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COLORADO WATER CONSERVATION BOARD
212 State Office Building
Denver, Colorado

September 9, 1955 later

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Gentlemen:

I am enclosing with this note a report entitled "Water Supply of the Western Slope of Colorado", composed of two parts: (1) An estimate of the supply and an estimate of the requirements based on certain assumptions, and (2) an Appendix which shows several estimates of supply, three of which have been printed in Congressional hearings during the past two years.

Inasmuch as all of the printed estimates disagreed by a wide margin, I have endeavored to form one based, in a large measure, on the Hill Report and to clearly bring out the main differences in the several estimates. The conclusions in the Hill Report are based largely on the data collected by the U. S. Geological Survey and the U. S. Bureau of Reclamation.

I am sure that we are all cognizant of the difficulties involved in passing Reclamation legislation. These difficulties are increased when the projects considered approach a subsidization of nearly 100 per cent. For this reason, I have not included in my water supply estimate those requiring a subsidization greater than that indicated. This does not mean that the projects requiring heavy subsidization are entirely outside the pale. Further study and re-arrangement may improve them. On the other hand, inasmuch as the data is all from reconnaissance reports, a feasibility report (detailed study) may in some cases weaken considerably the position of a few projects.

Sincerely yours,

Ivan C. Crawford
Director

ICC:pam

WATER SUPPLY OF THE WESTERN SLOPE OF COLORADO

By
Ivan C. Crawford, Director
Colorado Water Conservation Board

A Report to the
Colorado Water Conservation Board

September 1955

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Water Supply of the Western Slope of Colorado

by
Ivan C. Crawford, Director
Colorado Water Conservation Board

Is there any surplus water on the Western Slope? How much water does this part of Colorado yield each year? Should any more of this water be diverted to the Eastern Slope? These are the questions that have produced differences of opinion between the Western and Eastern Slopes.

The following article presents the physical facts so far as they are known and attempts to set forth the conflicting viewpoints of the two portions of the State.

The answers to the first and third questions depend upon agricultural economics and national political policy and therefore are not capable of exact answer at this time. However, the facts on which to base answers are known and must be taken into account in any thorough study of the problem.

Colorado's present water difficulties are due to the physical characteristics of the State and the distribution of precipitation. Stated briefly the situation is this: Thirty-seven percent of the area of the State lies west of the Continental Divide and possesses sixty-nine percent of the State surface water yield; or, conversely, sixty-three percent of the area of the State receives only thirty-one percent of the surface yield.

In a recent ten-year period, 1941-50, an annual average of 9,347,000 acre-feet of water originating in Colorado passed out of the State each

year through the main stem of the Colorado River and its tributaries. The percentage of contribution to this total by each of the several basins is as follows:*

Yampa & White Rivers	19.3 percent
Main Stem of Colorado	31.7 "
Gunnison River	21.4 "
Dolores River	7.5 "
San Juan River	20.1 "

In order to use the portion of this water that Colorado is entitled to, two things must be done:

(1) Small dams must be constructed high upstream on tributaries in Colorado to store water and divert it to proposed participating projects. Such projects, as the term is used here, are irrigation projects, and participate in the earnings of the large storage projects mentioned in the next paragraph.

(2) Cyclic storage (storage of sufficient capacity to hold water throughout a complete weather cycle) must be constructed on the river so that Lower Basin States may be assured each year of the share awarded to them by the Colorado River Compact, and secondly, so that electrical energy may be produced to pay the cost of this cyclic storage plus, in a large measure, the cost of the projects mentioned under (1).

*Depletion of Surface Water Supplies of Colorado West of Continental Divide by Leeds, Hill and Jewett, Bulletin No. 1, Surface Water Series, Colorado Water Conservation Board.

Estimated Water Requirements and Estimated Supply

This caption suggests two most important questions: (a) How much water will be required to satisfy future developments on the Western Slope? (b) What is the dependable supply?

2. Estimated Future Requirements

The average annual stream depletion (consumptive use) on account of possible future irrigation projects in the basin of the Colorado River in Colorado may be broken into the following units:

A. Projects now in the Upper Colorado River Storage Bill will use 62,400 acre-feet. These are:

Paonia	9,000
Smith Fork	7,500
Pine River Extension	27,200
Florida	12,900
Silt	5,800
Sub-total	62,400

B. Projects on the Gunnison River having a benefit-cost ratio* of 1.0 or higher, and which will require the irrigator to repay at least nine percent of the construction cost, will use 68,500 acre-feet. They are:

Fruitgrowers Extension	5,540
East River	2,100
Fruitland Mesa	25,000
Bostwick Park	4,800
Dallas Creek	31,000
Sub-total	68,500

*The benefit-cost ratio is the sum of the annual net benefits resulting from the construction of the project divided by the annual equivalent values of construction costs. It may be expressed as 1.35 to 1 or just as 1.35.

C. Projects on the Main Stem of the Colorado River having a benefit-cost ratio of 1.0 or higher, and which require the irrigator to repay at least nine percent* of the construction cost and which will not interfere with oil shale development and the proposed DeBeque Reservoir, will use 82,100 acre-feet. They are:

Parshall	28,600
Troublesome	13,000
Rabbit Ear	16,400
Eagle Divide	12,000
Woody Creek	1,400
Battlement Mesa	10,700
Sub-total	82,100

D. Projects in the San Juan Basin, the San Miguel, the Animas-La Plata and the Dolores, having a benefit-cost ratio of 1.0 or higher, and which will require the irrigator to pay at least nine percent of the construction cost, will use 143,780 acre-feet.

E. A project in the White-Yampa basin, the Savery-Pot Hook, conforming to the standards mentioned in B., C. and D., will use 20,000 acre-feet.

This gives a grand total of 377,000 acre-feet as the consumptive use that, on the assumptions mentioned, should be provided for in the future development of land by the Reclamation Bureau. On restudy, several of the projects included may not reach the benefit-cost ratio required.

*A lower repayment by irrigator than any participating project proposed by other Upper Basin States.

3. Estimated Water Supply

The Upper Colorado River Compact of 1948 allots to Colorado 51.75 percent of 7,450,000 acre-feet (Upper Basin share under Colorado River Compact of 1922) minus 50,000 acre-feet awarded to Arizona. Colorado's water supply thus reaches the total of 3,855,375 acre-feet. However, water supply measurements for the years since 1930 indicate that, for the present at least, the plans for the development of water uses in Colorado should be based on a smaller amount than that derived from the consideration of the Upper Colorado River Compact.

In 1953, the Colorado Water Conservation Board, under authority of the State Legislature, employed a firm of nationally known engineers with long experience in irrigation water supply engineering to make a study and report on the depletion of surface water supplies of Colorado west of Continental Divide. This firm, Leeds, Hill and Jewett, reported that the period 1930-1952 should be used to estimate the water supply inasmuch as the yield for this period was considerably less than the average over the period 1917-53. One of the conclusions reached in this study was that "the total of all depletions at sites of use (emphasis supplied) in Colorado of the flow of Colorado River and its tributaries may thus be limited to 3,100,000 acre-feet per year." This appears to be a very conservative estimate inasmuch as this period covers several years of severe drought. There is every reason to believe that the future yields will more nearly approach the long-time average which would give Colorado 3,855,375 acre-feet as its share of Colorado River water.

4. Mexican Treaty Commitment

A treaty with the United Mexican States guarantees that the United States will deliver 1,500,000 acre-feet annually to that country. In time of extraordinary drought this amount, under the terms of the treaty, may be reduced in the same degree that consumptive uses are reduced in the United States. The treaty was ratified by the United States Senate on April 18, 1945.

At hearings before the Senate Committee on Foreign Relations, several engineering experts testified that the return flow at the International Boundary would amount to 900,000 acre-feet or more. One, an anti-treaty witness, set the figure at 150,000 to 250,000 acre-feet. In the House of Representative hearings on the Central Arizona Project, H.R. 934 and H.R. 935, witnesses for Arizona set the amount of return flow at 900,000 acre-feet and the burden on the river, the amount of new water to be furnished to satisfy the Treaty demand, as 600,000 acre-feet. Colorado, as has been noted, is allotted, under the Upper Colorado River Compact, 51.75 percent of the (7,500,000 - 50,000) acre-feet allotted to the Upper Basin at Lee Ferry. Assuming a liability in a proportionate amount, Colorado's share of the 600,000 acre-feet to be furnished would be 156,000.

The figure given on p. 7 as Colorado's share of the Mexican Treaty Supply is obtained by assuming that it will be necessary for the Upper and Lower Basins to furnish 750,000 acre-feet of water in addition to a return flow of 750,000 acre-feet. Half of the 750,000 acre-feet must be furnished by the Upper Basin and Colorado's share would be 51.75 percent of 375,000 or 194,000 acre-feet.

Admittedly this quantity cannot be estimated closely. But the amount selected is as good a figure as can be secured for many years in the future, probably over fifty and perhaps one hundred.

5. Available Supply and Total Present and Future Depletions

1.	Estimated Supply (Hill Report)	3,100,000	acre-feet
2.	Now used and encumbered (Engineering Research Committee and Hill Report)	1,650,000	" "
3.		1,450,000	" "
4.	Industry on West Slope (Hill Report)	300,000	" "
5.		1,150,000	" "
6.	Mexican Treaty Commitment (see p. 6)	194,000	" "
7.		956,000	" "
*8.	Private Initiative Land (brought under irrigation in recent years) (106,400 estimated - 68,000 allotted in Hill Report)	38,400	" "
9.		917,600	" "
*10.	Future Private Initiative Land	125,000	" "
11.		792,600	" "
12.	Future Reclamation Projects (see p. 3)	377,000	" "
13.	Surplus	415,000	" " (approx.)

If all projects investigated (preliminary) by the Bureau of Reclamation having (1) a benefit-cost ratio of 1.0 or higher, (2) ability to pay operation, maintenance and replacement costs, and

*Private initiative land is that which has been or will be in the future brought under irrigation by farmers themselves without forming irrigation projects under Federal or other auspices.

(3) ability to pay 7 percent or more of the construction costs, are included, the depletion would be 432,000 acre-feet. Subtracting this quantity from 793,600 leaves a 361,000 acre-foot surplus.

In addition, there is this safety factor: Colorado's share of the water under the compacts referred to above is 3,855,375 acre-feet. Such a supply is conditioned on there being 7,500,000 acre-feet available each year to the Upper Basin States, a situation which may not always obtain as in the case of the 1930-52 period. However, nothing in the history of the flow of the river indicates the low yield of this period is to be a permanent condition. Under conditions which existed from 1906 to 1930, Colorado's annual share would have been 3,855,375 acre-feet if there had been sufficient reservoirs to store the yield of the high-flow years.

Water Supplies in the Several Basins

6. Colorado River Main Stem

A. Supply above Hot Sulphur Springs

In discussing this topic, Mr. Raymond Hill of the firm of Leeds, Hill and Jewett, Consulting Engineers, presents the following figures and conclusions in the report made by this firm on Depletion of Surface Water Supplies of Colorado West of Continental Divide:

> "Transmountain diversions through existing facilities above Hot Sulphur Springs could be 400,000 acre feet per year. This is about 350,000 acre feet in excess of the diversions which were made during the years 1939 to 1949, the period of less than average runoff which determines the safe yield of the stream. This safe yield, after reservoir evaporation losses, is only 420,000 acre feet per year, leaving about 20,000 acre feet per year for maintenance of a live stream. Hence, there is no opportunity for increasing transmountain diversions

from the watershed of Colorado River above Hot Sulphur Springs except to the extent of the allowances already made for present and committed uses." (Emphasis supplied)

Hot Sulphur Springs is situated above the confluence of the Williams Fork River with the Colorado.

B. Supply at Cameo

During the recent severe drought period, the years 1931-1940 inclusive, the average historic flow of the main stem of the Colorado at Cameo was 2,843,500 acre-feet.

The average yearly depletion of the river, for the period 1914-45, above Cameo and including Grand Valley Ditch was 384,900 acre-feet. To this depletion we should add some 44,000 acre-feet for an increase due to extension of farmers' ditches after the original construction, and an additional 82,100 acre-feet for new projects which may some day be constructed (see p. 4). For agriculture, there will therefore be a maximum water consumption (depletion) of 511,000 acre-feet on this portion of the Colorado River system.

Now, if there is added to 511,000 the amount of 300,000 acre-feet to be consumed in the future by industrial and municipal uses, 400,000 acre-feet for the northerly transmountain diversions and 69,000 for the proposed Fryingpan-Arkansas diversion, the total depletion of the main stem above Grand Junction will be 1,280,000 acre-feet.

The average annual virgin flow at Cameo (1931-40) was 2,843,500 plus 384,000 = 3,227,500 acre-feet. Subtracting the consumptive use of 1,280,000 from the virgin flow, there was left an excess of 1,947,500 acre-feet on an average to pass down the Main Stem of the River and out of the State each year of this long, dry period if the river basin had been fully developed.

C. Blue River Water Supply

A study of the yield of the Blue River at Dillon, Colorado, covering the years 1931-53, together with Snake River and Ten-Mile Creek, presents some interesting results. Taking into account the demands at Shoshone and at Cameo, there would have been available for diversion at Dillon 162,000 acre-feet if storage had been provided. In addition, there would have been sufficient yield to permit storage of 100,000 acre-feet in Green Mountain Reservoir each season, and 147,000 acre-feet in this reservoir after years of low runoff to refill the replacement capacity for Colorado-Big Thompson Project. The City of Denver and the Federal Government are presently engaged in a law suit over the rights to some of this water.

D. Effect of Fryingpan-Arkansas Project Depletions

In January of 1955, a study by the Colorado Water Conservation Board of the effect of depletions by the Fryingpan-Arkansas Project on the flow of the Colorado River showed that under the conditions existing in 1931-40, the driest ten years on record, with Colorado's average yearly share set at 2,330,000 acre-feet, there would have been 648,000 acre-feet of uncommitted Colorado water. This water would have

been present assuming that 1,035,000 acre-feet were consumed by agriculture, 60,000 acre-feet were taken for historic transmountain diversions and 587,000 acre-feet for possible additional depletions by present and committed uses.

If we consider the period 1934-53, assuming 1,035,000 acre-feet for agriculture, 131,600 for historic transmountain diversions and 561,000 for possible additional and committed uses, the uncommitted Colorado water amounted to 1,472,000 acre-feet. The share allotted by the Compact would have been 3,200,000. Should Colorado receive its full allotment of 3,855,375 acre-feet, the uncommitted water under similar conditions to the 1934-53 period would amount to 2,069,000 acre-feet, disregarding evaporation losses and salvage gains.

Under the most adverse conditions, the Mexican Treaty might call for 390,000 acre-feet per year from Colorado's share of the river flow. Expert opinion, as has been noted, is divided on this subject, some maintaining that this liability will never amount to half the quantity mentioned.

7. Water Supply of the Gunnison River

The Hill Report states that "Hence, 500,000 acre-feet per year is about the physical limit on diversions from the Gunnison River Basin into the Arkansas River". The proposed Curecanti Dam will be built to create a reservoir of 940,000 acre-feet with no idea of diverting water to the Eastern Slope.

Water is produced in this basin in large quantities, much of which flows across the state line and benefits the State only in helping to supply the required compact flow at Lee Ferry. For 1931-40, this discharge averaged 1,466,660 acre-feet per year, and for the period 1941-50, it was 2,007,000.

8. Yampa and White Rivers Water Supply

Under the Upper Colorado River Compact, Article XIII, the State of Colorado agrees that it will not "cause the flow of the Yampa River at the Maybell Gaging Station to be depleted below an aggregate of 5,000,000 acre-feet for any period of ten consecutive years . . ." An annual average of 50,000 acre-feet might be taken by the State of Utah under this agreement.

During the period 1931-1940, the drought years, the Yampa River passed an average of 852,300 acre-feet into the Green River and out of the State each year. The White River contributed 448,000 acre-feet more. From 1941-1950, the corresponding figures were 1,289,000 and 510,000 acre-feet.

9. San Juan River Water Supply

Under Article XIV of the Upper Colorado River Compact, Colorado "agrees to deliver to the State of New Mexico from the San Juan River and its tributaries which arise in the State of Colorado a quantity of water which shall be sufficient, together with the water originating in the San Juan Basin in the State of New Mexico, to enable the State of New Mexico to make full use of the water apportioned to the State of New Mexico by Article III" of the Compact. This might go as high as 800,000

acre-feet, approximately, in case Colorado secures its full allotment or an amount of 700,000 acre-feet in case the Upper Basin States have storage which limits them to 6,200,000 acre-feet, as mentioned in the Hill Report.

The San Juan and its tributaries took out of the State of Colorado annually during the years 1931-1940 an amount of 1,652,000 acre-feet; the Dolores, 546,200.

For the period 1941-1950, the annual outflow from the San Juan system was 1,956,000, and from the Dolores 700,000 acre-feet.

The Hill Report

10. A. "Conclusions

"We conclude from review of all available data and from independent analyses that:

"1. All of the 7,500,000 acre-feet of water per annum apportioned to the Upper Basin by the Colorado River compact may not actually be available for use because of the requirement that 75 million acre-feet be delivered at Lee Ferry during each consecutive 10-year period.

"2. Compliance with this provision and limiting the carry-over in cyclic storage to the 22 years from 1930 to 1952 would have required that reservoirs of 21 million acre-feet capacity had been available in 1927 for cyclic regulation and that the aggregate depletion in the upper basin be no more than 6,200,000 acre-feet per year.

"3. The total of all depletions at sites of use in Colorado of the flow of Colorado River and its tributaries may thus be limited to 3,100,000 acre-feet per year.

"4. Depletions in Colorado under present conditions aggregate practically 1,450,000 acre-feet per year.

"5. Commitments for extension of existing projects and for other projects authorized would increase present depletions almost 200,000 acre-feet per year.

"6. The present uncommitted surplus which can be relied upon for use in Colorado is thus 1,450,000 acre-feet per year.

"7. Development of the oil shale reserves in western Colorado should be anticipated and the consumption of water for industrial, municipal, and other purposes resulting therefrom may reach 300,000 acre-feet per year.

"8. Consumptive uses by expansion of irrigation on the western slope will depend upon the degree to which new projects are subsidized. Should the subsidy be limited to $200 per acre, the resulting depletion would be no more than 100,000 acre-feet per year. Should subsidies of $400 per acre be given, the stream depletion would be a little more than 400,000 acre-feet per year. Should subsidies as great as $600 per acre be permitted, the resulting stream depletion at sites of use might reach 800,000 acre-feet per year.

"9. Depletions by new transmountain diversions will likewise depend upon the degree to which irrigation agriculture may be subsidized. Some diversions could be financed by municipalities without subsidies, but these would be limited to about 200,000 acre-feet. Additional transmountain diversions for agricultural purposes in any substantial amount would require subsidies in excess of $400 per acre. Even if subsidies as great as $600 per acre were permitted, the total of all new transmountain diversions for all purposes would not be more than 300,000 acre-feet per year.

"10. If subsidies to agriculture at any point in Colorado be limited to $600 per acre, future depletions caused by expanded irrigation on the western slope and by transmountain diversions would amount to 1,100,000 acre-feet per year.

"11. If any greater subsidies were to be allowed, the potential depletion caused by consumptive uses in agriculture and industry and by transmountain diversions would be in excess of the supply of water available to Colorado.

"12. Increased diversions of water for use by agriculture and industry on the western slope and for transmountain diversions will depend upon the provision of sufficient storage capacity in reservoirs for conservation of flood flows and some cyclic regulation; in order that Colorado may make full use of the water allocated to it by the compacts, cyclic regulation of Colorado River over periods longer than 20 years will also be necessary."

B. Possible Diversions

The Hill Report indicates that the following diversions from the Colorado River drainage are physically possible in the amounts shown:

(1) From the Blue, Williams and Eagle Rivers and other streams on west side of the Gore Range some 430,000 acre-feet. This is the supply studied by the Bureau of Reclamation for the Blue-South Platte Project. The City of Denver proposes a diversion of 177,000 acre-feet from a portion of this area. The Report says that both of these would not be possible.

(2) From the Fryingpan River a total of 72,000 acre-feet into the Arkansas River. This is Fryingpan-Arkansas Project of the Bureau of Reclamation.

(3) From the Gunnison to the Arkansas, 500,000 acre-feet.

It should be noted that the Report states that these diversions are physically possible. The economics of the Gunnison-Arkansas and the Blue-South Platte are shown, in this report, to require a rather high degree of subsidization.

The Time Element

11. The Colorado River Project, as recommended to Congress by the Bureau of Reclamation, was comprised of the Glen Canyon and Echo Park Units and eleven participating projects. An illustrative schedule* indicated that the Colorado participating projects of Silt, Smith Fork, Paonia, Pine River Extension and Florida had completion dates of 1965, 1965, 1964, 1970 and 1967, respectively. These participating projects would be completely paid for in 2015, 2015, 2015, 2020 and 2018 A.D. It should be borne in mind that the construction and payment schedules given above are illustrative only. However, they do give a very good idea of the time element involved in bringing this portion of the project into being and paying for it.

*Hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, Eighty-Third Congress, Second Session on H.R. 4449, H.R. 4443 and H.R. 4463, chart facing page 192.

Unless new participating projects displace some of those already up for authorization such as the five mentioned, it seems that they, the new participating projects, are some distance in the future.

Legal Aspects

12. Can Unappropriated Water on Western Slope be Held for Future Use?

This subject is discussed by Jean S. Breitenstein, former attorney for the Colorado Water Conservation Board and now Federal District Judge in Denver, in the Ranch and Farmer, April 10, 1954. His opinions are of special importance because of his long association with Colorado's water problems and are presented here for this reason:

> "The West Slope in its demand for protection of its potentials is confronted with the principle that under the appropriation doctrine of water law the right to the use of water goes to him who first diverts it and applies it to beneficial use. Hence, if a transmountain diversion is made before an in-basin use, it has a priority which is protected by law. There is no method of procedure in Colorado whereby a block of water may be effectively and legally reserved for future use. (Emphasis supplied) The trouble with the appropriation system is that the race is always won by the swiftest. There are probably few who question the wisdom of the principle when it is applied to individual effort. The difficulty arises when consideration must be given to the over-all planning of vast projects requiring federal financing. It is a fair comment that Colorado's existing constitutional and statutory provisions were designed to meet the requirements of the era of private development. That has long since passed. To apply our existing laws to the vast public developments which must occur if Colorado is to utilize to the fullest extent its water resources is completely unrealistic."

Judge Breitenstein continues with the following:

> "Many suggestions have been made. One of these is that a water conservancy district or some other type of

entity should be created on the West Slope so there can be one responsible spokesman for that area and so that a comprehensive plan for in-basin development can be promulgated. Ancillary to this is the idea that if a similar organization were created on the East Slope these two legal entities could by contract agree upon a division of the water. The trouble is that such an agreement would probably not be binding upon individual water users and if it isn't binding, what good is the agreement. Another objection is that such a division constitutes in reality the creation of two sub-states. Each will have the greatest zeal to promote and protect its own welfare. Discord rather than harmony would result. With two sub-states there would be no available legal machinery for composing their differences. When states of the Union get into controversies, they can go to the United States Supreme Court for a decision. There is no such tribunal which can act to resolve the conflicts of the entities suggested for Colorado.

"Suggestions have often been made that the Constitution should be amended so as to relax the appropriation doctrine in its application to presently unappropriated water. At least one student of the problem has proposed that the remaining supplies of unappropriated water should be disposed of under lease arrangements in which continuing state control is assured. Another proposal has been that as to the unappropriated water existing adjudication method should be supplanted by a permit system under the control of an administrative agency. An additional idea has been that limitations should be imposed upon transmountain diversions by all corporations, both public and private, unless such diversions are approved by a state agency. At the moment there seems to be no great support for any of these proposals."

Conclusions

13. Is there surplus water on the Western Slope?

A consideration of the physical and economic facts connected with the water supply situation, lands available for irrigation, and costs of placing the water on these lands indicates that there is no definite answer to the question. Such a consideration leads to the following conclusions:

A. Costs of construction of facilities to bring the water to the land will limit sharply the total amount of land that will be brought under irrigation on both the Western and Eastern Slopes of Colorado. With a very few minor exceptions, lands must be subsidized considerably beyond interest-free construction costs. Of the eighteen projects studied on the Main Stem of the Colorado River, only six would bring in enough return to permit the irrigator to pay ten percent or more of the cost of construction. Of the Gunnison projects, fourteen in number, only two would permit the irrigators to pay ten percent or more of the cost; five would be unable to pay operation, maintenance and replacement costs. Ten percent is an arbitrary figure selected because no project in the Colorado River Storage Bill for which authorization is requested would return from the irrigators less than that percentage. This analysis excludes the five Colorado projects now in the Upper Colorado River Storage Bill for authorization--Smith, Silt, Paonia, Florida and Pine River Extension.

B. The cost of bringing water from the Western Slope to the Eastern Slope for irrigation purposes would entail as great if not greater subsidization than placing it on much of the acreage of the Western Slope. For this reason it seems unlikely that there will be further transmountain diversions of this character; that is, for agricultural purposes except as in the case of the proposed Fryingpan-Arkansas where

Eastern Slope lands with insufficient water supply and suitable for specialty crops could afford to pay more per acre foot for water than a project based on a lower agricultural income economy.

C. There is a demand on the Eastern Slope for additional municipal water. Water is worth much more per acre-foot for this purpose than for agricultural use. A limited amount is available for diversion from the Western Slope in case subsidization of agricultural land is held within the limits discussed on pages 3 and 4.

D. The amount of water available for irrigation on either Slope will be determined by national policy and must necessarily be settled at the Congressional level. The question involved is, to what extent will the Federal Government subsidize the irrigable land? If the limit is greater than $600 per acre, the potential depletion caused by consumptive uses in agriculture and industry including transmountain diversions will be in excess of the supply available to Colorado. (See p. 14)

E. Small storage reservoirs on the upper tributaries, above the participating projects, are an absolute necessity if Colorado is to use a portion of the spring run-off that now goes out of the State. Cyclic storage is also essential. From this storage will come the electrical current which will in a very large measure provide funds for the construction of the participating projects.

APPENDIX

Estimates of Water Supply and Water Requirements

Comparison of Estimates. Several estimates of the balance between the water supplies and requirements of the Western Slope have been made and three have been offered in testimony before committees of Congress. A comparison of these estimates is shown in Table I and graphically on Chart I. The important differences are seen to be:

(1) Merriell's estimate of industrial use and mining is 400,000 acre-feet greater than Jex's, and 500,000 acre-feet greater than the Hill allotment shown in the Crawford estimate. No supporting data is shown by Merriell.

(2) Merriell allots nearly double the amount to future irrigation projects that Crawford shows in his estimate of 377,000 acre-feet. He shows no construction costs in connection with his estimate of 750,000 acre-feet.

(3) Jex allots 259,000 acre-feet to the Mexican Treaty; Crawford, 194,000; and Merriell, nothing.

(4) Jex gives 447,000 acre-feet as the amount Denver claims. Crawford, Merriell, omit this item; Crawford indicates it may come from the surplus shown in his estimate.

(5) Crawford finds that there is a 415,000 acre-foot surplus. However, his estimate does not include the proposed Denver-Blue River Diversion or the Fryingpan-Arkansas.

Conclusions:

a. If the Jex estimate of 447,000 acre-feet for Denver be amended to 177,000, it makes 430,000 acre-feet available for future reclamation projects but nothing for surplus.

b. If the Merriell estimate of industrial use is cut to 400,000 acre-feet and his estimate of 750,000 acre-feet for future irrigation projects is cut to 376,000 acre-feet, there will be a total of 804,000 acre-feet available for the Mexican Treaty and surplus.

Estimates

The first of these estimates in point of time is the one by Mr. Silmon Smith, attorney, of Grand Junction. Inasmuch as it was made before the Hill or Cliffs-Divide Reports, it does not show the most recent data and, consequently, is somewhat out of date. It will be found on p. 225 of Hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, 83d Congress, 1st Session, on H.R. 236.

The estimate of Mr. Clifford H. Jex is to be found on page 406, Hearings before Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, United States Senate, 83d Congress, 2d Session on S. 1555.

Mr. Frank C. Merriell's estimate will be found on p. 435 of Hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, 84th Congress, 1st Session, on H.R. 270, H.R. 2836, H.R. 3383, H.R. 3384 and H.R. 4488.

The fourth estimate, made by the writer, is based on the Hill Report.

An attempt has been made in Table I and a chart to group the estimates of requirements under nine headings, explained later. It has not been possible to break down each estimate with exactness into these headings, but it is thought the results are close enough so that the totals will not be far out of the way.

Comparisons of the estimates, column by column, follow. The chart follows Table I.

Comparison of Estimates

Column 1 - Colorado's Share Colorado River Water

a. The amount of water available to the State of Colorado under the Colorado River Compact of 1922 was set at 3,855,375 acre-feet. Recent hydrologic studies show that in order to secure this amount of water, it would be necessary to provide storage for the Upper Basin to the extent of approximately 38,000,000 acre-feet and that the time required to fill this reservoir space might well be in the neighborhood of 35 years.

TABLE I

	(1) Colorado's Share Colorado River Water	(2) Now Used and Encumbered	(3) Industrial Use	(4) Future Reclamation Projects	(5) Mexican Treaty	(6) Surplus	(7) Asserted Denver Use	(8) Reservoir Evaporation	(9) Private Initiative Lands
Smith	3,855,000	1,673	765	896.5	106.5	0		414	0
Jex	3,037,000	1,646	400	169	259.0	0	447		116
Merriell	3,015,240	1,604	800	757.3	0	0			186
Crawford	3,100,000	1,650	300	377.7	194.0	415.9			162

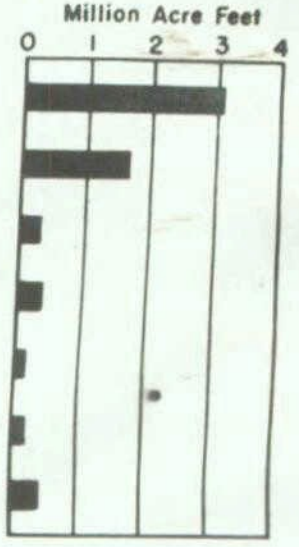
ESTIMATES
WATER SUPPLY OF COLORADO RIVER IN COLORADO

001156

SMITH

Total from the 2 Compacts	3,855,375 A.F.
Now used and encumbered	1,673,000
Industrial use and errors and Municipal use	765,000
Future Reclamation Projects	896,560
Reservoir evaporation	414,000
Mexican Treaty	106,475

CRAWFORD
(Based on Hill Report)



Total available with 22 year storage	3,100,000 A.F.
Now used and encumbered	1,650,000
Industry on Western Slope	300,000
Future Reclamation Projects	377,~~720~~ 000
Present and future Private Initiative Projects	162,400
Mexican Treaty	194,000
Surplus	415,~~660~~ 000

JEX

Total	3,100,000 A.F.
Now used and encumbered	1,646,000
Industrial use	400,000
Future Reclamation Projects	160,000
Present and future Private Initiative Projects	116,000
Mexican Treaty	259,000
Asserted Denver use	447,000

MERRIELL

Total 1930-54	3,015,240 A.F.
Now used and encumbered	1,604,240
Industrial and mining	800,000
Future Reclamation Projects	750,000
Present and future Private Initiative Projects	186,760
Mexican Treaty	0
Surplus	0

587-11026

b. A conservative estimate of the annual water yield available to Colorado, taking into account the period 1930-1952, would be 3,100,000 acre-feet. This quantity would require storage space in the amount of 22,000,000 acre-feet; the time required to fill the reservoir space might be twenty odd years in case the hydrologic conditions of the past quarter of a century are repeated. Jex, Merriell and Crawford agree closely with the conservative Hill estimate of 3,100,000 acre-feet as the amount available at sites of use.

Column 2 - Water Now Used and Encumbered

Encumbered water is considered to be that covered by a water right which is not exercised at the present time.

a. Smith estimate is only 23,000 acre-feet higher than the Hill estimate adopted by Crawford.

b. The Jex estimate is approximately the same as the Hill estimate.

c. Merriell shows the quantity of 1,791,000 acre-feet. He includes 186,760 acre-feet for private initiative land. If this were taken out, the figure would be 1,604,000 acre-feet and this again would be within striking distance of the other three estimates.

Column 3 - Industrial Use

a. Smith allots a total of 742,340 acre-feet. 300,000 is for oil shale and related industry and 389,340 acre-feet to take care of all errors in irrigation estimates, fuel development and

for atomic energy administration. Allowances for these latter items seem to be considerably out of line.

b. Jex estimates 400,000 for oil shale and associated industrial use and 100,000 for other in-basin industrial use. No substantiating data given.

c. Merriell estimates industrial consumptive use at 800,000 acre-feet for oil shale, coal, uranium and general industrial use. Source of data is not given. It would appear that this is more than twice as high as can be supported by any available data.

d. The Hill estimate of 300,000 acre-feet, adopted by the writer, is based on the closely reasoned analysis contained on pages 36-50 of the Hill Report and on pages 19 to 25 of Senate Document No. 23, 84th Congress, First Session, a reprint of the report, a portion of which follows:

DIVERSION REQUIREMENTS AND STREAM DEPLETION

> Failure to distinguish between rates of diversion of water and streamflow depletion resulting from industrial developments has been the source of much misunderstanding. All possible requirements of industry for the diversion of water could be provided for by the construction of suitable physical works. Streamflow depletion, on the other hand, involves the legal limitations imposed upon Colorado by interstate compacts. The diversion requirements of industry may be very large, but actual depletion of the flow of Colorado River at Lee Ferry will be relatively small.
>
> Oil Shale Processing
>
> Mining operations will naturally require very little water. This is fortunate because the cost of pumping water up to the mines would be high. Estimates range from less than 5,000 acre-feet per year to almost 10,000 acre-feet per year for shale oil developments aggregating one million

barrels per day. The most recent and probably the most accurate estimates are about 5,000 acre feet per year for this output of shale oil.

Various estimates have been made by the U. S. Bureau of Mines, the National Petroleum Council, and others as to the quantity of water that would be consumed in retorting oil shale. These range from an estimate of an actual gain to as much as 170,000 acre feet per year of streamflow depletion for an output of one million barrels daily of shale oil. This large value is based upon a retorting process requiring water. There are two basic reasons why this process would not be used on a large scale: First, the retorts would naturally be near the mines, approximately 3,000 feet above the level of Colorado River, so that the cost of delivering water to the retorts would be excessive; second, the process requiring water would result in the waste from retorts being saturated, which would make it impracticable to dispose of the spent shale in the tributary canyons to the depth necessary to accommodate mining operations for an extended period of years. The best estimates are that the actual consumption of water in the retorting process will be nominal and in any event will be less than 20,000 acre feet per year for an output of one million barrels daily of shale oil.

Refining operations may require the diversion of more than 150 cubic feet of water per second, but the actual consumption of water in the refineries will evidently not exceed 50,000 acre feet per year for the processing of shale oil at the rate of one million barrels daily.

Other Uses in Industrial Areas

Various estimates have been made as to the needs of other industries for water and of the quantity of water which would have to be provided to serve the increased population. In one case, it was stated that these requirements would be equivalent to the average flow of Colorado River at Rifle, from which the erroneous conclusion was drawn that industrial development of the area would be throttled if any more water were diverted from the river for other purposes. The writer of this statement was actually referring to diversion requirements which could be satisfied from storage reservoirs and no allowance was made for the very large proportion of the water diverted which would return to the stream system for satisfaction of Colorado's obligations to deliver water at Lee Ferry in common with the other Upper Basin States.

Future depletions caused by industrial and domestic uses of water can best be determined from experience in major industrial centers in the West where the quantity of water produced for use is measured accurately and the quantity returned through sewage systems is likewise known.

In the twelve-month period ending June 30, 1950, the total quantity of water produced for use in Los Angeles and the contiguous cities of Glendale, Burbank, Beverly Hills, and Santa Monica was 444,900 acre feet. The outflow through the sewage disposal plant which serves these five cities was 218,460 acre feet in the same year, leaving 226,440 acre feet unaccounted for by measured return flow. The population of these cities, according to the 1950 census, was 2,245,264. The water unaccounted for was thus one acre foot per year for each ten persons. The actual consumption of water was even less than that indicated because the San Fernando Valley portion of the city of Los Angeles, with a population of about 500,000, is largely unsewered and the return from domestic uses in this area augments the groundwater supplies from which a considerable part of the total water production is obtained.

Recently, a sewerage system was completed to serve the cities of Alameda, Albany, Berkeley, Emeryville, Oakland, and Piedmont in the San Francisco Bay area. During the months of June and July, 1953, a total of 156,400 acre feet of water was delivered by East Bay Municipal Utility District to consumers in these cities, and during the same months 111,700 acre feet were discharged through the sewer system. The quantity of water unaccounted for was thus 44,700 acre feet, which was 29 per cent of the total production. The gross annual requirements in the East Bay Area, including all industrial uses, are in the order of one acre foot of water for each five persons, so that the unit consumption must be about one acre foot of water per year for each 15 persons.

Comparable consumptive uses of water were found to be characteristic of the area served by Denver. Records furnished by that city for the five years from 1946 to 1950, inclusive, showed an average diversion for municipal purposes of 107,000 acre feet per year and returns through the sanitary sewers which averaged 68,000 acre feet per year. This leaves 39,000 acre feet per year as the apparent consumption of water. The average population during the five years was about 460,000 persons, so that the rate of depletion was only 0.085 acre feet per year per capita, equivalent to about 12 persons per acre foot of water per year.

The east shore of San Francisco Bay is highly industrialized and so is Los Angeles and the contiguous cities of Glendale and Burbank.

The population of the East Bay cities is approximately that for which provision should be made on the Western Slope and the population of the Los Angeles area is very much greater. It is reasonable to assume, therefore, that while diversion requirements for industrial and municipal purposes on the Western Slope of Colorado may be quite large, the actual consumption of water resulting in depletion of streamflows should not exceed one acre foot per year for each ten persons. In other words, allowance for the consumption of 100,000 acre feet per year in addition to the actual consumption of water in the mining and processing of oil shale should be ample to cover all other industries and the uses of the population supported by all industries.

It is thus unlikely that stream depletions resulting from full industrialization will amount to more than 200,000 acre feet per year; allowance for depletions aggregating 300,000 acre feet per year would certainly provide ample margin for any conceivable development stemming from processing of the shale oil reserves, and be enough to cover any probable use of the coal deposits.

Column 4 - Future Reclamation Projects

a. The Smith estimate was made before the publication of the Cliffs-Divide Report. Costs per acre of bringing the land under irrigation were not known and hence the estimate represents the stream depletion that would occur if lands were irrigated regardless of cost.

b. Jex makes no estimate of the water requirements for future irrigation projects. Assuming that Denver claims 447,000 acre-feet, he finds that there would be only 160,000 left for development of new land.

c. Merriell sets 750,000 acre-feet as the consumptive use on future Reclamation projects. This figure evidently includes all potential projects regardless of their economic feasibility.

d. The writer's estimate is based on two requirements (1) That the projects have a benefit-cost ratio greater than 1.0, and (2) the irrigator must be able to pay not less than 9 per cent of the construction cost. On this basis there will be a consumptive use of 377,000 acre-feet.

Column 5 - Mexican Treaty Obligation

a. Smith's estimate of Colorado's share is 106,500 acre-feet, while

b. Jex's is 259,000.

c. The writer fixes the amount at 194,000. Engineering experts, as has been noted, disagree and fix the amount as between 200,000 and 750,000 acre-feet as the total liability for the Upper Basin. The second figure would bring Colorado's share up to 395,000 acre-feet as a maximum.

d. Merriell finds no water available to satisfy this obligation.

Column 6 - Surplus

a. Smith says that there will be no surplus. This conclusion comes as a result of very high estimates of industrial requirements and the amount of land available for future reclamation projects. See page 23.

b. Jex finds that there will be no surplus, and that there will be only 160,000 acre-feet for future reclamation projects. He states that the Denver claim is 447,000 acre-feet. Recently according to testimony before Congressional committees, this figure

has been definitely set at 177,000 acre-feet. If this is the case, there would be available 430,000 acre-feet for new projects in the Jex estimate.

c. Merriell, on account of exceptionally high estimates for industrial use and future reclamation projects, finds no surplus.

d. The writer finds a surplus of 415,000 acre-feet, largely because of the application of an economic feasibility yardstick to future reclamation projects, and the adoption of the Hill estimate for industrialization requirements. Water for the Fryingpan-Arkansas Project and for Denver must come from this surplus.

Column 7 - Asserted Denver Use

Jex states that the amount of water Denver has requested is 447,000 acre-feet. Testimony at Congressional hearings does not support this assumption. Denver has now unequivocally stated the amount as 177,000 in recent Congressional hearings.

Column 8 - Reservoir Evaporation

The Smith estimate contains an item for evaporation at storage reservoirs. This is absent from the other estimates because the supply of 3,100,000 acre-feet is the quantity at sites of use.

Column 9 - Private Initiative Lands

(For definition, see page 7)

a. The Smith analysis does not include any allowance of water for private initiative projects.

b. Jex apparently includes 116,000 acre-feet for this purpose.

c. Merriell includes 186,760 acre-feet for this purpose--present and future.

d. The writer has included 162,000 acre-feet in his analysis although it is thought that this amount is entirely too large.

In this type of acreage and in other irrigation projects, the best land with the cheapest procurable water is irrigated first. New acreages will come in lesser quantities each year because they will be less desirable on account of greater unit cost. Therefore, the writer feels that the Jex, Merriell and Crawford estimates are all too high.

The Cliffs-Divide Report, Chapter IV, speaks of such possible developments but gives no information with regard to costs beyond saying "These lands are principally small tracts interspersed with or adjacent to lands presently irrigated. A water supply could be provided by the enlargement or extension of existing water delivery systems or by low-lift pumping. In some cases, it may be found that minor provisions for storage would be required."

It is evident that there has not been sufficient study to determine even in an approximate manner the cost of furnishing those lands with water.