CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

Report of

AN INVESTIGATION OF THE MOJAVE RIVER REGARDING THE FEASIBILITY OF FLOOD CONTROL AND IRRIGATION

By

Byron Hill

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June 5, 1925

An Investigation of the Feasibility of a Flood Control of the Mojave River.

The Mojave River is a small inland river in San Bernardino County. Its source is on the northern slope of the San Bernardino Mountains. It supplies the chief drain system for that side of the mountains. The river flows first to the north for thirty miles, then a little north of east for sixty-six and then north again for twenty miles.

This river differs from other rivers in that its mouth is an opening into the atmosphere rather than into an ocean or lake. While the ultimate reach of the stream is Silver Lake it is well to mention that this lake is a typical dry lake and most of its water is only a mirage. It differs from other rivers in that it has not cut appreciably into its channel but has built up almost its entire length. That is, the river has apparently found the country into which it flowed broken up into deep basins with small connections between them. It has apparently left these basins much as it found them, except that it has filled them. The sub-structure of the river channel then consists of a series of large basins separated by dykes of more or less width. In yet another way the river is different in that it flows into a country where water is so scarce that it is almost invaluable.

This stream flows into a country rich in valuable metals and numerous minerals. Thus it makes possible the extraction of these valuables by man for the local rainfall supplies only a few scattered springs of very small quantity. The Calico and Waterman silver mines used the water from the Mojave River for their operation. The Bagdad Chase mine at Ludlow was operated by shipping the ore to Barstow where the water from the Mojave was available. These examples are only a few of many cases of the water of the river being used for extensive mining operations.

The river has furnished a means of livlihood by agriculture for many years, though not extensively. The river flows upon the surface during the entire year only at a few points where the dykes between basins force it to the surface. At these points irrigation ditches have been built and alfalfa fields and a few orchards planted. At other points along the course the water flows on the surface only part of the time during the rainy and flood seasons. Floods reach Barstow nearly every year but they seldom reach Silver Lake. In the last seventeen years only four floods have reached Silver Lake as surface water. At these places where the water does not flow during the year, especially during the dry season, wells have been sunk and pumping plants installed. These have often been used only as auxilliaries to ditches from the river. In other cases the pumping plant has been the chief supply and a ditch has been used as an auxilliary.

The first white inhabitants of the valley were stock grazers who used the river as a water supply for the stock. Until the appearance of the stock raisers the valley was inhabited by Piute Indians who extracted a miserly existence from it. Arrowheads, grinding stones, etc. are present evidences of their past existence.

The river furnishes a route for two transcontinental railroads, the Santa Fe and the Union Pacific. One of the chief assets of the river course to the railroads is the good water supply. Not only is it used at points along the course but water is hauled from it farther into the desert where water is not available. Ludlow is an example of a small town supplied with water by railroad transportation.

The Mojave River course is interesting from a geologic point of view. There are evidences of two important changes in its course due to volcanic action. The stream once flowed to the north from Hicks into a deep basin which is now called Harpers Lake. A volcano occurred a few miles to the north of the basin nearly filling it with ash and clay and filling the entrance to such an extent that the river broke past Barstow and continued in that course. The present Harper Lake is lower than Barstow and there is considerable underflow from the river into the basin. This has been proven by taking an analysis of the water at different points along its course into the basin and finding the water the same. Also the action of water in dug wells in the entrance to the basin shows a flow toward the basin. That the water evaporates from the basin is evidenced by the very salty water found in the wells of the basin. It is interesting to note that this evaporation occurs in spite of the fact that the water level is nowhere less than fifteen or twenty feet from the surface. This flow of water has not been considered in most investigations of the Mojave River. Yet it must be considerable for the entrance is wide and deep and the slope is steeper than the slope along the new course of the river. The sand and gravel through which the flow occurs is finer than that of the new course, thus tending to decrease the flow of the former. No investigations have been made as to the quantity of this flow.

A similar condition existed farther downstream near Newberry. The river once flowed to the east past Newberry into a basin now known as Lavic Lake where it evaporated. A volcano occurred near Newberry which filled this basin sufficiently to cause the water to overflow at Caves Canyon and cut out a passage into Soda and Silver Lakes. Whether or not there is still an underground flow into Lavic Lake I have not learned, but, as there is a downward slope to it from the present course, it may be assumed that such a condition exists.

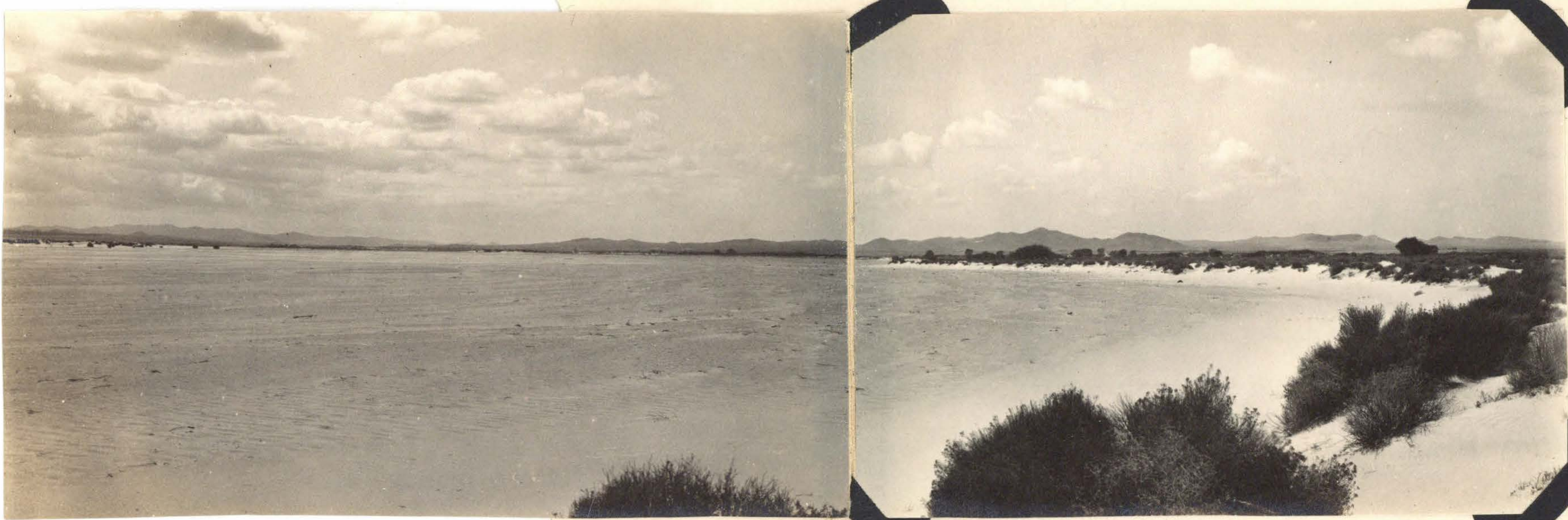
The source of the River is entirely within the San Bernardino Mountains. There is no tributary of any significance on the desert. The source consists of two main branches which unite at the foot of the mountains. The two forks are known as the West Fork and Deep Creek. West Fork continues to the west some six miles and then branches into the East and West Forks of the West Fork. This system drains a territory of seventy-five (75) square miles extending from Cajon Pass to and including Grass Valley near Arrowhead Lake. This system supplies considerably more than a third of the river's supply. Deep Creek extends through a deep, steep canyon into the heart of the San Bernardino Mountains. It drains an area of one-hundred-forty-two (142) square miles extending from Grass Valley on the west to the central part of Holcomb Valley on the east. The south-east part of Holcomb Valley drains into Bear Lake, the remainder into Holcomb Creek, thence into Deep Creek. The area of this watershed is nearly double that of the West Fork but its flow is not double. This is due to the fact that part of the Deep Creek watershed is so situated on the desert side that the rainfall is less. From this fact it may also be assumed that the runoff will be less uniform from this stream than from the West Fork. The rainfall and runoff of this watershed varies considerably from that on the southern side of the mountains. The rainfall is less and more erratic and there is less vegetation so the runoff is heavier and quicker for a given rainfall.

The elevation at the Forks is 3000-ft. and the highest point on the watershed is about 8000-ft. The elevation at Silver Lake is 900-ft.

The course of the river from the Forks on to Silver Lake is through alluvial soils deposited by the stream changed somewhat in character along its length by mixtures of materials from local washes. In some places the soil is very loose and is blown into sand dunes; in others it is heavier and in some places there are deposits containing large amounts of alkali. The river at flood times tends to meander back and forth across the valley. Thus, where the valley is broad, the river has wasted wide areas leaving only bare sand stretches often over one mile wide. According to reports this condition is recent. Early Spanish visitors reported the valley as covered with trees and grass.

Engineers making investigations for railroad routes found no such flood conditions in the fifties. The valley looked so attractive that the Mormons considered a settlement near Helendale. This is only another of the many cases of our destruction of forests causing damage to the watersheds. In the sixties and seventies saw-mills were started in the mountains and all of the available lumber timber was cut in the usual destructive manner. To add to this, practically all of the trees (mesquite and cottonwood) along the river were cut for fuel so that everything was nicely set for damage to be done. Since then the damage has been occurring every few years with each flood of reasonable size. There has been but little damage done by overflowing since the first cutting out of a large channel but the looseness of the soil allows a great amount of meandering. The stream will start cutting into the bank on one side and it continues year after year until a change in course upstream causes it to desist. During high floods this cutting is rapid. As an example, the Zanini Ranch was almost entirely destroyed during one night in the heavy flood of 1916-1917. The river had been pointing toward the ranch for a few years previous and had cut away a corner. Then during this flood almost the entire ranch of alfalfa and apples was undermined and washed away in a few hours.

Another cutting of interest is occurring about two miles below Hicks. The river strikes a clay bank on the south-east side of the stream just below Hicks. This deflects it so that it strikes strongly on the other side some two miles below. It has cut out a channel some two miles wide. A photograph of this expanse is shown. The point where the stream has attacked is comparatively low and, whereas previously the gound had a slope, the river has cut approximately on a level so there is very little bank left. In some places this is only a foot or two. Consequently, with each moderate flood in the past few years, there has been an overflow at this point with a great danger of the entire stream changing its course. This overflow follows an old channel which takes it about two miles to the north of the present course. Such a change in course would ruin several hundred acres of good land and would also bring the stream against the San Francisco branch of the Santa Fe Railroad for a distance of three miles. In its unprotected state the railroad would be completely destroyed for this distance. The situation is so serious that the railroad has co-operated with the farmers endangered in attempting to divert the stream back to its older channel.



The Mojave River between Hicks and Barstow.

This photograph was taken from the north side looking upstream. The river once flowed in a channel to the left beyond the line of dunes and brush seen. By continuous cutting in the loose soil it has spread to the right until here it is over a mile wide.

Various projects for the use of the Mojave, both sane and absurd, have been considered since 1870. Many small projects have been carried out, some of which have been successful and many of which have been failures. It is doubtful if any have proved to be a very good investment of the capital involved. Many of these small settlers, especially those whose lands are endangered by the cutting of the river, have long dreamed of having some form of flood control established to save their lands and to save the flood waters. If these lands near the river could be insured against washing away it would greatly increase their value. Also, a control system might easily be a most effective system of irrigation. Certainly the Mojave is almost perfectly adapted to this form of project. The string of basins, one after the other, makes a very desirable storage system from which each individual farmer may pump. The only waste is evaporation and if the valley is put under cultivation the evaporation will consist almost entirely of transpiration from the cultivated plants.

An average depth to the water-surface of lands in the valley as far down stream as Daggett is 15-ft.

An average overall head to pump would be about 30-ft. Power at present may be secured from the Southern Sierras Power Co. at a rate of an average of 1.8 cents per K.W.H. As an average it will require about 4 K.W. to lift 1 sec.ft. this height. Then $1.8 \times 4 \times 24 \times \frac{1}{2} = \$0.86$ per acre ft. cost of pumping. With a duty of 6 ft. this will cost annually $5.16 per acre.

The initial cost should average per 40 acres:

120' Well Casing 12"	@ $2.00 per ft.	$240.00
Drilling	3.00 " "	360.00
Pump (installed)		250.00
Motor		300.00
	T o t a l	$1550.00
Interest 7%		
Depreciation 5%		
Annual Cost		$186.00
Annual Cost Per Acre		4.65
Total Annual Cost of Pumping Per Acre		9.81

This amount of irrigation should produce an average of 6 tons of alfalfa per acre at an assumed value of $20.00 per ton unbaled.

The cost of labor per 40 acres, if well organized, should be:

Irrigator	$350.00
Haying Labor	600.00
Annual Cost of Equipment Including Work Stock	350.00
T o t a l	$1300.00
Total Per Acre	32.40
Total Cost Pumping & Labor	42.20
Net Gain $120.00 - 42.20 =	77.80
Value of Land Per Acre $77.80/.07	$1111.00

But these figures are for well managed conditions and few farms on the desert are so managed. The farms have been too small and the equipment too meager for hay raising. These figures do not include the cost of administration. It is doubtful if the land in this district will exceed a value of $400.00 per acre in alfalfa.

9.81/400 = 2.43%, the ratio of annual cost of irrigation to value of land.

Although farms on the desert pumping their water have not been profitable, there is little doubt but that they can be under the same conditions with better management.

Consequently there was a justification for investigating the possibilities of controlling the floods.

An investigation showed (as reports by investigators of the past have shown) that there are many good dam sites but they are mostly situated where they can be little used. The best dam site and reservoir site is at the Upper Narrows near Victorville, but this site is impossible for flood control as it would submerge the most valuable land on the river and would not control the stream at its worst, between the Forks and Victorville.

There is no possibility of a dam just below the Forks as the two streams converge right at the base of the mountains and the channel below is fully a half mile wide. Photographs of the Forks from below and above are shown.

The Mojave River at the Forks.

The photograph was taken at a point below the Forks looking east. Deep Creek Canyon is the canyon in the center of the picture. West Fork enters from the right through an opening hardly visible in the picture. An arrow in ink indicates the location of this canyon. The river flows away at the lower left.

The so-called Forks dam site is just above the Forks on the West Fork. This dam site is very favorable. A dam height of 150' will develop a storage of 102,000 acre feet. The channel is narrow and the rock is of a solid granite. No borings have been made to verify the expectations as to the understructure. This would have to be done before any real consideration of the project were allowed. The reservoir of this site would be bordered on the south by the mountain range and on the north by a high cliff which the river has cut from a mesa which slopes off to the north-east until it reaches the river again. This bank is somewhat porous and might leak too much water to justify its use for irrigation purposes. This high bank extends the full length of the reservoir site but terminates just above the dam site where the stream passes between a granite peak and the main mountain. At the junction of the bank and this peak there is a point about a hundred feet lower than the rest of the bank. This point would have to be built up to the height of the dam. Photographs of this dam site are shown from both above and below. However, no photograph was taken showing this low point in the bank.

The Mojave River Forks.

This view is taken from the mountain almost over the Fork on the north side. In the section on the left the Forks reservoir site is seen with Old Baldy in the background. This shows the site far better than words can describe it. The dam site is seen in the narrow gorge in the lower right of this section. The conical peak is seen on the right of this section and the left of the next one. The low point in the north bank is not shown because it lies just beyond the conical point. The view is taken looking upstream. In the center of the picture the river below the Forks is seen flowing away and turning to the right. The surface stream sinks at the point marked. The photograph was taken in March 1925. The sand wastes are seen stretching off into the distance. On the right is seen Deep Creek above the Forks with the Hesperia Ditch on the mountain side.

There are also good dam sites accompanied by a good reservoir site at the junction of the East and West Forks of the West Fork. Here a dam of 150' height will store only about 35,000 acre ft. and will cost more as the canyon is somewhat wider. Consequently, of the two choices, the first appears much the better. Also there is some flow into the stream between the two sites so the lower dam would control more runoff.

Forks Dam Site from Above.

The road on the right is the Arrowhead Lake Toll Road. The dry wash shows signs of heavy flows in the past.

An examination of Deep Creek, however, showed no reservoir sites of significance. The channel is very steep and narrow well up into the mountains. There it branches into several tributaries. The main tributaries are Willow Creek, Holcomb Creek and Little Bear Creek. On Holcomb Creek it was found that a dam with a height of 150 ft. would store about 3,500 acre ft. A similar situation was found in the upper part of Deep Creek. On Little Bear Creek, Lake Arrowhead is already developed. Here a dam 160' high stores 35,000 acre ft. But, unfortunately, the watershed is so small that its value is insignificant. The drainage area is only about 7 square miles. The average rainfall is 32 inches. 7 x 640 x 32/12 = 12,000 acre ft. The total rainfall and the runoff would be much less. The value which the Lake gives as a recreation and pleasure resort is undoubtedly far greater than it could possibly be as an instrument in flood control.

Upper West Fork Dam Site.

This view is taken looking downstream just below the Fork of the West Fork. Notice the growth of trees where, at the lower dam site, there was washed sand and gravel. This shows that a dam here would control less flood water than the one below.

There is a possibility of controlling the flood waters of Deep Creek by building a diversion dam somewhere above the Forks and passing the water through a tunnel to the reservoir on the West Fork. As this is a possibility it is worth investigating.

I regret that I have been unable to obtain either runoff or rainfall data, except the annual totals, so the following computations are based on my estimation of flow made by comparing my observations of results of floods with the annual flow data. With daily runoff or rainfall data which has been taken, but which I have been unable to secure, definite figures could be used instead of estimations from observance.

The maximum flow per season in the seventeen year period considered was 254,000 acre ft. The maximum flow without appreciable damage I have estimated at 80,000 acre ft. The difference is 174,000 acre ft. to be controlled. West Fork flow was 110,000 acre ft. 174,000 - 110,000 = 63,000 acre ft. to be diverted. This amount should be carried in a maximum period of seven days. 63,000 acre ft. per week = 9,000 acre ft. per day. 9,000 acre ft. per day = 4,500 sec. ft. Using a minimum diversion dam the length of tunnel must be 2½ miles with a slope of .0075. From cost data taken from the Engineering News Record for tunneling in hard Western rock, this would involve a cost of $150.00 per lineal foot. 150 x 2.5 x 5280 = $1,980,000 cost of tunnel. Assuming a diversion dam to have a height of 20 ft., a mean length of 200 ft., and that bed rock is approximately at the surface, the area of cross section will be 160 sq. ft.

200 x 160 = 32,000 cu. ft.

Assuming the cost of concrete at $6.50 per cu. yd., including forms, the cost will be

32,000/27 x 6.50 = $7,700.00

Allow $10,000.00 for this construction.

This is entirely out of proportion with the cost of the tunnel so the diversion dam should be made higher and the tunnel shorter.

An investigation shows that the minimum feasible tunnel will be 3/4 mile long and will require a diversion dam of 120' height. The cost of this dam, with adequate spill, considering the easy access to good rock and sand, and fair access to cement, should be about $600,000.00. The cost of the tunnel would be

$$150 \times \tfrac{3}{4} \times 5280 = \$595,000.00$$

The cost of the dam and the tunnel

$$\$600,000 \text{ plus } \$595,000 = \$1,200,000.00$$

This represents the minimum cost of such a tunnel diversion. The steep sides of the mountain, combined with a rather deep amount of loose, decomposed material, make an open cut unfeasible.

The cost of the dam at the Forks has been estimated at $900,000.00.

This gives a total of $2,100,000.00 as the cost of the control system.

Allowing two years for construction the interest on the cost of construction should be equal, approximately, to the interest on the total sum for one year:

$2,100,000.00 @ 6% = $126,000.00

Total cost $2,226,000.00

$2,226,000.00 @ 6% = $133,500.00 cost per year.

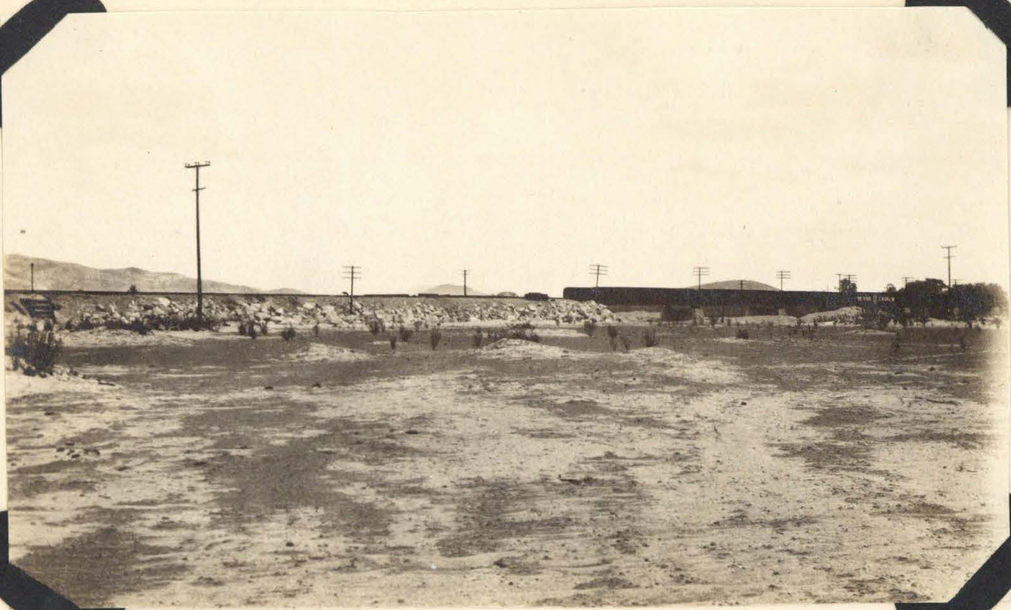
This sum represents the annual good which the flood control system must do for the valley.

The average annual flow is 90,000 acre ft. The duty of water for alfalfa is about 6 ft. It may be assumed that 2 ft. of this seeps down to the water level and may be used again allowing a duty of 4 ft. On this basis 22,500 acres may be irrigated. This involves an annual cost of $6.00 per acre for flood control.

This cost might not be prohibitive if the control were essential and if the acreage assumed as irrigable were to be put under cultivation at once. But, considering the small danger of injury to the majority of the land and the fact that the valley is being settled very slowly with only about 4,500 acres now under cultivation, the cost is prohibitive.

This cost to the land may be reduced by allowing for the value to the railroads and highways, along the course, of having their property protected against floods. The Santa Fe Railroad has been caused considerable expense in past years due to the stream cutting into its tracks. Also, they have had some trouble with the pile bridge at Barstow being washed out. The costs, however, are not available. Furthermore, the danger from cutting has been greatly reduced by changes in their line. The pile bridge has now been replaced by a plate girder bridge which should cause no trouble by washing out.

However, there is some danger of the river meandering around the bridge and causing an expense to the railroad to protect their approach. This happened in the flood of 1916-1917. The railroad had replaced the pile bridge at the channel of the river with three plate girder spans, but during this flood the channel swerved to the north and washed away about a hundred feet of the pile bridge. During the past year three more spans have been added on the north side of the first three. If the river should now diverge still more to the north at this point the railroad will be obliged to protect their northern approach, a difficult and expensive task when the stream points strongly in a given direction.



Santa Fe Railroad Bridge at Barstow.

This shows the approach on the north side slightly protected by granite boulders, but exposed to the whim of the river.

Certainly it would be of value to the railroad to have all floods prevented but there is apparently no basis for computing the value. The Wood Brothers Construction Co. of Lincoln, Nebraska, have proposed a patented type of flood control made of standard angle bars bolted together and wired with barbed wire. The estimated cost is $25,000 per mile. A mile of this would adequately protect the bridge and another mile would protect against the cutting below

Hicks, before mentioned. Therefore, if this method were successful the only value that could reasonably be allowed to the railroad now is about $50,000.00.

The highways have had some added expense because of the river . Most of this expense has been at the bridges at Barstow and Daggett. The bridge at Daggett is now standing high and dry with sand dunes piling up around it, while the river has moved to the south of it.

The bridge at Barstow would now be in the same predicament had not the County, in 1917, spent several thousand dollars to construct a system of pile guides to turn the river back to its course.

Mojave River at Barstow

This photograph shows the pile and brush breakwater chain which guides the river under the highway bridge at Barstow. The bridge is located on the right side of the rock butte which is seen at the extreme right of the picture. The river showed indications of cutting a new channel to the left of the butte. This chain of breakwaters was installed in 1917 with only a gamble as to its success. Had a heavy flood come the following year everything would have been destroyed. However, light floods came in the following years and the channel was gradually cut back to the bridge. One or two of the units were washed away but the rest held the stream in place.

However, the annual value of control to the highways, like that of the railroads, is of little significance.

There is a possibility of controlling only the West Fork and allowing the Deep Creek waters to pass unchecked. Discharge records show that in the 17 year period only twice would the flood have been damaging had only the West Fork been controlled. As the damage is done mostly by cutting rather than by flooding, the value would be nearly as great as a complete control. The cost would be $900,000.00, plus interest during construction of $54,000 = $954,000.00; an annual cost of $57,240.00 or $57,240/22,500 = $2.55 annual cost per acre.

In this case the lands adjacent to the river will be satisfactorily protected but the loss of water, due to flood waste, will not be so satisfactorily diminished.

Another proposed method of control is that of diverting the flood waters into the expanse of sands, between the Forks and Victorville, that have already been wasted by floods. Such a system would involve an annual expenditure rather than one initial expenditure; thus, only a small loss would be involved if the plan were a failure.

The approximate area of this wasted land is eight square miles. The average depth to the water level may be assumed at six feet. The average percentage of void in the sand is taken as .4. Then, 8 x 640 x 6 x .4 = 12,300 acre ft. This figure is insignificant and it is unnecessary to consider that it would be unfeasible to get all of this uneven area saturated.

The minimum cost of satisfactorily controlling the floods for protection appears to be about $57,250.00 annually. It is next necessary to determine the probable value of the protection to the farmers along the river.

As there is much more land along the course than can be irrigated by the water available, I think an estimate of value of protection should be placed only on those farms that are now developed and that are endangered, and assume that future development will be done on safe lands.

There are only 4500 acres developed. Of this, 2000 acres are entirely free from danger by floods. This leaves only 2500 acres to be safeguarded against the possibility of floods.

Within the past fifteen years several heavy floods have occurred yet my estimation of the acreage of cultivated lands destroyed is under 200. This figure is certainly sufficiently high. These 200 acres, priced at the value of $400.00 per acre, were worth only $80,000. This is a little more in fifteen years than the annual cost of the cheapest flood control and, very obviously, the flood control project has no justification.

There is left one form of flood control that can be justified. According to reports of early visitors to the valley there were no signs of such floods previous to the destruction of the timber on the mountains. Consequently, reforestation should prove an ample flood control. The reforestation will repay its cost in the value of the timber properly cut and, added to this, the river will be controlled.

According to the Bulletin No. 475 of the United States Department of Agriculture, the cost of reforestation ranges between two and twenty dollars per acre, depending on circumstances. The cost of planting young trees is higher and averages about ten dollars per acre. These prices were for 1917. The cost of labor would be a half more now than then. The average cost of seeding was placed between four and six dollars per acre. The conditions in these mountains are very favorable, there being good roads entering from both sides and an easy access to most of the area. So it may be assumed that the cost of seeding this area at the present time will be only about five dollars per acre. There are approximately 175 square miles that could be planted:

175 x 640 x 5 = $560,000, cost of planting.

On the area of less rainfall lying to the north of Deep Creek it might be necessary to plant young trees in order to insure a growth. Assuming 50 square miles of this area, the cost of planting should be:

50 x 640 x 10 = $320,000.00

Cost of seeding 125 square miles:

125 x 640 x 5 = $400,000.00

Cost for both areas = $720,000.00

This is $200,000 less than the cost of constructing the Forks Dam. The results should be more satisfactory from a control point of view and the forest would be a great asset.

Reforestation, then, is apparently the one practical solution for the controlling of the floods of this stream.

The Mojave River as an Irrigation Project

There have been many irrigation projects proposed for the Mojave River, most of which have been more or less absurd from an engineering point of view. One of the largest, and consequently the most absurd of the proposals made, was that of building a dam at the Upper Narrows at Victorville to impound the waters of the river. A tunnel twenty-two miles in length was to be dug through the San Bernardino Mountains and the water used in San Bernardino Valley. This proposition was first attempted by the Columbia Colonization Company in 1895. Nothing beyond the purchase of lands has ever been done.

A successful rival to this plan on the grounds of absurdity was the proposition of a promoter for diverting water from the river at Hicks by a canal 400' wide at the top and 250' wide at the bottom, 10-ft. deep and with a grade of 3-ft. per mile. This was to irrigate 10 townships or 230,400 acres of land below Daggett.

A very elaborate system was proposed by the Arrowhead Reservoir and Power Co. It was proposed to construct a main reservoir in Little Bear Valley.

Inlet tunnels were to be constructed from this reservoir to Deep Creek, Holcomb Creek and Crab Creek. Another reservoir was to be built in Grass Valley with a connection to the main reservoir by tunnel. The water was to be passed through a tunnel to the south side of the San Bernardino Mountains and used there for irrigation. Later, when long distance electrical power transmission was made possible the company considered the development of power. The dam in Little Bear Valley was constructed and some of the inlet tunnelling done when action was stopped by a decision of the State Supreme Court that flood waters could not be diverted from their natural drainage basin. This caused a cessation of all activities.

The Victor Valley Irrigation District proposed to purchase the property of the Arrowhead Company and use the waters developed for the irrigation of the lands on the West Mesa, consisting of the high ground between Victorville and the San Gabriel range. This plan was hardly feasible from a practical point of view so nothing was done.

The Mojave River Irrigation District proposed to construct a dam at the Forks and a diversion dam and tunnel from Deep Creek and to take the water to the lands lying to the east of the river known as the East Mesa. This plan seems to be the only one with any indication of practicality.

There are a number of ditches diverting water for irrigation mostly between Helendale and the Forks. Some of these have been in operation since 1870. The largest of these enterprises is that of the Rancho Verde. Some 1500 acres have been irrigated on this ranch. There are a number of small ditches between Victorville and Hicks. Then there are none of consequence between Hicks and Daggett, where the Daggett ditch irrigates some 250 acres and the Yermo ditch some 200 acres. The Hesperia ditch takes its water from Deep Creek and irrigates some 300 acres.

Judging the water rights by the ruling that claims must be backed by the actual use of the water, the owners of these ditches constitute the chief owners of water rights in the Valley. There are the owners of lands supplied by pumping to be added to this to make a total.

Due to the great discrepancies and variations in claims to water rights and amounts used it is probably safest to ascertain the consumption of water by allowing a given duty on the acreage irrigated.

There were in 1917, according to Bulletin No. 5, about 3000 acres in the valley irrigated by ditches. This number has not increased appreciably since then. The area irrigated by pumping at that time was 6775 acres. This area has been somewhat increased since 1917. The area irrigated by pumping is now approximately 7500 acres. This makes a total of 10,500 acres irrigated at the present time with undisputed rights to water. This is at considerable variance with the area taken by the Mojave River Irrigation District in their computations. Yet their data was claimed to have been taken from Bulletin No. 5.

4000 acres of this is assumed to be orchards with an average duty of 1.5 and the remainder to be planted to alfalfa with an average duty of 4 acre feet, allowing for seepage to be reused.

4000 x 1.5	=	6000 acre ft. for fruit lands
6500 x 4	=	28000 acre ft. for alfalfa lands
Total	-=	34000 acre ft. annual duty

The irrigation period is usually from March to September, but for this study a straight line curve for the year will be used.

The annual runoff data collected and estimated by the Mojave River Commission, and published in Bulletin No. 5, is shown together with the cumulative flow.

Cumulative Annual Flow

Year	Deep Creek	West Fork	Total	Cumulative
1897-98			27,040	27,040
98-99			13,900	40,900
99-00			18,132	59,000
1900-01			96,598	155,600
01-02			33,789	189,400
02-03			107,315	296,700
03-04			28,232	324,900
04-05			95,016	419,900
05-06	87,633	47,587	135,220	555,100
06-07	136,052	118,265	254,317	809,400
07-08	40,920	19,856	60,776	870,200
08-09	54,257	35,483	69,740	939,900
09-10	87,656	48,049	135,705	1,075,600
10-11	86,627	61,311	147,938	1,223,500
11-12	29,037	17,927	46,964	1,270,500
12-13	14,900	11,460	26,360	1,296,900
13-14	105,130	64,805	169,935	1,466,800
14-15	77,331	45,305	122,636	1,589,400
	Average		89,400	

There are about 23,000 acres of land in the East Mesa which are low enough to be irrigated from a dam at the Forks. The duty of the water for orchards for the area has been placed at 1.5 ft. This is a very high duty but with pipe distribution systems this should not be too high. The approximate monthly duty is as follows:

Month	Feet
March	.15
April	.21
May	.25
June	.27
July	.27
August	.24
September	.11
Total	1.5

Due to the lack of monthly flow records, a uniform annual demand will be used.

23,000 x 1.5 = 35,500 acre ft. annual demandof land.

With concrete lined canals and laterals, the losses may be neglected, though there would be some loss due to evaporation.

The surface exposed on the reservoir proposed would be 2000 acres. The annual evaporation at Lake Arrowhead is about 30 inches and at Victorville about 85 inches. The conditions of evaporation at the Forks dam site are much more like those of Victorville than Lake Arrowhead. Consequently, the evaporation at the

Forks cannot well be placed at less than 60 inches per year.

5 x 2000 = 10,000 acre ft. annually due to evaporation.

The seepage in the reservoir would be high but it cannot be determined in advance and need not be computed as the water will flow into the ground waters of the river and help supply the demands of the present consumers.

The annual demand, then, is a total of 45,500 acre ft. for the proposed project. This, added to the demand of the present users, produces a total demand of 79,500 acre ft.

The Forks dam will develop a storage of 102,000 acre feet with a dam height of 150'. However, the base of the dam would be on the 3000' contour and the lower end of the main canal must be at an elevation of 3075 in order to supply water to the proposed lands. Allowing 25' drop in the six miles of canal the outlet of the reservoir must be 100' above the base of the dam. This allows only 50 ft. of storage for irrigation use. In this 50' about 75,000 acre ft. can be stored as indicated by the 50' contours of the U. S. G. S. map.

If the demands of the present users are to be supplied each year before the proposed users may take any water the following conditions exist:

Year	Cumulative Flow in Acre Ft.	Cumulative Flow -34000 Acre ft.	Available for diversion acre.ft.	Reservoir Stage in acre ft.
1897-98:	27,040:	7,000;	45,500:	22,500
98-99:	40,900:	27,100:	22,500:	0
99-00:	59,000:	-43,000:	0:	0
1900-01:	155,600:	19,600:	19,600:	0
01-02:	189,400:	19,400:	0:	0
02-03:	296,700:	92,700:	45,500:	27,800
03-04:	324,900:	86,900:	22,000:	0
04-05:	419,900:	147,900:	45,500:	15,500
05-06:	555,100:	249,100:	45,500:	71,200
06-07:	809,400:	469,400:	45,500:	Full
			:	170,000 Spill
07-08:	870,200:	496,200:	45,500:	55,300
08-09:	929,900:	531,900:	45,500:	45,500
09-10:	1,075,600:	633,600:	45,500:	Full
				25,200 Spill
10-11:	1,223,500:	747,500:	45,500:	Full
				68,400 Spill
11-12:	1,270,500:	760,500:	45,500:	62,500
12-13:	1,296,900:	752,900:	45,500:	9,000
13-14:	1,466,800:	888,800:	45,500:	Full
				14,500 Spill
14-15:	1,589,400:	977,400:	45,500:	Full
				43,100 Spill

This table shows that in two of the eighteen years considered there would have been no water available for diversion and in three of the years there would have been less than half the required amount. There would have been ample for the remaining thirteen years. Furthermore, these dry years came in close succession so that the results would have been disastrous to fruit trees as well as their crops.

If the proposed irrigation project were to be allowed to divert its full amount of water regardless of the shortage of run-off the supply would be insufficient for one year of the eighteen.

Year	Cumulative Flow	Cumulative Demand	Reservoir Stage	Spill	
1897-98:	27,000:	45,500:	56,500:	0	
98-99:	40,900:	91,000:	24,900:	0	
99-00:	59,000:	136,500:	0:	-2500	Shortage
1900-01:	155,600:	182,000:	48,600:	0	
01-02:	189,400:	227,500:	31,900:	0	
02-03:	296,700:	273,000:	Full:	23,700	
03-04:	324,900:	318,500:	57,700:	0	
04-05:	419,900:	363,000:	Full:	32,200	
05-06:	555,100:	408,500:	Full:	89,700	
06-07:	809,400:	443,000:	Full:	208,800	
07-08:	870,200:	488,000:	Full:	15,300	
08-09:	939,900:	533,500:	Full:	24,200	
09-10:	1,075,000:	578,000:	Full:	80,200	
10-11:	1,222,500:	613,500:	Full:	102,400	
11-12:	1,270,500:	658,000:	Full:	1,500	
12-13:	1,296,900:	703,500:	55,900:	0	
13-14:	1,466,800:	748,000:	Full:	106,400	
14-15:	1,589,400:	793,500:	Full:	77,100	
	Average:		:	42,700	

This table shows that in seven of the eighteen years no water would be passed to the present users and in four more there would be a shortage. Yet this is the proposition of the Mojave River Irrigation District. Their argument is that the average flow is sufficient and that the basins of the river course will equalize the variations in flow. But they do not sufficiently consider that there is a shortage of eight consecutive years and that no equalizing system could be expected to provide for such a variation. Under the present conditions of unrestricted flow there is a shortage felt at some places following periods of low flow.

The acreage to be irrigated by the diversion could be decreased only at an increase in the unit cost which is already sufficiently high.

A higher dam for equalizing the flow more completely is impractical due to the low point in the bank on the north side of the reservoir and the prous nature of the entire bank. The increased pressure on the porous structure might cause sufficient seepage to injure the banks.

The conclusions reached are that the proposed system of diversion is the only feasible one but that this one is impossible because of the water rights of the present users.