

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.

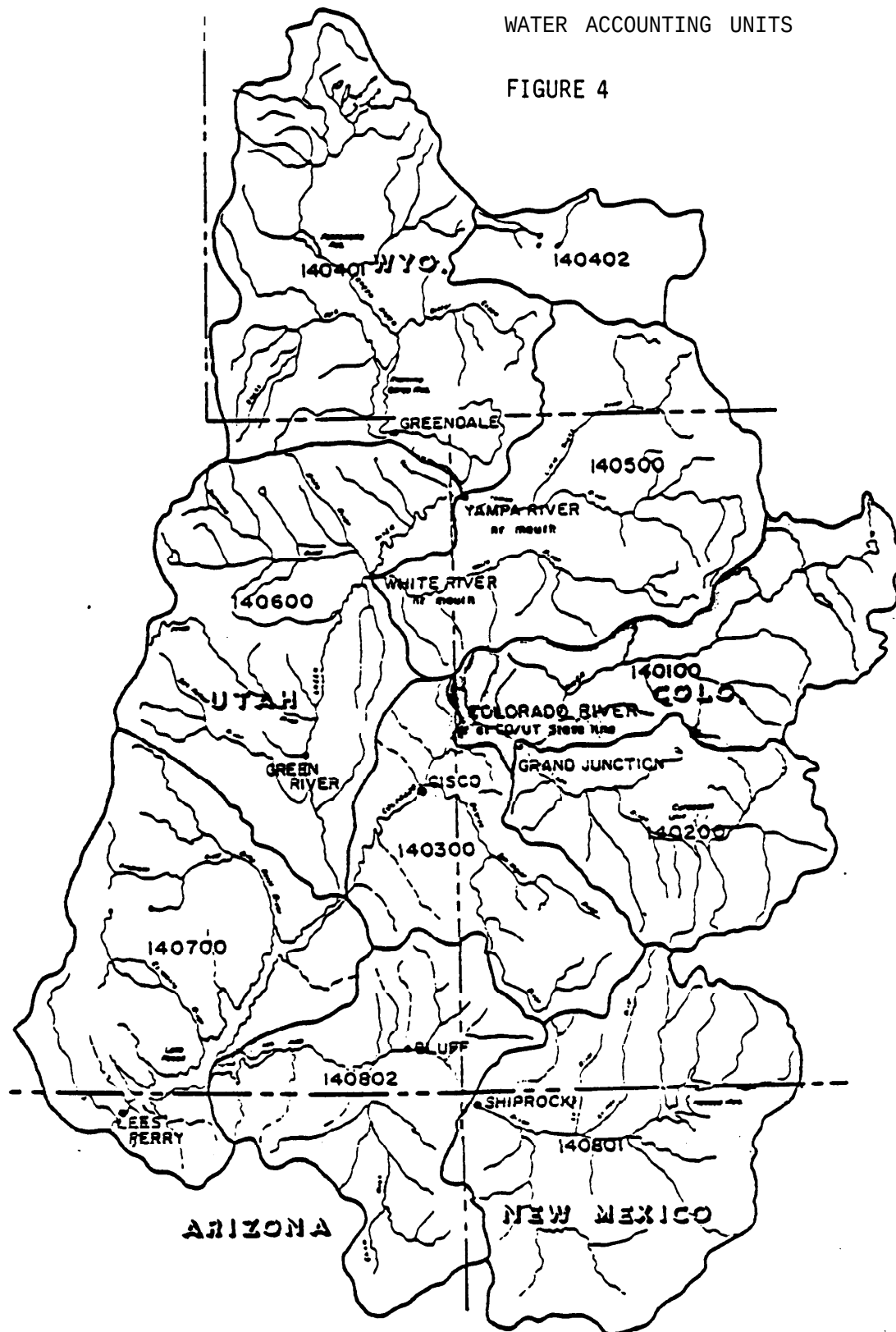
The Upper Colorado River Basin covers about one million square miles in four states: Colorado, Wyoming, Utah and New Mexico. These four states comprise the upper portion of what is the most complex, and disputed, water management system in the United States--the Colorado River Basin.

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.

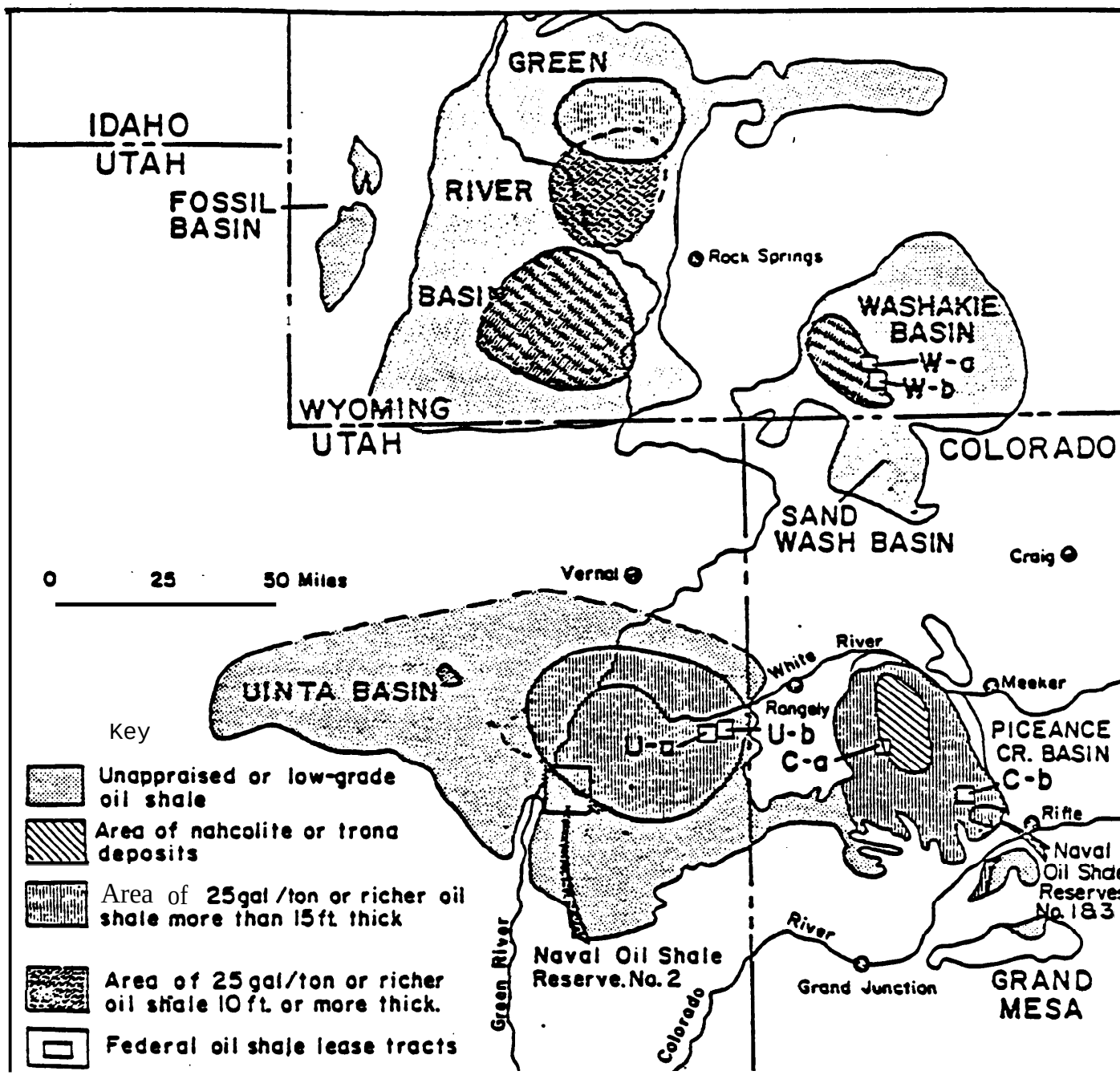
Consequently: the Upper Colorado River Basin in Colorado was selected for detailed analysis with particular focus on the impending oil shale development activity within the Upper Colorado River Basin above Grand Junction, Colorado and the new competition that it brings for water resources. This selection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


 ANTHRACITE & semi-anthracite

 Low-volatile bituminous coal

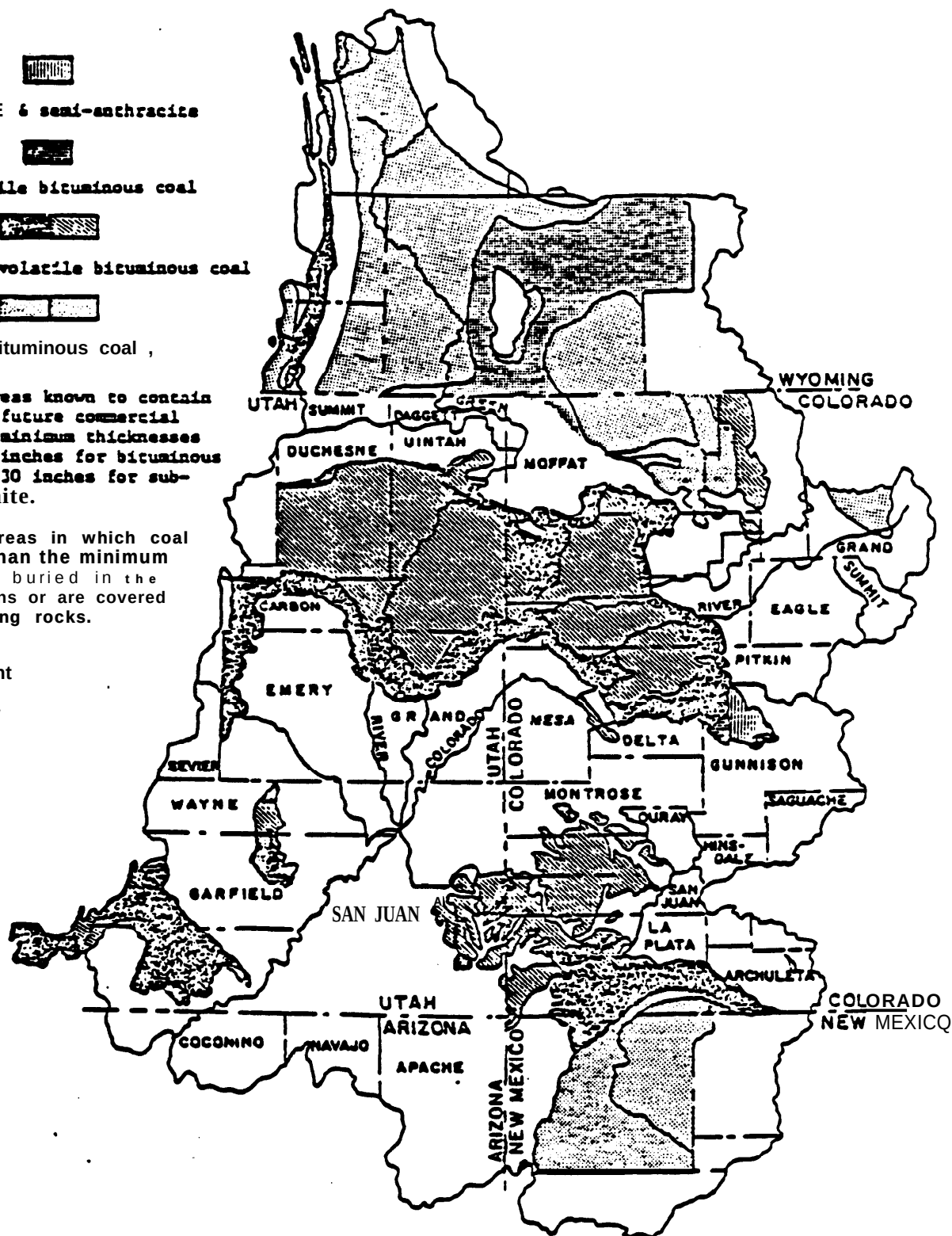
 Medium & high-volatile bituminous coal

 sub-bituminous coal

Dark color represents areas known to contain coal beds of present or future commercial value. In general, the minimum thicknesses of beds included are 14 inches for bituminous coal and anthracite and 30 inches for sub-bituminous coal and lignite.

Light color represents areas in which coal beds are generally less than the minimum thicknesses or are deeply buried in the center of structural basins or are covered by younger non-coal-bearing rocks.

NOTE: map is from 1971, and more recent studies in San Juan and Rio Arriba counties, New Mexico, show additional coal deposits of possible commercial value in that area.



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

IV-5

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.

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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:

- (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:

- o 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.

- o 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.
- o 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 is 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 stream-flow 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:

IV-13

	<u>Percent</u>	<u>Acre-feet</u>
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	<u>537,000</u>
		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 in 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	<u>Annual Virgin Flow</u>
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 Oil 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 Water 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.

- o 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.

- o 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 (evapotranspiration, 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 theoretically 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 exporter 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 trans-mountain 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 1/100th 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.

- o- 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:
 - o - 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:

<u>Condition</u>	<u>Synfuel (acre-feet)</u>	<u>Associated Growth (acre-feet)</u>	<u>Total (acre-feet)</u>
<u>Colorado Only</u>			
Baseline	23,000 ^a	6,000	29,000
Accelerated	70,000 ^b	14,000	84,000
<u>Total Upper Basin</u>			
Baseline	217,000~	35,000	252,000
Accelerated	374,000	68,000	442,000

^aEntirely for oil shale development

^b13,000 AF for low-Btu coal gasification

^c68,750 AF for high Btu coal gasification in Wyoming and the San Juan Basin in Colorado and New Mexico

^d13,000 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 is 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. The 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 sufficient water exists for a 1.5 million bbl/d syn-fuel 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. The 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 oil 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)
<u>-7.5 maf</u>	(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:

$$\begin{array}{r}
 6.3 \text{ maf} \\
 - 0.750 \text{ (Upper Basin Mexican Treaty Obligation)} \\
 \hline
 5.550 \text{ maf}
 \end{array}$$

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

$$\begin{array}{r}
 5.550 \text{ maf} \\
 - 0.645 \text{ (estimated annual evaporation from} \\
 \text{Flaming Gorge, Lake Powell, and the} \\
 \text{Curecanti Unit Reservoirs)} \\
 \hline
 4.905 \text{ maf}
 \end{array}$$

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, "the 1979 projections, combined with

conservative flow estimates, indicate there will be sufficient water in the Upper Basin for all consumers in 2000.^u (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-Making. 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 "Energy 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 Development 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 depletions 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.