

Rainfall in the City of Rio de Janeiro.

Although the rainfall in the City of Rio de Janeiro, which is situated on the Atlantic Coast, is not directly applicable in connection with the rainfall in the interior on the head waters of the São Francisco - (though they are but little north of the same latitude,) its study may aid indirectly, as showing more or less analogous irregular fluctuations, largely induced by causes operating at a remote distance from both regions.

Through the kindness of D. José Americo dos Santos, Civil Engineer, I have had access to printed records of the rainfall and evaporation kept at the Observatory in the City of Rio de Janeiro; the rainfall from 1851 to 1864, seventeen years, and the evaporation from 1858 to 1864, ten years. Professor O. A. Dury also obtained records of the rainfall in this City from 1782 to 1787 inclusive, six years; (and from 1808 to 1875 inclusive eight years. These give in all 31 years of records.

The Observatory, is in the City, on the Castello hill 62.7 meters (205.66 feet) above the sea, in Latitude $22^{\circ} 54' 12''$ South, and Longitude $43^{\circ} 08'$ W. from Greenwich. The record, during the 17 years, was kept by Antonio Joaquim Canello d'Almeida.

A table is appended, showing the rainfall, ^{for 17 years} in each month, and the evaporation in each month for ten years.

The average yearly rainfall for 17 years, from 1851 to 1864 inclusive, was 1112 millimeters.

The greatest yearly rainfall, in 1862, was 1536 "

The least " " , in 1855, was 827 "

The maximum yearly rainfall (in 1862) was }
1.82 times the minimum " " (in 1855) }

For the 10 years, from 1858 to 1867, the average yearly rainfall was 1152 millimeters

During the same 10 years the average yearly evaporation was 1647 "

The evaporation being 43 per cent. greater than the rainfall.

The average monthly evaporation was greater than the average monthly rainfall in all the months except March; although in the years 1861, 64, 65 and 66, the evaporation in March was greater than the rainfall.

In the exceptional year 1862, in the month of March the rainfall was 400 millimeters, while the evaporation was only 80.

The average annual rainfall of 1112 millimeters was exceeded during the years 1853, 57, 58, 59, 61, 62 & 65; while it fell below during the years 1851, 52, 54, 55, 56, 60, 63, 64, 66 and 67.

The highest monthly rainfall was in December, 149 mm.
The lowest " " " " " " " " " " June 43.5

The greatest rainfall in any month of the 17 years was in May, 1853, 408 millimeters
and nearly the same in March, 1862, 400.85 "

The least was in August, 1866, 3. "
(In June 1852, and in June 1862, it was only 3. "

For convenient reference the following results are tabulated from the records:

Monthly average rainfall.

	millimeters
January	119
February	92
March	143
April	106
May	108
June	43.50
July	49
Aug	67.50
Sept.	59
Oct.	76.50
Nov.	99.50
Dec.	149

Average yearly rainfall - 17 years.

Years.	Millimeters	
1851	966	mm
52	996.5	.
53	1311.3	+ mop
54	1012.5	.
55	827.	.
56	1060.4	.
57	1203.	+
58	1161.25	.
59	1197.69	.
1860	1010.82	.
61	1225.17	+
62	1536.23	+
63	1091.49	.
64	962.98	.
65	1256.36	+
66	981.67	.
1867	1098.95	.

Average 1112 for 17 years.

From some additional records the rainfall was as follows:

6 years

Years.	Millimeters
1782	1272
83	1093.
84	1354 +
85	1489 - +
86	1306 +
87	1067.

Average for 6 years 1263. mm

8 years

Years.	Millimeters
1868	978.
69	815.
70	824.
71	1012.
72	1773 +
73	810.
74	1453 +
75	1124

Average for 8 years 1099. mm

Summing the 17 years, 6 years (and 8 years), making in all 31 years, the average yearly rainfall would be 1138. mm

The fluctuations of the quantities of rain in different months, in different years, are very great, and quite irregular, as the annexed Table shows:

Months	Max. Rainfall millimeters	Years.	Months	Min. Rainfall millimeters	Years
January	248	1862	January	38.	1866
February	198.72	1865	February	19.50	1863
March	400.85	1862	March	58.	1852
April	268.40	1859	April	19.50	1867
May	408.	1853	May	14.	1864
June	88.52	1865	June	5.	1852
July	129.50	1865	July	4.	1853
August	286.00	1853	August	3.	1866
September	112.00	1854	September	15.	1851
October	160.29	1860	October	12.	1851
November	195.04	1862	November	37.	1853
December	258.75	1858	December	59	1854

While it is true that there was no month absolutely without rain, the minimum quantities in some months were quite insignificant. When it is considered that ten millimeters are only a little more than one third of an English inch, it will readily be seen that such small quantities as 3, 4, or 5 millimeters in a month, are of little account.

In 1855 the rainfall in the four consecutive months June, July, August and September, was only 101. ^{mm} (4 inches), while in the same months in 1853 it was 374 ^{mm} (14 $\frac{3}{4}$ inches)

Taking the six months in succession, December, January, February, March, April & May there fell
in 1861-62 1122 millimeters
and in 1851-52 560 "

The greater being almost exactly double of the lesser.

During
of the other six months, June, July, August, September, October & November, the maximum, in 1853 was 579 millimeters while the minimum, in 1851, was 243 "
The greater being 2.43 times the lesser.

The rainfall in August 1853 was 286 millimeters
while in 1854 it was only 7 "
In May, 1853, it was 408 "
while in May 1852 it was only 79 "

No regular periodicity ^{of maxima and minima} can be traced in these records; although the wet and dry seasons are tolerably well defined; - the wet season from December to May, inclusive, and the dry season from June to November, inclusive. There is, however, no rigid, unyielding line of demarcation; in some ^{years} seasons the rainfall is greatly reduced during the wet season, and in some years it is much increased during the dry season.

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During

A few years of personal experience on the slopes of the Serra do Mar about 60⁰⁰ Kilometers back from the City of Rio de Janeiro, ^{great} showed similar irregularities were noticed there; though it is not known that they compared with the irregularities at the City of Rio de Janeiro.

The evaporation in the City of Rio de Janeiro is, as the records show, considerably greater than the rainfall. The proportion of evaporation to rainfall is probably ^{still} greater throughout the Valley of the São Francisco. It is certainly so along the lower portion of the Upper river.

João Ernesto
by Sr. Rodocanachi

Since writing the foregoing we have been furnished with the ~~annual~~ tabulated statement of the rainfall at the observatory on Castello hill from 1868 to 1879 inclusive. During these 12 years the annual mean rainfall was 837.33^m; and taking the 29 years from 1851 to 1879 inclusive, the annual mean rainfall was 998.30

Years	Millimeters
1868	812, 2
1869	404, 1
1870	679, 5
1871	755, 5
1872	1149, 7
1873	814, 0
1874	1356, 0
1875	1036, 0
1876	1144, 0
1877	691, 7
1878	337, 2
1879	868, 08
Average	837, 33 for 12 years

Rainfall in Ceará, etc.

Appended is a table of the rainfall at Fortaleza, the Capital of the province of Ceará. It is situated on the Atlantic Coast in latitude $3^{\circ} 42' 50''$ South, and longitude $38^{\circ} 28' 38''$ West from Greenwich. The rain-gauge is kept ^{at} ~~of~~ Fortaleza.

The province of Ceará lies north of the Great bend of the São Francisco Valley, separated from it by the Serra do ~~Paraná~~ ^{Apuripe}. The distance from the São Francisco river to the southern boundary of this province does not exceed thirty five leagues or about 194 Kilometers.

Large areas in the interior of Ceará have at irregular periods suffered from destructive droughts, continuing sometimes for several years. That region is only now beginning to recover from a terrible visitation of drought which has continued for more than three years.

So far as I could learn no rain-gauges have been kept in the interior of the province, but from general information it is probable that the rainfall in the interior is much irregular and with greater fluctuations than it is along the Coast.

Senator Thomas Pompeu de Souza Brazil, [now deceased] published in 1877, a book entitled "Memoria sobre o Clima e Secas do Ceará", in which is given several ^{interesting} tables relating to the rainfall at Fortaleza; and as they appear to be confirmatory of the views naturally arising from a study of the ^{two} other records, they are here added. They have been re-arranged so as to be easily studied in connection with the other records, but the data presented by the Senator have not been in the least changed.

This record gives the average monthly rainfall at Fortaleza in each month during the years 1849 to 1876 inclusive, a period of 28 consecutive years. as follows:

Average during 28 years - Annual rainfall.

See pamphlet

	millimeters.
January	69
February	797
March	287
April	372
May	274
June	438
July	45
August	14
September	11
October	13
November	13
December	36
Average yearly for 28 years	1469

This table, by itself, would convey only an imperfect idea of the meteorology, even at Fortaleza; and still more imperfect with regard to the interior, where slight rains which would show in the rain gauge, are evaporated almost as soon as they reach the ground, and do not ^{good}.

The yearly rainfall during these 28 years.

	millimeters		millimeters
1849	1904	1863	1430
50	1022	64	1097
51	1414	65	1233
52	1514	66	2453 ⁺
53	1005	67	853 [*]
54	1568	68	1390
55	1076	69	1534
56	1760	1870	1614
57	1746	71	1440
58	1305	72	2290 ⁺
59	1337	73	2042
1860	1753	74	855 [*]
61	1426	75	1614
62	1466	1876	1634
	20299	average -	1489

21482

Independently of abnormal periods of drought, there is an annual periodicity, clearly establishing a rainy season and a dry season. Thus the average annual rainfall during the first 6 months of the year - January to June inclusive, was

1346 millimeters

while for the other 6 months it was only 143 "

The greatest rainfall during the 1st 6 months was 2335 " (in 1866)

The least " " " 2nd 6 " " 0 (in 1874)

The greatest yearly rainfall was in 1866, 2453 millimeters

in 1872 2290 "

in 1873 2042 "

in 1849 1907 "

The least ^{yearly} rainfall was ~~in~~ in 1867 853 "

in 1874 855 "

in 1853 1005 "

in 1850 1022 "

The greatest yearly rainfall, 2453 millimeters, (in 1866), was 2.84 times the least, 853 " (in 1867).

The minimum yearly rainfall was practically the same in 1874 (855 millimeters) as in 1867 (853 millimeters).

The greatest half-yearly rainfall, during the first 6 months, was as follows:

in 1866, 2335 millimeters

" 1872, 1929 "

" 1873 1902 "

" 1849 1760 "

The least half-yearly rainfall during the second 6 months,

in 1874 810 "

in 1852 29 "

in 1853 35 "

" 1846 36 "

" 1867 42 "

" 1857 46 "

Practically, it may be considered that during these years there was no rain for 6 months.

The greatest rainfall during the 6 months of dry season was in 1871, ^{millimeters} 1485 which proved to be one third of that year's rainfall.

The yearly rainfall was above the average ^(1489 millimeters) during the years 1849, 52, 54, 56, 57, 60, 66, 69, 70, 72, 73, 75 and 76, thirteen years. and below the average during the years, 1850, 51, 53, 55, 58, 59, 61, 62, 63, 64, 65, 67, 68, 71, and 74, fifteen years.

An inspection of the table of rainfall, or of the Curves made from it, will show only irregularity, without the slightest semblance of periodicity. But of course a record of only twenty eight years, considered by itself, may be inadequate to aid in the study of supposed long ^{periodical} cycles of years.

The ^{annual} average rainfall at (near) Sabará, in the Province of Minas Geraes, at the head waters of the São Francisco river as per the records was 1637 millimeters. At the City of Rio de Janeiro was 1112 " At the City of Fortaleza, (Ceará) was 1489 " And in each of the regions where the records were kept, there is ^{a decided} annual period of a rainy season and a dry season, ⁱⁿ each ^{case predominating} approximately, through the same months of the year.

Fortaleza and Rio ^{de Janeiro} are both Coast Cities; Fortaleza # being in latitude $3^{\circ} 40' 58''$ and Rio in $22^{\circ} 49' 19''$

The records show an average rainfall at Fortaleza 1.34 per cent greater than the average at Rio de Janeiro.

Comparing the records at these two Cities, it will be observed that their periods of ^{yearly} maxima and minima ^{of rainfall} do not correspond. Only in nine out of twenty five years, from 1851 to 1875, do they nearly correspond - namely, in 1851, 55, 57, 63, 64, 67, 68, 71 & 72. In the other 16 years they do not correspond at all, and in some years, as for example in 1866, the contrast is striking. That was the year of maximum rainfall in Fortaleza, while in Rio it was far below the average.

There was only one year, 1872, in which there was a marked coincidence, that being the maximum in both Cities; but in the succeeding year, 1873, the rainfall at Fortaleza, was far above the mean, while in Rio it was far below, and the next year 1874, it was very far below at Fortaleza, and far above at Rio.

So that there was ^{regular} no periodicity in either City of maxima and minima ^{in the rainfall,} and scarcely the semblance of any Correspondence between the two places in their years of greatest and least rainfall. The causes ^{being} what all these ~~various~~ ^{various} ~~names~~ ^{names} similar.

If thorough Calculations were to be made and theories or hypotheses ^{of causes} ^{enunciated} were to be based upon the rainfall records in one of these Cities, they could ^{not} be supported by the records in the other City.

It would require a long series of records, kept ^{in many} ^{years, in numerous} ^{places,} to obtain data upon which ^{general} correct theories could be founded; but the tables here considered are valuable, as far as they go; and they afford a tangible idea of the extent and periods of rainfall in their respective districts.

It is true that these ^{rain} tables are entirely insufficient to account for the occasional visitations of such destructive droughts as the one just ended, which embraced a large ^{part} ~~portion~~ of Ceara, ^{and} portions of Pernambuco, Piauhay, Rio Grande do Norte, and Parahyba.

The minimum amount of rainfall at Fortaleza, namely, in 1867, was 853 millimetres, and almost precisely the same in 1874; but in 1875, and 1876, nearly double the quantity fell. The minimum of 853 ^{millimetres} ~~centimetres~~ = 2.80 feet, or 33½ English inches, is quite sufficient in the temperate zone for agriculture; but it depends upon how, and when it falls, even there; and in the

Tropics it may be all important. But from the best attainable information respecting the interior of Ceará no such quantities of rain fell as are exhibited in the records kept at the Capital during the years 1877-78 & 79, as given ⁱⁿ the pamphlet just published by Chief Engineer Moring, giving a ^{very interesting} Historical Synopsis ^{leading to} of the Estrada de Ferro de Patente. The rainfall ^{in Fortaleza during} ~~for~~ those three years of terrible drought in the Province of Ceará is given as follows: in 1877, 355. in 1878, 517 and in 1879, 621.

Whereas ^{it is said that} there was no rain, sufficient to do good, throughout the parched region during ^{nearly the whole of} those years. The same publication states that the rainfall at Fortaleza was this year, 1880,

In January	14.8
February	27.8
March	193.5
	236.1

And it ^{is} reliably reported that in April ^{the rainfall} it was very much greater.

It is certainly very remarkable, that throughout an extensive region during a period of 31 years there should be an average rainfall of 1489 millimeters (58½ english inches) during ^{of those} 28 years, and then suddenly change during 3 successive years to an average of only 497 millimeters, (19½ inches). This is on the assumption that the rainfall in the interior of the Province ^{is measurably} ~~was~~ the same as at Fortaleza.

The importance of the subject is so great that no apology would seem to be needed for devoting a little time to its study. It is important in a scientific view; but vastly more important in an economic and humanitarian view that this imitation should be thoroughly understood, and ^{that} means organized - not to change the meteorological ^{cause or} ~~cause~~ ^{the evil effects} of similar disasters, but to provide remedial plans to guard against ~~them~~.

Estimada Cost.

The following is an approximate estimate of the Cost of the proposed improvement of the Upper São Francisco river.

From Pirapma Falls to the head of the Sobradinho rapids, 1328 Kilometers ("Clear river") - - - - -	35:000\$000
Improving all of the Cachoeiras, from the head of the Sobradinho rapids to Jabobá, the upper terminus of the Paulo Afonso Railway, 428 Kilometers	456:500\$000
	1491:500\$000
Add 20 per cent. for Contingencies & Superintendency,	98:300\$000
	589:800\$000
Add one light-draught steamboat	90:000\$000
" One small light-draught steamboat	25:000\$000
Allow interest on Capital, say,	40:000\$000
Total.	744:800\$000

In round numbers seven hundred and fifty Contos de reis.

If the work, as it could be, were required to be completed in two years, probably not more than fourth or one third would need to be expended the first year, which would be chiefly devoted to the final examinations on the Cachoeiras, and the preparation of materials; and experience might show it to be advisable to expend only a part of the residue during the second year; improving the worst rapids.

D. Sampaio's Report.

(1)

I deem to call particular attention to the Special report of D. Theodoro Fernandes de Sampaio, Civil Engineer, member of this Commission, who, under instructions from the Chief Engineer, dated December 22^o, 1879, proceeded across the Country from Caranhamba, in the Valley of the São Francisco to the City of Bahia; noting during his journey of about 150 leagues (833 Kilometers), numerous interesting and important features of the extensive region traversed.

D. Sampaio's report is so clear, and compact, and ^{so} full of valuable information as to entitle it to the most careful study of every person who takes an interest in the general and particular characteristics, capabilities, past and present condition, and future prospects of an extensive area of the interior of Brazil; part of which is directly connected with the more immediate Valley of the São Francisco River.

The report consists of four Chapters, followed by a statement referring to the excellent accompanying map of the Country between Caranhamba and the City of Bahia.

Chapter I. Begins at Caranhamba, on the left bank of the São Francisco River, 164^o Kilometers from the mouth, and describes the region thence to Monte-Alto, 15 leagues (83 Kilometers)

Chapter II. Describes the Country between Monte-Alto and the City of Caetite, a distance of 15 leagues (83 Kilometers)

Chapter III. Describes the region from Caetite to the town of Rio de Contas, 22 leagues (122 Kilometers) and 20 leagues (111 Kilometers) beyond Rio de Contas to Sta. Isabele do Parraguassu; together, 42 leagues (233 Kilometers)

Chapter IV. Describes the region from S^{ta}. Isabel do Parra-
quassu to S. Felix, opposite the town of Capoeira, about
65 leagues (361 Kilometers).

Thence to the City of Bahia, about 13 leagues (72
Kilometers, no new description was necessary.

After studying this report, I undertook to make a
synopsis; but it became so voluminous as to be almost
a repetition of its already Condensed matter; I will
therefore give here only the "Statement" of D. Sampaio,
Explanatory of the "Accompanying Map"; but respectfully
suggesting that the full report, which will be found in the
Appendix, demands careful perusal.

"Statement Accompanying Map."

"The Map which accompanies this report is the
result of our most scrupulous efforts in gathering exact
data and information for the organization of a better
map of this part of the province of Bahia than at present
exists.

Of all the Empire this province is ^{most meagre} the poorest as to
geographical data and the knowledge of its territory;
the part comprehended between the rivers "São Francisco",
"Verde", Paraguassu, and "das Contas" was indeed the
most unknown and most imperfectly represented in the
Maps hitherto published. It was on this account that
I, ^{undertook} ~~attempted~~ to cross the region in that part.

For the purpose of obtaining a more perfect
acquaintance with this region, we stayed a few days
at the heads of the districts comprehended in our
journey, and had the good fortune to gather ~~up~~
a great amount of information, as to the rivers, their
^{sources,} course, ~~size,~~ and principal affluents, and in regard to
the forests, Campos, lakes and marshes, villages, towns
and Cities of each Municipality.

So that the map which accompanies this report, if it does not present the exactitude of geographical and geodetical productions, has, nevertheless the advantage of being, among many, the nearest to correctness of any which I have examined representing this part of the Province of Bahia.

Thus, I did not meet with a single map of this Province in which the town of Alento-Alto figured in its true position: this town has always been represented at more than 30 leagues distance from the São Francisco River, and beyond the valley of this river, when it is well known to be only 15 leagues distant from the São Francisco, and as many more to the West of the Serra Geral, the limit of the valley referred to.

The same may be said as to the geographical position of the City of Caetite and other growing towns scattered over the very fertile table-lands of the Serra Geral.

The sources of the Rans, St. Onofre and Paramirim rivers, with other affluents of the São Francisco, and their bearings, are here more correct according to trustworthy information, and more in harmony with the oldest of the geographers of Brazil, Father Manuel Ayres do Casal, the most reliable in descriptions of the places I traversed.

The source and course of the Contas and Paraguassu rivers and their affluents, are in the same case.

With regard to the Paraguassu, I have to note, that no geographical map of this zone is exact as to the source and upper course of this long river.

Upon this point, fortunately, with the aid of the best information, and principally with the assistance of an historico-geographical notice of these remote districts which was forwarded to me a short time ago, by the vicar-General of the Rio das Contas Comarca,

(4)

Comra José de Sousa Barboza, I succeeded in making a Corometim as reliable as was possible with such assistance.

The Serras or Mountain-Chains are on this map more clearly laid down, and more in accordance with Nature than in other maps.

The forests, the Catingas, the Campos verdes, are also indicated here according to the data of our direct observations, and in accordance with good information from more than one individual consulted on the same subject.

Such are the improvements and Corrections that we have succeeded in introducing into the map of this part of the Province of Bahia.

"Theodoro Fernandes de Sampaio
Engenheiro Civil."

It may properly be added, that the above conveys only a faint idea of the extent and value of the information contained in the full report, which relates not only to the Geography, but to the Topography, Geology and Climate, as well as to the Mineral and Agricultural Characteristics of the different Zones between that part of the immediate Valley of the São Francisco and the Atlantic Coast.

Concluding Suggestions.

Should the government conclude to improve the Upper São Francisco river upon the general plan described in this report, it may be a question for consideration respecting the manner of doing the work; whether by the government directly, or by Contract, under government supervision. In the United States, wherever it may be practicable, such work is done by Contract, under government supervision.

In either case, if the government wishes to save time, it would be advisable to make arrangements for the construction and delivery in the Upper river of two stern-wheel, light-draught steamboats; the larger to be about 37 meters long and 6 meters wide, for a tow-boat, the smaller to be not more than 15 meters long and 4 meters wide, for an exploring boat. Neither should, when light, draw more than ^{about} half a metro.

Such boats could be contracted for and built in the United States and delivered, ^{and set up,} complete, in the Upper river (after the opening of the Paulo Affonso Railway,) for not exceeding the sums mentioned in the general estimate of cost: namely 90:000 \$000 for the larger, and 25:000 \$000 for the smaller boat. How much less than these sums can only be ascertained by special inquiries, or through proposals.

Secondly, in case the government should conclude to proceed at once with the improvement of the river, there would be an advantage in securing the services of some one who had had experience in planning

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and executing analagous river works. Although the works themselves are as simple as possible, money may be saved by judicious selection of the particular places in which cuts, rip-rap banks, or Chutes are to be put. An intelligent engineer unacquainted with river work might soon acquire the necessary experience; but experience is generally paid for by somebody.

It is not possible ~~to~~ to designate ^{in advance} exactly such improvements as may, upon more careful investigation be found desirable. The smaller Steamboat referred to is designed, mainly, to be used in making these final critical investigations on the Cachoeiras; and in the hands of one experienced in river-improvement, the examinations and decisions could be made very rapidly.

The general method of making these final examinations, during the low-water season, would be to have an experienced river ^{engineer} ~~man~~ in charge of the exploring Steamboat and with a small party of intelligent assistants, to be selected by himself, to ascend ^{and descend} all the navigable channels at every Cachoeira, noting the features appertaining to each channel, depth, width, current, volume of water, obstructions, etc, before determining which channel should be improved, ^{exactly} or how it should be improved.

These critical examinations cannot be properly made without the use of a proper light-draught Steamboat, as ^{indicated,} having power enough to stem the swiftest ^{currents} ~~water~~ of the natural channels. Steamboats, or Steam-Launches drawing a meter and a quarter to a meter and a half of water, are not at all adapted to this purpose.

(With the aid of sails, the Commission was enabled to sail up through some of the channels and note

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their features; but the wind is too uncertain an element to depend upon, as it sometimes failed us where we needed it most. Besides, a general examination of the river of the whole river, and also a critical examination at every safe Cachoeira, in one season, would have been an impossibility.)

It would not be necessary for the engineer in charge of the examinations to wait until the close of the season, or till after examining all of the Cachoeiras before reporting plans. That could be done seriatim beginning with the lowermost, very soon after the examinations should be completed at each, or at each particular set of Cachoeiras.

In a general way it is assumed that one low-water season would be consumed in making these preliminary investigations and arranging for the procurement and delivery, at convenient points on the river banks, of such undressed timber, and rough stone from quarries, as might be considered necessary for the improvement of certain Cachoeiras; and ^{during} that the succeeding low-water season the work should be done - if not at all, at ^{least at} the most difficult Cachoeiras; so as to ensure a considerably improved navigation for the third low-water season.

It should ^{be an important} ~~also~~ part of the duty of the engineer in charge, to keep carefully in view not only the improvement of the low-water navigation (by means of the simple works indicated) but to be sure that the channel should also be safe ^{for steamboats} in higher stages of the river. This ^{obviously} calls for the exercise of judgment based upon some experience in the action of rivers in their different stages.

It may be stated, that no river in the United States resembles ^{very} closely that portion of the São Francisco between Jaboa and Sobradinho - the Cachoeiras portion; and that therefore precisely similar works have not been required on any of those rivers; yet the same kind of judgment exercised in planning ^{for} and improving the low water navigation of the Ohio river is needed on the Upper São Francisco. There is this very important difference between these two streams; ^{namely,} that while the minimum flow of water in the Ohio, in some seasons, becomes very small, the minimum flow in the Upper São Francisco ^{even} in the very driest season ^{is} a large volume. The ~~large~~ great superiority of the low water supply on the São Francisco, more than atones for the greater declivity of the stream through the Cachoeiras; so that a better low-water navigation can be made on the ^{Upper} São Francisco than on the Upper Ohio, without the use of locks.

The labor of the Commission are now brought nearly to a close, and it gives me my great pleasure to bear testimony to the uniform kindness and courtesy of all its members; and to their cheerful and diligent fulfillment of the various duties devolved upon them; which has so essentially contributed to produce satisfactory results.

My association with these gentlemen in this Commission, for more than a year, in the field and in the office, has been most agreeable; the recollection of our intercourse will always be a source of sincere pleasure; and their future course as engineers, wherever they may be, will ever be regarded by me with especial interest.

Accompanying this is the report of Prof. A. O. Derby upon the geology of the São Francisco Valley.

1

Consideration of the population, and of the circumstances
in the São Francisco Valley, with the view of making an
approximate estimate of the probable traffic after the
river shall have been improved, and the Paulo Affonso
Railway opened.

Various estimates have been published of the population of this valley that could be regarded as tributary to river business, varying from a million and a half down to three hundred thousand.

It is difficult, or perhaps impracticable to obtain exact reliable statistics; but the Commission has sought to ascertain the truth upon this point, partly from personal observation and judgment and partly from such statistics as were attainable.

Four members making separate approximate estimates, each in his own way - varied between 450,000 and 580,000; the average being 516,000 inhabitants.

From the best attainable statistical sources relating to the parishes in the river provinces of Minas Geraes, Bahia, Pernambuco, Alagoas and Sergipe, the result stands 521,754, as the present number that may be considered contributory.

The number of houses could not be ascertained in all of the parishes; but in those which were obtained there were 70,622 houses to 461,533 people. In the same proportion for a population of 521,754, the total number of houses would be 79,837.

The average number of people to each house according to the above statistics, is six and a half.

Table () appended to this report, exhibits in detail the names of the provinces, ~~the~~ municipalities, and parishes, and the number of houses and inhabitants in each.

Accuracy is not required for the purposes of this report, so that the above numbers of houses and inhabitants may be taken as a sufficiently near approximation as a general basis.

Table () appended shows the names of the towns, ^{villages and cities} along the river margin in the respective provinces, to the number of forty one, and their distances in kilometers below Perapora, the elevation of the river at each place above the sea, and the number of the League upon which they are situated, designating also on which side of the river they stand. It shows also the names and distances ^{etc} of tributary rivers.

This table shows that the towns, ^{etc} along the river, where business will be collected for steamers, average less than ten leagues apart, ~~etc~~ ^{taking} the whole length of the upper and lower river, which is 382 leagues - from the sea to ^{Perapora}.

Between the towns, wherever the land is cultivable, which includes perhaps three fourths of the length, it is cultivated, as already stated, on the ^{margins} slopes, ~~lands~~, and ^{on} some of the low grounds; though toward the upper part of the valley there are large tracts of low-lying land not yet under cultivation.

To make an estimate of ^{practical} ~~any~~ value of the future trade of the valley of the river, two things should be considered: First, the effect

means of transportation of the improved ~~work~~ ^{means of transportation} upon the labor, habits and modes of the present inhabitants and their natural increase in number; and Second, the increase ^{by immigration} ~~of population~~, ~~time and~~ ^{the} consequences of such increase, in augmenting production as well as the demand for imported articles.

It is quite reasonable to infer, that if there had been ^{originally existed} a natural, practicable continuous navigation from the sea to Pirapora, that the circumstances of the ^{upper} Valley, and of the people, both in their number and their habits would have been essentially different from their present condition. The Country in the interior would have been far more advanced, ^{in all respects,} and manufactories of various kinds would probably have been long ago introduced at numerous points.

An artificially improved navigation, in connection with a portage railway around the Paulo Affonso Falls, while it is of course not equal ^{to a navigable} river, with a very great improvement over the present disjointed and obstructed stream; and as such it is reasonable to infer that it will, in time, exert a powerful and beneficial influence upon the business and general welfare of the whole Valley.

Time, is mentioned as an element, because experience all over the world has shown that Peoples are slow to change long established manners and customs, even when the strongest inducements are presented. Nevertheless there are men of natural

energy and enterprise in some of the Commercial ports along the river, who will step forward and use their influence in encouraging such changes as will tend to increase general trade.

Looking at the Circumstances, it has seemed reasonable to assume, that at first, a weekly line of Steamers plying between Jatoba and Pirapora, and chiefly between Jatoba and Jammaia, (which is 298 Kilometers below Pirapora), each Steamboat towing two barges, will transport all the exports and imports that will offer for that particular mode of transportation.

If the Cargo each time, each way, should average 250 tons, the Annual imports would be 13,000 Tons and annual exports 13,000 "

And if the number of passengers, of all kinds, should average only 20 each time, each way, it would give 2080 upward, and 2080 downward, per annum.

According to experience elsewhere, the amount of tonnage and number of passengers would soon be largely more than the above; but those amounts are independent of the traffic that might still go on for a few years under the present system of Carreas and Canoes; and of course do not include the very much greater business that the improved ^{navigational} ~~system~~ will be the means of developing in the future.

It is not in my power to specify amounts of future trade and travel on this river. An

estimate of that kind must necessarily be largely conjectural. The circumstances are here fairly presented; and those who are ~~well~~ familiar with that portion ^{of the Country}, can judge what is likely to be the result of opening such an extensive Valley, by comparatively easy communication, to general Commerce.

In the estimated cost of improving the river, ^{in another part of this report,} there is an item of 90:000 \$ 000, for the first Steamboat, of the Class recommended to be used on the Upper river; ^{but it is probable that} ~~my impression is that~~ four other similar Steamboats ^{could} afterwards be placed on the Upper river at a cost of about 75:000 \$ 000 each, or 300:000 for the four. The total cost of the 5 being, according to this estimate, 390:000 \$ 000.

The barges, to carry about 100 ^{fully equipped, and with sails,} tons each, ^{may} cost about 10:000 \$ 000 each; and it would require at least twenty barges, possibly thirty, to do the business ^{in many cases barges, would hardly be expected to contain profits,} satisfactorily. ^{After the construction of such barges} should be understood along the river, their cost might be materially reduced; but for present calculations, and to be on the safe side, let it be assumed that the first cost of thirty barges will be 300:000 \$ 000; and that they will last ten years.

The life of a Steamboat may also be assumed, for present calculations, at ten years; although numerous Steamboats are known to last much longer.

The first cost of 5 Steamboats, say	390:000 \$ 000
" " " of 30 Barges	300:000 \$ 000
	<u>690:000 \$ 000</u>
Add 10 per cent. for Contingencies, Superintendence, etc.	69:000 \$ 000
	<u>759:000 \$ 000</u>
Annual Interest at 7 per cent.	53:130 \$ 000

Annual Expenses.

Interest, as above.	53:130/000
Repairs and renewal of 5 Steamboats	51: L

Annual Expenses

Interest as above	53:130\$000
Repairs and renewal of 5 Steamboats.	57:480\$000
" " " of 30 barges	33.300\$000
Running 5 Steamers 1 Year including Officers, hands, fuel, oil and all ordinary running expenses at 34:000 each.	170:000\$000
Running 30 barges 1 Year including Captain, 4 hands, and all ordinary running expenses at 7:300\$ each	<u>219:000\$000</u>
	<u>389:000\$000</u>
Old Annual Cost of general Superintended	40.000\$000
Estimate	Total yearly cost <u>566:910\$000</u>

If we assume that 20,000 Tons would be Carried (each way) half the length of the improved river, or 877 Kilometers, the result would be as follows:

$$\frac{566:910\$000}{40000} = 14\$175 \text{ - per ton}$$

It would be that is the Actual Cost, if all be charged to freight, ~~at~~ 14\$175 per ton, for the distance of 877 Kilometers.

This would be at the rate of only 16 reis per ton, per Kilometer.

If double that rate, or 32 reis per ton, per Kilometer, were charged, upon such assumed business, carried 877 Kilometers, it would of course afford a profit of 16 ^{per annum} reis per ton per Kilometer, and 566:910\$000 a aggregate profit. ~~Whatever might be charged upon freight, in the case assumed, would be a trade additional profit. It is not intended by this showing to recommend any particular rates of charge.~~

Business of such regularity, to the extent of 40,000 tons yearly, must not be anticipated for some years. Certainly nothing of the kind could be relied upon in the beginning, the calculations serve however to show the small, ^{actual} cost of transportation under such exceedingly favorable circumstances.

It is impossible to say, in advance, what the business will be, either as to its extent or its character, during the first years after the establishment of good navigation. Parties who might be inclined to enter ^{into} the Steamboat and barge carrying trade on this river, should of course make a special examination and careful study of all the surroundings, without relying wholly upon preliminary estimates of any one.

In case there were 10,000 tons, carried ^{each way} an average distance of 877 kilometers, with 3 steamboats and 18 barges, calculating in a similar manner, the actual cost per ton for the whole distance of 877 kilometers would be 15\$772, or 18^{reis} per ton per kilometer. This would be 113 reis per arroba, for 877 kilometers, ~~or per arroba per kilometer.~~

The service, with 3 steam^{boats} instead of 5, assuming 13 trips per annum to each steam^{boat}, between Jaboa and Pirapora, would be at intervals of 9¹/₂ days ~~between steam^{boats}~~ instead of 7 days; ^{respectively of the tonnage carried.} (Five steam^{boats} are allowed ^{in the first calculation} in order to keep 4 steam^{boats} steadily running.) No allowance of another steam^{boat} is made in the succeeding calculations in the case of 3 steamers. In strictness, another steam^{boat} should be kept on hand, to maintain 3 regularly running. That would add about 15,000 \$000 to the annual cost.

7 1/2

^{cost of transportation etc}
But, ^{of} ^{the} ^{value} of this 4th Steamship - which might come later. 7 1/2

The first cost of 3 steamboats say	225: 000 \$ 000
" " " of 18 barges "	180: 000 \$ 000
	<u>405: 000 \$ 000</u>

Add 10 per cent. for Contingencies, Superintendence, etc. 40: 500 \$ 000

Total first cost 445: 500 \$ 000
Annual interest, ^{of above} at 7 per cent. 31: 185 \$ 000

Annual Expenses.

Interest, as above, for 1 year.	31: 185 \$ 000
Repair and renewal of 3 steamboats,	30: 888 \$ 000
" " " of 18 barges	19: 980 \$ 000

Running 3 Steamers 1 year, including
Officers, hands, fuel, oil, and all
ordinary running expenses at
34: 000 \$ 000 each, 102: 000 \$ 000

Running 18 barges 1 year, including
Captain, 4 hands and all ordi-
nary expenses @ 7: 300 \$ each, 131: 400 \$ 000 233: 400 \$ 000

Estimated Total yearly cost 315: 453 \$ 000

Carrying 10,000 tons Carried each way 877 Kilometers
it would be
$$\frac{315: 453 \$ 000}{20,000 \text{ tons}} = 15 \$ 772 \frac{\text{per ton}}{\text{actual cost}}$$

That would be the actual cost, if all were charged upon the above freight. Double that rate, or 31 \$ 544 per ton would show a profit equal to the actual cost, or 315: 453 \$ 000 for 1 year.

This charge would be at the rate of 36 reis per ton per Kilometer. It would be 225 Reis per arroba for the distance of 877 Kilometers.

Cost of Transportation, etc.

The peculiar Circumstances of the São Francisco Valley render it rather difficult to prepare a very satisfactory estimate of the present population Contributory to the river trade, and its present amount.

Various estimates have been made at different periods of the population. Engineer Krauss, in 1869, offers an approximate estimate making a probable population of 300,000; which seems to have been too little. Engineer Halford's estimate of 1,500,000, embracing all the Upper waters, and without designating the extent included laterally seems to have been an over estimate, when referring it to river business. From the best information that the Commission could gather, it is considered to be about 520,000 in the immediate Valley of the São Francisco of inhabitants who may fairly be regarded as Contributory to the trade on the river. [See Table appended to ^{this report}]

Engineer Krauss's estimate of the probable amount of business, in the beginning, after the Completion of the improvements was 600,000 arrobas, each way, equivalent to 1,200,000 arrobas one way.

He estimated the yearly Cost of transportation on the river by Steamers of 40-horse power each, with 20 barges, as follows:

7 percent. on Cost of 5 Steamers (Cost 400:000\$000)	28:000\$000
15 " " " Same Capital, amortização renovações d'Embarcos.	60:000\$000
Combustivel, azúte, graxa, etc	100:000\$000
Tripulação	90:000\$000
Agências, Geraes e diversos.	42:000\$000
<u>R\$</u>	<u>320:000\$000</u>

Estimada Cost of transporting 9600 tons (2000 lbs.)
 per annum $\frac{1}{3}$ of the total distance, or 100 leagues
 per tonelada e league $\frac{320:000 \times 100}{9600 \times 100} = 330$ reis per ton

or per arroba 5 to 6 reis."

Dr. Krauss estimated the cost of transportation on the
 river at 11 reis per arroba per league, and by
 pack-animals by land from Joazeiro to Patria,
 about 120 leagues, at 2\$600.

And by pack animals from Vargem-Redonda
 to Piranhas at 900 reis per arroba

and by river from Piranhas to Penedo, at 100
 reis per arroba

Dr. ~~Krauss~~ estimated the cost between Joazeiro
 and Patria by the proposed railway at 1\$820 per
 arroba; and 5.5 reis per arroba per league on
 the river, and 20 reis per arroba for transshipment
 at Joazeiro.

Dr. ^{proposed} estimated the cost via the Paulo Affonso
 Railway as follows:

Penedo to Piranhas (river) per arroba	100 reis
Piranhas to Jatoba (railway) "	350 "
Transshipments at Piranhas and Jatoba	40 "
Cost in navigation of Upper River to Joazeiro	80 "
	<u>570 "</u>

Com mais 5.5 reis por league da navegacao a
 vapor alto no.

The question of the future Cost of Transportation
 in the São Francisco Valley is one of importance,
 and deserving the fullest investigation. To assist
 in its elucidation, the annexed Table, prepared
 by Dr. Krauss, Engenheiro, in 1869, and contained
 in his report, is here quoted.

Tabella de fretos para as differentes vias de
Comunicação relativas ao Alto S. Francisco
Calculados por arbo. -

	Distança da navegação no alto S. Francisco até a villa de S. Jeronymo. leguas	A Bahia		A Penedo		
		frete pela viação Actual	por via da estrada fomea Bahiana - em projecto -	frete pela viação Actual	pela carreira de Paulo Affonso - em projecto -	
Barra do rio das Velhas	242	5,262	3,151	311	4,421	2,280
Villa de S. Romão	217	4,987	3,074	286	4,146	2,143
da Jannaria	190	4,690	2,865	259	3,849	1,995
de Carinhonha	160	4,360	2,700	229	3,579	1,830
do Urubu	120	3,920	2,480	189	3,079	1,610
da Barra do Rio Grande	80	3,480	2,260	149	2,639	1,390
de Rique Rique	68	3,348	2,194	137	2,507	1,324
di Pilas Areado	50	3,150	2,095	119	2,309	1,225
Arriac de Remanro	36	2,996	2,018	105	2,155	1,148
Villa de Santa Sé	18	2,798	1,919	87	1,957	1,049
do Jozzeis	+ —	2,600	1,820	69	1,759	950
do Capim Grosso	17	2,787	1,913	52	1,572	856
da Boa Vista	21	2,831	1,936	48	1,528	834
do Cabrobo	36	2,996	2,018	33	1,363	752
Estacao Jatoba.	69	3,359	2,200	0	1,000	570

This table of the probable cost of transportation may not show what the actual cost in practice may ^{be}; but it shows the relative cost, under the circumstances named, according to the judgment of an intelligent engineer, independently of any reference to the Capital employed in constructing the respective works.

According to this Table the cost of transportation
of freight between Joazeiro and Bahia, by land Conveyance
as used in 1869 was 2\$600 per arroba, or per ton, ^(2,000 lbs.) 162\$500

And by the proposed railway between
Joazeiro and Bahia, 1\$820 per arroba, or per ton 113\$750

And between Joazeiro and Penedo, by
upper river to Vargem Redonda, pack-animals
to Piranhas, and lower river to Penedo

1\$459 per arroba, or per ton 108\$937

And also by improved river from Joazeiro
to Jatoba, Jatoba's rail to Piranhas, and
Piranhas to Penedo by lower river.

950 reis, or per ton 59\$375

The table also gives the Comparison of probable
Cost from the Barra do Rio das Velhas to Bahia,
and Penedo, respectively; as follows:

From Barra do Rio das Velhas to Bahia, in 1869, via
river and the usual route over land between
Joazeiro and Bahia

@ 5\$262 per arroba, or per ton, ^(2,000 lbs.) 328\$876

From Barra do Rio das Velhas to Penedo,
in 1869, by upper river to Vargem-Rodonda,
pack-animals to Piranhas, and lower river
to Penedo, 4\$421 per arroba, or per ton 276\$312

Also, ^{improved} by river, and proposed railway from
Joazeiro to Bahia 3\$157 per arroba, or per ton 196\$937

And by improved river, and proposed railway
between Jatoba and Piranhas.

2\$280 per arroba, or per ton 142\$500

672,000 arrobas, ^{one way,} @ 950 reis	638:400\$000
And if the same amount the other way	638:400\$000
	<u>1,376:800\$000</u>

Calling 45 per cent of this profit would give 619:560\$000

D^r Krauss called the distance, on river 69 leagues, on railway 23 leagues.

This amount of 619:560\$000, after paying the interest on original Capital (420:000\$000) would show a net balance of 198:560\$000

There was, however, another important Consideration for the people of the São Francisco Valley, relating to the two routes to the Coast which, ~~was~~ ^{are} thus compared.

According to the above showing from D ^r Krauss' table, the inhabitants of the Upper São Francisco Valley would be taxed annually upon the conveyance of 672,000 arrobas, each way, between the valley and the Coast, ^{by rail} between Itaperio and Bahia,	2,146:080\$000
or or, by River, to Jatoba, and Postage railway to Pirankas, and river to Penedas,	1,376:800\$000
Difference	<u>1,070:280\$000</u>

And with double of the above tonnage 1,344,000 arrobas each way the annual difference would be doubled or 2,140:560\$000

With greatly augmented ~~of~~ Annual traffic, the difference would be proportionally greater, because the cost, per arroba, on the river, would diminish more than it would on the railway.

The foregoing, and all such calculations can be no more than approximations, valuable when considering different methods proposed for the accommodation of the trade and travel of the São Francisco Valley.

At present the trade upon the Upper river, exclusive of the purely local traffic between the towns scattered along the river margin, chiefly the exchange of food-products, is quite limited; much less than usual among a like number of people elsewhere. The reasons for this have been stated; chief among which is the isolation of this valley, and the general contentment of the population long accustomed to a humble way of living. Until this shall be changed the demand for imported articles must continue limited; and time is required to change the primitive agricultural methods to more modern systems. That advancements will immediately begin upon the opening of convenient and cheap transportation facilities, there need be no doubt. Enterprising men will stir up the latent energies of the people, and arouse their ambition to equal others who live in more favored regions. Besides, there are populations at some distance from the river now having little or no business connection therewith, who, when it shall be opened to the coast, as proposed, will be encouraged to raise products for shipment, which they cannot now afford to do.

It is therefore proper to look forward to a future large increase of valley business; though it may be impracticable to assign precise periods of time, or exact amounts of trade and travel.

Probable Actual Cost of Transportation, etc.

The ^{probable} actual cost of transportation, here, as elsewhere, is controlled by the circumstances. If there is a regular supply, in large quantities, of easily-handled products the minimum price may be charged; but if the supply is irregular, in small quantities, and the products, are troublesome to handle, the maximum price may be charged.

In the particular case of this river, when it shall be improved, one of the questions is whether the interest on the cost of improving it is to be charged against the trade and travel on the improved river. Assuming that the cost, in round numbers is 750,000,000, interest at 7 per cent. would be 52,500,000 per annum. On 10,000 tons, or 700,000 arrobas, this would amount to 5,250 per ton, or 77 reis per arroba. On 20,000 tons, or 1,400,000 arrobas, it would amount to 2,625 per ton, or 38½ reis per arroba. And so, in proportion, for larger amounts of tonnage, the charge per ton and per arroba would decrease.

In case the government should improve the river at the cost of the government, it will of course be optional with the government whether to charge, or not, the interest of the ^{first} cost to the future river traffic.

In case private parties ^{should} be authorized to do the work and maintain the improvement ^{at their own cost,} it would of course be incumbent upon such parties to count the cost of the ^{river} improvement, and its maintenance, or its further improvement as part of the capital upon which the traffic should be charged, the same as for the cost of Steamboats, etc.

It is therefore obvious that the rate of charges for transportation on the river, ^{may} ~~will~~ depend, to the extent just shown, upon the manner in which the river shall be improved—whether by the government, or by authorized individuals at their own cost.

It is not presumable that the government will undertake to put on steamboats, ^{and barges} and conduct the ^{general} transportation on the river, by government employes, even in the event of their improvement of the river; (except, ^{in that case,} the furnishing of the two boats mentioned in the estimate of first cost.)

If the government ^{should} ~~should~~ elect, and if a Company or an individual shall undertake to do the work, and furnish all the necessary appliances and means to maintain the improvement and conduct the ^{future} business on the river, there would of course be an understanding between the government and such Company or individual defining ^{the} rates proper to be charged for transporting freight and passengers.

With regard to the point, whether a Company or an individual ^{be likely to} propose to undertake such a Contract, I have no information; but judging from what has taken place in various parts of the empire, it would seem to be quite possible, ~~that~~ if the government so desired, ^{that} parties might be willing to make tenders for the right to construct and maintain the improvement, ^{steamboats and barges,} with the right to charge certain limited rates for the service of carrying freight and passengers.

It will be seen from the foregoing presentation of the difference in the cost of transportation, under different specified circumstances, that the limit of rates ^{on the river} would have to be arranged with reference to the extent and kind of business to be accommodated,

Having special reference to the annual amount of the tonnage, and ^{the} number of passengers. And, as the business is not likely to jump suddenly from a comparatively small tonnage to a large tonnage, all of the ⁵ steamboats and ³⁰ barges referred to as necessary to ensure weekly trips, on the whole length of the navigation, should not be at once placed upon the river; since such a ^{premature} course would undoubtedly involve dead Capital, and loss.

It is to be borne in mind, that not all of the present tonnage along the river, now conveyed in barcas and Canoes, will become part of the freight of the ^{boat} steam and barge system; because much of it is local freight of provisions not of a kind likely to be shipped to the Sea Coast; and because for a few years ^{at least,} the trips of the steamboat line, ^{might} ~~would~~ not be frequent enough to warrant ^{the people in} dispensing entirely with the present Barca system.

The Railway Connection with River Business.

It so happens, that the river improvement and transportation on the improved navigation, must be considered in conjunction with transportation on the Portage Railway around the Paulo Affonso Falls; for, without the opening and use of that railway, it is somewhat questionable whether steamboat transportation on the upper river could be made profitable.

If the future business between the upper and lower river were to be confined, as now, to carriage by pack-animals, that ^{fact} would constitute almost a blockade. It would be ^{quite a} sufficient ^{drawback} to deter the manifestation of enterprise along the upper river; and very little public benefit would arise from the improvement of the navigation.

It is therefore taken for granted that the railway between Piranhas and Jabobá which is now well advanced, will be completed, and run in connection with the steamboat navigation on the Upper river.

Again; without an improved river, affording a steamboat navigation from Jabobá, the railway would be comparatively useless, since during a large portion of the year, and perhaps at all times, there would have to be a trans-shipment, from railway to mules, and *vice versa* at Jabobá.

It is therefore very clear that the railway and the ^{improved} river are mutually complementary; and that ^{the con-}struction of either without the other, would be more or less a wasteful expenditure.

Upon the railway 117 Kilometers in length, between Piranhas and Jabobá, it will be easy to transport all the freight and passengers for a very much larger traffic than any herein referred to. If there were no more than 250 tons, each way ^(one steamer & barges per week,) per week, a single locomotive could carry ^{the freight} by running 4 days ^{two days each way,} per week; one locomotive running from Piranhas to Jabobá one day, and returning the next, ~~making~~ making 3 trips a week, would have to take only $83\frac{1}{3}$ tons per trip, each way, to do it easily; and yet in a year this would amount to 13,000 tons each way, or in all, once over the road, ^{to} 26,000 tons; equal to 1,820,000 arrobas. Double this quantity, ^{or} 500 tons each way per week, would demand two locomotives making, each, 3 round trips per week; and a ^{boat} steam with 2 loaded barges starting and arriving semi-weekly at Jabobá, would ^{carry} ~~do~~ the same amount.

It is not intended by any of these calculations to assign limits to the trade likely to arise

upon the Completion of the two improvements, ^{of} the railway and navigation; they are much presented as aids in the study of the financial question involved.

Calling the railway 120 Kilometers long, a Charge of 100 reis per Kilometer, per ton, would be 12\$000 per ton, and 20,000 tons @ 12\$000 per ton amounts to 312\$000 per annum.

Fifty passengers each way per week, would give 2080 passengers each way per annum, or 4160, one way. 4160 passengers @ 6\$000 each, would be 24:960\$000; Making a year's receipts on the railway, upon the foregoing assumption, 336:960\$000

Although the Circumstances of the São Francisco river Valley are peculiar, they are not so peculiar as to prevent entirely the application of general experience throughout the world where improved lines of transit have been opened. Invariably, they ^{quately} alignment the amount of freight transportation and travel; and it is only reasonable to assume that a few years after the opening of the improvements under consideration, the business from the Upper São Francisco will be much more important than it is at present.

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Agriculture - Irrigation - Minerals - etc.

In the valley of the Upper São Francisco Agriculture is now carried on just as it was, ^{fifty and perhaps} a hundred years ago, and by the same kind of people.

Owing to the peculiar physical Characteristics of the Climate, and of the river, ~~and~~ the Comparative isolation from the rest of the Empire, and the want of a proper Commercial Connection with the outer world, there has been very little inducement to Change the ancient routine.

Only such Cultivation as could be easily Conducted without the aid of Modern improved implements of husbandry has therefore been introduced.

Farming, in the ordinary meaning of the term, is yet unknown; the hoe and the axe being still the only implements. Ploughs, harrows, rakes, reapers, wagons, barns, etc, which usually belong to farming in other Countries have not been introduced; nor could they be introduced with much advantage without a radical Change in the Customs of the inhabitants.

These Customs, long ago established, are partly the result of the manner in which this valley was first opened to Civilization by the Jesuit Fathers, but also, ^{very} largely, to the anomalous Climate, which obliged the people, (who knew nothing ^{regularly} of "farming") to depend almost wholly for their support upon the Cultivation, on a limited scale, of only those lands which are annually inundated by the river freshets, on the islands and immediate borders of the stream.

There can be no doubt that these dominating Circumstances have fixed the nature of the prevailing occupations and habits of a large proportion of the present inhabitants, chiefly descendants of the original Indian and succeeding negro

populations. The comparatively small number of Whites in the towns and upon the limited number of fazendas, while they have of course contributed to the adoption of civilized customs, have not materially changed the old system of cultivation.

By far the greater proportion of the products is raised upon numerous, very small river-plantations, each one generally managed by a single family. Sometimes there are several families or parts of families in one house; and there are many places along the river banks, on both sides, where there are hamlets of several houses, and often of a considerably greater number. These clusters ^{of houses} all have names; which make an imposing show upon the maps. There are besides many small towns, and some considerable villas and cities; so that the banks of the Upper São Francisco are occupied and cultivated by a large population, almost wholly engaged in agriculture.

Here and there a family has a rough ox-cart, mostly in or near the towns; but usually each has a canoe or two, in which they convey their small surplus productions to the nearest local river market, and which are also used in visiting neighbors and for general river traveling. Some have in addition a few cows, horses and mules.

These little plantations, although very numerous, are often not more than two hundred or three hundred meters long, and very narrow, being bounded laterally by the generally limited width of the yearly inundated slopes. Upon this small patches, after the subsidence of the floods, the usual products of the valley are raised. Following their gradual subsidence, the families plant Mandioca, corn, beans, sweet-potatoes, rice, onions, a variety of melons, squashes, pumpkins, etc, and in some

places sugar-Cane, tobacco, Cassia-oil beans, and a little Cotton. They Cultivate from the high-flood line down to low water mark. A distinguished traveler remarked, that ~~a~~ ^{the} luxuriant growth of vegetation extended down to the water's edge. So it does; but he omitted to mention, that the only vegetation is between high and low water mark.

A large share of these crops is Consumed by the families who raise them; the residue is sold, or exchanged for other articles, Coffee, tea, dry goods, etc, at the nearest town. What money there is, mostly finds its way to the Coffers of the Merchants, and river-traders; many of whom are also Merchants. The Crews and passengers on the Canoes and Boats that ply along the river, also buy some of the products to replenish their stock of provisions.

Nearly all of the numerous islands are Cultivated, most of them being subject to overflow annually; and it is common to find a number of temporary houses or huts on an island occupied by as many separate families, each working their own particular part. When the yearly floods invade their grounds on the islands the people retire, having as a rule previously gathered their Crops, and seek more elevated ^{ground} ~~land~~ on the main land, where they have other houses or huts. The houses in general are one-storied, ~~consisting~~ ^{with} of walls composed of sticks and Clay, and having natural floors of earth. They are without Chimneys, and have thatched or tiled roofs. The furniture is exceedingly simple and scanty; bedsteads are very rare, hammocks or mats on the ground-floor being in universal use. The climate being very mild, out-door sleeping is quite common. The people rise early and begin work, usually resting an hour or more during the heat of the day.

Men women and Children work in Cultivating their little plantations, and the women and Children also watch the growing Crops, sitting in very small temporary Shelters which shield them from the Sun. They are Compelled to guard against the depredations of Crows, Black-birds, Wood-hogs, and other destructive animals, and it is said, that even Canoe-men and barca hands passing on the river will bear watching - although they are punctilious, and opposed to being seen taking Melons.

One of the Occupations of the women is Knitting lace, by hand, ⁱⁿ which they are very skilful; they may be seen knitting while watching their Crops or tending ^{their} babies. Children are numerous, and they seem to thrive wonderfully with scarcely any Attention, Cultivation, or Clothing. Grand-parents, their Children, and grand-Children are often found in the same diminutive house; and some times the great grand parents also.

Along some portions of the Valley the soil on and near the river banks contains considerable quantities of saline particles. Here the manufacture of salt occupies part of the time of the family, who dig the material, leach it in ox-hides, or rough boxes, and then evaporate the liquid by boiling, and gather the salt. The process is very crude and the salt is coarse and inferior to the imported article; but its manufacture is one of the industries, and although in most cases it is on a small scale in the aggregate a considerable quantity is produced; not, however, enough for the general consumption of the valley; so that many of the planters, large and small, buy more or less imported salt. The imported salt has been

delivered in Piranhas from vessels, and Carried by pack-trains to the Upper river, and shipped in Barcas or Cajunjs at Atalho, or at Cabrobó, for places further up the Valley. The general movement of Salt is up the river; while the general movement of the rapadura, or the Coane Sugar-Cakes, is down the river, ^{sent} chiefly from the tributaries. The Salt is for the Cattle and other stock, and for salting meat, and fish. Salt has also formed part of the imputations from Bahia, sent overland in pack-train, a distance of five hundred kilometers to Joazeiro, and shipped thence along the river. The movement of salt and Sugar-Cakes forms a considerable portion of the river Commerce resulting from the agricultural labors of the people of the Valley.

The sites of the comparatively few large fazendas in the immediate river valley have been selected as the most favorable for working plantations on a large scale, with slave-labor. They usually command a considerable extent of cultivated land along the river, ^{or} on islands conveniently accessible; but there are ^{very few} no considerable fazendas on the upper river for a long distance above the Paulo Afonso Falls. Food products for consumption in the valley are the present staples of these fazendas. To the question why they did not raise more, for shipment out of the valley, the answer was, that, owing to the great cost of transportation they could not afford to send their products to an outside market.

Pottery, on a small scale, is carried on in some parts of the valley; and there is an abundance of excellent clay which shows itself in numerous places along the river banks. It is of various colors, red, white, yellow, etc, and of different qualities, some very fine; but as in the case of

other products of the valley, the sales are confined to the Valley.

Tanning is one of the industries of the Valley; but it has only been introduced to a ^{very} limited extent, for the reason already assigned. With cheapened transportation the business may be extended. The manufacture of a peculiar leather hat has been started in the Villa of Parra Grande; but generally the leather hats, and coats, etc, worn commonly by the people are made all along the river. Shoe-making is also one of the industries; but a large proportion of the every-day protection for the feet is made by the people themselves, being simply cut from sole-leather and formed into sandals. Bare feet predominate everywhere.

There are stores in every town and villa, where dry-goods, hard-ware, and provisions are sold. They are generally quite small. In most of the towns weekly fairs are held. They are attended by the people who come from various points on the river in canoes and barcas, loaded chiefly with food-products; some come in from their plantations on horse-back. Carriages, for the conveyance of persons, are unknown, even in the largest cities on the river.

Everywhere the streets, as a rule, are unpaved, and sandy, like the soil around ^{the villas and} the cities.

In every one there are, comparatively, few well-to-do people, government or provincial officers, and merchants, with an occasional physician; but the large ^{majority of the inhabitants} are quite poor, with very humble wants, easily supplied, who have never known the use of luxuries, and who have not the means to purchase them. We met respectable, decently dressed women, past middle-age, who had never previously seen their faces in a looking-glass.

Unless, therefore, some new system shall be introduced, it would seem to be very improbable that a sudden, large increased demand for imported articles can arise; or that there will be an immediate growth of a great Commerce from the shipment of such products as will bear transportation to distant outside markets. Time will be required to revolutionize the fixed habits of a whole people. At present the major part of the labor of the inhabitants seems to be devoted to the sustenance of the people now living in the Valley; and the addition of any number of the same Class of Cultivators, working and living in a similar way, would add but little to the imports or exports.

There is one way in which it may be possible to augment the merchantable production of the immediate Rio Valley; namely, by the introduction of artificial irrigation, on such portions as have a good soil, where the natural moisture is at present insufficient to warrant an attempt at Cultivation.

Irrigation, has been proposed or suggested at various times by different writers; though it has never been fully tried in the São Francisco Valley. The proposition, to "irrigate," may at first view seem very simple; but when considered practically it will be seen that it is complex, in this Valley.

While it is true that there is much land with good soil, in some parts of the Valley, which if irrigated would yield abundant crops, it is also true that a great deal of the soil is too sandy and stony to be worth irrigating.

All of the land that needs irrigation lies above the level of river floods. In some places it is nearly level, in other places it is gently rising, while ⁱⁿ others it rises rapidly on the foot hills bordering the river. It may be considered that all of that part of the valley that is ^{low enough to be} annually flooded by the river, does not need artificial irrigation; though at times it becomes very dry, for, with proper management the crop can be gathered before the drought could seriously injure it. Along the lower half of the valley of the upper river, a large proportion of new cultivable land is now, ^{as it has been for years,} occupied and cultivated. On the upper half there are larger bodies of cultivable low lands, not yet cultivated; some of them being too slightly elevated above ~~the~~ ordinary low water to be very desirable. There is an uncertainty as to securing the crops upon such lands, ^{since} they are the first to be flooded, and the last to be free from the waters, ready for planting.

Farms, such as are common in Europe and in the United States, do not exist anywhere in the valley. There are only plantations; ^{a few} large, and numerous small ones, as already described.

It is not practicable to change these plantations, which are wholly dependent upon annual inundations from the river floods, into ordinary farms.

It is to be considered that a large population, depending for their existence upon the crops which these lands produce, already occupy and till them. So that any ^{sudden} considerable accession of new corners

would be awkward on account of the difficulty of securing sufficient arable land upon which the additional population could support themselves during the period required to establish artificial irrigation upon the dry lands.

Before such irrigation should be introduced in any part of the Valley, it would be necessary to make regular surveys of the particular region proposed to be irrigated, whether on a small or on a large scale.

The water must be either pumped up from the river, or conducted from it through Canals. Along this river such Canals, constructed so as to be secure from injury from the floods, would be very costly on account of the great rise of the freshets - often ten meters, and sometimes thirteen meters. Such Canals should only be thought of in connection with irrigation on a grand scale, and nothing short of careful surveys, having this particular object in view, and conducted by men of ^{important} intelligence and experience, could decide upon the ^{advisability of} ~~possibility~~ of their adoption. For private enterprise the plan of irrigating by means of Canals taking the water directly from the river without pumping would be altogether too expensive. Pumping up water into small irrigating Canals or ditches, would be the only feasible plan ordinarily.

In any case, careful surveys should be made in advance, from which it could be ascertained, how much good land could be irrigated at or near a given point, the cost of the necessary irrigating works - pumps and fixtures at the river, pipes, and the small irrigating Canals or ditches, and the cost of their ^{annual} maintenance, the amount of crops to be

Calculated upon, the Cost of their transportation to a market, and the Cash value of the probable sales. Unless a handsome profit could be reasonably assumed it might be difficult to obtain the requisite Capital for works upon a considerable scale.

On a small scale, such as individuals, ~~gaining~~ ^{gaining} small tracts, might irrigate, wind-mills would doubtless be the most economical power to be employed; the pumps being arranged to pump during the lowest stage of the river, which occurs during the dry period, when irrigation is most needed; though more or less pumping would be required at all stages.

It may be deemed certain that no system of irrigation on the Upper river, on any scale, large or small, will be undertaken so long as the stream ^{remains} in its present natural state, without improvement. The people living in the valley have conformed their methods of work, and their manner of living, to the circumstances of the river, and the climate, and the soil - following literally in the footsteps of their progenitors; so that unless new and important elements are introduced, there will be no change, unless it may be a slow, gradual change, involving the advent of another generation.

Only upon the assumption of an improved river, opening a real highway, and cheapening transportation, and encouraging additional cultivation, is it at all worth while to consider artificial irrigation in the São Francisco Valley as an element of any importance to its agriculture; but with an

improved river, giving this valley outside markets,
much may be accomplished by improved methods
of cultivation, and by selecting particular crops
which may be most profitably shipped.
Irrigation may follow, in due time.

Mineral resources, etc.

The natural mineral wealth of the Valley of the São Francisco remains to day as Nature left it. Although there has been a large population residing along the river for more than a Century, the Circumstances heretofore mentioned have not tended toward the development its mineral resources. With the exception of the manufacture of lime, on a limited scale and of salt from the saline earths there has been no attempt to utilize the wealth beneath the soil. Yet it is known that there are valuable deposits of excellent iron-ore, and there may be other valuable ores hidden in the recesses of the numerous unexplored mountains of an extensive region, Concerning which so little is known.

Professor Derby, an experienced geologist, who has for some years been studying the geology of the interior of Brazil, accompanied the Commission from the mouth of the river to the Falls of Pirapora. He embraced every opportunity to examine the immediate valley, being aided in his labors by the Commission, so far as could be without delaying its general progress up the river. His report may properly be regarded as part of the work of the Commission. It shows that the visible resources, other than agricultural, of the main valley explored by the Commission, and of the Valley of the Das Velhas, traversed by Professor Derby, from its junction with that of the São Francisco, ^{on the route} ~~to~~ ^{to} Diamantina to Barbacena, are very important.

Derby.

Yet the examinations made in 1879-80, added to the information derived from previous explorations, cover but a narrow zone, chiefly those portions in view of the immediate river valley. Some lateral explorations have been made affording a partial knowledge of the geological features of the plateaus and mountains, but there remains a vast unexplored region which may contain mineral deposits of great value. It is not impossible that coal suitable for fuel may be discovered, which, added to the other natural resources, would greatly enhance the commercial value of the valley. It would then be merely a question of time when its mineral wealth would be developed and utilized, when the Valley of the São Francisco, ^{should} ~~may~~ become the seat of extensive industries which cannot at present be undertaken with profit. The iron-ores on the Upper São Francisco are of a superior quality, and at several points they are known to exist in large quantities, but there is not sufficient timber, fit for coating, in their immediate neighborhood, nor has coal yet been found. Without an improved river, these great ^{iron-}ore deposits, and other analogous deposits that may exist in the numerous mountains, must remain undeveloped and useless; for even if to day there were opened and in use railways to the coast, the distance of railway transportation, more than five hundred kilometers, would be a bar against the investment of capital needed to work such mines, ^{as well as} ~~more~~ against the investment of capital in iron-works in the valley, unless upon a comparatively small scale for the supply of the valley and the interior. At present the consumption of iron, ^{compared with the population,} is quite insignificant; and it cannot be large without an essential change in the general business of the valley; which is not at all likely to take place until the river shall be improved.

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General Industries.

As yet, excluding sugar-making, there are no considerable manufacturing industries in the São Francisco Valley; nor is it at present an inviting field for the investment of Capital in the direction of new industries, for the reasons already assigned, and which must be obvious to those who have intelligently studied the Condition of the Country and the Character of the occupations and habits of the inhabitants.

On the other hand, with an improved navigation, extending its Commercial advantages throughout the entire length of this extensive Valley, starting currents of trade and travel which do not now exist, it will be contrary to general experience elsewhere if the effect shall not be to modify the habits, and augment the Commercial wants of the people, who, up to this time, have been secluded, actually out of the range of the general advance that has been and is going on in other parts of Brazil. There are regions in the United States which ten years ago were considered too sterile and forbidding to promise any local traffic, which already afford an amount of local trade and travel, arising from the transportation of iron-ores, silver-ores, limestone, lime, wood, coal, provisions, merchandise and passengers, fully equal to the large through business. ^{Excellent} ~~Spacious~~ marble, sand-stone, and granites, for building, and superior limestone for the manufacture of lime, are found at various points in the Valley.

Education, to some extent, ^{through} on a very moderate scale, is now going on in the more important towns in the river, and ^{abolished} in the course of many years its good

(16) (67)
effects will spread and become apparent; but it is a
slow movement, in which the great majority of the
people cannot directly join; but when this
region shall be unlocked, by means of a
reliable navigation; when it shall be opened
for the passage of steamboats, making frequent,
and perhaps in a reasonable time, daily
visits to the numerous ports, an impetus will
be given to popular education which will hasten
the day when the general population, ^{new} may rank
with the other more advanced population of Brazil.
Miracles should not be promised, or looked for; time is an
element in all such changes.

Directions

For making the final explorations, ^{etc.} of the Rapids of the São Francisco River, for the selection of Channels to be improved.

1. It is necessary to have a small, light-draft steamboat, which when equipped, with wood and water on board, should not draw more than about 0.40^m, and which should have sufficient power to stem a current of twelve kilometers per hour.
2. The object is, to find a natural channel among the rapids, (if one exists,) at a given rapid, which may be sufficient for steamboats and barges drawing one meter, during extreme low water; such channel to be not less than 30 meters wide in the narrowest place, and not less than 1.25 meters deep in the shallowest part. The channel to be so shaped that a steamboat 40 meters long, with two barges in tow, could, ^{safely} make the turns.
If it be found that such a channel can be obtained at a given rapid by blowing up and removing a few rock obstructions,

it may be better to select that one in preference to ~~an other~~ ^{an other} requiring closing of outlets, and cribs or rip-rap embankments, ^{or chutes,} for artificially augmenting the depth.

Where there may be a choice between the two methods, the selection of the one to be improved will be a matter of judgment, and calculation of cost, ^{etc.} by the engineer in charge.

In either case, after the selection is made, the work required to be done should be shown on a map, on a large scale, whether there be rock obstructions to be removed, outlets to be closed, cribs or rip-rap embankments to be made, or chutes to be constructed.

3. ~~The fact that~~ ^{on this river} a natural channel may have a very irregular, rocky bottom, and ragged, rocky sides, and yet be a good steamboat channel, if it has sufficient depth, and ^{if} the turns are not too sudden. In fact, if the declivity be considerable, the friction caused by the above mentioned irregularities, may materially reduce the velocity of the current and improve its navigation. Such channels can only be properly examined by the use of a steamboat.

4. An improved channel, 30 ~~metres~~ ^{metres} wide, two metres deep, having a velocity of 10 ^{to 11} kilometres per hour, or say ^{about} 3 metres per second, would

$50 \times 2 = 60$
 $60 \times 2 = 120$
180
72
252

180
45
225

require a flow of about ¹⁸⁰ ~~120~~ cubic meters per second;
and allowing 25 per cent. for waste through the
Crib or rap-rap banks, ^{the provision would be} ~~150~~ ²²⁵ cubic meters per second.

It is ^{here} not proposed, nor is it necessary, to treat this
point with accuracy; but merely to keep in mind,
approximately, ^{possible} the general requirement.

5. There may be cases when there is ^{already} a chan-
nel of good width, ^{or nearly free} free from rock obstructions,
~~(or ^{with} very little obstructions)~~ but too shallow
for the assumed navigation; needing ^{chiefly} ~~only~~ a
little additional depth of water. ^{sufficient} If additional
water can be admitted into such channel by
a Crib or rap-rap jetty at the head ^{of the island}, that mode
may be preferable; and no other work, or very
little other work ^{than} may be necessary.

6. In the case of the Sobradinho rapids, ^{for example,} the
examinations made by the Hydraulic Commission
in 1879, showed, that the proper plan for that
series of rapids, is the improvement of the channel
on the Pernambuco side; ^{though} ~~but~~ it will require
more careful examination, in detail, to determine
the ^{places and the} precise extent of the works needed. A jetty,
or projecting crib or mound of rap-rap at the
upper point of the Island of Cachoeira, will probably
be found necessary to secure an adequate quantity
of water to create sufficient low-water depths, in

4

the upper portion of the Channel. Small works of cribs or riprap banks, at the shallow points farther down, ^{by} Concentrating the natural low-water flow, may so increase the depth ^{at those places} that but little additional water may be needed at the head. In that case, the jetty would be skated accordingly, and the Cost of improvement ^{would be} lessened. It would be time lost if it were spent in making ^{further} examinations with the view of Constructing a steamboat Channel on the ^{outside of} Bahia side of the island of Cachoeira.

7. In the Case of the Series of rapids terminating with the "Vao", the examinations of the Hydraulic Commission in 1879, have shown, that there is a choice of routes on the Upper portion of the Series; while on the lower portion, the Pernambuco side is undoubtedly the proper side to be improved.

In case the Pernambuco side ^{along the upper part,} should be found generally preferable ^{either of} to the river Channels now commonly navigated, it will be necessary to build a jetty, or crib or riprap mound at the upper point of the ^{of Cuite} island, in order to throw more water ^{from the main river} into the comparatively narrow Channel between the island and the Pernambuco side.

There are five ^{along the island Cuite} small, local rapids, ^{at which} in this arm of the river, ~~where~~ some work will be necessary; where, by building low dams and ^{short} low Chutes, ~~some~~ navigable Channels may be made, needing only a little clearing of rocks, ^{and gravel,} and the additional flow of water from the head, to make a good Steamboat navigation.

The future final examination of the "river routes" from a point opposite Rodellas down to where the main river channels bear over to the Pernambuco shore, should be made with particular care, not only in order to secure an advantageous low water route but to be certain that the Channel will be safe in higher stages of the river.

Below where the river routes strike the Pernambuco side at the foot of the Island Cuati, the Channel to be improved will be common to all routes from above, and nearly the same amount of work will be required below in either case. The work below the Island Cuati will consist of the clearing of the outlets between islands to prevent waste of water, and the concentration of a larger flow in one Channel, and at several points - especially at the Vao, its further concentration by low dams and chutes in said ^{single} Channel.

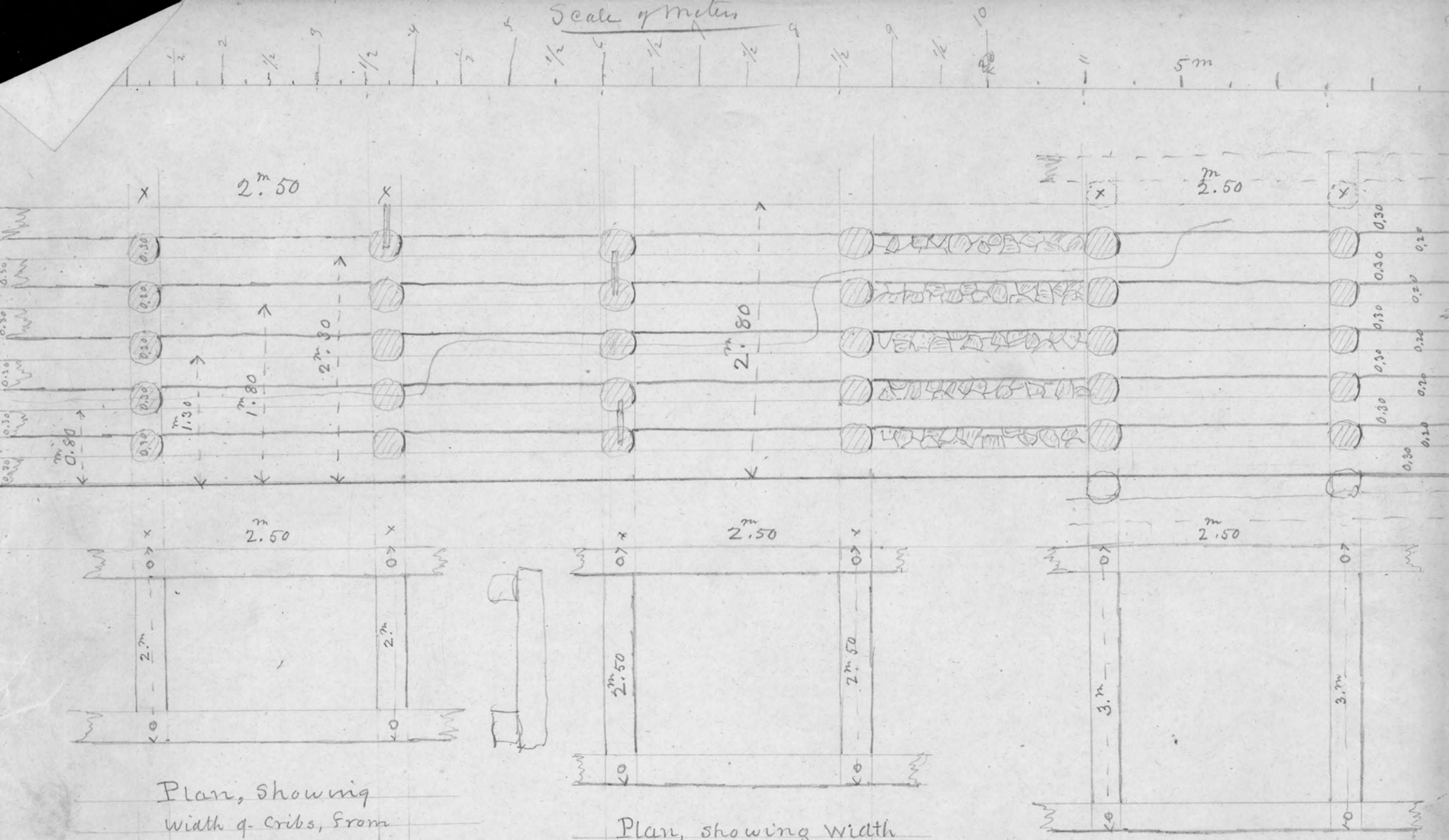
From the examinations already made it seems probable that the route on the Pernambuco side all the way from the head of the island of Cuati to the Vao, may prove safer than any outside Channel for all stages of the river; but this point cannot be settled until thorough examinations shall be made and the different routes are carefully mapped, and ^{etc} compared and compared.

8. While making the examinations with the Steamboat, it would be advantageous to have some practical man in charge of the boat who has had experience in running Steamboats on Swift rivers; on two accounts: first, to ensure safety in the management during the examinations,

(6)
and next to assist by his judgment in deciding respecting the probable safety of proposed Channels, in different stages of the river.

9. In regard to the general Conduct of the examinations, preliminary arrangements, preparation of the bills of materials, Contracts, etc; much will depend upon the manner in which the river improvement is to be carried out— whether directly, by the Government, or by a Contractor acting under Government supervision, or by a ^{Contract}Concessionaire.

It is not therefore considered necessary to enter further into detail at present.



Plan, showing width of cribs, from 0.80 to 2.30 high

Plan, showing width of cribs - from 2.80 to 3.80 high

Plan, showing width of cribs - from 4.30 to 5.30 high

Directions for making the drawings.

Separate drawings may be made, showing cribs of 0.80, 1.30, 1.80, 2.30, 2.80, 3.30, 3.80, 4.30, 4.80, and 5.30; though these may be several on the same sheet

Almost any length of timber will answer, as they may be "butted" any where between the cross-ties - or "spliced" on the cross-ties.

Drawings - all on one sheet, be made showing the sections of rap banks 2 meters wide on top - up slope $1\frac{1}{2}$ to 1 - down stream slope 2 to 1. At heights of 1m, 1.5m, 2m and 3m. It is not probable that rap banks exceeding 3 meters in height will be made any where.

Sketch

From which to make drawings showing the shape and size of cribs to be used in certain cases for preventing the flow of water out of channels, and in other cases for guiding an additional flow of water into channels.

Similar cribs are to be used for forming artificial chutes, in a few cases, where it may be found desirable to confine the water to a limited width, and to increase the natural length of the low-water slope.

It is contemplated that generally the cribs for preventing the outflow from channels will be quite low - ranging from 0.80 to 2.30 high, requiring a width of 2m.

Although a width of 3 meters is prescribed for cribs from 4.30 to 5.30 high, it is known that there can be very little of that height required. The only cases where it is possible is at the heads of islands for guiding additional flow of water into the channel to be improved.

The timber in the cribs may be of any ordinary sound wood of the country. It may be undressed, except notching of the cross-ties. The ties and longitudinal sticks, to be pinned together with 2-inch iron nails (wooden pins about 0.05 diameter ^{about} 0.50 long. No iron is needed. The timber should be about 0.30 in diameter; but accuracy is not at all necessary.

Although the drawings represent 0.30 for the height of the longitudinal timbers, 0.20 for the width of the spaces a little variation either way is of no consequence.

It will be a matter of convenience (and calculation) on a final examination of particular Cachoeiras whether cribs, filled with rough stone will be used; or simple rap-banks of rough stone dropped in, from scows; or any particular plan

It will be understood that there will be but two kinds of work upon the improvements of the Cachoeiras; namely rough timber cribs filled with stone, or gravel, and rip-rap embankments of rough stone.

- 1st For diverting water from the main river, or from side Channels, into the Channel to be improved.
- 2^d For stopping natural outlets, to prevent waste of water from the Channel to be improved.
- 3^d For forming Chutes or guides to limit the width of the Channel, or to augment the depth and lengthen the slope to diminish the velocity of the current.

The cost of timber along the Cachoeiras is greater proportionally, than the cost of stone, so that rip-rap banks, whenever the circumstances admit of them will be used in preference to the cribs.

Most of the work will be quarrying, delimiting rough stone, and dropping it from scows to form the ^{rip-rap} banks.

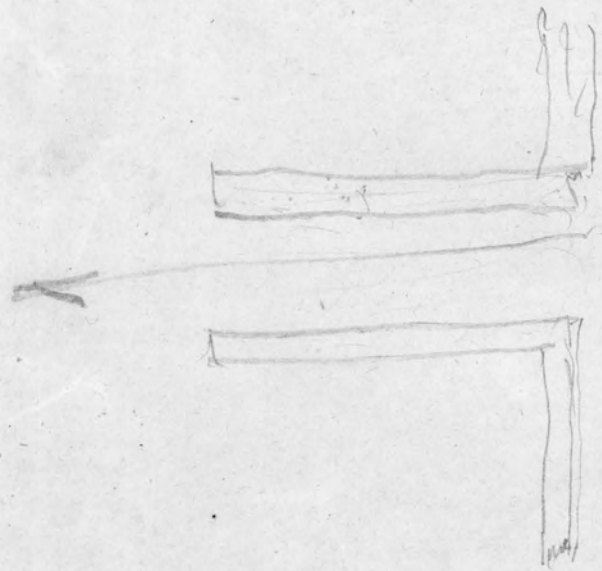
Only the simplest mechanical skill is required, except in the case of the removal of sub-merged rocks, where a few men specially skilled, would be needed.

Costly methods of saving water, such as might be necessary on a river of small volume, are not needed here, because there is an abundant flow of water at all times, and the leakage that may pass through the cribs and banks will not materially affect the navigation.

The cribs and banks need not be raised much above the low water surface, because when the river rises it must be allowed to flow freely over them; which will of course thus increase the depth in the channel.

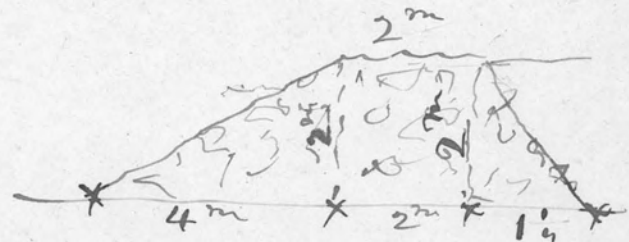
In some cases, where the stone from the quarries may be very large, it may be found advisable to drop smaller stone, or coarse gravel on the up stream side of the rip-rap banks, and thus lessen the waste of water.

No great pressure of water will come upon any of the cribs or rip-rap banks; ~~because~~ ^{as} the difference of level of the surface of the water on the two sides will be trifling in most cases, and no where very considerable.





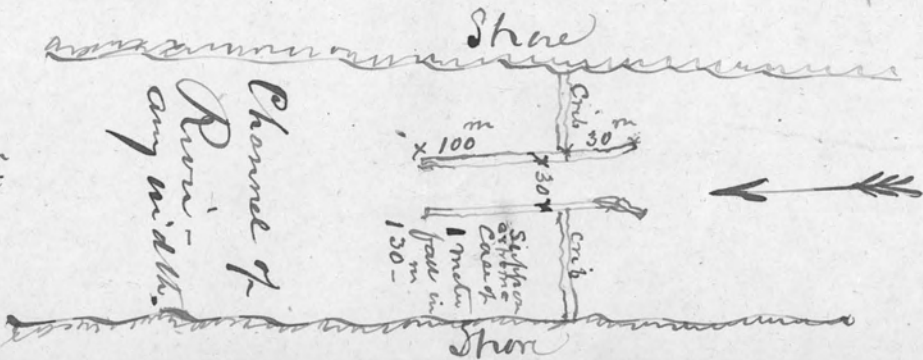
Sketch of Orb-dam - across an
 outl. of irregular bottom -
 Or. of a rough-stone embankment - as the case may be.



Rough-Stone
Embankment, or mound.
 2 meters wide on top
 Up-stream Slope $1\frac{1}{4}$ to 1
 Down-Stream 2 to 1 .
 Approximately.

200 meters width
 of river channel,
 on arms of river
 may be crossed.

Section.



Shore
 Channel of
 River -
 any width.
 100 m
 30 m
 30 m
 150 m
 1 meter
 150 m
 Shore
 Section
 Case of
 150 m

Memorandum to
accompany sketch
of the Sobradinho
Channel.

Cachoeira da Sobradinho.

The general plan proposed for the improvement of the Channel between the Alta da Cachoeira and the Pomaralco shore, includes the construction of a Jetty (of crib and riprap) at the head of the island to draw a large additional quantity of water from the main river into this Channel.

This will be the principal work; the additional depth of water to be created by this Jetty will render it unnecessary to do ^{any} ~~the~~ large amount of work between the head and foot of the island. All that will be needed ^{being} ~~is~~ some small, ^{rip rap} partial dams and low Chutes to concentrate the flow, and the removal of a few rocks, to make a safe Steamboat navigation. It is evident from the soundings, that an increase of less than half a meter in the depth of the flow, will require only a moderate amount of work along the Channel to create a minimum depth of $1\frac{1}{4}$ meters. We took seven hundred soundings, in the distance of about seven ^{or more} kilometers, ^(from $1\frac{1}{2}$ to 2 or more meters.) in this Channel. All except 98 were over 1 meter; 85 were 1 meter; 8 were $\frac{3}{4}$ meter; and 5 were $\frac{1}{2}$ meter, for very short distances; and some of these were out of the ^{barca} Channel.

This arm or Channel ^{of the river} is from 90 to 150 meters wide, generally about ^{to 110} 100 meters wide; free from sharp bends between the banks; although some of the ~~natural~~ natural low water Channels, for barcas and Canoes, present sharp turns. These ^{turns} can be avoided in the arrangement of the Chutes. There is not ~~at any time~~ in any stage of the water a current strong enough to occasion difficulty to Steamboat-towing, up this Channel; so that even now, without any improvement, with a small pump raising the water one meter, a Steamboat could navigate it.