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INTERNATIONAL AND INTERSTATE ASPECTS OF THE COLORADO RIVER PROBLEM[1]

THE Colorado River has a drainage basin 244,000 square miles in extent. Parts of seven states and a small section of Mexico are embraced within this watershed. But the amount of water contributed to the discharge of the river by the several states and by Mexico bears no definite relation to the extent of watershed in each. This will be seen from the following figures compiled from records of the United States Geological Survey:

Political Subdivision	Watershed Area
	sq. miles
Colorado	39,000
Wyoming	19,000
Utah	40,000
Nevada	12,000
New Mexico	23,000
Arizona	103,000
California	6,000
Total United States	242,000
Mexico	2,000
Total	244,000

The mean annual discharge of Colorado River and its tributaries is indicated by the following figures:

Name of Stream	Drainage Area square miles	Discharge acre-feet
Green River	44,000	5,510,000
Grand River (Upper Colorado)	26,000	6,940,000
San Juan River	26,000	2,700,000
Other tributaries, not including the Gila	91,000	1,560,000
Gila River	47,000	1,070,000
Colorado River at Laguna Dam		16,400,000

[1]Symposium on "The Problems of the Colorado River," American Association for the Advancement of Science, Salt Lake City.

Beneficial use of the waters of Colorado River commenced many years ago. No attempt will be made in this sketch to do more than to give the briefest outline of historical facts.

The extent to which the water of Colorado River is being used for irrigation will appear from the following figures compiled by Mr. E. C. LaRue for 1913.

Colorado; area irrigated in 1913 was 440,000 acres.

Wyoming; area irrigated in 1913 was 280,000 acres.

Utah; area irrigated in 1913 was 204,000 acres.

Nevada; area irrigated in 1913 was 5,000 acres.

New Mexico; area irrigated in 1913 was 40,000 acres.

Arizona; area irrigated in 1913 was 315,000 acres.

California; area irrigated in 1913 was 297,000 acres.

Mexico; area irrigated in 1913 was 50,000 acres.

In California the irrigated area now approaches 500,000 acres and in Mexico it is about 190,000 acres. There has, of course, also, been extension of irrigation in the upper states but later figures are not at hand.

No Colorado River water was used for irrigation in Mexico prior to the construction of the Imperial Canal from which water began to be used in 1901. By 1905 there were about 5,000 acres of land in Lower California being irrigated. In 1910 the area was probably about 20,000 acres and in 1920 had reached about 150,000 acres.

The potential use of water from this river and its tributaries can not be stated with any great degree of precision. Some allowances must be made for the fact that just at present each of the several interested states is endeavoring to secure recognition of extreme ultimate possibilities in this connection rather than of early future probabilities. For the purpose of a guide in this discussion the following figures are noted—the endeavor being to include in the areas noted as irrigable only such as would seem to justify construction of works within the next thirty years.

In the Green River Basin the extent of irrigation in 1913 was about 500,000 acres and expansion within thirty years to about 900,000 acres is to be expected; in the Grand River Basin from about 300,000 to about 420,000 acres; on the lower Colorado from about 400,000 acres to 1,500,000 acres; in the Gila River Basin from 280,000 to some uncertain extent possibly 400,000 acres; in the San Juan River Basin from 117,000 to 500,000 acres; in the basins of the lesser tributaries of Colorado River from about 61,000 acres in 1913 to about 160,000 acres, and in Mexico from 50,000 in 1913 and 190,000 in 1921 to 600,000 acres.

After the war between the United States and Mexico the boundary line between the two countries had to be fixed. This was done in a conference resulting in a boundary line treaty consummated in 1848. But it was soon found that portions of the line westerly from the Rio Grande should have been placed further south and negotiations were commenced for a modification of the line. The result of these negotiations (in 1853) was the acquisition of a strip of land, now the south portion of New Mexico and Arizona known as the Gadsden Purchase. There is a story current, though probably impossible of verification and to be considered for the present as without foundation in fact, to the effect that the Commissioners of the United States who made the purchase were given the choice of three locations for a new line. According to this story the line furthest to the south touches the head of the Gulf; but the payments to be made by the United States to Mexico were graded according to the distance that the boundary would be shifted southward and the line requiring the least payment was selected by the United States Commissioners. Whether this story be true or not we can now see how unfortunate it was to have fixed the line in its established position. It should have been as far south as the head of the Gulf of California so that the entire delta of the Colorado River would have been in the United States. The Commissioners accepted a location of the line which may at any time become a source of friction and which has already become a matter of great inconvenience and some embarrassment to the United States. The boundary divides the delta of the river not along a channel, which would be bad enough, but in such a way that most of the delta slope

toward the south and some of the slope toward the north remains in Mexico.

The absurdity of the resulting situation is daily becoming more apparent and the interruption of diplomatic relations with Mexico (from 1913 to date) has thus far prevented the taking of steps to ameliorate a situation, involving river work in Mexico for the joint benefit of the two countries, which is fast becoming intolerable. It may be remarked, too, that the seriousness of the situation and the importance of having adequate control of the delta section of the river vested in some agency which can accomplish results is not generally recognized.

Recall for a clearer understanding of this international political matter the essential physical facts:

The Colorado River was found on a course to the Gulf of California 400 years ago by Spanish explorers. These explorers, too, found a dry Salton Basin. As about 50 years were required to evaporate the water from this basin after the river ceased to discharge into it, there is, therefore, positive evidence that for over 450 years and probably for over 500 years the Colorado River has been flowing down the south slope of its delta cone. There is physical evidence, too, easily read, that in recent geological time the river has repeatedly changed its point of outfall from the Gulf to the Basin and back again to the Gulf. The following reference to the Salton Basin is found in the report of G. W. Blake, geologist of the transcontinental railroad survey, 1853:

"The present outflows, though but very slight, are probably similar (referring to Indian traditions of a great flood), and yet it is possible that the interior of the desert might be deluged at the present day, provided no elevation of the land has taken place and the river should remain at a great height for a long time—long enough to cause the excavation of a deep channel for New River."

The Indian tradition relating to the ancient lake is thus given by Dr. Blake:

"The great water (agua Grande) covered the whole valley and was filled with fine fish. There were also plenty of ducks and geese. Their fathers lived in the mountains and used to come down to the lake to fish and hunt. The water gradually subsided "poco poco" (little by little) and their villages were moved down from the mountains into the valley it had left. They also said that the waters once returned very suddenly and overwhelmed many of their people and drove the rest back into the mountains."

This ancient lake had a total length from northwest to southeast of 100 miles. Its northern limit was several miles above Indio and its southern margin was 15 miles south of the international boundary in Mexico. It has a mean width of 20 miles. The evaporation of this great body of water, after inflow ceased, caused the mineral contents of the water to be gradually carried to the lowest portion of the basin, where a crust of salts, mainly common salt, was left in sufficient quantity and of sufficient value to justify the establishment of salt works, which were operated for some years by the New Liverpool Salt Company.

It is within the area once covered by the ancient lake that all of the improved area of Imperial Valley lies. Calexico, at the Mexican boundary, is at sea level. Imperial, 12 miles farther north, is about 60 feet below sea level, and the cultivated lands near Brawley extend from about 100 to 200 feet below sea level.

At the northern end of the basin is Coachella Valley with Indio farthest north, and Mecca 190 feet below sea-level near the shore of the lake, when the lake was at its greatest extent in February, 1907.

And then there was another Indian tradition to the effect that the Colorado River flowed into a hole in the ground. The explanation of this tradition occurred to the author of this paper a few years ago and seems simple enough. When the Salton Sea was full, its surface extent was about 2,000 square miles. From this large area of water the annual evaporation was nearly 8,000,000 acre feet of water. This is one half of the normal annual discharge of Colorado River and more than the river's discharge in a year of light run-off. There were, therefore, probably periods of time sometimes exceeding a year in duration, aside from the filling period, when the Indian saw a river flowing into Salton Basin and saw no

water flowing out from this basin. What more natural than that he should assume a hole in the ground through which the river poured its waters into the bowels of the earth?

But of particular interest, because of its bearing upon the present discussion, is the main fact that periodically, say for a period of 500 to 1,000 years, the Colorado River had an outfall into the Salton Basin, that is, down the northern slope of its delta cone and again for a similar period of time the river has discharged into the ocean through the Gulf of California.

With this fact in mind let the boundary line be traced from the south boundary of Arizona following up the Colorado River for some 20 miles to Pilot Knob, and thence a little south of west in a straight line to the Pacific Ocean. This boundary line leaves a part of the Colorado River delta, Yuma Valley, in Arizona. It leaves the head of the Gulf of California and the main south slope of the river's delta cone in Mexico; and it leaves the major portion of the north slope of the delta cone, including what is now known as Imperial Valley and also the Coachella Valley, which was once deep under the waters of the ancient sea, in California.

From the earliest studies made of this region by citizens of the United States it is known that the Colorado River originally flowed from near Yuma to the Gulf of California in a meandering channel, having unstable banks, and inadequate capacity to carry all the water presented at flood stages. The distance in an air line from the head of the river's delta to the Gulf is in round figures 80 miles. In this distance the river falls 100 feet. It is about the same distance from the head of the delta to the lowest portions of Salton Basin but as the lowest part of the basin is over 280 feet below sea-level the fall in this direction is nearly 400 feet. If the river should be permitted to flow into the basin it would take 20 or 30 years to fill it up. There was no immediate danger of the river making a change in its course under the natural conditions that prevailed 50 to 75 years ago because at each flood stage the river banks were overtopped; they were well watered far back from the edge of the stream, and carried a luxuriant growth of trees, brush and grass and they were being constantly warped up by the sediment which the muddy water of the river spread out over the land.

But as soon as human activities modified these natural conditions, as soon as a small dredger cut invited the river down the steep northern delta slope, the river broke from its channel and temporarily abandoned its course to the Gulf. This happened in 1905 and it took a little more than a year to put the river back into its old channel. But while this was being accomplished the delta channels went dry. The vegetation on the parched bank land died out and fire destroyed the plant growth in large part which had, theretofore, protected the area nearest the river against erosion. And so, at the subsequent high stages of the river, there was more overbank flow and greater concentration of water in the swales leading away from the river and therefore increased danger of the river breaking out of its original channel. 1907 and 1908 passed without this happening, but in 1909 the river broke a new channel toward the west following the course of what was known as the Rio Abejas or Bee River. The point where this abandonment of the original river channel occurred was about opposite the south boundary line of Arizona.

The river has ever since, except for a few weeks while checked by a levee, been sending its water southwesterly in a round about way, through Volcano Lake and the Hardy Colorado into the Gulf. But its flow westerly was on or near the crest line of the river's very flat delta cone. Its channel is a broad shallow bed of sand of irregular alignment. At flood stages its water submerges broad stretches of country. Its flood waters would preferably drop off the delta cone to the north but have been prevented from doing this by levees. Herein lies the purpose of this statement of physical facts. The levees along the river and along the crest of its delta were and are required for the protection of property in the United States. All of Imperial Valley and of Coachella Valley are menaced. This does not mean that if a breach in the levees occurred and the river again discharged into Salton Basin that all of these valleys would be flood swept. Not at all. The river would simply

flow for a time into Salton Sea doing some damage but it would be turned back again toward the Gulf long before it could make any great headway toward filling the basin.

The interesting fact is that the levees which prevent the river from thus turning to the north and the great undertakings in 1906 and 1907 of turning the river from an erratic course back into its old bed, had to be done in foreign territory, and, moreover, without permission or sanction to do the work by any treaty arrangement. This will be explained by going back a little. When the Colorado River Land and Water Company (after reorganization the California Development Company) determined to put Colorado River water upon California lands it acquired a large tract of land in Lower California just south of and paralleling the boundary line. It organized in Mexico a subsidiary company, the "Compania de Terrenos y Riegos" and through the agency of this company constructed a few miles of canal from the boundary line, near the river, southerly and southwesterly, to a connection with a flood water slough known as Carters, or Salton or Alamo River. Meanwhile a diverting canal was constructed in California tapping Colorado River a few hundred yards north of the boundary line and leading into the upper end of the Mexican Canal. When water was turned into the canal in California it flowed to the Mexican Canal and thence to the Alamo channel and thence back into California. This became the nucleus of the Imperial Canal system. However, after a few years there was trouble at the head of the canal. Its upper section was too flat to pass all the silt entering from the river. And so in 1904 the Mexican Corporation made application to the Mexican Government for a water concession and the right to construct and maintain canals in Mexico. This was granted and provides that water may be diverted from the Colorado River in Mexico or may be brought into Mexico from California and conveyed across Mexican territory back into California, subject, however, to the condition that, to the extent of one half of the water in the canal, the landowners of Mexico shall have the right to use this water for irrigation.

When Imperial Irrigation District was organized and acquired the canal system of the California Development Company, it accepted the same subject to the conditions of the Mexican concession and for the purpose of doing work in Mexico it operates through its subsidiary, the Mexican Corporation.

It will be recalled that in 1909 when the Colorado broke from its channel into Bee River the Congress of the United States appropriated $1,000,000 to be used in protecting the Salton Basin against ultimate submersion. The Colorado River was to be turned back into its old bed and held there. As there was no treaty for the contemplated operations in Mexico, the President designated Mr. J. A. Ockerson to undertake the work. He in turn made the Mexican Corporation his agent and the work went on. It included not only the turning of the river but also the enlargement and extension of the levee north of Volcano Lake which has since become an increasingly important line of defense for the Imperial Valley.

When it is now considered that the control of the floods of the Lower Colorado will benefit about 800,000 acres of delta lands in Mexico and a somewhat larger area in California,—much of this, however, still in wild unimproved condition—the fact will be realized that there should be friendly consultation and cooperation between the United States and Mexico in order that the control of the lower river which must be put in a direct course to the Gulf and which must be kept there, may be placed in the hands of a competent agency, preferably the United States, and that arrangements may be made for reducing the flood menace by storing the waters of the Colorado at some point such as Boulder Canyon.

And then there is needed, too, some understanding between the two countries as to the quantity of water which will be allowed to flow into Mexico. It is probable that under regulation of stream flow by storage there will be enough water for all the lands in the two countries which may reasonably expect it. But practically all of the water which flows in the Colorado River originates in the United States and if the United States should choose to do so and physical conditions permitted, all of

the water could be withdrawn from the river for use within the United States. This will never happen, but negotiations in relation to this matter of giving definiteness to what Mexico may expect have already been too long deferred.

Not only is this the situation with reference to the irrigation use of water but immediate action in the matter of flood control is of paramount importance. On this phase of the problem only a word more need be said. Ever since the river changed its course in 1909 it has been depositing its load of silt, about 112,000 acre feet per year, in the Volcano Lake region. Drift and silt have filled depressions and choked old drainage channels. The first effect of the river's change in alignment was to depress the river's flood plane at the head of the Bee River six or seven feet and thence upstream by decreasing amounts to and above Yuma. But as the years rolled by and the warping up of the Volcano Lake regions has continued, the flood plane has been at a mean rate of about one foot per annum. Where no levee was required before 1908, to the north of the site of the lake (the lake itself has already been filled up with silt and obliterated) there is now a levee 14 feet high, with a railroad on top and with its water slope well faced with rock. And yet last year, 1921, the water at some points rose to the top of this levee. Attempt is now being made to coax the river into a more southerly course, but, even if this should succeed, the outfall of the flood waters will then be on a broad flat area which will quickly be filled to delta crest elevation and the same problem as the one of to-day will remain to be solved. The solution of this problem as already stated is comparatively simple when physical elements alone are considered. It is the international aspect which renders it complex. Action, at once, I repeat, by the United States is imperative.

It may be noted in this connection that about 70,000 people live in the area which is to be protected. Property values of $100,000,000 to $200,000,000 are involved. There are several hundred miles of railroads within the area that must be protected against the floods of the Colorado River.

In the matter of developing and putting to beneficial use the water resources of the Colorado River, it seems self-evident that the greatest ultimate good should be the main consideration. State lines cut but little figure in this matter. Opportunity by any state to divert and deprive earlier down-stream users of their water can carry no right to do so unless this be plainly in the public interest and unless it be done with due compensation for property values that are thereby destroyed.

It is wise, therefore, that steps have been taken for discussion of the river's problem as it affects the seven states within which the waters of the river originate. The Colorado River Commission is the medium for bringing these states into conference. What the outcome of this conference will be remains to be seen. Fortunately the production of water in the watershed of the river is so great that, despite all that can be done on its headwaters, to hold back and use the water locally, there will still enough water get by to make the storage on the lower river and the extension of irrigation in Arizona, California and Mexico desirable and economically feasible.

The development on the lower river is an interstate and international matter. It should be undertaken by the United States. The control of such a reservoir as that which is proposed for the Boulder Canyon site, for example, should never be relinquished to private interests whatever the agency by which the project is carried out. Boulder Canyon damsite is located on Colorado River just above the point where the river makes its abrupt turn from a westerly to a southerly course. It is some 60 miles in an air line above the point where California's east boundary line strikes the river and is but a few miles below the mouth of Virgin River. The Colorado River at this point forms the boundary between Nevada on the north and Arizona on the south. The canyon is narrow, being generally reported as about 250 feet in width for a distance of one half mile. The sides of the gorge are steep. The rock is granite. The project for storage at this site as now favored by the United States Reclamation Service involves the construction of a dam that would rise to a height of about

550 feet above the water surface of the river. The storage capacity of the reservoir to be created by such a dam would be in excess of 25,000,000 acre feet. The discharge of Colorado River at this point may be noted, in approximate figures, as ranging from 7,000,000 to 22,000,000 acre feet per year. The mean annual discharge may be about 15,000,000 acre feet. The surface area of the reservoir would reach 125,000 acres.

The feasibility of a dam of the dimensions proposed seems now to be generally accepted by the engineers who have investigated the dam site. A reservoir at Boulder Canyon would control the flow of Colorado River except the contributions by the Gila River, and the storage could be so manipulated that it would eliminate the lower river flood menace to the extent that this menace is due to up river high stages. Such a reservoir would also regulate the flow of the river for irrigation purposes, thereby permitting the extension of the irrigated area, and would generate upward of 600,000 horse power for electrical transmission.

It is not enough to know that this reservoir should be constructed. Equally important is the matter of urgency. And this applies with equal force to the reservoir control of the river and to the placing of the lower river upon a direct course to the Gulf.

C. E. GRUNSKY

PROGRESS IN POLYNESIAN RESEARCH

IN view of the many inquiries regarding the status of the anthropological studies in Polynesia, undertaken by the Bishop Museum, a summary statement of progress and results appears to be appropriate.

Systematic investigations of the origin and culture of the Polynesian peoples have been conducted by the Bayard Dominick Expedition and made possible by a generous gift of Bayard Dominick, Jr., of New York—funds given to Yale University and placed by the university at the disposal of Bishop Museum. During the summer of 1920 four field parties began their work—the first in Tonga, the second in the Marquesas, the third in Rurutu, Raivaivai, Tubuai and Rapa of the Austral Islands, the fourth in selected islands of the Hawaiian group. Through cooperative arrangements with scientists of New Zealand, physical measurements of the Maori and a complete survey of the Maoriori of Chatham Islands forms part of the program. By the end of this year all the field parties will have returned to Honolulu. These surveys supplemented by investigations in Tahiti and adjacent islands organized for 1923, will complete the present plans of the Bayard Dominick Expedition. Contributions to the physical anthropology of Samoa and of Tonga have been published by the museum; other papers are in press or in preparation for publication.

The prosecution of this search for Polynesian origins aims at the solution of two distinct problems: (1) the source of the physical racial characteristics, which have combined to make the Polynesian physical types; and (2) the source of the original elements which formed the basis of the ancient culture of the people. Dependent upon the solution of these is a third problem: the degree in which racial and cultural transplantation and stratification are correlated.

Dr. Louis R. Sullivan, physical anthropologist of the American Museum of Natural History, is devoting himself to the study of the racial data secured by himself and by other members of the expedition. He makes the following tentative classification of the physical characters which go to make up the two basic elements in the Polynesian peoples:

Type 1 is characterized by (1) tall stature, (2) moderately long heads, (3) relatively high, narrow faces, (4) relatively high, narrow noses, (5) straight or wavy black hair of medium texture, (6) well-developed moustache and moderate beard on the chin, (7) moderate amount of hair on the body and limbs, (8) light brown skin, (9) incisor rim present occasionally, (10) femur flattened (platymeric), (11) tibia flattened (platycnemic), (12) ulna flattened (platolenic), (13) lips above average in thickness. Type I is the so-called Caucasoid element in Polynesia; sometimes spoken of as Pseudo-Caucasian or Pseudo-Mediterranean. Macmillan Brown regards it as Nordic. In its characteristics it is intermediate between some