water in Federal reservoirs, the impact on the agricultural sector would be much more severe.

The case study of the Upper Colorado River Basin in Colorado herein goes into detail concerning the economic, political, institutional, and legal uncertainties which make it difficult to predict the level of future synfuel development in the Upper Colorado River Basin, and the source and amount of water supplied for this projected level of development.

Upper Missouri River Basin

To provide necessary water for projected synfuel energy development in this basin, major new water storage projects will be required because of the significant inter- and intra-year variation of streamflows for all rivers in the basin. Furthermore, the legal, institutional, political and economic issues are of such magnitude in this river basin that they do not allow unqualified conclusion as to availability of water for synfuel development. In the Yellowstone River Basin and the adjacent coal areas, it is not a matter, as in the Upper Colorado River Basin, of merely what the effects of transferring existing water for synfuel development will be, but rather whether this water will be available at all. Major state reservations of water on the mainstem Yellowstone River, Indian reserved rights, and the Yellowstone River Compact all present major uncertainties as to the availability of necessary water for synfuel development in this area. Section V, herein, details the nature and effects of these legal and economic, institutional and political uncertainties.

PHYSICAL AVAILABILITY

Estimates of water availability for synfuel development are based on streamflow measurements, groundwater data, and other hydrologic data.

Of the many data and information bases required for assessing water availability (e.g., future municipal demand projections, future cooling water requirements for coal fired electric generating stations, etc.), recorded historic streamflows are probably the most accurate and dependable. In the eastern basins, this recorded data base is used more or less directly to assess water availability based on 7-day, 10-year minimum low flows. The use of 7-day, 10-year low flow data for this purpose is desirable since this flow parameter: (1) coincides with many water quality regulations, (2) provides indication of low flow conditions for navigation, and (3) provides a useful estimate of flow in rivers with limited storage. Generally, the 7-day, 10-year minimum low flow estimate is based on original historic data. As flow depletions increase in the future, however, the frequency of the 7-day, 10-year minimum low flow estimate based on historic data will increase; i.e. the low flow associated with the 7-day, 10-year frequency will actually occur more often in the future than the expected 7-day, 10-year frequency would indicate. This bias in the 7-day, 10-year minimum low flow parameter must be understood by decision-makers when considering water availability for synfuel development based on 7-day, 10-year minimum low flow estimates.

In the western basins water availability assessments are based on virgin flow estimates since western state water laws and interstate compacts are generally predicated on this concept. Virgin flow estimates are based on recorded streamflow data and estimates of depletions. Significant effort is often made to estimate virgin flows, but the resulting data set may be inaccurate because of poor records of diversions, irrigated acreages, inaccuracies in estimating irrigation consumptive use, lack of records concerning return flows, etc. Therefore, the principal parameter in western basins on which water availability estimates for synfuel is based, mean annual virgin flow, incorporates considerable uncertainty. Furthermore, studies assessing water availability in western basins for synfuel development tend to treat mean annual virgin flow estimates as deterministic rather than stochastic variables. These studies do not clearly assess the uncertainty and risk (in the statistical sense) that exist in mean annual virgin flow estimates, thereby giving an unwarranted degree of certainty to the data set.

The use of mean annual or mean monthly flow flow estimates for assessing water availability is acceptable for rivers and tributaries where adequate storage exists to control the river. However, where little or no storage exists, or will exist in the near future, some estimate of low flows is needed. This could be weekly, monthly, or 7-day, 10-year minimum low flow data depending on local hydrologic conditions and data availability. Without this low flow data, decision-makers will have little idea how proposed synfuel water demands will affect instream uses: fish and wildlife habitats run-of-the-river hydropower generation, recreation, and water quality. Low flow data is especially important to assess the cumulative effect of all present and proposed depletions.

Groundwater quantity and quality are inadequate in all of the basin analyses and assessments reviewed. Some reports more or less ignore this potential water supply source for energy development because of insufficient quantitative data. Individual energy companies may have adequate groundwater data to assist in a specific siting decision, but this data may be unobtainable or do not exist on a regional scale for governmental decision-makers or entities concerned with state or regional water resources management. Use of groundwater for supplying synfuel development could, in some instances, reduce streamflow depletions, especially during low flow periods. Planned conjunctive use of ground and surface waters could result in more efficient use of surface water resources; i.e., more synfuel plants could be. sited within the basin with less impact on the water resource if conjunctive use is employed. However, because adequate groundwater data are not generally available to regional or state decision-makers, this opportunity may be lost.

ECONOMIC FACTORS

Within limits, cost data may not be very important to energy companies for selecting water supplies for synfuel development since cost of water is generally minor with respect to total capital and operating costs for a proposed synfuel development. Cost of water, however, is one determiner of the nature and extent of trade-offs that will occur as a result of water for synfuel development and, therefore, may be a very important parameter to governmental decision-makers or entities concerned with state and regional water resources management.

The cost data presented in most assessments of water availability for synfuel development are generally inadequate. There are several reasons for this inadequacy. First, dependable cost data are difficult to collect. No central collection of, for example, reservoir construction cost data exists and it must be collected from a number of individual sources. Second, cost data are site or project specific and generalization is often risky and inaccurate. Third, developing or obtaining comparable cost data may be impossible. For example, obtaining data on selling prices of irrigation water rights often results in a set of individual prices for widely different commodities. One selling price may be for a senior irrigation right or another may be for a junior right requiring construction of storage. Several examples of the variation are presented in the Upper Colorado River Basin section herein.

LEGAL. INSTITUTIONAL. AND POLITICAL FACTORS

Perhaps the most difficult requirement in assessing water availability for synfuel development is estimating the effects of legal, institutional, and political factors on future water availability. Future judicial decisions, compact interpretations, implementation of certain compact provisions, administrative decisions on marketing Federal reservoir storage, resolution of Federal and Indian reserved rights, reservation of water by states, and uncertainties in riparian law can all have a profound effect on water availability for future synfuel development. Estimating the quantitative effects of these possibilities in a water availability assessment and communicating these effects to decision-makers is a large task. This task is complicated by the fact that not only must the possible effects be indicated and analyzed but also some effort must be made to indicate the likelihood of occurrence.

In general, the reports and assessments reviewed herein contain highly variable analyses of the quantitative effects of future legal, institutional, and political constraints. These analyses are discussed further in Sections II through V herein.

Political, legal, and institutional factors affecting water availability are generally less numerous and less complex in the eastern basins than in the western basins. Complex local situations may exist but, in general, the political, legal, and institutional factors affecting water availability for synfuel development are less involved in eastern basins. The probable reasons for this are: (1) less competition for water in the eastern basins, (2) the relative simplicity of riparian water law for surface water, and (3) the general lack of, or relatively simple, groundwater regulatory law in the eastern states. As a result, forecasts of future water availability for synfuel development in the eastern United States may be somewhat less involved because of the reduced complexity of political, legal, and institutional factors.

The relative simplicity of riparian water law and riparian based groundwater law can, however, result in significant uncertainty concerning future water availability because of lack of protection given users against upstream diversions or pumping adjacent to their lands. In contrast, however, water law in western states can be a barrier to implementation of water supply alternatives. For example, western state water law is an obstacle to implementation of measures to increase irrigation efficiency since the Appropriation Doctrine does not generally allow users to retain a right to salvaged water.

Uncertainty resulting from legal, institutional, judicial, and political factors causes energy companies to be conservative in their water supply planning and require redundant supplies in order to be assured of adequate future water supply. The delays and uncertainties inherent in acquiring water rights, obtaining reservoir storage or otherwise initially securing water supplies also tend to cause energy companies to obtain redundant water supplies. This redundancy may extend until a firm supply is assured, or the additional water rights might be retained for future development.

WATER SUPPLY ALTERNATIVES

For all basins studied, the principal source of water supply considered in water availability analyses for synfuel development were: (1) direct diversion from rivers, (2) reservoir storage, or (3) acquisition of agricultural water rights. However, numerous other potential sources exist including: (1) development of groundwater, (2) conjunctive use of ground and surface water, (3) weather modification, (4) improvements in efficiency in agricultural and municipal use, (and subsequent use of water "saved" by synfuel industry), (4) change to more water efficient processes in synfuel production, and (5) watershed management to increase discharge. But in actual practice, significant legal, political, and economic forces oppose the implementation of these alternatives. In general, alternatives for synfuel water supply, other than the usual reservoir storage and direct diversion, are detailed in synfuel water assessment studies and reports with some limited discussion, without analysis of the legal, political, economic and institutional constraints which limit their consideration and practical implementation. Specific alternatives and problems with their implementation are discussed in Sections IV and V herein.

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The objective of this study has been to: (1) describe and analyze the hydrologic, institutional, economic, and legal issues involved in forecasting water availability for synfuel development and (2) evaluate the adequacy of currently used estimates of water availability for synfuel development. Based on this analysis and investigation, it is important to develop some possible recommendations for improving the future assessments of water availability for synfuel and energy development.

Because of the significant uncertainty which exists for forecasting future water availability beyond a 10-12 year period in the future, it is suggested that the primary use of synfuel water availability assessments should be to evaluate the availability of water for expected development of a synfuel industry in the next 10-12 years. Furthermore, it is suggested that rather than focusing on predicting water availability, the objective of the synfuel water availability assessment should be to acknowledge the significant uncertainties that exist and play out the consequences of some of the ways that generally unpredictable political, judicial, and administrative decisions may affect water availability.

It is likely that the present controversy and uncertainty concerning water availability for synfuel development will continue in the future. Doing additional studies in order to get "better" or more refined estimates of water availability for synfuel development will probably not significantly reduce the controversy surrounding water availability. The reason for this is that many assumptions must be made in aggregating data into forms useful to decision-makers and in forecasting future demand and supply. These assumptions cannot all be explicitly detailed, communicated to decision-makers and properly used by decision-makers in their own analyses. As a result of the general uncertainties surrounding these assumptions, there will always be potential for controversy over water availability.

This is not to say that 'improved" analyses of water availability cannot be made: they can and should be completed. Improved water availability assessments for synfuel "development as well as other sectors (municipal, industrial, and agricultural), can probably not be done by devoting increased resources to improving the studies themselves. Rather, improvement of these assessments is contingent on improving water resources planning in general in the United States. The results of the inadequate water resources planning system existing in most areas of the United States today is continuously evident in the water availability forecasts analyzed herein. Without general improvement in the existing water resources planning system, data discontinuities at state boundaries will continue, incremental studies will ignore cumulative effects of depletions, local or site specific studies will ignore downstream or basin impacts, and analyses of water availability for synfuel development (or many other purposes) will continue to be a one-time effort with no one responsible for a continuous update or modification. These deficiencies cannot be cured by concentrating additional resources on the reports or assessments -- the system itself must be improved.

SECTION I
INTRODUCTION

AUTHORITY FOR STUDY

Wright Water Engineers has performed this study for the Office of Technology Assessment under Contract 133-2060.0.

GENERAL PURPOSE AND OBJECTIVES

Development of a major synfuel industry in the United States in order to reduce our dependence on imported oil is now a national goal. Achievement of this goal is dependent in part on water availability. Water availability for energy development has been the subject of a number of recent studies with conflicting conclusions and forecasts.

“ In order to resolve some aspects of these conflicting studies, the Office of Technology Assessment commissioned the study herein to: (1) describe and analyze the hydrologic, institutional, legal and economic issues involved in assessing and interpreting estimates of water availability for synfuels development, and (2) evaluate the adequacy of currently used estimates of water availability as a basis for energy planning.

THE STUDY METHOD

Four major river basins were selected by OTA for this study: Upper Mississippi, Ohio/Tennessee, Upper Missouri, and the Upper Colorado= Major portions of the Nation’s oil shale and coal reserves exist within these river basins, and conflicts over water availability for synfuel development can be expected to occur.

These five river basins are extensive, cover a major portion of the United States, and contain many complex water resources problems. Because of the extensive nature of these basins and their water resources problems, and the limited resources of this study, it was necessary to select priority areas within the basins for in-depth analysis and assessment. As a result, the analysis and assessment herein generally focus on those subareas in each basin which: (1) are in proximity to major energy resources that could be used for synfuel development and (2) may experience increased competition for limited water resources.

Reports and other documents concerning water availability for synfuel development in each of the four basins were reviewed and analyzed with respect to their adequacy for decision-making purposes. In general, two types of reports were reviewed: (1) a site specific report concerning the adequacy of water resources at a specific location for development of a particular synfuel plant, and (2) a much more general report concerned with the adequacy of a region's or river basin's water resources for development of an extensive synfuel industry in the future.

The second category of reports is the major concern of the analyses herein. These reports and studies are intended to be of use for making policy and programmatic decisions concerning the synfuels industry by: (1) governors, their staffs, and state legislators; (2) Congress; (3) the White House and Federal agency officials; and (4) energy companies. Therefore, our review and analysis concentrates on the usefulness and effectiveness of the reports for programmatic and policy decisions by these categories of decision-makers.

Substantial differences in water availability exist among the four river basins studied. In addition, there is considerable disparity in the complexity of legal, institutional, political, and economic constraints among the basins. The volume of water available for synfuel development is much smaller in the Upper Colorado and Upper Missouri Basins than in the Upper Mississippi and Ohio/Tennessee Basins. In addition, there are more legal, institutional, political, and economic constraints affecting water availability in the Upper Colorado and Upper Missouri than in the eastern basins. Therefore, in addition to reviewing the major reports concerning water availability for synfuel development in the Upper Missouri and Upper Colorado basins, case studies of these two basins have been completed. The purpose of these two case studies is to analyze and illustrate more thoroughly the ramifications of the legal, institutional, political, and economic constraints on water availability for synfuel development in these two western basins.

BACKGROUND

A major effort of the analyses herein is to assess the soundness of the data and forecasts concerning water availability for synfuel. Various areas of expertise are required for analyzing these data and forecasts: hydrology, water law, water resources planning, etc. Some familiarity with terms and concepts associated with these disciplines is necessary to understand the analyses and discussion presented herein. Brief discussions of water law and hydrology necessary for understanding water availability for synfuel development are presented elsewhere and will not be repeated herein. For example, the Office of Technology Assessment Report, "An Assessment of Oil Shale Technologies," presents an excellent discussion in Chapter 9 of the doctrine of prior appropriation, federal reserve rights, interstate compacts on the Colorado River, etc. The General Accounting Office report, "Water Supply Should Not be an Obstacle to Meeting Energy Development Goals" also presents a glossary of terms concerning water supply for synfuel development. Because of the availability of this general material elsewhere, an effort will not be made herein to include a complete introduction to terms and concepts necessary for understanding analyses of water supply availability for synfuel development. A few terms and concepts, however, are presented in order to provide a reader who may be unfamiliar with water resources and water law terms and concepts with a basic introduction necessary for understanding the analyses herein:

Annual Flows - The quantity of water (generally measured in acre-feet) to flow past a specific point in a river or stream during a period of one year. Annual flows are used frequently in assessing water availability for synfuel development but do not provide any indication of the variation in flow throughout the year, especially low flows.

Appropriation - The taking and applying of a specific amount of water for a specific use. Under the prior appropriation doctrine a state entity establishes dates for seniority rights for water use.

Consumption - That part of water diverted which is no longer available because it has been either evaporated, transpired, incorporated into products and crops, or otherwise removed from water the environment.

Depletion - Basically the same as consumption, i.e., that part of water diverted which is no longer available because it has been either evaporated, transpired, incorporated into products and crops, or otherwise removed from the water environment.

Diversion - A withdrawal of water from a natural source by artificial means. Irrigation, mining, municipal, and manufacturing needs for water all require diversions.

Mean Monthly Flows - The average amount of water to flow past a specific point in a stream or river during a particular month (generally measured in acre-feet). Mean monthly flows provide some indication of the variation that exists in flows throughout a year. Mean monthly flows do not, however, give an indication of minimum flows during critical periods--for example, the flow that could be expected to occur during the driest seven-day period in ten years.

Minimum Low Flow - Numerous statistical parameters are used to describe minimum low flows, e.g. the seven-day, ten-year low flow; the monthly flow which has an 80 percent chance of exceedance in any one year; etc. All of these-parameters are an effort to provide some indication of minimum low flows during critical dry periods.

Operational Hydrology - A statistical procedure to generate long stream flow records (e.g. 10,OOO years of monthly flows) which will preserve important statistical parameters of the historic record while providing a number of different sequences of flow not present in the historic record. Operational hydrology is used to evaluate proposed management, development, and projects in water resource systems.

Synthetic Fuel Plant Water Demand - This refers to the estimated consumptive use requirement of a synfuel plant. This requirement is estimated based on thermodynamic and production properties of a proposed plant. The demand is generally expressed in acre-feet per year and will be relatively constant throughout the year.

Transfer - A transfer of water rights involves the sale of those rights and a change of use (for example, irrigation to manufacturing), location of the use, or point of diversion.

Water Right - Legally established right to divert and use a given quantity of water.

SECTION II

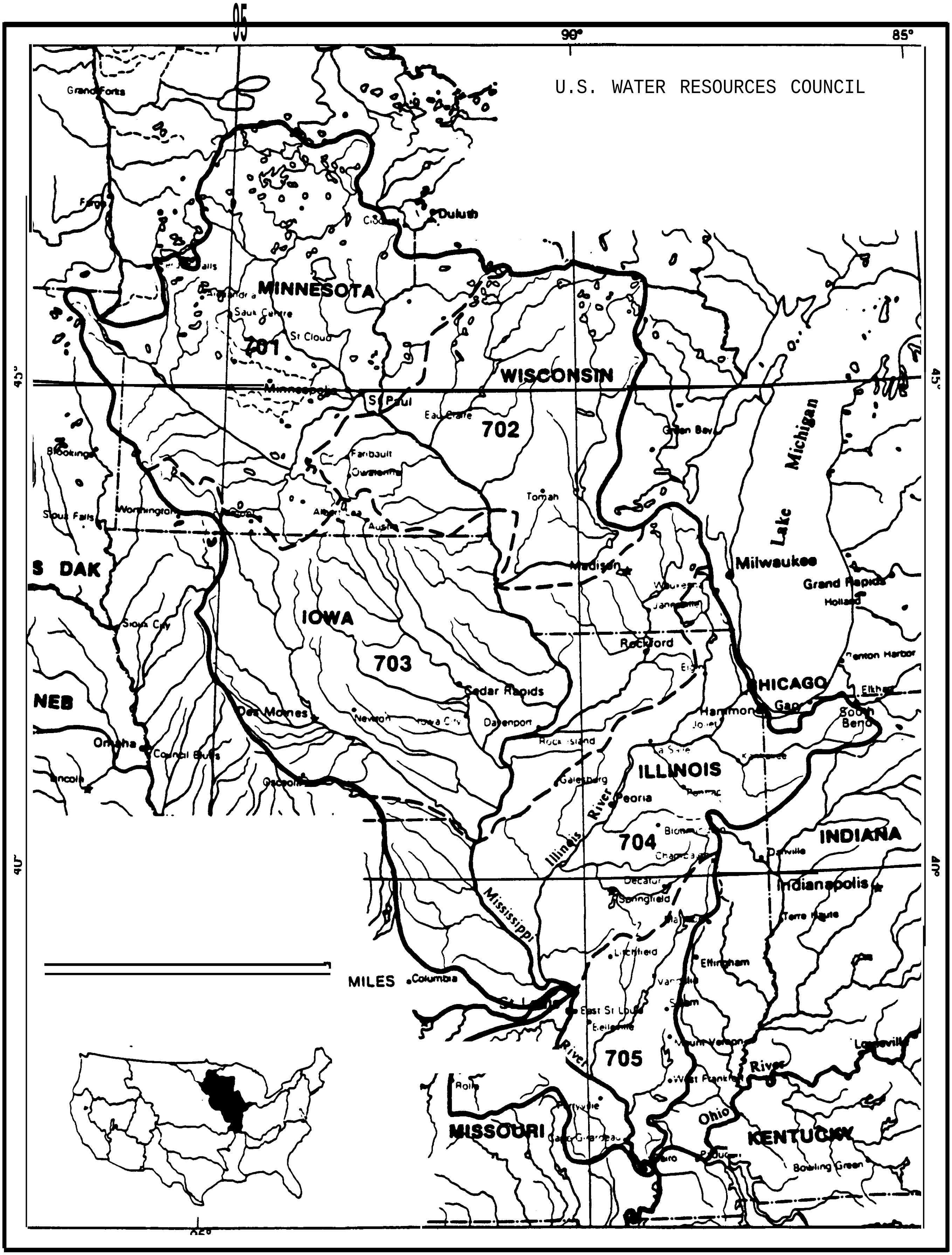
UPPER MISSISSIPPI RIVER BASIN

BACKGROUND

The Upper Mississippi River Basin is that portion of the Mississippi River upstream from the confluence of the Ohio and Mississippi Rivers at Cairo, Illinois and encompasses more than 115 million acres. The Upper Mississippi River Basin includes portions of the states of Minnesota, Wisconsin, Iowa, Illinois and Missouri. (See Figure 1.) Many rivers flow through the region in a generally north-south direction, and the Mississippi River bisects the area. The Upper Mississippi is a key element in the nation's inland waterway system. Large amounts of groundwater are stored within much of the region and the regional gross water supply is excellent (U.S. Water Resources Council, "The Nation's Water Resources," Volume 2, p. V-43). For a summary of hydrology in the Upper Mississippi Basin, see: U.S. Water Resources Council, "The Nation's Water Resources," Volume 2, Part V and Vol. 3, Appendix II.

Illinois is the only state in the Upper Mississippi River Basin with significant coal reserves: Illinois has 15.1 percent by tonnage of total demonstrated coal reserves in the United States or 16.6 percent of demonstrated coal reserves in the United States on the basis of heat value. Montana is the only state exceeding the reserves in Illinois. In comparison, no other state in the Upper Mississippi River Basin has more than 1 to 2 percent of demonstrated coal reserves in the United States.

Because of the concentration of coal reserves in Illinois, competition for water for synfuel development is expected to be significantly greater in Illinois than in other areas of the Upper Mississippi River Basin. Consequently, the assessment herein concentrates on availability of water for synfuel development in Illinois. This assessment is structured around review and analysis of available reports and information on water availability in Illinois. The discussion and conclusions resulting from this review and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analysis, however, extend beyond the reports reviewed and are generally applicable to those areas in the entire basin where demand for synfuel water supply exists, or will exist. Conclusions concerning deficiencies in analysis and forecasting procedures, deficiencies in quality and quantity of data, obstacles resulting from riparian water law, lack of economic and cost data, and statistical bias in streamflow data can be extrapolated to other states and areas in the Upper Mississippi River Basin outside of Illinois.

Reports reviewed were:

1. Smith, William H., and John B. Stall, "Coal and Water Resources for Coal Conversion in Illinois," Cooperative Resources Report for Illinois State Water Survey and Illinois State Geological Survey, Urbana, Illinois 1975.

2. Brill, E. Downey Jr., Glen E. Stout, Robert W. Fuessle, Randolph M. Lyon, and Keith E. Wojnarowski, "Issues Related to Water Allocation in the Lower Ohio River Basin," Volume III-G, Special Study Report, Ohio River Basin Energy Study, Phase I, May 15, 1977, University of Illinois at Urbana-Chanpaign.

3. Brill, E. Downey Jr., Shou-Yuh, Chang, Robert W. Fuessle, Robert M. Lyon, "Potential Water Quantity and Water Quality Impacts of Power Plant Development Scenarios of Major Rivers in the Ohio Basin," Ohio River Basin Energy Study, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, November, 1980.

4. Illinois Bureau of the Office of Planning, "The Availability and Resource Cost of Water for Coal Conversion," Springfield, Illinois, May, 1979.

5. Relevant Sections of U.S. Water Resource Council% Second National Assessment of the Nation's Water Resources.

The two reports from the Ohio River Basin Energy Study are relevant to the Upper Mississippi Basin since these reports cover rivers throughout the entire state of Illinois and are not limited to just the Ohio River Basin portion of the state.

Institutions in Basin

Major institutions involved with the availability of water for synfuel development in Illinois are: (1) the U.S. Congress, (2) the U.S. Army Corps of Engineers, (3) the U.S. Geological Survey, (4) the Illinois State Legislature and the Governor of Illinois, (5) various state agencies including the Illinois E.P.A., Illinois Dept. of Conservation, Illinois Department of Transportation, Division of Water Resources, Illinois Water Survey, and (6) various local governments including county and city governments and local drainage and levee districts. Other states in the Upper Mississippi River Basin have a very similar group of institutions affecting water availability for synfuel development.

Organization of Section

The analysis of these reports is woven into the discussion in this chapter regarding physical availability of supplies and institutional, legal and economic constraints.

PHYSICAL AVAILABILITY

Illinois receives more than 30-45 inches of precipitation in the average year and has relatively abundant water resources. Total runoff to streams in Illinois exclusive of the Mississippi River is approximately 26 million acre-feet per year and with the Mississippi about 59 million acre-feet per year (Smith and Stall, 1975). (In comparison, the Colorado River has a Mean annual “estimated flow of 13.8 - 15.0 million acre-feet per year.)

The three major reports reviewed for this study were the Smith and Stall analysis and the two studies by Brill, et al. Comparison of these three reports produces some interesting contrasts in study method. The Illinois Bureau of the Budget document is very general and wide-ranging. Despite its title, it provides limited information on water availability in Illinois which is of practical use in assessing water availability. Consequently, a detailed review is not included herein.

Smith and Stall did not attempt to project future consumptive use by municipalities, industry, and agriculture, nor did they base their analysis on future scenarios of energy development. They basically took a “snapshot” picture of water availability at the present time for coal conversion in Illinois and looked at the potential for development of additional water resources using reservoir storage and groundwater. By not presenting estimates of future depletions due to municipal, industrial, agricultural and other demands, the Smith and Stall report avoids many uncertainties associated with making future demand projections for these sectors. This, however, leaves the report reader to his or her own devices for estimating future depletions. This method avoids the various problems inherent in predicting future consumptive use and assuming various scenarios for energy development. Smith and Stall analyzed low flow data for Illinois rivers based on the one day, 50-year low flow. The one day, 50-year low flow statistic is an estimate of an extremely infrequent event. The question of whether this is a “correct” or desirable statistic for decisioninaking purposes involving water supply is a complex question beyond the scope of this investigation. On the basis of these flow statistics, they demonstrate that a number of streams and rivers in the state have more than adequate flow at present, without additional storage, to support a synfuel or coal conversion industry.

For example, the Mississippi River on the western edge of Illinois was estimated to have a one-day, 50-year minimum low flow of 6,500 million gallons per day, an amount 100 to 1000 times greater than the consumptive use of a coal conversion plant. Along the southwestern part of Illinois, estimated one-day, 50-year minimum flows in the Mississippi River are between 20,000 and 23,000 mgd. Even on the smaller rivers in Illinois, the flow is adequate for a significant coal conversion industry. One-day, 50-year low flows for the Rock River in northern Illinois range from 60 mgd near the

Wisconsin state line to 500 mgd where the Rock River meets the Mississippi River. Even this relatively low flow of 60 mgd could easily supply several unit-sized synfuel plants (assuming 7500 acre-feet per year or about 6.7 mgd consumptive use for a unit-sized synfuel plant).

In addition, Smith and Stall present accurate and up-to-date information and data on groundwater which indicate that in 17 locations in Illinois a system of wells could be constructed to provide water supply of at least 14 million gallons per day. Detailed information on potential reservoir sites is referenced in the Smith and Stall report which indicates 228 potential reservoir sites with a yield of greater than 6 million gallons per day.

Water supply for synfuel development could be available from existing federal reservoirs (Shelbyville and Caryle Reservoirs in southern Illinois) for synfuel development. These reservoirs together could provide more than 40 million gallons per day for coal conversion.

Brill, et al. (1980), take a somewhat different-approach to forecasting water availability for synfuel development:

(1) Based on forecasts of consumptive use by municipalities and industry for the years 1975, 1985 and 2000, they estimate water availability from Illinois rivers for energy development. This approach does not require forecasting the number of synfuel plants for various river basins in Illinois.

(2) In addition, they employ several energy development scenarios to forecast future water availability for all uses in major Illinois river basins.

In preparing their estimates of future water use, Brill, et al, (1980) are quite candid concerning the problems inherent in their forecasts:

> ‘Water use is difficult to measure and even more difficult to project since projections depend on population, income, relative prices, and technological developments. Thus the

> figures presented here should be interpreted cautiously and are more likely to represent orders of magnitude than specific values. This is especially true, of course, for the longer range projections.” (P III-G-57).

In implementing their first approach, Brill, et al (1980) estimate the number of power plants or coal conversion facilities which could be sited along the region’s rivers without total municipal, industrial and power water consumption exceeding certain consumption limits (e.g. 5-10 percent of the 7-day, 10-year low flows.) This approach is somewhat similar to that used by Illinois Water Survey in that it does not require the assumption of specific scenarios concerning future energy development but differs in that forecasts of future consumptive use by municipalities and industry are required. This approach indicates the potential cumulative impact of potential synfuel development on specific river reaches, but it does not hypothesize various synfuel development scenarios In their second approach, Brill, et al. (1980) developed various scenarios for siting coal fired power plants (these could easily be coal conversion plants as well) throughout the State of Illinois. This method also permits forecasting cumulative impacts of energy development on the area’s water resources but does have the disadvantage of overlaying the uncertainties of future energy development on the uncertainties of future municipal, industrial and agricultural consumptive use.

An interesting problem exists with the use of the 7-day, 10-year minimum low flows in that values for this statistical parameter are based on the historical record without attempting to correct for increased future depletions. If the 7-day, 10-year low flow of record occurred sometime in the distant past, the actual magnitude of a flow with this frequency will undoubtedly be less in the future because consumptive use will increase on most rivers and streams and will continue to increase in the future. This failure to correct the historical record for increased depletions in the recent past will bias frequency estimates of low- flows by underestimating the frequencies of low flow in the future. This failure to convert the historical record for increased depletions in the recent past will bias frequency estimates of low flows by underestimating the frequencies of low flows in the future. This apparent use of the 7-day, 10-year minimum low flow based on historical data, without attempting to correct the historical record for increased future consumptive use, appears to be characteristic of not only the reports reviewed for the Upper Mississippi River Basin but also for the Ohio/Tennessee River Basins. This failure to correct the historical record for increased diversions and consumptive loss in recent years before estimating the 7-day, 10-year minimum stream flows is apparently characteristic of eastern basins. In the western states, complex and tedious calculations incorporating many assumptions are used to transform the historical record into an estimate of "virgin flows," i.e., the estimated flow without any pumpage or diversions.

The Brill, et al. reports clearly specify the difficulties in estimating future consumptive use and developing scenarios for energy development. For example, a major problem in forecasting future consumptive use is that multiple sources of potential water supply exist in Illinois (as they do in many other areas). Consequently, assumptions must be made concerning whether future consumptive use will result from groundwater, direct diversions of surface water, or storage. Brill, et al, assume that the ratio of surface water to groundwater use for each county would be continued in the future. This is an example of the type of operational assumptions that must be made in order to assess availability of water for synfuel development, the importance of which may be ignored or misunderstood by decision-makers. It is difficult to say whether this assumption is adequate or not for general application. In northeast Illinois, this ratio will not remain constant in the future because communities and industry are changing to surface water supplies from groundwater because of the declining water levels in deep aquifers. Brill, et al.further assumed that groundwater withdrawal would not affect low flows; while incorrect hydrologically, this operational assumption may be acceptable for assessing water availability depending on local conditions. For example, in the 1980 Brill report (p.6-9), the demands of the Clinton Nuclear Power Plant in the Sangamon River Basin in central Illinois have not been included in overall consumptive use estimates for this basin since it is assumed that the plant will use stored water and would not affect minimum low flow on the Sangamon River, a major tributary of the Illinois River. In other words, a major power plant (approximately 600 megawatts) is assumed not to have any consumptive use depletions on the Sangamon River. The point of this example is not whether this assumption is correct or not, but rather to demonstrate that there are many options involved for determining future consumptive use demands on a river. Consequently, estimates of future water availability for power plant cooling or synfuel development could vary significantly depending on whether these plants are assumed to use surface water, stored water, or groundwater.

INSTITUTIONAL/LEGAL, ECONOMIC ASPECTS OF WATER AVAILABILITY

The institutional aspects of water availability for synfuel development in the Illinois portion of the Upper Mississippi River Basin are less complex than comparable institutional aspects in the western United States. This is also true for other states in the basin. For all practical purposes, there is no regulatory groundwater law in the State of Illinois. Surface water use and development is governed by riparian law, a less complex set of laws than exists in the western United States. There are no irrigation districts, water conservancy districts or similar entities in Illinois. There is only one state agency in Illinois charged with operational management and regulation of water quality. This is characteristic of other states in the basin. Fewer governmental entities are involved with water resources management, development and regulation than in the western United States. With the exception of a U.S. Supreme Court decree concerning diversion of Lake Michigan water, no interstate compacts exist in Illinois. There are no Federal or Indian reserved rights affecting water availability.

As a result, the reports reviewed for the Upper Mississippi River Basin are only minimally concerned with legal or institutional constraints to water availability for coal conversion or synfuel development.

The "laissez-faire" aspects of riparian based water law, however, do present constraints to water availability for synfuel development. For example, the State of Illinois owns a portion of the water supply storage in Shelbyville and Carlyle Reservoirs in southern Illinois. Both of these reservoirs are Corps of Engineers' projects. The State of Illinois has sought to sell this water for several years, thereby reducing its repayment responsibility to the Federal government. Energy companies have approached the State, but sales have not been made because of uncertainties with regard to delivery of the water. The most efficient scheme would be simply to release water from Carlyle and Shelbyville reservoirs and allow this water to flow down the Kaskaskia River to a convenient point for diversion to a synfuel or coal conversion plant. However, under existing Illinois riparian law, this water could be pumped from the river by any riparian land owner downstream from the reservoirs. Consequently, in order to insure delivery of this water, the energy companies would be faced with building an expensive pipeline for conveyance of the water directly from the reservoirs to the plant site. This conveyance problem, while having a direct engineering solution, poses an economic and legal obstacle to use of water stored in the Federal reservoirs for coal conversion purposes.

The lack of existing groundwater law also provides a constraint to water availability since development of a groundwater supply has very limited protection against over-pumping by adjacent wells under existing Illinois law.

The Smith and Stall report has especially good economic data on the costs of reservoir and groundwater development. This information and data is presented as a series of cost functions for development of various sources of water supply. While they must be used with caution, these cost functions should be very useful for programmatic analysis as well as initial screening of specific sites. In general, however, economic data on the cost of water for synfuel development, or any other use, is not available, except for site specific conditions or individual projects. There are no water rights to purchase so the cost of water is totally dependent on the cost of the riparian land and the costs of water control and conveyance facilities--all of which are site specific.

CONCLUSIONS

From a regional perspective water supplies for synfuel development in the Upper Mississippi River Basin are adequate. Localized problems, however, may result depending on the specific site for a synfuel plant. Water supply shortages and negative impacts on water resources are most likely to occur for synfuel sites on tributaries. These shortages and negative impacts can be eliminated or reduced by construction of reservoir storage on tributaries, conductive use of ground and surface water or other measures to reduce diversions from unregulated streams during low flow periods.

In general, there is relatively little available information and few reports on water availability for synfuel development in the Upper Mississippi Basin in comparison to that available for western basins where significantly more competition exists for water. The reports and information analyzed herein focus on Illinois since this is the area in the Upper Mississippi River Basin where synfuel development will most likely occur, and consequently the greatest demand for water for synfuel development. The results of the analysis are, however, generally applicable to other areas of the Upper Mississippi River Basin where synfuel development might occur because of the similarity in hydrology, water law and institutions, for all states in the basin.

The Smith and Stall report does a good job of presenting estimates of current water availability for coal conversion “or synfuel activities in Illinois. Since it does not forecast future consumptive use, it is of limited use for predicting future water availability. However, by limiting itself to present availability, it also avoids all of the significant uncertainties present in forecasting future consumptive use by the municipal, agricultural, and industrial sectors. In general, the Smith and Stall report should be of use to a number of decisionmakers and in a number of decisionmaking situations. It bridges the gap between the site specific and programmatic decision.

In comparison, the Brill, et al.reports present forecasts of water availability until the year 2000 and candidly indicate the difficulties and uncertainties in providing these forecasts. The portion of the Brill, et al. reports that do not depend on future energy development scenarios are probably more useful for site specific and programmatic decision-making than when the additional uncertainty of an energy development scenario is overlaid on the water availability estimates.

SECTION III

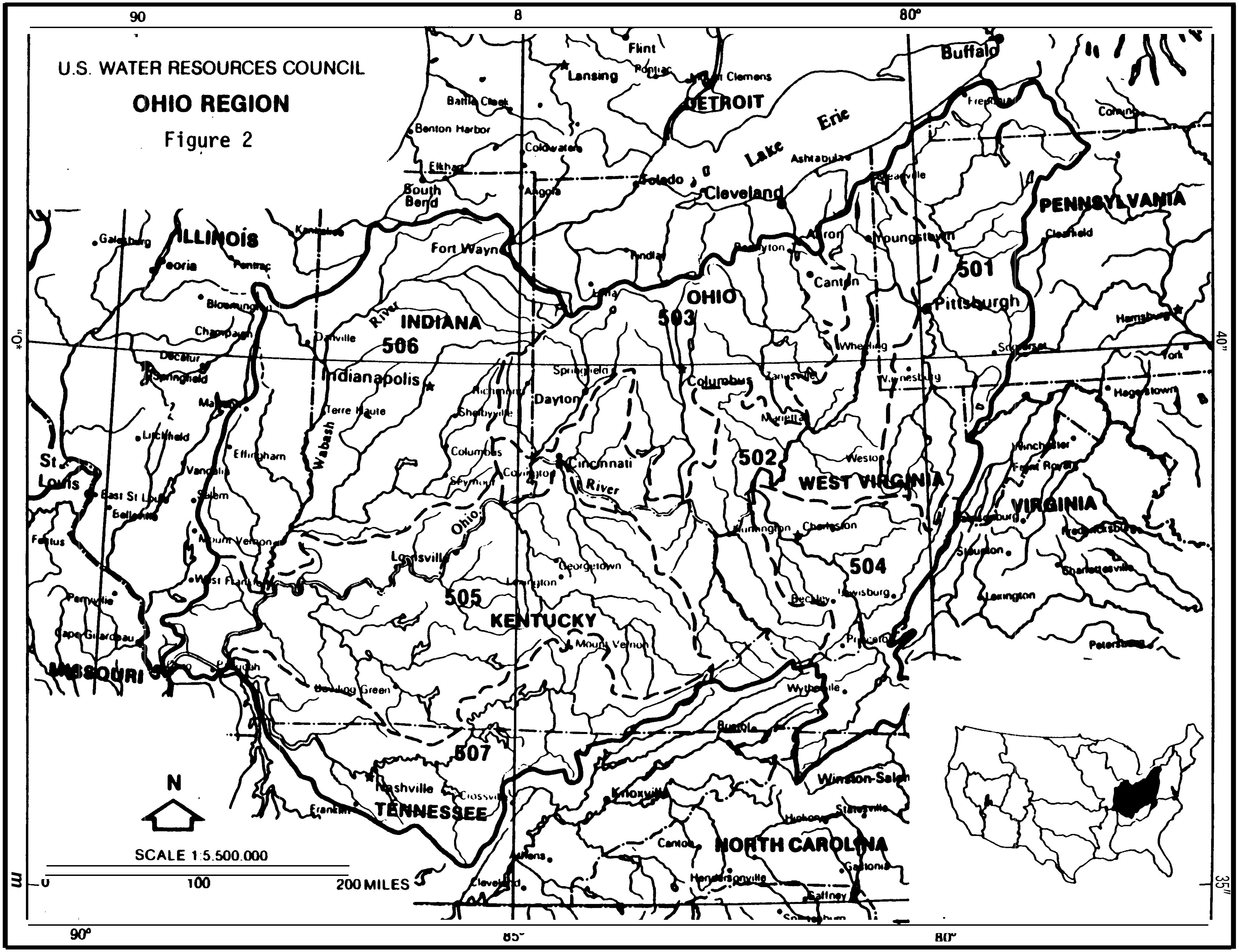
OHIO/TENNESSEE RIVER BASINS

/

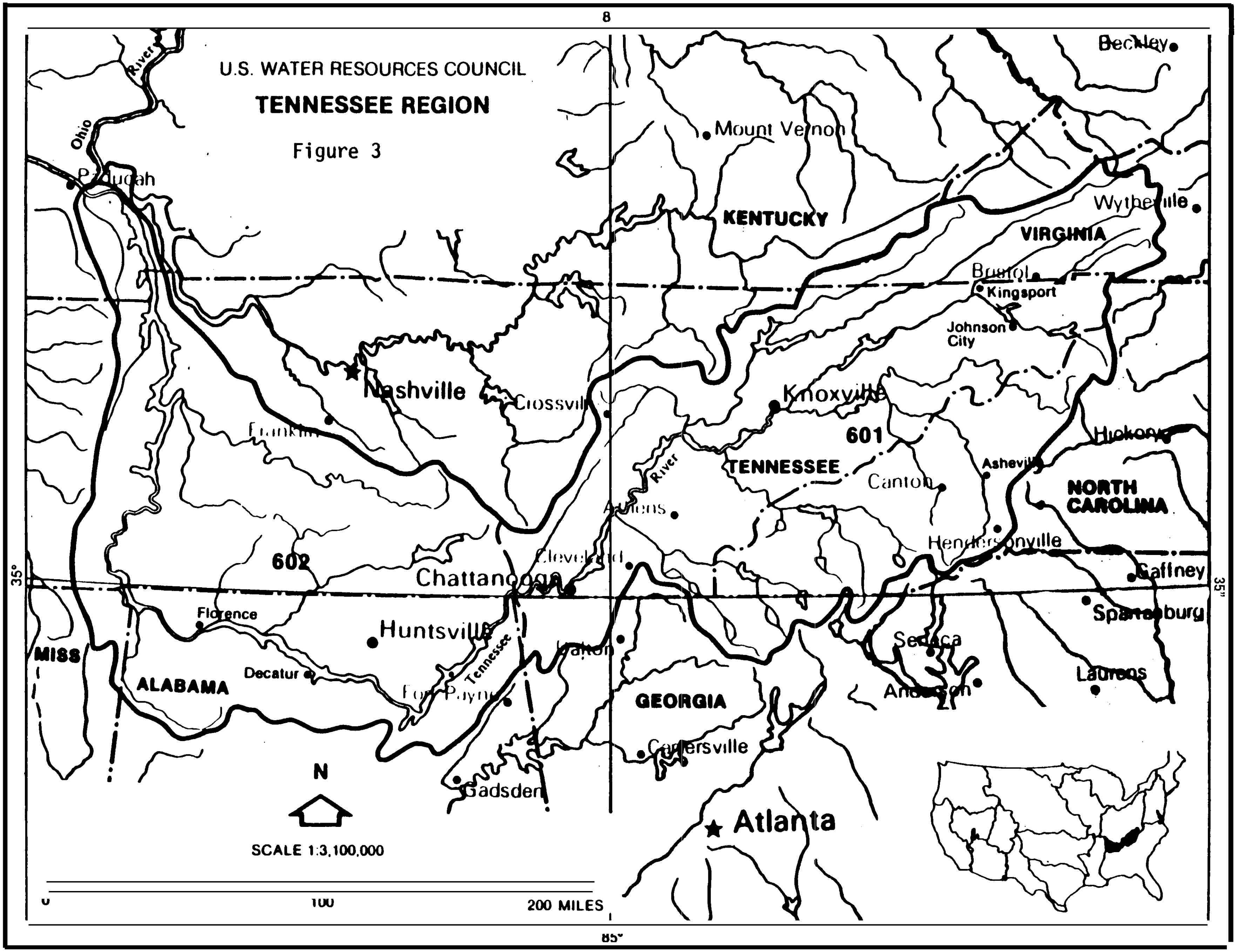
BACKGROUND

The Ohio River Basin covers 102 million acres in New York, Pennsylvania, Maryland, North Carolina, West Virginia, Ohio, Kentucky, Tennessee, Indiana, and Illinois (Figure 2). The Ohio River is formed by the confluence of the Allegheny and the Monongahela Rivers at Pittsburg and flows in a southwesterly direction to join the Mississippi at Cairo, Illinois. Overall, the basin has excellent potential for water supply (U.S. Water Resources Council 1978, Vol. 2, p. V-30) . The Ohio River contains vast coal resources, about 70 percent of the national reserves. Water withdrawals for mining of fuels are projected to increase from less than one percent of total withdrawals in 1975 to about two percent in 2000 (U.S. Water Resources Council, 1978, Vol. 2, p. V-30).

The Tennessee River Basin covers an area of 27 million acres (Figure 3). Seven major, and numerous small, rivers feed the Tennessee River as it makes its U-shaped course through the region. Parts of seven States are drained by the Tennessee River -- more than half of Tennessee and smaller portions of Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia. The Second National Assessment of the U.S. Water Resources Council indicates that estimated natural outflow from the Tennessee River Basin is about 46 million acre-feet per year. Estimated consumptive use of this total flow is less than one percent for 1975 conditions and about three percent for 2000 (U.S. Water Resources Council, 1979, Vol. 1, p. 55). In terms of monthly low flow conditions, consumptive use in 2000 is estimated to be about five percent of the monthly flow which on the average will be exceeded in 80 years of a 100-year period (U.S. Water Resources Council, 1978, Vol. 3, p.61). Because of the large available water supplies in the Tennessee Basin, there is little available information and no published reports concerning water availability for synfuel *or* energy development.



Source: Second National Assessment of the Nation's Water Resources



Source: Second National Assessment of the Nation's Water Resources

Based on the information and reports supplied by TVA (see below), it was concluded that no basin-wide problem existed in the Tennessee basin concerning water availability for coal conversion or synfuel development. If water availability problems do exist, they are of a local or site specific nature. The Tennessee Valley Authority has no published information concerning local water availability problems resulting, or expected to result, from synfuel development.

Therefore, this analysis concentrates on the Ohio River Basin and focuses on several investigations and published reports concerning water availability for synfuel and energy development in various areas of the Ohio Basin. Although the analysis herein concentrates on these investigations and reports, the resulting discussion and conclusions are applicable to the entire basin and the potential conflicts over water supply.

The major reports reviewed were:

1) Ohio River Basin Commission, "Synfuels in the Ohio River Basin, a Water Resources Assessment of Emerging Coal Technologies," (Prepared for U.S. Water Resources Council), January, 1980.

2) Ohio River Basin Commission, "Water Assessment for Monongahela Synfuel Plant," Ohio River Basin Commission, (Prepared for U.S. Water Resources Council.), June 6, 1980.

3) U.S. Water Resources Council, "Project Independence Report" (Tennessee Region 6), prepared for the Federal Energy Administration, November, 1974.

4) Tennessee Valley Authority, "Valley-Wide Assessment of Water Needs," 1974.

5) U.S. Water Resource Council, Second National Assessment of the Nation's Water Resources, 1975-2000. 1979.

In addition, the following two reports were reviewed for both the Ohio and Upper Mississippi Basins:

1) Brill, E. Downey, Jr., Glenn E. Stout, Robert W. Fuessle, Randolph M. Lyon, and Keith E. Wojarowski, "Issues Related to Water Allocation in the Lower Ohio River Basin," Vol. III-G, Phase 1, Ohio River Basin Energy Study, 1977.

2) Brill, Downey E. Jr., Shoou-Yuh Chang, Robert W. Fuessle, and Randolph M. Lyon, 'Potential Water Quantity and Water Quality Impacts of Power Plant Development Scenarios on Major Rivers in the Ohio Basin," Ohio River Basin Energy Study, 1980.

These latter reports form a major basis for the Upper Mississippi River Basin analysis herein since they cover the entire State of Illinois. General findings are not repeated in this section concerning the Ohio River Basin; only those findings specific to the Ohio are included.

The "Synfuels in the Ohio River Basin" report is a very broad report primarily useful for programmatic decisions concerning synfuel development in the Ohio River Basin. In contrast, the 'Water Assessment for the Monongahela Synfuel Plant" report is a site specific study useful for analyzing water demands and environmental impacts of this proposed plant.

Basin-Institutions

Ohio. In the Ohio River Basin, the relevant institutions are comparable to those in the Upper Mississippi (see Section II herein). For example, in the State of Ohio, the Federal agencies are the same and the water resources functions (research, data acquisition, regulatory, etc.) are concentrated in the Ohio Department of Natural Resources.

Tennessee. In the Tennessee River Basin, the Tennessee Valley Authority occupies a unique position in the management of water resources. As a result, Federal agencies, such as the Army Corps of Engineers, play a reduced role. State agencies, such as the Tennessee Department of Conservation, have responsibilities comparable to the agencies discussed in Section 11 herein.

Organization of Section

The analysis of the Ohio River Basin includes discussion of the physical availability; water quality; and institutional, legal and economic factors.

PHYSICAL AVAILABILITY AND WATER QUALITY

The major data base for the “Synfuels in the Ohio River Basin” and “Water Assessment for the Monongahela Synfuel Plant” reports primarily consists of 7-day, 10-year low flows. Use of a low flow parameter, such as the 7-day, 10-year low flows, rather than mean annual or mean monthly flows is desirable for rivers such as the Ohio and its tributaries which have relatively small amounts of storage in comparison to their annual flows. The 7-day, 10-year minimum low flow data are based on historical data and, as indicated in the review of the Upper Mississippi River Basin, will probably overestimate future minimum low flows of the same frequency because of future increased consumptive use in the Ohio River or its tributaries. The effect of this deficiency is not noted in either of these reports concerning the Ohio Basin.

The 7-day, 10-year minimum flow data are a convenient measure since this data base corresponds to criteria used in Federal water pollution control programs. The appropriateness of the 7-day, 10-year minimum flow as a statistical measurement of low flows is briefly discussed in Section II.

A major limitation of “Synfuels in the Ohio River Basin” is that it concentrates almost exclusively on plant sites on the mainstem of the Ohio River with little consideration of synfuel plant sites on the tributaries. While this assumption is apparently justified on the premise that it is cheaper to bring the coal to the water than the water to the coal, no information is presented in the report to support this premise. The report demonstrates the adequacy of mainstem flows for energy development and indicates that reservoir storage would be needed for tributary plant site water supply, but it provides few details. However, as demonstrated by the SRC-11 Plant at Morgantown, West Virginia, synfuel and other energy facilities are proposed for sites on the Ohio River tributaries. Consequently, this concentration on the mainstem of the Ohio significantly reduces the usefulness of the "Synfuels in the Ohio Basin" report.

The "Synfuel in the Ohio Basin" report states its purpose as: "...to define constraints and impacts relative to the development of emerging coal technologies in the Ohio River region." By limiting its scope to the Ohio mainstem, the report does not meet this stated objective. Furthermore, by limiting the scope of analyses to the mainstem of the Ohio, the conclusion of adequate water availability of synfuel development is nearly preordained because of the significant water availability in the mainstem. For example, the estimated mean annual discharge from the Ohio Basin is about 20 million acre-feet per year. Consumptive use for 2000 is expected to be about 0.2 percent of mean daily flow by the year 2000 or about 0.3 percent of low flow where low flow is the daily flow with a 95 percent chance of exceedence (U.S. Water Resources Council, 1980, Vol, p. 15). With 20 million acre-feet per year average annual flow and a 0.3 percent consumptive use, severe water availability problems should not be expected to arise. Even the highly aggregated data for the Ohio tributaries in the Water Resources Council's Second National Assessment suggest that the real water availability problem for synfuel development will be in the tributaries and not the main stem. For example, consider the Wabash River, a tributary of the lower Ohio which has substantial coal deposits in Illinois and Indiana (Assessment subregion 506). Expected streamflow depletion during a dry, critical month at present (1975) is about 9 percent and is expected to increase to 21 percent by 2000 (U.S. Water Resources Council, 1978, Volume 3, Appendix II, p. 141). Comparison of this forecasted 21 percent depletion with the 0.3 percent on the mainstem tends to confirm the conclusion that the water availability problem will be in the tributaries.

Therefore, based on this aggregated data, it appears that the "Synfuels in the Ohio Basin" report ignored the area with potential water availability problems for synfuel development.

Both the "Synfuels in the Ohio River Basin" and the "Monongahela Synfuel Plant" reports are based on data aggregated by Water Resources Council water accounting units. This highly aggregated data is of limited use for individual siting decisions and for forecasting hydrologic impacts at the specific sites. The aggregated data is only useful for estimating water availability for the entire water accounting unit (generally a river basin).

Water quality data and analysis in the "Synfuels in the Ohio River Basin" report is somewhat superficial and would be of limited use in either programmatic or site specific decisions, Only very limited water quality data are presented in the "Synfuels in the Ohio River Basin" report for the mainstem of the Ohio, and none is presented for the tributaries. The data presented for the mainstem (pp. 20-22) is in conflict with comparable data presented by Bri 11, et al (1980, p. 7-13). It is also clear that more severe water quality problems occur on the tributaries and not the main stem (see Brill, et al., 1980, Table 7. 4, p. 7-11). This omission of water quality data further indicates that the "Synfuels in the Ohio River Basin" report ignores the real problem: water availability for synfuel development and water quality in the tributaries.

In the 'Water Assessment for Monongahela Synfuel Plant" report, a disparity between water quality data available for Pennsylvania and West Virginia is noted. The report indicates that the only water quality parameters considered significant for this assessment were dissolved oxygen, pH, and total dissolved solids. It appears that significantly less data and information are available for the West Virginia portion of the Monongahela basin than for the Pennsylvania portion. Furthermore, West Virginia has no standards for total dissolved solids, and the data presented do not clearly indicate what the impacts will be on TDS in West Virginia. Because of the disparity in data availability and standards between the two states, forecasts of future water quality impacts would appear to be somewhat uncertain and the report does not highlight this uncertainty.

As discussed in Section IV herein, the cost of water is probably not a major factor in developing a synfuel plant because the cost of necessary water is very low relative to other factors. Cost data for alternative sources of water supply, however, are probably the most important parameter--next to legal and physical availability--in deciding on water supply sources for synfuel development. Consequently, cost data are important in analyzing the various trade offs, among water supply sources. Dependable cost data, however, are not easily assembled and the "Synfuels in the Ohio River Basin" report contains only minimal cost data. The lack of data for specific tributary reservoir sites is a major deficiency.

The difficulty in estimating the cumulative effect of depletions on water availability is exacerbated by the interstate nature of the Monongahela Basin and the inherent problems in coordinating forecasts of future consumptive use between two states. If the estimates of cumulatative impacts of synfuel development and other consumptive users of water are to be useful to the decision- makers, then the many inherent assumptions and certainties in these estimates of cumulative impacts must be clearly spelled out. This is not the case in either the "Synfuels in the Ohio Basin" report or the "Water Assessment for the Monongahela Synfuel Plant." There is a need for clearly indicating the accumulated impacts of future consumptive use and the uncertainties inherent in these estimates of future consumptive use, since any individual consumptive use, including that of a demonstration plant such as the SRC-11 plant, "is so small that it is difficult if not impossible to measure an adverse impact traceable solely to that use" (p.2 "Monongahela Synfuel Plant" Report).

Another complicating factor for forecasting future availability of water for synfuel development is the uncertainty surrounding future demand for lockage water on navigable rivers such as the Monongahela. Estimating demand for future lockage water is dependent upon complex projections of future demand for waterway transportation. The requirement for forecasting future in-stream demands for navigational lockage water, and the resulting uncertainty of this forecast, is a problem characteristic of eastern river basins. Navigation lockage requirements must be added to other instream demands (fish and wildlife habitat, recreation, and hydropower) when assessing water availability for synfuel development.

INSTITUTIONAL, LEGAL AND ECONOMIC FACTORS

The institutional and legal factors affecting water availability are less extensive and complex in eastern basins such as the Ohio than in western basins. This situation results because: (1) there are relatively few interstate compacts or Supreme Court decrees affecting water availability, (2) Federal or Indian reserved rights problems are absent, (3) riparian based state water law for Ohio Basin states is less complex than the appropriation doctrine of western states and (4) there are fewer entities (e.g., river districts, irrigation districts, Federal and State agencies, etc.) involved in water resources in the Ohio Basin states than in the west.

Institutional and legal constraints do, however, affect water availability for synfuel development in the Ohio Basin, but the reports reviewed do not address these constraints. Some consideration should have been given to this matter.

The operating policies of Federal reservoirs introduce institutional uncertainty into the assessment of water availability in the Ohio River Basin for synfuel development. Approximately 520,000 acre-feet of water supply storage exists in six Federal reservoirs in Ohio and Indiana (Ohio River Basin Commission, 1980, P.18). (In comparison, a 250 mi 1 lion scf/day coal gasification plant can be. assumed to have a consumptive use of about 15,000 acre-feet/year). The water marketing and operating policies for these Federal reservoirs can be surrounded with considerable uncertainty since the Federal government and the local project sponsor (generally the local or state government) share responsibility of water marketing and reservoir operation depending on the individual project. In the case of the SRC-11 coal conversion plant in the 'Water Assessment for the Monongahela Synfuel Plant" report, reservoir operating and water marketing policies for the proposed Stonewall Jackson Reservoir are critical in analyzing the hydrological effects of water demands for the SRC-11 plant. Uncertainties surrounding the marketing of water from the Stonewall Jackson Reservoir (e.g. price, priority, and availability) and the operating policy of this reservoir are major sources of uncertainty concerning water availability and future water quality conditions in the Monongahela River below the SRC-11 plant.

Uncertainty over water availability also results because, in general, we do not have institutions or mechanisms to produce dependable and uniform data on water availability for river systems which cross state boundaries. This problem of reconciling data between two states and the resulting uncertainty is demonstrated in the Monongahela Synfuel Plant Report where there is a significant disparity between water quality data in Pennsylvania and West Virginia. Probably a more important problem resulting from this continuing lack of coordination among the states is the lack of dependable information and data concerning future cumulative impacts of synfuel and other development on water availability. What is needed is a mechanism to bridge the gap on a continuing basis between the site specific report and general basin-wide analysis.

None of the reports reviewed included economic data on the cost of developing reservoirs. Since the potential for siting synfuel plants on tributaries is ignored in the "Synfuels in the Ohio River Basins," and, consequently, no reservoir storage is required, the report concludes (p. 56):

> The ready availability of water in the basin requires no unusual expenditures for synfuel development; therefore, costs have not been estimated. If facilities are located where water is not available, the costs for providing that water, such as building a reservoir, are part of the economic trade-off analysis which must be made for each site specific plant.

CONCLUSIONS

The water availability situation in the Ohio and Tennessee Basins is comparable to that in the Upper Mississippi. From a regional perspective sufficient water is available for projected synfuel development but localized problems or deficiencies may occur for synfuel plant sites on tributaries. The extent and nature of these deficiencies can only be predicted with site specific studies.

The Ohio River Basin Commission "Synfuels in the Ohio River Basin" report is of marginal utility to realistic decision-making situations since it ignores the areas where water availability for synfuel development may be a problem, the tributaries of the Ohio River, and instead concentrates on the mainstem where there is no apparent availability problem. The report contains no economic data and no discussion of political, institutional, or legal factors affecting water availability.

The Monongahela Synfuel Plant report is a straight-forward and generally adequate assessment of water availability for the proposed SRC-11 plant in Morgantown, West Virginia.

The Brill, et al. reports (1977 and 1980) are more useful reports for assessing water availability and are discussed in the Upper Mississippi River Basin section herein.

SECTION IV
UPPER COLORADO RIVER BASIN
AND COLORADO RIVER IN COLORADO CASE STUDY

BACKGROUND

This section looks at synthetic fuel development in the Upper Colorado River Basin, which encompasses the Colorado River above Lee's Ferry (Utah, Wyoming, and Colorado) (see Figure 4). Within the Upper Colorado River Basin there is potential for both shale oil and high Btu and low Btu coal gasification. The richest oil shale deposits are located in the Piceance Creek structural basin (or the river basins of the White and mainstem Colorado in Colorado) and the Uinta structural basin (White River Basin in Utah). The coal is found primarily in the San Juan Basin in New Mexico and southern Colorado. A location map for the oil shale deposits is found on Figure 5 and a map of the coal deposits is found on Figure 6.

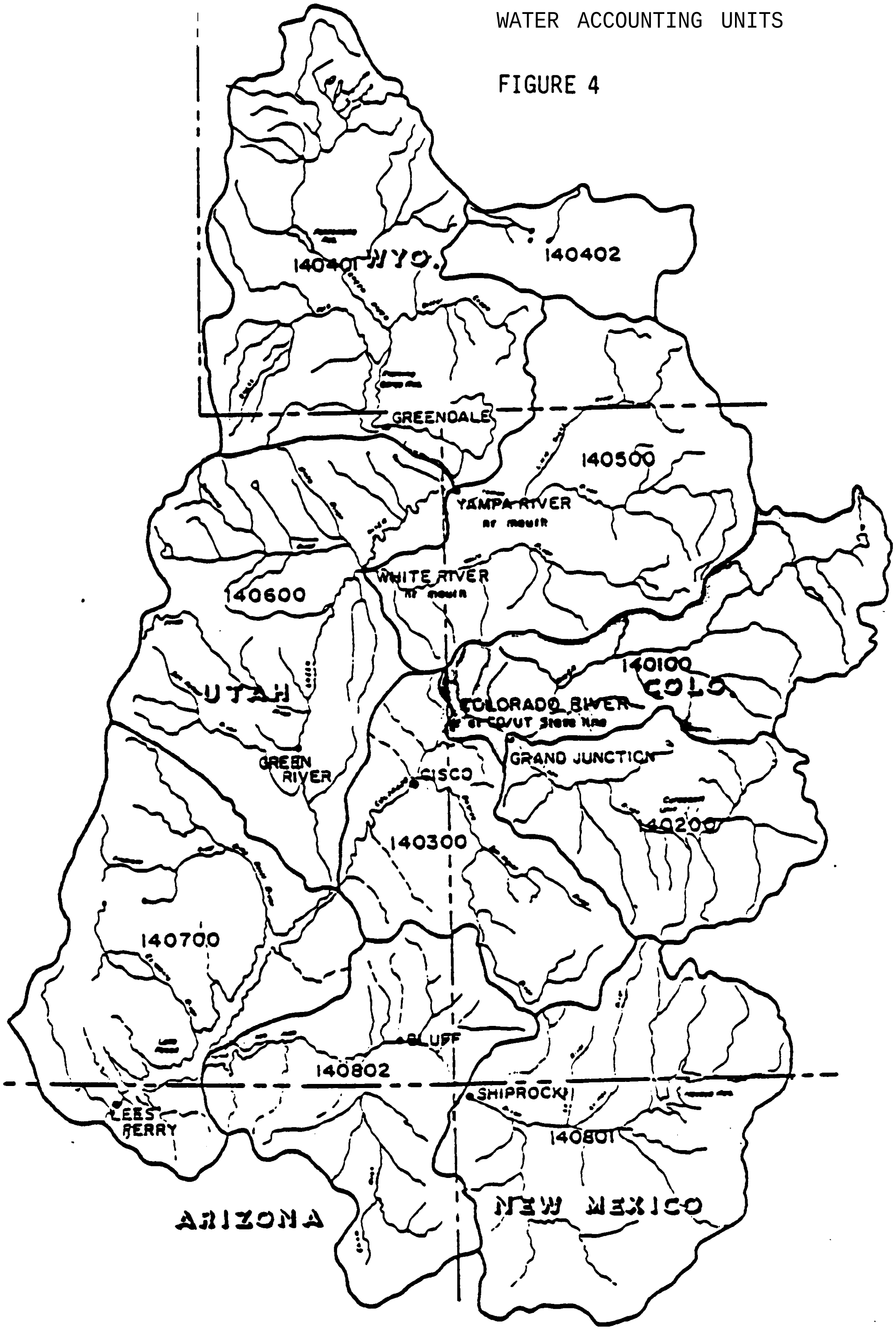
The Upper Colorado River Basin covers about one million square miles in four states: Colorado, Wyoming, Utah and New Mexico. These four states comprise the upper portion of what is the most complex, and disputed, water management system in the United States--the Colorado River Basin.

In order to meet the objectives of this study within the limits of available resources, it was necessary to select a portion of the Upper Colorado River Basin for detailed analysis. To attempt an assessment of water availability for synfuel development along with an analysis of existing data and information concerning water availability for the entire Upper Colorado River Basin would have led to a superficial and generality-laden report with little new information.

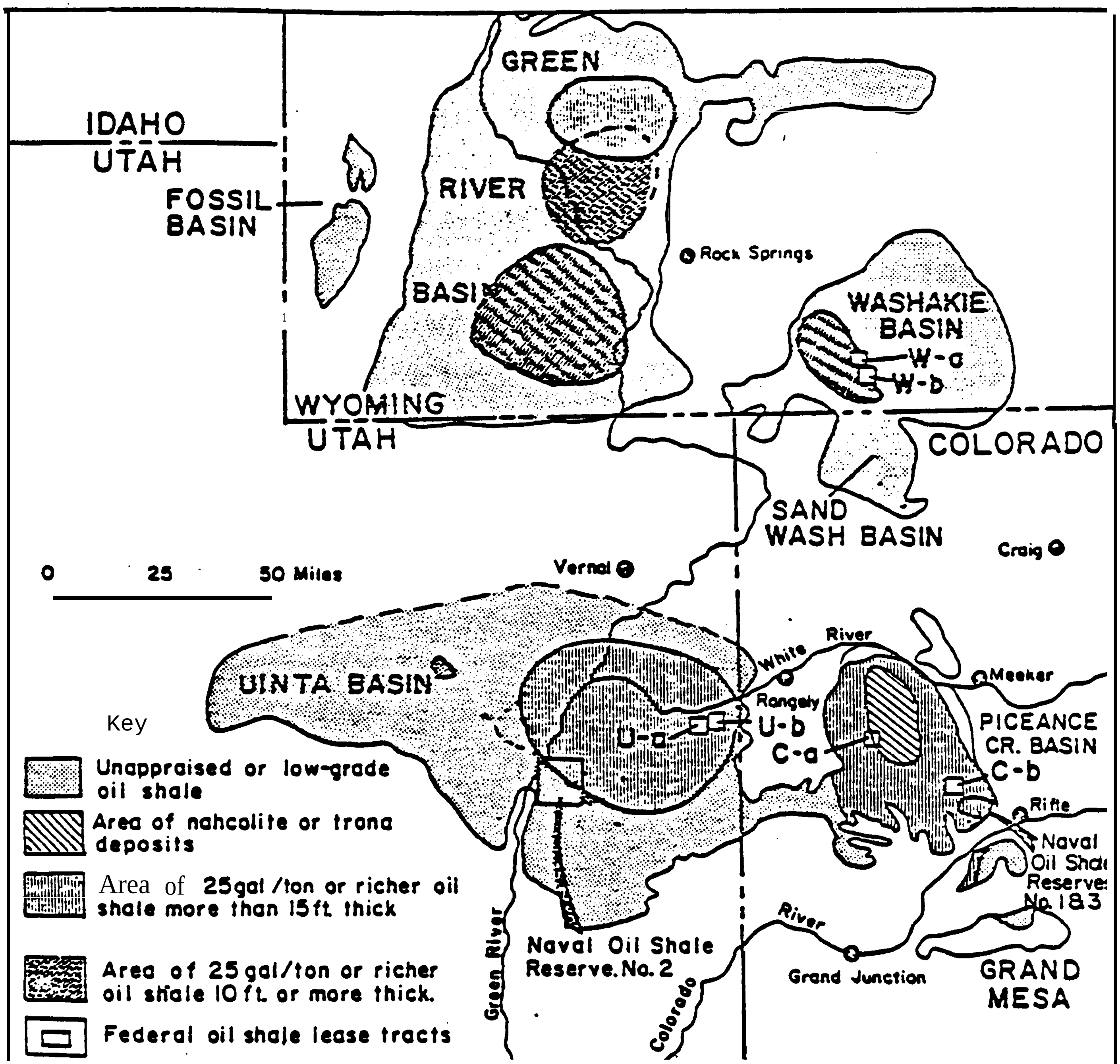
Consequently: the Upper Colorado River Basin in Colorado was selected for detailed analysis with particular focus on the impending oil shale development activity within the Upper Colorado River Basin above Grand Junction, Colorado and the new competition that it brings for water resources. This selection of the Upper Colorado River Basin in Colorado was made for several reasons:

UPPER COLORADO RIVER REGION AND WATER ACCOUNTING UNITS

FIGURE 4

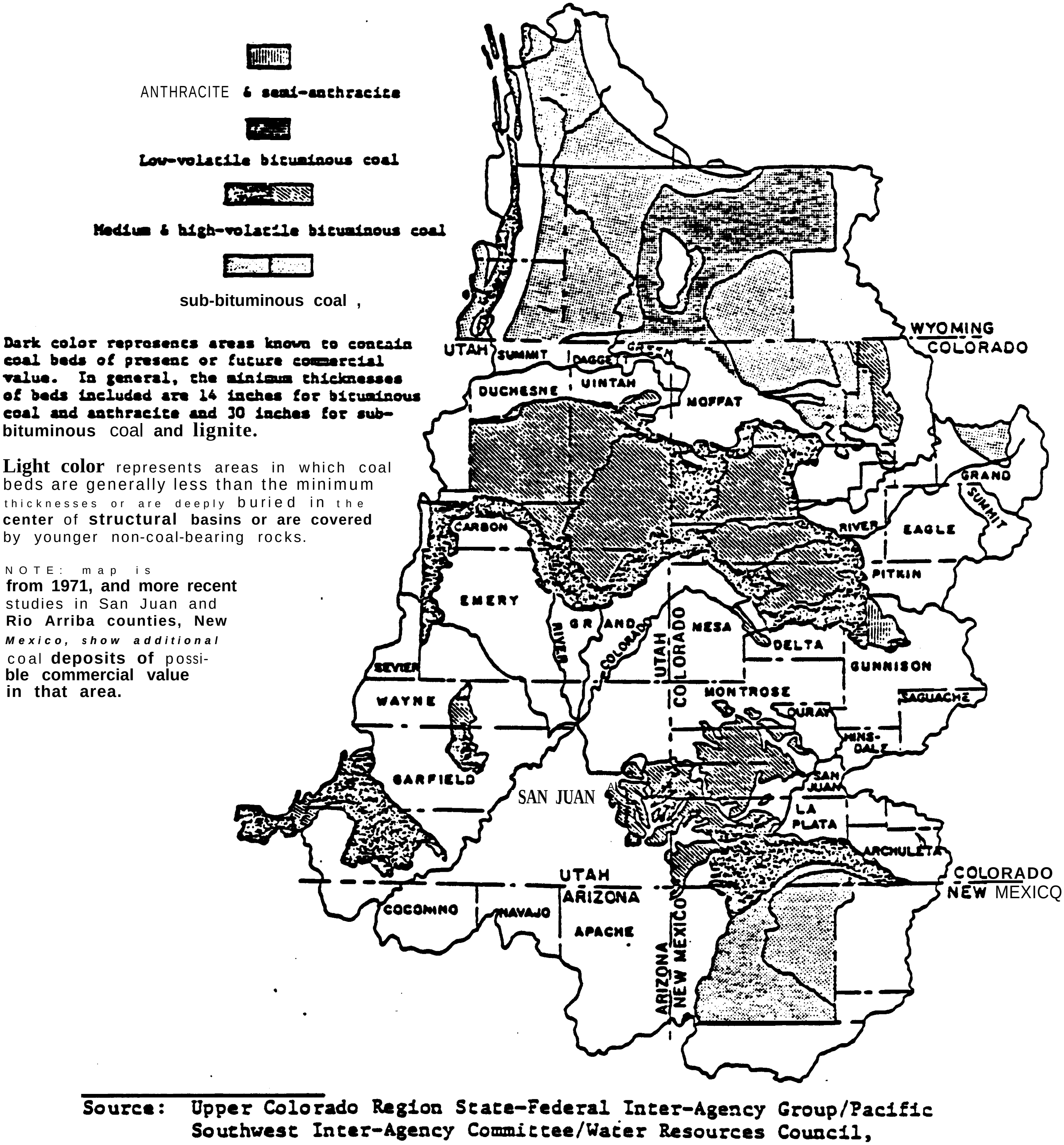


Source: Colorado Department of Natural Resources 13(a) Assessment



Source: Adapted from U.S. Geological Survey maps and Jaffee, F.C., "Oil Shale, Part II," Mineral Industries Bulletin, vol. 5, No. 3. Golden: Colorado School of Mines Research Foundation, Inc., 1962, p. 12.

Figure 5 GREEN RIVER FORMATION IN COLORADO, UTAH, AND WYOMING, SHOWING LOCATIONS OF NAVAL OIL SHALE RESERVES AND FEDERAL OIL SHALE LEASE TRACTS IN COLORADO AND UTAH



Source: Upper Colorado Region State-Federal Inter-Agency Group/Pacific Southwest Inter-Agency Committee/Water Resources Council, Upper Colorado Region, Comprehensive Framework Study, Appendix VII, Mineral Resources, June, 1971, p. 12.

FIGURE 6 GENERAL MAP OF COAL DEPOSITS IN THE UPPER COLORADO RIVER REGION

1. Major oil shale deposits are in this area and the Colorado River is viewed as the source of supply.

2. Oil shale development work is further advanced in this basin than elsewhere. For example, Exxon and Tosco are presently constructing the Colony Shale Oil Development. Work has advanced beyond the planning stage and application for Federal loan guarantee stage in the Upper Colorado River Basin in Colorado.

3. The Upper Colorado in Colorado is a more complex basin--with respect to institutions, economics, 'politics and legal matters--than other sub-basins in the Upper Basin that could have been chosen for in-depth analyses (e.g., the White River Basin).

4. The Upper Colorado River Basin in Colorado presents several interesting possible alternative sources of water for synfuel development. These alternatives are not available in other basins such as the White (e.g., reduction in municipal trans-mountain diversions through increased conservation measures and the use of the water "saved" for synfuel development). In summary, more conflicts and issues are presented in the Upper Colorado in Colorado.

5. More data, analyses and reports are available for the Upper Colorado in Colorado--probably as a result of the greater conflict and number of issues--than the other sub-basins.

Results of the analyses herein of the Upper Colorado River Basin in Colorado apply-with few exceptions to the remainder of the entire Upper Basin. The differences are primarily in degree of applicability. The institutional and legal systems with respect to water are very similar for the four states--a factor primarily responsible for the general application of the analyses results herein to the entire Upper Basin.

An effort has been made throughout this section to indicate the applicability of analyses results and conclusions based on the Upper Colorado in Colorado to other areas of the Upper Basin. Likewise, an effort has been made to indicate where these results should not be extrapolated.

An argument could be made for also studying the White River Basin in detail since the majority of oil shale in the Upper Basin is concentrated in that basin. The issues in the White River Basin, however, are fewer and less complex than in the Upper Colorado in Colorado. These issues primarily center around: (1) many of the same issues as in the Upper Colorado in Colorado (poor groundwater data, inadequate hydrologic data and interpretation of data, lack of adequate planning institutions, etc. and (2) the need of rational reservoir storage and conflicts over siting reservoirs in a wilderness area. This latter issue is quite similar to the new reservoir storage issue in the Yellowstone River Basin (see Section V), but on a much smaller scale. A subsection briefly focusing on the White River Basin and the problem of necessary new reservoir storage has been included at the end of the analyses of the Upper Colorado River Basin in Colorado.

Much of the discussion of the following case study is structured around existing reports” and published information concerning water availability for synfuel development in the Upper Colorado River Basin-inost notably the “Section 13(a)’ report” completed by the State of Colorado. The structuring of the Upper Colorado River in Colorado case study around this material should not be confused with a “book review” of these reports and information. This structuring was done out of necessity to meet one of the objectives of this study: to analyze the adequacy of existing information and reports for decision-making concerning water availability of synfuel development.

The availability of water supplies in the Upper Colorado River-Basin has been the subject of dozens of studies and reports during the last 75 years. Some of the more important recent State and Federal studies include:

Colorado Department of Natural Resources, The Availability of Water for Oil Shale and Coal Gasification Development in the Upper Colorado River Basin Upper Colorado River Basin 13(a) Assessment, A Report to the U.S. Water' Resources Council, October; 1979.

Colorado Department of Natural Resources, The Ground Water Resources of the Upper Colorado River Basin, Denver, Colorado, October, 1979.

Colorado River Basin Water Problems: How to Reduce Their-Impact, May 4, 1979.

Comptroller General of the U.S., Water Supply Should Not be an Obstacle to Meeting Energy Development Goals, Report to the Congress of the United States, January 24, 1980.

In 1974, the final environmental impact statement for the Colony Development Operation (U.S. Department of Interior, 1977) stated:

> It is also realized that in drought years there may not be sufficient water available at all points of use in the Upper Basin to meet use requirements. . . . These shortages will generally be sustained by agricultural water users because they cannot economically pay the cost to provide enough storage regulation to eliminate all shortages in their water supply.

A 1979 General Accounting Office report on the Colorado River Basin (Comptroller General of the U.S., 1979) presented the following picture of water demand estimates:

> Based on most projections of future virgin flows, the allocations substantially exceed the river's dependable water supply.

In the 1979 Summary Report on Energy From the West prepared for EPA (U.S. Environmental Protection Agency, 1979), the University of Oklahoma commented upon water availability in the Colorado River Basin.

> When energy requirements for water are added to non-energy requirements for the year 2000, the total exceeds minimum availability estimates by as much as one million acre-feet per year. Even using , the most optimistic combination of these estimates of water requirements and availability, energy resource development will consume a large percentage of unappropriated surface water.

The Colorado Department of Natural Resources Section 13(a) Assessment, completed in October, 1979, and the January, 1980 GAO report to Congress (Comptroller General of the U.S., 1980) began to suggest that adequate water supplies exist in the Upper Basin through at least 2000. Little attention is given to supplies beyond 2000, most likely due to the inaccuracies inherent in such long-range predictions.

The reason why there are reasonable differences about water availability, as noted above, is that many uncertainties underlie the data, assumptions, and estimation methodology. Some of the issues underlying areas of uncertainty which will be reviewed and discussed in this analysis of water availability for synfuel development in the Upper Colorado River are:

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(1) The data base and the methods used to establish the virgin flow (i.e., the total water resource available in the basin) are uncertain.

(2) The method for estimating current depletions from the basin is limited by the data base. Future consumptive use estimates are likewise limited.

(3) The effect of the Mexican Treaty of 1944-45 upon development of water supplies in the Upper Colorado River Basin is uncertain.

(4) Insufficient data exist to assess the contribution which non-tributary groundwater could make to the availability of supply.

In addition, the issues specifically related to the Colorado River above Grand Junction include:

(1) , The State of Colorado does not have a water administration plan developed to meet Colorado River Compact requirements once the Colorado River basin becomes fully developed. Therefore, the net water available to the sub-basins within Colorado is uncertain.

(2) Colorado water law is generally advanced by individual court cases and decisions, and the cumulative effect is uncertain.

Institutions in Basin

Within the basin water availability is governed by various institutions which-include the following:

Legal Institutions

State courts

Federal courts

Administrative/Water Management Agencies

State engineer (surface water and groundwater)

State natural resource departments
State water quality control authorities
U.S. Army Corps of Engineers (USACE)
U.S. Water & Power Resources Service (USWPRS)
Compact Commissions

Development Agencies

Water conservation districts "
State water development agencies
USACE
USWPRS

Organization of Section

This section is divided into three parts. The first part is the analysis of of the Section 13(a) Report as it specifically relates to the Colorado River in Colorado, as well as pertains to the entire basin. The second part is an analysis of three other reports pertaining to the Upper Colorado River Basin. The final part discusses the White River Basin and water availability for synfuel development in that basin.

SECTION 13(a) REPORT: THE UPPER COLORADO RIVER IN COLORADO AND THE UPPER COLORADO BASIN

The Upper Colorado River Basin in Colorado (see Figure 4 Water Accounting Unit 140100) is approximately 8,600 square miles in area, and much of it is located in mountainous country above 6,000 feet.

Physical Availability

Assessments of physical availability of water for synthetic fuel development in the Upper Colorado Basin and the Colorado River within Colorado have generally concentrated only on surface water supplies. Analyses of surface water availability have depended upon the following estimates:

- Estimates of virgin flows. Virgin flows are the natural streamflows undepleted by man's activity. These flows must be estimated from recorded streamflow data and estimates of depletions to the river. Virgin flow estimates are important data in assessing water availability because interstate compacts and water flow are predicated on virgin flow.

- Estimates of current and future depletions. Depletion is the difference between the amount diverted and the amount of water returned to the river ("return flow"). It is the amount of water removed from the system by evapotranspiration from plants, soil moisture absorption, reservoir evaporation, or other consumptive uses.

- Estimates regarding timing of water supplies. In the Colorado River Basin, surface water supplies can vary significantly from year to year. Within a year there s also considerable seasonal variation, with over one-half of the runoff occurring in the spring and early summer. Because of the year-round demand by synfuel plants, timing becomes an important factor in the availability of water, and estimates are made regarding the ability of reservoirs to smooth out the timing of water supplies. The long term stochastic nature of virgin flow is imperfectly understood. This results in difficulties in estimating statistical parameters (e.g. mean annual flow) of flow distributions.

Streamflow Data. Historic streamflow records for the Colorado River, one of the bases for determination of virgin flows, are probably the most accurate component in the various analyses of water availability. There are still, however, limitations to the quality of that data base caused by inaccuracies in measurement, icing at gaging stations in winter, and other recording errors.

Streamflow data are accumulated primarily by the U.S. Geological Survey, with additional gages operated by the State of Colorado and the Mater and Power Resources Service. In 1921 there were only 14 gaging stations within the study basin in Colorado, four of which were on the main stem of the Colorado River. The number of stations has grown to 121 in 1980.

Therefore, there are a limited number of long term records, and it may be impossible to estimate accurately the statistical properties of the streamflow distributions from the short term records.

The Section 13(a) report relies almost exclusively on mean annual flows for estimating water availability for synfuel development. For the mainstem, mean annual flow data provide a reasonable estimation of annual yields because of the significant amount of storage available to control river flows. However, for tributaries, where comparable storage volumes are not available, or will not be available in the near future, reliance on mean annual flow data is not adequate. In these circumstances, mean annual flow data provide little or no information to decisionmakers concerning the impacts of synfuel development water demands on low flows. Such data and information are important to assess water availability during low periods for meeting instream demands for fish and wildlife habitat, recreation, water quality and run-of-the-river hydropower.

Analysis of stream gage records does not give a good quantification or distribution of the virgin flow unless there are either no diversions upstream of the gage or the upstream depletions can be accurately measured. While there are many gages which measure virgin flow, these are in small, high mountain basins. In most cases the virgin flow is estimated from streamflow data and estimates of depletions. Depletions estimates, in turn, are another source of uncertainty in assessing water availability for synfuel development.

Historic Depletions. The Colorado Department of Natural Resources 13(a) Assessment estimates the average annual depletions in the Colorado River Basin upstream of Grand Junction (Water Accounting Unit 140100) for 1975/76 conditions to be 991,000 acre-feet, of which 454,000 acre-feet are in-basin depletions:

	Percent	Acre-feet
Thermal	1	1 000
Agriculture	43:5	432,000
Fish, Wildlife and recreation	.2	2,000
Minerals	. 7	7,000
Municipal & Industrial	1.2	12,000
Transbasin Diversions	54.2	537,000
		991,000

Future depletions for year 2000 exclusive of synthetic fuel uses are projected to be 1,138,000; 1,220,000; and 1,313,000 acre-feet for the low, medium and high scenarios in the Section 13(a) study.

These estimated historic depletions and forecasted future depletions comprise important data and information sets for estimating virgin flow, a fundamental parameter for determining water availability in the entire Upper Colorado Basin.

Of most significance to the estimation of depletions is the fact that the State Engineer's records (except in a few cases) do not and possibly cannot measure return flow to the stream, whether it is through wastewater outfalls, irrigation return flow or other sources of return flow to streams. Therefore, depletions must be estimated by indirect means. These estimated depletions subsequently form the basis for estimating virgin flows.

There are two methods by which depletions are estimated. The first and probably most accurate method is to correlate ditch diversion records with a depletion factor based upon type of use. For agriculture (the greatest source of in-basin depletions), ditch diversions would be correlated with the amount of land irrigated and type of crops to obtain an estimate of depletions. This method reflects the year-to-year variations in depletions as a result of changes in river flows. Since this method is extremely time-consuming on a basinwide study, a second method is used., This method identifies the amount of irrigated land by crop, usually from county agricultural statistics or aerial photos, and uses a unit consumptive use figure (e.g. , acre-feet per acre) to identify the total depletions. This, however, only provides generalized depletion estimates. This second procedure was used for the Upper Colorado Section 13(a) analysis: (1) crop acreages for the Upper Colorado Basin were obtained from agricultural census data, (2) evapotranspiration indices for the crops were developed for each year using a procedure such as the Blaney Criddle method, and (3) depletions were assumed to be equal to evapotranspiration.

Therefore, this discussion indicates that for the entire Upper Colorado River Basin and for the area encompassed in this case study: (1) estimated depletions are important parameters i n assessing water availability and (2) considerable uncertainty can exist in depletion estimates. Without a water use audit one cannot determine if depletions are over estimated or under estimated, let alone determine the magnitude of error.

Estimation of Virgin Flows. Virgin flow estimates are fundamental data for determining water availability in the Upper Colorado River Basin. -A look at the estimation of virgin flows for the entire Upper Colorado River Basin provides a good example of the deficiencies inherent in the quantification of natural flows.

Estimates of virgin flow for the Colorado River at Lees Ferry vary significantly according to the period of study:

Period	Years	Annual Virgin Flow
1906-1974	69	15.2 maf
1922-74	53	14.3 maf
1930-74	45	13.8 maf
1931-40	10	12.5 maf
1954-63	10	12.5 maf

The General Accounting Office study uses the 1906-74 period of record and assumes that the virgin flow of the Colorado River at Lees Ferry will average 15.2 million acre-feet per year (Comptroller General of the United States, 1980). The Section 13(a) Assessment identifies the range of 13.8 to 15.2 million acre-feet per year but chooses the 13-8 figure as the basis for its analysis. Studies by the Water and Power Resources Service in recent years (Comptroller General of the U.S., 1979) have used an annual virgin flow of about 14.8 million acre-feet, and the Denver Water Department in a 1975 report to the Colorado General Assembly quoted a flow of 13.0 million acre-feet per year.

Each of these studies confuses the sample mean with the population mean. A mean annual flow is a random variable just as annual flow is a random variable. Mean annual flow estimates have a statistical distribution. Mean values based on samples from this distribution (e.g., the 15.2 and 14.3 million acre-feet are only sample means and will have a considerable variance (in the statistical sense) about the population mean.

Therefore, 13.8 maf should not be taken as the population mean of the Colorado River; it should be viewed as only the arithmetic average of a series of annual river flows from 1930-1974. The mean of a future series of annual flows can, and probably will, vary considerably from this number.

The Section 13(a) report for the Upper Colorado River apparently makes the common mistake of treating the estimate of mean annual flow as a deterministic number when it is stochastic. Failure to emphasize-this stochastic nature of mean annual flow estimates tends to make estimates appear more certain than they are.

Groundwater. Most analyses of water availability for oil shale development in Colorado and the entire Upper Basin ignore the potential contribution from groundwater because of the lack of sufficient quantitative data. Use of tributary groundwater, which by definition in Colorado law is a continuum of the surface water system, will not increase the available supply but can alter the timing of supplies. Use of tributary groundwater can provide non-structural storage-of surface water by vacating the alluvium and providing storage for additional water to be pumped at a later date.

The use of non-tributary water, which is water not connected to the surface water system, can provide an additional source of water. The Section 13(a)" report indicates that between 2.5 and 25 million acre-feet are contained in the two deep aquifers underlying and overlying the oil shale deposits in the Piceance Creek Basin. The estimated average annual discharge from, and recharge to, the aquifer system associated with the Piceance Creek structural geologic unit ranges from approximately 24,000 to 29,000 acre-feet. Discharge occurs primarily by evaporation and by seepage to springs (Colorado Department of Natural Resources, 1979, p. 7-31). This amount of depletion would maintain an equilibrium in the aquifer while providing the water supply needs for four or five unit-sized (50,000 bb/d) shale oil plants exclusive of associated growth. However, there is controversy over whether the aquifers are tributary or non-tributary. This legal distinction affects the yield and legal availability of the water.

While non-tributary groundwater might be an attractive alternative supply for synthetic fuel development, knowledge and information about non-tributary groundwater is insufficient to use for reliable basin-wide planning. In general, groundwater data for tributary and non-tributary waters in the Colorado River Basin above Grand Junction are sketchy and inaccurate. One of the main sources of confirmation of hydrogeologic estimates in Colorado is the State Engineer's records on registered wells which records contain well completion reports. However, based on our experience it is believed that in some areas less than 50 percent of the wells are registered with the State.

The lack of a good tributary groundwater data base in the entire basin, both in the number of wells and well pumping data for alluvial wells, means that we cannot accurately estimate ranges of the cumulative effect of tributary wells on the alluvium and streamflow regime in the Upper Colorado River.

The lack of data regarding non-tributary supplies has great significance for basin-wide assessments of water availability. Should synfuel projects be able to obtain a significant portion of the water in the deep, non-tributary aquifers, this would lessen the burden on surface flows and provide back-up in times of water shortage. In effect, non-tributary groundwater is treated by water supply planners as a potential windfall source for energy development.

Legal. Institutional. and Political Uncertainties

Surface Water - Direct Diversions. Legal and institutional constraints significantly affect water availability for synfuel development. In the Upper Colorado Basin, these constraints include the:

- Colorado Constitution (pure appropriation doctrine),
- Colorado Water Right Determination and Administration Act, and other state water laws,
- Colorado River Compact of 1922,
- Boulder Canyon Project Act of 1928,
- Upper Colorado River Basin Compact of 1948,
- Mexican Water Treaty of 1944-45,
- Colorado River Storage Project Act of 1956, and
- Colorado River Basin Project Act of 1968.

A good summary of these compacts and Colorado water law appears in the June 1980, OTA report, Assessment of Oi1 Shale Technologies and the Section 13(a) Assessment. As a consequence, this background information is not repeated herein. In the future, as the water rights in the entire Colorado Basin become fully developed, the legal framework and its interpretation will become an even more critical factor in assessing water availability than at present. Because full development has not been reached, some provisions of the law and. compacts have not been exercised or tested. For example, the Upper Basin states have not fully developed their rights to Colorado River water, and there has been no need to date for limiting Upper Basin diversions. As a result, considerable uncertainty exists about procedures and priorities which will be used in the Upper Basin to call Upper Basin out-of-priority diversions when Colorado River Basin Compact requirements cannot otherwise be met. The legal uncertainties which exist are generally not fully recognized, or emphasized, in the Section 13(a) or other assessments of water availability for shale oil development.

The obligation of Colorado and other Upper Basin states under the Colorado River Compact is to deliver 75 million acre-feet at Lees Ferry "for any period of ten consecutive years." For planning purposes, this commitment is assumed to be 7.5 million acre-feet annually. However, there is a dispute regarding whether the Upper Basin states will be required to supply 50 percent of the 1.5 million acre-feet annual commitment to Mexico under the Mexican Mater Treaty of 1944-45.

Furthermore, Colorado has not determined how it will internally administer the state's water rights to meet its commitments under the Colorado River Basin Compact, the Mexican Treaty, and other legal constraints. As the basin becomes fully developed, other basin states will exercise their rights, and a demand will be placed upon Colorado to deliver required flows to the state line. There are at least two scenarios that could be used to administer the compacts within Colorado; but since no planning has been undertaken to date, prediction of a likely option is not possible. The first plan would follow the Appropriation Doctrine and curtail the most junior rights to meet the calls, irrespective of the sub-basin in which they were located. A second administrative scenario would allocate a percentage of the demand to each sub-basin. For example, the Colorado River mainstem at the state line could be required to deliver a certain percentage of Colorado's commitment to the compacts, and similar allocations would be undertaken for the White, Dolores, Yampa, and San Juan Rivers. If the first scenario were used, some basins would require more reservoir storage than if the second plan were implemented. The second scenario would allow the state to 'manage" the available water supply to mitigate against unequal impacts caused by Colorado's obligation. Political and legal influences will play major roles in determining any solution to this highly controversial matter.

Therefore, the various compacts and treaties add considerable uncertainty to the projected availability of water supply for synfuel development because many of their; provisions and conditions are not definite or have not been tested. Further uncertainty is added to water availability because state implementation procedures to meet various conditions and requirements of these treaties and compacts have not been developed. This uncertainty provides a significant cloud on the availability of water for synfuel development.

Federal Reservoirs. The Colorado Department of Natural Resources assessment predicated its conclusion of water availability on the assumption that water could be obtained from existing reservoirs or new reservoirs. While federal reservoirs, such as Ruedi and Green Mountain Reservoirs in Colorado, provide an attractive option to water supply for oil shale, the amount of water available is uncertain.

- Ruedi Reservoir. The total amount of firm yield that could be made available for sale from Ruedi Reservoir ranges from zero to 67,500 acre-feet--or the water needs of about 11 unit-sized (50,000 bbl/d) shale oil plants. While Ruedi Reservoir, located on the Fryingpan River near Aspen, Colorado, appears to be a logical and convenient source of water for oil shale development in the near-term, potential sales of water from Ruedi Reservoir to industry are subject to controversy and uncertainty.

  The primary purposes of Ruedi Reservoir, according to its authorizing statute, are to: (1) satisfy depletions caused by transmountain diversions to the Arkansas Basin in eastern Colorado, and (2) provide water for future users in western Colorado, in particular the municipal and industrial water needs associated with the shale oil industry. However, to date, no long term contracts have been entered into for water sales, even though water has been available since 1969. The impediments to sales appear to be:

  (a) Uncertainty as to the amount required for replacement of eastern slope diversions: While 28,000 acre-feet has been set aside for make-up water for out-of-priority diversions to the , eastern slope, WPRS has estimated that less than 10,000 acre-feet is needed for that purpose. Hydrological operation studies show that the 28,000 acre-feet requirement could be reduced to 10,000 acre-feet; however, these studies will need to be confirmed and agreed to by the parties of interest in the reservoir before the 18,000 acre-feet saving could be used on the western slope. This amount could satisfy another two or three shale oil facilities.

(b) Uncertainty about the firm yield of the reservoir: Controversy exists among the Southeastern Water Conservancy District, the Colorado River Water Conservancy District, the State of Colorado, and the Water and Power Resources Service regarding firm yield of the reservoir. As a result, no general agreement exists concerning the total amount of water ultimately available.

(c) Uncertainty about the contract terms in water sales: WPRS has not decided whether it will market a firm yield to lessees or contract for a percentage of the annual reservoir yield. Additionally, a price structure has not been determined. These uncertainties may have to be resolved in individual contract negotiations on a case-by-case basis.

-(d) Controversy regarding the principal purpose of the reservoir: A coalition of interests (including the towns of Aspen, Snowmass, Basalt, Carbondale, Glenwood Springs, and Pitkin County) is seeking to gain control of the marketing of Ruedi water, or severely restrict the amount of water which can be marketed from Ruedi Reservoir, so that the reservoir level can be maintained at a high and consistent level for recreation. Should the coalition be successful, all or most of the marketable water (estimated at 49,500 acre-feet) would be pre-empted for recreation. This would be an extreme outcome and it is assumed that a compromise might be a more realistic resolution.

(e) Uncertainty about the marketing agency: The above-named coalition of municipalities, the Colorado River Water Conservation Board, and the State of Colorado have been seeking to become the marketing agent for the sale of water from Ruedi. Each entity would have different management purposes, which would affect conditions placed on water available for sale. For example, the coalition of municipalities would restrict sales in order to maintain recreational values. The Colorado River Water Conservation District would manage Ruedi as part of a series of reservoirs (to be constructed or acquired) in a basinwide storage management plan. The State of Colorado would manage the reservoir sales in coordination with statewide water resource considerations (eastern slope and western slope). These entities would impose different restrictions on the type of sales and pattern of releases.

If Water and Power Resources, which is currently in negotiations regarding an application for lease of water to one oil company, grants the lease, some of the issues may be resolved and precedents established. However, if and as more and more contracts are let, the issues of a reserve for recreation and the firm yield of the reservoir will become more important impediments.

- Green Mountain Reservoir. Green Mountain Reservoir, located on the Blue River, was constructed in 1942 as a replacement reservoir for transmountain diversions to northeastern Colorado by the Colorado Big Thompson project. Of the 153,639 acre-feet total storage volume, 52,000 acre-feet is set aside for replacement of transmountain depletions and 7,000 acre-feet is dead storage.

  While the operating principles are defined in Senate Document 80, there has been a continuous dispute since the completion of the reservoir between Water and Power Resources Service and prospective users about who is entitled to use the water from Green Mountain Reservoir. The reservoir has been mainly operated to meet power plant requirements. This has meant that storage in Green Mountain Reservoir has been maintained at a minimum of 41,000 acre-feet to maximize power generation efficiency. Other uses-- except for Colorado Big Thompson Project replacement needs-- have been subordinated. Such an operating criterion reduces the dependability of supplies from Green Mountain Reservoir for meeting oil shale industry requirements.

  Firm yield of Green Mountain Reservoir (as noted in the 13(a) Assessment, p. 6-11) is further limited because of potential landslide problems. The Water and Power Resources Service believes that if the reservoir were to be lowered below about 41,000 acre-feet, the potential exists for a major landslide. These limitations reduce the effective capacity of the reservoir by 34,000 acre-feet, or the equivalent of the annual requirements of about 5 or 6 unit-sized oil shale plants.

This detailed discussion of water availability from Ruedi and Green Mountain Reservoirs is presented to demonstrate that water availability for synfuel development is uncertain even in the case of existing Federal reservoirs. Institutional and legal constraints, however, are creating delay and uncertainty concerning the availability of this water for synfuel development. This uncertainty and potential for delay reduce the attractiveness of this water supply to energy companies seeking a water supply for a shale oil plant.

Alternatives. Legal, institutional, and political factors can be major constraints against implementation of alternative means of water supply for synfuel development.

The Upper Colorado River Basin report provides a good discussion of alternatives for synfuel water supply. In addition to discussing traditional sources ‘of supply (e.g., development of surface supplies through use of original appropriation, construction of new reservoir storage, or water contracts from existing U.S. Water and Power Resources Service reservoirs), the report provides detailed discussion of: (1) purchase of surface water rights from existing irrigated agriculture, (2) development of groundwater, (3) improvements in use efficiency by irrigated agriculture and municipalities, and (4) weather modifications.

While the Section 13(a) report adequately presents these alternatives, it does not fully discuss the legal and institutional constraints which would hinder implementation of alternatives such as reducing exports from the basin.

o Agricultural Water Rights. The Section 13(a) Assessment states:

> Purchases of water from irrigated agriculture could more than satisfy the water requirements of postulated levels of EET (Emerging Energy Technology) development in this basin. Furthermore, if sufficiently senior rights were obtained, it would be possible to develop the necessary water supply through direct diversions alone without any reservoir storage facilities (Department of Natural Resources, 1979, p. 7-28).

The statement does not accurately reflect the limitations placed upon transfers of use under Colorado water law. A water right transferred from agriculture to industrial use in Colorado must be transferred by court decree and is limited to the historic consumptive use of that agriculture water right (evaportranspiration, plant absorption, etc.). The historic use applies not only to the quantity but also to the historic period of use and the location of diversion. Thus, a converted agricultural right could only be used during the irrigation season. If diversions are to be available from these transferred rights for oil shale development throughout the year, storage facilities would also have to be acquired or built to store flows during the irrigation season for replacement release during the non-irrigation season.

Energy companies have been acquiring irrigation water rights in the basin for many years; however, few companies have taken these water rights through the 6 to 24 month transfer process. The only major transfer of irrigation water rights for oil shale development purposes has been by Union Oil (Division 5, Water Court Case W-2206) where in 1975 more than 50 irrigation rights were acquired and transferred from ranches in the Roaring Fork and Parachute drainages to Union Oil operations in Parachute Creek. These irrigation rights total over 150 cfs which could have theoret.ically diverted 50,000 acre-feet if there were water physically available and they were in priority. After protests against the transfer by other water users such as the City of Denver, ARCO, Garfield County and several individuals, who sought to protect their rights from injury as a result of the transfer, the court allowed the transfer of about 5 percent of the original decrees, or approximately 2500 acre-feet.

Therefore, while transfers of water from agriculture provide an obvious alternative source to oil shale companies, the process is legally cumbersome and the final result is beset with considerable legal and institutional uncertainties which are inherent in the water rights appropriation system.

Increased efficiency in irrigated agricultural uses of water is often proposed as an alternative which would result in increased water availability for synfuel development. It has been suggested that energy companies could pay farmers for water conserving measures plus a premium for any inconvenience in return for water rights to water "saved" by the water conserving measures.

Measures can be taken to reduce both conveyance losses and on-farm losses. The most likely means of reducing conveyance losses is through channel and ditch lining. Channel lining will reduce seepage from canals; however, it must be recognized that losses due to seepage from a canal or ditch are not truly losses to the hydrologic system. Water that seeps from a ditch or canal will eventually return to the groundwater or the river to be used by others. However, downstream users and alluvial well owners in Colorado and elsewhere have become dependent on the return flows from unlined canals and ditches and are legally entitled to that water.

The other category of measures involves reducing losses on the farm. Measures that may be taken include changing to crops that require less irrigation water and changing to more efficient irrigation methods. The most likely of these include improved application and tailwater recovery systems. *Since most consumptive use of farm irrigation water is the result of evapotranspiration and seepage of excess water into deep substrata, significant "savings" in water consumption can be achieved by these methods.

However, the same problems that confront implementation of ditch lining also confront measures to increase efficiency on the farm: under

Colorado water law, downstream water rights holders are entitled to return flows resulting from the existing inefficient practices. A change in agricultural or irrigation practice to “save” water for sale to an energy company and subsequent use in oil shale processing can be, and probably will be, legally challenged.

o Reduced Basin Exports. The Section 13(a) report provides detailed discussion of potential improvements in water use efficiency by non-synfuel users. This alternative could be a potential source of supply for synfuel development since a reduction in projected water demand for uses other than synfuel development would increase the supply of surface water remaining for synfuel development. The report points out that reduction in exports from the entire Upper Colorado Basin for municipal use, primarily to the front range area of Colorado, could be achieved by the year 2000. The report concludes that a 20 percent reduction in per capita use by only that increment of population growth that is the basis for projected increases in exports would result in a reduction of 60,000 to 80,000 acre-feet per year in projected exports. The report further concludes that this is a ‘highly conservative estimate" and that if these demand reduction measures were applied to all customers, and not just new customers, then exports for municipal uses could perhaps be reduced by as much as 200,000 to 300,000 acre-feet per year. Since the report estimates approximately 200,000 to 250,000 acre-feet per year of consumptive use would result from the 1.5 million bbl/day synfuel industry, it is apparent that this reduction of 200,000 to 300,000 acre-feet per year would be quite significant.

No institutional nor financial mechanisms currently exist for achieving this 200,000 to 300,000 acre-feet per year reduction in out-of-basin exports. In order to implement this alternative an energy company on the western slope of Colorado seeking water supply for its synfuel development would have to go to a major exporte~ from the basin, such as the Denver Water Board, and attempt to buy necessary water rights. The proceeds of the sale could go toward implementation of water conservation measures such as universal metering. For political and institutional reasons, it is highly unlikely in the foreseeable future that the Denver Water Board, for example, would sell a water right to a major energy company. In addition to the lack of an institution to facilitate more efficient water use as a source of water supply for synfuel development, there are substantial legal and political obstacles arrayed against this alternative water supply source. The constitution of the State of Colorado protects the right of appropriation; therefore, there can be no restrictions against continued exportation by municipalities on the east slope. Colorado water law and the prevailing frontier ethic favor continued development of new sources of water supply rather than more efficient use of existing supplies.

In the future, a major out-of-basin exporter, such as the Denver Water Board, may be unable for legal, economic, or political reasons to construct necessary additional storage and conveyance facilities for transmountain diversion thereby: (1) reducing forecast exports, and (2) meeting future increases in demand by more efficient use. Such an eventuality, however, does not offer a potential source of supply to an energy company for synfuel development; the uncertainty of its occurrence is simply too great.

o Non-tributary Groundwater. In Colorado there is currently uncertainty concerning who can develop and use non-tributary groundwater. Non-tributary water is outside the normal appropriation doctrine and is governed by State law which allocates nontributary groundwater based on saturated aquifer thickness, specific yield, and the amount of overlying land owned by the well owner. Under Colorado law, a landowner can annually withdraw l/100th of the volume of water contained-in the aquifer beneath his property, assuming no recharge and providing this withdrawal will not interfere with preexisting wells in the area.

The existing law presents uncertainty for the shale oil industry. In order to develop much of the deep groundwater in the Piceance Basin, oil shale developers will need to prove to the State Engineer and the court the non-tributary nature of the aquifer.

- Federal Reserved Rights. Federal reserve claims in Colorado, other than those claimed by the Naval Oil Shale Reserve, are currently before the Colorado Supreme Court, with a decision expected this year. The lower court decision has limited the uses to which the water could be put and has specified a time period and method by which the claims are to be quantified. At this time, there is no quantification of the cloud which these claims hold over the river basin.

  In its original brief the Naval Oil Shale Reserve at Anvil Points, Colorado, has claimed the "direct, storage, and well water rights at such quantities of water unappropriated as of the reservation dates as are or will become reasonably necessary to fulfill the current and future purposes for which said Reserves were created." The reservation dates are 1916 and 1924, which if granted, would provide senior water rights to the reserve and would curtail current junior rights. The anticipated quantity reserved, as identified in the original brief 'for informational purposes only," is 200,000 acre feet per year (Department of Interior, Water for Energy Management Team, p. 10). However, this can be a misleading value given the uncertainty of potential needs of the reserve and the court process. The Naval Oil Shale Reserve case is temporarily dormant, with no foreseeable activation of the issue, but the senior nature of the yet unquantified claim presents a significant uncertainty to the assessment of water availability for oil shale development.

Economic Factors

Economic factors can be viewed from several points of view: the synthetic fuel industry, the other users within the basin, or the government decision-maker.

While the cost of water supply will be one variable used by energy companies to determine which source of water to use, it is not likely to be a critical factors. If a 50,000 bbl/d oil shale plant which uses 5,700 acre-feet of water costs $1.7 billion dollars and the cost of water were as high as $1,000 per acre-foot, the water cost would only represent 0.3 percent of the total cost. Therefore, ease of acquisition and certainty of yield will probably be more decisive factors in acquiring a water supply for synfuel development. The cost of water supply will probably be more of a constraint to those competing users--municipalities, agriculture, and other industries--than to synfuel development.

Obtaining reliable and comparable cost data on recent water sales is difficult, because of the variation in conditions surrounding each sale. For example, the seniority of a water right and the historic water use are important factors in determining the value of the water right. The location of the point of diversion of the original water right with respect to the site where the buyer proposes to use the water further determines how much a buyer is willing to pay. The necessity for additional conveyance or other water control structures required for utilizing the water by the buyer also determine costs. In order to provide some indication of the complexity and difficulty of comparing of water costs, the following examples are presented:

1. The Los Angeles Department of Water and Power recently negotiated a contract for about 39,000 acre-feet of water rights at $1,750 per acre-foot in Utah for cooling water purposes for the Interbasin Power Project. This sale compares to approximately $200-$300 per acre-foot for agricultural water rights under present sales in the area. In addition to the $1,750 per acre foot, the Los Angeles Department of Water and Power will have to expend additional sums for various water control structures.

2. The Colony Shale Oil project is currently negotiating with the U.S. Water and Power Resources Service for approximately 6,000 acre-feet of water from the WPRS's Ruedi Reservoir in Colorado. While negotiations are not yet complete, the WPRS'S presently proposed contract gives some indication of the final water price. It must be emphasized that this

sale is not for a water right, but rather a contract for water delivery. Colony Shale Oil project will divert this water under existing water rights from the Colorado River downstream from Ruedi Reservoir. The WPRS'S presently proposed contract calls for:

a. A $15 per acre-foot stand-by charge
b. A delivery charge of:

0 - 1000 acre-feet	at $35	per acre-foot
1000 - 4000 acre-feet	at $60	per acre-foot
4000 - 6000 acre-feet	at $85	per acre-foot

In addition, there would be a requirement to pay annually the delivery charge on at least the first 1,000 acre-feet.

3. In contrast to the WPRS'S proposed Ruedi Reservoir water sale to the Colony Shale Oil project, WPRS is proposing to sell water to Battlement Mesa, Inc. (a new town under construction by the Exxon Corporation near Parachute, Colorado) for a stand-by charge of $6.00 per acre foot and a delivery charge of $9.00 per acre-foot. This proposed sale would be a contract for delivery of up to 1,200 acre-feet of water annually.

4. A western slope community of approximately 1,000 population about 60 miles west of Denver has recently completed negotiations to buy a water right for approximately 2 cfs of flow from a small tributary of the Blue River, a tributary of the Colorado River, in western Colorado. The town would pay $100,000 for this water right which can be expected to provide the town with approximately 54 acre-feet of depletion in a dry year. The town will be able to pump considerably more water under this right but will only be able to deplete the flow of the stream by an expected 54-acre-feet during a dry year under this right. Furthermore, this depletion must occur in a pattern comparable to the irrigation depletion pattern of the original water right, i.e., this water right does not permit depletion outside the normal irrigation season. This 54

acre-feet will cost the town approximately $1,850 per acre foot of consumptive use.

The purpose of presenting these four typical examples is to demonstrate the difficulty of developing comparable data on water sales.

Industry will also, through site specific studies, have more cost data than will the governmental decision-maker or regional water resources manager. EVen then there are uncertainties regarding cost of Federal reservoir water, cost of groundwater development, and cost of new storage and transmission facilities. The decision-maker, however, must often rely on such generalized cost data regarding surface water and groundwater supplies that it is of limited use. This lack of specific data, coupled with industry's decision criteria generally being outside the market pricing mechanism, results in difficulty predicting which source industry will favor and use.

The economic constraint will be more of a factor to those competing uses--municipalities, agriculture, and other industries. The lack of certainty on availability of supplies and the quantity needed by various technologies leads oil shale company planners, their engineers, and water attorneys to be conservative in their planning needs and incorporate redundancy in their efforts to procure supplies. This redundancy increases the competition for supplies. As the synthetic fuels industry is able to pay higher unit costs for water, other activities may be constrained by costs of water rights and water development.

Demand Estimation

Two categories of demand are identified in the Section 13(a) Assessment: demand for synthetic fuel development (this is termed "emerging energy technologies" or EET in the 13(a) Assessment) and demand for non-EET uses.

Non-Emerging Energy Technology Demand. The Section 13(a) Assessment identified three future development scenarios from low to high development. The estimated depletions without synfuels development for the year 2000 are listed below. The Section 13(a) Assessment selected the middle scenario on which to base its conclusions.

	Upper Basin (values in ac/ft)	Colorado (values in acre-feet)
Low Scenario	4,099,000	2,129,000
Medium Scenario	4,482,000	2,211,000
High Scenario	4,783,000	2,304,000

The inaccuracies and uncertainties inherent in estimating depletions have been discussed earlier. Given those depletion estimates, however, what should be the basis for selecting one scenario over the other? It is unlikely that all three scenarios have an equal probability of occurrence. Thus, without using relative probabilities of occurrence, the criteria for selection of the middle scenario is purely subjective. A more precise decision-making mechanism (yet still influenced by subjective judgment) would give an estimation of probability for each of the scenarios and then develop an expected value of occurrence.

Very little attention in the Section 13(a) report is given to non- consumptive, instream uses such as kayaking, fishing, and other recreational benefits, as well as hydropower and water quality control. The various analyses indicate that such uses are difficult to quantify, and for a basin-wide assessment the occurrence of low flows and the impacts on instream uses for specific stream reaches cannot be adequately determined.

Synthetic Fuel Demand. The Section 13(a) report incorporates a range of synfuel industry demands. The forecast synfuel depletions for year 2000 are:

Condition	Synfuel (acre-feet)	Associated Growth (acre-feet)	Total (acre-feet)
Colorado Onlv			
Baseline	23,000[a]	6,000	29,000
Accelerated	70,000[b]	14,000	84,000
Total Upper Basin			
Basellne	217,000~	35,000	252,000
Accelerated	374,000	68,000	442,000

[a] Entirely for oil shale development

[b] 13,000 AF for low-Btu coal gasification

[c] 68,750 AF for high Btu coal gasification in Wyoming and the San Juan Basin in Colorado and New Mexico

‘13,000 AF for low-Btu coal gasification in Colorado and 82,700 AF for high-Btu coal gasification in Utah, Wyoming, and the San Juan Basin in Colorado and New Mexico.

The amount required for associated growth includes uses for municipal, power, dust control and irrigation of revegetated plots.

There are many uncertainties associated with these estimates for oil shale plants because: (1) the mix of technologies in unknown, (2) there are no commercial plants in existence on which to base estimates of water requirements for production levels, and (3) the industry is continually revising its estimates of water requirements. Currently estimated requirements for a 50,000 bbl/d surface retorting plant, as noted in the Section 13(a) report, range from 3,500 to 9,000 acre-feet per year. Estimates for a modified in-situ plant range from 2,000 to 5,000 acre-feet consumptive use per year. As noted in the Section 13(a) report, the choice of 5,700 acre feet per 50,000 bb/d oil shale plant is an arbitrary estimate. Assuming the availability of 250,000 acre-feet in the entire Upper Colorado Basin, the number of unit-sized oil shale plants could vary from 27 to 125 exclusive of associated growth, depending upon the technologies used and the extent to which coal is developed.

The Section 13(a) Report has assumed use-of the Lurgi process in high-Btu coal gasification and estimates the water consumption for a unit-sized plant (250 million scf/day) to range from 5,000-7,500 acre-feet per year. The Section 13(a) Report uses the high value (7,500 acre-feet) in order to be conservative. Similarly, for low-Btu gasification, the demand ranges from 3,000 to 14,500 acre-feet per unit-sized plant. The conservative figure of 14,500 acre-feet is used. The range of demand in both cases is dependent upon the extent to which dry cooling systems are employed, and this uncertainty is noted in the Section 13(a) Report.

Discussion and Conclusions

Physical Availability. It can be concluded that while water is available in the Upper Colorado River Basin to meet initial synfuel development the physical availability on certain tributaries and at certain locations may be limited. "Initial synfuel development" involves those synfuel plants presently in-some phase of planning and which will be constructed within the next 10-12 years. lhe errors in the data base and the uncertainties in assumptions become magnified as the focus narrows from basinwide to sub-basin to tributary to specific site application.

The estimates of depletions and virgin flows are very sensitive to assumptions and techniques in the methodology. For example, the "population mean" for virgin flows has not been determined. The estimates of annual average virgin flow which have been determined vary by 2.7 million acre-feet as noted between the 1906-74 period (15.2 maf) and the 1954-63 period (12.5 maf).

Because of the inability of reservoirs on tributaries to create the long-term carryover storage which is assumed in the basin-wide studies, dry year yields, rather than average annual flows, might be the limiting number.

The lack of data on the availability and access to non-tributary groundwater supplies provides a significant uncertainty regarding the quality and quantity of a potentially major alternative supply.

Economic Constraints. The cost of water will probably not be a limiting factor to development Of oil shale because of the small proportion of water costs to total plant costs. Water source selection by oil shale companies will be outside the market system, and primary factors of selection will be ease of acquisition and certainty of yield.

Because of the uncertainties of acquisition, however, synfuel planners are pursuing and optioning several water sources. Because of the redundancy in their search for and procurement of supplies, the economic constraint of rising water prices will be felt more keenly by the other water users, such as municipalities.

Demand Uncertainty. The various scenarios are given equal weight, so the choice among them is more subjective. The variation between the scenarios amounts to 175,000 acre feet for the Colorado River in Colorado, and 684,000 acre feet for the entire Upper Colorado River Basin. Estimates for oil shale water demands have such a wide range that it makes demand estimations unrealistic. However, the lack of adequate demand estimations means that high range of oil shale development cannot be determined, but a lower range can be estimated based on the surplus of supplies from other uses. This is similarly true for coal gasification.

Therefore, while the recent reports on the Upper Colorado River basin in Colorado indicate that sufficent water exists for a 1.5 million bbl/d synfuel industry (i.e., 200,000 to 250,000 acre feet), there is enough uncertainty in the data, assumptions, and estimation methodology to either erase that surplus or magnify it.

Legal Availability and Institutional and Political Constraints. The legal uncertainty of-the requirements of the Mexican Treaty of 1944-45 alone could reduce the amount of water to the Upper Basin by 750,000 acre feet, with the potential reduction in Colorado amounting to approximately half that amount.

Within the Upper Basin water will continue to be developed until limited by the Colorado River Compact, which is expected to occur by about 2000. However, within Colorado there are no state guidelines regarding how the water rights will be administered within the state to meet state line commitments for the Compact. The lack of an allocation plan means that the maximum water legally available to the various sub-basins within Colorado is unknown. The Naval Oil Shale Reserves in Colorado at Anvil Points, under the Federal Reserve Rights Doctrine, has filed on the water necessary to develop its oil shale resources. Such claims could range as high as 200,000 acre-feet per year, with appropriation dates of 1916 and 1922.

The conclusions of the Section 13(a) Assessment were premised on the availability of water from existing reservoirs or the construction of new storage facilities. However, the institutional and political constraints on two Federal reservoir facilities--Ruedi Reservoir and Green Mountain--could amount to a withdrawal from sale of up to approximately 100,000 acre feet annually from the available supplies.

Alternative supplies to synfuels include the transfer of agricultural water rights. lhe current amount of agricultural rights owned by energy companies is unknown; however, the extent to which synfuels interests will seek to transfer agricultural rights might be limited by the court transfer process.

General. The Upper Colorado River Basin Section 13(a) report meets some of its objectives as specified in the report:

> .....to assess, at a broad regional level of detail:
>
> (1) The water requirements of coal gasification and oi1 shale technologies and associated growth.
>
> (2) The availability of water for the potential development of these emerging energy technologies and the associated growth.

(3) The effects which these potential emerging energy technologies would have on the hydrology of the Upper Basin. . . .

In meeting these objectives, the assessment report does a good job in clearly laying out many of the assumptions, describing some of the various uncertainties resulting from potential legal and institutional constraints, and indicating some of the uncertainties that surround projections of future consumptive use. It does not address some of the important elements such as instream flows and trade-offs, nor does it quantify uncertainties. However, in short, this report probably does about as good a job as can be done in assessing future water availability for synfuel development and presenting the results in a form, and at a level, that will be of use to state, regional, and national decision-makers.

Despite this generally good effort, controversy and uncertainty will continue to surround the availability of water for synfuel development in the Upper Colorado River Basin. The reason for this is that so many assumptions must be made in aggregating data and information into a form useful to state, regional, and national decision-makers, that these assumptions cannot all be explicitly detailed in their entirety and communicated. As a result of the uncertainty surrounding these assumptions, there will always be potential for controversy over water availability.

A simple example from the Upper Colorado River Section 13(a) Assessment report can serve to demonstrate why controversy and uncertainty continue to exist in the entire Upper Basin about availability of water for synfuel development. Based on the report, assume that 13.8 million acre-feet is the mean annual streamflow for the Colorado River. Subtract from this the 7.5 million acre~feet that the Upper Basin States must deliver to the Lower Basin States:

13.8 maf (estimates mean annual streamflow of Colorado River)
-7.5 maf (required delivery to Lower Basin)
6.2 maf

Then, subtract the 750,000 acre-feet potential obligation of the Upper Basin states to fulfill their half of the Mexican Treaty requirement:

6.3 maf
- 0.750 (Upper Basin Mexican Treaty Obligation)
5.550 maf

Finally, subtract an estimated 645,000 acre-feet of estimated annual evaporation from Flaming Gorge, Lake Powell and the Curecanti Unit Reservoirs:

5.550 maf
-0.645 (estimated annual evaporation from Flaming Gorge, Lake Powell, and the Curecanti Unit Reservoirs)
4.905 maf

This computation indicates that about 4.9 million acre-feet is available for consumptive use in the Upper Basin States. Significant uncertainty and controversy, however, surround this estimate of potential consumptive use in the Upper Basin states.

A dispute exists concerning whether or not the Upper Basin states are responsible for one-half of the Mexican treaty obligation (i.e., 750,000 acre-feet) or whether the Lower Basin states are responsible for the total 1.5 million acre-feet. Uncertainty also exists concerning the virgin flow estimate for the Colorado River with estimates ranging from 13.8 million acre-feet annually to 15.0 million acre-feet.

The Upper Colorado River Basin Section 13(a) report estimates that the annual consumptive use for non-synfuel development will increase from the present (197$) levels of about 3.116 million acre-feet to a 4.099, 4.482, or 4.783 million acre-feet depending on assumptions. The report estimates that consumptive use of the proposed 1.5 million bbl/day synfuel industry* would be approximately 200,000 to 250,000 acre-feet per year. Comparison of the

*This represents 26 unit-sized oil shale plants” and 8 unit-sized high Btu gasification plants.

above estimates of future increases in consumptive use by non-synfuel users with the water remaining for consumptive use in the Upper Basin indicates that the possibility exists that there may not be 200,000 to 250,000 acre-feet of water remaining for synfuel development.

Furthermore, these estimates say nothing about possible additional future constraints on water availability resulting from salinity control programs, low flow requirements in tributaries to preserve squaw fish habitat and other endangered species, and realization of Federal reserved rights claims.

Therefore, even at highly aggregated levels for the entire Upper Colorado River Basin, the confidence limits or ranges that are placed on estimates of water availability are so broad that they tend to subsume the amount of water needed for synfuel development. It is clear for the rough estimate above, as well as from the Upper Colorado River Section 13(a) analysis, that adequate water exists at present for initial development (as defined earlier) of the synfuel industry in the Colorado River Basin. However, to go beyond that and make forecasts of water availability for the for the year 2000 requires discussion and quantitative analysis of the many uncertainties which surround crucial estimates of water availability for synfuel development. Reasonable people can disagree over many of these estimates. This is why there will be continuing controversy concerning future water availability for synfuel development.

ANALYSIS OF OTHER REPORTS

Water Supply Should not be an Obstacle to Meeting Energy Development Goals

The GAO report to Congress, "Water Supply Should not be an Obstacle to Meeting Energy Development Goals," is largely based on the Section 13(a) assessment prepared by the Colorado Department of Natural Resources. Since the later report is reviewed in depth herein, only a limited review is made of the GAO report.

Water Availability. Indeed, the GAO report relies too heavily on the Section 13(a) Report. The uncertainties which surround the prediction in the Section 13(a) Report are not identified in the GAO report. The conclusions are not only carried forward without adequate explanation but also are given with greater emphasis and certainty than in the original report. The report states flatly on its title page:

> This report disputes the common impression that the energy industry's thirst for water will create severe shortages throughout the water-short, energy-rich West. Recent evidence indicates that these predictions are unfounded or outdated and that adequate water is available for energy development through at least the year 2000.

The Interior Department in commenting on the report noted correctly that the potential constraints which would affect the predictions were not clearly identified. "We believe these constraints [legal, judicial and administrative, instream flows, Federal reserve rights, physical and economic barriers, etc.] are of significant magnitude to require reference in the digest and conclusions." (GAO, p. 54)

In response to these comments the GAO indicates in the digest (executive summary) that the uncertainties only limit the location of development, not the total quantity of water available.

> Uncertainties exist about the extent of energy development, the future of reclamation projects, environmental requirements, reserved water, instream flows, water rights transfers, and project development delays. However, since water requirements are modest and water supplies very large and broadly scattered, excessive water supply problems in one location will result in new site selection. With few exceptions, limited opportunities in one sub-basin will simply open opportunities in another sub-basin. (GAO, p. iii)

However, there is uncertainty regarding the quantity of water available, for example, in the Upper Colorado River Basin. The report notes that for the Upper Colorado River Basin, "lhe 1979 projections, combined with conservative flow estimates, indicate there will be sufficient water in the Upper Basin for all consumers in 2000." (Emphasis added) (GAO, p. 39) In fact GAO does not use the most conservative estimate. The most conservative estimate of water available to the Upper Basin by WPRS is given in the Appendix (GAO, p. 78) as 5.45 MAF per year. The GAO report, however, uses 5.8 MAF per year. Even then, as noted earlier, the achievement of those average annual flow yields depend on location and capacity of storage, permanent climatological changes, and accuracy of flow estimating methods.

Institutional, Legal and Economic and Social Aspects. The report does identify the legal and institutional complications which have arisen surrounding leasing of federal reservoir water. However, social factors (see discussion of Ruedi Reservoir, Chapter IV herein) are not identified.

In other areas there is only summary treatment of these factors. For example, the GAO elucidates the advantage of coal slurry lines and mentions general opposition has blocked development; however, adequate treatment of the legal, environmental, and social constraints is not given.

Effectiveness for Decision-Makinq. The GAO report is a summary statement which does not adequately qualify the sources of its data or the assumptions and the uncertainties implicit in its conclusions, thereby forcing the reader and decision-maker to accept at face value the conclusions and recommendations made in the report. The conclusions tend to be over-simplistic and dogmatic--as indicated by' the title of the report.

Review of Energy from the West by EPA

"Energy from the West: Policy Analysis Report" is a report produced by the U.S. Environmental Protection Agency concerning the various expected impacts from energy development in the eight state Rocky Mountain area (Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado, Arizona and New Mexico). As its title implies, it is concerned not only with synfuel development but with all forms of energy development in this area.

The analysis and conclusions of the report with respect to water availability are necessarily general and concern regional level impacts. The unique factor, and major strength of this document, is its detailed analysis of alternatives for water supply for energy development. For example, with regard to increasing water availability by implementing more efficient irrigation practices, the report not only summarizes the technical literature concerning the feasibility of various irrigation practices with increased efficiency, but also discusses the significant legal constraints against implementation of more efficient irrigation practices. In discussing various alternatives for increasing water availability for energy development, the report makes prominent note of the role played by the courts in western states and how they have characteristically operated very slowly and generally created piecemeal, localized, and short-term resolutions to problems.

Therefore, the "Enerqy From the West" report is a valuable adjunct to the reports such as the State of Colorado, Section 13(a) report because of the indepth analysis of alternatives presented in the EPA report.

Review of the Draft Environmental Impact Statement for the Colony Develo~-ent Project

The draft environmental impact statement for the 'Proposed Development of Oil Shale Resource by the Colony Development Operation in Colorado" is a site specific study of water availability for the proposed Colony Shale Oil plant located near Parachute, Colorado. The report discusses the statistical problems with estimating annual stream flows for the Colorado Basin and other data problems. In addition, it summarizes and discusses the various compacts and treaties which affect water availability in the Upper Colorado River Basin (the Colorado River Compact of 1922, the Mexican Water Treaty of 1944 and the' Upper Colorado River Basin Compact of 1948). The report also presents available estimates of present depletions of the Colorado River. Some projections for future water use and depletions are presented but not extensively developed.

The major problem 'with this report as with most site specific studies, is that the data and discussion and conclusions are presented in isolation from the proposed future development of the entire river basin; i.e., the incremental impacts from development throughout the river basin are not developed for discussion. For example, the estimated 12 cfs depletion from the proposed Colony Development is minuscule when compared to the estimated mean annual Colorado River flow of 3,659 cfs in nearby DeBeque, Colorado. This 12 cfs depletion only represents 0.7 percent of the lowest mean monthly low flow (February). This fact, when presented by itself and without reference to the cumulative impacts of expected future depletions, is somewhat misleading.

Therefore, the report does an adequate job of presenting many of the uncertainties facing water availability in the Upper Colorado Basin for synfuel development, but does not provide an overall picture of water availability in the future due to the accumulative impacts of depletions for synfuel and other development.

OTHER ISSUES IN THE UPPER BASIN

Introduction

Much of what has been discussed earlier has applied to the entire Upper Basin - and has been so noted in the Background Section and the analysis of the Section 13(a) Report. However, certain points concerning the White River Basin which are not covered earlier are discussed below.

The Setting

Additional shale oil development in the Upper Colorado River Basin would occur primarily in the Washakie Basin in Wyoming, Green River Basin in Wyoming and Utah, and the White River Basin in Utah and Colorado (see Figure 5). High Btu coal; gasification projects would occur in the Green River basin in Utah and Wyoming and the San Juan basin in Colorado and New Mexico (see Figure 6). Of these areas, the White River basin represents the area with the most uncertainties with respect to water availability.

The White River Basin in Colorado and Utah

The estimated average annual yield of the White River (1906-1974) is approximately ‘568,000 acre-feet, 61 percent of which occurs between April and July (DNR Section 13(a) Report, page 7-7). Baseline synthetic fuel development with associated growth, coupled with a middle scenario for non-EET development, would mean estimated depletions of 222,000 acre-feet by 2000. Of this amount, 142,000 acre-feet would be required for EET development and associated growth. The comparison of total annual virgin flow to total depretions is deceiving because sufficient storage is not present to even out the flows. The Section 13(a) Report properly points out that the necessary monthly diversions for even the low scenario/baseline EET development could not be met in August and September in one out of 10 years on the average. Therefore, adequate storage is a critical factor in providing reliable supplies in the White River Basin. Uncertainty surrounding construction of new reservoirs in the White River Basin contributes to general uncertainty of water availability for synfuel development in the White River Basin. Reservoir construction at prime reservoir sites on the White River has been stymied by wilderness designation for the area.

The future legal availability of water on the White River is clouded by the fact there is no compact between Colorado and Utah concerning the White River:

> The lack of such a compact will undermine the reliability of private water rights on the White River in Colorado. Other Upper Basin states, Utah in particular, will attempt to claim as much of the White River as possible for delivery to the Lower Basin, and for their own development. Water users on a number of other Colorado River tributaries will attempt to protect their existing and projected water uses against curtailment under the Upper Colorado River Compact by excluding as much of the White River from Colorado’s share under the Upper Compact as they can - the allocation of any part of Colorado’s Upper Compact share to the White River will correspondingly reduce the amount of water which is legally available on all other Colorado River tributaries in Colorado.
>
> All of the recent studies ignore the inevitable need for a compact apportioning the White River among the Upper Basin states and fail to consider how such a compact might legally constrain the availability of water for oil shale development in Colorado. These studies instead primarily base their conclusions about the

> availability of water on the White River on its unapportioned, virgin flows (Musick, p.15).

Institutional factors also contribute to the uncertainty of water availability for synfuel development in the White River Basin. The Section 13(a) reports that the water required for either baseline or accelerated EET development could only be achieved "if there is a highly coordinated scheme of reservoir regulation.” Such a scheme would probably require common ownership by a conservancy district or the state. Interstate coordination would be required, and there is no current mechanism to provide that function.

DISCUSSION AND CONCLUSIONS

The attention regarding water availability for synfuel development in the Upper Colorado River Basin is directed primarily to the White River in Colorado and Utah and the Colorado River Basin in Colorado which contain significant oil shale deposits.

Within the White River Basin sufficient supply depends upon the construction and management of new reservoirs. There is considerable uncertainty posed by the existence of wilderness areas at prime reservoir sites and the existence of endangered fish species in the White River. The magnitude of these constraints, as well as the lack of an interstate compact on the White River, is not sufficiently emphasized in the analyses of the Upper Colorado River Basin.

While water can be made available for synfuel development in the White River Basin, there are significant trade-offs. These trade-offs are similar to those in the~Upper Colorado in Colorado and include higher water costs for the non-energy sectors and potential reduction in agriculture. Constraints on availability are also similar and include institutional management of reservoirs, allocation of water resources once the Upper Basin is fully developed, and lack of legal and financial mechanisms to institute effective water conservation programs.

SECTION V

YELLOWSTONE RIVER BASIN AND ADJACENT COAL AREA AND UPPER MISSOURI RIVER BASIN

BACKGROUND

The Upper Missouri Basin contains significant deposits of coal and lignite. As a result of the ever increasing demands for energy, this coal has been mined for shipment and used locally in thermal-electric power plants. Now it is targeted for possible development of a synthetic fuels industry.

The most important coal deposits in the area are in the Fort Union formation of Wyoming, Montana, and North Dakota. The structural Powder River Basin of northeastern Wyoming and southeastern Montana contains the world's largest stripable sub-bituminus coal deposits. In southwestern North Dakota, extensive lignite deposits are attractive for coal development. These coal deposits lie within and adjacent to the Yellowstone River Basin and Upper Missouri River and its tributaries. Figure 7 shows the area described.

This analysis of the Upper Missouri River Basin is based primarily on the use of two water-planning documents.

1. U.S. Water Resources Council, "Section 13(a) Water Assessment Report-Synthetic Fuels Development for the Upper Missouri River Basin, 1980."

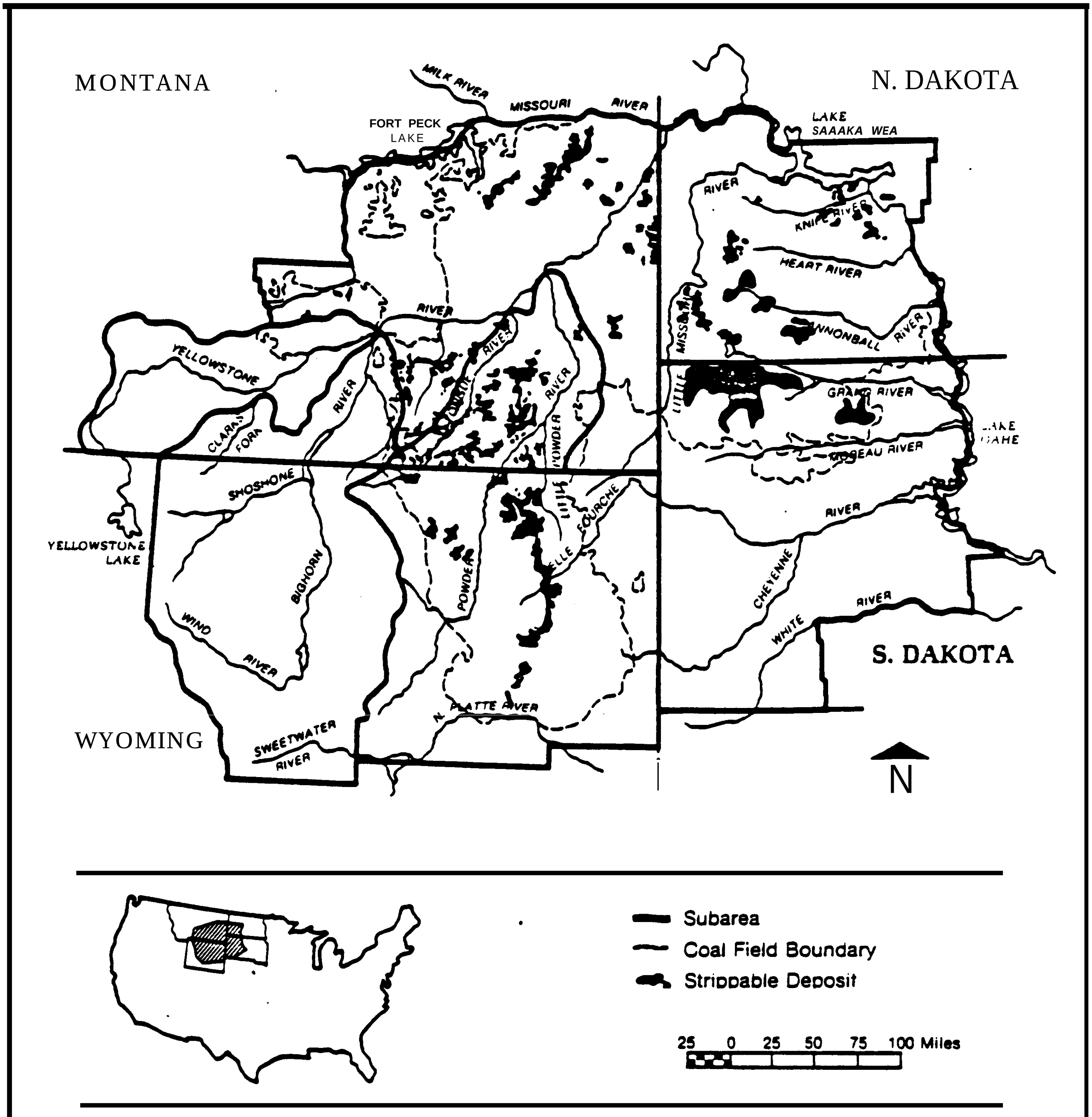
2. U.S. Water Resources Council, "Great Plains Gasification Project, Mercer County, North Dakota; Water Assessment," 1980.

Additional documents considered in the analysis were a book published by Resources for"the Future Inc. by Constance M. Boris and John V. Krutilla, <u>Water Rights and Energy Development in the Yellowstone River Basin, An Integrated Analysis</u>, 1980, and the <u>Report and Environmental Assessment: Yellowstone River Basin and Adjacent Coal Area Level B Study</u> prepared by the Missouri River Basin Commission. Additionally, there is an expanding body

Distribution of Coal Reserves

UPPER MISSOURI REGION

Figure 7



Source: Upper Missouri River Basin 13(a) Assessment Report of knowledge, which has built up over the years, on water supplies and demands including water for synfuels. Reports have built on other reports; for example, the WRC reportedly relied upon the Yellowstone Level B Study of water supply and demands from the Yellowstone River and its tributaries.

Institutions in Basin

The institutions within the basin are generally the same as those identified in the Upper Colorado River Basin. Identification of specific key institutions is made later in this section.

Organization of Section

This section of the report is divided into two parts. The first part is a case study of the Yellowstone River Basin and the second part is a review of the above-mentioned water planning documents. Conclusions are found at the end of the second part.

This analysis concentrates on the Yellowstone River Basin and adjacent coal area because this is where the significant coal deposits lie within the Upper Missouri River Basin. Additional attention is given to development in North Dakota. Although some deposits are found in western South Dakota, the key issues are in the Wyoming, Montana and North Dakota areas, as noted in the Section 13(a) Report.

This case study focuses on several points which underscore the uncertainties in the various estimates of water availability. These include:

o. The insufficient attention given by the various analyses to importance of, and necessity for, storage facilities to reduce annual fluctuations in flows and to provide firm supplies from year to year.

o The limited knowledge about groundwater resources and their unknown contribution to the supply side of the water availability equation.

- The strong legal and institutional barrier of the Yellowstone River Compact to out-of-basin use. This is an important limitation because significant coal resources are located outside the basin where water resources are limited.

- The range of estimated capital costs for additional water supply facilities, which is too broad to be used effectively in decision-making even at the policy level.

- Estimates of successful Indian reserve rights claims, which range from 0.5 maf to 1.9 maf per year.

WATER AVAILABILITY

Surface Water

A discussion of the basin and surface water regime is important to understand the absolute necessity of reservoir storage to meet the water demands for synfuel development in the Upper Missouri River Basin. The critical nature of this factor is not emphasized in the Upper Missouri 13(a) report, and the significance of storage in making a firm supply available each year may not be fully appreciated by the decisionmaker.

The Upper Missouri Basin encompasses four states and includes the Yellowstone, the Little Missouri, the Belle Fourche, and Cheyenne Rivers. These rivers are shown on Figure 8.

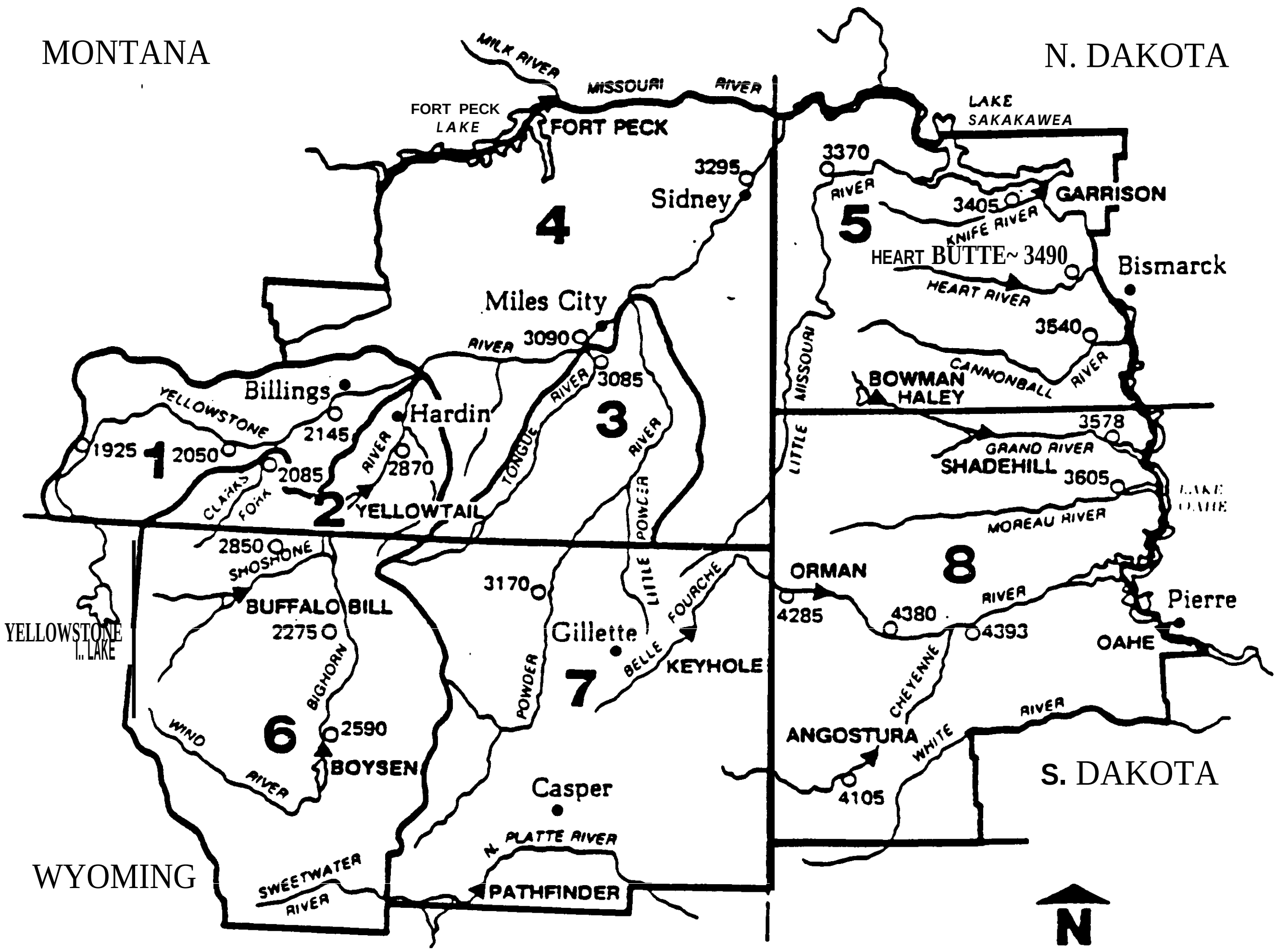
The surface water resources are summarized in Table 1 for several streamgages in the study area. The data in Table 1 are average annual streamflows based on streamgage records adjusted for stream depletions through 1975. The data are based on long term records consisting of 45 or more years of data for most of the streamgages.

Streamflows are quite variable, both seasonally and from year to year. Figure 9 illustrates the annual variability of streamflows and Figure 10 illustrates the seasonal variations. The high streamflows are somewhat coincident with the spring snowmelt runoff. Development of firm water supplies for large scale irrigation on the tributaries, for municipalities

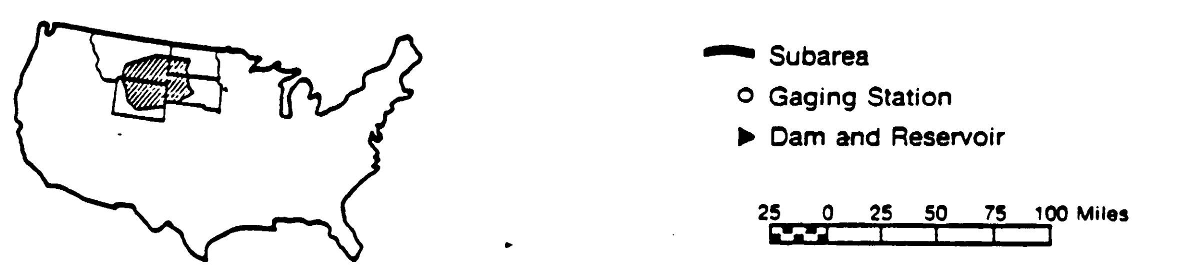
Major Rivers within Assessment Area

UPPER MISSOURI REGION

FIGURE 8



Legend



Source: Upper Missouri River Basin 13(a) Assessment Report

Table 1 - Average Annual Streamflow and Water Quality Data

sub-area	Stream and Location	Historical Flows	Adjusted to 1975 Depletions
		(1,000 Acre-Feet)	
1	Yellowstone R. at Huntley, MT	---	5,605
2	Clarks Fork near Edgar, MT	763.6	752.8
	Bighorn R. near St. Xavier, MT	2,609.8	2,367.6
3	Tongue R. at Miles City, MT	332.2	314.1
	Powder R. at Locate, MT	450.4	423.3
4	Missouri R. near Culbertson, MT	7,774	7,774
	Yellowstone R. near Sidney, MT	8,838.1	8,345.1
5	Heart R, near Mandan, ND	174.4	160.7
	Cannonball R. at Breien, ND	165.8	158.3
	Missouri R. near Schmidt, ND	---	16,352
6	Clarks Fork near Belfry, MT	689	675
	Bighorn R. at Kane, WY	---	2,422
7	Tongue R. at Wyoming-Montana State Line	381.1	370
	Powder R. at Arvada, WY	209.1	189.4
8	Missouri R. at Pierre, SD	---	16,939

Source: Yellowstone River Basin Level B Study; Wyoming Water Planning Program

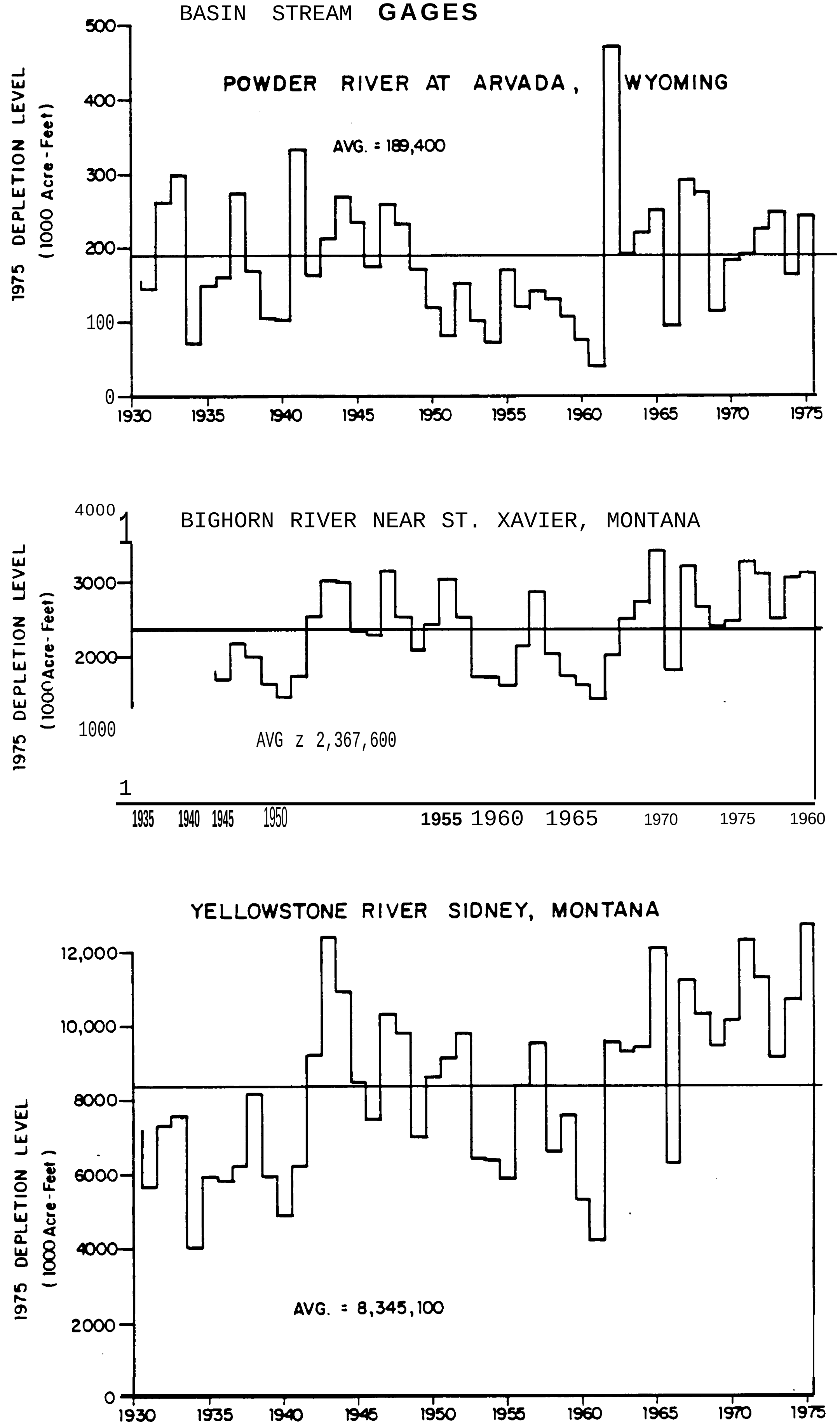
Sub-area	Stream and Location	Surface Water Quality, mg/l[1] Mean Flow cfs	Mean TDS[2]	Mean DO[3]	Mean BOD[4]
2	Bighorn R. near St. Xavier, MT	4,000	622	11.4	1.7
3	Tongue R. at Miles City, MT	594	560	--	--
4	Yellowstone R. near Sidney, MT	14,527	460	9.8	1.8
7	Powdu R. near Moorhead, MT	642	1,522	9.0	3.0
8	Heart R. near Mandan, ND	--	844	9.6	2.9

Source: Yellowstone River Basin Level B Study

[1]Based on Limited Data. [2]Total dissolved solids

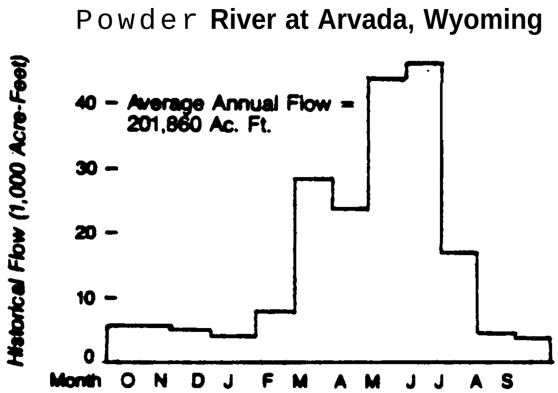
[3]Dissolved Oxygen. [4]Biochemical Oxygen Demand

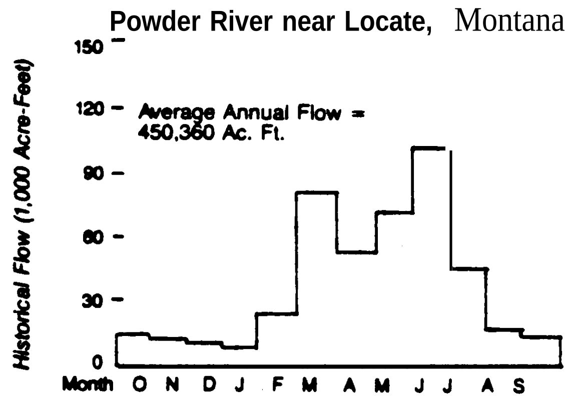
ANNUAL STREAMFLOWS, SELECTED YELLOWSTONE RIVER BASIN STREAM GAGES

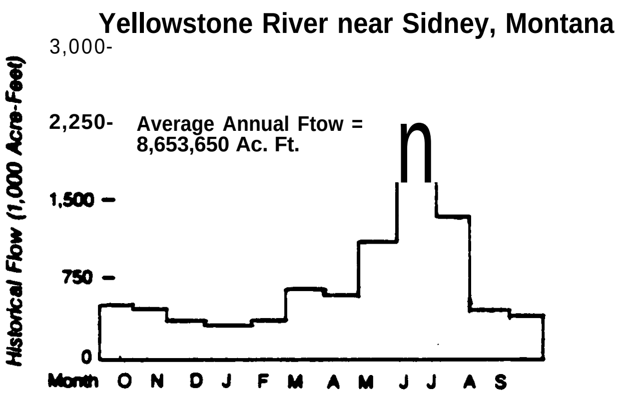


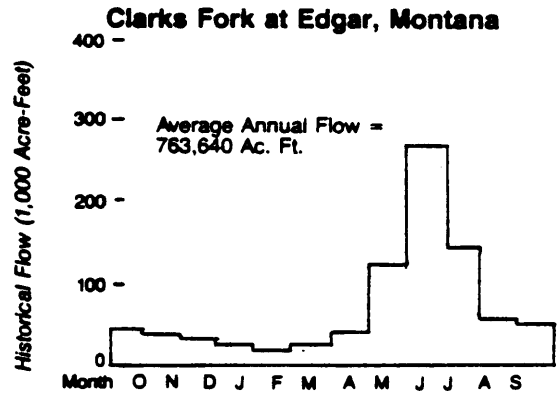
Source' Yellovmtone River Bosin Level B Study

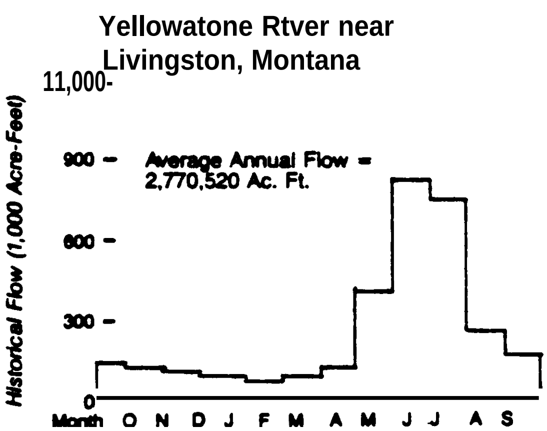
FIGURE 9

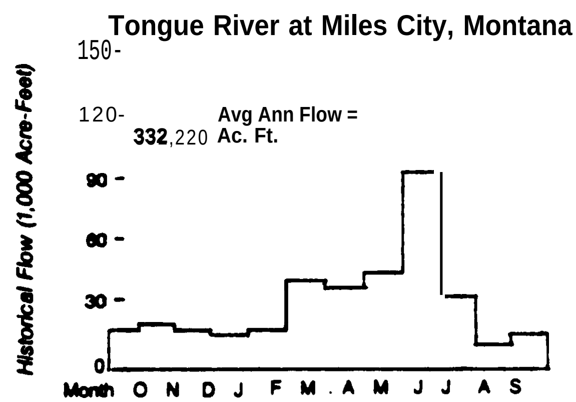












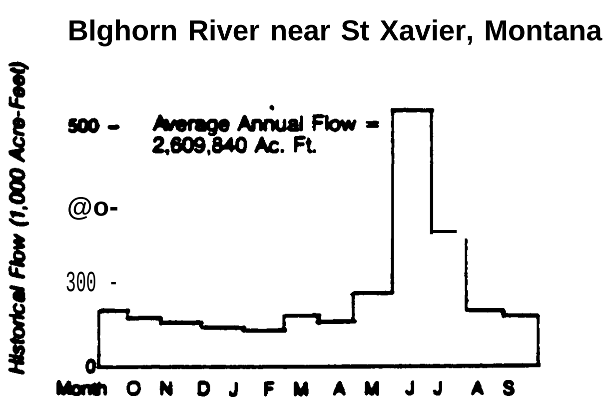


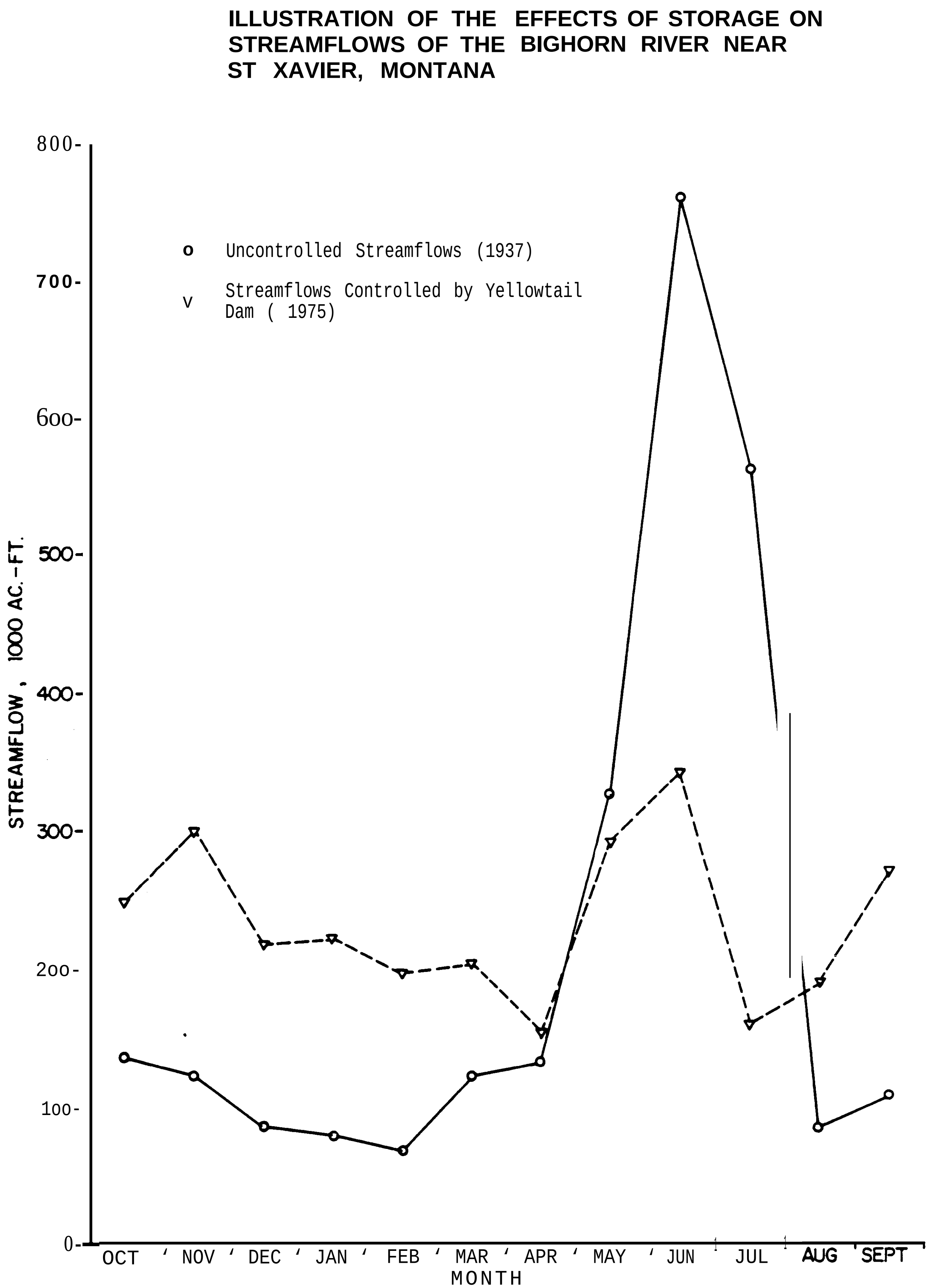
Figure 10
Monthly Flow
of Selected Rivers
in the
Yellowstone River Basin

Source : **Yellowstone** River Basin Level B Study and industry, and for use in Wyoming (particularly if instream flows are to be provided) will require storage.

The variation of annual flows on the Powder River, a Yellowstone River tributary in Wyoming and Montana, is shown in Figure 9. This high annual variation illustrates the necessity of storage for developing water supplies for the uses in the area where existing development makes essentially full use of the water supplies in drought years. The data shown for the Powder River on Figure 9 illustrates that little water is available in the stream in dry years. In fact, the Powder River is dry at certain times of each year at some locations.

The only major river control reservoirs in the Yellowstone River Basin are Boysen Dam and Yellowtail Dam (Bighorn Lake) on the Bighorn River. The effect of these dams on the streamflow is illustrated in Figure 11. The monthly streamflows for the water year 1937 illustrate conditions on the Bighorn River before either of the dams was constructed. The monthly streamflows for the year 1973 indicate a comparable year of annual runoff of the Bighorn River and illustrate the effect that the upstream storage has on regulating the river. Note that the summer peak flows are stored in the reservoir and the water is redistributed into the winter release. The 1973 conditions illustrate the use of Yellowtail Dam primarily for hydropower generation and river regulation considerations, not water supply demands.

Besides the two multiple purpose regulating reservoirs on the Bighorn River, including the 922,000 acre-foot Boysen Reservoir and the 1,375,000 acre-foot reservoir behind Yellowtail Dam, there are many smaller reservoirs on tributaries which have been developed primarily for irrigation and hydropower purposes. Buffalo Bill Dam on the Shoshone River, a tributary of the Bighorn River, could be enlarged to provide river regulation and additional water supply. Lake DeSmet, which is fed by tributaries of the Powder River, has been developed by Texaco to provide an industrial water supply. The Tongue River Dam in Montana has been under study for an enlargement to include industrial water supplies. The potential Moorhead Dam site on the



Source: Yellowstone River Basin Level B Study

FIGURE 11

Powder River could also be developed to provide future water supplies. The storage water in Boysen Reservoir and in Bighorn Lake (Yellowtail Dam) can be allocated for future industrial uses including synfuels production.

The Tongue River could be developed to provide new water supplies with an enlargement of the Tongue River Dam to 450,000 acre-feet. There would be enough water available for meeting the most energy intensive scenario postulated, provided the water would be used for energy alone (Boris, 1980). The storage facility would also provide water for the irrigation contemplated for the Montana reserved water rights and Indian reserved water rights; however, the resulting salinity from this irrigation would require instream flows for dilution. The uncertainty of developable supplies on the Tongue River relates to the uncertainties of the Indian claims and the resulting amount of developable water.

The Powder River Basin seems to offer a good potential for developing water supplies for energy. "There is no issue of Indian reserved rights claims in the Powder sub-basin nor substantial full service irrigation. The Powder sub-basin with the proposed storage appears to be the preferable sub-basin in which to locate any energy conversion facilities. ..in Montana" (Boris, 1980). This conclusion is reinforced by the probable occurrence of increasing salinity of water resulting from irrigation.

Although the Bighorn River Basin appears to provide a simple solution to providing water for energy development because of two existing reservoirs with uncommitted water available, it is the most complicated case studied (Boris, 1980). Not only are there Indian water rights claims and Montana instream flow reservations that affect the availability and the allocations of water, but also the Federal reservoirs offer more complexities for water marketing than would private reservoirs.

The mid-Yellowstone River has a 5.5 million acre-feet per year instream flow reservation placed on it by the Montana Board of Natural Resources and Conservation (BNRC) to maintain the qualities of the river as a free flowing stream. That, coupled with the existing uses of water and the reservations of water for future irrigation and municipal uses, creates a situation whereby water shortages would exist for as much as one-third of the time, depending upon the upstream development scenario utilized (Boris, 1980).

Average annual streamflows are a common indicator of surface water availability. However, the ability to average out flows is a function of the amount of storage available to carryover surpluses from wet and average years to dry years. Data on water availability for the Yellowstone River and its tributaries should be expressed in terms of the yield from long-term storage to be truly indicative of conditions on the tributary streams and even certain segments of the mainstem Yellowstone River. Such yield data on existing storage and proposed reservoirs are not presented in the Upper Missouri 13(a) report, and the decision-maker cannot determine the number or size of facilities which will be required to meet the demands. Additionally, the above-mentioned basin storage opportunities, which are identified by Boris, are not presented in adequate detail in the Upper Missouri 13(a) report.

Groundwater Resources

The Yellowstone River Basin and adjacent coal area, unlike other areas of the nation, does not have a significant shallow groundwater resource. There are shallow alluvial aquifers consisting of sand and gravel underlying some of the streams and rivers, but these have not been extensively developed because in many cases the water is of poor quality. There is a vertical series of sandstone and siltstone aquifers within the Wasatch formation and Fort Union group which underlie most of the study area. Some of these aquifers are also hydraulically connected to the surface streams.

A deeper series of sandstone and limestone aquifers extend across much of the Great Plains. Drilling depths range from 4,000 to 20,000 feet. These aquifers are estimated to have large quantities of water and are artesian in some areas. The Madison formation, which underlies part of the area, is of particular interest as a source of water supply for energy development.

Because groundwater development is limited, the hydrologic characteristics' of most aquifers are not understood and safe yields of aquifers have not been determined. However, there have been studies of the area in which estimates have been made and have been published. The Madison formation and associated aquifers are known to contain very large quantities of water; in - Wyoming, the average annual recharge rate (which determines the safe yield of the aquifer) is estimated to be 75,500 acre-feet per year (Wyoming State Engineer's Office, 1976).

The Upper Missouri 13(a) report dismisses groundwater as a primary supply alternative because of the lack of verified quantitative data. While deep groundwater will not be a primary source for the synfuels program, it can be used as a supplemental source. The conjunctive use of groundwater and surface water supplies is good water management for industry and municipalities and can serve to extend surface water supplies.

Water Laws and Management Agencies

All four of the states in the study area have water laws based on the Appropriation Doctrine. Beneficial use of water is the basis, measure, and limit of the water right. The first to beneficially appropriate the water has the senior or superior right to its use. A water right is perfected only by use and is subject to loss if the use is discontinued or abandoned. Appropriations of water are not restricted to the riparian area of a stream but may be used at sites long distances away from the water resource.

Each of the four states' water laws are somewhat different but have basic similarities. All of the states require a permit or other state license to appropriate and use water. The Wyoming water law was established in 1890 with adoption of its constitution, as was the North Dakota water law. In these states, a State Engineer grants permits for the use of water. In South Dakota the Board of Water Management, a division of the Department of Water and Natural Resources, oversees the management and regulation of water resources. Water right applications in excess of 10,000 acre-feet annually must be presented by the Board of Water Management to the South Dakota Legislature for approval.

In Montana, present water law was established by the revised constitution of Montana ratified in 1972. The Montana 1973 Water Use Act established for the first time a centralized system for the acquisition, administration, and determination of water rights. Prior to that time, water rights were determined by usage, and regulation among water right priorities was accomplished annually in the courts. The unique feature of the Montana Water Use Act is that the State of Montana, its agencies, and political subdivisions and United States Government and its agencies may apply to the Board of Natural Resources and Conservation to reserve water for existing or future beneficial uses or to maintain a minimum flow or quality of water. Reservations cannot affect existing rights. The Board is required to review reservations periodically to insure that the objectives are being met.

The significance of this authority is its impact on future water availability. In 1978, the Montana Board of Natural Resources and Conservation granted to the State Health and Environmental Sciences Department and the State Fish and Game Department the right to appropriate 5.5 million acre-feet per year of water in the lower Yellowstone River to ensure water quality and preserve wildlife for future years. The Board also reserved 535,000 acre-feet per year for future municipal and irrigation use. How the instream flow rights are to be recognized under the Yellowstone Compact is yet to be determined.

Of additional significance to synthetic fuel development is Montana's water law pertaining to water rights transfers. Boris notes (p. 22) that:

> Although the state water laws are designed to protect existing water rights, they also inhibit transfers of water rights in a way to reflect the changing relative value among uses as water becomes increasingly scarce in relation to the demands placed on it. The legislature, in changing the allocation of water among users from primarily a judicial process to primarily an administrative process, did not leave much scope for the market in allocating water. Under the Montana Water Use Act, the transfer of water rights is not governed by economic criteria.

The.. law states that an "appropriator may not sever all or any part of an appropriation right from the land to which it is appurtentant, or sell the appropriation right for other purposes or to other lands. ..without obtaining prior approval from the department." [Montana Water Use Act, Section 29(1) and Section 29(3)]. In addition to an appropriation transfer, change of use and change in place of use are also subject to approval by the Department of Natural Resources and Conservation. Boris notes that "at this time, however, holders of existing water rights are protected from the adverse effects of water rights transfers because freely transferable rights in water simply do not exist under present state law." "Transfers in water use are subject to the criterion of non-injury to existing water right holders. It is difficult to meet this criterion when transferring water use from irrigation agriculture to energy development, particularly since agricultural water rights are closely interrelated via irrigation return flow." (Boris, p.22).

A State Engineer, or equivalent, regulates water rights and water uses where necessary in all four of the study area states. The Wyoming State Engineer's staff, aided by county water commissioners, controls water storage, regulates diversions, and performs other water regulatory duties. This water administration function is carried out to a greater or lesser degree in each of the four states.

Each of the four study area states also has an agency with the authority to plan and develop water for irrigation, recreation, or other purposes. The degree of activity or extent and magnitude of projects varies, but none of the states has yet embarked on large projects that would develop extensive water supplies for large scale synfuels development.

The Water and Power Resources Service has been the primary large, multiple-purpose project developer in the Yellowstone River and tributary areas. The Us. Army Corps of Engineers has constructed large dams and reservoirs on the mainstem Missouri River. Both of these agencies have determined that water for synfuels can be marketed from reservoirs including Boysen, Bighorn Lake (Yellowtail Dam), Fort Peck, Sakakawea, and Oahe. Approximately 700,000 acre-feet may be available for industrial use from Boysen and Bighorn Lake alone. The U.S. Department of the Interior is the marketing entity for storage water from these reservoirs.

Interstate Compacts

Interstate stream compacts are agreements among the states to allocate water between states on streams which cross state boundaries. There are two interstate compacts which allocate the water resources within the Yellowstone Basin and adjacent coal area: the Belle Fourche River Compact and the Yellowstone River Compact.

The Belle Fourche River Compact recognizes the existing water rights in Wyoming and South Dakota as of 1943 and divides the remaining water between the states. Wyoming has estimated its compact water to average 7,000 acre-feet per year plus water for livestock reservoirs not exceeding 20 acre-feet capacity each.

The Yellowstone River Compact involves the States of Wyoming, Montana, and North Dakota. It recognizes all water rights existing as of January 1, 1950; provides for a supplemental water supply for these precompact water rights; and allocates the remaining unused and unappropriated flow of the interstate tributaries between Montana and Wyoming as follows:

Tributary	Montana Allocation	Wyoming Allocation
Clarks Fork “	40%	60%
Bighorn River “ (excluding Little Bighorn R.)	20%	80%
Tongue River	60%	40%
Powder River	58%	42%

The compact contains a formula for determining the compact water supplies and has several other significant provisions, including Article VI which states that nothing in the compact shall be construed as to adversely affect any rights owned by or **for Indians and Indian** tribes to the use of Yellowstone River and its tributaries. Thus the quantities available under the Compact are clouded by the uncertainty of the Indian water rights claims which have yet to be quantified and adjudicated.

Article X provides "No water shall be diverted from the Yellowstone River Basin without the unanimous consent of all the signatory States." Because a large quantity of the coal supplies of Wyoming are located outside the basin and because the Montana Legislature has been adverse toward approving out-of-basin diversions, Article X can provide a constraint on the availability of water supplies for development of these coal resources. Legislation in Montana has been proposed but not passed which would establish a review process for future out-of-basin transfer requests. The Upper Missouri 13(a) report does not recognize the fact that unless synfuels plants are located within the Yellowstone River Basin and the coal is transported to the plants, large legal and institutional impediments to' transbasin diversions must be overcome.

The Commission has ruled that consent for out-of-basin transfers must be given by the legislature in each state. Because of this ruling by the Commission, Intake Water Company has taken its petition for an out-of-basin transfer to the Montana court for determination of the constitutionality of the Montana law forbidding out-of-state transfers without approval of the legislature.

The issue of the absolute values of the states' allocations also creates uncertainty regarding the availability of water among the States. The State of Wyoming has made its own interpretation of the Compact and has estimated the unused and unappropriated waters that can be allocated to Wyoming and Montana. The compact water supplies were estimated by Wyoming to be:

Tributary	Montana Allocation Acre-Feet Per Year	Wyoming Allocation Acre-Feet Per Year
Clarks Fork	285,000	429,000
Bighorn River	500,000	1,800,000
Tongue River	144,700	96,400
Powder River	166,600	120,700

Montana has not agreed with the Wyoming estimate, but it has not developed its own estimates probably because instream reservations conflict with the consumptive use provisions of the Compact.

As previously stated, storage will be required to develop the compact allocations. This is because of the extreme variation in the remaining supply as a result of existing uses taking large portions of the firm water supply, particularly in dry years. Reservoir evaporation would decrease the usable quantities of water and would be a part of each state's Compact use. It may be unlikely that the full compact quantities of water would be developed, particularly in the Clarks Fork and Bighorn Rivers because of the limitations discussed earlier.

Federal Reserved Rights

The reserved water rights doctrine implies that water was reserved for use on Federal reservations of land in accordance with the purpose of the land reservations. The effect of Federal reserved rights includes the following: (1) when water is eventually used on the Federal reservation, the water rights of the United States become superior to private water rights that were acquired after the date of the reservation; (2) the Federal use is not subject to s$ate laws regulating the appropriation and use of water. States obviously disagree with these claims. These claims present a major source of uncertainty in water planning.

Indian water rights, which are a part of Federal reserved water rights, are also difficult to quantify in view of the varied interpretation of treaties and agreements between Indian tribes and the United States as approved by acts of Congress or formalized by executive orders. The "Winters Doctrine," which resulted from a 1908 court decision, maintains that the formation of an Indian reservation has necessarily reserved water without which the

Indian reservation lands would have no value. Varying interpretations of the Winters Doctrine would lead to variable quantities of reserved water for the Indian reservation. These interpretations fall into two categories:

(1) Restrictive Criterion. This interpretation states that the quantification of Indian rights should be based upon the amount of acreage which is "practically irritable." Case law has held that the quantities of the Indian water rights can be measured by the amount of water required for the practically irrigable lands within the reservation.

(2) Expansive Criterion. This interpretation is based on the premise that the Indians are entitled to the water necessary for all present and potential uses of water, and that such uses need not have been contemplated at the time of the reservation. lhese uses would include water for recreation, industry, energy related development, and instream flow. It is still unclear from case law whether the non- irrigation water uses can be considered as a portion of the irrigation water allotment simply changed from its original purpose or whether non-irrigation developments are in addition to the irrigation water quantities.

The two interpretations lead to a wide range in the potential impact of future consumptive use for Indian reserve rights. These estimates range from 0.5 to 1.9 maf. The only official estimates of Indian reserve rights are a 1975 Department of Interior report projecting diversions of 4.8 maf and depletions of 1.9 maf, and a 1960's Bureau of Reclamation study. The lack of quantitative data is a result of local and state political forces opposing a quantification of the Indian rights, as well as the reluctance of the tribes to provide information while litigation over their rights is proceeding.

Within the Yellowstone River Basin and adjacent coal area there are at least three general water rights adjudications currently in state courts to attempt to quantify the Indian and other Federal water rights. These cases involve the Wind River Reservation, Federal lands in Wyoming, and the ***Crow*** Indian Reservation - all of which affect the Bighorn River; and the Northern Cheyenne Indian Reservation, which affects the Tongue River. The State of Montana is attempting to negotiate Indian water rights through its Reserved Rights Compact Commission. The Crow and Northern Cheyenne tribes are involved in the Yellowstone water rights issue and negotiations are in progress with the Northern Cheyenne Tribe.

The effect of the Indian claims on projections of water requirements is illustrated in the next section of this report. These claims have helped create uncertainties of water availability in the Yellowstone River and its tributaries. In fact, the Water and Power Resources Service limited its water marketing from Boysen Reservoir for both irrigation and industrial purposes because of the Indian claims.

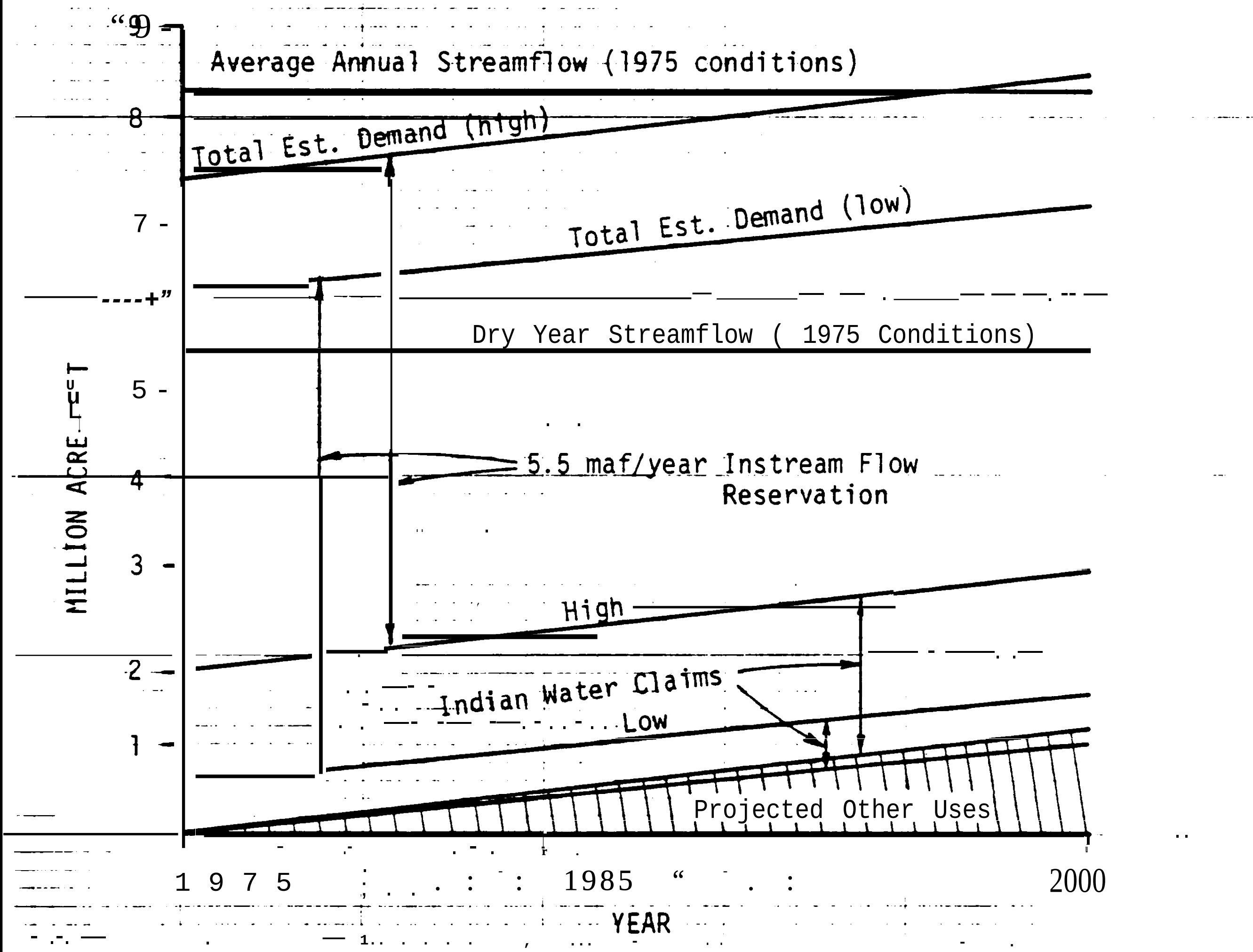
Reservations of water for other Federal purposes appear to be relatively small. They are related primarily to recreation, stock, and domestic water uses on the National Forests and on land administered by the Bureau of Land Management under various acts and reservations.

Proiected Water Uses

Projected new incremental consumptive uses or depletion of the Yellowstone River and tributaries are shown on Figure 12. The range of projected other uses was derived. from state estimates (higher values) and from the Yellowstone Level B study (lower values). The low estimate for Indian water claims include the depletions from water uses for irrigation, domestic, industrial, minerals, energy, and recreation claimed by the tribes on the Wind River, Crow, and Northern Cheyenne Indian Reservations (Boris, 1980). The low range of Indian claims on Figure 12 was derived by substituting estimates for irrigation made by the U.S. Bureau of Reclamation in the late 1960's. The State of Montana’s 5.5 million acre-feet per year instream flow reservation has been added to the low and high water use projections to illustrate its effect of committing flows of the Yellowstone River at

STREAMFLOWS AND PROJECTED INCREASED INCREMENTAL WATER DEPLETIONS, YELLOWSTONE RIVER AT SIDNEY, MONTANA

FIGURE 12



WRIGHT WATER ENGINEERS, INC.
ENGINEERING CONSULTANTS
2420 alcott street
Denver, CO 80211

Sidney, Montana. The dry year and average year annual streamflows are also plotted on Figure 12 to provide benchmarks of water availability.

Figure 12 shows two scenarios for projected incremental uses for the year 2,000:

(1) Projected other uses plus low estimates of Indian claims plus Montana's instream reservation show a total incremental demand of approximately 7 maf per year. These demands would not be met in a dry year without additional storage, but they could be met if sufficient storage were provided to average out the variation in annual flows.

(2) Projected other uses plus high estimate of Indian claims plus Montana's instream reservation show that not only would these demands not be met in a dry year without storage, but also they would exceed the average annual flow with storage. The estimated high incremental demand is approximately 8.5 maf.

Before concluding that insufficient water exists to meet the high scenario, one should remember the uncertainties inherent in these demands. The non-irrigation portion of the Indian water claims may not be recognized by the courts, and the irrigation claims may be either reduced or not brought into fruition because of economic considerations.

Most importantly, however, it is not clear from the estimates in the literature whether water for industrial, minerals, and energy purposes claimed by the Indians is duplicative of the "other" uses for these purposes. The high estimates for Indian claims include use of Indian water for energy development, industrial and mining. It is assumed that the Indians would lease their water for these purposes. The projected demands for “other uses” also includes water for energy, industry, and mineral development. It is unclear whether these estimates are additive or the estimates in the literature double count this demand. Also, the projected irrigation portion of other future water use may be limited by economics as well.

In other words, it is quite likely that increased water uses by year 2000 will not meet projected demand levels. It appears equally logical to conclude the Montana instream flow reservation also will not be realized for the dry year condition unless additional carryover storage in Montana is provided.

Compounding the uncertainties of demand illustrated above is the opposition in Montana to any new mainstem Yellowstone River storage reservoir. The State of Montana has made a strong commitment to the preservation of the free-flowing character of the Yellowstone River. New storage reservoirs on tributaries would most likely be constructed primarily to provide for new consumptive water uses, and such reservoirs have been encouraged in Montana for the most part.

Projections of water needs for synfuels are given at this point to faci” tate discussion. The WRC Section 13(a) projections give a range. Both scenarios result in higher water requirements than included in Figure 9 projections. The WRC projections are for two cases, or levels, of synfuels production: (1) a base case, which provides for President Carter's 1979 national goal to decrease oil imports; and (2) an accelerated case. Water use projections are based on assumed types of synfuels plants (primary water requirements) and ancillary development requirements (secondary water requirements for the various sub-basins shown in Figure 8. The water requirements are then aggregated for the total area in Table 2 (Section 13(a) study).

TABLE 2 - Primary and Secondary Synfuels
Water Requirements, Acre-feet per year

Water Use	Base[1] Case 2000	Accelerated Case 1985	Accelerated Case 2000
Secondary Uses			
Coal Mining/Land Reclamation	24,200	10,400	31,200
Off site Electric Generation	20,600	5,700	30,200
Municipal Water Supplies[2]	8,200	3,700	12,000
Subtotal	53,000	19,800	73,400
Primary Uses	194,000	78,000	276,000
Total	247,000	97,800	349,400

[1]No synfuels plants under base case in 1985.
[2]Diversion rates shown, depletion 50 to 100%, depending upon wastewater Treatment.

Comparable commercial scale plants which produce different kinds of synfuel products have different water demands. Also different plant processes for producing the same product require higher water demand than other processes. Therefore, it is advisable to utilize a range of water requirements in predicting the future, unless the specific products and processes are known. The Section 13(a) report provided a range as shown in Table 3 (Water Requirements); however, the report does not specify the unit values which were used to determine the ultimate water requirement so that the decision-maker can quantify the range of uncertainty in total projections. The unit values listed below were deduced from Tables 16, 17, 18, and 19 in the Section 13(a) report. These show that the projected water requirements for the high Btu gasification in the accelerated case could range from approximately 61,000 acre-feet below the estimate to 116,000 acre-feet above the estimate. The requirements for liquefaction might be approximately 28,000 acre-feet below the estimate. Thus the range of uncertainty from the estimated projections is -89,000 acre-feet to +116,000 acre-feet, or the total range in water requirements is 173,420 acre-feet per year to 378$060 acre-feet per year.

TABLE 3
WATER REQUIREMENTS FOR SYNFUEL TECHNOLOGY
(Section 13(a))

Unit Size Technology	Water Require- ments (ac-ft/yr)	Assumed Unit Value Used for water Pro- jections in Table 19, Section 13(a) (ac-ft/year)	Total Number of Plants in Acceler- ated Case (Table 16)	Total Estimated Water Require- ments (ac. ft/year)	Range of Uncertainty (ac-ft per year)
High Btu Gasification	5,960 to 14,030	Varies by subarea	22	192,170	131,120 to 308,660
LOW Btu Gasification	6,550	6,550	2	13,100	-o-
Liquefaction	4,700 to 7,800	7,800	9	70,200	42,300 to 70,200
TOTAL			33	275,470	173,420 to 378,860

ANALYSIS OF REPORTS

Background

This assessment evaluates two documents prepared by the U.S. Water Resources Council as required by Section 13(a) of the Federal Non-Nuclear Energy Research and Development Act of 1974:

1. The October, 1980, "Section 13(a) Water Assessment Report, Synthetic Fuel Development for the Upper Missouri River Basin," was prepared by the Water Resources Council essentially to assess the effects of a program of development which would be aided or stimulated by the Department of Energy. This study relied upon the Yellowstone River Level B study for its data on water availability.

2. The WRC 13(a) water assessment for the Great Plains Gasification Project reports its findings concerning a single proposed synfuels plant in North Dakota.

An expanding body of knowledge about the Yellowstone River and adjacent coal area has developed over the past decade. The Level B study used this information and a detailed coal related economic study for formulation of alternative plans for water resources activities and developments. The list of references at the end of the report shows the applicable studies.

The Section 13(a) assessment assumes synfuels development in greater amounts sooner in time than the Upper Yellowstone Basin Level B study, but the water requirements are less than were studied in the Northern Great Plains Resource Program (NGRP). On the other hand, the NGRP study, unlike the Level B and Section 13(a) studies, did not consider increased irrigation.

Upper Missouri 13(a) Report

The report was prepared to comply with the Federal Non-Nuclear Research and Development Act of 1974, which requires an assessment of the impacts of the development of a technology upon water resources if that technology will have a significant consumptive use of water.

The report covers the water resource availability and the probable impacts from developing water for 21 to 33 synfuels plants in the 156,000 square mile Yellowstone River Basin and adjacent coal area in Wyoming, Montana, North Dakota, and South Dakota. It is stated that the report was not prepared for site specific assessments.

Water Availability. Surface water availability is addressed on the basis of average annual flows in a manner similar to Table 1 of the case study. The variability of flows is indicated by graphs and percentages similar to Figure 6 of this case study. The annual variability of flow is indicated only for three rivers in the area by giving the percentage of dry year to average streamflows. The effects that reservoirs can have on stream flows such as Figure 11 of this case study is not given and the critical importance of storage to future availability is not quantified nor stressed in the report.

While the descriptions of impacts of development give percentage changes in low flows, present conditions of low flows are not given in the assessment; thus the absolute change and the severity of the impacts cannot be determined. For example, impacts on fishery habitat conditions with and without synfuels development are given for the year 2000, but without knowing what streamflow levels there would be, the reasonableness of the statements cannot be determined. The Section 13(a) report offers little data upon which to understand the differences between present conditions and year 2000 conditions with and without synfuel development, and this leads to uncertainty regarding the validity of the conclusions.

Table 4 in the Section 13(a) report presents "withdrawals" of surface water. Subareas 6 and 7 were checked with readily available information, and the values are apparently grossly understated. However, the inaccuracies in Table 4 do not affect the future depletion estimates in the report, which when checked against the increased depletions estimated by the states and by the Yellowstone Level B Study, appear to be reasonable.

Further comparison of depletions indicates that the states' and Level B figures include water development for synfuels production, although at rates much lower than the Section 13(a) report. This, however, is understandable, since the Section 13(a) report is based on an increased national program of synthetic fuels production to meet the nation's needs.

Three kinds of coal conversion technology are considered: high BTU gasification, low BTU gasification, and liquefaction; and ranges of water requirements are given for each of the technologies. The estimation of the ranges of unit water requirements for the various types of synfuels production are consistent w{th estimates being used internally by energy companies. The ranges of water use, however, are combined into a single water requirement level for each of the two projection levels of development--base case and accelerated development case. While this is normally done in water resources planning studies in order to reduce the number of cases which must be studied and presented in a report, the basis for selection of the unit value is not provided. The uncertainty which this causes is enumerated in the case study. “

The water requirements projections for synfuels production also include ancillary water needs for coal mining land reclamation, offsite electric generation, and municipal water supplies, These figures appear to be consistent with internal industry estimates and universal municipal standards.

The subject of groundwater is covered rather quickly, and groundwater is not considered as an alternative water source for synfuels development. While it is reasonable to assume that groundwater will not be the primary source for the 33 new unit-sized plants in the accelerated case, it can be used conjunctively with surface water supplies to enlarge the total water supply available. For example, it appears that the first gasification plant for Wyoming, at least, will utilize groundwater for a portion of its supply. Groundwater can also provide a supplemental source for the ancillary uses by mining and municipalities. Groundwater is presently supplying a significant portion of the water requirements for mining as a result of mine dewatering This use is noted in the assessment report, but none of the future water requirements for synfuels mines are assumed to be from groundwater.

The assessment presents three options of surface water development for meeting the synfuels water needs for the base and accelerated cases for the year 2000. The major variable in the three options for the basin is the water supply alternative for the Montana-Wyoming synfuels developments. Three options of water development from the Yellowstone River and its tributaries are diagramed. However, based on the foregoing discussion in the case study, it would appear that a section on river operation and reservoir management is needed in the assessment report, including a discussion of present and future reservoirs and their operations. However, no discussion is presented. The report relies on the stated availabi1ity of 700,000 acre-feet per year of industrial water supply from Boysen and Yellowtail reservoirs, pending completion of EIS and WPRS water availability studies.

Institutional, Legal and Economic Aspects. The institutions of state water laws, interstate compacts, and Federal and Indian reserved rights described in the overview section of this report are placed in an appendix to the Section 13(a) report. The effects of the institutional and legal constraints and the uncertainties described herein, however, are only given brief mention in body of the assessment. For example, in subareas 2 and 6 (which are the Bighorn River and which contain the two regulating reservoirs, Boysen and Yellowtail) the report only makes a few statements. "The legal availability of water may be influenced by quantification of Federal reserved and Indian water-rights in both subareas 2 and 6." "The legal availability of water in this subarea (6) may be influenced by quantification of Federal reserved and Indian water rights." "No synfuel siting was hypothesized for subarea (2 and) 6."

These statements are notable for what is not said more than what is said. For example, if the Indian claims prevail, there may not be 700,000 acre-feet per year available from the Bighorn River unless the Federal government markets the water without regard to the claimed Indian reserved water rights or unless the water is purchased from the Indians.

It is important to note that water from the Bighorn River will not be used within the Bighorn River Basin because of the lack of demand. It can be transported for synfuels production within the Yellowstone River Basin, but it cannot be used outside the basin without approval of the compact states. What seems to be overlooked in the report is the fact that a considerable amount of the coal for synfuels development lies outside of the Yellowstone River Basin. Unless the synfuels plants are located within the Yellowstone River Basin and coal is transported to the plants, the water cannot be taken to the plant sites without the approval of North Dakota, Montana, and Wyoming. While these states and the Yellowstone River Compact Commission have stated that approval of the states means approval of the state legislatures, the approval process is still uncertain as noted earlier.

The climate for approval by the state legislatures is cautious. Montana wishes to preserve the amenities of the Yellowstone River and has gone to great lengths in establishing streamflow reservations and non-energy reservations of water, making it more difficult for coal related water appropriations. Wyoming has placed restrictions on the exportation of water in coal slurry pipelines. In Wyoming there are many applications for reservoir permits for water developments presumably for synthetic fuels production, and the legislature has not yet entered the arena of limiting such appropriations. These illustrate the political constraints which energy development faces in the Yellowstone Basin.

The Section 13(a) report mentions that Indian reserved water rights and instream flows could create a limitation on available water supplies. In describing the water available for the lower Yellowstone in Montana (subarea 4), it is stated: "The aggregated requirements of synfuel development under the accelerated case would be about 2 percent of the average annual flow in 2000, and nearly 3 percent of the dry year flow, and about 15 percent of low flow conditions. These orders of magnitude indicate possible conflicts between instream uses and synthetic fuels development. The legal status of available water supplies may be affected by quantification of Federal reserved and Indian water rights in the subarea and upstream." The report goes on to describe the Montana 5.5 million acre-feet per year of instream flow water, and states, "This reservation will exceed the projected dry year flow of the Yellowstone River and may act as an important constraint on the availability of water supplies in this subarea for synthetic fuels."

This statement seems to miss the point that this instream flow requirement may also restrict the availability of water upstream of the subarea as well, since water from the tributaries makes up the instream flow. Water which could have been stored for upstream uses will need to be passed downstream to meet instream requirements. At least it would seem that this instream flow reservation could restrict appropriations of water in Montana, though not in Wyoming because the compact allocation is based on consumptive uses and Wyoming is not obligated to deliver water for non-consumptive uses.

Option 1 for meeting the projected synfuels water supplies is grossly shown as a diversion from the Powder River toward the Belle Fourche River Basin, and the report narrative states that water would be supplied for the development of streamflows near coal deposits with limited development of aqueducts, reservoirs, and pumping stations. By comparing the future water requirements given in the report tables within each of the subareas with the Option 1 map, it becomes apparent that outside of the rather large projected future water requirements in North Dakota, the largest combined water requirements are within the Tongue and Powder River basins and adjacent coal areas near Gillette, Wyoming. Comparison of the water requirements with the waters available in these two streams would indicate that water could be supplied if the institutional constraints of the Yellowstone River Compact are resolved. Apparently, the assessment report contemplates new storage on both the Tongue and Powder rivers, but this important factor is never spelled out.

Option 2 for meeting the synfuel water needs contemplates use of Yellowtail Reservoir water diverted from the Bighorn River in Montana. Once again, the Yellowstone River Compact and Indian reserved rights constraints could affect the amount of water that could be developed for the Gillette area coal fields.

Option 3 proposes a major aqueduct system diverting from the Yellowstone River downstream of the Bighorn River and pumping water back into the Montana and Wyoming coal fields. This option also has the Yellowstone River Compact out-of-basin diversion constraint. Apparently, the diversion would use identified water releases from Yellowtail Reservoir delivered to the aqueduct to avoid the instream flow problems.

The estimated capital costs for water supply in the Section 13(a) report range from $0.5 to $1 billion. No breakdown is given for these costs or for the cost for each option. Such a wide ranging estimate needs to be substantiated with assumptions, storage requirements, yield, and unit data. Without such documentation or basis, the values are meaningless for the decisionmaker. The annual costs for each surface water supply option ***are*** listed for the base case and accelerated case. For the accelerated case, year 2000 annual costs are as follows:

Water Supply Option	Million Dollars
1	38
2	51
3	63

These costs are for 50 year amortization at 6-5/8 percent interest, the rate specified by law for evaluation of Federal water projects. Again, the bases for these numbers are not given and the costs of storage and delivery are not apparent, even though they are critical components of future water availability.

WRC, Great Plains Gasification Project Section 13(c) Report

General. This is an assessment by the Water Resources Council of impacts on water resources which will result from the commitment of 12,800 acre-feet of water per year for a gasification plant near Beulah, North Dakota, in Mercer County. Water has been made available for the project from Lake Sakakawea under the U.S. Department of Interior water marketing program, and the state of North Dakota has granted a conditional water right permit for the project.

The report describes in some detail the plant processes and uses of water. Water requirements are summarized for the gasification process; associated electric power plant; mining; and increased rural, domestic, and commercial consumption. Groundwater resources are described briefly, and the conclusion is reached that the water requirements for coal mining activities (270 acre-feet per year), adjacent municipal water systems (amount not given), and rural domestic users (410 acre-feet per year) can be met from groundwater supplies.

The impacts of water supplies from the gasification project are listed to be the water use from Lake Sakakawea and the effects of mining on aquifers in terms of quality and quantity of water. It is stated in the impact section that the municipal water and waste water systems already have been upgraded to be able to meet the increased requirements for the project.

Effectiveness for Decision-Making. While The Great Plains Gasification Project Assessment Report appears to contain enough information to adequately assess the impacts of the project on water resources, it did not contribute to the decision-making process. All the major decisions had been made on the project before the report was prepared, and the report only served to meet the requirements of the law.

CONCLUSIONS

The studies indicate that for the year 2000 base level synfuels development of 1.1 million barrels of oil equivalent per day, water consumption would be 250,000 acre-feet of water per year. An accelerated development of 1.7 million equivalent barrels of oil would consume 350,000 acre-feet of water per year. Of the totals, 50,000 and 74,000 acre-feet per year would be consumed by coal mining and land reclamation, thermal electric power generation, and municipal water supply.

Surface water is generally available to support coal conversion development; however, the studies conclude that regional availability of groundwater can only be assessed by further field studies. If water requirements are met by development of water sources nearest the plant sites, up to 20,000 acre-feet per year of water may have to be transferred from current or projected irrigation use. Water requirements met by diversions from the Bighorn or lower Yellowstone Rivers would require no transfer of current or future water uses.

The Section 13(a) report indicates that additional water systems would require careful planning, particularly in the Tongue and Powder River basins, including determination of the magnitude and location of water requirements, full examination of water development alternatives, and minimization of conflicts with instream uses and existing water rights. This is an understatement in view of coal location and Yellowstone River Compact considerations.

These reports cover most of the aspects of water availability for synfuel development in the Yellowstone River basin; however, there are several critical factors which are not treated or treated too briefly for full appreciation by the decisionmaker:

- o The necessity of additional storage for meeting water supply requirements of proposed synfuel development.
- o The legal impediment of the Yellowstone Compact to out-of-basin transfers and the political reluctance to approve such transfers
- o The component costs of storage and conveyance facilities
- o The impact of Montana's instream flow reservation of 5.5 million acre-feet on water supply and timing of supplies
- o The uncertainty regarding the amount of water which is likely to be successfully claimed by Indian reservations
- o The potential impacts of additional regulation and synfuels use on downstream uses in the Missouri and Mississippi River Basin for hydropower navigation, fish and wildlife, and future consumptive uses.

These uncertainties cannot be adequately quantified because of lack of supporting data and assumptions. It can be concluded, however, that the low projections for future depletions can be met with additional storage reservoirs. However, whether or not the high projections shown in Figure 12 can be met is dependent upon the extent to which the constraints identified herein materialize.

SECTION VI
DISCUSSION AND CONCLUSIONS

It is recognized that estimating future water availability for synfuel development is a difficult and complex task often involving inadequate data, imperfect demand forecasting procedures, unforeseen political and legal factors, and time and budget limitations. Furthermore, it is recognized that it is always easy to criticize the work of others. The following conclusions and recommendations are not intended as criticism for the sake of criticism, but rather they are offered to help prepare the way for more effective assessments of water availability in the future--not only for synfuel development, but water resources management in general. They are also offered to highlight for the decisionmaker the difficulties and uncertainties underlying predictions regarding water availability.

The objective of the study has been to: (1) describe and analyze the hydrologic, institutional, economic, and legal issues involved in assessing and interpreting estimates of water availability for synfuels development, and (2) evaluate the adequacy of currently used estimates of water availabi1ity as a basis for energy planning. In accordance with this objective, the conclusions and recommendations are divided into several categories.

GENERAL

The reports and studies reviewed vary significantly in effectiveness for estimating water availability for synfuel development.

The site specific studies reviewed (i.e. "Water Assessment Report for the Great Plains Gasification Project, Mercer County, North Dakota" and the "Water Assessment for Monongahela Synfuel Plant") present adequate water availability assessments in accordance with the relatively limited objectives of the reports. However, the Great Plains 13(c) report was generally precluded from use by decision-makers because the study was done after the decisions had been made.

Reports such as the Section 13(a) assessments of water availability in the Upper Colorado and Upper Missouri Basins (Colorado Department of Natural Resources, 1979 and U.S Water Resources Council, 1980) are generally appropriate, within their limitations, for broad policy decisions by Governors, state agencies, Congress, and energy companies. These reports provide a general indication of water availability and the level of synfuel development that could be supported--if various uncertainties were resolved in specific ways (e.g. the State of Montana continues its reservation of 5.5 million acre-feet on the Yellowstone River). Therefore, the reports are useful to decision-makers concerned with broad policy decisions in the immediate future before the plethora of uncertainties in the long-term (perhaps after 10-12 years in the future) makes meaningful analysis difficult and speculative. Such reports, however, are generally inappropriate for use in specific synfuel facility siting decisions because they: a) present only aggregated flow data for major basins, b) contain only limited, general cost data concerning alternative supplies, and c) lack necessary data concerning reservoir operating policies, minimum flow requirements at specific points, and so forth.

The Upper Colorado River Basin 13(a) Assessment, “The Availability of Water for Oil Shale and Coal Gasification Development in the Upper Colorado River Basin,” represents the most useful and complete report reviewed. It: (1) provides a relatively good discussion of alternative sources of supply; (2) generally gives an adequate discussion of the legal, economic, and institutional constraints, and the uncertainty surrounding these constraints; and (3) provides ranges of future estimated demand and depletions while being candid about the uncertainty in these forecasts.

The various reports reviewed for the Upper Mississippi Basin were concerned with water availability for synthetic fuel development mainly in the State of Illinois because of the concentration of coal resources in that state. These reports (especially “Coal and Water Resources for Coal Conversion in Illinois”) should be useful to a wide range of decision-makers concerned with “real world” programmatic and policy decisions, and, in some cases, siting decisions for specific facilities. These reports avoid many complexities by concentrating on current water availability and not attempting to forecast detailed energy development scenarios for the Upper Mississippi Basin. In addition, they present the most complete set of cost data for water resource development of any report reviewed.

The Section 13(a) water assessment for the Upper Missouri Basin, "Synthetic Fuel Development for the Upper Missouri River Basin," will probably not be as useful a report to decision-makers concerned with water availability in the Upper Missouri Basin as the comparable report will be to decision=makers in the Upper Colorado. The main conclusion of the Upper Missouri report is that major storage and conveyance systems must be constructed before the extensive water demands of the projected synfuel industry can be met. The report, however, only presents general and schematic information on the location, capacity, costs, and other data of these required facilities. Furthermore, the report includes only limited information about the substantial institutional, legal, political and economic constraints which confront acquisition of necessary water rights and implementation of the required storage and conveyance facilities. Failure to communicate the magnitude of these difficulties and constraints to decision-makers is a major shortcoming of the report, which limits its usefulness. In contrast to the Section 13(a) report for the Upper Missouri River Basin, a non-governmental analysis of water availability for energy development in the Yellowstone Basin by Boris and Krutilla (1980) presents a more detailed and complete analysis of the institutional, legal, political and economic obstacles that confront development of required reservoir storage and conveyance and acquisition of necessary water rights.

The analysis of water availability for energy development in the Ohio Basin is probably the least useful of the reports and studies reviewed. It suffers from the usual difficulties (uncertain forecasts of future demand, lack of data, etc.) but has an additional deficiency in that it assesses water availability on only the mainstem of the Ohio River and ignores the tributaries. This limitation to only the mainstem substantially limits its usefulness to decision-makers for programmatic and policy decisions.

It is likely that the present controversy and uncertainty concerning water availability for synfuel development will continue in the future. Doing additional studies in order to get "better" or more refined estimates of water availability for synfuel development will probably not significantly reduce the controversy surrounding water availability. The reason for this is that many assumptions must be made in aggregating data into a form useful to decision-makers and in forecasting future demand and supply. These assumptions cannot all be explicitly detailed, communicated to decision-makers, and properly used by decision-makers in their own analyses. As a result of the general uncertainty surrounding these assumptions, there will always be potential for controversy over water availability. In other words, a finite limit as to quality probably exists for reports dealing with water availability for synfuel development. The Upper Colorado Section 13(a) Assessment probably approaches this limit.

This is not to say that "improved" analyses of water availability cannot be made; they can and should be completed. The point, however, is that seeking perfection in assessing water availability is an asymptotic process.

Because of the many difficulties and uncertainties inherent in predicting the timing and quantity of future demand by industrial, municipal and agricultural users and the related difficulty in forecasting depletions by these same users, considerable uncertainty exists in forecasts of water availability for synfuel development beyond the present. Reliability of forecasts of water availability for the period beyond 2000 is questionable.

In almost all of the analyses of water availability for synfuel development that were reviewed, the emphasis has been on "predicting" what will happen in a situation where unpredictable political, judicial, and administrative decisions are pending. It would appear that the degree of certainty conveyed in many of these reports is misleading--especially to high level decisionmakers who are unfamiliar with the many assumptions upon which the individual reports are predicated. Rather than focus on "predicting," it is recommended that the objective of these reports should be to acknowledge the intractable imponderable and to play out the consequences of some of the ways in which the decisions may go. Such analysis should concentrate on evaluating possible tradeoffs that could result.

Therefore, it is suggested that the primary use of the reports and assessments reviewed should be to assess the availability of water for initial development of synfuel industries in the respective river basins and tributaries. "Initial development" includes that group of synfuel plants presently in some phase of planning and which can reasonably be expected to be in operation in the next 10-12 years.

Furthermore, it is suggested that water availability assessments not be predicated on an energy or synfuel development scenario for the river basin. Except for the case of a report prepared specifically for national level decision-makers concerned with whether the United States can meet a national synfuel production goal by a certain date and whether individual regions can make specific contributions to this goal, the specification of a synfuel development scenario for a river basin does nothing except insert more uncertainty and speculation into the report. Instead, the water analyses assessments should concentrate on future water availability (net of all depletions except for synfuel development) and generally allow decision-makers to supply their own synfuel development scenarios. In addition, the assessments could detail the various tradeoffs that could occur if various levels of synfuel development were to occur.

WATER AVAILABILITY FOR SYNFUEL DEVELOPMENT

The purpose of this section is to bring together information presented elsewhere in this report which will allow a reader to obtain quickly an overview of water availability for synfuel development in a specific basin.

Upper Mississippi River Basin

The Upper Mississippi River Basin is that portion of the Mississippi River upstream from the confluence of the Ohio and Mississippi Rivers at Cairo, Illinois. The Upper Mississippi River Basin includes portions of the states of Illinois, Missouri, Iowa, Wisconsin, and Minnesota. Synfuel development will probably be concentrated in Illinois since this is the only state in the basin with major coal resources.

From a regional perspective water supplies for synfuel development in-the Upper Mississippi River Basin are adequate. Localized problems, however, may result depending on the specific site for a synfuel plant. Water supply shortages and negative impacts on water resources are most likely to occur for synfuel sites on tributaries. These shortages and negative impacts can be eliminated or reduced by construction of reservoir storage on tributaries, conjunctive use of ground and surface water or other measures to reduce diversions from unregulated streams during low flow periods.

Ohio/Tennessee River Basin

These two major river basins include portions of Pennsylvania, West Virginia, North Carolina, Ohio, Kentucky, Tennessee, Indiana, Illinois, Maryland, New York, Alabama, and Georgia. Major coal deposits are scattered throughout many states in these basins and significant potential for synfuel development exists.

The water availability situation in the Ohio and Tennessee Basins is comparable to that in the Upper Mississippi. From a regional perspective sufficient water is available for projected synfuel development but localized problems or deficiencies may occur for synfuel plants sited on tributaries. The extent and nature of these deficiencies can only be predicted with site specific studies.

Upper Colorado River Basin

The focus of synfuel development in the Upper Colorado River Basin is on the impending oil shale development activities. Projections for synfuel development in this area range from approximately 1,000,000 barrels a day to more

more than 8,000,000 barrels per day. Much of this development is expected to take place in a three-county area in northwestern Colorado which experiences an annual average precipitation of less than 12 inches and presently has only one town with a population greater than 5,000.

Water is available, and can be made available, in the Colorado River Basin in Colorado to meet oil shale development in the future. The question is not really whether water is available, but rather what the impacts on agriculture and other sectors will be from allocating this water from its present and potential use to synfuel development. For example, approximately 150,000 acre-feet of water storage presently exists in two federal reservoirs on the Western Slope of Colorado which, in part, could be made available for synfuel production. Assuming the consumptive use requirement of a 50,000 bbl/d shale oil plant is approximately 5,700 acre-feet per year, the available stored water in these two federal reservoirs alone could supply a number of unit-sized synfuel plants, more than the number of synfuel plants presently in some state of planning within Colorado. This available stored water could be more efficiently used and stretched further as a source of synfuel water supply when combined with existing junior rights of energy companies. If, however, the projected plants were to rely on water transferred from agricultural use rather than existing available water in federal reservoirs, the impact on the agricultural sector would be much more severe.

The case study of the Upper Colorado River Basin in Colorado herein goes into detail concerning the economic, political, institutional, and legal uncertainties which make it difficult to predict the level of future synfuel development in the upper Colorado River Basin, and the source arid amount of water supply for this projected level of development.

<u>Upper Missouri River Basin</u>

Within the Upper 'Missouri River Basin, synfuel development can be expected to occur primarily in the Yellowstone River Basin and the adjacent coal area. This area encompasses portions of Montana, Wyoming, North Dakota and South Dakota.

In order to provide necessary water for projected synfuel development in this area, major new water storage projects would be necessary because of the significant inter- and intra-year variation of stream flows for all rivers in the basin. Furthermore, the legal, institutional, political and economic issues are of such magnitude in this river basin that they do not allow an unqualified conclusion as to availability of water for synfuel development. In the Yellowstone River Basin and the adjacent coal areas, it is not a matter, as in the Upper Colorado River Basin, of merely what the effects will be of transferring existing water to synfuel development, but rather whether this water will be available at all. Major state reservations of water on the main stem Yellowstone River, Indian reserved rights, and the Yellowstone River Compact all present major uncertainties as to availability of necessary water for synfuel development in this area. Section V herein details the nature and effect of these legal, economic, institutional, and political uncertainties.

PHYSICAL AVAILABILITY

Of the many data-and information bases required for assessing water availability (e.g., future municipal demand projections, future cooling water requirements for coal-fired electric generating stations, etc.), recorded historic streamflow is probably the most accurate and dependable. In the eastern basins, this recorded data set is used more or less directly to assess water availability based on 7-day, 10-year minimum low flows. The use of 7-day, 10-year low flow data for this purpose in eastern basins is desirable since the 7-day, 10-year flow parameter: (1) coincides with many water quality regulations, (2) provides indication of low flow conditions for navigation, and (3) provides a useful estimate of flow in rivers with limited storage.

In the western basins, water availability assessments are based on virgin flow estimates since western state water laws and interstate compacts are predicated on this concept. Virgin flow estimates are based on recorded streamflow data and estimates of depletions. Significant effort is often made to estimate virgin flows, but the resulting data set may be inaccurate because of poor records of diversions, irrigated area, inaccuracy *in* estimating irrigation consumptive use, etc.

Depletion estimates are uncertain because of inadequate records, unrecorded return flows, illegal diversions, and other limitations. Therefore, the principal parameter in western basins on which water availability for synfuel development is based, mean annual virgin flow, incorporates considerable uncertainty. Furthermore, studies assessing water availability in western basins for synfuel development tend to treat mean annual virgin flow estimates as deterministic rather than stochastic variables. These studies do not clearly express the uncertainty and risk (in the statistical sense) that exist in mean annual virgin flow estimates, thereby giving an unwarranted degree of certainty to this data set. For example, some analyses of water availability in the Upper Colorado River Basin treat the estimated mean annual virgin flow as a deterministic, stationary quantity rather than a stochastic variable.

The use of mean annual flow and mean annual virgin flow estimates for assessing water availability is acceptable for rivers and tributaries where adequate storage exists to control the river. However, where little or no storage exists, or will exist in the near future, some estimate of low flows is needed. This could be weekly, monthly or 7-day, 10-year minimum low flow data depending on local hydrologic conditions and data availability. Without this low flow data, decision-makers will have little idea of how proposed synfuel water demands will affect instream uses: fish and wildlife habitat, run-of-the-river hydropower generation, recreation, and water quality. Low flow data is especially important to assess the cumulative effect of all present and proposed depletions as well as the statistical persistence inherent in the hydrologic record.

Groundwater quantity and quality data are inadequate in all of the basin analyses. Some reports more or less ignore this potential water supply source for energy development because of insufficient quantitative data. Individual energy companies may have adequate groundwater data to assist in specific siting decisions, but this data may be unobtainable or do not exist on a regional scale for governmental decision-makers or entities concerned with state or regional water resources management. Use of groundwater for supplying synfuel development could, in some instances, reduce streamflow depletions, especially during low flow periods. Planned conjunctive use of ground and surface waters could result in more efficient use of the surface water resources; i.e., more synfuel plants could be sited in a basin with less impact on the water resource if conjunctive use is employed. However, because adequate groundwater data are not available to regional or state decision-makers, this opportunity may be lost.

ECONOMIC FACTORS

Data concerning costs of developing necessary water resources for supplying synfuel plants were generally inadequate in all reports reviewed with the exception of "Coal and Water Resources for Coal Conversion in Illinois" (Smith and Stall 1, 1975) and Water Rights and Energy Development in the Yellowstone River Basin - An Integrated Analysis, (Boris and Krutilla, 1980). An effort was made in both these reports to present representative and dependable cost data. There are several reasons for the general inadequacy of available cost data.

First, dependable cost data are difficult to collect. No central collection of, for example, reservoir construction cost data exists; data must be collected from a number of individual sources. Second, cost data are site or project specific, and generalization is often risky and inaccurate. Third, developing or obtaining comparable cost data may be impossible. For example, obtaining data on selling prices of irrigation water rights often results in a set of individual prices for widely different commodities. One selling price; may be for a senior irrigation right while another will be for a junior right requiring construction of storage. Several examples of this variation are presented in the Upper Colorado River Basin section herein.

Within limits, cost data may not be very important to energy companies for selecting a water supply for synfuel development since cost of water is generally minor with respect to total capital and operating costs for a proposed synfuel plant.

Cost of water, however, is one determiner of the nature and extent of tradeoffs that will occur as a result of supplying water for synfuel development. Cost data, therefore, should be important to regional and state decisionmakers for: (1) evaluating alternatives for water users displaced by synfuel development and (2) determining the total estimated costs of water resources infrastructure (reservoirs, pipelines, etc.) necessary to support various levels of synfuel development. For example, in the U.S. Water Resources Council's Section 13(a) Assessment of water availability in the Upper Missouri River Basin, it was indicated that major storage and conveyance systems must be developed if the forecast levels of synfuel development were to take place and that the cost of this water resources infrastructure would be an estimated $0.5 to $1 billion dollars. More detailed cost data were not presented. Such aggregated data are not very useful since they do not indicate proposed sources and amounts of funding, cost of specific major projects, and other matters. Without such information it is difficult to evaluate the likelihood that this water resource infrastructure will or should be built. Without such an evaluation, it is difficult to assess water availability for synfuel development with any certainty.

Economic factors are, without question, important in determining the source of water supply for a particular synfuel development. As discussed throughout Sections II-V herein, there are many factors and constraints besides economics, which ultimately determine the source of supply, depletion, and impact on the water resource of a synfuel development. The succeeding section summarizes some of these factors and constraints which may force energy companies to go to more remote or expensive sources for necessary water supplies.

LEGAL, INSTITUTIONAL, AND POLITICAL FACTORS

Perhaps the most difficult requirement in assessing water availability for synfuel development is estimating the effects of legal, institutional and political factors on water availability.

Future judicial decisions, compact interpretations, implementation of certain compact provisions, administrative decisions on marketing federal reservoir storage, resolution of Federal and Indian reserved rights, reservation of water by states, and uncertainties in riparian law, can all have a profound effect on water availability for synfuel development. Communicating the quantitative effects of these possibilities in a water availability assessment is a large task. This task is complicated by the fact that not only must the possible effects be indicated and analyzed, but also some effort should be made to estimate the likelihood of occurrence.

For example, no interstate compact exists between Colorado and Utah for the White River, a tributary of the Upper Colorado River. Seventy-five percent of synfuel development in the Upper Colorado Basin is forecast to take place in the White River Basin (Colorado Department of Natural Resources, 1979). A White River compact could, therefore, be a major determinant in water availability for synfuel development in the White River Basin. Tracing out the quantitative effects on water availability of such a future compact is a difficult but necessary task in assessing water availability.

In general, the reports and assessments reviewed contain highly variable analyses of the quantitative effects of future legal, institutional and political constraints. Probably the best example is the Boris and Krutilla (1980) study which presents detailed and quantitative analyses of a number of legal, institutional and political factors affecting water availability for the Yellowstone Basin.

Political, legal and institutional factors affecting water availability are generally less numerous, and less complex, in the eastern basins than in the western basins. Complex local situations may exist but, in general, the political, legal, and institutional factors affecting water availability for synfuel development are less involved in eastern basins. The probable reasons for this are: (1) less competition for water in the eastern basins, (2) the relative simplicity of riparian water law for surface water, (3) the general lack of, or relatively simple, groundwater regulatory law in eastern states and (4) the difference in hydrologic regimes. As a result, forecasts of future water availability for synfuel development may be somewhat less involved because of the reduced complexity of political, legal and institutional factors.

The relative simplicity of riparian water law and riparian-based groundwater law can, however, result in significant uncertainty concerning future water availability because of lack of protection given users against upstream diversion or pumping adjacent to their lands. In contrast, water law in western states can be a barrier to implementation of water supply alternatives. For example, western state water law is an obstacle to implementation of measures to increase irrigation efficiency since the Appropriation Doctrine does not generally allow a user to retain a right to salvaged water. These measures could, in turn, provide the water saved to synfuel development.

In all the basins reviewed, existing federal reservoir storage can be a significant source of water supply for synfuel development. However, uncertainty over marketing policies and contract terms and bureaucratic and legal delays reduces the potential of this source of supply for synfuel development. This is unfortunate, since these reservoirs are already in place and additional construction would not be necessary.

Uncertainty resulting from legal, institutional, judicial and political factors causes energy companies to be conservative in their water supply planning and acquire redundant supplies in order to be assured of an adequate future-water supply. The delays and uncertainties inherent in acquiring water rights, obtaining reservoir storage, or otherwise initially securing a water supply also tend to cause energy companies to obtain redundant water supplies. Because of this redundancy, future consumptive use may be less than expected.

PROJECTION AND FORECASTING PROCEDURES

Estimating water availability for synfuel development requires a number of projections and forecasts. These range from estimating future population levels and municipal and industrial water demand for specific areas of river basins to projecting the effects of future legal and institutional mechanisms on water availability. This collection of projections and forecasts must be combined in order to estimate the availability of water for synfuel development. Assessments of water availability for synfuel development are generally developed by aggregating existing forecasts of water demand and use in the various river basins. These existing forecasts are of highly variable quality and sophistication.

Lack of effective mechanisms for water resources planning in many basins which are experiencing, or will experience, synfuel development is a serious limitation in producing dependable forecasts and projections of future water availability for synfuel development. Consider the example in Section III herein of the difference in data availability between West Virginia and Pennsylvania for the Monongahela River. The lack of a consistent data base between these two states makes forecasting various effects of synfuel development difficult or impossible. Furthermore, the compilation of data for various political jurisdictions (e.g., states) which do not correspond to hydrologic boundaries and the use of this data for forecasting purposes also creates bias, error, or uncertainty in the resulting forecasts. States and other political entities generally are optimistic when predicting future water demands and assume significant growth in water use by the industrial, agricultural, and municipal sectors. The total future water use for a basin must be equivalent to the sum of the parts. Reconciling the projections and forecasts of the individual entities so that the total is reasonable is a major job for which there may not be a responsible entity. A major effort was made in the Second National Assessment of the Nation's Water Resources (U.S. W. R. C., 1978) to reconcile the “state futures” with the “national futures,” i.e., to insure that the whole was equivalent to the sum of the parts. In many river basins, no planning entity exists that can produce uniform, consistent and dependable forecasts or predictions of parameters affecting water availability for synfuel development.

Another deficiency in currently available forecasts for water availability for synfuel development is that these forecasts may have good procedures for estimating future water demand, but that procedures for translating these demands into surface or groundwater depletions may be surrounded with uncertainty for a number of legal, political and institutional reasons. Consider, for example, the Colorado River Basin in Colorado. A number of estimates of future synfuel development for various sub-basins of the basin can and are being made. Reasonable forecasts of water demand for synfuel development and associated municipal demand can be made. However, demand estimates are not usually the final desired forecast or estimate. The final desired forecast involves those parameters characterizing expected quality and quantity depletions of the ground and surface waters of the region. Translating demand forecasts into depletion estimates requires numerous assumptions concerning future institutional, political and economic parameters. For example, on the Sangamon River in the Upper Mississippi Basin (see Section II herein) estimating future demand for cooling water for the Clinton Nuclear Power Plant is a reasonably straight-forward exercise. (Estimating future water demand for a synthetic fuel plant at the same location would be a comparable task.) Translating this demand forecast into estimates of future depletions in the Sangamon, Illinois and Mississippi Rivers, however, is far more difficult and requires numerous assumptions about future economic and institutional conditions. For example, economics will largely determine if the source of supply is groundwater, direct diversion from the river, or tributary storage. Each of these sources will have very different effects on depletions during low flow periods on the Sangamon, Illinois and Mississippi Rivers.

Therefore, with respect to the adequacy of forecasting and projection procedures, the following conclusions can be made:

1) Forecasts of water availability for synfuel development in a particular river basin depend on aggregation of a number of individual forecasts in a number of sectors: agriculture, manufacturing, energy, municipal, etc. There may be significant variation in the quality and dependability of the forecasts in these various sectors.

2) Forecasts of water availability for synfuel development require combining data and forecasts for water demand from various political entities (e.g. states) in the river basin. There may be significant variation in the quality and quantity of data and forecasts from these political entities which may seriously limit the ability to predict or forecast impacts of synfuel development on the water resources of a region, river basin, or sub-basin. The lack of an efficient and effective planning entity in most river basins indicates this situation will probably not change in the immediate future.

3) Many forecasting procedures associated with assessing water availability for synfuel development are designed to ultimately produce estimates of water demand. Translating these demand forecasts into estimates of quality and quantity depletions of ground and surface waters involves, perhaps, even more uncertainty than the original demand forecasts. This uncertainty results from potential future legal, political, economic and institutional constraints that may develop.

4) Assessments of water availability for a period of 10 to 12 years into the future should be reasonably good since we generally have some indication for this period concerning what plants may be built, what water supply sources will be used,” specific plant sites, etc. However, after this 10-12 year period, the legal, political, economic and institutional uncertainties become much greater and the dependability of the forecasts diminish.

ALTERNATIVES

For all basins studied, the principal sources of water supply considered in the reports for synfuel development were: (1) direct diversion from rivers, (2) reservoir storage, or (3) acquisition of agricultural water rights. However, numerous other potential sources exist including: (1) development of groundwater, (2) conjunctive use of ground and surface water, (3) weather modification, (4) improvements in efficiency of agricultural and municipal use (and subsequent use of water "saved" by synfuel industry), (4) change to more water efficient processes in synfuel production, and (5) watershed management to increase discharge. Detailed discussion of these alternatives for synfuel development water is presented elsewhere and will not be repeated here (Office of Technology Assessment, 1980; U.S. Environmental Protection Agency, 1979).

Some of these alternatives appear to offer attractive sources of water supply for the synfuel industry but their practical implementation is constrained by political, legal and institutional barriers. For example, the Colorado River Basin assessment report (Colorado Department of Natural Resources, 1979) discusses the possibility of employing municipal water conservation measures to reduce exports from the Colorado Basin for municipal use (primarily to the Denver metropolitan area) and using this saved water for synfuel development water supply. Numerous studies throughout the United States have demonstrated the cost-effectiveness and feasibility of reducing municipal demands by 10 to 30 percent. Therefore, this alternative would appear, at first impression, to offer an economically efficient and environmentally desirable water supply for synfuel development in the Upper Colorado River Basin. However, as discussed in the Upper Colorado River Basin section herein, substantial political, legal and institutional barriers -confront implementation of this alternative. These constraints are not discussed in the Section 13(a) study for the Upper Colorado.

This situation is typical of the treatment of other alternatives in the Upper Colorado River Basin Section 13(a) assessment as well as in other reports reviewed. In general, alternatives for synfuel water supply, other than the usual reservoir storage and direct diversion, are detailed with some limited discussion, but without analysis of the legal, political, economic and institutional constraints that limit their consideration and implementation in the real world.

BASIN COMPARISON

The objectives of the study have been to analyze the various factors involved in assessing water availability for synfuels development in four major river basins and evaluate the adequacy of currently used estimates of water availability as a basis for energy planning in these basins. With respect to the objectives of this study, there are considerable differences among the four basins studied.

In the eastern basins, the Ohio/Tennessee and the Upper Mississippi, significantly less competition exists for water than in the western basins. As indicated in the Ohio/Tennessee and Upper Mississippi discussions herein, the expected future total depletions, both for the mainstems and tributaries, are far less than in the Upper Colorado and Upper Missouri River Basins. In general, for the Ohio/Tennessee and the Upper Mississippi, adequate water supply exists for presently proposed and future synfuel development on the mainstems and larger tributaries without major new reservoir storage. Instream requirements and local shortages may limit availability in some areas and arrangements for alternative water supply during drought periods, (e.g., groundwater, or side channel and tributary reservoirs) may be necessary. This water can be made available with a minimum number of potential legal, institutional, and political obstacles.

The relative' absence of legal, institutional and political obstacles to water-availability in the eastern basins primarily results from the relative simplicity of eastern riparian water law, lack of interstate compacts, no major Federal or Indian reserved rights questions, and the few institutions concerned with water resources. While this environment of simpler law may make water available more easily, it does not provide the assurance of continued supply that the appropriation doctrine water law of most western states provides. Riparian water law in states such as Illinois, Indiana, Tennessee and other eastern and Midwestern states gives a groundwater or surface water user little protection against depletion by others. This is in contrast to the western basins where appropriation based law and the more complex institutional and political setting will probably provide more obstacles to obtaining a water right; but once the right is obtained, the user has a more certain supply. Therefore, while the legal, institutional, and political environment of water availability is far less complex in the eastern basins than in the western basins, this relative simplicity and ambiguity are responsible for considerable uncertainty concerning future water availability.

For the eastern basins, the absence of interstate compacts, the lack of the general accounting requirements of western appropriation law, and the relatively few institutions concerned with water resources result in no entity having responsibility for regularly assessing the total cumulative depletions or diversions for a particular stream or aquifer. The lack of such an entity creates additional uncertainty concerning future water availability due to disparities among states in water quality and quantity data and estimates of depletion due to future development.

For the western basins, the Upper Missouri and the Upper Colorado, the opposite of much of the above is the case. The complexities of western states' water laws, the numerous interstate compacts, and Federal and Indian reserved rights create obstacles and uncertainty concerning future availability of water for synfuels development. However, these same factors also create a relative certainty of supply once that supply is obtained. In addition, these same factors have resulted in a form of regional and basin accounting of depletions.

Similarities also exist among the basins. In all basins, groundwater data is marginal or inadequate for purposes of assessing its potential as a source of supply for synfuel development. Forecasting demand for all water uses is a very uncertain process everywhere. As a result, assessments of water availability for the future (e.g., beyond 2000) are uncertain at best and must be interpreted very carefully. In general, the reports reviewed are mainly useful for assessing water availability at present for initial development of synfuel industries within the next 1O-I2 years.

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