English Original
Report on the S. Francisco River.
Acted May 31, 1880

Letter to Minutes dated June 21, 1880
Relatório de
W. Minha Robot
Engenheiro-Chefe da
Comissão Hydraulica
Sobre o
Exame do
Rio de São Francisco
Dado o Mar até a Cachoeira de Pirapora,
2122 kilometers.
Feito em 1879-80.
Por ordem de
Sua Excelência
O Comelheiro
João Lino Vilela Camargo do Sílimbi
Quando Presidente do Comelho
Ministro e Secretário do Estado de Negócios
da Agricultura, Comércio e Obras Públicas
Rio de Janeiro, 31 de Maio de 1880.
I have the honor to present herewith my report upon the examination of the São Francisco River, made by the "Comissão Hidráulica", during the year 1879-80, by order of His Ex." O Comitê de Hidráulica, Júlio de Almeida Camarão de Sousa, Presidente do Comité e Secretário da Comissão e obras públicas da Agricultura, given in His Ex."s Office, April 29th, 1879.

In obedience to the instructions of your Ex.,

The Comission saile from the City of Rio de Janeiro on the 31st of July, 1879, on the Coast Steamer Bruna, for Macio, to proceed thence to the River.

The Comission placed under my charge consisted of the following gentlemen.

Sr. Dr. Antonio Plácido Perúno de Amarante, Primeiro Engenheiro.

Sr. Rudolph Weier, Chefe da Seção.

Sr. Sr. Domingos Segis de Sábia e Silva, 1º Classe Engenheiro.
The Commission arrived at Maceio on the 6th of August, when we met His Excellency, Cincinnati Pinto da Silva, President of the Province of Alagoas, who promptly extended every facility to his Command to facilitate the movement of the Commission to the São Francisco River.

The steam-launch, on board of the Coast Steamer, which was to have been put off at Maceio, could not be taken off, on account of the inadequacy of the appliances on the Steamer, and they being now of sufficient power in the Harbor, I therefore proceeded with the Steamer to Pernambuco, where I called upon His Excellency Cavalcanti Albuquerque, the President of the Province, who at once ordered the proper officers of the port to assist in discharging the Launch from the Steamer, which they did.

Leaving the Launch in Charge of the President of the Province, to be sent to the São Francisco river, we returned on another Coast Steamer to Maceio.

Having completed the necessary preliminary arrangements, through the kind Attention of the President of the Province of Alagoas, the Commission left Maceio on the evening of the 11th of August, on the Steamer "Gigia", (then drawing 10 feet water), and on the 12th morning, over the Outer Bar of the São Francisco River, and entered the River without the least delay or difficulty; but at the distance of about twenty
Kilometers from the mouth the steamer was anchored, and the boxes, baggage, instruments, etc., were then shipped from the steamer to large lighter, while we proceeded on board of a small, new steam-launch to Penedo, fifty kilometers from the Ocean, on the left bank of the river. At Penedo we had to wait for the return of the steamer, the "Scribner", which runs regularly between Penedo and Piranhas, a distance of 189 kilometers.

We left Penedo on the "Scribner", August 17, re-

mained overnight at Pão d' Açucar 142

kilometers above Penedo, arriving at Piranhas on the 18th. We were thus met and courteously re-
cived by Dr. Reinhard von Kniger, Chief Engineer of the Paulo Affonso Railway, and his staff, who did what they could to facilitate the Movement of the Committive overland to Jacobi.

We made an examination of the line of the railway, and of the works as far as the town Commercial, and partly continued in Company with the Chief Engineer and his Assistants.

Paulo Affonso Railway.

This railway is located on the left bank, or Alagons side of the river, amidst the falls of "Paulo Affonso". It has a gauge of one meter, and is designed to connect the lower river at Piranhas, with the upper river at Jacobi. Its length in one hundred and seventeen kilometers. Jacobi is not yet a town; it is only a convenient point on the river for the transfer of freight and passengers.

The grades and curves generally are moderate, but in rising from the river at Piranhas, to the elevated, rolling plateau, a maximum gradient of 3 per cent. was adopted. The hill bounding the narrow valley are rocky, rugged, and steep, and a large amount of relocation was encountered.
The general location of the line appears to have been judiciously made. The work on the first section was far advanced when the law of firing was in August, and nearly completed when we saw it again the following January. The criticism made was, that the plans and style of work were of a more costly character than the situation and circumstances seemed to me to require; but it promised to be a first-class, metre-gauge railway. The engineer expected that the railway might be completed during the year 1882; until the work was to be delayed, from want of funds, or some unforeseen causes. Further particulars of the railway will appear elsewhere.

In Piranhas, we purchased saddle-arms, and engaged pack-animals to transport the construction and the instruments, tents, provisions, and baggage our land to Gayode. We left Piranhas August 22nd, accompanied by the Chief Engineer of the Railway, and his assistants; traveling along the railway line. En route, we visited various places of interest, on river and examined the great Falls of Pará's Affero. They are truly grand and beautiful; but this is not the place to enter upon a description. The accommodation given by Captain Hulin, is excellent.

We arrived at Gayode, August 23rd, but finding no conveniences for proceeding or arranging a journey for the next expedition, we pushed on eleven kilometers farther, to Atlasche, and encamped opposite the Cape of José Manoel de Souza, which, with one other Cape, constitutes the Town, at that spot. José Manoel de Souza kindly assisted us in our preparations, and accompanied us in our preliminary examination of the Capes of the Vargueiros River, just below Atlasche, and of the...
de Vao, (and others adjoining) eighty one kilometers above Atalho. 

Our trip was uneventful as far as the arrival of the boats from Piranhas to continue the journey, considerable time was lost.

We were informed at Piranhas that large canoes could readily be procured on the upper river, but we found it quite otherwise. We were also told that sails were in common use on the upper river, but on arriving at Atalho we learned that sails had never been in use in navigation, either up- or down-stream.

Fortunately, however, we had had sails made in Piranhas, and we had men with us who knew how to let them up, and work them. The boats did not reach Atalho till Sept. 10.

My examination of the rapids of de Vao showed that only canoes, with the aid of cordeira, could pass during the dry season, in the low stage at which we saw them, and I at once communicated this fact to the Chief Engineer of the Paulo Afonso Railway, and through him to the government.

Upon the arrival of the boats at Atalho we immediately fitted up two cabins, and a canopy each with sails. D. Amarante, Engineer, having previously spent many days along the river in proceeding to travel to canoes, while a considerable part of the provisions, baggage, etc., in order to lighten the canoes of the "Ajuares," (upon which the communications had to do most of their work,) was sent forward by canoe, or pack-animals to Calvo, a distance of the river of 169 kilometers.

By the advice of Chief Engineer Krüger, an escort of twelve armed men accompanied the expedition.
The men were afterward made useful as sailors, but were not to be any necessity for the presence of an armed force, with a peaceable government. Commerce alone was the aim of the voyage. Presently, even, where we found the regular Canoes, and familiar friends, already hail ing our party, with the kindest manifestations.

We left Atalco Sept. 15th, sailing and pushing up stream. We had one excellent man named Andres, a canoe-man, and two first-class Indian pilots, brothers, who managed the joysticks with great skill and dexterity. They very soon learned how to handle a sail, although they had had no previous experience in sailing.

Our system was, to encamp on the evening's advance, and remain encamped on the shore in the tents; remaining early before six o'clock in the morning, lying about ten miles for breakfast.

The observations, bearings, and notes, were made, Chiefly on board, as we ascended the rapids and capes, hearing the maps of engineers, helped always before us, which proved to be of essential service throughout all examination.

We sailed, or forced up all the rapids, stepping at the most difficult ones to examine different channels, some of which while not unfavorable to steamboat navigation, are at present not advantageous for the Canoes and transport.

We arrived at the head of the Sobradinho rapids October 20th. The succeeding day was devoted to a further examination of these rapids, through the different channels. In the evening of Octo ber 21st, we proceeded five kilometers further up, to Santa Anna, a small town on the left bank of the river, in the Province of Bahia.
At Santa Anna we found the steamer "Presidente Dantas," which had been lying there eight years. I had heard of this at Cabo Rojo, and by the aid of special messengers and the telegraph from Penedo to Brazil, I received a skirmish from the President of Brazil, Sr. L. A. Santo-Angelo, de Araújo Duarte to use the steamer in our examination of the "Clear River," above the rapids. Presidente Duarte kindly sent a special messenger over land from Penedo to Joaçapes with the official authority, Sr. Manuel Fidelis Nunciado, then the Sub-delegado-Nacional-Chancey-Chancey of the steamer, and all on his power, aided by Sr. Captain Frank Longden, who had previously had charge of her, to facilitate the business.

On the evening of our arrival at Santa Anna, we took possession of the steamer, her engineer, Sr. Joaquim de Paula. Leaving Comendant to the head of Sobradinho rapids to meet us.

As the steamer had not made a trip for three years, many little matters had to be arranged before she was prepared to leave upon her long voyage. The Engineer expressing doubt as to the distance the vessel is able to run. On our account of the distance, although so greatly decreased as we had no little hope of getting up as far as Carapeguá; especially as the steamer had never been higher up than Januáns.

We had to provide a pilot; and by the advice of our friend at Joaçapes, and the approval of the Engineer, who knew her well, we engaged the services of "Felicí", a good Brazilian pilot, who had piloted the steamer some years ago. We were obliged to employ two steermen, two farmers, and two hands from among the men.
we had with us. We fortunately succeeded in getting very good men who performed their duties in a highly satisfactory manner.

We cleared out from Santa Anna on the 26th of October, leaving the officers in care of a reliable man until we returned there.

Thenceforth, for about two months our home was on the steamer. The accommodation on board though not extensive was sufficient for the members of the Company. At night, we lived on board, a part of our crews sleeping in the hatches and men of the crews living on deck.

When we arrived at night on shore, which amounted very few ways occasionally, our Custom was to start before 8 A.M., and to stop and anchor about 9 P.M. Taking our meals on board.

There being, of course, no previous arrangement along the river for fuel, we were compelled to stop frequently to our wood for the steamer, racing time in some cases by having men to assist. We also made contracts for the gathering of wood at several points along our absence up the river, which saved time on our descending voyage.

At January, 313½ Kilometers below the Falls of Pergamum, we engaged another pilot, an intelligent colored man, who, although he had never piloted a steamer, knew that part of the river well. He guided the steamer back and forth, and back to January. The site of Pergamum was not occupied until the fall of the fort. We arrived at the Falls of Pergamum, December 14, and examined them. We ascertained the total height of the falls and rapids, by levelling, to be 85 meters, or a length of about 1900 Kilometers.

On the 15th, the next day, we started on the return voyage, remaining over at the Barra das Velhas, 27½ Kilometers below, taking wood, till the 17th, at the place now known as Guia, being at the junction of the Das Velhas and São Francisco.
At this place, Prizes were daily arranged to procure our
up the valley of the Bedobsas
land, to Pemanquin, and thence to (Paracanão) to
the City of Rio de Janeiro. On the same day, Dec. 24th,
we left the junction on the Downward Trip.

Here was a small fishery on the River, where
white ascending

tum, although it had fallen in different places,
in the water and thence, from one to two meters.

The general height of the stream on our return, was about
two meters above low water; making a very fine navigation.

The former line, on late as the Middle and Latter part
December, is usually considerably higher than found at

At Caramancho on the 23rd of December, Dr.
Mr. Heado Fernandez, Campio, one of the engineers
the Comission, and had under his special charge the
making of an improved map of the region, with written
instructions from the Chief of the Commission, proceeded over
land through the Province of Bahia, observing the
Geological, making notes, and sketches and collecting
specimens along the route he traveled between
Caramancho and the City of Bahia, meeting the
Commission in that City on their return, Commission
from the São Francisco river to the City of Rio de Jan-
iero. By the route he traveled the distance is about
835 kilometers, though the country is by
no means dense.

In another place will appear a detailed description
of this region, a portion of which would naturally be tribu-
larory to the São Francisco Valley, to a greater extent than
it is at present, if the navigation were improved. It is
Chief in this view that this portion of the Province of
Bahia bears to this Colony associated with the future of
the São Francisco river.
We returned with the Steamer to Santa Anna on the evening of December 31st, 1857, and left her in Charge of her engineer, and transferred our things to the Ajunco, preparatory to making the ascent of the rapids from the head of the Sobra d'oro to Joaquin. (It is only just to a worthy officer to state here that Sr. Ignacio Chávez, The provincial government engineer in Charge of the Steamer, performed his arduous duties faithfully and intelligently. He was ably assisted in his labours by Francisco Canuto de Arango, who had previously received several years of Mechanical engineering education, and was attached to the Commission as time-keeper and in fulfilling other duties. In their attention and watchfulness, and to the skill and care of the pilot, Rafael, the Commission is greatly indebted for the safe voyage, covering 2644 kilometers of ascending and descending navigation.}

On the 1st of January, 1858, having resumed the Ajunco, we proceeded to Santa Anna, and to the Steamer "Presidente Donato," and started down stream, passing through the left Channel of Sobra d'oro rapids, and arrived at Joaquin at noon of the 2nd of January.

At Joaquin, two of the Ajunco's were disposed of, and a Barca was purchased. The pilots declaring it unsafe to run the lower rapids with heavily laden Ajunco, which had been was true. During our stay at Joaquin we received kind attentions from Sr. Mayor Luis Man. de Godínez, and Antonio Quijano, Col. Bonito de Mercurio de Mendoza, we left Joaquin on the 5th of January, and arrived at Cañon de on the 10th of January. At this place the horses had been left in pasture, and they were taken charge of by our men and sent overland to Atahualpa.
in the evening.

We returned to Atalho, January 15th. Here we parted with our excellent pilots and Carneiros, and engaged pack-animals to convey our things to Póranhas.

On the 17th, we made a detour to our friends João Manuel de Sousa, and returned to Póranhas. We passed much of the way over the route of the Paulo Affonso Railway. A portion of the Communion was taken to Póranhas, while a portion travelled on to the Falls of Paulo Affonso. We had a second view of that grand natural spectacle, at a time when there is a Considerably larger volume of water passing over it. With the stream raised by a great flood, it must be a lovely sight. It is a great object, but in any case, the water from the falls must be magnificent. The first view was not to be had without some laborious walking, our conveyance, much blackened and polished rocks.

During our absence on the upper portion of the river, some rain had fallen along the lower part of the valley above the falls, and the surface had changed, but there had not been sufficient rain to create flowing water in the lower tributaries. The upper large river Moço, where we crossed it, and travelled for miles on it, for many kilometers, then, only a dry, sandy bed; though by digging wells, it was found that the ground was, as it were, bed-rock.

The inhabitants along the banks of the São Francisco, were apprehensive of an unusually small annual rise of the river, and of a consequent short production, while away from the immediate river banks, the country was threatened with a continuation of the destructive drought which has already prevailed for several years.

We arrived at Póranhas on the 21st of January.
in the afternoon we joined the rest of the expedition at the house of Pedro Espírito, and

get granted by telegraph.

At Piaúnas, authority was denied from the government to charter the steamer "Pernambuco" to facilitate the examination and sounding of the lower river and of the Channel through the bar at the mouth of the river. From this point onwards, I was also ordered to examine the entrance to the harbor of São Miguel.

Accordingly, after sounding the lower river and passing the Courses of the Channels as we descended the bar and entered the Channel, we proceeded along the Channel across the bar, the Commissary proceeded with the steamer named "Pernambuco" to Macéio, where we met his excellency Sr. D. Cincinnati Pinto da Silva, President of the Province of Alagoas, who wished to accompany the Commissary during our examinations of the entrance to São Miguel harbor. This examination was made on the 31st of January. The steamer returned with his excellency and a number of his friends who had accompanied us from Macéio.

The same evening we arrived in Macéio, where we were received by the President of the Province, Sr. Antônio de Oliveira Barreto, and at his request I prepared a brief account of my trip to the São Francisco, which was published the next day.

We started to leave from the 4th, but the English steamer was detained, and we did not sail until the 5th, arriving in the City of Rio de Janeiro on the morning of the 8th of February; after an absence of a little over six months.
It may be proper to mention that when we were about to start from Rio de Janeiro, on the 31st of July, 1879, there was no expectation that the Cauquinim would be able to get all the way up, and return in one season. But, indeed we have done so, but for the use of the steamer "Presidente Dantas" on the "Clear river." With the aid of that steamer, we were enabled to make a more satisfactory examination, and in a shorter time than we could have done were we on our journey, or on baccas. In fact, but for that steamer, we should have returned sooner, but only by leaving a thousand kilometers up the river without examination.

Upon the whole, we have reason to regard the season's work of the Cauquinim as very satisfactory.
Approach from the sea—The outer bar—The tide.
Inside Harbor—The river, etc.

The ocean approach to the bar off the mouth of the São Francisco River is very favorable. The light house stands on the north eastern side of the mouth on a point projecting about three kilometers beyond the general line of the coast. It is twenty one meters high, and in clear weather it is visible at the distance of eighteen kilometers.

In approaching the bar the depth outside decreases gradually to nine meters (5 fathoms) when about three kilometers from the light house, increasing gradually to five meters or less. At this time (November, 1880) there is a good channel across the bar having a depth of four and a half meters at high tide. The east of the bar with this, continues for about one third of a kilometer, deepening inside of the crest to nine meters. Near the point of land, on the Alagoas shore there is a depth of nine meters, increasing to fifteen meters opposite the light house.

The mouth of the river is one and a half kilometers wide, but the navigable depth inside is narrowed just above by a large sand-bar on the Sergipe side to about half a kilometer, still leaving a clear, unobstructed Channel of ample width with a central depth of six to fifteen meters, thus forming a good harbor at all seasons for vessels that can cross the bar.
This harbor, opposite Atalacia, is more than a kilometer in width and ten to fourteen meters deep. From this point to Penedo, fifty kilometers from the Ocean, the Channel depths at low tide vary between Nine and Thirteen meters, the general depth being from four to Six meters. The Channels in this part of the River are generally wide and easily followed by experienced pilots and Captains.

The Coast, etc.

All along the Coast of Atalaca, North east of the river for eighteen kilometers to Point Penda, high sand-chains from the conspicuous characteristic; while the Speriche or South Western lead of the River the sand-chains are much smaller and not so conspicuous. This difference is owing primarily to the direction of the prevailing winds, which is from the North and East. The sand from these large chains on the North Eastern side of the River entrance is Constantly drifting down the Coast to the River edge; due to further Coast movement, from the wind, is checked, and the sand is blown onto the River, whence it is Carried out to sea by the outflowing Current, and ultimately dropped on the bar, adding to the Sedimentary Deposit brought down the river during floods.

The prevalence of North Eastern winds naturally establishes a Littoral Current along this part of the Coast, which helps to sweep away the outer portion of the Bar, and thus to widen its extension seaward. During high winds, when the River Current is strongest, the Littoral Current does not strike the River Current at Right angles; their resultant
Currents are inclined Considerably Southward. In low water stages the large bar inside directs the river current more toward the north, nearly at right angles to the coast current. When the river is in its low stage, having its minimum flow, its scouring power is diminished, and its direction is now easily deflected by sand bars, and by the littoral current, at the same time its force is much less. Construed by the action of the ocean waves, but as no sediment is carried out in suspension during its low stage, the deposits on the outer bar are now diminishing rather than increasing in quantity by the cutting action of the stream. The general tendency of the littoral current is to cut away the seaward edges of the bar, carrying the sand southward and distributing it along the coast below the river. Hence this bar naturally increases more on its north than on its seaward side. Although, owing to temporary local causes of winds and currents, it may be otherwise for a time. From a comparison of maps dating back to the last century and others in the beginning of this century, as well as the more recent charts of Captain Monchey, and of Vieira of the Brazilian Navy, it appears that the general line of the coast has changed but little for a long period. The present coast of the outer bar projects rather less than three kilometers beyond the general line of the coast. It is known that large quantities of materials, consisting of mud and sand, partly in suspension and partly moved along the river bottom, are brought down during every flood, so the action appears to have moved seaward very slowly. While the area of the delta may change slowly, changes in the shape and position...
of the channels through the bar sometimes occur in a comparatively short time. At present, the main channel is about where it was twenty-five years ago; but at one period, being the deeper channel passed out along the Cerro Loco, south of the large inner bar, where now it is quite shallow and not navigable for vessels.

As long as the bulk of the river flow runs out through a single channel, it is likely to maintain a great navigable depth across the bar, but, if it should be divided materially, and pass out on two principal channels, the depth will be correspondingly lessened.

Should circumstances necessitate it expedient to undertake works with the design of establishing a permanent channel through this bar, it will be necessary to make a very careful survey, at the time, before deciding upon particular plans. At present the entrance is good, with quite as much depth on the bar as any in a number of places on the river below Penedo. The tide flows some distance above Penedo, but the rise of the tide, ordinary, as that place is less than a meter; through the usual flood, from great floods is eight meters. The highest

rivers, floods in the Lower River are usually between December and March, and the low water period is from May till October, included.
The São Francisco River has sometimes been likened to the Mississippi, both being large, sediment-carrying streams, detaching themselves. But when studied in connection with improvements appropriate to each, they are found to be radically different.

The lower São Francisco and its mouth are very unlike the lower Mississippi and its mouth. The Mississippi, from a point a little way above the head of its delta plain, and hence for a hundred and forty kilometers, to the city of New Orleans, holds its depths of thirty meters, and this continually with little variation for a hundred kilometers further. There is besides an interruption in navigation for large steamers for sixty-five kilometers, to fall between below the Falls of the Missouri in Montana Territory.

On the other hand, the São Francisco, excepting the short distance through the harbor near its mouth, has little, greater average depth than that of the Channel across its bar, and at the distance of less than two hundred and fifty kilometers it ceases to be navigable; hence the prime reason for deepening the bar at the South pass of the Mississippi, namely, the great depth and extent of deep river navigation is entirely lacking on the coast of the São Francisco.

The general latitude of the São Francisco is much greater than that of the Mississippi; but what the Mississippi lacks in breadth is made up by its greater depth. The greater width of the São Francisco is a disadvantage, by proportionally reducing the depth of the navigation. Again, the deepening of the Channel through
the bar at the mouth of the Mississippi was of paramount importance, in order that the largest ocean steamers could reach the great Commercial port of New Orleans; but if the bar at the mouth of the São Francisco were deepened, it would enable large ships to pass up, even to Pernambuco, on account of insufficient depth in the river, while on the falls of the São Francisco River would exclude vessels from proceeding to the upper river.

As yet there does not seem to be a necessity for expending money at the mouth of the São Francisco on account of the river commerce. Hereafter, upon the extent and character of the future trade that may be concentrated on the lower river — after the completion of the railways around the Falls of the São Francisco — and the improvement of the upper river, will depend the kind and extent of improvements proper to be undertaken along the lower river and on its outer bar.

It may however be remarked, that no material permanent increase of depth can be maintained at the outer bar of the São Francisco river — in case it would be desired by merely dredging. Nothing short of piers could be relied upon, and fixed cost, acts under the existing circumstances would seem to be premature. There may not be any necessity for considerable government expenditure in the lower river, until the upper river shall have been improved, and the business of the São Francisco Valley shall be more developed.

If the government should desire to make the entrance of the river a harbor of refuge for vessels of deep draught, it would be practicable by means of jetties...
The São Francisco River, may be considered
in five principal sections, beginning at the
Ocean Bar, as follows:

Section

I. The Lower River, from the Ocean Bar to Piranhas,
two hundred and thirty-eight kilometers (43 leagues),
navigated regularly by steamers; usually navi-
gated by ocean vessels to Penedo, fifty kilometers
from the sea.

II. The Falls of Paulo Affonso, and the imparable
rapids below and above, between Piranhas
and Jaboticaba, one hundred and twenty-eight
kilometers (23 leagues), not navigable and not
improvable.

III. The imparable rapids, and the navigable
ports between Jaboticaba and the head of the So-
bradinho rapids, four hundred and twenty-
eight kilometers (77 leagues).

IV. The "Clear River," from the Sobradinho rapids
to the Falls of Pirapora, thirteen hundred and
twenty-eight kilometers (289 leagues), needing
very little work to make a safe steamboat,
navigation.

V. From the Pirapora rapids to the sources of the
main river, about eight hundred kilometers
(about 146 leagues), greatly obstructed by rapids.
[This section has not been examined by the Com-]
On the first section, from the Ocean to Panamá, it is not
proposed to expend much money at present, or until
the Completion of the Panama Canal Railway, and the
Improvement of the Upper. The expenditures should then
have reference to the new circumstances.

The Completion of the Panama Canal Railway will
effect the Commercial Connection between the Lower and
the Upper River.

The third section, from Abalos to the Upper ter-
mination of the railway, to the head of the Sobreute rapids,
it is proposed to improve so that Steamboats can readily
pass all the rapids at all seasons at all stages
of the river.

The fourth section, from the Sobreute rapids to
the Falls of Perapora, commonly known as "the clear
river," is already a tolerably fair navigation for
Canoes, Canoes and small steamers, needing only
a little work to make it more safe.

The fifth section, from the head of the Perapora
Falls to the Sources of the stream, has not been ex-
amined by the Commission, and has only inci-
dentally mentioned, Dr. [Illegible] who surveyed this part of the
Upper river in 1865, reports that it abounds with
difficult rapids, and that it would be very costly
to improve.

Until the third phase have been improved it seems seem to be unnecessary to expend money
on other parts of the river.
General Engineering features of the River.

The most striking and the most important characteristic of the São Francisco River is its abundant supply of water in its low stage, during the dry season.

One of the material benefits of this is seen as already shown, at its mouth, where the current maintains at nearly all times a depth of about four meters across the bar at ordinary high tides.

If this river were subject to a small minimum flow, such, for example, as the low-water discharge at the mouth of the Nile, the depth on its outer bar might be reduced to even less than two meters, without any well-defined channel, as in the case of the bar at the mouth of the Nile when it is low. There, during the annual floods, with their augmented draining power, partial channels are maintained; but when the floods abate, the volume and velocity are so reduced that the current is too weak to counteract the force of the ocean waves, which drive the sand inward and choke up the channels.

The São Francisco River is not thus exposed. This permanent and ample volume of water is also of paramount value in connection with the proposed improvement of the navigation through the rapids of the Upper River.

During floods these rapids have been passed by canoes, but the natural channels in some of them need considerable work to make a safe practicable steamboat navigation. For more than half the year they are not navigable except by light canoes, and during the lowest stage the canoes pass with difficulty.
The difficulties at some of the rapids are not entirely due to their greater declivity, although that is partly the cause; it is largely owing to the division of the streams, by islands and rocks, into several channels, thus leaving an inadequate quantity of water in any one.

In the dry season, none of the tributaries on the Upper River, for 1027 kilometers above the mouth, discharge any water into the Muni River. Hence only the same quantity, less the evaporation, that flows at that point reaches the sea; but this quantity is very large.

Our measurements at different places, beginning at Piranhas, and ending at the junction of the Das Velhas with the São Francisco, reduced to the gauge of low water, show that the low-water volume is not less than one thousand cubic meters per second.

This quantity, in a single channel, with a current of two and a half meters per second, would be equivalent to a cross-section 100 meters wide and 4 meters deep. This is much more than enough to make a good steamboat navigation.

When improved, as they can be, none of the selected channels through the rapids need have a greater velocity than two and a half meters per second; while generally the current rates will considerably less, during medium and low stages of the river.

It is therefore obvious that only a portion of the low-water volume is required to be concentrated in one channel to secure a navigation for properly constructed steamboats.
Between Jatobá and the Sobradinho rapids nearly all of the Channels through the rapids have rough, rocky ridges and beds. Our observations of the flow through these Channels show that the friction caused by these irregularities materially checks the current. Theoretically, due to the delay in the flow with an abundant supply of water, this will help to lessen the cost of making the Channels navigable. Generally, the only improvement needed is the concentration of the water by means of rough dams and side walls in some places, so as to lengthen the slope; additional at certain points by the removal of obstructing rocks.

Above the Sobradinho rapids, along the "Clear river," the navigation would be better if the river were not so wide. Its average width is a few hundred kilometers, and in many places it is from two to three kilometers, and it is divided at numerous points by islands into two or more Channels. Rock obstructions occur at intervals along the first sixty kilometers above the rapids; although an experienced pilot, with care, can avoid them. The removal of some and the marking of others will be required to make a safe steamer navigation.

Above this rocky portion of the river very little work is necessary. Most of the way there is already a safe, clear Channel of ample width and depth. Sand-bars abound, but almost invariably they serve to improve the navigation by contracting the adjacent and thereby deepening the Channels. In all cases, where there is only a single Channel, contracted by the sand-bar to a width of three hundred miles or less, it is very easy
The islands and the river banks are generally alluvial, sand and clay; in some places almost pure sand, in others almost pure clay; and on a large portion of the stream they are cut away in certain localities, during floods, while in other places bars and new land may be forming. At such times, some of the sand-bars are cut away and others increased, or new ones formed.

The river passes through many sweeping bends, but it does not make extensive "cut-offs," like those along the lower Mississippi. The current merely abrades the banks and islands; the effect of which has been to widen the river. This, while it is injurious at low water, by decreasing the natural depth, is beneficial, by lowering the height of the floods. The great floods, which occur only at intervals of many years, attain a height of about 12 meters above low water, while the rise of the ordinary annual floods is from eight to ten meters, varying at different points along the stream.

The Declivity, on the Clear river, from Pernambuco to the head of Sobradinho rapids, averages only 0.07 per kilometer. There are a few places where it is considerably more, but it is no where steep enough to create a Current sufficient to prevent the running of steamboats.
Engineering section of the Pan-American.

The first section extends from the ocean to Piranhas, one hundred and thirty-eight kilometers (43 leagues). The height of the river at Piranhas during the low water period at low tide, eighteen meters above the sea.

At Penado, on the left bank, forty-nine kilometers from the ocean, at the same period, it is about one meter above the sea.

In my great projects the river at Piranhas rises twelve meters and at Penado eight meters.

During these abnormal floods the surface slope from Penado to the sea is greatly augmented, being then at the rate of 0.15 per Kilometer, when the current velocity is correspondingly increased.

A flood of six meters, at Penado, gives a slope of twelve meters in forty-nine kilometers, or at the rate of 0.14 per Kilometer.

The current is not known strong enough at any time to prevent the ascent of steamers and sailing vessels. With the river having strongly up stream, as it does almost daily, barcas and other vessels sail off against the current.

The usual low water activity during half the year, from May to October, from Piranhas to Baell Asuncion, a distance of fifty-four kilometers, is twelve and twenty meters, or at the rate of 0.17 per Kilometer; and from Baell Asuncion to Penado, one hundred and fifty-nine kilometers, the activity is nine meters, or at the rate of 0.163 per Kilometer.

The average width of the river between the ocean and Penado is about fifteen hundred meters, the greatest width, including islands, being thirty-three hundred meters, and the least twelve hundred meters. Although some of the navigable
channels, at islands, are only about four hundred
miles each.
The widths of the streams between Peneda and Peranhas
are also various; though every where ample
for navigation. For about 77 Kilometers above
Peneda the average width is 1000 Metres, the
greatest 2000 Metres, and the least 400 Metres.
Through the Narrows, for Sixteen Kilometers below
Peranhas where the Mountains slope more into
the river, the average width is four hundred Metres,
Contracted in a few places to two hundred Metres.
Whereas it is thus Contracted it is very deep, in some
places over 20 Metres in the lowest water.
The depth of the river below Peranhas varies
Considerably at different seasons of the year, de-
pending on the quantity of water coming from
the Upper river; but even at its lowest stage there is
generally a good depth for the steamers navigating
to Peranhas. There are rock obstructions on the
river at several points below Peranhas, which in low
water cause Curved Channels, where Care and
Skill must be exercised by the pilot or Captain. The
Steamers has been running regularly, making many
tours between Peneda and Peranhas for a number of
generations, and also steamers from Bahia and from
Pernambuco. Canoes, canoes, and large canoes
are constantly navigating this part of the river;
being Decks when ascending, and canoes when
descending.

According to our observations and companions
with Maps of Ingenio's chart's office in 1832, 33 and 34.
The Changes in the Stream for about 130 Kilometers
below Peranhas have been few and unimportant.
Among the Quarter of a Century that has elapsed,
the Regiment of these parts of the stream being well
established.
The changes, farther down, and especially between Pinedo and the mouth, are nearly the result of the action of the currents, wearing away the banks, islands, and sand-bars in some places, and filling up, and forming land in other places. At some points, owing to the great breadth of the river, and consequent loss of its scavenging power, when the river is at its lowest stage and at low tide it is shallow; but by watching the hour of high-tide, and selecting the deepest channel, ocean vessels that can cross the outer bar ascend to Pinedo. When the river is above its lowest stage, which is nearly half the year, from October or November to April or May, there is ample depth. The sand-bars are, however, liable to shift, and change the direction of the Channels; but these changes are only noted by the pilots and others navigating the lower river.
Engineering features of the Second Section.

The second section of the river extends from Piranhas (league 330') to Jatoba (league 316') a distance by the river of one hundred kilometers, and it is unnavigable. It is true that canoes, etc., can ascend a few leagues farther, against the current, among the rocky channels; but practically, Piranhas is at the head of convenient steamboat navigation.

This section includes the great Falls of Paulo Affonso—one of the largest objects in nature. The descent of the principal falls in the distance of about one kilometer, as ascertained by the Comitato Standartica from measurements and leveling of the height, is eighty meters; most of which occurs in two principal falls near the lower end.

The total descent in the river, between Jatoba and Piranhas is one hundred thirty-eight meters. This includes also the Falls of Itaparica, forty-four kilometers above the great Falls, and all the intervening rapids.

It is not practicable to make a navigation along this section of the river without constructing a very costly system of locks and connecting canals, since there to overcome the fall of one hundred and thirty-eight meters.

Allowing three meters to a lock it would take sixty-six locks. The first cost of these locks, and difficult ground, and the yearly expense of superintendence and repairs would be very great, and entirely out of proportion to any advantage of a system involving so much capital—not less than twenty millions of reis.

The railway now under construction around the rapids and falls, is undoubtedly the proper means of connecting the upper and lower river commercially.
A railway of even greater transhipments, but the movement over the railway, including the transhipments, if properly arranged, will be more rapid than it would be through locks and canals, and the annual cost of freighting and transhipping on the railway will be less than the interest on the capital required to build, manage and maintain the locks and canals. So that in a commercial, and social, as well as in an engineering view the flume railway system adapted to the government for this second section of the valley is the proper one.

The Santa Fe Iron Railway.

The flume railway, above referred to, has a gauge of one meter, and, crossing near the terminal points, where the line has to rise from the river to the high, rolling table lands on the left, at Alagras side, the grades and curves are generally moderate. The maximum gradient of 3 per cent. occurs at the lower end, descending from Piranhas.

The first section of the railway involves much heavy cutting and filling, owing to the ruggedness and steepness of the pedra hills; a large portion of which excavation was through rock. The gradients on this section are finished, ready for track-laying.

The engineers in Chief, Mr. Reinaldo von Kreiger, expected that track-laying would begin in March (1880), and the road might be finished within a year, if no unforeseen delays occurred. A large proportion of the Carnegie had been delivered and iron and locomotives were arriving.

The region through which this railway so locates is very dry, with a sandy soil, and in many places rocky. In two places on the route strong water is found, and at the Crossing of the Moreno
Any water can be obtained during the rainy season by digging down through the sandy bed to the underlying rock. In the rainy season, at times, there is an abundance of flowing water. Excavations have been made in the rock at a number of points, to be used as catchwater reservoirs. At the time we saw these, the water in them was of a very inferior quality. As a whole, but a limited amount of traffic can be furnished from the immediate vicinity of the railway line; but it is probable some business from Jacarara and places along the Valley of the Moxote. Its chief traffic will be the carriage of freight and passengers between the Upper and Lower River; the extent of which will depend upon the improvement that may take place in the trade and travel along the Valley of the São Francisco and its tributaries.

It is thus seen that no work is required to be done on the river, on the second section, excepting such local improvements of wharves as may be necessary in connection with the railway terminal points at Piranhas and Jatobá, which appertain to the railway.
Engineering features of the 3rd Section.

Between Jatobá and the head of the Sobradinho rapids, four hundred and twenty-eight kilometers; consisting of falls and impassable rapids.

The 3rd Section, while it is almost free from actual "falls," especially during its highest stage, is materially obstructed at many points by rocky rapids; and when the river is low, some of the main channels through these rapids present impassable pitches, or small falls. Although during considerable periods it is practicable to navigate the whole of this section by proper steamboats, yet for at least half the year a number of the rapids become un navigable; chiefly, in consequence of the division of the natural flow into several island-channels, resulting in irregular, crooked courses of insufficient depth, and in some cases injuring, narrowed by rocks.

The total fall in the 3rd Section is 96.8 meters in the distance of 427 kilometers. The fall from the head of Sobradinho rapids to the foot of the de Vale is 85.8 meters in the distance of three hundred and fifty kilometers, an average of 0.285 feet per kilometer.

If the fall was equally distributed throughout, and the flow divided centripetally to one channel, with the large volume of water, that is, always in the river, it would make superior Steamboat Navigation; but the fall is unequally distributed, and as the rapids, generally, in every case, there are several Channels dividing the volume, neither one of which has throughout sufficient depth to afford a navigating the low water river, excepting for canoes and light abras and balsa; although portions of
Each may be navigable.

In the ports, between the rapids, the natural navigation, even during the lowest water, as well as in all other stages, is generally fair, for barks. These pieces need but little work to make a safe steamboat navigation.

The circumstances of the 3d Section present a simpler engineering problem. There is an ample supply of water; and it is only necessary to concentrate enough of this never-failing flow in one channel, to secure a sufficient depth. The examinations of the Commission have shown that this can be accomplished at comparatively moderate cost.

The most difficult rapids are those below the Rodellus and Stebbins, a distance of one fourth and three fourths of a kilometer, where the fall is seven meters, an average of 0.87 per kilometer. A portion of these rapids two and three fourths kilometers in length, falls two and four tenths meter, or at the rate of 0.290 per kilometer.

There are some shorter pieces of rapids Considerably steeper; but the greatest natural current of low water in any channel proposed to be improved will be only about two meters per second, or at the rate of nine kilometers (5.5 miles) per hour. For very short distances, in some of the rapids, the natural current is about twelve kilometers (nearly 7.5 miles) per hour.
Engineering features of the 14th Section.

The 14th Section is commonly known as the "Clear River." It extends from the head of the Labradorie Rapids to the Falls of Pocaqua. Nineteen hundred and twenty-eight kilometers.

The total fall in this distance is 209.7 meters, or an average of 0.076 per kilometer. The slopes vary on different portions of the stream from nearly level to 0.038 per kilometer, the greatest.

Although designated as the "Clear river," there are rock obstructions, high and low; and in some portions, which, in order to make a safe steamboat navigation, should be cleared. There are other rocks that need only to be marked, so that they may be avoided.

Above this rocky portion, numerous islands and sand-bars occur; and here the regimen of the stream is quite different; rocks in the river being almost continuous, and the channels for the most part entirely clear. The islands, of course, check the flow of the river, but there is always a channel on one or the other side of sufficient depth for loaded vessels, and light-draught steamboats.

The river is generally very wide, ranging from three-fifths of a kilometer to one and a half kilometers. In a few instances where flat sand-mounds extend almost to the bank, some of the rivers, there is no deep channel; but wherever sand-bars from the sides and islands encroach greatly upon the breadth, where the Channel may be contracted to three hundred meters, and occasionally somewhat less, it is invariably a deep, safe, and beautiful navigation.
Sands-bars, constitute a marked feature of the Clear River, for a thousand kilometers; but as a rule the materials, forming the navigation by Contracting the Navigable Channel and Correspondingly deepening it.

There is a common impression that sands-bars are only an evil, and so they may be in a narrow sluggish stream, having a small minimum flow; but in the San Francisco, on part of which is its sudden birth, with its abundant supply of water, they become valuable adjuncts in maintaining the Navigable Channels.

Some of the sands-bars remain for long periods without material change, others shift from or low, after the annual floods. The islands and river banks being mostly sandy, allow material, easily undermined, and carried away by the flood, are eroded, sometimes on one side and sometimes on the other side, especially on the Centre, which are numerous. The river, in eddies, is filling up at the same time that it is cutting away the banks where they are exposed to the strong currents. While islands and parts of islands are at times cut away, and disappear, while others are enlarged, or new ones gradually formed; large quantities of materials are cut away on the Concord side, and great sand-bars are sometimes washed away, and the Navigable Channel may be shifted from one side of the river to the other side. A majority of the straight portions of the river generally have more permanent banks, many of which are as high as the high water line. In other cases the banks are low, and the floods overflow large areas between.

Along the upper portions of the South Branch,
about Jamaica, where trees first come to the margin of the stream, trees are occasionally undermined by the water and fall into the river. Some of these afterward become fastened on the bank, bars as islands. At the time of our examination (1879) there were comparatively few that were actual obstructions. The pilots who run the river regularly in charge of loaded vessels find no special difficulty in avoiding such obstructions. There is always a sufficient channel on one or the other side of them. The navigation is comparatively free from obstructions. The natural flow of the large volume of the stream serves to maintain a good channel. The shallow places are few, and even through them there is almost always a depth of one and a half meters, or more, rarely less than one and a half meters. A large portion of the navigable channels have a depth ranging from two to four or more meters.

No part of the São Francisco river is subject to extensive "Cut-offs", such as are common on the Mississippi river. It continues, substantially, in its ancient route, the same as that of the valley; the changes in the width, cutting and filling, by the currents and eddies, are comparatively local.

There are no artificial levees on the margin of the river; nor is there any necessity for them; the land that is annually flooded is greatly benefited and renders more fertile as a consequence. In many places the banks of the river are somewhat higher than the land some distance back, in other places it is level, and in other places it begins to rise at once. The soil is generally more or less sandy, but along the upper part of the river clay is more abundant than it is below, and
the banks are not easily cut away by the action of the stream. Shallow lakes occur at intervals a few kilometers back from the river, through which it flows beside the stream flows.

Upon a large portion of these thirteen hundred kilometers of Clearwater, the scenery is remarkably picturesque and beautiful, varied as it is, by near and distant mountain ranges and peaks, handsome islands, and the magnificent lake-like surface of the broad river. These lend a charm to the grand engineering features which Nature has established.
Examining features of the Fifth Section.

The Fifth Section includes the Rio São Francisco above the Falls of Pirapora, and the whole of the Rio das Velhas and their tributaries to their sources. These were not examined by the Commission.

The reports and maps made by others, especially by M. Liais and his Assistants, are in the possession of the government and were placed at the service of the Commission.

In 1865 surveys were made by Emm. Liais and Eduardo José de Morais and Lachitão de Souza Mello Netto, of the Rio São Francisco upon four hundred and forty kilometers above the junction of the Rio das Velhas.

It appears from the report that the São Francisco above the Pirapora Falls is greatly obstructed by numerous rapids, which prohibit navigation in low water and ordinary depths of the river.

Mr. Liais estimated the cost of improving the river for navigation at $8,700,000; the lower portion being designed for a navigation of 1.2 meters depth, the middle portion for 1.4 meters, and the upper portion for 0.60 meter depth.

These 264 kilometers ended at the mouth of the Pariquera river, above which it appears to be impracticable without enormous cost to make the river navigable.

The large sum, $8,700,000, estimated

* Excepting that Professor Derby, geologist, who accompanied the Commission throughout their examinations, afterward went overland up the Valley of the Rio das Velhas, and made a special report upon the region traversed; which will be more particularly referred to elsewhere in the report.
as required to make a navigation from the junction to the mouth of the Parapuba river, would seem to be altogether disproportionate to any benefit that could result. Possibly, this part of the river might be considerably improved, though not to the extent or in the same manner desired by M. Liais, for a very much smaller sum; but unless the Falls of Pirapora should be rendered navigable by means of locks (or some other less costly plan), it would be a waste of money to expend any considerable sum in improving the numerous rapids above the Falls.

The length of the Rio São Francisco, from the junction to its sources, appears to be about eight hundred kilometers. Approximately, the same on the São Roque, from the junction below Sabará.

The Rio Velhas River, according to the plan of M. Liais, is directly very susceptible to the same improvements. It has been navigable from the junction to Sabará, a distance of 164 kilometers; but in low water it is materially obstructed at numerous points by shallows, and rocks, and is un navigable except for light canoes. M. Liais estimated the cost of improving this navigation at 2,600,000, as follows:

This amount, though very much less than the estimate of the cost on the Upper São Francisco, appears in large compared with the present needs of that region. Possibly, some improvement of the Rio Velhas could be made, suited to the present and immediate future demands, for a very much smaller sum: leaving the radical improvements for a superior navigation to some future period when the augmented population and business of that part of the interior seemed assured it.
The Das Velhas, from its mouth to its sources is 650 and a half leagues or 2740 miles. The principal affluents take their rise between Latitude 20° and 21° South.

M. Lissium gives the position of the following ports:

- *Barra da Vela* at 17° 11' 54" S. 1° 43' 35"
- *Sabadâ* 19° 35' 52" S. 1° 13' 49"
- *Barbacena* 21° 19' 9" E. 69' 48"

Barbacena is near the Valley of the São Francisco. M. Lissium gives its height above the sea 1137'.

- In the Southern side of the Great dividing ridge separating the waters of the São Francisco from those of the Rio Grande and Paranahiba.

The fall of the river Das Velhas, from Sabadâ to the Barra das Velhas is according to M. Lissium 562.75 m and the height of Sabadâ above the sea 695.65 meters.

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### The Width of the São Francisco above the Province of Minas Gerais
- The width of the São Francisco above the Province of Minas Gerais is 4000 feet (1219 meters).

### The Length of the São Francisco above the Province of Minas Gerais
- The length of the São Francisco above the Province of Minas Gerais is approximately 4500 feet (1371 meters).

### The Current of the São Francisco
- In low water, the current of the São Francisco from Barra das Velhas to the São Francisco is described as follows:
  - At 138.55 cubic meters per second.
  - At 97.08 cubic meters per second.
  - At 335.51 cubic meters per second.

The quantity of the São Francisco above the Province of Minas Gerais is nearly 2.5 times that of the Barra das Velhas.

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In 1871, the small steamer *Saldanha Manha* commanded by 1º Lt. T. M. Alvaro de Araujo navigated the river as high as Sabadâ, 694 kilometers. M. Lissium and M. A. Symphonic de Avelo ascended in a large barca called *Putoimarin*. It was said that another steamboat was never run on the river between Sabadâ and points below. In connection with some mining business.

In December 1871, the Hydraulic Company bought the steamers.
Barra do Velho to Parainé: 1,800,000 km
Parainé to Itiquira: 1,700,000 km
Itiquira to Rio do Macahuta: 1,950,000 km
Rio do Macahuta to Sabará: 2,000,000 km
Total: 2,600,000 km

1.50 dm
1.95 km
1.20 km
0.60 km
In the examination of the San Francisco river, from the sea to Peralta, the labors of the Commissary were greatly facilitated by the maps and reports, and report made for the government by Hon. Guillaume Halfeld, Civil Engineer, and the surveys made by him in 1852-53 and 54. The copies of these which we had with us were constantly referred to and compared with the river, its islands, channels, etc., both in ascending and descending the stream.

Most of the changes that have taken place since the date of Engineer Halfeld's survey have been caused by the action of the stream upon the bars, islands, and sand-bars during the twenty-five years between 1854 and 1879. Comparative little change seems to have occurred in the aspect of the country bordering the river, or in the hills and cities, or in the position and number of houses, which are in sight from the river, or in the general population on the island, and river margins.

The maps at the time they were made probably presented a faithful picture of the characteristics of the stream, its curves, winds, and depths; its islands, channels, sand-bars, rapids, falls, and rock-obstructions; and in many places the geology of the rocks and valleys inland, etc. Together with other useful information. In a great majority of cases their correctness has been confirmed by our observations.

The Commisioner also obtained valuable information from the report and maps of the survey.
Subsequently made by D. Carlos Krauss, Civil Engineer, whose report, maps and estimates, etc., of 1868-69, were placed at our disposal by the government. Engineer Krauss' work applied especially to what Ivan designated as the 2nd & 3rd section of the river valley; namely, to the route for the railway between Piranhas and Jatobá, and to the rapids portion of the river between Jatobá and the Sobradinho rapids; and, as he states, his labors were materially lessened in consequence of the previous surveys of Engineer Halfpenny.

Third Engineers differed widely respecting the mode and estimated cost of improving the river, and as to the manner of uniting commercially the Upper and Lower São Francisco. Engineer Halfpenny considered the improvement of the river between Boa Vista and Jatobá entirely impracticable, declining even to attempt any estimate of cost, recommending instead a Canal from Boa Vista on the Upper river to Pão de Açúcar on the Lower river for a hundred kilometers long, at an estimated cost of 82, covering a project which may be regarded, in view of the circumstances, as inexpedient and impracticable.

Engineer Krauss estimated the probable cost of improving the rapids portion, from Jatobá to the head of the Sobradinho rapids—including four years interest on capital, at 2,100,000$00; and he estimated the cost of constructing and equipping the railway between
Pirakas and site, at the 3,735,000-000.

Counting the present estimated final cost of the railway, I have no definite information (it has been referred to as between 400,000 and 450,000,000,000,000), that...

The judgment of that at the time Argentine kauns' estimate of the cost of improving the river was made, in 1868, with the European experience in steam navigation of deep streams that existed at that period, and from the presumed difficulty of making larger slopes in the rapids, consequently an increase in cost. Their estimate of the probable cost between Jaffna and Perarpana, 1,000,000,000 (including interest) may have been a reasonable approximation. He estimated the cost between Kandy and Jaffna: 47 leasins, at the 1,438,000,000.

My estimate of the probable cost of improving the river so as to make a practicable steamboat navigation, is based upon the following premises:

That the least depth in any rapids at the extreme low water stage, should be not less than one meter, or so as to pass safely, boat drawing one meter, and that the current in the improved rapids, in the low water stage shall not exceed 20 kilometers per hour. This navigation to be attended Containing, available by using light draught, stern-wheel steamboats, with power sufficient to stem a current of 20 kilometers per hour, with two engines, 100 tons each, in tow. Under this system, but little change is needed at a number of the rapids, and the improved slopes being short, The Cost is reduced accordingly. Under these conditions, the navigation will be easiest that the sum of 1,438,000,000, except such a navigation can be received between Jaffna and Perarpana, including the cost of 1,000,000,000,000 to the navigation.
Appropriate to the foregoing, bearing upon the recommendations about to be made for the improvement of the San Francisco Bay.

The work proper to be done at the Barros should be determined by the manner in which it is intended to navigate the important channels; and that, in part, is more or less controlled by the nature of the present river breezes; but having reference also to its probable future Channel. Although, as mentioned elsewhere, how long been two steamers on the Upper River for some years, the river traffic has not been changed in consequence of the few trips that were made some years since by these steamers, as before it is still carried on by barcas, aponjas and canoes; of footing, when ascending, and by canoe when descending. Under the present management of pilots, these ascend and ascend through numerous channels and parts of Channels where steamers could not now run; and these are other Channels where proper steamboats could not run through which barcas, aponjas and canoes cannot ascend by poling, on account of the depth, and the strength of the Current; although, at times, with strong up-stream winds it is practicable to sail up some of these deep Channels, as was formerly. Still, as already pointed out, sails for navigating up or down are not used on the Upper River, nor even on the "Clear River." As the Channels now are, in low water, sails could not be generally used to advantage, through the rapids. It would not answer for the barcas to depend wholly or principally upon sails; crews of barca-men, free and slow, would still be necessary, so that this would often be an encumbrance rather than an aid.
With improved Channels through the rapids, enabling steamboats to pass and pass up and down, it is expected that the system of much of the river business will change, or that few hands would be needed on a barge, although considerable local trading will probably continue to be done as at present with canoes, apros and canoes.

Many of the larger canoes might at first be towed by the steamboats, but in time larger barges would supersede them.

The channels to be selected and improved would be steamboats with barges in tow. The width of Channel in the Conjoined Places should be less than fifteen feet, and generally not less than twelve feet, in the narrow places. As examinations have shown, it seems to be the large portion of the river through the Cachoeiras, they with much more than twenty meters wide.

Steamboats could run through a number of the Cachoeiras, with barges in tow, with scarcely any alteration of the present Channels. In others, some are dangerous rocks in the way which should be removed by blasting.

The sides and bottoms of the Channels are almost invariably solid rock, where dredging would be impracticable, if it were not for these, which it is not. Instead of dredging, the systems required by the circumstances is, increasing the depth of water, by Confining the streams of water, or by introducing an additional volume of water into the Channel to be improved. There is an abundant supply of water available, in every Case.
The examinations that have been made of the San Francisco River, while they are sufficient in connection with previous surveys to afford a fair view of the most important characteristics, as well as of many details, have not been critical enough to enable an engineer without additional investigation, occupying part of another reason, to prepare complete detail plans of the particular work needed at each Cachoeira, which improvement may be necessary; but the observations and order made in 1879-80, aided by the former experience of the senior member of the Commission, will suffice for an approximate estimate of the probable cost of making a proper steamboat navigation. The final cost of each Cachoeiras may prove to be somewhat more or less than the present estimate; but the intention is to present an estimate which is as a whole will not be likely to vary materially from the sum that this work will cost.

The description commences from the leading points relating to the Jefferson Cachoeiras. They are all to day substantially as they were when examined by Engineer Strauss in 1868, and as they were in 1852-53 and 54, when surveyed by Engineer Holtham. Nothing has been done to improve them; and the effect of the Currents and Pointed, during the quarter of a Century that has passed, upon the rocky flanks and ridges is imperceptible.

For convenience, the description has been arranged to begin at "Serradinho," the uppermost Cachoeira, giving them in their ascending order.
Very little engineering is necessary in connection with
the examination of the Cachoseras as to be improved into
a steamboat navigation. River work experienced is the
chief thing needed, aided by good judgment.
The ample supply of water in the river during
the entire season, being established, and the Cacheorias
being known to have sleeping channels (more or less
irregular) with rocky beds and to have, and the velocity
of the currents not being greater than a girt, light-throated
steamers can readily cover the same; all that is left to be deter-
mined in the most advantageous and economical
method of concentrating a sufficient quantity of
water in one channel, so as to make a practicable
navigation during the dry season, and which will
also be navigable at all other stages of the river.
Practical judgment, based upon most experience
and be useful in selecting the channel to be improved,
and in determining the kind and extent of work
needed to produce the desired result.

The works for the improvement of the navigation
are of the simplest kind. No locks, or gates, or
regular dams will be necessary, in any case.
The bottoms of the channels in the Cachoseras being
very hard, dredging is out of the question. (Blasting)
of isolated rocks, in some cases, will be expedient,
but the quantities, in cubic meters, will not be great.
The work in the Cachoseras will, by first, the
Closing of natural outlets, to prevent the waste of
water from the particular Channel selected for
improvement. This will be accomplished by
filling the space or cut through which the water wets, or with a rough bank of stone, or a low crib of
unembowered timber filled with rough stone.

Second: Raising fettors, of moderate extent, at the head of a few of the islands, to divert an
additional quantity of water, from the abundant supply of the main stream, into the Channel to be
improved. These fettors may be either rough stone banks, or cribs filled with rough stone, as may be
found most advisable in each particular case.

Third: At a few places, especially at the Cachoeiras
from the Redele to the do Vao, artificial Chutes may
be introduced for concentrating the water and sending
the current in a safe manner through the local
Cachoeiras. This work at the Chutes will require
longitudinal range of rough stone banks, or cribs filled
with rough stone. In some cases, there will be low,
closed canes of rough stone, or cribs filled with rough
stone, extending from the side of the Chute to the
shore; the object of these being to build, or raise the
water to increase its depth through the Chute.

No other work will be necessary on the Cachoeiras.
It is proposed to make the Minimum depth in the
current stage of the river 1.4 meters, and the Minimum
breadth of the Channel about 30 meters; although
the greatest portion of all the Channels will be 50
meters or more in breadth, so that the Minimum
breadth of 30 meters will occur at Comaparoche,
for places, and the depth generally will be more than 1.4
The cribs mentioned, are to be blank so that the top of the
timbers will, after completion, always be covered with water,
and therefore not subject to decay. All prospects may
the
Observations descriptive of the Third Section, or
Cachoeira Station of the river between the Cachoeira
do Sobradinho and Iaraçu - 478 Kilometers.

The low-water examinations of the Commission
on this Section of the river were made in the months
of September and October, while ascending.
Other observations were made during the Months
of December, 1879, while descending; when there
was a small fisher, from two to two and a half meters
above extreme low water; the height of different places
depending on the local declivity and height of
the stream.

The numbering of the Leagues, as originally given
by Sargento Halfeld, and afterward adopted by En-
gineer Sauer, is retained; and for Convenience
this Section will be described in the same descending
order; (although for the general description of the
river, the River and Valley it was deemed advantageous
in our opinion from the Ascending Examinations).

It may be here remarked that a rise of two or
three meters along the banks changes the condition
of many of the Cachoeiras materially, so that
some that in low water are quite difficult or
much more easily navigated, especially by the
Ascending Canoes.

The aggregate fall in these 478 Kilometers
is 96.30, or an average of 0.20 Feet per Kilometer,
very nearly. This fall is very unequally distributed;
being in a few instances as high as 0.80
for short distances, and not more than 0.10 on
some of the intermediate points.
This is the uppermost of the Cachoeiras on the 3rd section. It is in the Province of Bahia; the upper end being ten kilometers above the clinician line between Bahia and Pernambuco, on the left bank of the river.

It begins just above League 239, and ends just above League 240, being five and a half kilometers long.

The fall in this distance is 2.64 m. in low water, or an average of 0.48 per kilometer, but it is irregularly divided by several minor Cachoeiras.

Much of the larger portion of the river flows down the wide Channel on the Bahia side of the Island de Cachoeira, the smaller volume passing through the arm between the Island and the "Pernambuco" 241 (as it is commonly called, though as above mentioned it is above the Province).

Our examination was made on both sides of the island. They showed that on the Bahia side, from the first of the Cachoeiras up to four and a half kilometers there is a good natural Steamboat Channel, but that thence to the head of the island there are formidable obstructions, including the difficult Cachoeira de Volta, which renders that side impassable in low water for loaded Barcas or Canoes; although we did succeed in working a light Canoje Circumvally through the entire Cachoeira, aided by sails, poles, oar and Cordelling. It would have exceedingly difficult if not impracticable without the help of a sail.

The Construction of a safe Steamboat Navigation on that side of the river would be very expensive.
It is not known necessary to enter into Calculation of Cost on that side, as the examinations show that the smaller arm of the channel on the Left side is naturally very far superior, and that it can be made navigable for Steamboats during low water at Moderate Cost.

The prominence, or the special importance which appears to have attached to this Cachoeira, has arisen mainly from the Circumstances that it is the only one between Jazeiro and the "Clear river"; hence are the freeways and travel between Jazeiro and the numerous places along the Clear river, for over forty hundred kilometers have been and is yet subject yearly, during the low water season, to various impediments; although this Cachoeira can be passed at all times by light craft, by canoes, and Cordelling.

As a large Share of the entire Business of the Upper Sao Francisco has been and still is done in Jazeiro, this has been and still is an enormous obstructive Tax.

The permanent improvement of the low water navigation at this Cachoeira is clearly indicated by the Circumstances. The chief need is always Welcome of water in the Navigated Channel. This can be obtained by building a Jetty of Rough Stone, or a crib of Lumber and Rough Stone, not over two hundred meters long, running out obliquely from near the head of the Island into the Main river, leaving its top about two hundred meters above ordinary low water. This will intercept and divert into this Channel a Considerable Addition of water. In the Channel below, dense rocks can to be removed, and
it may be necessary to build a few small guiding
oats of undrowned timber filled with rough stone to
prevent the water from spreading and to straight-
the direction of the current.

In building out the jetty from the head of
the island it may be found that at a length of
less than two hundred meters and leave
a sufficient additional depth of water. No
extension should be stopped when enough has
been obtained.

As there is a small island, Called "Millo ou
Cachoeira", in this Channel no far below the head
of the Cachoeira, it may be found advisable to
clive one side of it (at the height of low water)
by a rough stone bank, so as to throw most
of the water to one side, instead of having the
flow divided, as it is now.

No other works than those above described
are needed to make a good Steamboat Naviga-
tion with a clear depth of 1.5 Meters in extreme
low water. Next to the head the Channel will
be two or three meters above, at the soundings there.

From the port of the "Cachoeiro de Sobra
Arriba"-League 240, to the head of the Cachoeira
das Conchas- League 246.50, 160 Kilmelos.
The river is nearly clear; a few rocks only should
be removed to render the navigation safer for
Steamboats; though a Steamer with a regular
Pilot can navigate there, displ. nine Kilmelos
now, in any stage of the water.

The important "Villa de Cachoeira", is at
League 246.50, on the Bahia (left), and the Villa
de Petrolina is opposite, on the Perambucos side.
252.50
Cachoeira das Conchas.
The slope of the river is 0.36 per kilometer. In 5½ kilometers, the river falls two meters. The current averages about 6½ kilometers per hour. There is a deep, wide steamboat channel. Those who should be removed to make the channel safe for a little higher stage of water but no large expenditure is necessary.

259.45-259.10 Cachoeira Pedras e Cachii da Missoi.
The river is near the foot of the Serra de Pentol, on the Pernambuco side of the island, where there is a fine wide channel, and a good steamboat navigation. It may, on Cape, examine it and find a narrow to receive a few rocks; but with a good pilot, a steamer can be safely-rowed with the river flowing in its natural state.
The velocity of the river here is only 0.16 per kilometer.

260.25-260.60 Cachoeira de Genipabu.
The slope of the river is true 0.17 per kilometer. The current at low water is about 5 kilometers per hour. There are numerous rocks in the river, extending from the Pernambuco side to beyond the middle of the river—which is here one kilometer in width. But the Bahia side is clear, and there is a good steamboat channel along this part of the stream.

There is a good channel on the Bahia side all the way down to the Cachoeira Genipabu.

262.80 Cachoeira Genipabu. Clear river on Bahia side.
League

265.85

Cachoeira Caraibas. This is only a wide, deep channel through a rocky ledge which lines the river. The slope of this part of the river is slight, and the current in low water is not over 1/2-kilometer an hour. It is an excellent steam-boat Channel, on the Brazil side. It is opposite the Ilha da Caraibas.

269.50

Cachoeiras do Atouge - da Velha and da Velha Vieira. The Cachoeiras are between the Ilha da Missao and the Pernambuco side, just above the narrow island de Atouge. The declivity here is about 0.70 per kilometer.

This Cachoeira runs into another, the Cachoeira de Atouge, and that into another, the Cachoeira da Velha Vieira; the first 9 written at about League 269.5.

These three Cachoeiras may be considered together, extending through about two and a quarter kilometers, from League 269.5 to League 269.9.

The channel is crooked, and shallow in places.

Some work will be required to make this a good steamboat channel in low water. The present kind of work should not be determined without a more careful examination during low water. It may be found advisable to increase the flow of water through the Pernambuco arm of the river by a small dam at the head of Pequena Island. Then, by removing a few stones, and building two, or possibly three, low guides-cribs, 15 to 20 meters of depth can be maintained in the lower stage of the river.

The present low water current, for short distances, are from eight to ten kilometers per hour. In moderate stage of water steamboats can descend and ascend without difficulty.
Cachoeira da Pradella de Durado.
This is a trackless place for loaded Canoes or Carava to ascend, because they cannot
put in the main Channel on account of
its great depth, and the shore line is composed
of black, polished, jagged irregular rocks.
The Cachoeira Channel is no where less
than twenty four miles wide, and the Cur-
nent is from seven to eight Kilometres per
hour, while the general Current is quiet
enough for steam navigation with a good
pilot and ordinary windmills; very little of any
work will be needed here.

Cachoeira da Villa.
This is between the Bahia shore and the Iha
Grande. It continues for about two Kilometres, among
a number of small islands, between the Iha Grande
and da Villa de Santa Maria.
Some work, removing rocks, is required above and
along this Cachoeira to make good steamboat
Channel. The Cachoeira itself is not of much account.
The average slope of the run is about 0.6 per kilometro.
A careful examination should be made from Bahia
including the Cachoeira 244 to 374, 89 in order to determine which
side of the Iha da Villa de Santa Maria can be the
best to improve. Work will be needed in either case.
If the Bahia side be adopted, then the Cachoeiras
Cantagalo and Do Boi, which are on the Pernamb-
ouco side, will be avoided.

275.30
Six leagues from the Cachoeira da Villa to the port above

There are Cachoeiras among the islands, on the Bahia side, on the Pernambuco side, and on the intermediate channels.

On the Bahia side, there are the Cachoeiras do Pernambuco, da Ilha Roçada, and da Cruz; on the Pernambuco side, there are the Cachoeiras S. Félix, C. Victoria, da Sibarona, and da COSTA Cacapé; intermediate, there are two Cachoeiras, on the Ilha da Ilha, and Ilha da S. Félix.

On our upstream examination we passed through the Pernambuco side or left bank of the river, and then through the corn of the streams between the Ilha da Ilha and Ilha de Taipá, there being the regular channel run by the pilots. To be sure, members of islands and tributaries channel along this part of the river, we made a special examination of the channels on the Bahia side with a view to a steamboat channel, both above and below league 277.

Below league 277, between that and leagues 281.5, we found a Channel on the Bahia side, needing a comparatively little work to make it good for steamboats, and above 277 up to 275 ½, it is practicable to arrange a steamboat channel within great cost on the Bahia side.

The regular, pilots' channel, between the islands, can also be made into a steamboat channel.

During our examination that a good steamboat channel could be made between league 275 ½ and 281.5, nothing, for a much smaller item than former estimate (crossed out)

but it will be necessary to make a more careful examination of all these channels, during low water, before finally deciding the particular route to be adopted for improvement. Villa de Pombi 282.
Cachoeira do Ferroinhó.
This is opposite the upper end of the Ilha de Paranagua in the main river on the Bahia side of the island. The velocity of the stream is 0.37 per kilometer. There is a strong current through this channel, about nine kilometers per hour. At a low-water stage of the river it is a fine steamboat channel.
In low water it is rather troublesome for ascending barcas and Carros.
Some time may be needed to make a safe steamboat Channel in the lower stage of the river, by the removal of a few rocks.

Cachoeira da Farella.
This Cachoeira runs from the Ilha da Farella obliquely toward the foot of nine small islands. It is a difficult Channel for ascending Barcas and Carros in low water. There are currents of nine kilometers per hour. The velocity of the stream is 0.37 per kilometer. In a careful examination it may be deemed advisable to remove a few rocks to make a safe steamboat Channel in low water. On a low-water stage the Channel is very good for steamboats.
A small Cachoeira—without name near Uha da Vaga. This is about three fourths of a kilometre above the point of the large Uha d' Azemalpão. It is scarcely observable in a two metre clay of the river, and there is a good steamboat channel outside of it.

From league 283.30 to league 284.30, a distance of fifteen and a half kilometres, there is a clear river, with very deep water, 20 to 25 metres deep for two kilometres, in league 286.
Leagues.
286.305 to 287.20 Five and a half kilometers. This includes a series
of six Cacheceiras, called respectively, Moore, La
Logue, de Carvalho, Quebra Canôa, Crama, and
Brandão.

The rate falls in these 5.5 kilometers is two meters,
or an average of 0.040 per kilometer.

The upper end of these Cacheceiras is near the foot
of the Ilha da Vera Visto, and the lower end is near
the Ilha de Vera Vista.

Here is a channel through these Cacheceiras
deep enough and wide enough to pass steam-
boats, and the current does not exceed nine
kilometers per hour. It is necessary to make
further careful examinations in order to locate cer-
tain rocks for removal, and to mark a fever
which needs not be removed, to make the chan-
nel safe for higher stages of the river.

The cacaus and asajus cannot ascend this
channel. They are compelled to wind
their way through side channels, where steamboats can
not navigate.

Estimated costs of making the series of Cache
ceiras into a safe steamer channel.

288.5 to 289.5 Five and a half kilometers. Five Cacheceiras, da Perreira,
and las Herce. They have a fall of 2 meters,
or an average of 0.060 per kilometer.

These Cacheceiras are on the Pernambuco side of the
river, between the Ilha Grande and the left
bank. The steamboats channel is on the right
side of the Ilha Grande; or, their three Cacheceiras
Do not constitute an obstruction to steam

Navigation, although they interfere with the move-
mom of cacaus and groups. But it may be found
advisable to remove a few boulders to make the channel safe.
291.25 Leagues. 291.35 The Cachoeiras da Minas and de Minas, embracing about 2.16 kilometers.
The cacity on this part of the river is 0.20 per kilometer.
The channels through here are wide and deep, and the current is greatly checked by the rough rocky beds and bottoms, and it does not exceed two kilometers per hour.
There is a small rocky island; there is bare on low water, which should be removed; for although steamboats can pass on higher bed, and it will be dangerous; especially when there is only about one meter depth of water, over it.
A fine straight channel leads on to the head of the Cachoeiras da Minas, the uppermost of three two.

291.40

Cachoeira de Revão. This is on the Bacia side of the river, opposite the large island (ilha Grande) and nearly opposite the head of ilha do Sorocóribo.
The barca and canoe navigation is here somewhat complicated and difficult; and in bad to pass with any agility around the quickest pitch of the Cachoeira; but in a "rapido," not a "fall," and there is deep water. The current is so broken by the irregular bottom and sides that a powerful steamer can pass; and the natural channel, the actual path of the river is about 0.20 per kilometer. No work of consequence can be required here.

292.50

Cachoeira do Cantagallo.
This part of the river is very rocky. The average cacity along here is about 0.70 per kilometer, but the cemenes is somewhat checked by the rocks on the bottom and sides.
A steamboat cannot reach through a channel among the rocks; but to pass in bad times rocks should be removed. The particular works to be removed...
can only properly be designated after a more careful examination of the Channel. The Currents are about eight to nine Kilometers per hour in low water.

**Cacheoera da Cima.**

The river in its vicinity is dotted with rocks and rocky islets. The Channel abounds with rocks, some of which are partially submerged. A few of these should be removed, and the channel should be straightened to make a Channel that will be safe at different stages of the river. The average velocity is about 0.70 per kilometer.

**Cacheoera de Baixo.**

The Barco and Coroa Channels are much more intricate and tortuous, but there is a very deep Channel here, apparently needing little work. This is only a short distance above the head of the Ilha do Cacambra. The Main Channel is between the island and the Bahia side of the right bank of the river. The river has a strong current along here, the average velocity being about 0.80 per kilometer, to the foot of the rapids. The flow then becomes more gentle to the next rapids below, the Cacheoera de Sacco.

**Cacheoera do Sacco.**

This Cacheoera does not interfere with the steamboat Channel. The Channel is deep on the Pernambuco side of the island of Jerumelha. There are many rapids in this part of the river, but there is a Channel here. The average velocity is here about 0.80 per kilometer. A careful examination of the Main Channel should be made, but probably very little work will be needed here.
Cachoeira da Senhora da Annexa.

The Cachoeira de Dois Irmãos near to the Perumutre road, and has hard rocks in it, but there is a good steamboat channel through this Cachoeira, approximately middle of the river, and deep; there is a swift current, but not exceeding nine kilometers an hour. The average declivity is about 0.30 per kilometer for a short distance. The general declivity along here is about 0.50 per kilometer.

Cachoeira de Dois Irmãos.

There is swift water through this Cachoeira; but with a good channel for steamboats. The current is mire rapid (in low water) than it is, but for the inconvenient of the rocky bottom and rocks, which breaks the natural current, and the swift current, which cuts the natural flow due to the declivity. The declivity along this part of the river in low water is about 0.30 per kilometer; a little steeper in the quickest part, or a short distance. Perhaps a few rocks may be removed to make the channel safer.

Cachoeira de Costaíma.

This is very similar to the Cachoeira de Dois Irmãos. The current is about the same, and there is a deficient channel for steamboats. The declivity is about 0.50 per kilometer, and the actual current rate in low water about nine kilometers per hour.

A careful examination of these Cachoeiras, ten kilometers after the Rodilhos, shows that a few rocks should be removed; but no large expenditure can be needed to make a good steamboat channel in that part of the river.
Cachoeira de Rodella, 
" de Fura Abas
" de Cavaleiro 
" de Porto Velho 
" de Tamaraba
" de Espinho
" de Cruzeiro
" de Vai.

The foregoing eight Cachoeiras, Covering a
Length of Eleven Kilometers, and a Total Fall of
Seven Meters, belong to one Series, and Stream
In Consequence together.

The average fall is 0.64 per Kilometer; but in
Several places, for short pitches, the Declivity is greater,
Varying in different stages of the River; the Short
Pitches gradually flattening as the Waters Rise.

This is by far the most important Cachoeira, and the most difficult to improve between
Sobradinho and Jaboré.

With sides of the River now examined, partly in
Air, and Canoes, and partly on the Bahia Side
in Land, but we found only one, the Parangaba
Side, at the lower end, navigable in low water,
For light Barcas or Canoes; and then only when
Aided by Cordelling.

A nearly Vertical fall of 120 ft. on the Bahia
Side, and a number of wide, broken, shallow,
Cachoeiras prohibit Navigation, and the Cost
of making a Steamboat Channel on that Side
would be very great, and it is not necessary to
Incur, since the Channels toward the Parangaba Side Can be improved at much less
Cost. By our Calculation the Fall is 5 Miles in 21/2 Kilometers, or at the
Rate of 2 ft. per mile, or 1 ft. per mile, in floods, Steamboats might pass safely.

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on the Bahia side; but this could only be for a short

time each season.

On the upper portion of the river, there is a
change of Channels, which, besides being
matters of improvement, but
in the lower portion there is no Channel, and
the improvement must be made along the Pernan-
buco side, opposite the Ilha do Ecoelho.

At present, the best natural Channel for ascend-
ing is broad here. Opposite Rocinha about mid-
way of the wide river above the Cachoeiras, and
meanders down the middle, making a final
Considerable bends, and then inclining toward
the Pernambuco Channel, and continues
that Channel, passing between islands and the Per-
nambozo shoal, through the Cachoeiras Tacural,
Espirito, Cunha and de Vaa.

But there is another route which can be
improved in as to offer a safe steamboat
navigation, and which will probably be better
throughout the varying stages of the river along
the upper end of the river, and to
be the same in both.

This is by proceeding at the head of the Ilha da Caut, by
the arm of the river between that land and the
Pernambuco shoal, and improving that Channel.
In that case, it will be necessary to build
a jetty, of rough stone and stone, projecting out
from near the upper part of said island about
two hundred meters into the main river, for the
purpose of forming an additional quantity of
water into that Channel.

The narrowest part of this arm is 50 meters
in width, and there is already a sufficient
depth, from the main Channel, of the
island, to this arm.
By the adoption of this route, the Cacheiras Furtivas, \( \text{etc.} \) and De Redelices will be avoided. In their stead there will be the Cacheiras do Cavallar, and do Porto Velho, which are on the arm of the river, and these are smaller and more easily managed than the other two in the main stream. Here are two other small cacheiras in their arms, but with the continuous supply of water they can be made navigable by means of small dams and guide-cribs filled with stone.

One advantage of this route is that it will be about one kilometre longer, and having nearly the same total fall, the locality, per kilometre, will be somewhat less.

At the foot of the Ilha da Cuiti, this Channel now receives an additional volume of water through an arm of the river between the Ilha da Cuiti and the Ilha dos Caobos.

At the foot of the Ilha dos Caobos, there is a very large accumulation of water from the wide Channel between that island and the Ilha dos Tacanitas; sufficient if it all remained in the Pernambuco Channel, to maintain an adequate navigation on the way through; but at the foot of the Ilha da Tacanitas, between that island and the Ilha de São Miguel, a large body of water, and part of it equally due to the Pernambuco Channel, other portion flow outward between the Ilhas São Miguel and Cruzeiro, and between the Ilha Cruzeiro and Serra da Canga.

By obstructing the outward flow by means of strong crib-dams, or rip-rap mounds, built up to the level of low water, an ample supply of water can be kept in the Pernambuco Channel.
There will then be needed at the Cachoeiras da Esperança, Córrego and de Vão, a moderate amount of work, in the shape of low end dams and guide cribs, to make straight Central Channels through these obstructions, when there will be a Complete and Safe Steerage Channel in the area covered stage of the river throughout twelve kilometers, on the Paranaguá side, making a good navigation at all seasons.

Definitely, the route of the Channel to be improved, on the upper part of the series of Cachoeiras, a Careful examination, in low water, should be made of the route now taken by the Córrego, with a view to compare the cost and advantage of that route with the cost and advantage now the Paranaguá Channel. Below the point of the idea of Córrego the same Channel and the same works above could be required as in the case described.

My approximate estimate of the probable cost of making a good, safe Steerage Channel, with a least depth in the shallow up place, in extreme low water of one and one fourth meters, (and ordinarily of one and a half meters,) with a general depth of one and a half to two meters, is 250,000,000. This improvement could be effected in two reasons: one of examinations and preparation of materials, the other for constructing the works.
Cachoeira da Stacutara.

Through this Cachoeira there is already a good steamboat Channel of ample width and depth. Only at one place towards the upper end is it narrowed to 20 meters. It may be advisable to remove or mark distinctly three rocks to ensure safety at all stages of the water. No work need be done below the proper steamboat shall be put upon the lower part of the river.

Cachoeira da Vargem Redonda.

This Cachoeira has a sufficiently wide and deep channel, with a current of the same pace of Nine Kilometers per hour. A proper steamboat can navigate both ways through this Channel without any difficulty. The boring of the water towards the lower part of the Cachoeira, caused by the great friction of the stream against the sides and bottom of the Channel materially checks the superficial current and renders the upward passage of steamers easier than it would be if the sides and bottom were smooth.

For the part of this Cachoeira to Jarara there is clear navigation all the way.
Topography, etc., of the immediate Valley.

Along the lower river, for about forty kilometers from the sea, the Country on both sides is elevated but little above the tidal Stream and it is annually more or less overflowing. Here the land is all adapted to the raising of sugar, rice, corn, etc., and large quantities are produced. Hills then appear, and in places come near to the stream, and before reaching Piranhas, the head of navigation in the lower River, the Mountains extend at intervals to the water's edge.

Chains of rocks crop the river below Piranhas, the Channels Courting among them, some being Considerably Curved; but all the rest of the river is regularly navigated by Steamboats and other Vessels, and Barcas and Canoes. The natural slope of this part of the River is about one third of a Meter per Kilometric, and the Currents vary from five to four kilometers per hour. Barcas and Canoes sail up against the Currents without difficulty.

The bottom of the river is Sandy Characteristic of the river bottom continues with only occasional exceptional lights through the Cañon in which the river runs, including the Falls of Paulo Affonso, and of Itaparica, to the head of the Water of Redonda rapids, 374 Kilometers from the sea, and about two kilometers above Jatobá.

The general surface of the plateau rises faster than the current of the river, attaining nearly the height of the Upper Valley nor far from Piranhas, where, in consequence, the Railway is located with an ascending grade of five per cent, to a point about three kilometers from Piranhas and twenty-five kilometers from the sea.

The Falls of Paulo Affonso, though not in one perpendicular fall like the Falls of Niagara,
present every abrupt ascent. We pass several grand falls, the ascent in the distance of one kilometer being 80 meters. The total fall in seventy-seven kilometers is 105 meters. The main fall is three hundred and eighty-five kilometers.

The river above the great falls is obstructed by islands, and roches to the foot of the falls of Stapanica, where another abrupt ascent renders all that portion of the stream unnavigable. This series of falls and rapids descends seven meters in the distance of five and a half kilometers. The fall of Stapanica are 354 kilometers from the sea, and twenty kilometers below Jutobai.

The river here presents a census aspect during low water, being very where cannot with irregular, blackened, polished rocks of the most fantastic description.

The river at Jutobai is two hundred and thirty-five above the sea level, and the country slopes gradually from the margin — the land being sandy, stony, and in some places rocky, covered with a thin growth of small trees and cactus. Above Jutobai, along the streams, pomegranates alternate with rapids, and the river margins rise at the same rate with the increasing elevation of the river; the banks being steep, rocky, and in some cases rocky, but along the ordinary height of the water, the soil is generally sandy. In some places, clay predominates. The islands are almost wholly alluvial, and very fertile.

Advancing up the river valley, the river banks become much flatter, and the gentle slopes are very generally cultivated.

In some cases, the land back from the river banks for some distance lies below the exterior pocket height and...
Scene, subject to annual flooding, is cultivable, and is for the most part cultivated. Back of that, the Country may, in some places, gradually, in others abruptly, Connecting with Mountain Ranges.

The Mountain ranges visible from the river, immediate Valley, are of various heights and of different Character. Some of them are quite regular in outline for many Kilometers in length, others are irregular, others polygonal, and others present masked, isolated peaks visible at great distance. Some of them are granitic, others are composed of sandstone, others of Slate, others of Sandstone, etc.

Many of these Mountains are named upon the Maps which accompany this Report, but a Complete Presentation of the Numerous Mountain Systems observed from the river would require a vast amount of time and labor, unless is that special subject.

In many instances, the scenery of the Mountain and the Valley, with the foreground of the river, are wonderfully beautiful. Pleasures arise of the mountain scenery, Nature, occur at almost every Great Bend of the River. Even the mere presence of the river, these Mountains become so far away that they are not visible from the river. Large, comparatively flat areas occur, small portions of which are cultivated. In some cases, being high above, the water extends over a length of ten Kilometers, or more, and the river meanders for many leagues into remote high-valley Canyons. The Maps exhibit such Characteristics better than verbal descriptions.

With the exception of that portion of the Valley in which the Pueblo Announces Falls, it is upon a Comparatively gentle plain. Even including the Falls,
The average declivity of the plains is only 0.25 per
kilometer from the Pirapora Plateau to the sea.

The Mountains, in the upper part of the
Valley are from three hundred to six hundred
meters above the river, or eight hundred to
clear hundred meters above sea-level.

The two streams on the respective Mountains, in
different parts of the Valley, appear to depend
in part upon Climatic Causes, and in part
upon their geological formation.

It will be observed that so long as the
River and Valley below the "funden" maintain
a general northwesterly course, nearly parallel with
the Atlantic Coast, its declivity is less; and it is,
Comparatively, free from troublesome rapids; but that
as soon as it bends suddenly eastward, it pre-
vents a greater declivity, and abounds with
rapids and falls prone to tide-water.

Had the typography permitted this stream to flow
northwesterly and debouch into the Basin of the Ama-
azon, the increased length, in that Atlantic,
bright might have resulted in a Contiguous Amazon
River. From the São Francisco, all the way down
the Coast to the Narr de Reis Point, the streams, which
discharge into the Atlantic, present rather
short, abrupt Courses between the Elevated plat-
forms and Tide water. The advantage of being
broad and Bahia Province, instead of flowing directly to the
sea, is Carried by short streams into the São Francisco,
following its Circulating Courses to the Ocean, passing
between the elevated platforms of Bahia and Espírito
Santo, then falling on the
Valleys of the Rivers, and
Eventually, the Mouth of the São Francisco.
There are back bow dividing grounds ranging near the middle of the Province nine or less regularly parallel with the general Course of the Coast line (about North East and South West, as far down as the City of Bahia, and below that neary North and South). The Serra Chapada Diamantina in the Northern and the Serra Das Abas in the Southern part of the Province are conspicuous as dividing grounds.

The Western portion of the Province of Bahia is bounded by the Serra da Tabatinga, the Serra das Trincheiras, and the Serra do parça-de-Piana, and on the Drainage on the eastern side of these back bow dividing grounds flows through tributaries of the São Francisco.
The area of drainage on its northern face is quite narrow, averaging only about fifty kilometers from the small Rio Cava to the small Rio Caba on the upper bank—nor far above Xiquiteque. Near the area begins to widen, and from the mouth of the Rio Grande—one of the great tributaries to the mouth of the Caranuhanha—another important tributary, the Generl, width of the region from the rim to the terminus of the Serra da Sabana is from two hundred and fifty to three hundred kilometers. The Rio Grande, the Carenha, the Caracara, and the Caranuhanha each more than three hundred kilometers long. The Rio Caranuhanha is the boundary between Bahia and Marim Gerre.

From the Rio Cava to the Rio Caranuhanha along the river the distance is eight hundred to one thousand kilometers (from league 233 to league 87) two three an numerous bends in the Sao Francisco which lengthen its course materially.

The actual area claimed in the Province of Bahia on the west side of the river is approximately one hundred and five thousand square kilometers. On the east side of the river, all the drainage of the western, eastern, and southern portions of the Province of Bahia flows to the Sao Francisco, amounting approximately to one hundred and fifty-thousand square kilometers; making the total approximate area of drainage in this Province flomn to the Sao Francisco two hundred and fifty thousand square kilometers.

The entire area of the Province of Bahia is approximately four hundred and sixty-six thousand square kilometers, or that considerable one half of its entire surface drains into the Sao Francescо; right.
long been in use. One of the Commissioners, as elsewhere men-
tioned, made a special examination across a part of this
Country, from Cararangaba to the City of Bahia (863
Kilometers). The results of which are given in his report
and are shown in part on the map of the Province
prepared by him based on the best available author-
ties and his own personal observations.

A large proportion of the immediate valley of the
São Francisco in the province of Bahia, excepting the
river margins and islands, is yet uncultivated, partly
in consequence of the general dryness of the Climate, and the
irregularity of the rainfall, and partly on account of the
high cost of transporting the produce to a market; but in
the more southerly portion upon the tributaries there has
been some cultivation, where the rainfall is greatest and
more reliable, especially at some distance from the main
stream on the higher slopes of the rising lands, and on
top of the more elevated plateaus. The extent of such
farming cultivation has not been great; vast areas are still in
a state of nature; the predominating aspect being
Mountainous, with large plateaus greatly, cut up
by the minor streams, interspersed with fertile valleys.

Although the Province of Paraná is very much
smaller than the Province of Bahia, a greater proportion of its
area drains into the São Francisco. Only about the
third of this Province drains directly into the Atlantic;
while the other two thirds drain into the rivers. In dry
seasons however it furnishes very little water to the
São Francisco, and sometimes none at all.

The Western streams of the tributaries that enter between
Cabo de and the Rio Casa Nova (the coastal
stream) and the Rivers Paraná (which drains Paraná into the Province) are chiefly on
the Serra da Estrela. The Northern tributaries that
erin below Cabo de, have their sources partly in the
Same range and on its castly, Protagonum, the Sena do Piatãpo, the Rio Made, the most castly tributary having its sources in the Province.

The prevailing Characteristic of these tributaries on the left bank, at Pernambuco, side of the São Francisco, is, dry beds, with occasional flowing water at irregular periods; and sometimes Considerable floods, caused by heavy rains suddenly discharging large volumes of water among the head waters and along the valleys.

The general width of this province above Cabuçu, is about One hundred and twenty, kilometers, and below Cabuçu One hundred and twenty, kilometers.

The area of the province, draining into the São Francisco is approximately One Hundred and Forty, kilometers; the area draining into the Atlantic by other streams, into the Rio Cabelaré and the Ipojuca, is about Forty, thousand square kilometers; making the total area of the province about One Hundred and forty, kilometers.

The city of Recife is the great seaport and the capitol of this Province. The principal town ports of this Province are: São Vicente, 530 kilometers from the mouth; Nova Victoria, 622 kilometers above the mouth; and Recife, 782 kilometers above the mouth.

The province of Alagoas, which lies in the left bank of the river from the mouth to a Point distant about the Paulo Officio, has an area of about, Raízes, one-thousand square kilometers in the interior, only a narrow strip of land forming about one-fourth part, territory along the section, Chaeni into the São Francisco. The western part of the Province Chaeni directly to the Atlantic, and the river the principal stream being the Vera River, which runs in the mountains of Northern Bahia.

The most frontier of the Province of Alagoas on the São Francisco is 520 kilometers from League 2, 811 League 323.3.

Above Recife, which is a town near, there is no real drainage into the São Francisco, excepting During rains or for short periods therefore, Ordinarily, all the tributaries, from the mouth, north-kilometers up the course, of the São Francisco, the capital and principal sea port of this Province, in the right bank. Capitólio, and between the Province of Alagoas and Pernambuco, are the provinces now.
Topography, continued.

The Province of Sergipe, extends along the right bank of the river from its mouth to the Rio Sergipe (atLeague 3120) a distance of 2741 kilometers, or nine fathom. The Rio Sergipe is 94 kilometers below the Falls of Paiva Affonso, and it borders the Province of Sergipe from the Province of Bahia.

It has an area of about thirty-three thousand square kilometers, only a narrow strip of which comprising not over one fourth of its territory, all in the Sumari river valley, drains into the São Francisco. The residue of the Province drain directly into the Atlantic South of the river. Its principal stream is the Vasa Harris, which rises among the Mountains of Northern Bahia.

There is no town of importance at the Mouth of the São Francisco, either to Sergipe or Alagoas. Sergipe do Rio, the Coast port of the Province of Sergipe, is about 1400 kilometers south-westward from the Mouth, down the Coast. The Villa de Riojano is the principal port of the Province on the river. It stands on the river banks 83 kilometers above its mouth.

The Upper São Francisco and its upper tributaries, above the province of Bahia, all lie within the province of Minas Gerais.

The length of the main river in Minas Gerais is 1278 kilometers, of which 478 kilometers are below the junction of the Dois Vélas, and 800 kilometers above. The Upper tributaries are very numerous, and as one of them contains flowing water throughout the year.

The prevailing topography is Mountainous, with occasional high, broad plateau, and generally narrow valleys; though there are some twenty kilometers or more in width.

As the field work examination of the Commissary did not extend beyond the upper end of the Pirapora Falls, the information here regard to the region higher up is derived from reports and maps made by others, supplemented by
The special examination made under the auspices of the Commission by authority of the government by Professor Orville H. Derby, geologist, during the years 1877-1880, whose report shows that the general topography of the upper Das Velhas and its tributaries is of a very similar mountainous character, with interesting fertile valleys.

The report and maps of H. Diaz, who, in company with Edmundo José de Morais and Camelão de Sousa Mello Neto, Civil Engineers, surveyed the Das Velhas and upper São Francisco, in 1865, have furnished much information respecting the parts of Minas Gerais, and of the Characteristics of the river.

I am also indebted to the work of Coronelio Henon de oliveira for information contained in his "Carta Physica do Brazil," published in 1876.

The drainage area of the São Francisco and its upper tributaries within the Province of Minas Gerais is approximately two hundred and twenty-six thousand square kilometers. It is this extensive territory, chiefly a mountain region, the rainfall of which supplies the abundant, never-failing flow of the São Francisco River, although the Rama or, the Correntes, the Rio Grande, which enters below the Cambaranha in the Province of Bahia, also furnish large quantities.

The extreme upper boundaries of the basin of the São Francisco and of its great Confluence, the Das Velhas, are also the boundaries of the head waters of the streams flowing southward into the other Rio Grande, and the Paranahiba. In fact, the sources of the Paranahiba lie far north of the drains of the São Francisco, whereas

* This Rio Grande joined north Confluence with the Rio Grande on the south side of the Great Cauca River, which flows to the Panama and the estuary of the La Plata.
of the Backbone dividing ridge. Thus the head waters of the São Francisco are over five hundred kilometers south of those of the Paraná River.

On the eastern side of the great valley of the São Francisco the range which extends, the eastern faces of the Veas Ubas divides them from the water flowing eastward to the Atlantic. Through the lower Paraná, entering the ocean in the Province of Rio de Janeiro, and other streams flowing eastward to the Red River, entering the ocean through the Province of Espírito Santo. This mountain range is called the Serra do Espinhaço. Its elevation is about 1,300 meters above the sea.

The sum of the approximate area of chainsage in the provinces of Alagoas, Sergipe, Bahia, Rio de Janeiro, and Minas Gerais is about twelve hundred square kilometers. These are mainly portions of the Province of Goiás, chained by several tributaries of the São Francisco; but the area is insignificant. (The Province of Goiás is drained northward by the Tocantins, and the Granda (a third river of that name) or Araguai, into the Amazon; and it is drained southward by the Rio Paraná into the Paraná, and La Plata.)

The large mountain range between the waters of the São Francisco and the Tocantins, and which separates Minas Gerais from Goiás, is called the Serra da Tereza. Further north the same range, dividing the waters of the São Francisco from the waters of the Tocantins, and also separating Minas Gerais and Bahia from Goiás, is called the Serra da Tabatinga.

Emm. Line is gain the elevation of 130 meters above the sea, and 10,125 meters above the sea.
The meteorology of this large valley varies considerably in different parts, resulting in essential differences of climate, owing to the different periods and quantities of the rainfall; and these differences permanently affect the growth and maintenance of forests, and likewise the agricultural capabilities of the respective districts. Near the sea, and along the Lower river generally, there is sufficient rainfall to ensure good crops of sugar, rice, corn, mandioca, tobacco, melons, etc. every year; but, beginning in the neighborhood of Piraquara, 235 kilometers from the sea, the uplands, which are there from 200 to 250 meters above the sea, and quite near to the river, are subject to great droughts, rendering large tracts unsuitable for general agriculture; the true pastures of the Pecão supporting a limited number of cattle and horses.

Such is the character of the soil on both sides of the valley opposite the Falls of Paulo Affonso, and for a long distance up, varied with better soil in places. The rainfall is exceedingly irregular, and generally inadequate to sustain ordinary agriculture, excepting in occasional years.

Only the alluvial, sloping river banks, and the numerous alluvial islands, which are annually inundated by the river floods, are naturally arable. These are regularly cultivated, and yield abundant crops. On the main upper river valleys is cultivated only in a few places, to any extent; the Chief supply for the valley being raised in the valleys of the large tributaries. A small quantity of cotton is raised, but not enough for shipment at present.
The general climate is so dry that agriculture cannot flourish near the river only where there is natural or artificial irrigation. Sometimes for several ascents. Census reasons the climate throughout this extensive region is so arid that the lower tributaries of the upper river, excluding the large river Moxeza, for many kilometers above their mouths, contain no flowing water, and their dry beds in certain favorable places are temporarily converted into small plantations upon which corn, melons, etc., are raised.

At the period of an examination in 1879-80, many of the tributaries at their mouths had any flowing water for a distance of one thousand kilometers from the sea. The entire region on both sides of the river covering a very large area had been parched and suffering from want of moisture for several years. Considerable parts of Paraná, Santa Catarina and the eastern portion of Minas Gerais were thus affected, the western portion of the São Paulo supplying only a limited number of cattle and hogs, along the river both sides of the Paraná up to the level of the valley opposite the City of São Paulo, the others almost entire kilometers above.

The rainfall is very irregular and not sufficient to sustain ordinary agriculture excepting during occasional rains. Only the Alluvial, along the main channel, and the numerous alluvial islands which are annually inundated by the main floods are naturally arable. These are regularly cultivated and yield abundant products of maize, cassava, corn, sweet potatoes, rice, melons, etc.

On the main upper river region Cultivation only at a few places on a large scale, the chief supply being raised along the large tributaries. A little Cotton is raised, but not any at this time for shipment.
The general climate is so dry that agriculture - as generally understood, near the sea in a long chain ocean, Paulo Affonso either flourishes, and where there is natural or artificial irrigation. Sometimes for several successive years, the crops throughout this region are scarce. In the small tributaries, including the large river Madeira, for many kilometers up, cotton and sugar water, and the dry beds in favorable places are temporarily converted into small plantations where corn, beans, potatoes, and melons, etc., are raised.

At the time of our examination, in 1879-80, none of the tributaries were thickly populated along the river, and there was a flourishing trade at their mouth. The whole region on both sides of the river comprising a very large area, had been protected and suffering from want of moisture for several years.

Considerable parts of the Province of Pernambuco, Bahia, and the eastern portion of Minas Gerais were then affected.

See page 48 (pencil)
A hundred kilometers or more off from the river are the higher lands, rising in numerous places into mountainous ranges with elevated plateaus. There is more rainfall, though the country is also subject to long continued droughts. Even at the junction of the Dae Velhas with the Mau river, five hundred meters above the sea, and two hundred kilometers distant from it by the river, injurious droughts sometimes occur. This region is known in general much more moist than the region farther down the river. Here are true forests, abounding in valuable woods, and where the trees have been cleared off for cultivation the soil is generally very rich and fertile.

On the upper waters of the Dae Velhas, the Pinares, Paracatu and other upper tributaries, the yearly rainfall is usually quite heavy; ample for the support of general agriculture, if properly attended to; although as yet agriculture has been introduced only to a limited extent. Even these months of June, July, and August, and sometimes of May, and September, it rains, rare without rain.

The quantity of the yearly rainfall varies greatly in different years as is shown by the varying annual heights of the floods. In some years the floods rise twenty or more meters, while in others the rise is only ten or twelve meters; the discharge from the river in some years being three times that of the discharge of other years.

The minimum discharge just below the junction of the Dae Velhas as shown by Nefflen was 335.5 Cubic meters per second. Maximum measurement in 1865 gave 655 Cubic meters per second.

Our measurement, Dec. 16, 1879, gave 1629 Cubic meters per second; but the river was then nearly two meters above its usual low water. Assuming for an approximation the height of the quantity for the low water flow it would be 541 Cubic meters.
But in such case, where the object is to find the minimum flow of extreme low water, the lowest measurement, in this case 3.5 cubic meters per second, should be adopted.

One hundred and thirty-eight kilometers below the junction after receiving the intermediate streams and the large flow from the main Paracaté, the quantity is more than fifty percent greater. In extreme low water, the minimum flow at the mouth of the Rio Verde is 1066 cubic meters per second below the junction may be safely assumed as 5000 cubic meters per second per second. Accuracy in regard to the extreme minimum flow is unobtainable except by actual measurement as the time of such minimum flow; nor is accuracy a necessity in connection with the works made for the improvement of the navigation. The lowest measurement made by the Commission, in 1879, gave 1104 cubic meters per second, when the stream was not more than 0.30 above extreme low water.

Rain-gauges have not been kept any where in the valley of the Sáo Francisco, and Considering the peculiar and very irregular meteorological phenomena in the Middle and lower portions, rain-gauge records there would possess little practical value unless the extended through a lengthened period of years. Then they alone exhibit the remarkable irregularity of the rainfalls; but only at the spot where the rain-gauge was stationed; for the rains, besides being so irregular, are quite local. Light rains which would flow in the rain-gauge, would cause no flowing water on the surface of the ground, and the moisture resulting from them would be evaporated by the sun in an hour or two.

One of the evidences of the lack of moisture is the absence of springs along the banks and margins.
of the stream, such as are quite common along rivers. Draining regions once regularly supplied with rain. The people along the river depend wholly upon the river for their water supply. Fortunately, this water is excellent.

The small scattered tree growth, the abundant natural Cedar, the general scarcity of grass, and the absence of water, and the dryness of the air and soil during a large portion of the year, prove the leading characteristic to be insufficient and irregular rainfall. During certain years, no rain falls at all. Natural marshes enough in the vale for general agriculture beyond the reach of the river inundations are quite exceptional and rare.

As already indicated, the large quantity of water at all times, flowing in the river, in many of ample rainfall higher up the valley, and the annual great floods of December, January, and February among the Amazon, from there it has heavy rainfall during three months in the upper water*, while the period of low water from May to September, (and October, in the lower part of the stream) shows a time of drought throughout the valley.

**Rainfall.**

Rainfall in Bahia, Minas Gerais.

in the City of Rio de Janeiro

in Ceará

*Since writing the above, records of the rainfall, kept at Petrolina on the northern side of the Cerrado Ridge, not far from the highest deems of the Serra do Carioca, has been obtained. It extends, from 1866 to 1879, inclusive, 25 years. This will be more particularly referred to further on.
Climates.

It is not easy to convey an exact idea of the peculiar climate or climates of the Valley of the São Francisco. It is warm, during the day, at all seasons of the year; and in the sun it is generally hot, excepting on the river, where there is almost always a breeze, during the day time, and sometimes during the night. Situated between eight and a half degrees south, at Cabojo, and twenty-one degrees south, towards its sources, rising gradually from the sea-level to nearly six thousand meters above the sea at its head-waters, some differences of general climate are to be expected, and these differences, but along the lower and middle portions of the Valley of the Upper River, where not injured by rainfall, for example, during long droughts, the different dearsino of the year finds little change in the aspect of the country.

Truck, annually, the sun is vertical in every part of the Valley; as it passes through the tropic, and on its return, and on the 21st of June, when it is at the Northern tropic, it is about forty-four degrees north, vertical at the head of the Valley, and forty-two degrees north of vertical at Cabojo.

At an elevation of six thousand meters above the sea, with the sun so far from vertical, and in a region where timely and sufficient rains occur, the general climate is very favorable, not only in point of comfort, but for the growth of a great variety of agricultural productions, and for general business. At that elevation, even when the sun is vertical, the general range of temperature, in the trade is rarely above 80° Fahrenheit.

The average elevation of the Upper Valley of the
San Francisco is about 400 meters above sea level, between the State of París and the State of Pirapir-á, a distance of eighteen hundred kilometers. This is not sufficient, of itself, to create an appreciable difference of temperature, though it has some influence.

The general range of temperature along the valley is about 85°, rising sometimes to 90°, and occasionally to 95°, hardly to 100°, during the hottest part of the day. The nights are generally much cooler, and the early mornings are often quite cool; sometimes below 70°; but without any regularity.

Along the upper part of the valley, below the junction of the París River, during the rainy season, in September and November, the thermometer sometimes falls to 60°, and thin wooden clothes are comfortable; but as a rule, throughout the valley, the weather is warm enough to dispense with heavy clothing. In the vicinity of the Barras de Vellas there is sometimes frost.

The agricultural products along the valley do not show exactly the capabilities of the climate and soil in different parts of the country, nor are they raised everywhere. The crops vary with the climate and soil conditions, from one end of the valley to the other, namely, on the Atlantic and interior sides, and islands. There are Mandevilla, Corn, beans, of various kinds, and Melons. But for hundreds of kilometers, oranges and bananas are not seen; and only here and there a little sugar-cane, and little less Cotton. Not because the climate is unsuited to them, when they are watered; but because, done scarcely, any thing is raised for shipment,
from the valley, they continue to plant and cultivate only a few articles. Nature has been adapted to the circumstances, and they are obliged either to confine themselves to the comparatively limited areas of ground which are annually irrigated by the fingers of the river, or introduce artificial irrigation. So long, however, as the inhabitants dwelling along the river margins and islands, continue without artificial irrigation have enough to satisfy their moderate wants and until the commercial circumstances change, they will not be likely to resort to artificial irrigation.

The general absence of moisture in the soil, away from the islands and river banks, is permanently characteristic; and the presence of moisture, sufficient for agriculture, is only occasional, and does not occur at regular intervals, or so as to be calculated upon.

Whatever may be the causes which control the abundance or scarcity of rain, and the distribution of atmospheric moisture along this valley, they have been in operation for ages, and there seems to be nothing within the power of human efforts to change them. All that man's judgment and skill can hope to accomplish is to take advantage of the circumstances, as experience may suggest.

Nature, in addition to her regularity and erratic supply of moisture, has left the river in a very inconvenient shape as an avenue of commerce and if that is allowed to remain as nature left it, since the people have conformed themselves to their realities,
to it, the probability is that little change will take place, to change the present aspects of the valley.

Even a perfect, correct and unquestionable diagnosis of the Meteorological reasons for the prevailing climate of the place, would not in the slightest degree help to change the action of nature's laws. It is obvious, the circumstances of the valley, did not create the Meteorological phenomena - which exist outside of it; but that the Meteorological phenomena have established the character of the valley. It is too much to say that these may not change, but it is too much to say that they cannot be changed by human means. Proper forests, which exist in the upper portions of the valley, are not the cause, of the Meteorological Characteristics they are the Consequences.

The climate is as good as the climate of Lower Egypt. In that part of Egypt the sandy deserts is entirely sterile, till it is, artificially, irrigated. The line of demarcation between sterile and abundant yield is very clearly defined by the water line.

The level, or comparatively level uplands of the São Francisco above the level of the floods, are not so rich as the alluvial lands, or the so-called deserts of Egypt, nor are they as rich as the alluvial lands of the São Francisco; but if they were watered many of them would yield well. The climate is good enough to bring forth from the soil, just as it is in Egypt.

Rainfall

Rainfall in Sabara - Maria Gomes
in Rio de Janeiro
in Carara - Jovália - Carara.
Rainfall in Sabara

Attached is a Table of rain-gauge records, kept by the St. John del Rey Gold Mining Company, during 25 years, from 1855 to 1879 inclusive.

This rain-gauge was at a point about two leagues south-east of the Village of Sabara. Sabara is on the Das Velhas river in the Province of Minas Geraes, in Latitude 19° 53' 52" South, and 1° 13' 49" West from the City of Rio de Janeiro, assumed to be approximately 1437 meters above the sea.

This Table was kindly furnished to Professor Derby by Messrs. Minoves, the gentleman in charge of the Company's works. It was afterward reduced by Prof. Derby from feet and inches to Millimetres, as given in the Appendix.

This is the only record known to have been kept of the rainfall in the region near the Sources of the Das Velhas, or San Francisco river; and its study has afforded some interesting meteorological facts, some of which may have an important bearing upon the future agricultural resources of the Upper Valleys of those rivers, as well as the Upper Part of the Valley of the Main Stream.

The average annual rainfall during the 25 years from 1855 to 1879 inclusive, was 1637 Millimetres (5.38 feet).

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<td>1487</td>
<td>1488</td>
<td>1489</td>
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</tbody>
</table>

The average annual rainfall was 1037 Millimetres.

This Table may be put in one Column.
The average rainfall in the different quarters of the year (Trimeter) was:

- For January, February, and March: 772
- April, May, and June: 103
- July, August, and September: 77
- October, November, and December: 745
Total average: 1637 for 25 years.

The average monthly rainfall was:

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean</th>
<th>Range</th>
<th>Decile</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>299</td>
<td>825</td>
<td>99</td>
</tr>
<tr>
<td>February</td>
<td>221</td>
<td>523</td>
<td>59</td>
</tr>
<tr>
<td>March</td>
<td>192</td>
<td>309</td>
<td>34</td>
</tr>
<tr>
<td>April</td>
<td>52</td>
<td>87</td>
<td>14</td>
</tr>
<tr>
<td>May</td>
<td>36</td>
<td>95</td>
<td>2</td>
</tr>
<tr>
<td>June</td>
<td>15</td>
<td>118</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>11</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>13</td>
<td>88</td>
<td>0</td>
</tr>
<tr>
<td>September</td>
<td>53</td>
<td>141</td>
<td>1</td>
</tr>
<tr>
<td>October</td>
<td>121</td>
<td>343</td>
<td>30</td>
</tr>
<tr>
<td>November</td>
<td>234</td>
<td>394</td>
<td>106</td>
</tr>
<tr>
<td>December</td>
<td>390</td>
<td>762</td>
<td>775</td>
</tr>
</tbody>
</table>
Total: 1637 during 25 years.

The greatest rainfall in one month during the 25 years was 845 millimeters in January, 1855. The next greatest was 762 millimeters in December, 1855.

The least or minimum rainfall during different months was as follows:

<table>
<thead>
<tr>
<th>Month</th>
<th>Millimeters</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>99</td>
<td>1873</td>
</tr>
<tr>
<td>February</td>
<td>59</td>
<td>1873</td>
</tr>
<tr>
<td>March</td>
<td>21</td>
<td>1877</td>
</tr>
<tr>
<td>April</td>
<td>14</td>
<td>1873</td>
</tr>
</tbody>
</table>
No rain fell in June during the years 1855–1858, 1862, 1865, 1867, 1869, and 1877.

No rain fell in July during the years 1855, 1859, 1860, 1868, 1869, 1876, 1878 and 1877.

No rain fell in August during the years 1860, 1862, 1863, 1865, 1871, 1869, 1872 and 1878.

The least rainfall in September was 7 in 1874 (and 2 in 1865).

In October 35 in 1865.

In November 106 in 1865.

In December 137 in 1875.

The following shows the order of the months as to their quantity of average rainfall annually:

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (millimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>390</td>
</tr>
<tr>
<td>January</td>
<td>299</td>
</tr>
<tr>
<td>November</td>
<td>234</td>
</tr>
<tr>
<td>October</td>
<td>121</td>
</tr>
<tr>
<td>September</td>
<td>53</td>
</tr>
<tr>
<td>April</td>
<td>52</td>
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<tr>
<td>May</td>
<td>36</td>
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<tr>
<td>June</td>
<td>15</td>
</tr>
<tr>
<td>August</td>
<td>13</td>
</tr>
<tr>
<td>Year</td>
<td>11</td>
</tr>
</tbody>
</table>

Greatest: December 390

December was the most rainy month, having 30 per cent more than January.

In the 3 months, November, December and January, there was an average of 923 millimeters, or 36 per cent of the yearly rainfall.

In the 4 months, November, December, January and February, the average was 1157 millimeters, or 76 per cent.

In the 6 months, April, May, June, July, August and September, the yearly average was only 180 millimeters, or 11 per cent of the annual rainfall; while in the 6 months, October, November, December, January, February and March, the yearly average was 1453 millimeters, or 89 per cent of the annual rainfall.
It will be observed that in the month of June, there were seven years, when no rain fell; namely, 1855, 1858, 1863, 1865, 1867, 1869, and 1877.

In the month of July, there were eight years during which no rain fell; namely, 1855, 1859, 1860, 1868, 1869, 1870, 1878, and 1879.

In the month of August, there were eight years during which no rain fell; namely, 1860, 1862, 1863, 1865, 1867, 1869, 1872, and 1878.

The total average yearly rainfall for the three months June, July, and August, was only the trifling quantity of 39 millimetres.

The rainy season is therefore very clearly marked; namely, from October to March inclusive; six months; the other six months, from April to September, inclusive, being the dry season.

It will also be observed that the monthly variation, in every month, is very great. The maximum year, in January, shows a rainfall eight times greater than the minimum. In February, the same, eight times. In March, fifteen times. In April, five times. In May, forty seven times. In June, as 113 to 1. In July, as 64 to 1. In August, as 88 to 1. In September as 141 to 1. In October, 248 to 1. In November, nearly four times. In December, nine times.

The quarter-year (trimester) variations were also very marked; in the three months, January, February, and March, the maximum average was 1292 millimetres (in 1858), while the minimum was only 279 millimetres (in 1873), the being four times greater than the other.
In the three months April, May, and June, the maximum was 199 millimetres (in 1874) and the minimum was 47 millimetres (in 1836, and also in 1861) the one being four times greater than the other.

For the three months July, August, and September, the maximum was 168 millimetres (in 1858) and the minimum was 2 millimetres (in 1869), the one being 84 times greater than the other.

For the three months October, November, and December, the maximum was 121.9 millimetres (in 1856) and 448 millimetres (in 1877). One being two and three fourths times greater than the other.

The half-yearly variations are also striking. For the rainy season, from October to March inclusive, the maximum was 2202 millimetres (in 1858) and the minimum was 1911 millimetres (in 1859-60) almost exactly double of the other; one being 1.11 times greater than the other.

For the dry season from April to September inclusive, the maximum was 346 millimetres (in 1857) and the minimum was 71 millimetres (in 1878) the one being nearly 5 times greater than the other.

The yearly variations are also quite notable. The maximum was 2220 millimetres (78.28 feet) in 1858, the minimum was 1154 millimetres (3.78 feet) in 1873, the one being nearly double of the other.

As a matter of some interest it may be noted, that the following years were below the average, namely, 1855, 52, 55, 59, 61, 65, 69, 71, 76, 77, and while the following were above the average, 1857, 60, 62, 63, 64, 66, 67, 68, 69, 70, 71, 73, 74, 78, and 1879.
It is obvious that there was an abundance of rainfall, suitable for agricultural purposes, even in the year of least rain, in 1872, when the quantity was 11.54 in. (298.6 mm), but it is also clear that there is a long period without any rainfall, every year, namely, in a part of May, all of June, July and August, and part of September, and in years the dry season runs through all these four months.

Agricultural operations in this region should be arranged in view of this important fact, especially the planting or sowing. Deciding things if planted or sown with judgment, keeping in view the pending of the drought, might be successfully cultivated, which if planted or sown day as late as the latter part of June or the early part of July might wither, and fail, before the annual rains should come to their relief, in September or October.

Although there are no rain-gauge records kept below Saturá, throughout the San Francisco Bay Valley, there is no doubt that throughout a great portion of it, the periodical drought is longer and more injurious to general vegetation than it is on the Upper Water.

The monthly, quarterly, semi-annual, and annual variations in the quantities of the rainfall, as shown by the records, are so great, and so irregular, as to render it certain that the Cauca is not in the region where the rainfall falls, but far away; and dependent upon circumstances, or phenomena entirely outside of it. Similar variations occur...
in various parts of the United States, in the City of Philadelphia, where the features of the region have not been materially changed — so far as they might be affected or influenced by the Meteorological phenomena — for fifty years past, there has been in some years only half the rain that fell in other years. The same phenomena occur in the Valley of the Ohio, the Upper Mississippi, and the Mississippi, which together form the great river Minnehaha, at Cairo; the quantity of water discharged by these rivers is sometimes only half as much in one year as it is in another year; although there is no evidence to show that the average yearly quantity is any less, or any more now, than it was fifty or a hundred years ago. The stream does not fall any lower now than they did fifty years ago, nor do the floods rise any higher. They are arising, after, in both directions, as they could not be.

These facts also tend to prove that the Meteorological Causes of the Irregularities are not in these countries, located by the stream, named, but far away, and outside of them. The stream running in this place the firmness forms into the region of firmness.