THE MATTER OF THE COLORADO RIVER

A BRIEF

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The problem of the economic use of the waters of the Colorado River, as well as the best method of curbing and controlling its wild nature, has caused a discussion which has been shared in by many men which has continued over years of time, and thus far little or nothing of a concrete intelligent economic engineering plan has come out of the welter of words and figures, which are more properly a mass of opinions than dependable records.

At this time, the net result of all the discussions, plans, selfish interests and personal ambitions, is, that the Nation is up against a proposition which, if approved by its lawmakers and executive, will mean the expenditure of unknown, but most certainly vast sums of federal funds, for the construction of a project, one in size, in complexity of design, length of time of completion, and one to stagger the imagination of even the most optimistic engineer. And the question is, has the most important, the most absolutely essential vital factor, the one underlying all others; that is, has the correct solution of the intricate problem of the Colorado River, looking not only to the present, but to the years to come with the undreamed development which they will surely bring, been correctly reached. That is the question to which serious study and profound consideration should be given, not only for the interests of the present, but more especially of those of future generations, for the river is their birthright equally with ours. It is far better to avoid making a mistake than to suffer for years from its ill effects, and then to correct it in the end.

Flood Control Most Important Object

It has been, and on the face of assertions, it is still claimed that in point of importance, the results sought to be obtained are in order: Flood control, irrigation, silt control, and lastly, production of power. But an unprejudiced study of the proposed legislation, which is now before Congress, leads unerringly to the conclusion that the latter object

is the one most insistently sought, and the one most predominantly in view. This brings us at once to the important question: Is a vast amount of additional power needed now, or will it be needed within a reasonable lapse of years, in the zones within the limits of which it can be economically transmitted? If the answer is yes, can such power be economically developed on the Colorado River, and if so, should the Federal Government, by the taxation of all of its people, undertake to shoulder the financial burden of providing for the welfare and prosperity of a relatively small number of them at the expense of the rest? The stress which is being placed upon the necessity of curbing the horrific Power Trust, need not be discussed, as the suggestions and thoughts which may be set forth here are intended to be economic and not politic.

The case of national assumption of the cost of flood control of the Mississippi River is quoted in support of the policy that it is the power and duty of the Federal Government to assume the cost of regulating the Colorado River. The two cases are entirely dissimilar. It is undoubtedly law that the National Government has control of navigable streams. Also it has always been recognized that the States have jurisdiction over the beds of navigable streams within their boundaries. The Mississippi River is a navigable stream, and for many years all the funds which the Federal Government spent on that river for flood protection were spent under the guise of improvement to navigation.

The Colorado River is in no practical sense a navigable stream, and since the advent of lines of transcontinental railroads no attempt at navigating it has been made, and it is safe to predict that none will be in the future. These are views which present themselves to a layman, and no attempt is made to construe the law anywhere within the limits of this paper. But the policies of the past are open to the ken of even the non-legal mind.

But assuming that by whatever power or at whose expense the river is to be **regulated**—and by regulation is meant not only its control, but also its development so as ultimately to produce its greatest wealth which is of vast potential value—the question then arises how, or by what plan should such a most desirable and essential end be reached? The assertion is here made, and it is made on a strictly economic operating basis, that no one engineering project, creation, or installation can properly serve the conflicting needs of the various demands which

may be made upon it. The call of power, in the regulation and distribution of water, more especially if it was under legal contract for delivery and the amortization of capital invested depended upon it, would naturally be given first consideration and other needs would suffer.

One Dam Cannot Serve All Purposes

It is not claimed that a makeshift operation would not be possible, but in the case in point the units are so vast and the interests so enormous, that only the best solution of the problem should be found and none other should be tolerated on the plea of expediency. This means that the methods of flood control and of providing for the needs of future irrigation, should be entirely separate from those of power. No heaven born genius has ever yet evolved a machine that will successfully catch fish, lay eggs, and give milk at the same time, and that is exactly what the proposed Boulder Dam is so insistently and vociferously advertised to be able to accomplish. It is this erroneous and loudly asserted claim which is being set forth and being promoted at considerable financial expense by interested parties, that if it should materialize would prove a serious mistake, and one to be regretted and corrected in the future.

Acknowledging that it is easy to criticise and to tear down, it is only just to indicate a way to provide a method of building up, constructive in its nature, one that will lead along true economic engineering lines, and one that will conserve to the utmost the potential resources of the Colorado River, to whose power nature has given control of the weal or woe of millions of our future population.

The potential water power of the Colorado River, has been estimated to be four and one-half million H. P., and the great portion of such power is concentrated in that stretch of the river beginning approximately at Lee's Ferry, near the boundary line between the States of Utah and Arizona and which extends westerly and southerly some four hundred miles to a point about one hundred miles north of Topock, where the Santa Fe Railroad crosses the river. At this point the fall of the river becomes much lighter throughout the remaining distance to the Gulf of California. It is along the former stretch of the river that sites for developing power are found. Scattered along this stretch are many potential dam sites, the most of which have never been tested. The site which has been selected for the proposed enormous dam is practically at the foot of the heavy fall of the river.

A Dam of Doubtful Stability Would Be a Tragedy

A cursory examination of the site does not disclose any serious physical reason to cause doubt, but that, in time, and with much money a dam even of the gigantic proposed section can be built, although its construction involves features and problems which as yet have never confronted our engineers. The burning question is, how much time and how much money will be required; this question has not yet been satisfactorily answered. As no final complete plan of the proposed work is available, in discussions contained in this paper, comment upon its probable stability, if built, is necessarily withheld. It goes without saying, however, that no dam should be built in the Colorado River, the stability of which would be open to the least question, as the collapse of a dam holding back twenty-six million acre feet of water, would entail consequences too fearful to even contemplate. They would stagger the imagination.

Nevertheless, the fact that the engineers of the Reclamation Bureau, whose plans and estimates of cost were made some years ago, as evidenced by their report of February, 1924, are revising such plans at the present time (so reported) would seem to indicate that the Reclamation Bureau is not satisfied with its own plans, and that it is endeavoring to meet some pertinent criticisms, notably the one leveled against the plan of the tremendous weight proposed, forty tons per square foot on the foundations, a pressure fully twenty-five per cent greater than has ever been sanctioned by competent engineers. If such a modification of the plan to the latter pressure is in contemplation, it is pertinent to inquire why nearly five years have elapsed before the necessity for such modification became apparent to the Bureau, and a natural doubt comes to one's mind, as to the technical capacity of the engineers who designed the original plan.

The geological features of the proposed site look to a layman as though a safe foundation could be provided for the dam. While the rock is dense and hard (this applies to both Boulder and Black Canyon) it is coursed with many seams which may properly be called small faults. It is thought, however, that dangerous leakage through foundations and side walls could be prevented by proper treatment. Borings indicate that rock foundation can be had at a depth of one hundred and fifty-eight feet at Boulder and one hundred and twenty-five feet at Black Canyon, neither of which depths are impossible, but which are

complicated in the uncertainty of time and expense occasioned by the very unfavorable conditions which exist.

The great height of the canyon walls (and this discussion applies to the Black Canyon site as well as to the Boulder) which rise several hundreds of feet above the proposed dam, would render construction work awkward and unusually expensive. Heavy expenditures would also be necessary to provide suitable room for camps and locations for construction plant, and the great depth of the canyon would be a costly handicap during the entire progress of the work, and this handicap is one that can not be overcome.

Cost of Dam Difficult to Estimate

One great difficulty in estimating the approximate cost of such a development as is proposed at Boulder Dam is the climatic conditions which prevail for several months of the year. In the intense heat, at times as high as one hundred and twenty-five degrees, with little relief at night, the efficiency of the workers would be much below normal. Shut down in the bottom of a narrow canyon whose walls are a third of a mile high, life even without exertion is barely endurable during those months. All estimates of the value or efficiency of man labor that are not depreciated on account of the fierce heat are valueless; such efficiency as could be obtained would probably not exceed seventy per cent of normal, and this would vitiate any estimate of cost based on what might be hoped for theoretically.

It would be necessary to construct an expensive railway from either the Union Pacific or the Santa Fe Railroad to the site of the proposed work, and the cost of either of these branch lines with equipment is included in the estimates as given in the engineer's reports. The railway would be of no value when the dam was completed, excepting such value as might be found in old material recovered.

The most serious comments as to the feasibility of the construction of this enormous work, can be made as to the difficulties which most certainly would be encountered in putting in the foundations. Volume Number Five of the Bureau of Reclamation Reports, Department of the Interior, covering (Investigations, Plans and Estimates) Boulder and Black Canyon, as of date, February, 1924, goes very much into minute details, and the one predominant note running through it all, is that of extreme optimism. All difficulties are foreseen and discounted, and

means for the elimination of every obstacle are provided. This should offer great encouragement, but an experience of a full half century in construction work, mostly of much less magnitude, forces one to the opinion that if one gets an even fifty-fifty break with fortune, one is lucky. There is reason to believe that the chances might be even less in this case.

While heartily complimenting the Reclamation Bureau engineers on the vast amount, and the infinite variety of details which their work as given in the nine volumes pertaining to the Colorado River contains, most especially as most of the details and conclusions are based upon incomplete data, or none at all, one instinctively thinks of the cynical comment once made on a famous treaty on geology, that "only God could create such a work and only God could understand it."

The method proposed of passing the normal low flow of the river during the work of constructing foundations is explained fully and would doubtless succeed, providing that only low water prevailed while work was in progress. At the same time it is suggested that possibly other means less expensive and entailing less loss of time to care for the water might be devised, one that would obviate the necessity for constructing the tunnels and the really enormous and fantastic temporary cofferdams. This thought is merely thrown out for what it is worth, but it is believed to be worthy of the consideration of experienced, unprejudiced engineers. According to the program, the sequence of construction proceedings as laid down in the engineer's report referred to above, it is proposed to blast, move, and to place in the river for the upper temporary dam alone, some six hundred and twenty thousand cubic yards of rock in sixty-nine days, "or conservatively in three months." Such an accomplishment would certainly mark an epoch in engineering construction, and can be safely regarded as an impossible thing under the conditions.

Hundred Per Cent Efficiency Cannot Be Secured

It is pertinent here to refer to the proposed plant and operation of same. As is entirely proper, the most modern and efficient units of the different classes of plants are evidently planned, and theoretically a hundred per cent plant is undoubtedly to be provided. Practically we never get such a one, and generally much less, very much less do we get one hundred per cent operation, even under conditions which are nearly ideal, and such as do not labor under the severe handicaps which

would inevitably and constantly harass work in the deep canyon. If one can, over a long period of time, obtain eighty per cent efficiency under favorable conditions of a good plant, one adapted to the work in hand, he is doing very well. If he thinks that he is doing much better than that, he is probably setting his standards too low. To expect such results in the operation of plants as are confidently predicted in the engineer's report, is to close one's eyes to the realities of the situation, and to a forecast of the conditions which would probably confront one. With all due respect to the profession, one is forced to say that a "few feathers plucked from the wings of imagination and inserted in the tail of judgment," would cause more reasonable estimates of time and money to be made. The "temporary" cofferdams in themselves are no mean undertaking, and their successful completion in two or three times the number of days predicted could justly be regarded as a piece of exceedingly good fortune. Incidentally, in passing, it may be remarked that if these dams **should** fail during such a flood as the one of 1920, the resulting rush of water below the canyon would probably amount to four hundred thousand cubic feet per second, or to more than five times the danger point in the lower river. This is not pleasant to contemplate, but it is one of the contingencies which is possible.

Problems of Construction Are Serious

The excavation of the hundreds of yards of mixed material for the placing of the concrete in the permanent dam, below low water, presents an extremely difficult and uncertain problem. Passing over any comments in regard to the very optimistic predictions in the matter of operation of the plant, one is confronted with the tremendous uncertainty as to what the river would do meanwhile, and whether in its vagaries and humors it would synchronize with the different stages of construction work as so confidently prophesied. Dame Nature does not work on any exact fixed schedule, especially in the case of mountain streams, and the times and occasions when she elects to go on the warpath are matters of the utmost uncertainty. It is entirely within the realm of possibility, nay, it may be probable, that floods may occur the result of which would be the filling up perhaps several times of the partially or wholly completed excavations, in which case neither the length of time necessary to do the work nor its cost could even be approximately foretold. This would be the major difficulty which would confront the engineer, and it is serious enough to cause one of experience

to fail to share the optimism which is so confidently expressed in the report. All of which, in connection with the other unusual features, makes one regard the estimate as given as the cost of the work, to be of even doubtful approximate value, the chances are that it would greatly exceed it, probably by many millions.

It sounds good and is soothing to the proponents of a big proposed work to have some experienced engineer or contractor, perhaps disinterested, declare that the estimate is ample, and that the work can be done within its limits, but it is quite another thing for him to enter into a formal contract accompanied by an air-tight sufficient bond which can be enforced in case of failure. It can be confidently expected that if tenders were received from competent and reliable contractors for the foundation work especially, they would much exceed the estimates set forth in the reports. The only safe method for a contractor in bidding on this work would be on a cost plus basis, which of course could not be considered.

Capacity Requirements of Reservoir and Dam

The acre foot capacity of the proposed five hundred and fifty-foot high dam is entirely unnecessary for the legitimate purposes to which the dam might be put. In fact four million acre foot storage has been declared by experts as sufficient for flood protection. But it is evident that a flood of two hundred thousand cubic second feet is not a record. Evidence exists, which while perhaps is not an official record, but which is competent evidence, that the Colorado River has carried floods of twice that size or four hundred thousand cubic second feet, and perhaps more. But as far as human foresight can judge, undoubtedly a provision for a reservoir capacity of ten million acre feet would be ample, and this of course would be in excess of requirements for irrigation for many years to come. As far as provision for eliminating silt is concerned, that will be considered later.

Geologists tell us that the Salton Sea was formed by the action of the river in depositing silt, forming a dam which cut off the upper end of the Gulf of California. Now the Virgin River, which enters the Colorado but a short distance above the site of the proposed dam, carries but a small amount of water, coming as it does from a comparatively level desert region. But its lower valley would contain about one-fourth of the acre feet of the proposed Boulder Dam reservoir. There is reason to suppose that a certain deposit of silt in the reservoir

would cut off the Virgin River Valley capacity and the effect of the high dam would, in producing storage capacity, be diminished at least one-third or some eight to nine million acre feet. But the extra height of the proposed dam would be needed for power purposes, and for nothing else, and that is the true purpose of its proposed creation. In all of these comments the term "Boulder Dam" is used, as it is the term generally known to the public, although a site in Black Canyon has been selected for the proposed mammoth structure.

The Power Situation

It is set forth, although hard to believe possible that its proponents are sincere, that the sale of power will in time repay the Federal Government for its expenditure of funds for the construction of the dam, power plant, transmission lines, interest, and so forth, as well as the cost, interest and so forth of the so-called "All American Canal," of which latter more anon. This amazing result is predicated upon such unknown and uncertain factors as to seem to be not much more than a beautiful dream.

The loud and insistent present demands for power and more power, are not apparent; at least, if they exist, they exist only in a remarkably quiet form. There is no demand for any power of consequence in the zones of practicable transmission of electricity east of the Colorado River. The claim is made that Southern California, which may be called the Los Angeles District, is being held back in its expansion by lack of power. Recent guarded inquiries indicate as a fact that the private companies producing electricity have a surplus of power on their shelves, and are keeping well ahead of demands and sales, and can continue to do so.

In the matter of price, that is an unknown quantity, for living man cannot in the least forecast what it would cost the Federal Government to produce power in the unknown future at Boulder Dam, for no living man, engineer or layman can safely set the limits of the cost of the plant, and it would be probably not less than ten and possibly twelve years before anything like approximate correct figures of cost of power could be made available. But with the constant reduction in the cost of production of electric power, by the use of oil and gas as valuable in producing steam, and the very certain tremendous overhead expense which would be incurred in building the dam and its accessories, it is more than doubtful if water power at Boulder Dam could meet steam power

on the coast in even equal terms of price. The loud and insistent demand for power seems to resolve itself into the claim of the Los Angeles District that it must have large quantities of cheap power to enable it to pump water some two hundred and fifty miles over a mountain range, or else its growth will be stopped and its people suffer the pangs of thirst. And it wants the balance of the United States to pay for producing such power.

The claim that it has exhausted all practical sources of water supply in its immediate region may be correct. But so far, we have only exparte evidence as to the correctness of such a claim. Equally competent and credible witnesses declare the contrary, and it would seem to be common business prudence for the Federal Government to ascertain what are the facts in the case before launching out millions of dollars of the people's money to build a power plant in the Colorado River Canyon, simply for the benefit of the Los Angeles District, for that is the real purpose of the movement. A suggestion is made that a small committee of eminent disinterested hydraulic engineers, the members to be chosen east of the Rocky Mountains, might be able to give us the truth in regard to available water supply in Southern California. One cannot avoid thinking of San Francisco and Hetch Hetchy. Neither can one forget that there are large areas of desert land in the district mentioned, where even a promise of water to be provided through the beneficence of Uncle Sam, would revive a land boom which long ago lost its former magnificent proportions.

Government Would Shoulder Large Loss

It is entirely problematic when, granted that the Boulder power plant is built, the Federal Government could begin to realize from its sale of power to Los Angeles or to whomsoever the contracting party or parties might be, and neither could it know in advance how much or how little its income would be from such source, as that would depend wholly upon the amount of power used, and that again upon the amount of water pumped. Some two hundred and fifty thousand H. P. is mentioned as being needed to pump water, but this is merely guesswork of the rankest sort, no one can forsee with the least degree of certainty. It is possible, nay probable, that power to be generated at the proposed dam would find no market in competition with other sources of supply, and that the Federal Government would enjoy no revenue whatever from its investment. It would be left to hold the bag filled with de-

ficits, and to the melancholy satisfaction of viewing an imposing monument to unrealized hopes.

The provision in the proposed legislation before Congress under which the Secretary of the Interior must obtain valid contracts for the sale of power in sufficient amounts to assure the financial safety of the project before any actual construction work is begun, would be humorous only, if it were not nullified by another clause embodied in the bill. The provision that responsible business concerns would enter into legal contracts to purchase power ten to possibly fifteen years in advance of delivery is too puerile to be seriously considered. The whole proposed financial scheme as set up is either the product of amazing ignorance, or a carefully wrought out plan intended to lull the fears of taxpayers, probably the latter. If the Boulder Dam project goes through upon the basis as set up, the Federal Government will shoulder a very large financial loss for many years to come. From a business point of view the thing is hopeless, and it is easy to conceive what an association of clear headed business men accustomed to handling large financial undertakings would answer if it was submitted to them as the basis of an investment.

All American Canal

Attached as a sort of vermiform appendix to the legislation proposed for Boulder Dam is the so-called All American Canal. This is a very peculiar proposition and one that possibly contains dynamite. The present so-called Imperial Canal which supplies water to the Imperial Valley, to lands both in the United States and Mexico, was built years ago under an arrangement made by private United States citizens and the Mexican Government. In return for a right-of-way for the canal over a part of its course where it runs in Mexico, the Mexican Government receives by agreement one-half of the water which the canal carries, and this agreement has been carried out and has been lived up to since the canal has been in operation, although as yet the amount of water delivered on the Mexican side has never yet reached the full one-half. The lands which are under cultivation across the international line, and which are served by the canal, are largely owned by Americans and devoted to the raising of cotton, and very successfully.

The reasons for the building of the proposed new canal, all on American territory, are not convincing. One argument advanced is

the necessity of having a canal which could be protected in case of war with Mexico. Such a contingency is unthinkable. As a matter of fact, in such a deplorable event the present canal could be as easily protected as could one wholly on American soil immediately paralleling the international line. Another reason advanced is that we could take all of the water away from Mexico; this of course should never be considered, as such a suggestion is utterly repugnant and entirely out of line with justice and fair dealing. The United States has, in its policies in dealing with smaller nations, always gone beyond the strict letter of the law, has in fact been generous, as it should be.

Furthermore, while the arrangement in regard to the present canal probably does not commit our government to anything, the Mexican Government would not so regard the situation if the matter came up for negotiation, and it would insist that in any new arrangement, its present rights would be continued. Our relations with the Mexican Government, and with those of the other Latin American countries are not so amicable that we can afford to throw fresh fuel onto international fires. Before anything whatever is done in regard to future regulation and disposal of the waters of the Colorado River, an amicable treaty with Mexico should be negotiated and concluded between the two nations.

While the construction of an All American Canal presents some unusual features, such as the digging very deeply through several miles of drifting sand dunes, it is not impracticable. Its cost would be heavy and its maintenance a grave problem, but both can be accomplished at a price. But it is difficult to understand why or how the lands on the American side in the Imperial Valley could be any better off, or better served than they are by the present canal, and there is no apparent reason why they would be. The majority of the farmers there are tenants, and it is not so much a question of the struggling individual farmer to whom benefit would come, but to large corporations, and to absentee landlords. Naturally the bulk of the people there favor the building of the new canal, for the expenditure of millions of government money in their midst would be very satisfactory to them. It would likely start a boom in lands, the sale of which is now, owing to the uncertainty which is hanging over the valley, practically nil, and many of the present holders are looking for a boom in order that they may sell and leave the valley. The subject of this proposed canal is here touched upon, because its cost is included with that of the Boulder

Dam, and undoubtedly was with the hope that the latter will carry the former along with it in legislation. There is no valid reason apparent why the All American Canal should be built at all.

Flood Control and Irrigation Needs May Be Co-ordinated

The Federal Government has long pursued the established policy of supervision, control and the financing of irrigation. By the action of the recent Congress in regard to the Mississippi River, it may be assumed that the Federal Government has embarked upon a similar policy in the matter of flood control. Fortunately these two major demands in river regulation so co-ordinate that the planning of works to make both effective is much simpler than if it was complicated with the one of developing power. To reiterate: works to control floods and to regulate the distribution of water for irrigation can, as an economic engineering proposition, be one and the same thing, to be located as near as conditions will permit to the lands to be protected and to be benefited, and nature has fixed such a location in Mohave Canyon to conserve the lands in the lower valley and the delta of the river.

The needs of irrigation in these districts require no comment, neither does the operation of irrigation plants. The need for flood control, particularly in the Imperial Valley, has been so widely heralded, and the danger to which that district is exposed has been so long the topic which has filled the minds of its people, that it has cast a shadow over every enterprise in the region. It claims and deserves protection, but its case is somewhat dissimilar to that of the Mississippi Valley. There human life is threatened whenever a flood goes over the river banks. But in the Imperial Valley floods for several years could break through the levees and unless a person deliberately got into its path his life would not be endangered. The Salton Sea could for a number of years absorb annually recurring floods before the rising waters would encroach upon the farms and homes in the valley itself enough to imperil human life. Property losses would undoubtedly be great, and until safety from floods is assured the valley will not go forward to its full development, or capital and labor rest in confidence. Therefore the work of providing for the elimination of this blight which now hangs over a wonderful region, should go ahead to completion as rapidly as possible.

Proposal of Dam in Mohave Canyon

The best location for a dam in Mohave Canyon is at a point about two and one-half miles down the river from Topock. At places in the canyon the walls are several hundred feet high, and at the location in question they narrow down to a width of two hundred and fifty feet. The general character of the rock is described by the geologist as being granite. It is massive, hard, and "there is no reason to doubt that in strength and resistance to leakage these rocks are very satisfactory for the foundations and abutments of a dam." "In other words, if a dam is built at this site, it is believed that it would effectually close the basin to the north, there being no possible seepage through unconsolidated materials at the same or lower levels." Further investigation is, however, recommended, as no borings have as yet been made.

A dam to raise the water ninety-five feet would create a storage capacity of four million acre feet, and would reduce to seventy thousand second feet a flood like the one of 1920. But conditions would seem to justify that greater provision should be made to provide for flood control, and the extremely favorable features of the site, having in mind the regulation of water for irrigation, flood control, and the elimination of silt, that the dam should be higher, and all factors considered, a dam of one hundred and fifty-eight feet in height above the level of ordinary low water would seem to best fulfill all of the economic requirements. Such a dam would create a storage capacity of ten million three hundred thousand acre feet. It is estimated that the net amount of yearly evaporation would not exceed fifteen thousand acre feet. Such an unusually favorable site is remarkable, and it is probable that few if any other sites exist anywhere in the United States, excepting where a natural lake can be utilized, that offers such storage capacity, with a comparatively low dam such as can be built at this location, and at such low cost. And yet this site has been ignored by Reclamation engineers, as far as making any borings to ascertain the depth of foundations, as in fact have practically all other dam sites on the river, the only sites seriously considered being those of Boulder or Black Canyon, which, without any definite knowledge, at least any that is public in regard to other sites, are pronounced the best, in fact the only ones. Many competent engineers take issue with them in this respect. Mohave damsite is easily accessible, far more so than any site on the Colorado River, being only two and one-half miles distant from the main line of the

Santa Fe Railroad. Its many favorable features are well set out on pages thirty-seven and thirty-eight of Water Supply Paper 556, United States Geological Survey, Department of the Interior. The dam can be built in three or four years time and thus provide a quick means of relief from flood menace that offers anywhere along the river, in contrast to a delay at Boulder Dam of providing such relief of from eight to possibly twelve years.

The building of such a dam would require the changing of some twenty miles of the Santa Fe railway track, giving the latter a much better line over that distance, better grades, better alinement, and a double track bridge across the river, which it has not at present. It would also necessitate the moving of the railroad town of Needles to a higher location, a fine site for which is available. In view of the great improvement of the railway by reason of the change, it is altogether likely that the Railway Company would readily approve such a change.

As noted above, no mention is made of utilizing a dam at Mohave Canyon for the purpose of generating power. While a moderate amount of power could be produced by such a dam, for reasons discussed elsewhere, such a proceeding would not conform to correct principles nor be economically justifiable.

In view of its many advantages, it would seem very singular that no borings have been made at this site, and one can only conclude that it was condemned, or at least passed over intentionally. However, the report of the Designing Engineer to the Chief Engineer of the Reclamation Service, as of October 8, 1923, of his visit to the site is distinctly favorable, both as to the general situation and probable depth to bedrock, which he estimates at one hundred and twenty feet (same as at Boulder), but nothing further was done excepting to make a very elaborate detailed estimate, which is chiefly remarkable for its mass of details, bearing in mind the lack of necessary data. This estimate totals, roughly, twenty-six million dollars. Included in this total is four million seventy-five thousand dollars for right-of-way, and eight million five hundred thousand for moving the railway. Buried in the latter item is an unknown amount for "capitalization for increased length of line", but no credit is given for better alinement, for reduced grades, for less rise and fall, or for the larger value of a double track bridge over the present single track one. The item should be reduced at least two and one-half million dollars.

Mohave damsite offers the lowest damsite on the Colorado River, the one nearest to the lands to be irrigated, and nearest to lands, property and people to be protected from flood menace. It would almost seem that nature had designedly indicated a plain remedy for whatever menace the river may afford, as well as an evident method whereby man can avail himself most readily of the natural value of the Colorado River. It is generally agreed by all parties that regulating works for flood control and for the purpose of irrigation should be located as near to the people and to the lands affected as natural conditions will permit, and the site in Mohave Canyon fills this requirement perfectly.

Silt Problem Bound Up With Control and Regulation

One of the most important subjects to be dealt with in any discussion of plans for regulating the Colorado River, is the one of silt, of which such enormous quantities are constantly being carried in suspension at all times in the waters of the river. Enough valuable data has been gathered about silt to make volumes, and now apparently the novelist has broken into the field. Its presence in the waters, and the deposits of silt which occur whenever and wherever the velocity of the current is checked, is the cause of great expense, and is an ever present handicap to the successful irrigation of lands lying under the systems which carry the water of the river, both main canals, laterals, and field ditches. The annual cost to the owners and cultivators who must use the water is incalculable, although one authority claims that three dollars per acre per year represents about the cost on a certain five hundred thousand acre area. In any case, it is an extremely serious problem.

The only remedy, and that is only partial, that so far has been applied, is to hold the silty water in quiescence as long as possible, or as long as the demands upon it will allow, and this can only be accomplished by creating large reservoirs or basins by the construction of dams where the greatest capacity can be had at the lowest cost. But the soil of the river bed and of its banks, where it is other than rock, is of such a character that once water is released from these reservoirs, only partly cleaned, it soon picks up enough silt on its headlong course to the Gulf, that the problem again soon becomes acute, and there is at present no apparent means by which the trouble can be entirely eliminated; the best that can be hoped for is a mitigation of the difficulty. To this end every dam which is built on the river must perforce con-

tribute in proportion to the capacity of the reservoir which it has created. And so every such reservoir, from the upper reaches of the river down to the lowest intake dam, must act as a catch basin, ultimately to be completely filled, unless the silt is removed, which can only be done by constant, persistent labor.

Taking the figure of eighty thousand acre feet capacity per year required to store the silt load at Yuma, a merely theoretical calculation can be made as to where and how such an acreage can be made available. It is admitted by everyone, as reputable authority, that the nearer to the irrigated lands that settling basins can be located, the more effective they will be in operation. Upon the theory that eighty thousand acre feet of silt annually passes through Mohave Canyon, and that all of it, an impossibility, could be held up in the reservoir created by the suggested dam in that canyon, then it would take one hundred and twenty years to completely fill the ten million three hundred thousand acre feet capacity reservoir, which would of course put it at the end of that period out of commission for the purposes of irrigation and flood control. But it could take and hold that amount of silt for sixty years and still have a capacity sufficient to take care of its two designated functions. And sixty years is a long time, and before it elapsed other reservoirs could be created at relatively short distances above which would materially lessen its heavy burden of silt, and thus extend its life indefinitely. A certain amount of relief can be obtained from time to time by sluicing out relatively small quantities of the silt through outlets provided for that purpose, and thus lengthen the length of time when the reservoirs would be filled, and thus, so to speak, prolong their life.

And all the time every reservoir created on the river from Green River down, on the San Juan and the Little Colorado, would, in all probability, be taking some of the burden. Especially so in regard to the immense reservoir created by the Marble Gorge Dam, and every power dam which might be built from there down to the foot of the rapid fall in the river. The silting up of a reservoir created by a dam built solely to develop power, would not affect its value for such a purpose, as long as it kept its height of fall, or head, and its flow was regulated by such works as are suggested at Marble Gorge, which would prove of inestimable economic value.

The land owners and tenants of Imperial Valley are anxiously looking to the Federal Government for relief from the handicap and

expense caused by silt, which as far as now known cannot be given excepting in a degree. Officials of the largest owners and operators in the valley assert that they can "take care of themselves for several years if then the Government will come to their relief." Of course if such relief, or relief to any extent can be afforded as an incident in connection with dams and reservoirs for flood protection and irrigation, well and good, but upon what theory the Federal Government through taxation of all of its people should assume any other burdens is difficult to understand.

The whole matter of relief from silt deposits is bound up with the control and regulation of the river. It is thought that it would be quite equitable, fair and honest that if the present generation solve such problems, as in this case for a couple of hundred years to come, that the people of those far away future years could justly be expected to take up and solve any such problems which might then confront them.

Regulation of River for Power Development

Assuming that the great wealth of the Colorado River which exists potentially in the form of power, will in some future time be developed, and made to serve our increasing population, how best, and how with true economy should it be done. There are very few streams on which power is, or can be developed, which will give a regular flow of water without artificial regulation, and the Colorado River is decidedly not one of them, and regularity of flow is a vital necessity in the certain and economic production of power. And the proposed Boulder Dam would be in the worst possible location as a regulator of the river for power purposes; it would be absolutely valueless to regulate the three million or more H. P. which could be developed in the river above it.

As before noted, the point where the rapid fall of the river begins, that is, the point where its value for power purposes first becomes available, is near the line between Arizona and Utah, and that is where regulation works should be installed, and where sites for such works exist, which, however, have not been thoroughly enough investigated to base a decision as to which one should be selected. The reports of the Reclamation Bureau go somewhat into the availability of these sites, and elaborate detailed estimates are embodied in these reports. But in the apparent irrevocable decision approving nothing but the Boulder Dam site and plan of a structure, which contrary to established stand-

ards of economics would be expected to do everything, all other sites and plans have been thrown into the discard.

The one site at the head of the rapid fall of the river which seems to best fill all of the conditions to be met, is located in Marble Gorge, some three miles below the well-known Lee's Ferry.

At this point the State of Arizona, aided by the Federal Government, is just completing a highway bridge across the river, a remarkable structure, a single span of six hundred feet in length with a deck level of four hundred and sixty-five feet above low water, the highest vehicular traffic bridge in the world. This bridge is located about one hundred and thirty-five miles north of Flagstaff, its nearest railroad point. A good highway extends from Flagstaff over about sixty miles of the distance and it is the intention of the State to complete this highway north to the Utah line, crossing the Colorado River on the new bridge above mentioned.

The gorge at this point is about four hundred and fifty feet in depth, six hundred feet in width at the top, with almost vertical walls, and its geological formation is, from the top down, hard limestone, hard sandstone, both very massive and compact, and below these what is termed Hermit Shale, which analyzes about seventy-two per cent silica. It is a very hard rock, capable of sustaining a tremendous load, and as far as investigations have gone, impervious to water. Test cores taken from the bed of the river in solid formation, show a compressive strength of from eleven thousand seven hundred to fifteen thousand nine hundred pounds per square inch, a strength far in excess of what concrete would be required to show. Only a limited amount of drilling has been done at this site, and more should be, as the site offers such favorable features for the location of constructing a high dam for the regulation of the river, that it merits the fullest investigation, which it has not had, for obvious reasons.

The dam suggested at this site would be approximately four hundred and fifty feet in height, and would provide storage capacity of eleven million acre feet, and would create a lake some one hundred and sixty miles in length, which incidentally would provide a unique and wonderful attraction for the constantly increasing thousands of tourists of our mountain regions.

Below this dam site in the three hundred and fifty miles of river length, which covers its heavy fall, there are at least ten damsites

where two thousand five hundred feet or more of fall can be utilized to develop power. Without storage of water, the total power capacity of these sites is one million seven hundred and fifty thousand H. P. With a regulating dam at Marble Gorge built to store eleven million acre feet of water the power capacity of these ten sites would be increased nearly fourfold, or to four million three hundred thousand H. P. And it would greatly reduce the cost of installing power plants down the river, by permitting dams of a reasonable size and cost, to be built from time to time as power needs increased. Power in large amounts could of course be developed at Marble Gorge Dam, if considered advisable, but it is believed that a true economical solution of the problem would be the installation of smaller dams below, built to conform to the call for power, and only as it was needed.

The estimated cost of a properly designed and consequently safe dam for this site, and one that would largely assist in accomplishing the results so vital to a true solution of the river problem, both plan and estimate having been made by thoroughly competent and experienced engineers, not in anyway connected with any government bureau, is available. The estimate discloses that assuming that the depth to which foundations must go down would be one hundred and thirty feet, as the limited borings indicate, the cost, excluding interest during construction and cost of the highway from Flagstaff, in round figures would be twenty million dollars, and including the above omitted items would be twenty-two million six hundred and seventy thousand dollars, of which one million dollars is allowed for highway construction, which probably is an improper charge, as the State is going ahead to build the highway. No railway would be needed, as the highway would fill all transportation needs, and already, with no highway over some seventy-five miles of the distance, excepting such as nature has provided, all of the material, including the heavy steel sections which went into the construction of the new highway bridge, has been successfully transported by motor trucks from Flagstaff to this dam site. Material for construction with the exception of cement can be found within reasonable distances from the site. Room for working yards and for camps are ample and immediately at hand. The fact that the plateau through which the gorge cuts its way is practically level, a mile or more in width on each side of the gorge, free of lateral gorges, and at the level of the top of the suggested dam, makes the location ideal from a construction standpoint. It is so far superior in this respect to that of Boulder, that there is no comparison whatever.

As remarked above, thorough tests by borings should be made at the site and for half a mile at least above it. But the writer feels very confident that the results of such tests would fully confirm his opinion that the Marble Gorge site for a high river regulation storage dam would demonstrate its excellence for the purposes named and would justify the cost of its erection.

Considering the vast increase in potential power, two million five hundred thousand H. P., which would result down the long reach of the heavy falling section of the river, from the erection of a dam at Marble Gorge, it would seem that no valid argument could be brought against the policy of such development.

Granting that additional power will be needed as the years go on, the policy of installing smaller plants down through the canyon as they are needed, keeping down excessive capital charges and interest, and avoiding the old and oft fatal mistake of putting the eggs all in one basket, would certainly be founded upon correct business principles, such principles as seasoned business men would adopt in planning investments which they would expect to show a fair return.

An Important Financial Aspect

There is another phase of the problem which is of interest when the financial aspect of the problem comes under discussion. The Federal Water Power Act, which after some twelve years of deliberation became a law on June 10, 1920, provides, among other things, Regulation Fifteen, Section One, "Whenever any licensee hereunder is directly benefited by the construction work of another licensee, or a permittee, or of the United States, of a storage reservoir, or other headwater improvement, the Commission will require as a condition of the license that the licensee so benefited shall reimburse the owner of such reservoir or other improvement for such part of the annual charges for interest, maintenance, and depreciation thereon as the Commission may deem equitable." Here then would be a constant and certain revenue which would accrue to the regulating dam at Marble Gorge, a charge legally levied on every H. P. ultimately installed up to more than four million along the river through the canyon. But no such revenue could be collected for the Boulder project, as it could not, owing to its unfortunate location, afford any regulation of the river for power purposes whatever.

If the Federal Government is to be committed to the policy of providing power for selected localities and people, at the expense of its entire population, there would seem to be no valid reason why it should not do so through its legally constituted instrument, the Federal Power Commission, whose powers seem to be broad enough to cover almost anything on any stream whether navigable or not, and if those powers are not ample, Congress could make them so, in view of the arbitrary action which is proposed in the much discussed Boulder legislation. If the Federal Government goes into the Boulder Dam project as a financial proposition, the people as a mass will be the ones really doing the gambling, and should acquaint themselves with the true inwardness of the situation, and to whatever extent the Federal Government is overlooking its hand.

Proposed Legislation a Grave Injustice to Arizona

If the Federal Government goes into the business of developing and selling the power of the Colorado River, private capital might or might not interest itself in like manner; probably it would not, at least not until the government had by experience demonstrated, as it would be certain to do, its utter inability to successfully handle such business, and had written off its losses, while the people would "pay the freight." Meanwhile the State of Arizona, which owns three hundred and forty miles of the heavy falling river and a one-half ownership in one hundred and twenty miles of the rest which has water power value, would be deprived of receiving any revenue whatever from one of its most, probably the most, valuable of its assets. From every point of view, excepting that of pure selfishness, and with no condoning features whatever, the proposed Boulder Dam is worthy only of condemnation. It is "neither fish, flesh, fowl, or good red herring."

The State of Arizona is relatively poor. Much of its area is taken up by mountains of little or no value agriculturally, and of problematic value as producing minerals. She has thousands of acres of desert lands which for topographical reasons can probably never be irrigated. Large areas within its boundaries are occupied by Indian Reservations, over which it has no control and derives no revenue. Its lands which can be made of agricultural value are desert and can become an asset only by the application of water through irrigation. She has nearly a million and a half acres of choice arable desert land, about twice the area of the State of Rhode Island, land and water included,

which lie immediately adjacent to the Colorado River, and which are well located for natural irrigation, and can be so irrigated when the need for such irrigated land becomes apparent, providing she can retain the use of her own water for the purpose. These lands are now frozen assets, but will become of immense value to her in the future if she can hold what is entirely her property until such time as she can realize. The State asks no charity and no consideration beyond what is her due in strict justice. If the great State of New York happened to want the building material which composes the State House of Connecticut, and the Federal Government through the discovery of some fancied constitutional power should approve New York's action in taking Connecticut's Capitol Building without remuneration, it would differ in degree only and not at all in principle with the action which is sought to be forced in the Boulder legislation.

In passing it may be remarked that when speculating on any probable income which might accrue to either Boulder or to Marble Gorge plant, that the latter would cost about one-half as much as the former, and consequently its value from a capital investment point of view would be doubled.

The results of the research work and of the experiments in which science is engaged may modify or greatly change our economic structure. Only a few years ago one who would have predicted that such a marvelous thing as radio existed, and had only to be harnessed, would have been regarded with mild amusement. Scientific people are working on the theory that invisible power exists, but if so, whether it can be harnessed in sufficient amounts for the use of man they have not as yet discovered. It would be no greater marvel if the two questions are answered in the affirmative, and if they are, then possibly the investment of huge amounts of capital in enormous hydraulic power plants may be poor judgment even at this time. No one should be rash enough to predict to the contrary, for time alone will tell.

The compact between the seven states which was attempted but never consummated, aimed to arbitrarily divide the water of the river between the two groups of states in the basin, four in the upper, and three in the lower, the line of division being fixed at Lee's Ferry. Various and somewhat widely different figures are given by authorities as to the average annual flow of the river. The belief is held here that this average flow is represented by the lesser rather than by the larger fig-

ures. It is hoped that a recent check which has been made by competent parties will make clearer the real situation.

It is a matter of principle, however, and not altogether one of quantities with which this discussion is concerned. Under the proposed division of the water, forty-eight per cent of the whole would come to the two States of Arizona and California, and of this amount California claims two-thirds, which claim if granted, would leave Arizona but eighteen per cent.

As has already been shown, Arizona owns three hundred and forty miles of the river in its entirety, and it also owns a one-half interest in common with Nevada and California in three hundred and eighty miles more down to the international boundary line. In other words, Arizona owns more than seventy-three per cent of the river south of the Utah line, and the area of land in the Arizona basin is nearly twenty times that of California, and in this basin she has more than three times as much arable desert land lying immediately adjacent to the lower river than has California.

And Arizona's share of the waters of her own river, despite her overwhelming preponderance of desert land capable of irrigation, is allotted, as the compact would work out, less than one-fifth of the water which theoretically would pass into the lower basin. This in effect means that at least a million acres of Arizona's best land, areas that would possess, with water, vast potential value, must forever remain a desert, instead of being transformed into thousands of farms, the products of which would add millions of wealth to the state.

This confiscation of Arizona's own water which in effect would be spoliation of her domain, together with depriving her of legitimate income which ordinarily would come from improvements installed and operated within her boundaries, would constitute two of the most flagrant of the many samples of injustice which selfish interests are seeking to force upon her. And the Federal Government, probably without constitutional authority, is asked to cast the mantle of its great power over the proceeding.

There are many details in the proposed legislation, and with hardly an exception they are all detrimental to Arizona's interests, and to her future. But as this discussion is limited to economic engineering features, further comment upon politic matters need not be continued.

CONCLUSIONS

That the time has arrived when comprehensive economic engineering plans should be adopted for the control of, and the development of the Colorado River.

That the only urgent necessity for control and development at the present time, is for flood control and incidentally for irrigation, and the elimination of silt.

That the pressing need for large additional quantities of power is not apparent, and that an inquiry should be made by disinterested parties to develop the real situation.

That the problems of flood control and irrigation synchronize in operation, but that they do not with the operation of hydraulic power, and therefore should be separated from it.

That the proper location for works to control floods and to distribute water for irrigation is in Mohave Canyon.

That development of the Colorado River means Regulation, and that in turn means the adoption of methods which will result in the scientific and economic supervision of its waters under all conditions.

That practically all of the hydraulic power of the river below Lee's Ferry which is of potential value, is located between miles three hundred and seven hundred, measured from Yuma.

That only by a constant uniform flow of water when hydraulic plants are in operation, can reliable and economic electric transmission of power be successfully secured.

That the power developed in hydraulic plants, is derived solely from the gravity of falling water, and that electricity is merely a form of transmission of such power.

That the power which can be made available at various points along the river, miles three hundred to seven hundred, should be developed in relatively small units, and at such times that will correlate with actual legitimate demands.

That the construction of abnormally large hydraulic plants for the development of huge quantities of power, at enormous cost, is contrary to economic and well established business principles.

That the construction of such a plant as is being urged and known as Boulder Dam cannot be recommended for the above reasons, among others.

That the location as selected for such plant is evidence of poor judgment and that the true economics of the situation have not been thoroughly studied nor understood.

That works to regulate the flow of the river in order to develop to its fullest extent the latent power which it possesses, should be located a short distance below Lee's Ferry.

That complete and thorough investigations, including extensive drillings of the bed of the river, should be made in that vicinity to determine the best site for a dam.

That thorough drillings should be carried out in Mohave Canyon with as little delay as possible.

That drillings should be made at two at least of the obvious dam sites above mile three hundred and fifty, to determine the best location for the first power plants to be installed.

That no dam should be constructed of such dimensions that would result in a pressure to exceed, as a maximum, thirty tons per square foot on its foundations.

That the planning, calculations of, and the estimates of cost of any dam to be built in the Colorado River, should only be entrusted to a commission of thoroughly competent and conservative hydraulic engineers and geologists.

That the recent collapse of large dams conceived and created by one man's initiative and responsibility, fully confirms the wisdom of this conclusion.

That while the Federal Government has engineers of undoubted ability in the Bureau of Reclamation, it also has many fine engineers in its other departments, whose knowledge and experience should be made available, as well as that of engineers in civil life, whose knowledge and judgment is not cramped and dwarfed by the paralyzing blight of "System," which is the inevitable accompaniment of bureaucracy.

That the regulation of the Colorado River does not call for the construction of a reservoir for any purpose whatever of a capacity of more than ten million acre feet.

That the construction of a reservoir of twenty-six million acre feet by means of the Boulder Dam, is wholly unnecessary, and that its promotion is being urged primarily for the purpose of developing power.

That the fact that criticisms and unfavorable comments upon the plans and estimates of Boulder Dam were repressed by the Bureau of Reclamation, and that engineers of other departments were estopped from being consulted, gives rise to the thought that confidence in its own engineers may not have been overly strong.

That the modifications reported as being made in the plans of nearly five years ago, indicate that its designers themselves doubt the suitability, and possibly the safety of such a dam.

That no dams of any size, excepting the comparatively small one suggested for flood control and the regulation of water for irrigation, should be built in the Colorado River until the whole important subject of regulation has been studied and threshed out by a body of competent engineers.

That such a body should be made up not only of representatives of the different departments, but also of representatives of engineers in civil life.

That such a body of engineers should be provided with ample funds by special appropriation, to enable it to secure the necessary data which is now lacking.

That the construction of an All American Canal is not necessary and cannot be justified.

That it is not a wise move for the Federal Government to embark upon a policy of manufacturing and selling power, a policy which will inevitably lead to a huge wastage of the people's money.

That transportation and other service corporations are regulated by Federal or State law, and there is no apparent reason why power companies cannot be.

That any proposed legislation concerning the Colorado River, which may become law, should be based upon justice and fair dealing in all matters affecting the States concerned, as well as upon economic business principles. In these fundamental essentials, the proposed legislation for Boulder Dam is decidedly not in harmony.

That before any important change is made, or any final determination is reached in the matter of the regulation of, or the disposal of the water of the Colorado River, an amicable understanding should be had by the Federal Government with the Government of Mexico.

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Denver, Colorado,
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