

m1  
English Original  
Report on the S. Francisco Rivd.  
dated May 31. 1880

Letter to Minutes dated June 21. 1880

Relatório de

H. Milner Roberts

Engenheiro-Chefe da

Commissão Hydraulica

Sobre o

Exame do

Rio de São Francisco

Desde o Mar até a Capoeira de Pirapora,  
2122 Kilometros.

Feito em 1879-80.

Por ordem de  
Sua Excellencia

O Comelheiro

João Lins Vieira Camansão de Sinimbu

quando Presidente do Conselho

Ministro e Secretario d' Estado dos Negocios

da Agricultura, Commercio e Obras Publicas

Rio de Janeiro, <sup>May 31<sup>st</sup></sup> ~~April~~ 1880.

1/2

# Introductory

I have the honor to present herewith my report upon the examination of the São Francisco River made by the "Commissão Hydraulica", during the year 1879-80, by order of His Exp.<sup>ty</sup>, O Comelheiro João Luis Vieira Camansão de S. Simão, Presidente do Conselho, Ministro e Secretario d'Estado das Negocias da <sup>Commercio e Obras Publicas</sup> Agricultura, given in His Exp.<sup>ty</sup>'s Officio dated 29 de Julho, 1879.

## Introductory

In obedience to the instructions of His Exp.<sup>ty</sup>, the Commission sailed from the City of Rio de Janeiro on the 31<sup>st</sup> of July, 1879, on the Coast Steamer *buena* for Macaio, to proceed thence to the river.

The Commission placed under my charge consisted of the following gentlemen:

Dr. Dr. Antonio Placido Pereira de Amarante	Primeiro Engenheiro.
Dr. Rudolph Weiser	Chefe de Secção.
Dr. Dr. Domingos Sergio de Saboia e Silva	1 <sup>o</sup> Class Engenheiro

Sr. Dr. Alfredo Lisboa 1<sup>o</sup> Classe Engenheiro.  
 Sr. Dr. Miguel Antonio Lopes Pecegueira 2<sup>o</sup> " "  
 Sr. Dr. Theodoro Fernandez Sampaio 2<sup>a</sup> " "  
 Sr. Dr. Thomas Aquino de Castro 2<sup>o</sup> " "  
 Professor Orville A. Derby, Geologist, selected by the Government  
 to accompany the expedition.

The Commission arrived at Maceio on the  
 6<sup>th</sup> of August, where we met His Ex.<sup>cy</sup> Sr. Dr.  
 Cincinato Pinto da Silva, Presidente of the Province  
 of Alagoas, who promptly extended every facility at  
 his Command to facilitate the movement of the  
 Commission to the São Francisco river.

The Steam-Launch, <sup>the ~~ship~~</sup> 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 there being none  
 of sufficient power in the harbor. I therefore proceeded  
 with the Steamer to Pernambuco, <sup>taking Engenheiro Carrão with me,</sup> where I called  
 upon <sup>Dr. Adolfo de Barros Cavalcanti Albuquerque</sup> <sup>de Lacerda</sup> the Presidente  
 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 Presidente  
 of the Province, to be sent to the São Francisco river,  
 we returned on another Coast steamer to Maceio.

Having completed <sup>the</sup> ~~certain~~ necessary prelimi-  
 nary arrangements, through the kind attention  
 of <sup>the</sup> Presidente of the Province of Alagoas, the Com-  
 mission left Maceio on the evening of the 11<sup>th</sup>  
 of August, on the Steamer "Gigua" (then draw-  
 ing 10 feet water) and on the 12<sup>th</sup> <sup>we</sup> passed  
 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 transhipped from the steamer to large lighters, <sup>while</sup> ~~and~~ 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 weekly steamer, the "Sinimbu", which plies <sup>regularly</sup> between Penedo and Piranhas, a distance of 189 <sup>11/2</sup> kilometers. We left Penedo on the Sinimbu, August 17. Remained over night at Pão d'Asmear 142 kilometers above Penedo, arriving at Piranhas on the 18<sup>th</sup>. We were there met and courteously received by D. Reinaldo Von Krüger, Chief Engineer of the Paulo Affonso Railway, and his staff, who did what they could to <sup>forward</sup> ~~facilitate~~ the movement of the Commission overland to Jatobá.

We made an examination of the line of the railway, and of the works as far as they were constructed, and partly constructed, in company with the Chief Engineer and his assistants.

PAULO AFFONSO RAILWAY.

This railway is located on the left bank, or Alagoas side of the river, <sup>opposite</sup> ~~near~~ the Falls of "Paulo Affonso". It has a gauge of one meter, and it is designed to connect the lower river, at Piranhas, with the upper river at Jatobá. Its length is one hundred and <sup>seventeen</sup> kilometers. Jatobá is not yet a town; <sup>as yet</sup> it is only a convenient point on the river, <sup>selected</sup> 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 hills bounding the narrow valley are rocky, rugged and steep, and a large amount of rock excavation was encountered.

## Introductory - Continued

The general location of the line appears to have been judiciously made. The work on the first section was far advanced when we <sup>first</sup> saw it, ~~very~~ in August, and <sup>very</sup> nearly completed when we saw it again the following January. The criticism I 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 promises to be a first-class, meter-gauge railway. The engineer expected that the railway might be completed during the year 1880; unless the work should be delayed, from want of funds, or some unforeseen cause. Further particulars of the railway will appear elsewhere.

In Piranhas, we purchased saddle-horses, and engaged pack-animals to transport the Commission and ~~the~~ instruments, tents, provisions, and baggage overland to Jatobá.

We left Piranhas August 22<sup>a</sup>, accompanied by the Chief Engineer of the Railway and his assistants; traveling along the railway line. En route, ~~on~~ ~~various~~ ~~occasions~~ ~~at~~ ~~various~~ ~~times~~, we visited and examined the great Falls of Paulo Affonso.

They <sup>Falls</sup> are truly grand <sup>and</sup> beautiful; but this is not the place to enter upon a description. <sup>I would however remark that</sup> the description <sup>the traveler</sup> given by Captain Bentin, is excellent.

We arrived at Jatobá August 28<sup>th</sup>; but finding no <sup>there</sup> conveniences for procuring or arranging a journey for the new expedition, we pushed on eleven kilometers farther, to Atalho, and encamped opposite the Casa of José Manoel de Souza, which, with one other Casa constitutes the town, at that spot.

José Manoel de Souza kindly assisted us in our preparations, and accompanied us in our preliminary examinations of the rapids of the Vargin Redonda, just below Atalho, and of the

# de Vão, (and others adjoining) eighty one kilometers above Atalho. ~~Due to an unlooked for delay in the arrival of the boards from Piranhas for constructing the Ajuijos, 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 navigating, either up-stream, or down stream.

Fortunately, however, we had had sails made in Piranhas, and we had men with us who knew how to set them up, and work them. The boards <sup>for the Ajuijos</sup> did not reach Atalho till Sept. 10<sup>th</sup>.

My examination of the rapids of de Vão, <sup>made previously,</sup> showed that only Canoes, with the aid of Cords, 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 Affonso Railway, and through him to the government.

Upon the arrival of the boards at Atalho we immediately fitted up two Ajuijos, and a Canoe, each with sails, D. Amarante, Mineiro Engineer, having previously spent many days along the river in procuring suitable Canoes, which <sup>proved to be a difficult matter.</sup> A considerable part of the provisions, baggage, etc. in order to lighten the cargoes of the "Ajuijos," (upon which the Commission had to do most of their work,) was sent forward by land, on pack-animals to Calrobo, a distance by the river of 169 <sup>stat.</sup> Kilom. <sup>N.</sup>

By the advice of Chief Engineer Krüger, an escort of twelve armed men accompanied the expedition.

Introducing - Continued

These men were afterwards made useful as laborers; but there did not seem to be any necessity for the presence of an armed force, with a peaceful government Commission, <sup>where</sup> any along the river. Invariably, <sup>very</sup> everywhere, we found the people <sup>and</sup> courteous, ~~and~~ friendly, <sup>always</sup> ready to oblige; ~~and~~ hailing our party with the kindest manifestations.

We left Atalho Sept. 15<sup>th</sup>, sailing and poling up stream. We had ~~an~~ excellent <sup>crew</sup> ~~number~~ of Indian Canoe-men, and two first class Indian pilots, brothers, who managed the ajoujos with great skill and judgment. They <sup>also</sup> very soon learned how to handle <sup>the</sup> sails; although they had had no previous experience in sailing.

Our system was, to encamp in the evening, and remain over night in show in the tents; resuming work before six o'clock in the morning, stopping about nine for breakfast.

The observations, soundings, and notes were made, chiefly on board, as we ascended the pools and rapids, having the maps of Engineer Halped always before us, which proved to be of essential service throughout our examinations.

We sailed, or <sup>as the case might require,</sup> poled <sup>up</sup> all the rapids, stopping at the most difficult ones to examine different channels, <sup>paths</sup> some of which, while not unfavorable for <sup>improvement,</sup> steamboat navigation, are at present not advantageous for the canoes and barcas.

We arrived at the head of the Sobradinho rapids October 20<sup>th</sup>. The succeeding day was devoted to a further examination of these rapids, through three different channels. In the evening of Sept-ember 21<sup>st</sup> we proceeded five kilometers farther up, to Santa Anna, a small town on the left bank of the river, in the Province of Bahia. ⊗

788 kilometers from the mouth and, 70 kilometers above Jajoba, in the Province of Pernambuco  
division on the left bank of the river between the Province of Pernambuco and the Province of Bahia; and in the night bank, 52 kilometers farther to the Rio Verde.



Introductory - Continued

At Santa Anna we found the Steamer "Presidente Dantas", which had been lying there idle several years. I had heard of this at Cabrobó, and by the aid of special messengers and the telegraph from Penedo to Bahia, I received permission from <sup>his excellency</sup> the President of Bahia Sr. D. Antonio Augusto de Aragão Pulcão to use the steamer in our examinations of the "Clear river", above the rapids. President Pulcão <sup>had</sup> kindly sent a special messenger overland from Bahia to Juazeiro with the official authority. Sr. Manoel Fidélis Nunes de Silva the Sub-<sup>residing near Juazeiro, then</sup> Delegado, having charge of the steamer, did all in his power, aided by Sr. Captain Francisco Luiz Ferreira who had previously had charge of her, to facilitate the business.

On the evening of our arrival in Santa Anna, we took possession of the steamer; her engineer, Sr. Jovino Ant. Pereira having come down 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 start upon her long voyage; the Engineer expressing doubts as to the distance she would be able to run. On this account, although we greatly desired it, we had <sup>at that time</sup> little hope of getting up as far as Pirapora, especially as this steamer had never been higher up <sup>the river</sup> than Jannania.

We had to provide a pilot; and by the advice of our friends in Juazeiro, and <sup>with</sup> the approval of the Engineer, who knew him well, we secured the services of "Fabio", a good indian pilot, who had piloted the steamer some years ago. We were obliged <sup>also</sup> to improvise two steersmen, two firemen, and <sup>the</sup> deck-hands from among the men.

## Introductory - Continued.

we had with us. We fortunately succeeded in getting  
 very good men, <sup>for the respective positions,</sup> who performed their duties in a  
 highly satisfactory manner.

We steamed out from Santa Anna on the  
 26<sup>th</sup> of October, leaving the ajoujos in care of a  
 reliable man until we should return.

Thenceforth, for over two months our home was  
 on the steamer. The accommodation on board  
 though <sup>not extensive,</sup> was sufficient for the members of the Commission,  
 though <sup>not without some inconveniences,</sup> but the canoe men, and most of the ~~others~~ <sup>others</sup> slept  
 at night on shore; which answered very well except occas-  
 ionally <sup>when it rained.</sup> Our custom was to start before six A. M., and to  
 stop and anchor about six <sup>or dusk;</sup> P. M., taking our  
 meals on board.

There being, of course, no previous arrangement  
 along the river for fuel, we were compelled to stop fre-  
 quently to cut wood for the steamer; saving time  
 in some cases by hiring men to assist. We also  
 made contracts for the delivery of wood at several  
 points during our absence up the river, which  
 saved time on our descending voyage.

# At Jauana, 313½ Kilometers below the  
 Falls of Pirapora, we engaged another pilot, an in-  
 telligent Colored man, who, although he had never  
 piloted a steamboat, knew that part of the river, well.  
 He guided the steamer safely up and back to Jauana.  
 The pilot Fabio was not acquainted with that part of the river.  
 We arrived at the Falls of Pirapora December 14,  
 and examined them. We ascertained the total height  
 of the falls and rapids, by levelling, to be six meters, on  
 a length of about One Kilometer.

On the 15<sup>th</sup>, the next day, we started on the return  
 voyage, remaining over at the Barra Das  
 Velhas, 2½ Kilometers below <sup>Pirapora,</sup> getting wood, till the  
 17<sup>th</sup>, at the place now known as Guiachury, at the  
 junction of the Das Velhas and São Francisco.

Guiachury

Introductory - Continued -

9

~~It is~~ in the Province of Minas Geraes

At this place, Professor Derby arranged to proceed over-  
land, <sup>up the Valley of the Das Velhas</sup> to Diamantina, and thence via Barbacena to  
the City of Rio de Janeiro. On the same day, Dec 17<sup>th</sup>,  
we left the junction <sup>with the steamer</sup> on the downward trip.

There <sup>has been</sup> ~~was~~ a small freshet in the river, <sup>which we met</sup> ~~at~~  
<sup>while ascending,</sup> although it had fallen, in different places,  
as the water line showed, 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 <sup>steamer</sup> navigation.

The freshet line, so late as the middle and latter part of  
December, is usually considerably higher than we found it.

At Caranhata on the 23<sup>d</sup> of December, Sr.  
Dr. Theodor Fernandez Sampaio, one of the engineers of  
the Commission, who 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

country, making notes, and sketches and <sup>geological</sup> collecting  
<sup>and agricultural</sup> specimens along the route he traversed between  
Caranhata and the City of Bahia, meeting the  
Commission in that City on their return, Coastwise  
from the São Francisco river to the City of Rio de Jan-  
eiro. By the route he travelled the distance is about

# 835 Kilometers; though the course is by  
no means direct.\*

\* In another place will appear a detailed description  
of this region, a portion of which would naturally be trib-  
utary to the São Francisco Valley to a greater extent than  
it is at present, if the navigation were improved. It is  
chiefly in this view that this portion of the Province of  
Bahia seems to be closely associated with the future of  
the São Francisco river.

Intermontory - Continued

We returned with the Steamer to Santa Anna on the evening of December 31.<sup>st</sup> 1889, and left her in Charge of her engineer, and transferred our things to the Ajunjos, preparatory to making the descent of the rapids from the head of the Sobradinho to Jatoá.

(It is only just to a worthy officer to state here that Sr. José Ant<sup>o</sup> Pereira

the provincial government engineer in Charge of the steamer, performed his arduous duties faithfully and intelligently. He was ably assisted in his labors by Francisco Canuto de Araujo who had previously received several years of mechanical engineering education, who was attached to the Commission as time-keeper, <sup>etc,</sup> and in fulfilling other duties. To their attention and watchfulness, and to the skill and care of the pilot, Fabio, the Commission is greatly indebted for the safe voyage, covering 264.4 Kilometers of ascending and descending navigation.

On the 1.<sup>st</sup> of January, 1880, <sup>the next day,</sup> having ascended the ajunjos, we bade adieu to Santa Anna, and to the Steamer "Presidente Dantas", and started down stream, passing through the left Channel of Sobradinho rapids, and arrived at Joazeiro at noon of the 2.<sup>d</sup> of January.

At Joazeiro, two of the ajunjos were disposed of, and a barca was purchased, the pilots declaring it unsafe to run the lower rapids with heavily laden ajunjos, which doubtless was true. During our stay at Joazeiro we received kind attentions from Sr.

Major Luiz Man.<sup>l</sup> Da Costa and Ant<sup>o</sup> Luiz Vianna Cd. Benedes Moura de Paes

We left Joazeiro on the 5.<sup>th</sup> of January, and arrived at Cabroá on the 10.<sup>th</sup> 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 Utaho.

## Introductory - Continued

We returned <sup>in the morning</sup> to Atalho, January 15<sup>th</sup>. Here we parted <sup>with</sup> our excellent pilots and Canoe men, and engaged pack-animals to convey our things to Piranhas.

# On the 17<sup>th</sup>, <sup>the 17<sup>th</sup> of January</sup> we bade adieu to our friend José Manoel de Souza, and resumed <sup>horses for the good-bye trip to Piranhas.</sup> ~~our horse back riding.~~ We passed much of the way over the route of the Paulo Affonso Railway. A portion of the Commission went direct to Piranhas, while a portion turned in to the Falls of Paulo Affonso, <sup>where</sup> we had a second view of that grand natural spectacle, at a time when there was a considerably larger volume of water rushing <sup>down</sup> over it. With the steam raised by a great flood, it must be a still more striking object; but in any stage of the water some of the <sup>from favorable points</sup> views are magnificent. The finest views are not to be had without some laborious walking over excessively <sup>conspicuous</sup> high, blackened and polished rocks.

During our absence on the upper portion of the river, some rain had fallen along this lower part of the valley above the Falls, and the Sertão had <sup>considerably</sup> been refreshed; but there had not been sufficient rain to create flowing water in the lower tributaries. The large river Negro, where we crossed it, and <sup>where we</sup> travelled in sight of it for many kilometers, showed only a dry, sandy bed; though by digging wells through the sand, water, having a rather sweetish taste, was found <sup>at the bottom</sup> underlying the bed-rock.

The inhabitants along the banks of the <sup>Upper</sup> 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 Piranhas on the 21<sup>st</sup> of January, ~~where we would again start, and re-visit the Commission~~

~~on the occasion of our first visit we were happily met by the~~  
~~at the hands of Chief Engineer [unclear]~~

At Piranhas authority <sup>and granted by telegraph</sup> was asked from the government to charter the steamer "Sinembu" to facilitate the examination and soundings of the lower river and of the Channel through the bar at the <sup>of the river.</sup> mouth, ~~also~~ <sup>at the same time</sup> ~~by telegraph.~~ Instructions were <sup>also</sup> received to examine the entrance to the harbor of São Miguel, accordingly, after sounding the lower river and noting the Courses of the Channels as we descended on the steamer, and after <sup>inside of the bar and</sup> sounding through the Channel across the bar, the Comissão proceeded with the <sup>same</sup> steamer ~~Minister~~ to Macaio, where we met his excellency Sr. D. Cincinnato Pinto da Silva, Presidente of the Province of Alagoas, who wished to accompany the Comissão during our examination of the entrance to S. Miguel harbor. This examination was made on the 31<sup>st</sup> of January. The steamer returned with his excellency and a number of his friends who had accompanied us from Macaio, the same evening to Maceio; where we bade adieu <sup>them adieu.</sup> ~~to his excellency and the other gentlemen.~~ From Maceio <sup>we</sup> ~~the steamer~~ steamed down the Coast to the City of Bahia, where we arrived February 2<sup>d</sup>. Here we paid our respects to the Presidente of the Province, # Sr. Ant<sup>o</sup> Augusto de Araújo Bulcão and at his request I prepared a brief *resumé* of our trip on the São Francisco, which was published the next day. We expected to leave <sup>Bahia</sup> ~~there~~ on the 4<sup>th</sup>, but the English steamer was detained, and we did not sail till the 5<sup>th</sup>, <sup>arriving</sup> ~~arrived~~ in the City of Rio de Janeiro on the morning of the 8<sup>th</sup> of February; after an absence of a little over six months.

It may be proper to mention that when  
 when we were about to start from Rio de Janeiro, on the 31<sup>st</sup>  
 of July, 1879, there was <sup>little or</sup> no expectation that the Commission  
 would be able to get all the way up <sup>to Pirapora</sup>, and return in  
 one season; nor, could 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  
<sup>or</sup> ~~with~~ our *ajinjos*, or on *barcas*. In fact, but for that  
 steamer, we should <sup>it is true</sup> have returned sooner, but only by  
 leaving a thousand kilometers ~~of the upper~~ <sup>of the upper</sup> ~~of the river~~ <sup>of the river</sup> without  
 examination.

Upon the whole, we have reason to regard the  
 season's work of the Commission as very satisfactory.

# 3

Page 9

# Report.

Approach from the Sea - The outer bar - The inside Harbor - the <sup>tidal</sup> 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 easterly 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, shoaling gradually to five meters or less. At this time (January, 1880) there is a good channel across the bar having a depth of four and a half meters at high tide. The crest of the bar with this <sup>depth</sup> 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 Atalaia, 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 three 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 Alagoas north east of the river for eighteen kilometers to Point Peba, high sand-dunes form the conspicuous characteristic; while the Sergipe or South Westerly side of the river the sand-dunes 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 dunes on the north easterly side of the river entrance is constantly drifting down the Coast to the river edge; but its further Coast movement, from the wind, is checked, and the sand is blown into the river; whence it is carried out to sea by the out flowing current and ultimately dropped on the bar, adding to the sedimentary deposit brought down the river during freshets.

The prevalence of north easterly 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 retard its extension seaward.

During high freshets when the river current is strongest the littoral current does not strike the river current at right angles; their meeting

Current is then inclined considerably southward. In low river stages the large bar inside diverts the river current now 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 more easily deflected by sand-bars, and by the littoral current; at the same time its force is more readily counteracted 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 then 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 northern than <sup>on</sup> its northern 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, <sup>as well as</sup> ~~and~~ the more recent charts of Captain Mouchez, and of Lieut. Vital d'Oliveira of the Brazilian Navy, it appears that the general line of the coast has changed but little for a long period. The present crest of the outer bar projects rather less than three kilometers beyond the general line of the coast. It is known that large quantities of detritus, consisting of mud and sand, partly in suspension and partly mixed along the river bottom, are brought down during every flood; yet the delta 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 since, the deeper Channel passed out along the Sergipe side, south of the large inner sand-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 good navigable depth across the bar; but if it should be divided, materially, and pass out in <sup>of some</sup> two principal Channels, the depth will be correspondingly lessened.

Should circumstances hereafter render 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 there is in a number of places in the river below Penedo. The tide flows some distance above Penedo; but the rise of the tide, ordinarily, at that place is less than a meter; though the fluvial rise in great floods is eight meters. The highest river-floods in the Lower River are usually between December and March; and the <sup>equal</sup> low water period is from May till October, inclusive.

(4) (13)

## The São Francisco - Compared with the Mississippi.

The São Francisco river has sometimes been likened to the Mississippi, both being large, sediment-carrying streams, debouching through deltas. ~~But~~ when studied in connection with ~~improvements~~ <sup>improvements</sup> 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 passes, and thence for a hundred and forty kilometers, to the City of New Orleans, holds its depth of thirty meters, and this continues with little variation for several hundred <sup>kilometers</sup> ~~meters~~ farther. There is besides continuous navigation for large steamers for six thousand kilometers, to Fort Benton, below the Falls of the Missouri, in <sup>Lower</sup> Montana Territory.

On the other hand, the <sup>lower</sup> São Francisco, excepting the short distance through the harbor near its mouth, has little greater average depth than that of the Channel across its outer 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 in the case of the São Francisco. The general width of the São Francisco is much greater than that of the Mississippi; but what the Mississippi lacks in width is made up by its <sup>remarkable</sup> ~~great~~ depth. The great width of the São Francisco is a disadvantage, by proportionally reducing the depth of its 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 ships could reach the great Commercial port of New Orleans; but if the bar at the mouth of the São Francisco were deepened, it would not enable large ships to pass up, even to Penedo, on account of insufficient depths in the river; while of course the Falls of Paulo Affonso must exclude <sup>all</sup> vessels <sup>from</sup> ~~of any~~ passing 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 railway around the Paulo Affonso Falls, 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 increased depths can be maintained at the outer bar of the São Francisco river - in case it should be demanded, by merely dredging. Nothing short of jetties could be relied upon, and such costly works under the existing circumstances would seem to be premature. There may not be any necessity for considerable government expenditures on 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 decide to make the entrance of the river a harbor of refuge, for vessels of deep draught, it would be practicable by means of jetties\*.

\* but no very reliable estimate of the cost could be made in the absence of a special survey having that object in view. Undoubtedly it would amount to a large sum.

The São Francisco River, may be <sup>conveniently</sup> considered in five principal sections, beginning at the Ocean bar, as follows;

Sections

49X

I. The Lower River, from the Outeira bar to Piranhas, two hundred and thirty eight kilometers (43 leagues) navigated regularly by Steamers; usually navigated by ocean vessels to Penedo, <sup>forty nine</sup> ~~forty~~ kilometers from the sea.

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

III. The improvable rapids, and the navigable pools between Jatobá and the head of the Sobradinho 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 (239 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. munião Hydraulica]

overleaf

On The first section, from the Ocean to Piranhas, it is not proposed to expend much money, at present, or until the Completion of the Paulo Affonso Railway, and the improvement of the Upper. The expenditures should then have reference to the new Circumstances.

The Completion of the Paulo Affonso Railway will effect the Commercial Connexion between the Lower and the Upper River.

The third section, from Jacobia at the upper terminus of the railway to the head of the Sobradinho 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 Sobradinho rapids to the Falls of Pirapora, commonly known as "the clear river", is already a tolerably fair navigation for Canoes, Barks and small Steamers, needing only a little work to make it more safe.

The fifth section, from the head of the Pirapora Falls to the sources of the stream, has not been examined by this Commission, and is here only incidentally mentioned. Dr. <sup>Emmanuel</sup> <sup>Licias</sup> <sup>Director</sup> of the

<sup>Astronomical Observatory of Rio Janeiro</sup> 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 <sup>section</sup> shall have been improved it would seem to be unnecessary to expend money on other parts of the river.

17

## 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 driest seasons.

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 become reduced to even less than two meters, without any well defined channel, as in the case of the bars at the mouth of the Nile when it is low. There, during the annual floods, with their augmented scouring 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 freshets these rapids have been passed by barcas, 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 stream, 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 main 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 be 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 Jabola and the Sobradinho rapids nearly all of the Channels through the rapids have rough, rocky sides 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 declivity.

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; assisted 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 on ~~six~~ hundred Kilometers is ~~fifteen~~ hundred meters, in many places it is from two to ~~three~~ thousand meters, and it is divided at numerous points by islands into two or more Channels.

Rock obstructions occur at intervals along the first ~~sixty~~ ~~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 Steamboat 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 width and thereby deepening the Channel. In all cases, where there is only a single Channel, Contracted by the sand-bars to <sup>a width of</sup> three hundred meters or less, it is very <sup>deep</sup>.

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 freshets, 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 <sup>not</sup> make extensive "cut-offs," like those along the lower Mississippi. The current merely abrades the banks and islands; one effect of which has been to <sup>materially</sup> widen the river. This, while it is injurious in low water, by decreasing the natural depth, is <sup>at other times</sup> beneficial, by lessening 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 freshets is from eight to ten meters; varying in different years, and at different points along the stream.

The declivity, in the Clear river, from Pirapora to the head of Sobradinho rapids, averages <sup>nearly</sup> only 0.<sup>m</sup>6 per kilometer. There are a few places where it is considerably more; but it is nowhere steep enough to create a current sufficient to prevent the running of Steamboats.

62

21

## Engineering features of the São section.

The first section extends from the ocean to Piranhas, two hundred and thirty eight kilometers (43 leagues). The height of the river at Piranhas during the low water period or low tide eighteen meters above the sea. At Penedo, on the left bank, forty nine kilometers from the ocean, at the same period, it is about one meter above the sea.

In very great freshets the river, at Piranhas, rises twelve meters and at Penedo eight meters.

During these abnormal floods the surface slope from Penedo to the sea is greatly augmented, being then at the rate of  $0.{}^m 18$  per kilometer, when the current velocity is correspondingly increased.

A flood of six meters, at Penedo, gives a slope of seven meters in forty nine kilometers, or at the rate of  $0.{}^m 14$  per kilometer.

The current is not however strong enough at any time to prevent the ascent of steamers and sailing vessels. With the wind blowing strongly up stream, as it does almost daily, barges and other vessels sail up against the current.

The usual low water declivity during half the year, from May to October, from Piranhas to Pão d'Assucar, a distance of forty four kilometers, is seven and half meters, or at the rate of  $0.{}^m 17$  per kilometer; and from Pão d'Assucar to Penedo, one hundred and forty three kilometers, the declivity is nine meters, or at the rate of  $0.{}^m 063$  per kilometer.

The average width of the river between the ocean and Penedo 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 navigated

channels, or islands, are only about four hundred meters wide.

The widths of the stream between Penedo and Piranhas are also various; though every where ample for navigation. For about 77 Kilometers above Penedo the average width is 1000 meters, the greatest 2000 meters, and the least 400 meters.

Through the narrows, for Sixteen Kilometers below Piranhas where the Mountain slopes run into the river, the average width is four hundred meters, contracted in a few places to two hundred meters. Whenever it is thus contracted it is very deep; in some places over 20 meters in the lowest water.

The depth of the river below Piranhas varies considerably at different seasons of the year; depending 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 Piranhas. There are rock obstructions in the river at several points below Piranhas, which in low water cause curved channels, where care and skill must be exercised by the pilot or Captain. The Steamer <sup>Dinimbia</sup> has been running regularly, making weekly trips between Penedo and Piranhas for <sup>several</sup> a number of years, and also steamers from Bahia and from Pernambuco. Canoes, ajajis, and large barcas are constantly navigating this part of the river; using sails when ascending, and oars when descending.

According to our observations and comparison with maps of Engineer Halsted's survey in 1852-53 and 54, the changes in the stream for about 130 Kilometers below Piranhas have been few and unimportant during the quarter of a century that has since elapsed; the regimen of that part of the stream being well established.

The changes, farther down, and especially between Penido and the mouth, are merely 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 width of the river, and consequent loss of its scouring 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 Penido. 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 339) to Jatobá (League 316) a distance by the river of one hundred <sup>and twenty eight</sup> Kilometers, and it is unnavigable. It is true that barks, 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 Afonso - one of the grandest objects in nature.

The descent of the principal falls in the distance of about one kilometer, as ascertained by the Comissão Hydraulica 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 Jatobá and # Piranhas is one hundred & thirty eight meters. This includes # also the Falls of Itapanica, 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, necessary to overcome the fall of one hundred & thirty eight meters. # Allowing three meters to a lock it would take sixty six locks.

The first cost of these works, over 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 Milreis.

The railway now under construction around the rapids and falls, is undoubtedly the proper mode of connecting the upper and lower river commercially.

A railway of course involves transshipments; but the movement over the railway, including the transshipments, if properly arranged, will be more rapid than it would be through ~~the~~ locks and Canals; and the annual cost of freighting and transshipping over 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 ~~Portage~~ railway system adopted by the Government for this second section of the Valley is the proper one.

### The Paulo Affonso Railway

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

The first section of the railway involved much heavy cutting and filling, owing to the ruggedness and steepness of the side-hills; a large portion of which excavation was through rock. The <sup>ing</sup> gradation on that section is finished, ready for track-laying.

The Engineer in Chief, Dr. Reinaldo Von Kreiger, expected that track-laying would begin in March (1880), and <sup>that</sup> the road might be finished within a year, if no unforeseen delay occurred. A large proportion of the Crops had been delivered and iron and locomotives were arriving.

The region through which this railway is located is very dry, with a sandy soil, and in many places <sup>is</sup> rocky. In two places on the route <sup>Spring</sup> water is found, and at the Crossing of the Maxoto



water can be obtained during the <sup>dry</sup> 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 <sup>been</sup> made in the rock at a number of points, to be used as catchwater reservoirs. At the time we saw <sup>excavations</sup> these, the water in them was <sup>scarce, and</sup> of a very inferior quality. As a whole, but a limited amount of <sup>local</sup> traffic can be furnished from the immediate vicinity of the railway line; but it <sup>should</sup> ~~may~~ secure some business from Jacaratá, and places along the Valley of the Maxoto. 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 <sup>hereafter</sup> 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 in the river, on the second section, excepting such local improvements of wharves or piers as may be necessary in connection <sup>with</sup> the railway terminal points at Piranhas and Jatobá, which appertain to the railway.

# Engineering features of the 3<sup>rd</sup> Section.

Between Jacobi and the head of the Sobradinho rapids, four hundred and twenty eight kilometers; Consisting of pools and impassable rapids.

The 3<sup>rd</sup> Section, while it is almost free from actual "falls", especially during its higher stages, 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 freshets 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 unnavigable; chiefly in consequence of a division of the natural flow into several island-Channels, resulting in irregular, crooked courses of insufficient depth, and in some cases injuriously narrowed by rocks.

# The total fall on the 3<sup>rd</sup> 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 Vão  
# is 85.8 meters in the distance of three hundred & thirty six  
# Kilometers, an average of 0.255 per Kilometer.

If this fall was equally distributed throughout, and the flow ~~was~~ confined 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 very unequally distributed, and at the rapids,  
# in every <sup>generally</sup> case, there are several Channels, dividing the volume, neither one of which has throughout sufficient depth to afford a navigation <sup>during</sup> the low water period, excepting for canoes and light ajouris and bacas; although portions of

each may be navigable.

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

The Circumstances of the 3<sup>d</sup>. Section present a simple 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 between the Rodellas, and Sorobabi, a distance of ~~fifteen~~ <sup>twelve</sup> ~~and one fourth~~ <sup>one fourth</sup> kilometers, when the fall is seven meters; an average of  $0.57^m$  <sup>0.57</sup> per kilometer.

A portion of these rapids two and three fourths kilometers in length, falls two and four tenths meters, or at the rate of  $0.90^m$  per kilometer.

There are some short pieces of rapids considerably steeper; but the greatest natural current in low water in any channel proposed to be improved will be only about ~~two~~ <sup>two and a half</sup> meters per second, or at the rate of nine kilometers ( $5\frac{1}{10}$  miles) per hour. For very short distances, in some of the rapids, the natural current is about twelve kilometers (nearly  $7\frac{1}{2}$  miles) per hour.

(29)

## Engineering features of the 4<sup>th</sup> Section.

The 4<sup>th</sup> Section is commonly known as the "Clear river". It extends from the head of the Sobradinho rapids to the Falls of Perapora, thirteen hundred and twenty eight kilometers.

The total fall in this distance is 209.7 meters ~~or~~, or an average of <sup>(nearly)</sup> 0.16<sup>m</sup> per kilometer. The slopes vary on different portions of the stream from nearly level to 0.38<sup>m</sup> per kilometer, the greatest.

Although designated as the "Clear river", there are rock obstructions, here and there, on its lower portion, which, in order to make a safe Steamboat navigation should be removed. 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 unknown, and the channels, for the most part, <sup>being</sup> entirely clear.

The islands, of course, divide the flow of the river, but there is always a channel on one or the other side of sufficient depth for loaded barcas, and light-draught steamboats.

The river is generally very wide, ranging from <sup>#</sup> three fourths of a kilometer to one and a half kilometers.

In a few instances where flat sand-shoals extend <sup>#</sup> entirely <sup>across</sup> wide parts of the stream, there is no deep channel; but whenever sand-bars from the sides and islands encroach greatly upon the width, where the channel may be contracted to three hundred meters, and occasionally somewhat less, it is invariably a deep, safe, and beautiful navigation.

Sand-bars, constitute a marked feature of the Clear river, for a thousand kilometers; but as a rule they materially improve the navigation by contracting the navigable channel and correspondingly deepening it.

There is a common impression that sand-bars are only an evil; and so they may be in a narrow, sluggish stream, having a small minimum flow; but in the São Francisco - on account of which is its unusual width, with its abundant supply of water, they become valuable adjuncts in maintaining the navigable channels.

Some of the sand-bars remain for long periods without material change, others <sup>they shift,</sup> more or less, after the annual floods. The islands and river banks being mostly sandy, alluvial material, easily undermined and carried away by the freshets, are eroded, sometimes on one side and sometimes on the other side, especially on the curves, 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. Whole islands and parts of islands are at times cut away and disappear, while others are enlarged, or new ones gradually formed. Large quantities of material are cut away on the concave side, and great sand-bars are sometimes washed entirely 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 flood line. In other cases the banks are low, and the floods overflow large areas between.

Along the upper portion of the fourth section,

above Jamana, where true forests come to the margin of the stream, <sup>large</sup> trees are occasionally undermined by the water and fall into the river. Some of these afterward become fastened on the sand-bars as snags. At the time of our examinations (1879) there was comparatively few that were actual obstructions. The pilots who run the river regularly, in charge of loaded barcas, 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 fourth meters. A large portion of the navigable channels have ~~the~~ depths 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, on its ancient route, in the same part of the valley; the changes in the widths, <sup>caused by</sup> from cutting and filling, by the currents and eddies, are comparatively local.

There are no artificial levees on the margins of the river; nor is there any necessity for them; the land that is annually flooded is greatly benefited and rendered <sup>more</sup> ~~very~~ fertile in consequence. In many places the banks at the river are somewhat higher than the land some distance back, in other places it is level, and in others 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 during high freshets the stream flows.

Upon a large portion of these thirteen hundred kilometers of Clear river, 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.

Engineering 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 this 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 Moraes and Ladislão de Souza Mello Netto, of the Rio São Francisco upon three # hundred and forty ~~four~~<sup>two</sup> kilometers above the junction of the 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 stages of the river.

# M. Liais estimated the cost of improving ~~xxx~~<sup>264</sup> kilometers <sup>to the Parapiaba River,</sup> at 8,700:000 \$ 000; the lower portion being designed for a navigation of 1 1/2 meters depth, the middle portion for 1 1/4 meters, and the upper portion for 0.60 meters depth.

# These ~~244~~<sup>264</sup> kilometers ended at the mouth of the Parapiaba river; above which it appeared to be impracticable without enormous cost to make the river navigable.

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

\* Excepting that Professor Derby, geologist, who accompanied the Commission <sup>up the river</sup> throughout their examinations, afterward went overland up the Valley of the Das Velhas, <sup>and on its tributaries</sup> and made a special report upon the region traversed; which will be more particularly referred to elsewhere in this report.



as required to make a navigation from the junction to the mouth of the Parapouca 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 designed 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 source, <sup>is assumed</sup> appears to be about eight hundred kilometers, ~~approximately the same as the São Francisco above the junction.~~

# The Das Velhas River, according to the <sup>and the examinations of others,</sup> survey of M. Liais, is much more susceptible to <sup>than is the São Francisco above the falls, frequently frozen</sup> improvement. It has been navigated <sup>from the junction to Sabara, a distance of 694 kilometers; but in low water it is materially obstructed at numerous points by shallows, and rocks, and is <sup>then</sup> unnavigable, <sup>in many places</sup> except for <sup>very</sup> light canoes. M. Liais estimated the cost of improving this navigation <sup>upon the plans proposed by him</sup> at 2,605,000 \$, as follows:</sup>

Barra das Velhas to Paranaíba 480:000 \$ for 1.50 depth  
Paranaíba to Segitibá 1.750:000 \$ " 1.25 " 1.25  
Segitibá to Rio de Macaé 200:000 \$ " 1.00  
Rio de Macaé to Sabara 2,605,000 \$ " 2.605,000 \$

# This amount, though very much less than the estimate of <sup>the</sup> Cort on the Upper São Francisco, appears very large compared with the present needs of that region. Possibly some improvement of the Das Velhas could be made, suited to the present and immediate future <sup>river</sup> demands, for a very much smaller sum; leaving the radical improvement <sup>of the river</sup> for a superior navigation, to some future period when the augmented population and business of that part of the interior would <sup>require</sup> need it.

Barra do Paraopeba. Sat. 19° 13' 30" - Longitude 1° 50' 50" } Wagner  
 Poço das Antas. " 19. 34. 30 " " 2. 3. 18 "  
 Pitangui " 19. 52. 20 " " 1. 44. 50 "

The Das Velhas, from its mouth to its source is considered to be about eight hundred kilometers in length. <sup>about the same as the São Francisco.</sup>

Its principal affluents take their rise between latitude 20° + 21° South.

M. Liáis gives the position of the following points, making the City of Rio de Janeiro the zero, for longitude.

Rio de Janeiro	Latitude	22° 53' 52" Lon.	0. 0. 0.
Barra Das Velhas.	"	17° 11. 54" "	1. 43. 35"
Sabara	"	19° 53' 52"	1. 13. 49"
Barbacena	"	21° 13' 9"	0. 49. 45"

Barbacena is not in the Valley of the São Francisco, M. Liáis makes its height above the sea 1137<sup>m</sup>. It is on the Southern side of the great dividing ridge <sup>Espigão Geral das Vertentes</sup> separating the waters of the São Francisco from those of the Rio Grande and Paranaíba.

The fall of the river Das Velhas, from Sabara to the Barra Das Velhas ~~is~~ according to M. Liáis, <sup>m</sup> 262.7, and the height of Sabara above the sea, 695 meters.

# The width of the São Francisco above the junction <sup>where it joins the flow</sup> ~~is~~ <sup>more than double</sup> ~~and a half times~~ greater than that of the Das Velhas the Das Velhas being <sup>about</sup> ~~200~~ <sup>171</sup> meters and the São Francisco <sup>about</sup> ~~500~~ <sup>359</sup> meters; <sup>and in low water, the flow</sup> from the two streams is, <sup>approximately</sup> as follows: according to <sup>Halper's</sup> ~~the~~ lowest measurement:

#	From the São Francisco	238.43	Cubic meters per second.
#	" " Das Velhas	97.08	" " " "
#	Total	335.51	" " " "

The quantity from the São Francisco being nearly 2½ times that from the Das Velhas.

\* In 1871, the small steamer "Saldanha Maranhã" Commanded by 1° tenente F. M. Alvaris de Araujo navigated the river as high as Sabara, 694 kilometers. <sup>descended from Sabara with three Canoas.</sup> M. Liáis, and D. A. Symphronio de Abreu descended in a large barca called "Quatinosino".

It is said that another small steamer has been run on the river between Sabara and points below in connection with some mining business. In December 1879, <sup>the Hydraulic Commissão brought the steamer</sup> ~~Presidente Dantas~~ <sup>to the mouth of the Das Velhas,</sup> ~~but she has not been up that river.~~

Barra das Velhas to Paranaíba 480:000 ft for 1.50 depth  
 Paranaíba to Jequitibã 1.750:000 ft " 1.25 " "  
 Jequitibã to Rio de Macaé 795:000 ft " 1.00 " "  
 Rio de Macaé to Sabara 200:000 ft " 0.50 " "  
 Sabara to Barra das Velhas 2,605:000 ft " 2.00 " "

Barra das Velhas to Paraiuna	480:000 <del>8000</del>	m 1.50 depths
Paraiuna to Jequitibá	1.780:000 <del>8000</del>	m 1.25 "
Jequitibá to Rio de Macahubas	195:000 <del>8000</del>	m 1.25 "
Rio de Macahubas to Sabará	200:000 <del>8000</del>	m 0.60 "
Total	2,605:000 <del>8000</del>	

General Remarks - Engineering Features, etc.

In the examination of the São Francisco river, from the sea to Pirapora, the labors of the Commission were greatly facilitated by the maps and profiles and a report made for the government by Henrique Guilleime Halpeld, Civil Engineer, of 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 Halpeld's survey have been caused by the action of the stream upon the shores, islands and sand-bars during the twenty five years between 1854 and 1879.

Comparatively little change seems to have occurred in the aspect of the country bordering the river, or in the villas and cities, or in the position and number of <sup>the numerous</sup> houses, which are in sight from the river, or in the general population on the islands and river margins.

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

The Commission also obtained valuable information from the report and maps of the survey

## General Remarks to

Subsequently made by Dr. Carlos Krauss, Civil Engineer, whose report, maps and estimates, etc., of 1868-69, was placed at our service by the government.

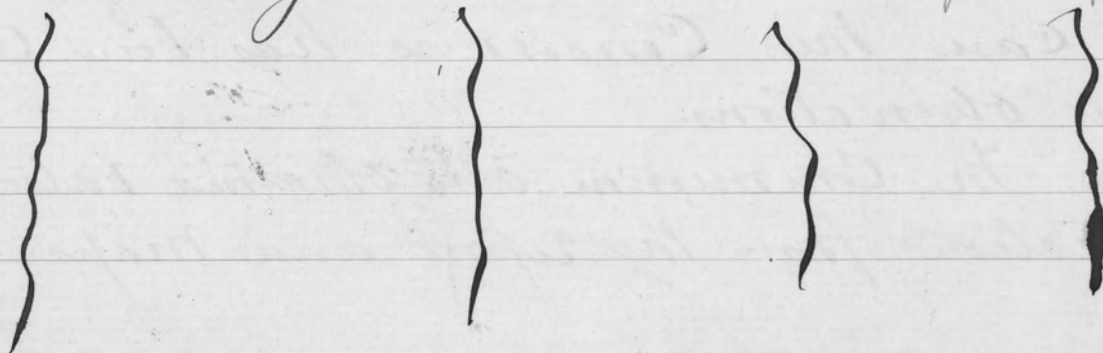
Engineer Krauss' work applied especially to what I have designated as the 2<sup>d</sup> & 3<sup>d</sup> Sections of the river valley; namely, to the route for the railway between Piranhas and Jatobá, and to the rapids portion of the river between Jatobá and the Sobradinho rapids; and, as he states, his labors were materially lessened in consequence of the previous surveys of Engineer Hatfield.

These 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 Hatfield 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 d'Assucar on the Lower river four hundred Kilometers long, at an estimated cost of \$2,000,000,000, 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 \$ 000; and he estimated the cost of constructing and equipping the railway between

see pencil page 37



Piranhas and Jaboa, ~~at~~ <sup>at</sup> \$ 3,735:000 \$ 000.

(See.) # Concerning the present estimated final Cost of the railway, I have no definite information. (It has been referred to as between four, ~~thousand~~ <sup>thousand</sup> and forty five hundred Contos de reis.)

My judgment is, that at the time <sup>that</sup> Engenheiro Krauss' estimate of the Cost of improving the river was made, in 1868, with the European experience in steam navigation of swift streams that existed at that period, and from the presumed necessity of making longer slopes in the rapids, consequently at increased Cost, <sup>approximately</sup> this estimate of the probable Cost between Jaboa and Pirapora \$ 1,800:000 \$ 000 (excluding interest) may have been <sup>considered a</sup> reasonable approximation. He estimated the <sup>probable</sup> Cost between Boa Vista and Jaboa - 47 leagues, at \$ 1,435:000 \$ 000.

My estimate of the probable Cost of improving the river so as to make a practicable Steamboat navigation, is based upon the following Promises:

That the least depth in any rapids, at the extreme low water stage, shall be not less than <sup>and one fourth</sup> ~~one~~ meter, or so as to pass safely <sup>at all seasons</sup> boats drawing One meter; and that the Current, in the improved rapids, in the low water stage, shall <sup>generally</sup> not exceed <sup>the rate of</sup> Nine Kilometers per hour. This navigation to be rendered conveniently available, by using light-draught, stern-wheel Steamboats, with power sufficient to stem a Current of <sup>double</sup> that Velocity, with two barges, <sup>carrying</sup> ~~of~~ One hundred tons each in tow. Under this system, but little change is needed at a number of the rapids, and the <sup>proposed</sup> ~~estimated~~ improved slopes being <sup>comparatively</sup> short, the Cost <sup>will</sup> be reduced accordingly. Under these conditions I estimate that for the sum of \$ 750:000 \$ 000, such a navigation can be secured between Jaboa and Pirapora, including the Cost of one steamer <sup>delivered on the upper river</sup> ~~to be used~~ to the navigation, and <sup>the</sup> Cost of one small exploring steamer.

(1)

Appropriate to the  
Considerations bearing upon ~~the~~ Recommendations ~~proper to the~~  
to be made <sup>proposed</sup> for the improvement of the São Francisco River.

The work proper to be done at the <sup>Cachoeiras</sup> rapids should be determined <sup>chiefly</sup> by the manner in which it is intended to navigate the improved Channels; and that, in part, is more or less controlled by the nature <sup>and extent</sup> of the present river business; but having reference also to its probable future ~~extension~~. Although, as mentioned elsewhere, there has been two steamers on the Upper River for some years, the river-trading has not been <sup>in the least</sup> changed in consequence of the few trips that were made some years <sup>since</sup> by those steamers; as before, it is still carried on by barcas, ajoujis and Canoes; using poles when ascending, and <sup>or floating</sup> oars when descending. Under skilful management of pilots, these <sup>vessels</sup> ascend and descend through numerous Channels and parts of Channels where steamers could not now run; and there are other Channels where proper steamboats could <sup>navigate,</sup> ~~not run~~ through which barcas, ajoujis and Canoes cannot ascend by poling, on account of the <sup>great</sup> depth, and the strength of the currents; although, at times, with strong up-stream winds it <sup>would be</sup> practicable <sup>for them</sup> to sail up some of these deep Channels, as was formerly <sup>with our ajoujis;</sup> ~~done~~, as already noted, sails for navigating up or down are <sup>in use</sup> not used on the Upper river; not 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 mainly upon sails; crews of barca-men <sup>accustomed to</sup> ~~use~~ pole and row, would still be necessary; so that sails would often be an incumbrance rather than an aid.

With improved Channels through the rapids, enabling Steamboats to tow Bercas and Barges up and down, it is expected that the system of much of the river business will be changed, so that <sup>only a</sup> few hands would be needed <sup>in a barge</sup>; although Considerable local <sup>river</sup> trading <sup>will probably</sup> continue to be done as at present with Bercas, Ajunjos and Canoes.

Many of the larger Bercas might at first be towed by the Steamboats, but in time larger Barges <sup>would</sup> supersede them.

The Channels to be selected and improved should be <sup>made for</sup> Steamboats with <sup>at least two</sup> Barges in tow, <sup>and the</sup> <sup>minimum</sup> <sup>width</sup> of Channel in the <sup>most</sup> Confined places should not be less than ~~thirty~~ <sup>forty</sup> meters, and generally not less than ~~thirty~~ <sup>forty</sup> meters, in the narrow places. Our examinations show that <sup>upon</sup> ~~the~~ <sup>for</sup> the larger portion of the <sup>formed</sup> routes through the Cachoeiras they will be much more than ~~thirty~~ <sup>forty</sup> meters wide.

Steamboats could now <sup>safely</sup> ~~run~~ through a number of the Cachoeiras ~~without~~, with Barges in tow, with scarcely any alteration of the present Channels. In others <sup>however</sup> there 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 <sup>necessary</sup> ~~desirable~~; which it is not.

Instead of dredging, the system required by the circumstances is, increasing the depth of water, by confining <sup>it, and</sup> ~~by means of low dams,~~ 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 São 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 investigations, occupying part of another season, to prepare complete detail plans of the particular works needed at each Cachoeira where improvement may be necessary; but the observations and notes made in 1879-80, aided by the former experience of the senior members of the Commission will suffice for an approximate estimate of the probable cost of making a proper steamboat navigation. The final cost, at particular Cachoeiras may prove to be somewhat more or less than the present estimates; but the intention is to present an estimate which as a whole will not be likely to vary materially from the sum that the works should cost.

(Preceded by explanatory observations,)  
 The description annexed, shows the leading points relating to the different Cachoeiras. They are all to day substantially as they were when examined by Engineer Trauss in 1868, and as they were in 1852-53 and 54, when surveyed by Engineer Halfeld. Nothing has been done to improve them; and the effect of the currents and frosts, during the quarter of a century that has passed, upon the rocky shores and river beds is impucessible.

For convenience, the description <sup>of the Cachoeiras</sup> has been arranged to begin at "Sobradinho", the uppermost Cachoeira, giving them in their descending order.

(4)

## Works required.

Very little engineering, <sup>proper</sup> is necessary in connection with <sup>further</sup> the examination of the Cachoeiras, <sup>which are</sup> to be improved into a steamboat navigation. River work experience is the Chief thing needed; aided by good judgment.

The ample supply of water in the <sup>general</sup> river during the drier season, being established; and the Cachoeiras being known to have sloping Channels, (more or less irregular,) with rocky sides and bottoms; and the velocity of the currents not being greater than a good, light-draught Steamer can readily overcome; all that is left to be determined is 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 river experience will be useful in selecting the Channel to be improved; and <sup>also</sup> 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, <sup>or masonry,</sup> will be necessary, in any case.

The bottoms of the Channels in the Cachoeiras being solid rock, 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 on the Cachoeiras will be, first, the closing of lateral outlets, to prevent the waste of water from the particular Channel selected for improvement. This will be accomplished by

filling the space or outlet through which the water wastes, either with a rough bank of stone, or a low crib of undressed timber filled with rough stone.

Second; Putting jetties, of moderate extent, at the heads 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 jetties 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 Rodellas to the do Vao, artificial Chutes may be introduced, for Concentrating the water and guiding the Current in a safe manner through the local Cachoeiras. This work at the Chutes will be merely longitudinal ranges of rough stone banks, or Cribs filled with rough stone. In some Cases, there will be low, lateral banks of rough stone, or cribs filled with rough stone, extending from the sides of the Chute to the shores; the object of these being to swell, or raise the water, <sup>so as</sup> 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 lowest stage of the river  $1\frac{1}{4}$  meters, and the minimum width of the Channel about 30 meters; although the greater portion of all the Channels will be 50 meters or more in width; so that the minimum width of 30 meters will occur at comparatively few places; and the depth generally will be more than  $1\frac{1}{2}$  meters.

The cribs mentioned, are to be sunk so that the top of the timbers will, after <sup>the</sup> completion, <sup>of the cribs,</sup> be covered with water, and therefore not subject to decay. All junks may pass freely over them, as <sup>the</sup> raising of water, at such times, is unnecessary. With a general increase of the river flow, from floods, the depth in the improved Channels will of course be increased.

Observations descriptive of the third Seção, or Cachoeiras portion of the river between the Cachoeira do Sobradinho and Jatoba - 428 Kilometers.

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

The numbering of the Leagues, as originally arranged by Engineer Halford, and afterward adopted by Engineer Krauss, is retained; and for convenience this Seção will be described in the same descending order; (although for the general description of the entire river and Valley it was deemed advantageous to refer to them from the ascending examinations).

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

The aggregate fall in these 428 kilometers is 96.<sup>m</sup> 30, or an average of 0.<sup>m</sup> 23 per Kilometer, very nearly. This fall is very unequally distributed, being in a few instances as high as 0.<sup>m</sup> 80 for short distances, and not more than 0.<sup>m</sup> 10 on some of the intermediate pools.

No of  
League  
from  
Peraíba

Kilometers  
above  
Databa

238.70  
to  
239.70

7  
Cachoeira do Sobradinho.

This is the uppermost of the Cachoeiras on the 3<sup>d</sup> Seccão. It is in the Province of Bahia; the upper end being ten Kilometers above the Division 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.<sup>m</sup> 64, in low water, or an average of 0.<sup>m</sup> 48 per Kilometer; but it is irregularly divided, by several minor Cachoeiras.

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

Our examinations were made on both sides of the island. They showed that on the Bahia side, from the foot of the Cachoeira up for 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 da Volta, which render that side impassable in low water for loaded Barcas or Canoes; although we did succeed in working a light Ajunjo circuitously through the entire Cachoeira, aided by sails, poles, oars and Cordelling. It would have exceedingly difficult if not impracticable without the help of sails.

The Construction of a safe Steamboat navigation on that side of the river would be very expensive.

It is not however necessary to enter into Calculations of Cost on that side, as the examinations show that the smaller arm of the stream 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 Circumstance that it is the only one between Joazeiro and the "Clear river"; hence all the trade and travel between Joazeiro and the numerous places along the Clear river, for over fourteen hundred Kilometers has been and is yet subjected yearly, during the low water season, to serious impediment; although this Cachoeira can be passed at all times by lightening the barks, and Cordelling.

As a large share of the entire business of the Upper São Francisco has been and still is above Joazeiro, 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. Its chief need is a larger volume of water in the navigated Channel. This can be obtained by building a Jetty, of rough stone, or a crib of undressed timber and rough stone, not over two hundred meters long running out obliquely from near the head of the island into the main river, having its top about level with ordinary low water. This will intercept and divert into this Channel a considerable additional quantity of water. In the Channel, below, several rocks are to be removed, and

it may be necessary to build a few small guiding  
cribs of undressed timber filled with rough stone to  
prevent the water from spreading and to straighten  
the direction of the current.

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

As there is a small island, called "Ilhoa da  
Cachoeira", in this Channel not far below the head  
of the Cachoeira, it may be found advisable to  
close 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 least depth of  $1\frac{1}{2}$  meters in extreme  
low water. Most of the way the Channel will  
be <sup>when improved as proposed</sup> two or more meters deep, as the soundings show.

From the fort of the "Cachoeira do Sobra-  
dinho" - League 240, to the head of the Cachoeira  
das Conchas - League <sup>246.50</sup> ~~246~~ <sup>sixty nine</sup> Kilometers,  
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  
river pilot can navigate there <sup>sixty nine</sup> kilometers  
now, in any stage of the water.

The important "Villa do <sup>Cidade</sup> ~~Paizis~~", is at  
League 246.50, on the Bahia side, and the Villa  
do Petrolina is opposite, on the Pernambuco side.

252.50

Cachoeira das Conchas.

The slope of the river here is 0.36 per Kilometer.  
In 5½ Kilometers the river falls two meters. The Current averages about six Kilometers per hour.

There is a deep, wide steamboat Channel.

There rocks should be removed to make the Channel safe, for a little higher stage of water; but no large expenditure is necessary.

259 to 259.20

Cachoeira Pedras e Cach. da Missão.

This is near the foot of the Ilha da Pontal, on the Pernambuco side of the Island, where there is a fine wide Channel, and <sup>already</sup> a good steamboat navigation. It may, on ~~the~~ careful examination, be found advisable to remove a few rocks; but with a good pilot, a steamboat can be safely run with the river ~~run~~ in its natural state.

The declivity of the river here is only 0.16 per Kilometer

260.20 to 260.60

Comeco da Cachoeira do Genipapo. Falls 12 in 0.35

The slope of the river is here 0.17 per Kilometer. The Current in 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 Genipapo.

262.80

Cachoeira Genipapo. Clear river on Bahia side.

We had to "Cordel" our Ajoujes through this Cach-  
<sup>on the Pernambuco side,</sup> oera, because we could not work up the deep <sup>in the Bahia side,</sup> Channel.  
But there is a good steamboat Channel on the Bahia side of the river. The declivity here is 0.40 per Kilometer.  
The rocks are not in the way of steam navigation.



League

page (H)

(5)

265.85

Cachoeira Caraiabas. This is only a wide, deep Channel through a rocky ledge which lies across the river. The slope of this part of the river is slight, and the current in low water is not over <sup>three kilometers</sup> ~~two miles~~ an hour. It is an excellent steamboat Channel, on the Bahia side. It is opposite the Ilha das Caraiabas.

269.50

to 269.90

Cachoeiras do Atoque - da Fusil and da Velha <sup>Vieira</sup>

These <sup>three</sup> Cachoeiras <sup>are</sup> between the Ilha da Mirrao and the Pernambuco side, <sup>of the river,</sup> just above the small island da Fusil. The declivity here is about 0.70 per kilometer.

This Cachoeira <sup>do Atoque</sup> runs into another, the Cachoeira <sup>da</sup> Fusil, and that into another, the Cachoeira <sup>da</sup> Velha Vieira; the foot of which is at about League 269.9.

These three Cachoeiras may be considered together, extending through ~~down~~ 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 precise kind <sup>and extent</sup> of work should not be <sup>finally</sup> 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 <sup>low or better</sup> dam at the head of Pequena Island. Then, by removing a few rocks, and building two, or possibly three, low guide-cribs, 1 1/2 to 2 meters of depth can be maintained in the lowest stage of the river.

The present low water currents, for those distances, are from eight to ten kilometers per hour. In <sup>the moderate</sup> ~~a good~~ stage of water steamboats <sup>could</sup> ~~can~~ now ascend and descend without difficulty.

#

20:000 \$ 000  
20:000 \$ 000

272.25

Cachoeira da Pandella do Dornado.

This is a troublesome place for loaded Canoes or Barcas to ascend, because they cannot pass 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, <sup>however</sup> no where less than twenty five meters wide, and the current is from seven to eight kilometers per hour, while the general Current is direct enough for steam navigation with a good pilot and ordinary soundings. Very little if any work will be needed here.

275.30

Cachoeira da Villa.

This is between the Bahia shore and the Ilha Grande. It continues for about two kilometers, among a number of small islands between the Ilha Grande and <sup>Ilha</sup> da <sup>Villa</sup> 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 river is <sup>only</sup> about 0.16 per kilometer. A careful examination should be made from League 274 to League 276.50, <sup>including this Cachoeira,</sup> in order to determine which side of the Ilha da Villa de Santa Maria will be the <sup>best</sup> ~~best~~ to improve. Work will be needed in either case.

If the Bahia side be adopted, then the Cachoeiras Cantagallo and Dos Bois, which are on the Pernambuco side, will be avoided.

276.50

League.

275.50 to 281.5  
276.50 to 277

Six leagues from the Cachoeira da Villa to the port above <sup>the villa do Pambú.</sup>  
There are Cachoeiras among the islands, on the Bahia side, on the Pernambuco side, and in the intermediate Channels.

On the Bahia side, there are, the Cachoeiras do Per-  
cassi, da Ilha Redonda, and da Cruz; on the Pernambuco side, there are, the Cachoeiras S. Felis, (Orco), <sup>on near</sup> Victorina, da Imburana, & do Destaco Calção; intermediate, there are, two Cachoeiras, between the Ilha das Almas, and Ilha de S. Felis.

1257  
1214

On our upstream examination we passed ~~the~~ in the Pernambuco side or left bank of the river, and then through the arm of the stream between the Ilha da Aracapa and Ilha da Japira, that being the regular Channel run by the pilots. There being numbers of islands and several Channels 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 league 281.50, we found a Channel on the Bahia side needing comparatively little work to make it good for Steamboats; and above <sup>league</sup> 277 up to 275 <sup>we found it also</sup> it is practicable to arrange a Steamboat Channel without great Cost on the Bahia side.

The regular, pilots' Channel, between the islands, can also be made into a Steamboat Channel.

~~It~~ It is ascertained that a good Steamboat Channel can be made between league 275 <sup>1/2</sup> and 281.5, six leagues, for a much smaller sum than former estimates; ~~(not including the cost of the)~~ but it will be necessary to make a more careful examination of all these Channels, during low water, before finally selecting the particular route to be adopted for improvement. Villa do Pambú <sup>end of</sup> 282 L

Maple's Canal Para Vista to Pás d'Assunção 400 Kilometers to 32, 472: 700,000

#

275.50 to 281.50

Continuation of  
 The Cachoeira, do Fernando (League 279.85), do Maria, (League 280.10) do Cayaby (League 280.50) Cax-a no name (League 280.70) Cachuara Fa, (League 281) da Pedra Moleque (League 281.30) and do Force, are all included in the foregoing.

In these six leagues, or 33 kilometers, the fall is 10 meters, or at an average rate of 0.30 <sup>m</sup> per kilometer; and the current in the swiftest places does not exceed nine kilometers per hour.

282.35

Cachoeira do Pambuzinho.

This is opposite the upper end of the Ilha de Pambuzinho in the main river on the Bahia side of the island. The declivity of the stream is 0.37 <sup>m</sup> per kilometer.

There is a strong current through this Channel, <sup>in places</sup> about nine kilometers per hour. At a two-meter stage of the river it is a fine steamboat Channel. In low water it is rather troublesome for ascending barcas and Canoes.

Some work may be needed to make a safe steamboat Channel in the lowest stage of the river, by the removal of a few rocks.

283.10

Cachoeira da Favella.

This Cachoeira runs from the Ilha da Favella obliquely toward the foot of three small islands.

It is a difficult Channel for ascending barcas and Canoes in low water. There are currents of nine kilometers per hour. The declivity of the stream is 0.37 <sup>m</sup> per kilometer. On a careful examination it may be deemed advisable to remove a few rocks to make a safer steamboat Channel in low water. At a two-meter stage the Channel is very good, for steamboats.

283.20

A small Cachoeira without name. Near Ilha da Onça. This is about three fourths of a kilometer above the foot of the large Ilha d' Assumpção. It is scarcely observable in a two-meter stage of the river; and there is a good steamboat Channel outside of it

~~From league 283.30 to league 286.30, a distance of sixteen and a half kilometers, there is a clear river~~

From league 283.30 to league 286.30, a distance of sixteen and a half kilometers there is a clear river, with very deep water, 20 to 26 meters deep for two kilometers, on league 286.

Leagues.

286.30 to 287.20 Five and a half kilometers. This includes a series of six Cachoeiras, called respectively, Moco, Latoque, do Capauhy, Quebra Canoa, Craua, and Brandão.

The total fall in these 5.5 kilometers is two meters, or an average of 0.<sup>m</sup>40 per kilometer.

The upper end of these Cachoeiras is near the foot of the Ilha da Boa Vista, and the lower end is near the ~~Villa da Boa Vista~~. Opposite the foot of I. do Capuira.

There is a Channel through these Cachoeiras deep enough and wide enough to pass steamboats, and the current does not exceed nine kilometers per hour, but in places it is much stronger. It is however necessary to make further careful examinations in order to select certain rocks for removal, and to mark a few <sup>others</sup> which need not be removed, to make the channel safe for higher stages of the river.

The barcas and ajinjos cannot ascend this deep, swift channel, they are compelled to wind their way through side channels, where steamboats could not go, excepting low water.

~~Estimated cost of making this series of Cachoeiras into a safe steamboat channel \$~~

288.5 to 289.5 Five and a half kilometers. Two Cachoeiras, da Quixaba and das Flores. They have <sup>together</sup> a fall of 2 meters, or an average of 0.<sup>m</sup>36 per kilometer.

These Cachoeiras are on the Pernambuco side of the river, between the Ilha Grande and the left bank. The steamboat channel is on the right side of the Ilha Grande; so that these Cachoeiras do not constitute an obstruction to steam navigation, although they interfere with the movement of barcas and ajinjos. But it may be found advisable to remove a few rocks to make the channel safer.

See books again.

291.25 to 291.35 The Cachoeiras da Minao and do Imbrucis, embracing about 1.10 kilometers.

# The declivity on this part of the river is 0.80 per kilometer.

The Channels through here are wide and deep, and the Current is greatly checked by the rough rocky sides and bottom, and it does not exceed <sup>more</sup> ~~eight~~ kilometers per hour.

There is a small rocky islet, that is bare in low water, which should be removed; for although steamboats could pass on either side, ~~it~~ it will be dangerous; especially when there is only about one meter depth of water over it.

A fine straight Channel leads in to the head of the Cachoeira do Minao, the uppermost of these two.

291.40.

Cachoeira do Rosario. This is on the Bahia side of the river, opposite the large island (Ilha Grande) and nearly opposite the head of Ilha do Serroteiro.

The banca and canoe navigation is here somewhat complicated and difficult <sup>on account of rocks,</sup> and in had to pass with an ajunja around the swiftest parts of the Cachoeira; but <sup>it is a</sup> "rapids", not a "fall", and there is deep water; ~~and~~ The water is so broken <sup>and the current so much checked</sup> by the irregular rough bottom and sides that a proper steamer <sup>readily</sup> can navigate the natural Channel. The declivity <sup>on a stretch of a league along</sup> of this portion of the river is <sup>only</sup> about 0.20 per kilometer. No work of consequence can be required here.

292.50

Cachoeira da Cantagallo.

This part of the river is very rocky. The average declivity along here is about 0.70 per kilometer, ~~but~~ <sup>but</sup> the Current is somewhat checked by the rocks in the bottom and sides. A steamboat could <sup>now</sup> be worked through a Channel among the rocks; but to render it safe, some rocks should be removed. The particular rocks to be removed

League.

can ~~may~~ properly be designated <sup>only</sup> after a more careful examination of the Channel. The currents <sup>are</sup> ~~run~~ about eight to nine kilometers per hour in low water.

292.65

Caxauhy Cachoeira de Cima.

The river in this vicinity is dotted with rocks and rocky islets.

The Channel <sup>also</sup> abounds with rocks, some of which were partially submerged. A few of these should be removed, and others marked in order to secure a Channel that will be safe <sup>for steamboats</sup> at different stages of ~~the~~ the river. The average declivity is about 0.80 per kilometer.

292.90

Caxauhy de Baixo. The banca and canoe channels in low water are <sup>here</sup> somewhat intricate and troublesome; but there is a very deep steamboat Channel <sup>toward mid-river</sup> ~~to the~~ apparently needing <sup>little, if any</sup> ~~no~~ work.

This is only a short distance above the head of the Ilha da Canabrava. The main channel is between that island and the Bahia side or right bank of the river. The river has a strong current <sup>about 9 kilometers per hour</sup> along here, the average declivity being about 0.80 per kilometer, to the foot of these rapids. The flow then becomes more gentle to the next rapids below, the Cachoeira do Sacco.

293.80

Cachoeira do Sacco.

This Cachoeira does not interfere with the steamboat Channel. The Channel is deep <sup>it is</sup> in the Pernambuco side of the island of Jurumella. There are many rocks in this part of the river; but there is a Channel <sup>formed by them</sup>. The average declivity 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.



294.50

Cachoeira da Panella do Damado.

The canal channel runs nearly to the Pernambuco side, and has hard turns in it, but there is a good Steamboat Channel through this Cachoeira, apparently needing <sup>little or</sup> no work, as it is <sup>direct,</sup> wide, and deep; There is a swift current; but not exceeding nine kilometers an hour. The average declivity is about 0.<sup>m</sup>60 per kilometer for a short distance. The general declivity along here is about 0.<sup>m</sup>50 per kilometer.

295.80

Cachoeira do Boi Velho.

There is swift water through this Cachoeira; but with a good channel for steamboats. The current would be more rapid (in low water) than it is, but for the irregularity of the rocky bottom and sides, <sup>creating</sup> ~~which creates~~ powerful reacting currents, and "boils", which check the natural flow due to the declivity. The declivity along this part of the river in low water is about 0.<sup>m</sup>50 per kilometer; a little steeper in the swiftest part for a short distance. Perhaps a few rocks may be removed to make the channel safer.

296.60

Cachoeira do Cortume.

This is very similar to the Cachoeira do Boi Velho. The current is about the same, and there is a sufficient channel for steamboats. The declivity being about 0.<sup>m</sup>50 per kilometer, and the actual current rate in low water about <sup>eight to</sup> nine kilometers per hour.

A careful examination of these Cachoeiras, for ~~ten~~ <sup>ten</sup> kilometers above the Rodellas, <sup>will probably</sup> ~~show~~ show 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.

296.85	Cachoeira de Rodellas	}
297.15	" de Fura Olhos	
297.35	" do Cavallito	
297.45	" do Porto Velho	
297.65	" do Tacuraba	
298.00	" do Espinho	
298.50	" da Onzeira	
298.85	" do Vão.	

The foregoing eight Cachoeiras, covering a length of eleven kilometers, and a total fall of ~~seven~~ <sup>seven</sup> meters, belong to one series, and should be considered 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 ~~water~~ <sup>water</sup> rises.

This is by far the most important series of Cachoeiras, and the most difficult to improve between Sobradinho and Jarobá.

Both sides of the river were examined, partly in ajinjos and Canoes, and partly (on the Bahia side) on land, but we found only one, the Pernambuco 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 1.35 m on the Bahia side, and a number of wide, broken shallow Cachoeiras prohibit navigation <sup>in low and ordinary stages of the water,</sup> and the cost of making a steamboat channel on that side would be very great; <sup>but</sup> ~~and~~ it is not necessary to encounter <sup>such cost,</sup> since the channels toward the Pernambuco side can be improved at much less cost. By our leveling, the fall is 5 meters in 2 1/2 kilometers, or at the rate of 2 <sup>meters per kilometer on the lower end of the Bahia side.</sup> meters per kilometer, in floods, steamboats might pass safely

on the Bahia side; but this could only be for a short time each season.

On the upper portion of the series, there is a choice of Channels, <sup>as well as of</sup> ~~the~~ methods of Improvement; but in the lower portion there is no choice, ~~and~~ the improvement must be made along the Pernambuco side, Opposite the Ilha do Sirobabe.

At present the best natural Channel for ascending <sup>and arriving</sup> ~~bars~~ starts Opposite Rodellas about midway of the wide river above the Cachoeiras, and meanders down the middle, making several Considerable <sup>to the right and to the left,</sup> bends, and then inclines toward the Pernambuco Channel, and continues in that Channel, passing between islands and the Pernambuco shore, through the Cachoeiras Tacuraba, Esposito, Crueira and do Vão.

But there is another route which can be improved so as to offer a safe Steamboat navigation, and which will probably be better throughout the varying stages of the river along its upper <sup>end.</sup> ~~XXXXXX~~ <sup>channel at the</sup> ~~XXXXXX~~ <sup>XXXXXX</sup> lower end of the series will be the same in both.

This is by <sup>beginning</sup> ~~XXXXXX~~ at the head of the Ilha da Cuite, in the arm of the river between that island and the Pernambuco shore, and improving that Channel. In that case, it will be necessary to build a Jetty, of rough Crib and Stone, projecting out from near the upper point of said island about two hundred meters into the main river, for the purpose of throwing 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 river Channel above the island into this arm.

By the adoption of this route the Cachoeiras Fura  
Olho and De Rodellas will be avoided. In  
 their stead there will be the Cachoeiras dos Cav-  
allos, and do Porto Velho, which are on this arm  
 of the river; ~~and~~ these are smaller and, <sup>can be</sup> more  
 easily managed than the other two in the  
 main stream. There are two other small Cachoeiras  
 in this arm; but with the increased supply of water  
 they can be made navigable by means of small low  
 dams and guide-crisbs 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 declivity, per kilometre, will be somewhat  
 less.

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

At the foot of the Ilha dos Cabocos there is a very  
 large accession of water from the wide Channel  
 between that island and the Ilha da Sacariba;  
 sufficient if it all remained in the Pernambuco  
 Channel, <sup>to</sup> maintain an adequate navigation on the  
 way through; but at the foot of the Ilha da Sac-  
ariba, between that island and the Ilha de  
São Miguel, a large <sup>of water</sup> body flows outward, and  
 passes obliquely on to the Bahia Channel.  
 Other portions flow outward between the Ilhas  
São Miguel and Crueira, and <sup>also</sup> between the  
Ilhas Crueira and Serrote.

By obstructing the outward <sup>above referred to,</sup> flow, by means  
 of rough crib-dams, or rip-rap mounds,  
 built up to the level of low water, an ample  
 supply of water can be kept in the Pernam-  
buco Channel.

There will then be needed at the Cachoeiras do Espírito, <sup>da</sup> Cineira and do Vão, a moderate amount of work, in the shape of low crib dams and guide cribs to make straight Central Channels through these obstructions, when there will be a complete and safe Steamboat Channel in the very lower stage of the river throughout twelve Kilometers, on the Pernambuco side, making a good navigation at all seasons.

Before <sup>determining</sup> finally the route of the Channel to be improved, on the upper part of this series of Cachoeiras, a careful examination, in low water, should be made of the <sup>general</sup> route now taken by the Barcas, with a view to compare the cost and advantage of that route, <sup>when improved</sup> with the cost and advantage via the Pernambuco Channel. Below the foot of the Uha dos Cabacos the same Channel and the same works would be required as in the Case <sup>above</sup> described.

My approximate estimate of the probable cost of making a good, safe Steamboat Channel, with a least depth in the shallowest place, in extreme low water, <sup>of</sup> 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 seasons: one of examinations and preparation of materials, the other <sup>in</sup> constructing the works.

League

309.70

24

18

### Cachoeira da Itacutiara.

Through this Cachoeira there is already a good steamboat Channel of ample width and depth. Only in one place toward the upper end is it narrowed to 20 meters.

It may be advisable to remark or mark distinctly three rocks to ensure safety at all stages of the water. No work need be done however till proper steamboats shall be put upon this part of the river.

313.70

to 314.70

### Cachoeira da Vargem Redonda.

This Cachoeira has a sufficiently wide and deep Channel, with a current in the swift part of nine kilometers per hour. A proper steamboat can navigate both ways through this Channel without any difficulty. The boiling <sup>or reaction</sup> of the water toward the lower part of the Cachoeira, caused by the great friction of the stream against the <sup>rocks</sup> 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.

From the foot of this Cachoeira to Jacobá 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 overflowed. Hence the land is well 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 on the lower river, the Mountains extend at intervals to the water's edge.

Chains of rocks crop the river below Piranhas, the Channels running among them, some being considerably curved; but all this part of the river is regularly navigated by Steamboats and other vessels, and Barcas and Canoes.

The natural slope of <sup>for ten Kilometers below Piranhas</sup> this part of the stream is ~~about one~~ <sup>fourth</sup> ~~and~~ of a meter per kilometer, and the <sup>stronger</sup> currents vary from five to seven kilometers per hour. Barcas and Canoes sail up against the currents without difficulty.

This rocky character of the river bottom continues with only occasional exceptional intervals through the Canon in which the river runs, including the Falls of Paulo Affonso, and of Aparica, to the head of the Vargem Redonda rapids, 374 Kilometers from the sea, and about ten kilometers above Jacobi.

The general surface of the plateaus rises faster than the ascent of the river, attaining nearly the height of the Upper Valley not far from Piranhas, where, in consequence, the railway is located with an ascending grade of 3 per cent, to a point about three kilometers from Piranhas, and ~~metres above the sea.~~

The Falls of Paulo Affonso, though not in one perpendicular fall like that at Niagara,

present a very abrupt descent through several grand falls, the descent in the distance of one kilometer being 80 meters. The total fall in seventy seven kilometers is

160 meters. The main fall is three hundred and eight <sup>Kilometers</sup> ~~meters~~ <sub>from the sea.</sub>

The river above the great falls is obstructed by islands and rocks to the foot of the Falls of Itaparica, where <sup>there</sup> is another abrupt descent, rendering all that portion of the stream unnavigable.

This series of falls and rapids descends seven hundred meters in the distance of five and a half kilometers.

The Falls of Itaparica are 354 kilometers from the sea, and twenty kilometers below Jatoba.

The river here presents a curious aspect during low water, being everywhere covered with irregular, blackened polished rocks of the most fantastic <sup>shapes.</sup>

216<sup>m</sup> # The river at Jatoba is two hundred and <sup>thirteen</sup> ~~and~~ <sup>back</sup> meters above

sea level, and the country slopes gradually <sup>up</sup> from the margin - the land being sandy, stony and in some places rocky, covered with a thin growth of small trees and cactus.

Above Jatoba, along the stream, pools alternate with rapids, and the river margins rise at the same rate, with the increasing elevation of the river, the banks being <sup>more</sup> thirty, <sup>twelve</sup> forty and in some cases <sup>fifty</sup> ~~fifty~~ <sup>meters</sup> feet above 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 their gentle slopes are very generally cultivated.

In some cases the land back from the river banks for some distance lies below the ordinary <sup>freshet</sup> height and



being subject to annual overflow is <sup>and fertile,</sup> Cultivable, and is for the most part cultivated. Back of that, the Country rises, <sup>in some places</sup> ~~gradually~~ <sup>very</sup> gradually, in others abruptly, connecting with Mountain ranges.

The Mountain ranges visible from the river, <sup>and its</sup> ~~and its~~ 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, <sup>or undulatory,</sup> broken, and others present marked, isolated peaks visible at great distances.

Some of them are granitic, others are composed of sandstone, others of Macolomite, etc.

Many of these Mountains are shown <sup>in part</sup> ~~on~~ <sup>on</sup> the maps which accompany this report; but a complete presentation of the numerous Mountain Systems observed from the river, <sup>would</sup> ~~would~~ require a vast amount of time and labor devoted to that special purpose.

In many instances the scenery of the Mountains, <sup>and</sup> the valley, <sup>with</sup> ~~with~~ the foreground of the river, are wonderfully beautiful. Picturesque views of the most pleasing nature occur at almost every great bend of the stream. <sup>along</sup> ~~at~~ some portions of the stream, <sup>where the land is low,</sup> the Mountains stand so far away that they are not visible from the river. Few large, comparatively flat areas occur; small portions of which, <sup>are at times</sup> ~~are at times~~ cultivated. In some cases, during high freshets, the water extends over a width of ten Kilometers, or more; and the river <sup>is divided</sup> ~~is divided~~ for many leagues into several high-water Channels. The maps exhibit such Characteristics better than verbal descriptions.

With the exception of that portion of the Valley in which <sup>are</sup> the Paulo Affonso Falls, it is upon a comparatively gentle plane. Even including the Falls,

The average declivity of the plane <sup>of the valley</sup> is only 0.25 per <sup>m</sup> Kilometer, from the Pirapora Falls 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 eleven hundred meters above sea-level.

The tree-groves on the respective Mountains, in different parts of the Valley, appear to depend in part upon Climatal Causes, and in part upon their geological formation.

It will be observed that so long as the river and Valley below the "junction" <sup>of the São Velhas</sup> maintain a general northerly Course, nearly parallel with the Atlantic Coast, its declivity is less; and it is <sup>also</sup> comparatively free from troublesome rapids; but that as soon as it bends suddenly eastward, it presents <sup>much</sup> a greater declivity, and abounds with rapids and falls thence to tide-water.

Had the topography permitted this stream to flow northerly and debouch into the Basin of the Amazon, the increased length, in that direction, might have resulted in a continuously navigable river. From the São Francisco, all the way down the Coast to the Barra do Rio <sup>vassa</sup> Barris the streams, which discharge into the Atlantic, <sup>generally</sup> present rather short, abrupt Courses between the elevated <sup>general</sup> plateau and tide water. The drainage <sup>more than half the</sup> of ~~the~~ area of Bahia Province, instead of flowing directly to the sea, is carried by tributaries into the São Francisco, following its circuitous Course to the Ocean, passing <sup>between the</sup> through <sup>the</sup> provinces of Alagoas and Sergipe.\*

~~In a more limited extent it is the same with the case the western portion of the Province of Bahia is bounded by the <sup>of the western part of Pernambuco Province</sup> Serra de Tabatinga, the Serra de Imitiba, and the Serra de Barbacena, and all the drainage on the eastern side of these backbone dividing grounds flows by tributaries to the São Francisco~~

\* Nearly half of the Province of Bahia drains into the São Francisco. There are <sup>in</sup> back bone dividing grounds <sup>in</sup> the Province of Bahia, which are parallel with the general Course of the Coast line, which is bounded by the Serra de Imitiba, the Serra de Barbacena, and the Serra de Tabatinga. The drainage of the Province of Bahia is carried by tributaries into the São Francisco, following its circuitous Course to the Ocean, passing between the provinces of Alagoas and Sergipe.\*

There are backbone dividing grounds ranging near the middle of the Province more or less irregularly 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 nearly north and South). The Serra Chapada Diamantina in the Northern and the Serra Das Almas 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 ~~dos~~ <sup>de</sup> ~~São~~ <sup>de</sup> ~~Amãos~~ <sup>Guyguera</sup>, and the Serra da ~~Barba~~ <sup>Piaupy</sup> ~~de~~ <sup>Cera</sup>, and all the drainage on the Eastern side of these backbone dividing grounds flows through tributaries of the São Francisco.

Kilometers 855  
The frontage on the left bank is 855  
leagues. 154 leagues.  
Rio Verde Grande (which divides Bahia and Minas Geraes).  
Rio Grande from the Rio Corumbinha, 241 leagues.  
A large portion of this extensive area cannot be viewed from the immediate  
front valley and much of it remains unexplored; although some general features are known along routes of travel which have been noted on page 43 pencil.

This area of drainage in its northern part is quite narrow, averaging only about fifty kilometers from the small Rio Casa Nova to the small Rio Xopa on the left bank - not far above Dique Dique. Then the area begins to widen, and from the mouth of the Rio Grande - one of the great tributaries - to the mouth of the Caranhaha - another important tributary, the general width of the region from the rim to the summits of the Serra da Tabatinga is from ~~two hundred~~ <sup>two hundred</sup> and fifty to three hundred kilometers. The Rio Grande, the Correntes, ~~(the Ramalha)~~ and the Caranhaha are each more than three hundred kilometers long. The Rio Caranhaha is the boundary between Bahia and Minas Geraes.

From the Rio Casa Nova to the Rio Caranhaha along the river the distance is eight hundred + ten kilometers (from league 233 to league 87) but there are numerous bends in the São Francisco which lengthen its course materially.

The actual area drained in the Province of Bahia on the west side of the river is approximately one hundred and five thousand square kilometers. On the <sup>right bank</sup> ~~eastern~~ side of the river, ~~all~~ <sup>the</sup> drainage of the northern, westerly and south westerly portions of the Province of Bahia flows to the São Francisco; amounting approximately to one hundred and forty six thousand square kilometers; making the total approximate area of drainage in this Province flowing to the São Francisco two hundred and fifty one thousand square kilometers.

The entire area of this Province of Bahia is approximately four hundred and ~~sixty~~ <sup>twenty</sup> six thousand square kilometers; so that considerably over half of its whole surface drains into the São Francisco; <sup>the residue drains directly into the Atlantic</sup>

Bahia has a frontage on the river on the <sup>right</sup> ~~left~~ bank of 1392 kilometers; namely, from the Rio ~~Verde~~ <sup>Bingo</sup> just below the Falls of Paulo Afonso, (which divides Bahia and Sergipe) to the \*  
League 30 1/2 to League 331 1/2

long been in use. One of the Commissioners, as elsewhere mentioned, made a special examination across a part of this Country, from Caranhamba to the City of Bahia (833 Kilometers) the results of which are given in his report and also shown in part on the Map of the Province prepared by him based on the best attainable authorities 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 in account of the high cost of transporting the products to a market; but in the more southerly portion upon the tributaries there has been some cultivation, where the rainfall is greater 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 cultivation, <sup>however</sup> has not been great; vast areas are still in a state of nature; the predominant aspect being mountainous, with large plateaus greatly cut up by the minor streams, interspersed with fertile valleys.

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

The western sources of the tributaries that enter between Cabrobo and the Rio Casa Nova (~~the smallest which divides Pernambuco from Bahia~~) are chiefly in the Serra <sup>dos</sup> ~~Borbarama~~ <sup>Dous Trindades</sup>. The northerly tributaries that enter below Cabrobo, have their sources partly in the

Same range and in its easterly prolongation, the Serra do Patricipe. The Rio Moxos, the most easterly tributary having its sources in the Province.

The prevailing characteristic of these tributaries on the left bank, or 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 their <sup>main</sup> valleys.

The general width of this province above Cabrobo, is about one hundred and twenty kilometers, and below Cabrobo one hundred and seventy kilometers.

# The area of the province draining into the São Francisco is approximately ~~eight~~ <sup>ninety</sup> ~~thousand~~ <sup>thousand</sup> square kilometers;

# The area draining into the Atlantic by other streams, notably the Rio Cabibariba and the Ipojuca, is about ~~thirty~~ <sup>thirty eight</sup> thousand square kilometers; making the total area

# of the Province about ~~one hundred and forty~~ <sup>one hundred and twenty eight</sup> thousand square kilometers.   
 The city of Pernambuco is the great seaport and the capital of the Province. The principal river ports of the Province on the São Francisco river are Cabrobo, 550 kilometers above the mouth; Boa Vista, 632 kilometers above the mouth; and Petrolina, 753 kilometers above the mouth.

The province of Alagoas, which lies on the left bank of the river from the mouth to <sup>the Rio Moxos</sup> a short distance above the Paulo Afonso Falls, has an area <sup>triangular in shape</sup> of about ~~thirty~~ <sup>four</sup> thousand square kilometers, only ~~a narrow strip of territory~~ <sup>one third of which</sup> comprising about ~~one fourth~~ of its territory along the lower river, drains into the São Francisco. The remainder of the province drains directly to the Atlantic, <sup>North</sup> ~~South~~ of the river, the principal stream being the Vaza Boreas, which ~~is in the mountains of Northern Bahia~~

The river frontage of the Province of Alagoas on the São Francisco is 322 kilometers - (from League 381 to League 323.2)

Above Piranhas, <sup>which is</sup> on the lower river, there is no real drainage into the São Francisco, excepting during rains, or for short periods thereafter. Ordinarily, all the tributaries are dry at their mouths. Maceo, <sup>120 kilometers up the coast</sup> is the capital and principal sea port of this Province.

\* Senedo, and São d'Assucar, and Piranhas, are in principal river parts.

Alagoas + Sergipe + Pernambuco. New Committee.

The Province of Sergipe, extends along the right bank of the river from its mouth to the Rio Junco (at League 331.20) a distance of 274 kilometers of river frontage. The Rio Junco is 34 kilometers below the Falls of Paulo Afonso, and it divides the Province of Sergipe from the Province of Bahia.

# It has an area of about thirty <sup>two</sup> ~~eight~~ thousand square kilometers, only a narrow strip of which comprising not over one fourth of its territory, all in the Lower river valley, drains into the São Francisco. The residue of the Province drains directly into the Atlantic South of the river. Its principal stream is the Vasa Barris, which rises among the Mountains of Northern Bahia.

There is no town of importance at the Mouth of the São Francisco, either in Sergipe or Alagoas. Sergipe <sup>Sergipe</sup> d'El Rey, the Coast port of the Province of Sergipe, is about ~~140~~ ninety kilometers south westward from the Mouth, down the Coast. The villa de Propria is the principal port of the Province on the river. It stands on the right bank 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 Geraes.

The length of the main river in Minas Geraes is 1278 kilometers, of which 478 kilometers are below the junction of the Das Velhas, and 800 kilometers are above. The Upper tributaries are very numerous, and as a rule they contain flowing water throughout the year.

# The prevailing topography is mountainous, with occasional high, broad plateaus, and generally narrow valleys; though there are some <sup>valleys</sup> twenty kilometers or more in width. As the field work examination of the Commission did not extend beyond the upper end of the Pirapora Falls, the information in regard to the region higher up is derived from reports and maps made by others, supplemented by

place  
in this  
page  
see margin

The special examination made under the auspices of the Commission by authority of the government, by Professor Orville A. Derby, geologist, during the season of 1879-1880, whose report shows that the general topography of the Upper Das Velhas and its tributaries is of a very similar mountainous character, with intervening fertile valleys.

The report and maps of <sup>Emm.</sup> H. Liais, who, in company with Eduardo José de Moraes and Ladislás de Souza Mello Netto, Civil Engineers, surveyed the Das Velhas and Upper São Francisco, in 1865, have furnished much information respecting <sup>these</sup> parts of Minas Geraes, and of the characteristics of the rivers.

We are also indebted to the work of <sup>F.I.M.</sup> Cornelheira, Armem de Mello for information contained in his "Carta Phisica do Brazil," published in 1876.

The drainage area of the São Francisco and its upper tributaries within the Province of Minas Geraes 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 Ramalha, the Correntes, <sup>and</sup> the Rio Grande, which enter below the Caranhonha in the Province of Bahia also furnish large quantities.\*

The extreme upper <sup>mountain</sup> boundaries of the basin of the São Francisco and of its great Confluent, the Das Velhas, are also the boundaries of the head waters of the streams flowing southward into the other Rio Grande, and the Paranaíba. In fact, the sources of the Paranaíba lie far north of the sources of the São Francisco, westward

The total area of Minas Geraes is 575,000 square kilometers.

\* This Rio Grande should not be confounded with the Rio Grande in the southern side of the great water-shed, which flows to the Parana 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 Paranaíba.

On the eastern side of the great Valley of the São Francisco the range which bounds the eastern sources of the Das Velhas divides them from the waters flowing eastwardly to the Atlantic through <sup>tributaries of</sup> the lower Parahyba, entering the Ocean in the Province of Rio de Janeiro; and other streams flowing eastwardly to the Rio Doce, entering the Ocean through the Province of Espírito Santo. This mountain range is called the Serra do Espinhaço range. Its elevation is about say 1300 meters above the sea.\*

The sum of the approximate areas of drainage in the provinces of Alagoas, Sergipe, Bahia, Pernambuco and Minas Geraes is ~~eight hundred~~ <sup>five</sup> ~~and fifty eight~~ <sup>eighty seven</sup> thousand, ~~square kilometers.~~ <sup>or in round numbers eight hundred and fifty thousand</sup> square kilometers.

There are <sup>very</sup> small portions of the Province of Goyaz drained by ~~the~~ <sup>through the Paracatu into</sup> tributaries of the São Francisco; but the area is insignificant. (The Province of Goyaz is drained northward by the Tocantins, and the Grande (a third river of that name) or Araguay, into the Amazon; and it is drained southward by the Rio Paranaíba into the Parana, and La Plata.)

The high mountain ranges between the waters of the São Francisco and the <sup>Paranaíba,</sup> ~~Paranaíba,~~ and which separate <sup>in part</sup> Minas Geraes from Goyaz, <sup>are called</sup> ~~is called~~ the Serra da Tiritica. Farther north, the same range, dividing the waters of the São Francisco from the waters of the Tocantins, and also separating Minas Geraes and Bahia from Goyaz, is called the Serra da Tabatinga.   
\* on the southern part Serra de Canastra, Serra de Matta do Corda, and on the northern part Serra da Tiritica and Serra do Paranau.

\* Emm. Liáis gives the elevation of Barbacena at 1137 meters above the sea, and Sabara, at 695 meters.

5 places in this page

- # If the Meteorology on the whole of the <sup>five</sup> ~~eight~~ hundred and <sup>eighty seven</sup> ~~fifty~~ thousand square kilometers of drainage area of the São Francisco were similar to that which exists in the upper tributaries, it would be one of the grandest <sup>among</sup> natural agricultural valleys; but it is quite otherw<sup>ise</sup>.
- # The rain tables which have been kept <sup>near Sabara</sup> ~~at Sabara~~ and which were kindly furnished to Prof. Derby by M. Morrison, show approximately, at least, the rainfall on the head waters of the São Francisco. Not accurately of course, because <sup>Sabara</sup> ~~Sabara~~ is on the <sup>waters of the Das Velhas</sup> ~~opposite side of the Mountain range~~ and at a ~~greater elevation than any part of the Valley of the São Francisco.~~
- # <sup>The rain fall varies</sup> ~~The rain fall varies~~ from 1154<sup>mm</sup> to 2220<sup>mm</sup> depth per annum.

These rain-gauge records, will be referred to more in detail under the head of the Meteorology <sup>and climate</sup> of the valley.

Rainfall.

Meteorology and Climate of the valley  
See page 46 1/2

## and Climate Meteorology of the Valley

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 Piranhas, 238 Kilometers from the sea, the uplands, which are there from 200 to 250 meters above the sea, even quite near to the river, are subject to great droughts, rendering large tracts unsuitable for general agriculture; the thin pasture of the Pertão supporting a limited number of cattle and horses.

Such is the character of <sup>the</sup> soil in 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 seasons.

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 sugar 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 very little cotton is raised, but not any for shipment, at present.

The general climate is so dry that agriculture can only flourish near the river only where there is natural or artificial irrigation. Sometimes for several successive seasons the drought throughout this extensive region is so severe that the lower tributaries of the Upper river, including the large river Moxoto, 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, none 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 Pernambuco, Bahia and the <sup>extreme northern</sup> eastern portion of Minas Geraes were thus affected, the thin pasture of the Sertão supporting only a limited number of cattle and horses.

Such is the character of the climate <sup>along the river on both sides</sup> and soil ~~on both sides~~ of the Valley opposite the Falls of Paulo Affonso, and for hundreds of kilometers above.

The rainfall is very irregular and not sufficient to sustain ordinary agriculture excepting during occasional seasons. Only the alluvial, dipping 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 products of manioc, corn, sweet potatoes, rice, melons, etc.

On the main upper river sugar is cultivated only in 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.

all

625  
625  
625  
625

The general climate is so dry that agriculture - as generally understood, near the river for a long distance above Paulo Afonso Falls, <sup>can</sup> flourish only where there is natural or artificial irrigation. Sometimes for several successive seasons the drought throughout this region is so severe that the lower tributaries, including the large river Moxoto, for many kilometers up contain no flowing water, and the dry beds in favorable places are temporarily converted into small plantations where corn, sweet potatoes and melons, etc, are raised.

At the time of our examinations, in 1879-80, none of the tributaries for one thousand kilometers along the river had any flowing water at their mouths. The whole region on both sides of the river comprising a very large area had been parched and suffering from want of moisture for several years.

Considerable parts of the Provinces of Pernambuco, Bahia and the eastern portion of Minas Geraes were thus affected.

See page 48 (pencil)

A hundred kilometers or more off from the river on the higher lands, rising in numerous places into Mountain ranges with elevated plateaus, there is more rainfall, though the country is also subject to long continued droughts. Even at the junction of the Das Velhas with the main river, five hundred meters above the sea, and two thousand kilometers distant from it by the river, injurious droughts sometimes occur. This region is however in general much more moist than the region farther down the river. Here are two 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 Das Velhas, São Francisco, 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 thus the months of June, July and August, and sometimes of May, and September, in part, are 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 seasons the freshets rise twelve or more meters, while in others the rise is only six or seven meters; the discharge from the river in some years being more than double the discharge of other years.

# The minimum discharge just below the junction of the Das Velhas as given by Halpeld was <sup>335.5</sup>~~340~~ Cubic meters per second. M. Liais measurement in # 1865 gave 655 Cubic meters per second.

Ozer measurement, Dec 16, 1879, gave 1623 Cubic meters per second; but the river was then nearly two meters above extreme low water. Assuming for an approximation one third of the quantity for the low water flow it would be 541 cubic meters.

But in such cases, where the object is to find the minimum flow of extreme low water, the lowest measurement, in this case 319 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 river Paracati the quantity is more than fifty per cent greater. In extreme low water the minimum flow at the mouth of the Rio Verde

# 1066 kilometers below the junction may be safely assumed as ~~at least five hundred~~ <sup>one thousand cubic meters</sup> cubic meters per second. Accuracy in regard to the extreme minimum flow is unattainable; except by actual measurement at the time of such minimum flow; nor is accuracy a necessity in connection with the works needed for the improvement of the navigation. The lowest measurement made by the Commission, in 1879, gave ~~1101~~ <sup>1101</sup> 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 São Francisco, and considering the peculiar and very irregular meteorological phenomena on the middle and lower portions, rain-gauge records there would possess little practical value unless they extended through a lengthened period of years. Then they would exhibit the remarkable irregularity of the rainfall; but only at the spot where the rain-gauge was stationed; for <sup>many of</sup> the rains, besides being so irregular, are quite local. Light rains which would show 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 more regularly supplied with rains. 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 cactus, 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.

Seasons when there may be natural moisture enough in the soil 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 is proof of ample rainfall higher up the valley; and the annual great floods of December, January, and February <sup>sometimes</sup> and March, prove that there is heavy rainfall during those months on the upper waters,\* while the ~~long~~ period of low water - from May to September, (and October, on the lower part of the stream,) shows a time <sup>annual</sup> of drought throughout the valley.

Rainfall.

- Rainfall in Sabara - Minas Geraes
- " in the City of Rio de Janeiro
- " in Ceara

\* Since writing the above, a copy of the record of the rain-fall, kept at <sup>Sabara</sup> ~~Parabacana~~, on the <sup>western</sup> ~~southern~~ side of the <sup>great</sup> ~~mountain~~ dividing ridge, not far from the highest sources of the <sup>Rio das Velhas</sup> ~~Sao Francisco~~, has been obtained. It extends from 1855 to 1879, inclusive, 25 years. This will be more particularly referred to further on.



2

(50 1/2)

## Climate No.

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 <sup>strong</sup> breeze, in the day time, and sometimes during the night. Situated between eight and a half degrees south, at Cabrobo, and twenty one degrees south, towards its sources, rising gradually from the sea-level to nearly, <sup>or quite</sup> a 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, when not varied by rainfall, for example, during long droughts, the different seasons of the year find little change in the aspect of the Country.

Twice, annually, the sun is vertical in every part of the Valley; as it passes south, to the tropic, and on its return; and on the 21<sup>st</sup> of June, when it is at the northern tropic, it is about forty four degrees north of vertical at the head of the Valley, and thirty two degrees north of vertical at Cabrobo.

At an elevation of a thousand meters above the sea, with the sun so far from vertical, and in a region where timely and sufficient rains occur, the <sup>general</sup> 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 shade is rarely above 80° Fahrenheit.

The average elevation of the Upper Valley of the

Climate continued

# São Francisco <sup>may be about</sup> 1400 meters above sea-level, between the Falls of Paulo Afonso and the Falls of Pirapira, a distance of eighteen hundred kilometers. This <sup>elevation</sup> is not sufficient of itself to create any <sup>marked</sup> ~~marked~~ difference of temperature <sup>in the Tropics;</sup> though it has <sup>beneficial</sup> some influence.

The general range of temperature along the valley is about 85°, rising sometimes to 90°, and occasionally to 95°, rarely 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 Das Velhas, during the rainy season, <sup>the latter part of</sup> in November and December, the thermometer sometimes falls to 60°, and thick woolen 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 Barragem das Velhas there is sometimes frost.

The <sup>present</sup> agricultural products along the valley do not show exactly <sup>or all</sup> the capabilities of the climate and soil in <sup>all</sup> ~~different~~ parts of it. Certain crops are <sup>now</sup> raised <sup>along the river margins</sup> every where, under very similar conditions, from one end of the valley to the other, namely, on the <sup>river slopes</sup> alluvial ~~regions~~ and islands. These <sup>crops</sup> are, <sup>chiefly</sup> mandioca, <sup>rice</sup> corn, beans, <sup>sugar</sup> of various kinds, and melons. But for hundreds of kilometers <sup>above the Falls of Paulo Afonso and</sup> oranges, bananas, are not seen; and only here and there a little sugar-cane, and still less cotton. Not because the climate is unsuited to them, <sup>and other products,</sup> when they are <sup>sufficiently</sup> watered; but because, <sup>as</sup> scarcely any thing is raised for shipment,

from the valley, they continue to plant and cultivate only ~~new~~ articles ~~various~~ but adapted to the <sup>and chiefly for their own consumption,</sup> circumstances; and they are <sup>thus</sup> obliged either to confine themselves to the comparatively limited areas of ground which are annually irrigated by the freshets of the river, or introduce artificial irrigation.

So long, however, as the inhabitants dwelling along the river margins and <sup>on the</sup> islands, can, without artificial irrigation raise enough to satisfy their moderate wants, and until the Commercial Circumstances, <sup>shall be changed by an improved river</sup> ~~be changed~~, they will not be likely to resort to <sup>artificial</sup> 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 <sup>safely</sup> calculated upon. \*

Whatever may be the Causes which control the downfall of rain, and the distribution of atmospheric moisture along <sup>much of</sup> 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 <sup>such</sup> advantage of the circumstances, as experience may suggest.

Nature, in addition to her niggardly and erratic supply of moisture throughout a large portion of this valley, 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, and their habits

\* It is true that these <sup>a few</sup> ~~were~~ taxendas or rather cattle-raising places some distance back from the river, where cattle mounds have been built across little valleys, which act as catch-water and serve to sustain the people, and their animals, <sup>off</sup> ~~the~~ rain. <sup>men are aged for a considerable time; but this system is not limited in its operation, and it cannot seriously alter the general conditions.</sup>

53 Paper will be changed in final arrangements.

4. only a very slow movement

to it, the probability is that <sup>little</sup> change will take place, to change the present aspects of the Valley.

Even a perfectly correct and unquestionable diagnosis of the Meteorological reasons for the prevailing <sup>in this case</sup> absence of moisture, would not in the slightest degree <sup>help to change</sup> the action of Nature's laws. It is obvious <sup>that</sup> 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.

<sup>It is</sup> <sup>too much to say</sup> that these <sup>outside controlling causes of nature</sup> may not change; but it is <sup>quite</sup> <sup>not</sup> ~~too much to say~~ <sup>reasonable to conclude</sup> that they cannot be changed by human means. Proper forests, which exist in the upper portions of the Valley, are not the Causes of the Meteorological <sup>and especially of the rainfall;</sup> Characteristics, they are the Consequences.

The climate is as good as the climate of Lower Egypt. In that part of Egypt the sandy desert is wholly sterile, till it is artificially irrigated. The line of demarcation between sterility and abundant yield is ~~now~~ clearly defined by the <sup>irrigating</sup> 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 so 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 <sup>abundantly</sup> from the soil; just as it is in Egypt.

### Rainfall

Rainfall in Sabara. Minas Geraes

in Rio de Janeiro

in Ceará - Ceará

# Rainfall in Sabara

Appended is

~~In the Appendix will be found~~ a copy of the 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 <sup>kept</sup> at a point about two leagues south east of the village of Sabara. Sabara is on the Das Velhas river in the Prov-  
# ence of Minas Geraes, in latitude  $19^{\circ} 53' 52''$  South, and  $1^{\circ} 13' 49''$  West from the City of Rio de Janeiro, assumed to be approximately 1137 meters above the sea. 695

# This table was kindly furnished to Professor Derby by Mr. Pearson Morrison, the gentleman in charge of the Company's works. It was afterward reduced by Prof. Derby from feet and inches to millimeters, 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~~ <sup>or</sup> São Francisco rivers; 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 millimeters (5.37 feet.)

The annual rainfall was as follows:

Years.	millimeters.	Years.	millimeters.	Years.	millimeters.
1855	1838	1864	1573	1873	1154
56	2194	65	1634	74	1458
57	1475	66	1462	75	1690
58	2220	67	1578	76	1708
59	1746	68	1623	77	1666
1860	1441	69	1574	78	1553
61	2031	1870	1631	1879	1498
62	1507	71	1625		
63	1310	72	1724	Average	<u>1637</u>

This Table may be put in one column.

The average rainfall in the different quarters of the year (Trimestres) was:

For January, February, and March,	millimeters. 412
" 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:

	Average millimeters	Greatest	Least
For January	299	825	99
" February	221	523	59
" March	192	309	(34) 21
" April	52	87	14
" May	36	95	2
" June	15	113	0
" July	11	64	0
" August	13	88	0
" September	53	141	1
" October	121	243	20
" November	234	394	106
" December	390	762	575
Total	1637 during 25 years.		

The greatest rainfall in one month during the 25 years was 825 millimeters, in January, 1858.  
The next greatest was 762 millimeters, in December, 1856.

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

	millimeters	Year
The least rainfall in January was	99	in 1873
" " " in February	59	in 1873
" " " in March	21	in 1877
" " " in April	14	in 1873

" " " in May " 2 in 1876

No rain fell in June during the <sup>7</sup> years 1855-1858, 1863, 1865, 1867, 1869 and 1877.

No rain fell in July during the <sup>8</sup> years 1855, 1859, 1860, 1868, 1869, 1876, 1878 and 1879.

No rain fell in August during the <sup>8</sup> years 1860, 1862, 1863, 1865, 1867, 1869, 1872 and 1878.

The least rainfall in September was <sup>millimeters</sup> 7 in 1874 (and 2 in 1869)

" " " " October " 30 in 1865

" " " " November " 106 in 1865

" " " " December " 137 in 1875

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

	millimeters	Remarks	
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 56 per cent of the yearly rainfall.	
January	299		
November	234		
February	221		In the 4 months, November, December, January and February the average was 1157 millimeters, or 70 per cent.
March	192		
October	121		
September	53		
April	52	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.	
May	36		
June	15		
August	13		
Least: July	11		

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, 1876, ~~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 millimeters.

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 variations, in every month, are very great. The maximum year, in January shows a rainfall eight times greater than the minimum <sup>of January.</sup> In February, the same, eight times. In March, <sup>fifteen</sup> ~~fourteen~~ times. In April, six times. In May, 47 times. In June, as 113 to 0. In July, as 64 to 0. In August, as 88 to 0. <sup>in</sup> September as 141 to 1. In October, as 243 to 20, or 12 times; In November, nearly four times. In December more than 4 times.

The quarter-year (Trimester) variations were also very marked; In the three months, January, February and March, the maximum average was 1292 millimeters (in 1858) while the minimum was only 279 millimeters (in 1873) one being four times greater than the other.



In the three months April, May and June, the maximum was 199 millimeters, (in 1874) and the minimum was 47 millimeters (in 1856, 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 millimeters, (in 1858) and the minimum was 2 millimeters (in 1869). the one being 84 times greater than the other.

For the three months, October, November, and December, the maximum was 1219 millimeters, (in 1856) and 448 millimeters (in 1877). One being two and three fourths times greater than the other.

The half-yearly variations are also <sup>very</sup> striking. For the rainy season, from October to March inclusive, the maximum was 2002 millimeters (in 1857) and the minimum was 1011 millimeters (in 1859-60) the one being <sup>almost exactly double of the other.</sup> ~~times greater than the other.~~

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

The yearly variations are also quite notable: The maximum was 2220 millimeters (7.28 feet) in 1858; the minimum was 1154 millimeters (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 <sup>above</sup> the average, namely, 1855, 56, 59, 61, 65, 72, 75, 77; and while the following were below the <sup>average</sup>, 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, in <sup>every</sup> year for agricultural purposes, even in the year of least rain, in 1873, when the quantity was 1154 millimeters (3.78 feet); but it is also clear that there is a long period without any rainfall, <sup>nearly</sup> every year; namely, in a part of May, all of June, July and August, and part of September; and, <sup>in many</sup> years the dry season runs through all of these five months.

Agricultural operations in this region should be arranged in view of this important fact, especially the planting or sowing. <sup>Exercises</sup> ~~Many~~ things if planted or sown with judgment, keeping in view the periodicity of the drought, might be successfully cultivated, which if planted or sown say as late as the latter part of June or the early part of July might either, and fail, before the annual rains should come to their relief, in September or October.

Although there were no rain-gauge records kept below Sabará, <sup>along</sup> ~~throughout~~ the São Francisco river-valley, there is no doubt that throughout a greater portion of it the periodical drought is <sup>even</sup> longer and more injurious to general vegetation than it is on the upper waters.

The monthly, quarterly, semi-annual, and annual variations in the quantities of the rainfall, as shown by the records <sup>on the upper waters</sup>, are so great, and so irregular, as to render it certain that the cause is not in the region where the rain falls; but far away; and dependent upon circumstances, or phenomena entirely outside of <sup>the valley</sup> ~~the valley~~. Similar variations occur

in various parts of the United States. <sup>and near</sup> In the City of Philadelphia, where the features of the region have not been materially changed - so far as they might be supposed to affect the Meteorological phenomena - for <sup>or a hundred</sup> fifty years past, there has been in some years only half the rain that fell in other years. The same <sup>or rather similar</sup> variations occur in the Valley of the Ohio, the Upper Mississippi, and the <sup>rivers</sup> Mississippi, which together form the Great River Mississippi, 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 streams do not fall any lower now than they did fifty years ago, nor do the floods rise any higher, <sup>or any</sup> they are as irregular, in both directions, as they could well be.

These facts also tend to prove that the Meteorological Causes of the irregularities are not in those Countries watered by the streams named, but far away, and outside of them. ~~It is~~ ~~necessary in this place to pursue them into the region~~ ~~of hypothesis.~~