

ABSTRACT

OF THE REPORT OF THE

Hydraulic Commission of Brazil,

W. MILNOR ROBERTS,
CHIEF ENGINEER,

UPON THE EXAMINATIONS OF

The São Francisco River,

Made in 1879-1880.

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Upon their examinations of the São Francisco River,
made in 1870-80.

The mouth of this river is in about latitude 10 degrees 27 minutes south, and longitude about 36 degrees 20 minutes west from Greenwich.

There is usually from twelve to fourteen feet depth on the bar at high tide; the fluctuation being only four or five feet.

There is at all times a large volume of water flowing from the river, and inside of the bar the depth is thirty feet for some distance; but it gradually lessens to from ten to fourteen feet.

For convenient reference, this river may be considered in five principal sections:

| | | *KILOMETERS. | MILES. |
|-------------|---|--------------|--------|
| SECTION. I. | From the Ocean to Piranhas..... | 238 | 148 |
| “ II. | “ Piranhas to Jatobá..... | 128 | 79 |
| “ III. | “ Jatobá to the rapids of Sobradinho..... | 428 | 265 |
| “ IV. | “ Rapids of Sabradinho to Pirapora Falls... 1,328 | 823 | 512 |
| “ V. | “ Pirapora Falls to the sources..... | 800 | 496 |
| | Total length..... | 2,922 | 1,811 |

* A kilometer is about $\frac{5}{8}$ of a mile; it is 0.621 mile. A meter is 3.28 feet.

SECTION I.

FROM THE OCEAN TO PIRANHAS.

Lower River.

Penedo, a tidal port, is forty-nine kilometers from the ocean on the left bank or Alagoas side. Propria, on the right bank, or Sergipe side, is eighty-nine kilometers from the ocean. Pão d'Assucar, on the left bank, is one hundred and ninety-four kilometers from the ocean.

The elevation of the river at Piranhas during the low water season is eighteen meters above sea level. In great freshets the stream rises twelve meters at Piranhas, and eight to nine meters at Penedo. The current is strong; but steamers and barcas with sails, aided by the up-stream daily winds, can stem it.

The average width of the river up to Penedo is about fifteen hundred meters, although it is much wider in places. Some of the navigable channels, at the islands, are about four hundred meters wide.

Above Penedo it continues very wide as far as Pão d'Assucar; above that place it becomes narrower, with occasional broad places to

Piranhas ; but the narrowest part is two hundred meters wide, affording a fine, deep navigation through the narrows. Steamers run regularly, making weekly trips between Penedo and Piranhas; and ocean vessels, not of a large class, generally ascend to Penedo.

No work is recommended to be done at present on the first section. There is a sufficient navigation for all present needs between the ocean and Piranhas. Hereafter it may perhaps be deemed advisable to remove a few rocks to straighten the channel below Piranhas ; but the fact that the steamer Sinimbri has been running there regularly for several years without accident, shows that the necessity for work on that part of the river is not urgent.

SECTION II.

PIRANHAS TO JATOBÁ

Between the Lower and Upper River.

This portion of the river is not navigable, and no improvement of the stream is proposed.

The great Paulo Affonso Falls, one of the grandest objects in nature, and the Falls of Itapanca are on this section. The Paulo Affonso Falls is seventy-eight kilometers above Piranhas. It falls about 80 meters in one kilometer, in several nearly vertical pitches, and intermediate furious rapids. The total fall from Jatobá to Piranhas, in 128 kilometers, is 196 meters (643 feet).

The Government is building the Paulo Affonso Railway, 117 kilometers long, one meter gauge, between Piranhas on the lower river, and Jatobá on upper river. This undoubtedly, is the proper mode of connecting the upper and lower river commercially ; and the construction of a railway here, is in fact the only practicable improvement of the second section.

SECTION III.

JATOBÁ TO SOBRADINHO RAPIDS.

A Section of Numerous Rapids.

Its length is four hundred and twenty-eight kilometers (265 miles). It is a series of rapids and intermediate sloping pools. The Vargem Redonda rapids is the first above Jatobá, and the rapids of Sobradinho is the uppermost. There are in all fifty-two rapids, many of them in connection with a light-draught steamboat navigation, are unimportant, offering very little impediment ; a few are troublesome, requiring considerable improvement. The fall from the head of the Sobradinho rapids to the foot of the rapids called the Vão, is 85.8 meters in 336 kilometers (208 miles), or an average of 0.255 meters per kilometer (about 1.35 ft. per mile).

During the season of low water, which lasts about half the year, the channels in the rapids, in many cases, are so shallow and crooked that they are with difficulty navigated even by light *barcas* and canoes ; while through some of the rapids there is already a good natural channel in their entire length well adapted to steamboats, but which the *barcas* and *ajorijos* cannot ascend on account of the velocity of the current and the great depth of the water, preventing the use of poles.

These currents are rarely so great as ten kilometers an hour (about 6 miles), and proper steamboats could ascend them without difficulty.

The most difficult single series of rapids occurs between Rodelles and the Vão, a distance of twelve and one-fourth kilometers (7.6 miles) where the fall is seven meters (23 feet) or an average of 0.57 meters per kilometer (3 feet per mile). A portion of this series, two and three-fourths kilometers long, falls 2.40 meters, an average of 0.87 meters per kilometer.

There are some very short rapids considerably steeper, but the strongest natural low water current, in any channel it is proposed to improve, will be only about two and one-half meters per second, or at the rate of nine kilometers per hour. For very short distances on a few of the rapids, the present low water current is about twelve kilometers per hour ; while in others it is not more than four or five kilometers per hour.

There is an abundance of water in the river, during its extreme lowest stage ; but it is divided into several channels, and in many instances the stream spreads out to a great width, over a rough, rocky bottom.

The general principle of improving these rapids will be the same in all ; namely, selecting the most promising channel, and concentrating enough water in it to produce the required depth, by means of low crib, or low rip-rap dams and chutes confining the low water flow within limits.

The minimum volume of water passing through these rapids, during extreme low water, is more than one thousand cubic meters per second. A channel thirty meters wide, two meters deep, flowing at the rate of two and one-half meters per second, requires only one hundred and fifty cubic meters per second, or less than *one-sixth* of the minimum flow.

The abundant supply of water in this river is the key-note to the improvement of the rapids, while the rough, jagged, rocky sides and bottom of the channels assist materially, by the friction they create, to check the rate of the current, and thus to facilitate the safe navigation by steamboats, both in ascending and descending.

As above indicated, some of the rapids need no improvement, and others only the removal of a few rocks ; a few of the rapids require considerable work to secure a reliable depth and proper shape for safe navigation.

The natural river through these rapids remains from year to year without perceptible change, notwithstanding the annual passage through them of enormous floods.

SECTION IV.

RAPIDS OF SOBRADINHO TO THE PIRAPORA FALLS.

The fourth section is commonly known as the clear river ; being free from troublesome rapids, and having only swift water in a few places. It is thirteen hundred and twenty-eight kilometers in length. The total fall is 209.7 meters, or an average of nearly 0.16 meters per kilometer. The surface slopes very considerably along different parts of the stream ; from almost level, in an occasional pool, to 0.28 meters per kilometer in the steepest part.

Steamboats can now easily navigate the whole of this section ; but there are some rocks in a number of places, especially along its lower portion ; these should be removed in order to make a safe navigation.

For a long distance, more than one thousand kilometers (over 600 miles), there are no obstructing rocks in the stream ; the characteristics being, a wide river, numerous alluvial islands, and large sand-bars ; with navigable channels, generally on the side of the river opposite the sand-bars.

The islands of course divide the flow of the river, sometimes into three or four channels, generally into two ; but there is always a navigable channel on one or the other side of an island, and occasionally on both sides. Generally the clear river, from bank to bank, is very wide ; ranging from three-fourths of a kilometer, in the narrower places, to one and a half kilometers, and in some cases it is much wider.

The sand-bars, which form a prominent feature, by occupying large portions of the width of the river, create an advantageous augmentation of depth in the channel thus contracted. In every instance, where these immense sand-bars encroach extensively upon the natural width, so as to reduce the channel to about three hundred meters (984 feet) and in a few cases to somewhat less, it is invariably very deep (ten, twenty or more meters), constituting at all seasons a very superior navigation, wholly free from impediment. Sand-bars along the shores of the upper São Francisco, between Jatobá and the Falls of Pirapora, are nature's grand and simple method of maintaining a navigable stream.

There are only a few shallow places on the clear river, where sand-bars, owing to peculiar local circumstances, extend across the wide river ; but generally through these the pilots can find a channel of one and a half meters depth. In a few cases only, a minimum depth of one to one and one-fourth meters is found during extreme low water—but for very short distances.

Nothing of consequence is necessary to be done on the greater portion of these thirteen hundred and twenty-eight kilometers. As a whole, for light-draught steamboats, and barge towing, it is naturally a magnificent navigation.

SECTION V.

FROM PIRAPORA FALLS TO THE SOURCES.

The junction of the Das Velhas, its great affluent, with the São Francisco River, is twenty-seven kilometers below the Falls of Pirapora. The personal examinations of the Hydraulic Commission extended only to the upper end of the Falls of Pirapora, on the São Francisco, and a few kilometers up the Das Velhas River above the junction.

The river length is about eight hundred kilometers on each of these two very crooked streams, between the junction and their sources, making above the junction, exclusive of their tributaries, sixteen hundred kilometers. The Das Velhas is navigable for canoes in low water ; but it has numerous obstructions. It has been navigated as high as Sabará, by a small steamer. Surveys were made along these two streams in 1865, by Emm Lias, and Eduardo José

de Moraes and Ladislão de Souza Mello Netto, upon three hundred and forty-two kilometers of the São Francisco, above the junction, and upon six hundred and ninety-four kilometers, from Sabará, in the province of Minas Geraes, to the junction, in the same province.

On two hundred and sixty-four kilometers of the São Francisco, above the junction, to the mouth of the Paraopêba River, an important tributary, the estimated cost of improvement was Rs. 8,700,000 \$000 (eight millions and seven hundred thousand milreis). Above that point improvement was pronounced impracticable.

The estimated cost of improving the Das Velhas River, from Sabará to the junction was Rs. 2,605,000 \$000 (two millions six hundred and five thousand milreis). These are large sums, compared with any benefits likely to arise at present ; but probably some desirable amelioration of the navigation, particularly on the Das Velhas, might be effected at comparatively small cost.

This completes the general description of the São Francisco River.

In the examination of this river, from the sea to Pirapora and back, the work of the Commission was very greatly facilitated by the maps, profiles and report made for the Government by Henrique Guilherme Fernando Halfeld, Civil Engineer, of his elaborate surveys of 1852, 53 and 54 ; and valuable information was obtained from the report and maps of the survey subsequently made by Dr. Carlos Krauss, Civil Engineer, in 1868, upon the rapids portion of the stream. These engineers differed widely respecting the mode and estimated cost of improving the rapids ; and also as to the proper manner of uniting commercially the upper and lower São Francisco. Engineer Halfeld considered the improvement of the river between Boa Vista and Jatobá entirely impracticable, and recommended instead, a *Canal* from Boa Vista on the upper river, to Pão d'Assucar, on the lower river, a distance of four hundred kilometers, at an estimated cost of Rs. 32,472,700 \$000 (thirty-two millions four hundred and seventy-two thousand seven hundred milreis) ; a project which may fairly be regarded, in view of the circumstances, as inexpedient and impracticable.

Engineer Krauss estimated the cost of improving the entire series of rapids (already described) at Rs. 1,800,000 \$000 (one million eight hundred thousand milreis), exclusive of interest on capital. Of this sum, Rs. 1,435,000 \$000 (one million four hundred and thirty-five thousand milreis), applies to the 260 kilometers between Boa Vista and Jatobá ; leaving Rs. 365,000 \$000 applicable between Boa Vista and the head of Sobradinho rapids. Probably at the time this estimate was made, and in view of the European experience in the construction and use of steamers, it may have appeared to be a reasonable estimate.

My estimate of the cost of making a good steamboat navigation for loaded vessels drawing one meter, from the head of Sobradinho rapids to Jatobá, is very much less than the previous estimates. It is founded on experience in the United States, and it is based upon the use on the improved navigation of light-draught, stern-wheel steamboats : say about thirty-seven meters long, six meters wide, and one and a half meters deep, drawing without cargo not more than 0.6 meter of water, and having power enough to overcome currents of ten kilometers per hour, with two loaded barges in tow.

This reference to the proposed maximum draught of one meter for vessels navigating the Upper São Francisco, without a few words explanatory, might convey the very erroneous impression that the general depth of the river is only a little more than one meter; whereas the general depth of the channels is more than two meters, in low water; and, on a large portion of the river the channel is three or more meters deep. Only at the more difficult rapids, and during the lowest stage of the river, will there be less than one and a half meters depth, excepting the few points mentioned, among the sand-bars, on a small part of the clear river.

It is assumed that the navigation can be improved in two years; the first year for examination and preparations; having, also, in use the first year a small, light-draught, stern-wheel steamboat, for explorations among the rapids, and to aid in selecting channels, during the low water season, May to October; and the second year so far finishing the works that the larger, light-draught steamboat, referred to, can pass all the rapids during low water.

The time required to do the work will depend considerably upon the skill and energy of the parties who may have it in charge. Should the Government conclude to proceed at once with the improvement of the river, upon the general plan indicated, it might be advisable to order first, the construction of the small light-draught exploring steamboat, and to arrange so as to have the larger steamboat delivered during the second season. The amount to be expended during the first season need not be large; although, if considered desirable a portion of the work might be done at some of the rapids during the first season; especially on the series of rapids between the Rodelles and the Vão. The only works required, will be low cribs of rough timber filled with stone, or rip-rap banks for closing side channels to prevent waste, or for diverting more water from the main river into the channel to be improved; and, in a few places, for confining it in low chutes about 100 feet wide, with a minimum depth of about 5 feet.

The following is an approximate estimate of the cost of the proposed improvement of the upper river:

| | | |
|--|-------------|-------|
| From Pirapora Falls down to the head of the Sobradinho rapids, Clear river. | Rs. 35,000 | \$000 |
| Improving all of the rapids from the head of Sobradinho rapids to Jatobá, the upper terminus of the Paulo Affonso Railway. | 456,500 | \$000 |
| | <hr/> | |
| | 491,500 | \$000 |
| Add 20 per cent. for contingencies and superintendence. | 98,300 | \$000 |
| | <hr/> | |
| | 589,800 | \$000 |
| Cost of one light-draught steamboat | Rs. 90,000 | \$000 |
| “ one small “ “ | 25,000 | \$000 |
| Allow for interest on capital. | 40,000 | \$000 |
| | <hr/> | |
| | Rs. 744,800 | \$000 |

In round numbers seven hundred and fifty thousand milreis.

RIO DE JANEIRO, April 20, 1880.

The foregoing is the substance of an “abstract” furnished to the Brazilian Government at the request of the new Minister of Agriculture, Conselheiro Manoel Burarque de Macedo; the Bureau of Public Works being attached to the Agricultural Department of Brazil.

It will be noticed that this great river presents one remarkable characteristic—being divided into two streams, the upper and lower rivers, by impassable, abrupt falls and rapids: so that the two parts are as distinct as if they were different rivers. This separating barrier has never been overcome by any improvement; excepting that there has always existed a mule-path portage, over which the moderate amount of trade and travel between the lower and upper valleys has been packed.

These valleys were occupied by the Jesuits who came from Portugal two hundred years ago, and a number of churches were built by them on the river margins and islands, aided by funds from Portugal. The native Indians, being tractable, were easily Christianized, and their descendants still occupy little farms or rather marginal river plantations, and continue to be devout members of the Catholic Church. The Jesuits did not bring with them any considerable number of European settlers; consequently the upper valley has not been settled in the sense that valleys generally are settled. Later, planters carried in numbers of negro slaves, many of whom have since become free, and now the principal population of the upper valley consists of the descendants of Indians and negroes; the white Brazilian population being only a small per centage, although they are the controlling element.

The barrier referred to, has served as effectually as a Chinese wall, to keep out enterprising settlers from other countries and from other parts of Brazil, because there has been scarcely any encouragement for the people of the upper valley to raise more than enough for their own consumption. Manufactories have not been introduced, and foreign importations have been upon a very limited scale, only adapted to the needs of a people living for the most part in a very humble manner, having few wants and little money.

The peculiar meteorology of the upper valley has also greatly influenced the method and limited extent of the cultivation. Evaporation along this part of the river is very great at nearly all seasons, and for half of every year there is little or no rainfall. Slight rains, such as in other regions might be somewhat beneficial, are here almost immediately evaporated without being of any service. Sometimes for several years in succession, the rains are insufficient to support general agriculture; notwithstanding, the great river flows perennially through the valley, never failing to send a large volume of water over the grand Falls of Paulo Affonso, and thence through the lower valley to the ocean. There is an abundance of rainfall every year upon the mountains in which are the sources of the São Francisco.

As a consequence of this peculiar meteorology, cultivation along the immediate river valley has been almost wholly confined to the sloping banks, and the more level low margins, and the numerous alluvial islands, annually inundated by the periodical freshets, which rise from twenty-five to forty feet, in places; varying considerably in different years. Upon a few of the upland small side valleys, here

and there, artificial mounds of earth have been thrown up, which catch and hold for some months the rain water, and which serve to sustain the persons who build and maintain them, and their cattle, horses and mules, etc., during the dry periods ; but these constitute but an insignificant proportion of the whole area.

On some of the larger upper tributaries, irrigation, on a small scale, has been introduced ; but it has not been undertaken on the main stream. The circumstances already mentioned are sufficient to account for the lack of improvements of that kind, since heretofore there has been no chance of remuneration for the necessary investment of capital.

There are valuable iron-ore deposits at several points along the river ; but there has not yet been the slightest inducement to establish iron-works in a valley where the demand for iron is very small, and which could not profitably ship any of the product out of the valley. At some future day after the river shall have been improved, these ore deposits may be utilized.

There are also gold mines and diamond mines in the valley of the Upper São Francisco, which have been worked for many years, some of which are still being worked ; and doubtless there are large areas of country that have not been thoroughly explored, which upon proper scientific investigation may, and probably will disclose many valuable mineral deposits.

Two hundred years of isolation has left this extensive valley very nearly in the same state that nature formed it. All that has been done by the hand of man is truly insignificant. What may be accomplished when the river shall be improved and a convenient railway connection made between the upper and lower river, it is not easy to forecast.

The climate is warm ; the valley being situated between seven and twenty degrees south latitude ; but as a whole, it is very healthy ; and longevity appears to be one of the characteristics of the population, notwithstanding that the proportional number of physicians in this valley is very much smaller than in any other country with which Americans are familiar.

There are about thirty towns and small cities on the banks of this river, varying in population from a few hundred to five thousand. In all of these are striking evidences of poverty among the bulk of the inhabitants ; although there are a few well-to-do persons, and a few good houses in each. The church is always conspicuous.