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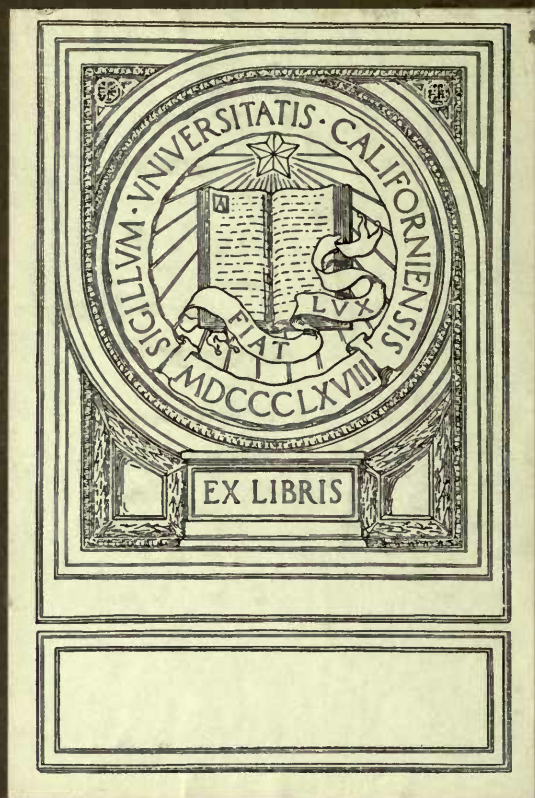


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The Problem  
of the  
Lower Colorado River

by  
C. E. Grunsky

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June 30, 1907







C. E. P.

The Problem of the Lower Colorado River

W. H. Hensley, Consulting Engineer in the Reclamation Service.

June 30, 1907.

Sir:

GENERAL STATEMENT.

A comprehensive study of the situation on the Colorado River below the Grand Canon, must include a consideration of the main facts relating to a utilization of the river's water for irrigation in Lower California, Mexico and in the Imperial Valley, Cal., as well as of the physical features of the river country and of other lands which the river commands and furthens. In this presentation of the subject, consideration will, therefore, be given to the character of the Colorado River, in the last 40 miles of its course, to the scenery through which it flows to the development already accomplished and prospective in the region bounded by the river and finally to the relations which the two countries, the United States and Mexico, should assume in the matter of holding the river on a permanent course with outfall into the Gulf of California.

THE LOWER COLORADO RIVER.

At the present time (June 1907) the Colorado River flows to the Gulf of California, as it has flowed for more than 500 years, excepting the period of a little more than a year (December 1796 to February 1907) during which it took an inland course. The river as it issues from carries the runoff water from a drainage basin of about 225,000 square miles. This drainage basin includes some of the highest portions of the Rocky Mountains. It extends into Wyoming, includes the portions of Colorado, Utah and Arizona and some parts of Nevada, California and New Mexico. Below these some additional areas fall within the river's watershed notably the southerly slope of the Sierra Madre Occidental in Mexico. All these areas are well supplied as water producing because the rainfall over them is a light, only 2 to 3 inches per annum, but there is practically no runoff from them. All the water of the Colorado River is therefore to be considered as originating in the United States.

The river flows entirely within the United States to a point at Pilot Knob about 7 miles below Yuma. From that point, at which the main boundary line of California strikes off westerly toward the Pacific Ocean, the right or west bank of the river is in Mexico, and the left or east bank within the United States. The river in this corner boundary between Lower California, Mexico and Arizona for about 18 miles.















THE DISCHARGE OF COLORADO RIVER.

The spring rise of Colorado River is caused by melting snows and some rainfall in the upper portion of the river's drainage basin. It commences usually about April first but its beginning may be as much as a month earlier or later. Ordinarily the rise is gradual with slight fluctuations and irregularities in the rays of rise until the maximum stage is reached. This is generally at or soon after June first but may be as late as the end of June or beginning of July. The river at Yuma frequently flashes up, sometimes to a maximum stage in the months of January and February due to a freshet flow of the Gila River which enters the main stream just above Yuma. The river also shows frequent lesser disturbances caused by the Gila in the fall of the year, but these rarely reach the maximum stage, though it may happen, as on November 29th and 30th, 1905, that extreme flood conditions, of short duration result from these unseasonal freshet stages.

The normal condition of the river is indicated by the following figures, which are based on the river's discharge from 1894 to 1905, both inclusive, at Yuma:

The year, 12,000 sec.ft. 8,930,000 acre ft.

It should be noted in this connection that if any weight be given to the river discharges indicated by the gage readings at Yuma between 1876 and 1894, the above normals would be materially reduced and that if the year 1906, which was a year of about twice the normal flow and 1907, which gives promise of being the same, were included in the computation, a material increase of the above figures would be the result. The maximum discharge for the year 1907 (to date) and probably for the year, occurred on June 23rd. It was estimated on the basis of a gaging at 112,000 sec.ft. (Probably somewhat in excess of the actual discharge).

THE LOWER COLORADO RIVER VALLEYS.

After the Colorado River emerges from its canons in which it is closely confined by the cliffs which rise from its bed to great heights, it flows through a succession of valleys encompassed by low ranges of mountains and hills and separated one from the other by the relatively narrow gorges at the points where these mountains approach or extend to the river from opposite sides. It may be noted in passing that these gorges are the sites that first attract attention as possibly favorable locations for dams. Many of them have been examined with a view to ascertaining the depth to bed rock but in no case, with borings to 100 ft. in depth, has bed-rock been found continuous from bank to bank.

The lower river valleys begin a short distance above Mojave more than 400 miles from the river's mouth and may be said to terminate with the Yuma Valley which lies east of the river below the mesa at Yuma. The Yuma Valley is practically







also a part of the delta cone of the river. This delta cone spreads out fanshaped from the head of this valley toward the south and west and finally swinging around toward the north, sloping far to the northward into Imperial Valley.

The river in its course through the lower valleys is a broad shallow stream. Its width is generally 600 to 800 ft. At some points it is much wider. It carries a large amount of sediment, much of which is a very fine silicious sand. In consequence of the muddy condition of the stream at all stages and the unstable character of the land resulting from the deposition of this sediment, the river has a pronounced tendency to build bars wherever an obstruction retards the flow of water and to cut new channels into or across its friable banks. During the low water period the river is a shallow stream, its line of greatest current meandering from side to side of its broad flat channel. At high stages the flow is in better accord with the alignment of its banks and its current is swift as may be expected in a stream with a frequent annual maximum discharge of about 100,000 sec.ft. and a fall of more than one foot per mile.

At high stages, and particularly at a stage about bankfull, after the river has been high for some time, it develops a strong tendency to attack concave banks. The breaking away of several hundred feet of bank in a single season, in fact within a few weeks, is said to be a frequent occurrence and much more is known to have been cut away in a season at certain points where sharp concave turns subjected the bank to more than ordinary attack. Where the river has long straight reaches, its banks acquire a certain amount of stability. In such reaches the swiftest current is off-shore near the center of the channel. The banks are protected by weeds, by willows and by occasional patches of reeds (carisa) which overhang the bank slopes. The roots of plant life matting near the surface and the slimy deposit from the river water, add to the stability of the material of which the bank is formed. Such a straight reach may be maintained until some such circumstances as the lodging of a snag with accumulations of drift disturbs the regularity of flow and causes one bank or the other to be attached or until a concave bank from above works its way down the valley and gradually invades and destroys the straight reach.

Throughout its entire lower course, wherever flowing between alluvial banks of recent formation, the river when at full flood is at or above a bankful stage. This does not mean that the riverbanks are awash at all points, because there are always some places where sedimentation has progressed less rapidly than at others, but that at its highest stage the water must be at or somewhat above the general level of the high bank lands which are the result of sedimentation that could not have taken place except during occasional submersion.

It is hardly necessary to add that this river, whose water is, as stated, heavily charged with sediment, belongs to that type of streams whose banks grow by sedimentation more rapidly than the country back from the stream; that, therefore







there is a slope inland away from the river, which becomes more and more pronounced the longer that the river holds to a particular alignment. The portion of the river under special consideration, that is the river from Yuma to the Gulf of California, has advanced so far in this direction of building up high bank lands that the danger is imminent of a sudden permanent change of alignment such as that which has recently been checked under great difficulties and at great expense.

It is to be noted however, that there is a force opposed to that which would turn the river from its course and across country to a new point of outfall. This is the resistance offered to the overbank flow, by the vegetation which springs up and grows luxuriantly on the well watered lands that flank the river and the many high water channels in which overflow waters accumulate. So it happens that the delta cone of the river, the Yuma Valley and the country which slopes away, fanshaped, from near Yuma to a southern limit at the Hardy Colorado and a western or southwestern limit at the base of the Cocopa Mountains, is, in its natural condition, well watered in parts and densely overgrown with vegetation particularly near the river and that thus a grass, weed and tree covered barrier of high ground has been interposed by nature between the Colorado River and the great depression in the northwest toward which the river would like to take its course if permitted.

#### IRRIGATION ON COLORADO RIVER.

The water of some of the streams whose discharge goes to make up the Colorado River, is already in part utilized for irrigation. The exact amount of the area already thus served is of little moment in the present discussion, because the excess water over and above that required for this irrigation, is the water yet to be apportioned to lands commanded by the river but not yet irrigated, i.e., the water still flowing in the Lower Colorado.

In order, however, that it may be understood that such irrigation is already established and is of notable extent though in many cases with inadequate systems the following figures are quoted from the Bureau of Census report for the year 1902:

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Other lands which should be served with water by the Colorado River and its tributaries, apart from the Gila, which contributes only irregular freshet flows to the lower river, may for the purpose of a general discussion be assumed at the following figures:

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These figures do not include lands other than in the Imperial Valley which are already under ditch. They may be considered to represent the area served or to be served with water that under present conditions reaches Yuma and the international boundary in the main channel of the river.

For the irrigation of this land 4,000,000 to 5,000,000 acre-feet of water per annum will be required. This is about one-half of the river's normal flow. It is about equal to the river's run-off in a year of minimum rainfall. But even in years of maximum flow, this water could not be made available for the land at times and in quantities required by irrigation without storage. Storage is essential for the regulation of the river's flow to meet the needs of the land, to make the surplus of the spring months available in summer and autumn. Consequently storage of the river's flood waters must be made a feature of every general Colorado River project. Storage to a considerable extent is feasible moreover, it being known that large reservoir sites exist on some of the tributaries of the main river, and a combination storage and silt trapping reservoir at some point below the Grand Canon is not out of the range of possibilities.

It may be anticipated, as one project after another, by private enterprise, or under Government aid and supervision is carried to successful completion that the shortage of water will in the course of time at certain seasons become a matter of moment and will be made a matter for joint action by all parties at interest, or possibly congressional approval might be secured of a comprehensive project for this river which would at the outset include this storage feature.

In consideration of an arrangement with Mexico, this feature and the other question relating to the best point on the river for a permanent diversion of water for use in the Imperial Valley are of minor importance and uncertainties and unsolved problems relating thereto need not delay action in the main matter now under consideration. It should, however, be made clear to Mexico that the extension of irrigation in the United States will materially deplete the ordinary flow of the river below Yuma and that ultimately even under such agreements, as hereinafter suggested, the United States would be compelled at times to furnish, some water from artificial storage basins to Mexico to meet deficient river flow.

#### THE RIVER'S DELTA CONE.

There is good reason for assuming that at one time the Gulf of California extended about 150 miles further toward the northwest than it does to-day and that the mouth of the Colorado River was then at Yuma. The discharge must have been at sea level as the water surface of the river is now at 117 to 130 ft. above sea level, the river was then more than 100 ft. deeper in the ground than it is to-day. The sediment which it brought to its outfall upon the easterly shore of the long arm







of the ocean has in the course of time built up the barrier which now separates Salton Basin from the Gulf of California and has contributed materially to the filling in of the lowest portions of the great depression which before its recent submersion was still at about 280 ft. below sea level. It is not necessary to follow closely the processes by which the delta was given its final shape but a general reference to its present physical features will aid in the study of the recent phenomena.

From a point opposite Pilot Knob about 8 miles below Yuma, which may for convenience be regarded as the apex of the river's delta cone, the land falls away toward the south and southwest. In the direction toward the Gulf of California this fall may be noted at about 110 ft. in 80 miles, toward the southwest on the shorest line toward the Cocopah Mountains the fall is 80 ft. in a distance of about 40 miles, but with a gradient at points near the river of 3 ft. per mile, the country flattening out as distance from the river increases; westerly swinging around the southerly edge of a broad expanse of sandhills the general fall of the ground's surface is about 3 ft. to the mile increasing above this amount northerly toward the Salton Sink. Before conditions had been modified by the construction of artificial channels, there was a frequent overbank flow from the river to the right and left. The river banks were ordinarily submerged only to a slight depth and the overflowing water did not as a rule concentrate in pronounced depressions or high water channels until it was at some distance, generally several miles from the river. As the overbank flow was widely distributed and generally of comparatively short duration, and as the periodical occurrence of this overflow stimulated plant growth, there was small chance of any such high water channel cutting back to the main stream. There is no doubt, however, that there have in the past been sudden radical changes in the river's course, and that the river has swung back and forth a number of times from one extreme location to another on the delta cone. But from the records of the early explorers, Diaz and Alarcon, in 1540; Don Juan de Onate in 1604; Padu Eusibio Francisco Kino in 1701 and 1702; Ugar in 1721; Fernando Corsay in 1744; Padre Garces in 1771 and 1776; Lieut. R.W.H. Hardy of the British Navy in 1826; James P. Pattie and father in 1827 and from the later records of the settlement on the river at Yuma by our own people, and the explorations of Lieut. G.H. Derby in 1850-51 and of Lieut. J.C. Ives in 1857, it is known that the river has for some 500 year until the recent break, held to its present course, from Yuma to the Gulf, making only such lesser changes of alignment as must be expected on any sediment carrying river such as the Colorado.

Among the high water or overflow channels several are worthy of note. There is one far down on the stream on its easterly side in Mexico, Rio Santa Clara, which is supposed at one time to have been the river's main channel, and which again becomes notable on account of a report brought in by an intelligent Indian that during the present freshet of the river (May and June, 1907) this slough has again become the river's







main outlet to the Gulf. It is stated that practically the entire river now takes its course through this slough which is more than 40 miles long and enters the Gulf upon its easterly side about 20 miles southeasterly from the present mouth of the river.

Santa Clara slough and numerous other smaller inundation or high water channels on the east side are however of no material concern in this discussion, except that if the fact is as reported and the river is now flowing down the Santa Clara, it serves as a further illustration of the ease with which the Colorado River turns from its present course.

It is to be noted, however, that on the east side there are high water channels of similar character though of lesser capacity and extent than upon the west side and that the same natural tendency exists to pour water overbank upon the east side as upon the west. As illustrations, there may be mentioned a low east side depression with upper end only on short distance below Yuma; and again at the big bend now known as Nigger Bend, the American slough which though breaking out from the river, had no great capacity and is now shut off by the levee of the Yuma Reclamation Project.

On the west side of the river is by far the greater portion of the delta cone and it is with this that the problem of the Lower river has special concern. The drainage system of this region appears complicated if an attempt is made to trace out the network of overflow channels and drainways, some of which are yet immature and difficult to follow while others scatter their waters over wide areas from which the outflow may be in several directions.

Paredones River is reported to have had, in the past, a direct connection with Colorado River. Evidence of such connection still exists in the shape of several shallow depressions or inundation channels of small capacity in the river bank. These have been so reduced in size by sedimentation of their beds and banks that at all points within several miles of the river they appear as insignificant channels on low flat sediment ridges. But further inland the Paredones, collecting overflow from a considerable area, part of which was until modified by artificial works tributary both to this river and to the Alamo, becomes a channel of considerable width and depth and is capable of carrying a large volume of water, southwesterly down what may be considered a median line of the delta cone. During the unusual outpouring of Colorado River water in 1905 and 1906 there was a large run of drift down the Paredones. This accumulated along a stretch of this channel some 6 to 8 miles above Volcano Lake and caused the Paredones to enlarge some of its inundation channels, particularly some of those leading off toward the south. In its condition of a few years ago the Paredones like the main Colorado was sometimes bank full and spilled over in low places, sending some water southerly into feeders of Pescadero River and some northerly into







the overflow region between the Paredones and the Alamo from which through several channels known as Garza slough and some recent unnamed washes it entered New River, or at times in part flowed into the northerly end of Volcano Lake.

Alamo River as originally known had its gathering ground at the northerly edge of the delta cone, along the southerly base of the sand hills already referred to, which overlap the International boundary from the north extending westerly from Pilot Knob for some 30 miles. The river took a westerly course spreading out here and there in broad sheets, 'Las Lagunas', and finally, in a well defined channel, emerged from mosquito thickets somewhere near Seven Wells. It crossed the International boundary line at a point about 40 miles westerly from Colorado River and is reported to have occasionally carried water as far north as Salton Sink. The overflow water within Mexico from this stream could not flow north on account of the sand hills, but the stream could spill over to the south. At Las Lagunas there was a channel, Quail River slough reported to have carried some of the water there accumulating, to the Paredones. Lower down the outflow was into the low areas between the Paredones and the Alamo from which with Paredones water its course was westerly into New River. One of the main points of outflow from the Alamo was at Beltran Slough, which may be regarded as a feeder of the low region drained to New River by Garza Slough. In fact, since the recent long continued outpouring of the river's flood into the regions drained by the Paredones and the Alamo, the two sloughs are said to represent practically a continuous waterway.

New River in its upper portion near Volcano Lake may be a remnant of the overflow channel which led from the ancient inland lake of Salton Basin hereafter described, to the Gulf of California. For some miles northerly from Volcano Lake this river is located at the base of the Cocopah Mountains. It holds this position until well within the area once covered by the ancient Salton lake then continuing in the same general direction and crossing the International boundary at Calerrio, it followed (before the recent change of regimen) a gentle depression down the lowest west side portion of the valley to Salton Sink. At certain points of its course it spread out in a broad channel 8 to 12 ft. in depth, forming occasional ponds or lakes. Such were the well known Cameron Lake at Calexico and Blue Lake some miles further north. It is now in a great barranca from a point about six miles south of Calexico to its outfall into the Salton Sea.

Pescadero River is on the southerly slope of the river's delta cone. It receives overflow water from the Colorado and from the Paredones. All of its flow is westerly toward Volcano Lake, southwesterly toward the Hardy Colorado and toward other channels leading ultimately into the Gulf of California. The Pescadero and a network of other channels are the drainways of that part of the delta cone which lies west of Colorado River and has a slope toward the Gulf.







Volcano Lake, like New River, may be a remnant of the old overflow channel from the ancient Salton Sea to the Gulf. It is a flat basin five or six miles long from northwest to southeast and about three miles wide. Its bed is about 10 to 15 ft. above sea level and its high water stage is reported at about 34 ft. The lake receives water from Paredones River, from the Pescadero system of sloughs and from other overflow channels that carry Colorado River flood waters westerly. Its position on the summit of the low flat divide between the Gulf and the Salton Basin is such that its discharge is both toward the north and toward the south. By far the greatest discharge has in the past been toward the south into the Gulf of California, if the size of outlet channels be accepted as a criterion. The outlet toward the north is New River, which leaves the lake at its most westerly point near its northerly end. The water leaving the lake at that point is divided almost immediately after it has entered New River, a part flowing south in Salt Slough, which drops its water into the Hardy. The rest remains in New River which has a channel several hundred feet wide with bank height of 8 to 10 ft. Toward the south the main outlet is Hardy Colorado, which is a broad, deep channel of large cross-sectional area, possibly 500 ft. wide and 20 ft. deep at maximum stages, but of relatively light gradient, its total fall dependent upon lake stage ranging from 15 to over 30 ft. in a distance of 45 to 50 miles. Besides the Hardy a number of small sloughs lead from the lake toward the south. During the exceptional conditions of general inundation which prevailed between the Alamo and Paredones rivers in 1905 and 1906, a new broad channel was eroded from this region into the northerly extremity of the lake.

Some of the channel changes which have recently been made by the inland flow of Colorado River have already been referred to. Most pronounced as a result of the great flood discharge across a region of considerable surface slope and for the most part unprotected by vegetation, has been the cutting out of deep barranca like channels. Near Colorado River the changes in the condition of overflow channels except in the case of the Alamo have been few. The gouging out of the great barrancas commenced far to the north, in California, where the waters of the New and Alamo rivers swept over a flat surface having a gradient of 4 to 6 ft. per mile toward the lowest points of the basin in which their waters were accumulating. Both Alamo and New rivers so far as they lie in California were converted into deep gorges with vertical crumbling banks. Their water surfaces originally submerging adjacent lands are now 30 to 80 ft. in the ground. The New River barranca from Calexico to Salton Sea has an average width of about one quarter mile. The head of this barranca is some 6 miles south of Calexico in Lower California, toward which point from Calexico there is a gradual decrease of width and depth. Above this point there are a number of channels or washes of less depth in which the flood scattered its energy. These channels mark on the ground the course which was taken by the Colorado River waters during the time the river discharged inland. At first







the excessive volume of water coming down the Alamo spread out in Las Lagunas, most of it reaching the next lower section of the Alamo and the remainder going through Quail River Slough and other depressions to the Paredones. Later the Alamo became a deep and well defined channel through Las Lagunas and its main overbank discharge was concentrated at and some distance below Beltran Slough. The result of this concentration was a cut through the river bank at a point near the old station, Alamo Mocho, about 2 miles below Beltran Slough from which the water took a course southwesterly toward Pink Mountain. This cut from the Alamo is wide and deep. It has been closed by an earth dam in order that the water coming down the Alamo for the canals of Imperial Valley may continue on to Sharp's Heading.

### SALTON SEA.

The most noteworthy feature, however, which has resulted from the inland discharge of Colorado River is the Salton Sea, now a large body of water occupying the lowest portions of Salton Basin, having a greatest length of 40 miles from near Mecca southeasterly to a point about 7 miles northerly from Brawley.

The average width of this body of water is 10 miles and its surface area somewhat more than 400 square miles. The water surface of Salton Sea is at present about 203 ft. below sea level and the greatest depth of water is about 75 ft. The water of Colorado River is known to have reached Salton Sink a number of times in the past, notably in 1862 and in 1897 but until 1905 the inflow of water from the Colorado continued only during the flood stage of the river. It ceased as soon as the river fell to a stage within natural banks. It was not until June, 1905, that a channel through the river bank following an artificial cut, was enlarged to a capacity and depth great enough to take the river's low water flow. A few months later in the same year an unusual and extraordinary freshet rise, coming down the Gila River, plowed out this new channel to still greater dimensions and made it the main channel of the river. For more than a year thereafter the river poured its waters across its west bank in Mexico, inland and most of the water thus discharged accumulated in Salton Basin.

By January 1st, 1906, the water had risen about 30 ft. and the lake covered an area of 247 square miles. It rose nearly 50 ft. more in the year 1906 and had reached a stage at the time water was shut off in February, 1907, about 1 foot higher than the present water surface, or 202 ft. below sea level.

The water of the lake is muddy near the points where Alamo and New River discharge and has a slight turbidity at







other points. Its salt contents are barely sufficient to give it a very slight saline taste.

### THE ANCIENT SALTON SEA.

At an elevation of about 30 ft. above sea level on the west side of Salton Basin and at elevations ranging from 30 to over 50 ft. on the east side an old beach line is traceable. This marks the limit of an ancient lake. It is probable that the water surface of this lake stood for many centuries at an elevation about 30 ft. above sea level. During that time the Colorado River was discharging either continuously or periodically into the southeasterly extremity of the lake and its overflow was along the line now marked by New River, Volcano Lake and the Hardy. The fact that east side beach elevations are reported higher than those on the west side of the valley (Surveys of W. Carvel Hall, U.S. Geol. Survey in 1905) leads to the assumption that there has been a slight up lift of the east side country subsequent to the drying up of the ancient lake.

The formation of such a lake is readily accounted for. The Colorado River pushed its delta formation southwest-erly from Pilot Knob across the one time great submarine valley and gradually built up the divide between lake and gulf and raised it to 30 ft. above sea level. The river has since that time for a long period, probably repeatedly discharged into this lake and kept it full, thus giving time for the formation of the beach. When the river finally for the last time broke a channel to the south, to a direct outfall into the Gulf of California, the lake dried up. Its bed is still copiously strewn with several varieties of fresh water shells, the most abundant being a small spiral shell and a fresh water bivalve. The lake when full had a surface area of about 2,000 square miles and a greatest depth of over 300 ft. The lowest portion of the Salton Basin is somewhere in the neighborhood of 280 ft below sea level. Referring to this ancient lake, Dr. W.P. Blake, Geologist, who assisted in the explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean, writing in 1855 says: "The former existence of a fresh water lake in the northern part of the desert is shown not only by the extensive deposit of alluvial or lacustrine clay, containing fossils, but by the existence of extended shore-lines and beaches along the sides of the bordering mountains."

Speaking of the possibility of a deluge of Colorado Desert (Salton Basin) Dr. Blake says: "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."



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THE AUSTRIAN RIVER

At an elevation of about 30 ft. above sea level on the west side of Salton Basin and at elevations ranging from 30 to over 50 ft. on the east side an old beach line is traced. This marks the limit of an ancient lake. It is probable that the water surface of this lake stood for many centuries at an elevation about 30 ft. above sea level. During that time the Colorado River was discharging either continually or periodically into the southeasterly extremity of the lake and its overflow was along the line now marked by Low River, Volcano Lake and the land. The fact that east side beach elevations are reported higher than those on the west side of the valley (Surveys of W. Garvel Hill, U.S. Geol. Surv. v. 1905) leads to the assumption that there has been a slight up lift of the east side country subsequent to the drying up of the ancient lake.

The formation of such a lake is readily accounted for. The Colorado River passed the delta formation southwest-ly from the divide which crosses the great mountain valley and gradually built up the divide between lake and Gulf and raised it to 30 ft. above sea level. The river has since that time for a long period, probably repeatedly discharged into this lake and kept it full, thus giving time for the formation of the beach. When the river finally for the last time broke a channel to the south, to a direct outfall into the Gulf of California, the lake dried up. Its bed is still copiously strewn with several varieties of fresh water shells, the most abundant being a small spiral shell and a fresh water bivalve. The lake when full had a surface area of about 2,000 square miles and a greatest depth of over 300 ft. The lowest portion of the Salton Basin is somewhere in the neighborhood of 280 ft. below sea level. Referring to this ancient lake, Dr. W. B. Blake, Geologist, who assisted in the explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean, writing in 1855 says: "The former existence of a fresh water lake in the northern part of the desert is shown not only by the extensive deposit of alluvial or lacustrine clay, containing fossils, but by the existence of extensive shore-lines and beaches along the sides of the bordering mountains."

Speaking of the possibility of a delta of Colorado Desert (Salton Basin) Dr. Blake says: "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 Low 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' (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 southerly margin was 15 miles south of the International boundary in Mexico. It had 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 Liver-pool Salt Co.

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 further north is about 60 ft. below sea level and the cultivated lands near Brawley extend from about 100 to 200 ft. below sea level.

At the northerly end of the basin is Coachella Valley with Indio farthest north about 20 ft., and Mecca near the present lake shore about 190 ft. below sea level.

#### THE EARLY IRRIGATION PROJECTS.

What is now universally referred to as Imperial Valley was once generally known as the New River country. The phenomena which attended the periodical over bank flow of Colorado River were fairly well understood at an early date in the history of California. It was recognized to be feasible to lead Colorado River water across lands in Mexico to California and it was known that much land could be thus covered with water. A first idea that the creation of an inland sea by filling the basin with water from the Colorado would be desirable and would prove beneficial to climatic conditions soon gave way to the projects for supplying water to the basin lands for irrigation. Through the efforts of Dr. O.H. Wozencraft and associates the passage of a resolution by the legislature of California was secured, calling upon Congress to make a cession to the State of 3,000,000 acres of land for the purpose of reclamation by irrigation. This land was in a compact body in the southeastern part of California and included all that







part of Colorado Desert which is now known as Imperial Valley.

A proposed act for the cession of this land to California met with the approval of the Public Lands Committee of the House of Representatives in 1862, but due to the troublous times upon which the country had entered and other causes, the proposed legislation failed. But the feasibility of irrigating lands on the Salton Basin was no longer a conjecture. Surveys by Ebenezer Hadley, the County Surveyor of San Diego County, had established the fact that water from the river would flow to the land. He reported irrigation to be practicable as water from the Colorado River "flows there now". The plan which he suggested was substantially the same as that which was ultimately carried out. He proposed to tap the river at the point or rocks adjacent to Pilot Knob and immediately above the international boundary line. He called attention to the fact that the hills along the boundary west of the river would make it necessary to locate the canal for some distance through Mexican territory. He proposed a canal 25 ft. wide and 10 ft. deep.

Under direction of Lieut. George M. Wheeler there was an examination made in 1875 and 1876 to determine whether it would be feasible to divert water from the Colorado River at any point below the Grand Canon for the irrigation of lands in California. This examination was entrusted to Lieut. Eric Bergland who reported adversely, stating that a canal from some point below the boundary would be more practicable and less expensive. He suggests that one of the branches of New River (evidently the one later known as the Alamo, or Carters or Salton River) leaves Colorado River near Algodon station and that this natural channel might be utilized for carrying water into the depressed area to the northwest. He thinks that to avoid the sand ridge the canal should be as far south as Seven Wells in Mexico, then turning toward the northwest. Referring to the amount of cutting required to construct such a canal he thinks it would be moderate "as the water flows into this area from the river when it overflows its banks."

#### IRRIGATION ENTERPRISES.

The necessity for carrying water through Mexico to reach the New River country in California was discouraging to later promoters of irrigation projects and no scheme entirely north of the line could be worked out the expense of which was not prohibitive. The enterprise therefore remained dormant until revived by the Colorado River Irrigation Co. in 1892, which had plans for the irrigation of lands in the United States and Mexico upon both sides of the river. But this enterprise was not a success. The Company went into the hands of a receiver.







When this Company failed, its properties, notably the surveys which had been made, were acquired by a new corporation, the California Development Co., which had been organized on April 24, 1896, under the laws of New Jersey.

This Company contending against difficulties that often seemed insurmountable has succeeded in making the irrigation of land in the Imperial Valley an accomplished fact and has maintained most of its canal system in operation since 1901. In that year the delivery of water commenced. It increased materially in 1902 and by 1903 the demand for water was in excess of the facilities for diverting and delivering the same. Under these circumstances the Company thought it necessary to safeguard its rights to water from the Colorado River. It requested Congress to recognize its right to divert water from this river heretofore regarded as navigable. Failing to secure favorable action in this direction, Congress was requested to declare Colorado River non-navigable. The only outcome of this request was a resolution directing that an examination and report be made bearing upon the matter of navigability. Thereupon the Canal Company through its affiliated Mexican corporation sought certain rights in Mexico and obtained a concession as hereinafter explained. It constructed new inlets to its canal and one of these, the one usually referred to as the Lower Mexican Heading, was in consequence of its unprotected condition and unusual floods in the river enlarged by the flood waters until near the close of 1905 it became the main channel of the river.

Attempts to close this heading and to turn water away from it failed one after the other until Nov. 4, 1906, when the river was forced back into its proper channel. It was held there until Dec. 7, when it broke through a levee at a point a short distance south of the original break and resumed its flow inland. It was again checked and turned to the Gulf along its proper course on Feb. 11, 1907. It is now flowing to the Gulf and the defensive works can be reported to have stood the test of a high water reaching 29.2 at Yuma and a maximum discharge of about 112,000 sec.ft. without having shown any signs of weakness.

#### THE MEXICAN CONCESSION.

This in brief is an outline of what has occurred but some further explanation is necessary for a full understanding of the situation.

It is to be noted in the first place that there has been no agreement entered into between the United States and Mexico under which the latter country grants the former or any of its citizens the right to conduct water across Mexican territory. Neither has there been any direct grant to any United States corporation of any such right. The concession which has been made is to a Mexican corporation whose operations so far as constructing works and conducting water are concerned are



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confined entirely to Mexico. But the concession permits a Mexican corporation, La Sociedad de Yrrigacion y Terrenos de la Baja California (Sociedad Anonyma), to receive at the international boundary line or to divert from Colorado River on Mexican territory water which after flowing through Mexico may be delivered to canals for the irrigation of lands in California.

This concession is held by a corporation whose capital stock is owned by the California Development Co. and thereby the latter retains its control over operations in Mexico on which it is dependent for its supply of water. The matter of conducting water through Mexico was further simplified by a purchase for the Mexican corporation of a tract of 100,000 acres practically paralleling the international boundary, within which lie the various artificial channels and structures that were necessary for a control of the irrigation water. By this ownership of land in Mexico canal construction from the boundary at Hanlon's on the Colorado to the Alamo, from Las Lagunas to the Lower Alamo, and from near Sharp's Heading to various points on the boundary line was made possible as early as 1901 and 1902.

The concession above referred to was in the nature of an agreement between the proper authorities of Mexico and a representative of the Mexican corporation and bears date May 17, 1904. It was ratified by the Congress of Mexico the following month. Under it the right to divert 284 cubic meters per second (10,000 sec.ft.) of water from the Colorado River on Mexican territory was granted subject however to the use of a part of this water as required, not to exceed one half, upon lands in Mexico. The right was also granted to receive this water from a canal heading in California north of the boundary line and to convey the same in canals or in natural channels through Mexico. The concession is coupled with other conditions usual in such cases such as the deposit of \$10,000 in Mexican bonds, the monthly payment of \$300 to Mexico; the approval of plans and inspection of works. It is also subject to the condition that the Mexican company shall not sell or mortgage its property to any foreign government or state and shall not take any foreign government into partnership. All stockholders in the company may be foreigners. Relating to the navigability of the river the concession is coupled with the condition that the diversion shall be without injury to the right of a third party or to the navigability of the river.

The canal companies under this concession have acquired permission and have apparently assumed an obligation to irrigate lands in Lower California. It is not known at this time what area of land in Mexico west of Colorado River can ultimately be brought under irrigation. It is known however that the area commanded by water diverted at or near Pilot Knob is very large, somewhere in the neighborhood of 800,000 acres and that under certain agreements of rather vague tenor, rights are claimed to water from the Mexican Company's canal system for nearly 700,000 acres.







## IRRIGATION OR NAVIGATION.

Although the navigation interests on Colorado River have never been sufficient to justify the expenditure upon this river of any funds for the improvement of navigation, it is nevertheless a fact that the lower river in its natural condition is navigable. This was recognized by the two countries when entering into treaties relating to the International boundary. Under the provisions of the treaty of 1848 neither country is to permit works throughout the portion of the river where it is a common boundary, that would interfere with the navigability of the river. The subsequent treaty of 1853 cancels this provision but guarantees to the United States the free and uninterrupted passage of vessels and citizens so far as the river forms the common boundary between the two countries.

Owing to unusual difficulties, such as lack of depth on the bars, swift shoal waters and a tidal bore in the river's mouth, where the range of tide is reported to be upward of 30 ft., there has been practically no commerce on the river below Yuma since 1876, the time of the completion of the Southern Pacific Railroad which crosses the river at this point. Several examinations made by the engineers of the U.S. Army have resulted in reports unfavorable to any expenditure for the improvement of navigation on the river.

Permission has been given to the Secretary of the Interior by Congress to divert water from the Lower Colorado River for irrigation purposes. (Act approved Apr. 21, 1904, entitled "An Act making appropriations for current and contingent expenses of the Indian Dept", etc.) Under this permission the Reclamation Service is constructing a diverting dam across the river at Laguna about 12 miles above Yuma. This dam as planned makes no provision for navigation, and the proposed diversion, at this point, of water for the Yuma project will at times deprive the river of the greater portion of its low water flow. It seems therefore that the time has come when Congress should take some definite action in the matter of confirming a right to the use of the Colorado River water to the lands which have become dependent thereon such as Imperial Valley. Action in this matter appears the more important because it seems necessary to set a limit upon the amount which should be taken from the river for this purpose in order that interests elsewhere on the river may be suitably protected.

The concession made by Mexico to the Mexican corporation, 284 cubic meters per second or 10,000 sec.ft., is nearly three times as much water as the river carries at an extreme low stage. A canal of capacity to carry this amount of water would be adequate for the irrigation of about 800,000 acres







of land. It should be assumed preliminarily that about 300,000 acres of land in Imperial Valley can be brought under profitable cultivation, and that suitable restriction upon the use of water in Mexico should limit the area there to be irrigated to about 150,000 acres. Over 200,000 acres of land in Imperial Valley are covered by water stock in one of the other of the mutual water companies, and therefore have been paying for water, and probably more than 100,000 acres have been under crop and therefore irrigated in a single season. Furthermore the river water, supplied by the canals, is the only water available for domestic use in Imperial Valley. The canals supply water to the municipalities. Imperial Valley is therefore to an exceptional degree dependent upon the canal system from Colorado River for its prosperity. Without the service rendered by the canal system, the country would have to be at once abandoned.

In view of these facts, some suitable assurance should be given to Imperial Valley that it will be protected in the use of some specified quantity of Colorado River water. But here again action by Congress for the protection of the water users should be coupled with such conditions that such a confirmation of water rights will be of real benefit to the land irrigated and will not go solely toward the enrichment of private corporations (possibly including a foreign corporation).

#### THE MENACE.

The temporary flow of Colorado River inland to an outfall into Salton Basin resulted from the making of a rather insignificant cut through the river's high bank land. It is to be assumed that without such artificial weakening of the natural barrier which flanks the river, there would have been no change of this kind, at this time in the river's course. But the river is, and for many years has been, ready to swing away from the outfall to the Gulf back to a course inland; and it has by the mighty sculpturing of deep channels during 1905 and 1906, greatly increased the probability that such a change would be made and would become permanent if large volumes of over-bank water are hereafter allowed to reach the region drained by the Alamo and New rivers.

A permanent change of the course of Colorado River away from the Gulf would bring disaster to large areas in the United States as well as in Mexico. In this general review of the situation no attempt will be made to present the consequences of such a change in an exhaustive way but some references to the changes which will take place is necessary in order that the need for permanent river control may be made apparent.







Such a change would first of all mean the gradual submersion of Salton Basin. Even now some improved lands southward from Mecca and others northwesterly from Brawley are already under the water of Salton Sea. Waters rising higher would cover the improved lands of Coachella Valley; Mecca, Thermal, Coachella and even Indio would be deeply submerged. The farming lands near Brawley would ultimately be covered with water 130 ft. deep, Imperial, El Centro, Holtville, Calexico and the country far to the east and west would be at the bottom of the sea. The water would ultimately spread out over about 1900 square miles of land in California and would cover about 100 square miles of land in Lower California. The industries of prosperous communities would thus be wiped out without hope of any early restoration of the original conditions because it would first take the river some forty years to fill the basin and should the river then be turned back to the Gulf it would take 50 years more to dry up the inland sea. But the damage would by no means stop with the inundation of about 1,250,000 acres of land in California and Lower California, for during the filling of the basin there will be a deepening of the river channel upstream along some route of least resistance, probably along the present course of New River to Pasqualito Bend, 6 miles south of the international boundary, thence along the washouts already scored across the country, easterly, past Pink Mountain to the Alamo; up the Alamo to the Colorado and thence up this river past Yuma an indefinite distance. This deepening of river channel which may be 100 ft. or more at Yuma would not only deprive the bottom lands in the valleys of the Colorado of their water but the stream as it cuts bank to the right and left would swing from side to side cutting away the rich alluvion of these valleys. Some 400,000 acres of land in the United States would thus be menaced. Some of these lands are improved, some are now being brought under irrigation, as at Palo Verde and at Yuma, but the greater portion thereof belong to the area which it is hoped will some day be protected against overflow and supplied with water for irrigation.

Furthermore, all of the river's delta cone now to some extent watered by the annual outpouring of the flood waters would be deprived of moisture. These delta lands would be out of reach of the Colorado River water and would quickly assume the character of a desert. All of the 800,000 acres of land on the west side of Colorado River in Lower California would become a dry, barren waste and some of it would later be submerged, while in Sonora on the east side of the river additional large areas of land would lose the benefit of the annual inundation water.

Permanent maintenance of defensive works such as those now in service on the west bank of Colorado River below Pilot Knob, will deprive a large area lying between the Paredones on the south and the sand hills on the north, of the







natural periodical watering received in the past. This area may be brought under cultivation by irrigation. But whether this be the case or whether the land be allowed to lie waste, the natural thicket of trees, weeds, brush and grass will disappear, except close by the canal, and the land's surface will in time become bare and will fall into a condition most unfavorable for resisting the erosive force of any flood which may break through the defenses at the river.

That these defenses are good has already been stated, but their permanent safety will depend upon the foresight and vigilance of those in control. It may be noted that the menace most likely to cause concern and most difficult to guard against will be an attack upon the river bank by the swirling waters of the river. It is quite possible that, under such attack, sections of the levee will drop with the caving bank and that breaches may result therefrom which would reestablish the inland flow. Such an attack results often from accidental causes. The time and place of its occurrence cannot be foreseen and it can be permanently guarded against only by holding the river for a long distance up and down stream to an alignment from which it can make no change.

Today those in control of the works on the river bank are thoroughly prepared to conduct defensive operations. They are alive to the importance of holding the river where it is. But as years roll by, as managements change a time may come when this vigilance will be relaxed. It may be expected to drop in the course of time to a minimum, if allowed to remain in the hands of any private corporation. This is a situation which, in view of the growing industries and increasing population in the threatened areas of both countries, is intolerable. It calls for immediate relief. A relief which should unhesitatingly and immediately be extended by the governments of both countries.

The United States cannot protect the interests of its people in California and Arizona without some arrangement with Mexico because the danger point lies in Mexican territory. But as above shown, Mexico herself is vitally interested in the situation and as the need is pressing, there will no doubt be hearty cooperation in this matter by the two countries.

#### THE WATER COMPANIES.

The problem of dealing with the situation in Imperial Valley is not confined to physical features but has been made more difficult of solution by the complications resulting from the inter-relations of various corporations and obligations assumed by these and by the settlers who have already brought a large body of land in the valley under profitable cultivation.







The essential facts relating to the operations and functions of the principal water corporations appear to be as follows:

The California Development Co. gave notice of an appropriation of water from Colorado River on Apr. 25th, 1899. The notice being one signed and posted by Mr. C.N. Perry at a point a short distance north of the international boundary, in California.

The water as finally diverted in California, was carried in a canal to the boundary, where it was delivered to an extension of the canal, built by a Mexican corporation La Sociedad de Yrrigacion y Terrenos de la Baja California (S.A.). In this canal on Mexican territory the water flowed to the upper Alamo, thence through las Lagunas and down the lower Alamo to Sharp's Heading, where also upon Mexican territory, works were constructed for its diversion into canals for special districts located in California and Mexico. Some water remaining in the Alamo flowed in this channel into California and was taken out for irrigation at points north of the boundary.

The Mexican corporation thus received water from the California Development Co. and conducted it through Mexico, delivering all but a small portion used on Mexican lands to customers of the California Development Co. at the points where it recrossed the international boundary.

The water was first made available for irrigation in 1901, but did not come into use to any considerable extent until 1902. The development of the resources of Imperial Valley was rapid in that and following years.

After Mexico had granted a concession to the Mexican corporation which carried with it the right to divert water from the Colorado River in Mexico, two openings were cut south of the international boundary from the river to the canal, and for a time some of the water in Imperial Canal came from this source as well as from the canal head in California.

Now both the lower and the upper headings in Mexico are closed and all of the water in the canal flows through the heading in California, the inflow being controlled by a concrete structure.

The water thus carried through Mexico for the California Development Co. is not delivered by this Company to individual irrigators but is delivered to a number of sub-corporations known as mutual water companies. Each of these is a stock company and has assigned to it a fixed territory. The number of shares of its capital stock corresponds to the assumed area of irrigable land within its territory.







All of the companies thus organized entered into some kind of arrangement with the parent company for the construction of their ditch systems. Through this arrangement the California Development Co. came into possession of the stock of the sub-companies and fixed the price thereof. Each share of stock carried with it the right to water for an acre of land.

There are at present six of these mutual water companies each of which has, it is understood, entered into contract with the California Development Co. and the Mexican corporation for water. Water is to be furnished to the local company as demanded, but conditioned upon a total delivery not exceeding 4 acre-ft. for each acre of land covered by water stock. Payment is to be made for all water delivered at 50¢ per acre foot, some allowance is to be made for loss by evaporation and seepage. Annual payments are to be for not less than one acre-foot of water for each share of stock outstanding.

The California Development Co. agreed to construct a canal from the international boundary to the laterals of the stockholders of the local water companies, of sufficient capacity to supply 4 acre-feet of water per annum for each outstanding share of stock, and it also agreed to construct a system of distributing ditches for the delivery of water to a point on each quarter section of land from which it would be practicable to irrigate the same by gravity flow. All laterals and ditches become the property of the local water companies. These local companies take complete charge of the distributing system, the expenses being met by stock assessments.

When in 1905 the water could not be shut off at the head of the lower intake in Mexico, financial assistance came to the canal companies at an opportune moment. It is understood that sometime early in that year application had been made by representatives of the Cal. Development Co. to the Southern Pacific Co. for a loan of \$200,000. This application was under consideration when in June, 1905, it became apparent that the canal company was meeting with indifferent success in its attempt to reduce the inflow of water into Salton Basin. The railroad company determined to come to the aid of the settlers in the valley and at the same time protect its own interests, its main track near Salton being threatened, by advancing the money as requested and taking a hand in the management of the canal company's affairs. The first loan was quickly followed by others and it is due to the unstinted financial support of the railroad company and to its placing tracks and rolling stock and plant of every character at the disposal of the men in charge of the work at the river that the effort to turn the river, which at times appeared well-nigh hopeless, was made a success. Word was given out that so long as there was a fighting chance every effort would be made to







accomplish the desired result and this declaration was fully lived up to. It is not necessary to describe in detail what was done. This will be done in proper time and place by the men who have been in charge and from them too there can be obtained as required a statement of what the cost has been. The work was to a large extent emergency work done with facilities within reach. The cost of some of it was therefore necessarily relatively high. What has been accomplished is not only the closing of the break in the river bank at the Lower Mexican Heading, but there has been constructed from the concrete headgate at Pilot Knob down stream for 15 miles along the west bank of Colorado River and inland along the high land following the Paredones, a levee generally about 8 ft. in height. The levee terminates inland about 3 miles distant from the Colorado. Its extension farther inland possibly entirely down the Median line of the delta cone to the base of the Cocopah Mountains is under consideration. By such extension it is hoped to keep all the overflow of the Colorado on the southerly slope of the delta cone toward the gulf and away from Salton Basin.

The lands of Imperial Valley commanded by the canal system were and in part still are of pronounced desert type. They lie in a region whose normal rainfall is only 2 to 3 inches, in which there was originally great scarcity of vegetable and animal life, and which formed a part of the Colorado desert. Colorado River is the only source of water available for these lands. The lands now covered by canal were a part of the public domain at the time that the canal enterprise was undertaken and were therefore subject to entry under the desert and homestead laws. As title to land under the desert land act cannot be secured without a water right from some reliable source, the desert land entries in the Imperial Valley are therefore all dependent upon the California Development Co. which controls the supply of water to this region. Of about 250,000 acres of land that have been filed upon in the Imperial Valley approximately 90% was entered as desert land.

The Cal. Development Co. at the beginning of its operations when money was needed for construction purposes fixed the price of a share of the water stock of a mutual company, face value being \$10.00 at \$8.75, but each of the first 50,000 shares sold carried with it a drawback of \$3.00 in company bonds, receivable for final payments on the stock, thus reducing its actual cost to \$5.75. Later sales of stock were made above par. Its selling price to settlers rose to \$11.25 for the shares of the second block of 50,000 shares, \$15.00 for the third and \$20.00 thereafter. It is understood to be now obtainable at \$12.00 to \$20.00 per share. Over 200,000 shares of stock are at present outstanding. The figures here noted are necessarily approximations which however give some idea of what the land owner has had to pay for a right to







receive water from the canal system. They do not represent the receipts of the Cal. Development Co. from stock sales. It is known that this company used water stock at a valuation entirely independent of the price at which it was offered to settlers in other transactions; that it used it in making purchases; that it sold large blocks of stock at a low figure at times when it was in need of funds, and that it conducted the sale of the stock through an agent - the Imperial Land Co.- at a commission of 25%, this commission however covering also expenses of advertising and locating settlers and the like. The canal company moreover placed itself under obligation to construct the canals and distributing ditches in the several water districts, and therefore required those who bought stock in large blocks to assume this obligation.

Consequently, access to records would be necessary to make an estimate of what was realized by the Cal. Development Co. from the sale of water stock.

### THE OUTLOOK.

Notwithstanding various obstacles to progress that arose from time to time, there has been a rapid development of the resources of Imperial Valley. The settlers now look into the future with confidence. All will come out right in the end, is the prevailing sentiment, and although there has been misunderstanding between some of the corporations and a lack of harmony of action under trying situations, still all are sanguine that a way will be found to assure permanent prosperity to this promising region. No one however seems to have any clear idea as to what is to be done.

It may be all right at the present time and under present management to have the Imperial Valley dependent for its water upon the operations of a Mexican company in Mexico, but satisfactory service may cease when new difficulties or complications arise. The residents of both Imperial and Coachella Valley may for the present be content to trust this same foreign corporation for protection on the banks of the Colorado River in Mexico, but the same persons will not always be in control, the same policy will not always prevail, and it must be foreseen that a period of uncertainty and unrest will come when control of these works by higher authority will be demanded.

From the standpoint of Mexico the situation is not much better. The water for the irrigation of delta lands west of Colorado River in Lower California is diverted in California by a United States corporation and







delivered to the Mexican corporation for distribution. Here again it cannot be hoped that satisfactory service will always be rendered by a corporation of a foreign country operating in foreign territory, and here too it becomes questionable whether the work of more than local benefit the maintenance of the river in its proper channel should be permanently entrusted to a private corporation.

#### THE RIVER BELOW THE LOWER MEXICAN HEADING

#### AT THE HIGH STAGE OF JUNE 1907.

During the high stage of the river culminating in the first week of June with a gage height at Yuma of 29.2 ft., there came a period just preceding the maximum stage of the river when at a point about six miles south of the Lower Mexican Heading the river began to fall. This fall while volume of flow was still increasing and while the river at and above the Lower Heading was still rising, seemed to indicate either that there had been material channel enlargement for some distance down stream or that a sudden cutting through of some neck of land had shortened the river or that there had been a material enlargement of some high water escapeway not far below the point where the fall of the water surface had been noted.

Personal exploration a few days later of the region in the vicinity of Volcano Lake disclosed the fact that there had been a rapid rise of this lake, and reports were current that there was more water in the delta country southward from Paredones River than ever before. Paredones River was not at that time high enough to send any water toward the north. Consequently, this river could not have been a large contributor to the lake. It was known in this connection also from personal inspection that the amount of water which had flowed westerly along the new levee on the west bank of the Colorado River was small in amount. The water had not been of sufficient depth over the land to wet the base of the levee throughout its entire length. This fact of an accumulation of large volumes of water at and east of Volcano Lake in connection with the drop of the water surface as above noted in Colorado River pointed to the probability that there was an unusual overbank flow westerly within the territory tributary to feeders of the Paredones and the Pescadero River systems, probably somewhere near the point where the river ceases to be the boundary line between the United States and Mexico.

On June 15th and 16th, 1907, an inspection trip was made down the river to verify this fact and to ascertain whether there was any new breach in the river bank at any point tributary to either the Paredones or the Pescadero. The trip was made by steamer and was extended down stream







about 50 miles from Yuma to a point over 20 miles by river below the Arizona boundary. The river was carrying about 94,000 sec.ft. of water and its stage was 28 ft. on the gage rod at Yuma or about 1.2 ft. lower than it had been earlier in June. (From the gagings made every few days at Yuma it became apparent that the maximum discharge of the river had not been coincident with its maximum stage at which in the first week of June the discharge was only about 80,000 sec.ft.)

It was found that the river from Yuma down to a point about 10 miles below Lower Mexican Heading was less than bankful. It had been at a bankful stage earlier in the month. Below the Lower Mexican Heading on June 15th and 16th going down stream the water surface elevation gradually reached and finally exceeded bank heights there being a pronounced overbank flow at many points (and at some points for long stretches), commencing about 4 or 5 miles below the recently made cut-off at Nigger Bend. (Nigger Bend is about 5 miles below the Lower Heading).

This condition of overbank flow in the last 15 miles traversed, was almost continuous. The water which went out of the channel toward the east returned to the river at the points where the east side Mesa breaks off to the stream at 4 and 12 miles below the Arizona boundary. The water which went out to the west was without doubt caught by the feeders of the Pescadero Slough system and much of it reached the country near Volcano Lake through this system. Some of it, at the highest stage of the river, when the river was more than a foot higher than on June 15th and 16th, found its way to the Paredones River but not enough to cause this river to send any water into its north side overflow channels. At the highest stage of the river in the early part of this month, June, 1907, the general overbank flow commenced at a point close below the Lower Mexican Heading and as far down stream as the river was examined there had been at least one foot greater depth of water on the banks than at the time of the inspection. The outgoing water was here and there seen concentrated in small channels of slight depth. None of these however had the appearance of streams which are enlarging their beds. Most of the water in the banks was flowing inland, through weeds and between trees, with considerable velocity. During the highest stage of the river the outgoing water must have been a large proportion of the river's flow.

It was plain from this inspection that a series of changes in alignment, all of a minor order besides the material change at Nigger Bend, had been taking place within the last year or two. The river had been shortened somewhat by these changes. To this shortening to gradual







increase of channel capacity while the river is high and to the new regimen resulting from the Nigger Bend cut-off where the river length was suddenly reduced about 3 miles in Nov. and Dec., 1905, there should, no doubt, be ascribed the lower high water surface elevation, in reference to bank heights above Nigger Bend than below it during the freshet stage of this year (1907). The summer high stage has come on so gradually that the river has had time to lower its bed up stream from Nigger Bend, and channel capacity has therefore been increasing. This increase of channel capacity is best illustrated by the discharge record at Yuma. At the highest stage in the first week of June 1907 with the gage at 29.2 the discharge was about 80,000 sec.ft. It increased to over 90,000 sec.ft. while gradually falling and upon again rising to the highest stage 29.2 in the last days of June the discharge had increased to 112,000 sec.ft. or 40% more than for the same water elevation early in the month. This increase of channel capacity as already explained, kept this season's flood fairly within natural banks from Yuma down to Nigger Bend. Banks were overtopped only here and there in a few low places, and practically no water has stood against the levees. Under these circumstances the levees have not turned any water back into the river channel and have had no appreciable effect upon the stage of the water, as might have been the case if there had been a considerable submerision of the bank lands on which they are built.

The conditions as described have been favorable for the protective works on both sides of the river. It should not be supposed, however, that the same conditions will always prevail. The river channel now comparatively free from great serpentine bends, is restoring these as fast as it can carve away the friable soil in a number of concave banks. The great width of river at many points below the Lower Heading resulting from the addition of long stretches of abandoned channel to the ordinary waterway cannot be long maintained, because the bars already formed in these old channels will quickly be covered with a dense growth of trees and brush.

It is to be noted too, that, owing to the lack of overbank flow in this section of the river during the year 1906, when the river had abandoned its course to the Gulf, there was a cessation of plant growth on much of the ground which is this year under water. Large areas were fire swept. Consequently this year's high water found less obstruction to its flow inland across country than had heretofore been interposed and the river did not rise as high above banks as usual. Such causes are necessarily only of temporary effect in reducing the elevation of the flood plane at and above the Lower Mexican Heading.







They however removed all cause for anxiety in the matter of the maintenance of the river in its proper channel during this year's summer high stage, but they must not be assumed to have produced changes that will last indefinitely. The scoured out channel will be refilled in a measure by the slackening current of the falling river and at the close of the freshet season the river channel may again be reduced to about what it was at the beginning of the present June rise. When it is now considered that there was this year snow enough on the ground in the high mountain watersheds of Colorado River to have sent the river far above its first high stage in the first days of June, if the temperature conditions of this spring had been normal, it will be seen that in subsequent years much higher water should be expected. This year the very early warm weather of March brought down some of the lower snow and reduced the area of the snow-fields exposed to the sun's rays later in the spring. April and May were cool months, yet warm enough to keep some of the snow coming and to keep the river at a high stage and at work cutting its channel deeper, so that the freshet stage of June found the river channel below the Lower Mexican Heading fairly well restored to normal conditions. Most of the new obstructions were cut out and river was being deepened under the scouring action of the flood stage so that a second pronounced increase of flow with volume about 40% greater than at the crest of the first rise found the river capable of carrying this water at Yuma and, in fact, all the way to and below the Lower Heading at elevations no greater than those of the first rise.

On a falling river, and during the long low water period which will follow this flood stage, there will as above stated, be channel deterioration. The conclusion is not warranted that because the river carried 112,000 sec. ft. on June 26, 1907, at a gage height of 29.2 ft. that it would do this again 6 months later, under some sudden outpouring of a flood down the Gila Valley, nor that it would rise no higher if the Colorado discharge increased rapidly next spring from a low water to a high water stage. In other words, no condition has been found along the river to warrant any belief that the future high waters will not as in the past, from time to time, overtop banks along that portion of the stream where the overbank flow would be a direct menace to Imperial Valley and an indirect menace to other interests as already pointed out. A levee system as commenced by the canal companies is necessary to prevent this flow across country toward the channels which fall into Salton Basin.







## THE HEAD OF IMPERIAL CANAL.

The original intake of the canal of the Cal. Development Co. was in California several hundred feet north of the boundary line. A timber headgate controlled the inflow of water. Later as described, two openings were cut from river to canal in Mexico. Both of these are now closed; the upper one by means of an earth embankment forming a part of the river levee brought up from the Lower Heading; the other closed, after having been for a time the main channel of the river, by means of the Hind and the Clarke dams constructed of broken rock, gravel and earth. The head of the canal is now several hundred yards further up stream than originally and its inflow is controlled by a headgate of reinforced concrete which rests upon solid rock, a small spur of Pilot Knob having been cut away to receive it and afford a good foundation and a secure landside abutment. The west side levee above referred to is connected with the river end of the concrete gate. The levee follows the right bank of the river distant therefrom generally 200 to 300 ft. It is about 1400 ft. from a levee on the opposite side of the river, the latter being one of the features of the Yuma Reclamation project. At the Lower Heading 4 miles from the concrete headgate the levee drops away from the river about one-half mile connecting with the dams that were constructed by the canal companies across the first and second breaks in the river bank. The levee then pushes forward again to near the river holding a position within a few hundred feet of the bank for about 3 miles then is carried obliquely inland along the high ground built up by the one time upper section of Paredones River. It terminates about 10 miles from the Lower Heading. Its lower end is about 3 miles from the river. The fall of the country along the line of this levee after it leaves the river bank is about 3 ft. per mile.

Some security in addition to its own stability is given to this levee from the head of the canal for 4 miles down to the Lower Heading by a secondary embankment along the canal which is generally from a few hundred feet to a quarter of a mile or more further inland. The secondary embankment is connected with the main levee near the concrete headgate and again at the northerly end of the dams at the Lower Heading. On the south side of the wash in which the river flowed before it was turned back into its proper course, is another secondary embankment a deflecting or spur levee over a mile long putting off inland at an oblique angle, which, in case of any accident to the main defense south of the Lower Heading, would prevent water from taking a short cut into the Alamo, compelling it to flow over a long stretch of unbroken ground before it could reach this channel.



THE LEVEE OF THE CANAL

The original break of the canal of the Canal Development Co. was in 1850. It was a simple earthen levee about 10 feet high and 10 feet wide. A timber trestle controlled the flow of water. Later as described, the openings were but from river to canal in 1850. Part of these are now closed; the upper one by means of an earth embankment forming a part of the river levee extending up from the lower levee; the other closed, after having been for a time the main channel of the river, by means of the Hind and the Clarke dam constructed of broken rock, gravel and earth. The end of the canal is now covered by a levee 12 feet up stream from the original and its width is controlled by a concrete of reinforced concrete built upon solid rock, a small part of which having been cut away to remove it and afford a good foundation and a concrete inside structure. The west side levee above referred to is connected with the river and at the distance of 1000 feet follows the right bank of the river distance from the levee on the opposite side of the river, the latter being one of the branches of the Yuma River. At the lower levee a mile from the concrete levee the levee drops away from the river about one-half mile downstream with the dam that was constructed by the canal company across the river and beyond breaks in the river bank. The levee then crosses the river again to near the river and is about 10 miles from the lower levee. The levee on the right bank is about 3 miles from the lower levee. The fall of the canal along the line of this levee is about 3 feet per mile.

Some sections in relation to the canal is given to this levee from the end of the canal for a mile down to the lower levee by a secondary embankment along the canal which is generally from a few hundred feet to a quarter of a mile or more from the canal. The secondary embankment is connected with the main levee but the concrete levee and main levee are on the north side of the canal. On the south side of the canal is another secondary embankment a distance of 1000 feet from the main levee. In case of any overflow to the main levee south of the lower levee, which would prevent water from taking a short cut into the canal, compelling it to flow over a long stretch of broken ground before it could reach the canal.



The main levee has a height of about 8 ft., is about 10 ft. wide on top, has side slopes of 1 on 3 and has been covered with a layer of gravel about 1 ft. in thickness. A deep refilled trench under the levee decreased the probability of any dangerous seepage of water under the structure. A railroad track on this levee throughout its length, is an excellent provision for safeguarding it. During the spring rise of the river which has just taken place, equipment, material and men were constantly held in readiness to meet any emergency which might arise. Locomotives, a pile-driver, dredges, cars loaded with piles and lumber, others loaded with rock and gravel, were ready to be sent at a moment's notice to any point of the works. They were not required. The levee has barely been wet. Neither has the river given any trouble. Along the entire protected front there has been no serious caving of bank and no call for emergency work. It is not likely that the falling river and the river at its low stages will materially alter this situation. But it must be noted that the slightly concave easterly or Arizona bank of the river opposite the Lower Heading is one on which the river may at any time concentrate its energy, and if this occurs there may be a rebound to the other side with bank caving at some point below the Heading; the same favorable situation now prevailing is not therefore assured for succeeding seasons.

#### DAMAGE FROM DISCHARGE INTO SALTON BASIN.

That some damage has already been done by inland flow of Colorado River and the rising waters of Salton Sea will appear from the following:

The water accumulating in Salton Sea in 1904 and 1905 drowned the salt beds and forced the New Liverpool Salt Co. out of business. In the spring of 1905 the Southern Pacific Railroad Company was forced by the rising waters to shift 15 miles of its main track near Salton to higher ground. Later the same year 25 miles of track including these 15 miles, were thrown upon still higher ground; and before the water flowing to Salton Sea was finally stopped the track had to be again moved, the change of line this time covering about 40 miles of track. Even this track at an elevation approximating 200 ft. below sea level was finally so near submersion that preparations were made to make a further much more extensive change, a grade having been thrown up at an elevation about 50 ft. above the extreme reached by the water of Salton Sea. The railroad company was also compelled to shift track repeatedly at the crossing of Alamo River and along New River in the Imperial Valley near Brawley where the widening barrancas cut away the land far beyond the limits of the railroad







right of way. At Calexico too and in Lower California the railroad was damaged. Its station building and other improvements at Calexico dropped with the caving bank; the entire station grounds at Mexicali went into the river, and miles of track in Mexico were destroyed by the overflow and subsequent channelling out of new water ways.

The rising waters of Salton Sea not only submerged the Salt beds of the New Liverpool Salt Co. but at the time that the highest stage of the water was reached at the close of 1906, covered a few acres of improved land near Mecca, and covered several hundred acres of land northwesterly from Brawley on which some work of preparation such as ditching, clearing of brush, and leveling had been done. The flooding and subsequent barranca cutting interfered with the canal service of the Imperial system causing loss of crops and threatening general ruin. Farming operations were restricted, due to the uncertainty of water service and whole districts such as Nos. 6 and 8 on the west side of New River lost their water supply and are at this writing still without water. Drinking water is hauled many miles by the few families who have here held out in the hope of early restoration of the water service.

Along both the Alamo River and New River, but mainly along the latter, a large area some 6000 to 10000 acres in great part under cultivation, has been destroyed, having been gullied out to great depth and being no longer available for ordinary farming purposes.

Before the great barranca of New River had formed, the waters which flooded large areas south of the international boundary threatened to sweep northerly through the heart of the improved lands of Imperial Valley. This great catastrophe was averted by strenuous effort and at large expense, the main canal of District No. 1 having been made the line of defense. At Calexico and Mexicali, 5 miles of embankment about 5 ft. high were required to prevent the flooding of these towns, both of which afterwards suffered losses where the water which had dropped into a deep channel undercut the high banks.

#### TIME REQUIRED TO FILL AND TO DRY UP SALTON BASIN.

Records of the flow of Colorado River since 1894 supplemented by gage heights at Yuma since 1876, indicate that the normal annual discharge of this stream past Yuma is about 9,000,000 acre-feet. On the assumption that this amount would be the inflow each year into Salton Basin and on the further assumption that the annual evaporation from an open sheet of water in the Salton Basin would amount to a little over 6 ft. in depth, a continuous discharge of the







river into Salton Sea for over 40 years would be required to fill the basin.

The rate at which water will disappear from Salton Sea depends upon the rate of evaporation. Not enough is known of this to attempt a close prediction. It is probable when all inflow ceases that the drying up will be at least 6 ft. per year. It would at that rate take about 12 years to dry up the present lake, and it would take approximately 50 years for all the water to disappear from the basin if it were full to the brim.

#### RIVER WORK REQUIRED.

What is necessary to be done on the Colorado River to keep the river permanently on its course to the Gulf of California, should be made a subject for the careful consideration of a board of competent engineers. It may be preliminarily stated however that this work will include the holding of the river channel to a selected alignment from Pilot Knob down to the point where the river ceases to be on the boundary line between the two countries, a distance by river on the probable final alignment of about 18 miles. It will be necessary throughout this distance and probably up stream as far as Yuma, 7 miles further, to construct works that will prevent bank cutting. These works may be in the nature of a reliable bank facing on lines that will so far as possible prevent concentration of flow against either bank. It may be assumed that such works where a change of alignment is necessary would include the making of a deep trench, having a sloping landward bank, to be refilled with large rock resting on a suitable bed of finer material all so arranged that at this trench bank cutting will be halted. The excavation from the trench may be used for a low embankment on which there should be a railroad track. This embankment will be an outlying defense against inundation of bank lands. Where the selected alignment of the river bank crosses a concave bend some years may be required to force the river into its final position. This must be done before the work can be completed. At the present time the river's alignment is unusually favorable for the treatment which is required, and this is a reason in addition to others herein referred to why early action should be had in the matter of securing government control of this work.

Both banks of the river require treatment, because if either be left unprotected against undermining the unprotected bank may be attacked and the current thrown from bank to bank in such a way as to endanger any protection works located on one side only.







The required river bank protection should be first provided for that stretch of river which extends downward from the canal heading at Pilot Knob. Here the work will probably be the most expensive, as it should be so thoroughly done as to be beyond the peradventure of failure. Work of this nature may cost \$50,000 to \$150,000 per mile of river bank and may well be preliminarily estimated at an average cost of about \$100,000 for the entire stretch of river which requires bank revetment.

On the Mexican side of the river it must be supplemented by a levee so high and strong that it cannot be overtopped nor breached. The levee now in use, as recently constructed by the Mexican corporation, should be extended down stream- at a suitable distance back from the river, and by hydraulic dredging of material from the river a banquette of earth should be filled in upon the levee's land side to make the levee so wide of base that underflow through cracked soil and through burrows made by animals will be made as nearly impossible as practicable.

As a first forecast, \$4,000,000 to \$5,000,000 should be assumed ultimately requisite to hold the river on its course to the Gulf of California. To this amount there should be added a part of the cost of the work already done on the river, which amount is subject to determination. The amount which Mexico should contribute toward the cost of holding the river in its proper course may tentatively be assumed at \$1,500,000 to \$2,500,000, leaving possibly \$3,000,000 to \$4,000,000 to be borne by the United States.

#### VALUE OF PROPERTY REQUIRING PROTECTION.

There has been no appraisement made of the value of the property interests in the United States that would be preserved and protected by this work. It can be stated, however, that this value will probably lie somewhere between \$10,000,000 and \$15,000,000, without including property of an intangible nature, such as the good-will of a business, or franchises, or the losses and expenditures connected with a forced abandonment of homes by some 6000 to 8000 people. The potential value of all the property that would be ultimately destroyed if the river were allowed to take its course into the Salton Basin, lands, improvements, railroads and the like, covering property now productive and much more that can be made productive only in case the river is kept in its proper channel is many times greater than these figures.







## GOVERNMENT AID AND CONTROL ESSENTIAL.

The fact that it has fallen to an irrigation company to carry out the protection work on the west bank of Colorado River and that a failure of this work would have brought immediate disaster to the Imperial Irrigation enterprise and to one of the U.S. Government irrigation projects, at Yuma, on which there has already been expended about \$1,500,000, has created in the minds of many an impression that the control of the lower river should remain in the hands of those only who are interested in the irrigation of the lands which the river threatens to destroy and that the cost of the work is a legitimate charge against the lands which are to be protected and preserved for development under irrigation. But the problem of holding the Colorado River in its channel leading to the Gulf of California is one of more general concern; it is one that should be considered and that can be treated as a separate problem, to be studied and solved apart from the carrying out of irrigation enterprises. There are interests to be protected in both the United States and Mexico which have nothing to do with irrigation, and there are lands whose character and availability for use by man, will be seriously modified, if the river is not held in its proper course, even where irrigation is now only a remote possibility or entirely out of consideration.

But it must be admitted, on the other hand, that the future work of utilizing Colorado River and its tributaries for irrigation to a legitimate extent, involving as it does the storage of a material part of the river's flood flow in large reservoirs such as that at Brown's Park on Green River (possibly 1,500,000 acre-feet capacity) and the Kremmling on Grand River (1,000,000 acre-feet capacity) will be a potent factor in simplifying the control of the river in its lower reaches, and that as hereinbefore pointed out, the holding of the river in its proper channel will make possible the continued irrigation of 100,000 acres, and the ultimate extension of the irrigated area in the United States alone by some 600,000 acres.

Failure by the United States to undertake the work of holding Colorado River permanently in its proper channel, would leave the protection of large interests in the United States, as hereinabove pointed out to Mexico or to a Mexican corporation. Mexico has so little improved territory at stake, compared with that in the United States that no action by Mexico except under cooperation with the United States can be hoped for. The Mexican corporation, has entered upon the work of controlling the river apparently for two reasons; first, because an unprotected canal inlet constructed by this company, was the immediate cause of the break in the river's bank, and second,







because a continuation of the discharge inland would have been a death blow to the Imperial canal enterprise including all irrigation development in Lower California.

There is a limit, however, to the work of this character which a private corporation in building up and maintaining what it hopes to make a profitable enterprise, will and can do. There is a good reason, in fact, to doubt whether the work of turning the river would have been continued by this corporation after the break in the defenses on Dec. 7th, 1906, had it not appeared probable immediately thereafter that the United States would repay the cost of further work. (See correspondence between the President and Mr. F.H. Harriman, Dec. , 1906.).

Too much is at stake and the river is too treacherous to trust to a private foreign corporation for its permanent control.

On the assumption that the United States, with or without the aid of Mexico will undertake to hold the Colorado River on a course to the Gulf of California, there will arise the question of apportioning expense, first to the two countries, second to the properties in the United States, that will be directly or indirectly benefited.

The apportionment of cost to the two countries may be made according to some agreed basis, possibly to the apportionment of the irrigation water which crosses the international boundary in river and canal, or as alternative, according to acreage of land that will be benefited.

In the matter of the source of funds for the United States' share of the cost the simplest case will be that in which this entire share is appropriated from the general fund in the U.S. Treasury, letting benefit fall where it will. A more equitable case would be one in which the United States would undertake the work practically as an agent of those whose properties will be benefited. In this event the appropriation for the work would be a conditional appropriation subject to a guarantee of certain repayments, some from private interests, such as railroads, water companies, and the like; some from municipalities; some from lands privately owned; some from lands already covered by irrigation projects or that may hereafter be so included; and some from the unsold Government land whose price may be increased according to benefit received. As an offset to indirect benefit the United States should waive interest on funds advanced for these works and should allow a long time for repayment, 20 or even 40 years.







## CONCLUSIONS.

It appears from the foregoing:

1st. That unconditioned aid by either the United States or Mexico or by both jointly, in the matter of holding the Colorado River in a permanent channel as far southerly as the south boundary line of Arizona, would be of benefit to large areas of land located in each of the two countries, it would be of benefit to many established industries, and various public service corporations, railroads and water companies and would be of direct financial benefit to the Mexican corporation, which backed by the Cal. Development Co. and the S.P. Co. has carried the work of protection to its present stage and which would thereby be relieved of the work of holding the river in its proper channel.

2nd. The work done, subsequent to some date in Dec., 1906, yet to be agreed upon, was done by the Mexican corporation operating with funds advanced by the S.P. Co., at a time when the U.S. appeared ready to take over the work, apparently under an implied obligation by the U.S. that money thereafter advanced by the railroad company and suitably expended would be refunded. The return of such money to the railroad company will release the Mexican company from its obligation to repay unless the transaction be coupled with suitable conditions.

3rd. The maintenance of the Colorado River in a permanent channel throughout the distance in which it is the boundary between the two countries is essential for the protection of large interests in both countries and is a matter for joint action which should be had speedily.

4th. A right of way through Mexico for water for the irrigation of lands in California is necessary. It has already been granted to a Mexican corporation controlled temporarily by a U.S. corporation, but the existing arrangement does not and possibly cannot be made to adequately safeguard the interests that are growing up under the canal system, nor other property interests equally menaced though in no wise concerned or connected with this enterprise.

5th. The quantity of water to be delivered to Mexico in any canal heading in California or to be left in the Colorado for diversion at points below Pilot Knob should be defined by treaty.

6th. No diversion should be allowed through the westerly bank of the Colorado River at any point where this river is on the boundary between the two countries except with the approval of the U.S.







7th. Before entering into a convention with Mexico for the treatment of the Lower Colorado River, suitable agreements should be made with the Cal. Development Co. and with the Mexican Co. through the former, relating to the terms on which all properties and rights possessed by them and necessary for the irrigation of lands in California will, through proper U.S. authorities or otherwise, be transferred to the landowners who are dependent upon the water. Repayment of money already expended and future protection are considerations that should make satisfactory agreements possible.

8th. A convention with Mexico as above set forth must be coupled with authority to expend money to acquire property and construct works in Mexico or conjointly with Mexico on the Lower Colorado.

9th. In the supposed case, that money expended on the Lower Colorado will be considered as an expenditure for local benefit, that should be recovered from the property which is benefited, it will be necessary to have satisfactory assurance that repayment of money thus expended will be made. It is no longer a question of repairing the damage done by a Mexican corporation in Mexico, but it is the greater problem of giving permanent protection to large areas of land and diverse industries in California and Arizona, some of which, such as those in Coachella Valley, and the Lower Colorado River valleys are in no wise dependent upon the Imperial canal system for their irrigation water. The cost may be apportioned upon some basis such as cultivable area benefited but its collection from districts in which lands are already privately owned will depend in large measure upon the will of the people.

10th. In the supposed case, that the U.S. will join with Mexico in the protection of the lands which are threatened, there should be an equitable apportionment of cost of construction of works and their maintenance to the two countries on some agreed basis such as areas of lands benefited or the apportionment to the two countries of irrigation water at the international boundary.

11th. In the supposed case that the U.S. joins in the work of protecting a prosperous and promising section and of making possible the development of an additional large section along the Colorado River, without requiring that funds thus expended shall be made a charge against property benefited, this expenditure should be made conditional upon a satisfactory adjustment of the complications now existing, relating to the conveying of water through Mexico and its delivery to certain water companies, and to the water users. Service by a Mexican corporation should be eliminated, a right of way through Mexico should be secured; the land owner should become the proprietor of the canal system, a district organization







should take the place of all the irrigation canal companies. Aid by the United States before such arrangements are planned and agreed to, particularly repayment of any money already advanced, would be of such direct help to the parent canal companies, and would give them such improved facilities for rendering reliable service that they would be in position, if so minded, to use their improved financial position as a basis for claiming more favorable terms when asked to withdraw from the field, than they could otherwise expect.

12th. Benefits falling upon lands that lie within a project for reclamation by irrigation can probably be added to the irrigation charge against these lands, the protection work being essential for the success and permanency of the irrigation project. In this way or by an addition to the price at which benefited government land is hereafter sold, sooner or later all the valley lands along the Lower Colorado River, not in the meanwhile irrigated by private enterprise could be made to contribute to the cost of the work.

13th. An irrigation district organization under California laws is suggested as probably the best method of uniting all interests in the Imperial Valley and making all property there located that is benefited pay for the protection. Moreover, such district organization is also probably the best suited for taking over the properties controlled or owned by the various water companies operating in Imperial Valley.

14th. In such regions as the Coachella Valley, northward from the Salton Sea, where the benefit consisting as it does only in the removal of a barely recognized menace, is somewhat remote, and it may be found impracticable to secure any except voluntary contributions from land - and other property owners, toward the cost of work on the Colorado.

#### THE UNITED STATES AND MEXICO SHOULD ACT.

Under the circumstances as herein set forth it appears that the U.S. should, if a way can be found, provide the required protection at the river; this seems possible.

- a. Under treaty with Mexico, as a U.S. work, to be constructed and maintained in foreign territory, with or without a cost contribution by Mexico.
- b. Under cooperation with Mexico, cost being equitably apportioned to the two countries.







There is good reason why Mexico should participate in this work. She has large interests that are menaced if the work be not done. No arrangement would be equitable that would relieve Mexico of a contribution to the cost of construction and maintenance. Moreover, as a party interested in holding the river in its proper channel, Mexico will no doubt demand a voice in the planning and execution of the necessary works.

Finally the troublesome stretch of river bank is upon Mexican territory and the immediate cause of an increase of the menace was the insufficient protection of work done on this river bank, by a Mexican cooperation.

In any event there should be early action by the U.S. This may be prepared for by the enactment of a suitable treaty with Mexico, which depending upon the policy determined upon by the two governments should provide:

In case of construction of protective works by the U.S:

(1) That the U.S. shall have the right to conduct water diverted from Colorado River for the irrigation of lands in California, through Mexican territory, in a main canal and branches, occupying for this purpose any necessary part of the public domain of Mexico and being empowered in case such course appears desirable to exercise the right of eminent domain in securing any lands required for canal purposes that are in private ownership. (Compensation in all condemnation cases to be fixed by appraisers, etc.).

(2) That the U.S. shall have the right to enter upon the bank lands of Colorado River in Mexico along that portion of the river which lies between the southerly boundary line of California and the southerly boundary line of Arizona, for the purpose of constructing and maintaining works to keep the river from taking a course inland, and shall have the right of eminent domain to secure privately owned lands, rights of way and easements for such works (compensation in all condemnation cases to be fixed by appraisers, etc.).

(3) That Mexico will pay to the U.S. as a contribution to the cost of the works constructed and maintained as set forth in the preceding paragraph and of any works in California and Arizona along Colorado River as an extension of or for safeguarding the works located in Mexico, (one-third) of the total amount expended thereon and will contribute (one third) of the total annual operating, repair and maintenance expenses.







(4) That the U.S. agrees to deliver to Mexico (at points to be mutually agreed upon) from any canal entering Mexico from the State of California, or will leave in the river for diversion into any canal which Mexico or any of her citizens may take out from Colorado River below the California boundary line, an amount of water as required by Mexico not to exceed in any year 600,000 acre-ft. This delivery is not to exceed in any month the following amounts: (subject to modification)

In the case of the delivery of any of this water to Mexico in the river channel, no water in the river channel is to be regarded as a part of the delivery which together with the water delivered in any canal or canals exceeds the above named amounts for single months.

(5) That no cut is to be made in the west bank of Colorado River, between the California boundary and a point on the river opposite the southerly boundary of Ariz. without the consent of the U.S.

(6) That free entry shall be granted to the U.S. and to citizens of the U.S. into Mexico of all materials, supplies, machinery and other articles of whatsoever nature required for or in connection with the construction of the protection and canal works and their maintenance and operation or in any wise appertaining thereto.

(7) That U.S. officials and employes and citizens of the U.S. shall have at all times the right of access to the works at the river and to the canal system and proposed sites of works for examination, survey, construction, maintenance and operation.

(8) That all expenditures by La Sociedad de Yrrigacion (Riegos) y Terrenos de la Baja California (S.A.) or by any other corporation or person subsequent to Dec. 7th, 1906, upon works at and near the point known as the Lower Mexican Heading in Mexico for turning the Colorado River from a course inland, back into its proper channel and of holding it there, shall be considered a part of the cost of river control hereunder contemplated and shall be repaid to the parties who have made the expenditures after examination and approval of accounts by the proper U.S. authorities, and that Mexico will reimburse the U.S. to the extent of (one third) of the amount thus paid out.

(9) That both contracting parties recognize the use of water from the Colorado River for irrigation to be superior to its use for navigation purposes and that no claim shall be made by either country for injury to navigation interests by reason of any diversion of river water for irrigation.







(10) That in the execution of a plan for river control the alignment of the river from the south boundary line of California to the south boundary line of Arizona may be modified to any extent thought desirable by the U.S. and that the center line of this section of the rectified channel shall thereafter be the boundary line between the U.S. and Mexico.

(11) That the U.S. waives all rights which it or any of the citizens of the U.S. may have against Mexico for any damage that has resulted from the inland flow of Colorado River or any portion of the waters of Colorado River during the years 1903, 1904, 1905, 1906 and in 1907 to and including Feb. 11 of the last named year.

In case that the works for holding the Colorado River to its proper course are undertaken conjointly by the U.S. and Mexico, the treaty provisions should include clauses substantially as follows:

1. That the U.S. shall have the right to conduct water diverted from Colorado River for the irrigation of lands in California through Mexican territory, in a main canal and branches, occupying for this purpose any necessary part of the public domain of Mexico and being empowered in case such course appears desirable to exercise the right of eminent domain in securing any lands required for canal purposes that are in private ownership (Compensation in all condemnation cases to be fixed by appraisers, etc.).

2. That the U.S. agrees to deliver to Mexico (at points to be mutually agreed upon) from any canal entering Mexico from the State of California, or will leave in the river for diversion into any canal which Mexico or any of her citizens may take out from Colorado River below the California boundary line, an amount of water as required by Mexico not to exceed in any year 600,000 acre ft. This delivery is not to exceed in any month the following amounts: (subject to modification).

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In the case of the delivery of any of this water to Mexico in the river channel, no water in the river channel is to be regarded as a part of the delivery which together with the water delivered in any canal or canals exceeds the above named amounts for single months.

3. That both contracting parties recognize the use of water from the Colorado River for irrigation to be superior to its use for navigation purposes and that no claim shall be made by either country for injury to navigation interests by reason of any diversion of river water for irrigation.







4. That in view of the threatened change in the course of Colorado River across Mexican territory into the depression known as Salton Basin, by a breaking of the river bank at some point of the river's course where the river is the boundary between the U.S. and Mexico, and in view of the great damage that would result from such change of course to lands and other properties in both countries, the necessity for joint action of the two countries is hereby recognized and it is agreed that works for the correction of river alignment and the making of a permanent river channel with such works as may be necessary to hold the river in its proper course to the Gulf of California, shall at once be undertaken at joint expense.

5. That this river work shall be placed in charge of a joint Commission of Engineers to be composed of two civil engineers, named by the President of the U.S., and two civil engineers, named by the President of Mexico, who shall be given full power by their respective governments to plan the necessary works and to cause the same to be constructed and maintained.

6. That salaries and personal expenses of each of the members of the Colorado River Commission, constituted as set forth in the preceding paragraph shall be borne by their respective countries, and that all other expenditures shall be made temporarily from funds set apart for this purpose by the U.S. upon vouchers approved by the Commission.

7. That at the end of each fiscal year (June 30) the Commission shall make an estimate of the amount of money due to the U.S. from Mexico as its share of the year's expenditures on the river work and that such amount shall at once become due and payable by Mexico to the U.S.

8. That the cost of all the work required to be done by the Colorado River Commission, to hold Colorado River permanently in its proper channel, shall be met jointly by the two countries, each sharing a definite proportion thereof.

9. That the proportionate amount of the cost of the river work referred to in the preceding paragraph, to be borne by each country shall be determined by the Commission (substantially according to benefits conferred or better) on the basis of the apportionment to the two countries of the irrigation water crossing the California boundary. (This may be assumed preliminarily as 600,000 acre ft. per annum to Mexico and 1,200,000 acre ft. to the U.S.).

10. That free entry shall be granted to the U.S. and to citizens of the U.S., into Mexico of all materials,







supplies, machinery and other articles of whatsoever nature required for or in connection with the construction of the protection and canal works and their maintenance and operation or in any wise appertaining thereto.

11. That any work along the river in Arizona and California at points below Yuma, which is considered necessary by the Commission as an extension of or to safeguard the work already done, or to be done, in Mexico to hold the river on its proper course, shall be considered a part of the work authorized to be undertaken by the Commission at joint expense of the two countries.

12. That U.S. officials and employees and citizens of the U.S. shall have at all times the right of access, for purposes of examination, survey, construction, maintenance and operation, to the canal systems and sites of any proposed works in Mexico which are in any way connected with the conveying of water for use on lands in the U.S.

13. That all expenditures by La Sociedad de Yrrigacion (Riegos) y Terrenos de la Baja California (S.A) or by any other corporation or person subsequent to Dec. 9, 1906, upon works at or near the point known as the Lower Mexican Heading in Mexico for turning the Colorado River from a course inland, back into its proper channel and of holding it there, shall be considered a part of the cost of river control hereunder contemplated and shall be repaid to the parties who have made the expenditures after proper examination and approval of accounts by the Commission, out of any money placed at the Commission's disposal, and shall be apportioned to the U.S. and to Mexico on the same basis as other expenditures made by the Commission.

14. That the Commission shall have the right of eminent domain in the U.S. and in Mexico to secure such rights of way, easements or lands as may be necessary for the construction of the works hereunder authorized and their maintenance.

15. That in the execution of a plan for river control the alignment of the river from the south boundary line of California to the south boundary line of Arizona may be modified to any extent thought desirable by the Commission and that the center line of this section of the rectified channel shall thereafter be the boundary line between the U.S. and Mexico.







CONDENSED RECAPITULATION OF DATA.

Colorado River, early exploration of the lower river:

Francisco Alarcon, by water, in	1540
Melchior Diaz, overland,	" 1540
Don Juan de Onate	" 1604
Padre Eusibio Francisco Kino	" 1701 and 1702
Ugarte	" 1721
Fernando Corsay	" 1744
Padre Garces	" 1771 & 1776
Lieut. R.W.H. Hardy	" 1826
Jas. P. Pattie & father	" 1827
Lieut. G.H. Derby	" 1850-51
Lieut. J.C. Ives	" 1857

Colorado River, at Yuma

Drainage basin about	225,000 sq.mi.
Low water discharge (Dec. to Feb.) ordinarily	3000 to 5000 s.f.
High water discharge (June) ordinarily	40000 " 100000
High water discharge, extreme record on Nov.29, 1905,	115,000
Mean discharge, about	12,000
Annual discharge, normal about	9,000,000 a.f.
Annual output of sediment reported by Prof. R.H.Forbes for 1900 at	61,000,000 tons
Low water elevation	120 ft.
High water elevation ordinary (gage 29)	131 "
High water extreme about	135 "
High water of spring 1907 (gage 29.2)	131.3 "

Colorado River, at Lower Mexican Heading:

Elevation of river bank lands about	115 "
Elevation of top of dams, about	126.9"
Elevation of bed of inland channel Feb. 11/07	100 "
Elevation of bed of inland channel June, 1907,	104 "
Elevation of low water in river about	108 "
Elevation of high water in river, ordinary, about	118 "
Elevation of high water in river June, 1907,	118 "
Dredgercut, river to canal, completed	Oct.1904
River broke through bank and followed canal inland	Nov.1905
River was turned back into proper channel	Nov.4,1906







Levee broke and river resumed flow inland  
 Dec.7,1906  
 River was again turned into  
 proper channel Feb.11, 1907

Colorado River, irrigation, reported by U.S. Census  
 of 1902.

Colorado River direct	18,713 acres
Grand River & tributaries	303,718 "
Green River " "	253,662 "
Gila River " "	228,580 "
San Juan River & "	56,705 "
Virgin River	15,651 "
Little Colorado River & "	11,776 "
Fremont River " "	15,701 "
Other tributaries	7,553 "

(Some of this land is no doubt only partially irrigated)

Colorado River, Irrigable lands, not including lands already irrigated except in the case of Imperial Valley and at Yuma and excluding Gila and Salt River lands, approximate:

Above the Grand Canon, about	450,000 acres
Lower Colorado River valleys about	400,000 "
Imperial Valley, about	300,000 "
In Mexico, if limited	150,000 "

Colorado River, storage possibilities, excluding the Gila River and its tributaries, approximate:

On Taylor River, Gunnison Basin	100,000 acre ft
On Grand River	1,000,000 "
On Green River	1,500,000 "
In Strawberry Valley (Green R. Basin)	50,000 "
On Little Colorado River	50,000 "
On Bill Williams Fork	100,000 "

Colorado River, Yuma project, Reclamation Service:

Area of land one time or another irrigated about	10,000 acres
Area of valley lands	92,150 "
Area of Mesa lands	40,000 "
Estimated cost (allotment)	\$3,000,000
Expended to date, about	\$1,500,000

Imperial Valley, Imperial canal system:

Area covered by water stock of mutual companies, over	200,000 acres
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Area of land prepared for irrigation probably	150,000 acres
Area of land, actually irrigated in a single season, about	100,000 "
Area of land ultimately to be irrigated, about (Laterals and distributing ditches are not yet complete).	300,00 "

#### Salton Sink:

Salton Sink began to receive water early in 1905.	
Elevation of water surface of ancient lake, about	30' above sea
Elevation of bottom, about	280' below "
Elevation of water surface, Jan. 1, 1906,	253' " "
Elevation of water surface, Feb. 11, 1907,	202' below "
Elevation of water surface in June, 1907,	203' below "
Elevation of Calexico	at sea level
" Imperial	63' below sea
" Brawley	108' " "
" Imperial Junction	125' " "
" Mecca	195' " "
" Indio	20' " "
Area of Ancient lake, about	2000 sq. miles
" Salton Sea, 1/1/06	247 "
" " 2/11/07	440 "
" " if filled would be	1947 "
Time required to fill, in case the river again flows inland about	40 yrs.
Time required for a full basin to dry up, about	50 "
Time required for water now in basin to evaporate, about	13 "

#### Volcano Lake:

Area of water surface when full, abt	20 "
Elevation of lake bed, about	10 to 15' above sea.
Elevation of water surface when full, about	34' above sea
Summit of divide between Gulf of Cal. & Salton Basin near Volcano Lake, about	35' above sea







California Development Co:

Organized on Apr. 24, 1896.

First delivery of water to lands in Cal. 1901

La Sociedad de Yrrigacion (Riegos) y Terrenos de la Baja  
California (S.A.) the Mexican corporation:

Received water concession from Mexico 6/7/04

Now irrigates in Mexico about 5000 acres

Is supposed to have agreed to deliver  
water to large areas in Mexico, approx. 700,000  
acres.

(Sgd) C.E. Grunsky

Consulting Engineer.

Hon. James Rudolph Garfield,  
Secretary of the Interior.















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