INTRODUCTORY REPORT

ON THE

PAPANASAM HYDRO-ELECTRIC DEVELOPMENT

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THE PAPANASAM HYDRO-ELECTRIC DEVELOPMENT

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WITH

TABLES, PLANS, CHARTS AND ESTIMATES.

April 1928.

THE PAPANASAM HYDRO-ELECTRIC DEVELOPMENT

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THE PAPANASAM HYDRO-ELECTRIC DEVELOPMENT

SECTION 1—INTRODUCTORY REPORT.

In accordance with instructions from Government the possibilities of developing power from the Tambraparni River have been examined and the general conclusions arrived at are as follows.

The Tambraparni is a perennial stream, but the flow during the dry months of the year is insignificant. To ensure a continuous power supply, water must be stored.

The available head—335 feet—is very low, necessitating a large storage capacity in order to ensure a comparatively small, continuous power supply. The cost of storage per unit is thus high. For instance, the water required at Papanasam to develop a certain amount of power is nearly ten times that needed at Pykara for an equivalent amount.

The project was also carefully studied with a view to diverting the river into an adjoining catchment, and obtaining a higher head, but no feasible scheme was found possible.

The only power demand which is reasonably assured at present is about 6,300 KW. to be used in a proposed factory for the manufacture of paper from 'eta' bamboo. There is in addition a promising potential power market around Tuticorin, Tinnevelly, Kovilpatti and Sattur. This market would, however, require time to develop, and it is essential during the development period that sufficient revenue is obtained to cover, at least, all operating charges, if the scheme is to be classed as commercially feasible.

A possible large power consumer is Messrs. A. & F. Harvey, but they cannot be relied upon to take power at the outset. At present this firm is operating two mills in the districts under review ; one at Papanasam requiring a maximum of 1,100 horse-power, and another at Tuticorin with some 2,000 horse-power installed. The power at Papanasam is obtained from the Tambraparni River, and developed by two impulse wheels. The machinery is of old design and low efficiency. This, however, is of little consequence, as the lease grants them the right, with certain reservations, to take as much water from the river as needed. The lease was extended in 1927 for fourteen years, the annual payment being twelve annas per spindle, which amounts to about Rs. 26,000 per year. The operation and maintenance expenses of this plant are very low, while it is quite probable that the original capital outlay has already been written off. Power is thus costing them not more than Rs. 30 per horse-power year. Assuming a working year of 3,000 hours, a KWH. costs about 0·20 anna. Government could not possibly compete with such low costs. The water rights now held by Messrs. Harvey might be strictly determined according to a clause in the 1913 agreement, which allows ten cusecs from February to May and twenty cusecs from June to January. These rights might be transferred to Government, who in return would guarantee the equivalent in electric power at the present rate, up to the expiration of the lease, when a new contract could be made. Any power demand in excess of this amount would be paid for at the normal rate. Due to the difference in the over-all efficiencies of the industrial plant, and the main generating station, also in the heads of the respective installations, about 30 per cent more power could be developed in the main plant for the same amount of water. This, however, would not be of much advantage during the first few years of operation, as the extra water would only be needed during the dry months. Again Messrs. Harvey are not likely to go to the expense of electrifying the mill unless further inducements are offered them. Government, on the other hand, would be supplying a block of power below cost and may not care to further handicap the scheme by bearing all or part of the cost of this electrification. An interpretation of the original agreement reserves to Government the power to take over this supply for public requirements, and the Government of Madras are constituted the judges as to whether public requirements demand the stoppage of the supply. It thus appears as if the lease could be legally revoked at any time, but it is presumed that the present agreement will be respected until its expiration. A possible solution would be a comprehensive power contract, at an attractive rate, embracing the mills of Messrs. Harvey at Papanasam, Tuticorin and Madura.

There is also the possibility of a seasonal power supply, which is discussed later. Meanwhile the revenue obtained from the water rights under discussion must be credited to the Papanasam Power Project, if developed. Regular and careful measurements of the supply of water to the factory must also be made.

Referring again to the proposed Paper Mills, the process of extracting pulp from 'eta' bamboo is entirely new, and may be considered somewhat experimental. It is also well known that, for any pulp mill to be a commercial success, the cost of power has to be very low if, in addition to the motor drive, all heating is to be done by electric energy.

In order, therefore, to be assured of this load it is clear that Government must be prepared to treat it as a special case, and fix a tariff below the normal industrial rate. The fact that it is a new industry, and that the Forest Department will derive a certain benefit, must not be lost sight of. From correspondence and conversations with Mr. Webb of Messrs. Boving & Co., who has studied the question from the manufacturer's point of view, a figure of Rs. 50 per KW. per year has been mentioned as the maximum rate for power. The load factor assumed is 85 per cent. At this rate the cost of power is 0·107 anna per KWH. This would cover operating costs, and a normal depreciation contribution, and return about 3·2 per cent on the investment; so unless Government were prepared to subsidize the industry, such a rate could not be considered.

The whole development has been carefully studied from all angles, and the writer has satisfied himself that such a small amount of power cannot be developed, on a commercially paying basis, at these low rates, if the works are constructed according to reasonably sound designs and specifications. The problem therefore resolves itself into finding out the lowest possible rate at which power can be offered to the Paper Mills, and the question of seasonal power naturally arises. The estimates can be considerably reduced, if no storage, beyond a reasonable pondage, has to be provided. An examination of table V on page 20 shows that, for an average year, the flow is sufficient to generate over 6,300 KW. for eight and a half months in the year, while from 1,070 to 3,440 KW. is available for the remaining part of the year. These figures represent continuous power and, as the Paper Mill load factor would hardly reach 100 per cent and sufficient pondage would be available, the above figures could be increased accordingly.

For the minimum year—which can be expected once in twenty years—the results are less satisfactory.

The estimated cost of a power development to utilize the seasonal flow of the river is Rs. 50,53,000. This will be called Scheme (*a*), and under this scheme it is proposed to offer the Paper Mills seasonal power up to 6,300 KW. for a fixed payment of Rs. 4,33,920 per year. This amount just covers operation and maintenance charges, reasonable depreciation, and interest at 6 per cent. If the actual cost of construction is less than the estimate or the rate of interest is reduced to the normal Government rate, then the annual charge for power will be proportionally reduced. This proposal is advanced in the hope that the paper interests, after a study of table V, may find an economic solution by taking seasonal load, and using oil or coal fired boilers during the dry months. The possibility of creating a demand for seasonal load in Tuticorin and Tinnevelly is discussed in another part of this report.

Scheme (*b*) contemplates a continuous power supply to the Paper Mills up to 6,300 KW., and the transmission and distribution of power to Tuticorin, Tinnevelly, Kovilpatti and Sattur. The estimated cost of this scheme is Rs. 98,56,300 in the first year rising to Rs. 1,38,54,300 in the fifth. It is proposed to offer continuous power supply to the Paper Mills installation of 6,300 KW. for a fixed payment of Rs. 4,80,000 per year; the reservations regarding lower construction costs and interest

rates still to hold. Should they wish to increase their installation from 6,300 KW. to 10,000 KW., as already intimated, the maximum annual charge would be Rs. 6,75,000. At the same time the development of the power market in the districts named would be proceeded with. The results would be small and unprofitable at first, but it is reasonable to assume that the load development would progress at least as fast as indicated, and that finally a most prosperous enterprise would have been built up.

According to the load and revenue forecast, 7·2 per cent return on the capital can be expected in the tenth year; after all arrears in interest charges are paid, a surplus of Rs. 58,060 is left. On a 5 per cent interest basis the results will be better still—vide Financial results, page 32.

It is therefore strongly recommended that, in view of the fact that the manufacture of paper by this process is a new industry, that it will prove beneficial to the Forest Department, and that the assurance of this load may mean the development of the Papanasam Power Project and an opportunity to develop the potential power market in Southern India, Government should be prepared to waive the idea of any immediate profit derived from the revenue due to the sale of power to the Paper Mills, and be content with an even balance. In any case, once a transmission and distribution system has been constructed, and a demand for power has been established, the proportion of the investment chargeable to the Paper Mills would be lower and the operating and maintenance costs less. Under these conditions this load would actually be more profitable than shown. After all, it is very questionable if water power, when developed and managed by the State, should be operated with the sole idea of direct profit. It is not the policy usually pursued, unless the profits are used for extensions to the power system or reduction in power rates. The profits of the Ontario Power Commission and the New Zealand Government undertaking are all reinvested in the generating and transmission system, or returned to the consumer as rebates or a reduction in rates.

It is therefore recommended that the above proposals be submitted to Messrs. Martin & Co., the promoters of the proposed paper industry, and if either is found acceptable, the construction of the project may be proceeded with.

Should Messrs. Martin & Co. not find the proposals of Government sufficiently attractive, the offer may be modified or an endeavour made to interest other firms in the undertaking. This also leads to a further examination of the proposal.

Assuming that the Government are prepared to deliver power to the Paper Mills at the rate advanced—Rs. 50 per KW. per year—advance the capital necessary for the power development and give Messrs. Martin & Co. the contract to construct the work at cost plus, say, 10 per cent, Government will gain Rs. 15,000 per year, which, it is understood, is the amount tentatively agreed upon to charge Messrs. Martin & Co. for the forest rights, another industry will be started giving employment to a few hundred people, and the revenue returns will be slightly increased by a few small taxes. On the other hand, by selling power below cost, there will be an annual deficit of from Rs. 1,41,400 on the hydro-electric side for scheme (*a*). For scheme (*b*) the deficit will be about Rs. 2,30,000 which will have to be covered by the sales of power to other consumers, and would take some years to make up.

For Messrs. Martin & Co. conditions are very different. In the first place, they are not going to embark on the scheme until they have assured themselves that it is commercially feasible. Their commitments then amount to an annual payment of Rs. 15,000 for the forest rights, a very low rate for power, and a capital outlay of Rs. 40,00,000 for the paper mill, of which Rs. 5,00,000 will be obtained as contractor's commission for constructing the hydro-electric works. Thus for an outlay of Rs. 35,00,000 they can establish what promises to be a profitable industry. The percentage return should be high.

It is rather difficult to see how Government will derive any advantage from any of the tentative proposals which have been advanced to date by Messrs. Martin & Co. or their representatives.

It will be noted on referring again to the above figures that for an additional capital outlay of Rs. 40,00,000, the estimated cost of the factory, Government themselves can construct the whole works and start the factory.

This scheme appears highly advantageous. The consolidated estimate would be less than the sum of the two amounts given above, as establishment and general charges would be less, and such items as construction plant, buildings, transport, etc., would serve for both the works.

In the case of the paper mill, the general supervision could be carried out by Government officials but the actual buildings and equipment would be erected by experts sent by the manufacturer of the machinery. As much of the whole work as possible would be carried out by small contracts.

The paper mill erected and the process established, Government could either lease the mill to some firm, or contract out the annual supply to some business interests, who possessed the necessary commercial relations and selling organization.

Government, in this case, would be selling power at a small profit, while the Forest Department should be receiving an annual revenue far in excess of Rs. 15,000.

If the Forest Department are assured of power at the rates offered, they may also find it possible to develop other industries in addition to the manufacture of paper.

It may be asked why, if Messrs. Martin & Co. consider our power rates too high, these should not be too high for a Government-owned factory.

In the first place, Government do not—or should not—expect such a high return on the investment. Furthermore the writer, while not pretending to be conversant with the details of the processes by which paper is manufactured, has been interested in the supply of power to paper mills in other countries. In all cases they were prosperous undertakings, and the rate for power was higher than that now proposed.

Should, by any chance, the new industry not prove a commercial success, after it has been well established, efforts would have to be redoubled to develop the outside power market and bring in new industries. If such new industries were charged the same rate for power as the paper factory, it would be an added inducement and should prove most attractive. Government in any case would not have committed themselves seriously as there would not be much difficulty in loading up the machinery already installed.

One point which may be worth considering in the event of Messrs. Martin & Co. accepting the terms offered them and the enterprise proving a pronounced commercial success, is how far Government, in return for the low power rates and the forest concession, should share in the profits above a certain fixed return on the investment.

In the following pages the more technical details of this project will be discussed under the heads:

Power Demand and Revenue Forecast.

Rainfall, Run-off and Storage.

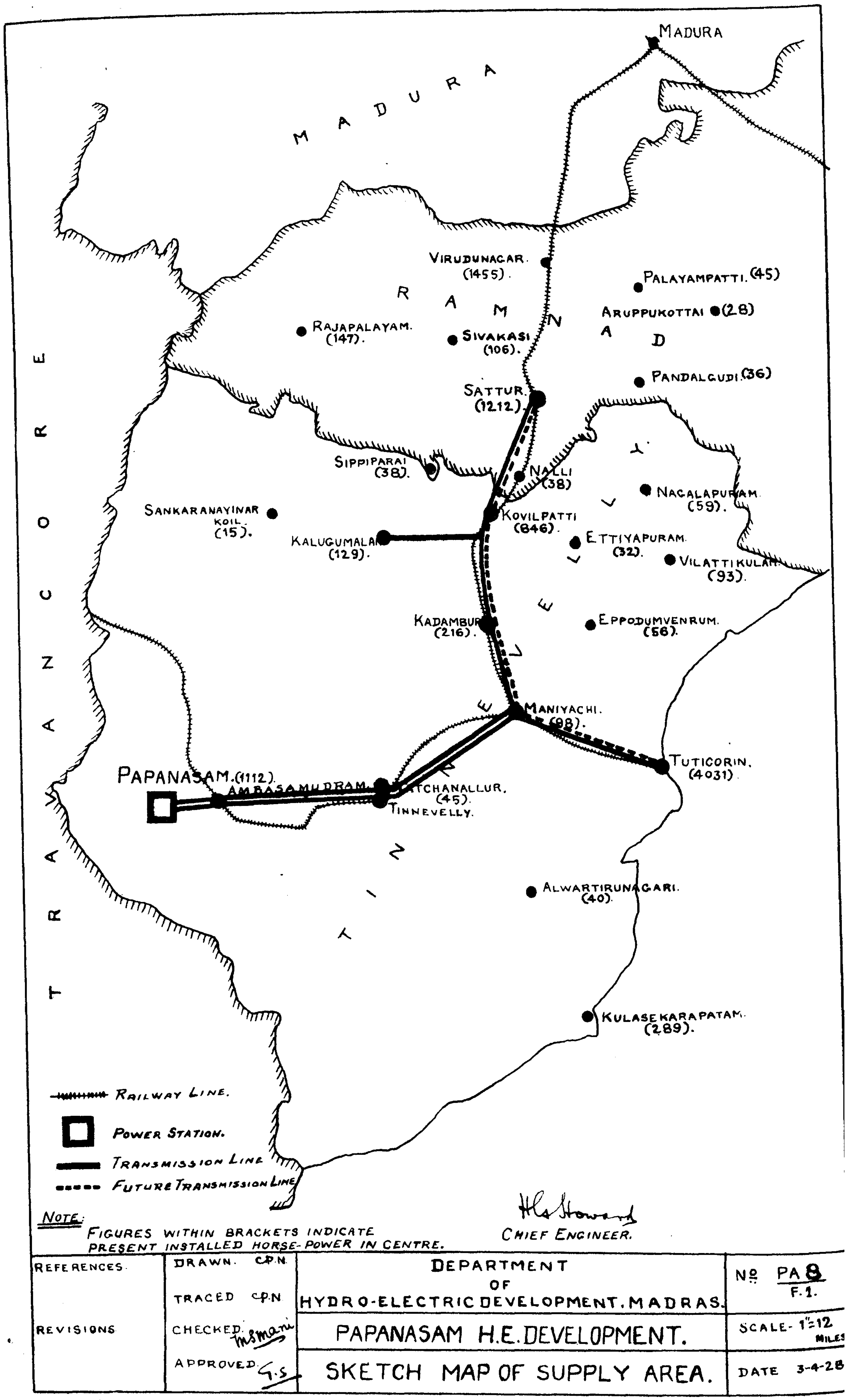
The Development.

Financial Results.

It will be seen that if a sufficient power demand can be created, the development has most attractive possibilities.

H. G. HOWARD,
Chief Engineer.

March 31, 1928.



SECTION 2—POWER DEMAND AND REVENUE FORECAST.

An analysis has been made of the power market, in much the same manner as for Pykara.

Generally speaking, there appears to be a possibility of a very satisfactory development in the districts under review. The writer has not, however, investigated this power market to the same extent as that of Pykara. For this reason, and in order that the forecast may be termed conservative, the annual estimated increases in the load are not so high. When an opportunity arises, a more detailed survey will be undertaken, especially as regards seasonal load.

Drawing $\frac{\text{P.A. 8}}{\text{F-1}}$ is a sketch of the districts showing the mechanical load installed at present, while Table XI shows, in some detail, the load that may be expected during the next ten years; a summary of the load details is given in Table XII. The forecast is undoubtedly conservative, judging from statistics of consumption in similar areas elsewhere.

TABLE No. XII.
Power House Load Details.
Scheme (*b*).

Year of operation.	Demand. K.W.	Generation. K.W.H.	Average load. K.W.	Load factor. Per cent.
1	7,280	47,290,000	5,400	74
2	8,050	48,550,000	5,540	69
3	9,100	50,480,000	5,760	68
4	10,000	53,060,000	6,060	61
5	13,800	77,850,000	8,890	64
6	14,040	78,750,000	8,990	64
7	14,410	79,950,000	9,130	63
8	14,620	80,850,000	9,230	63
9	14,890	82,000,000	9,360	63
10	15,190	83,200,000	9,500	63

Papanasam.—The proposed Paper Mills and a Textile Mill of Messrs. A. & F. Harvey are located here, and have been referred to in other parts of the report. It is assumed that if the Paper Mills are not established here, other industries may be attracted by the cheap power rate, and the estimated load and revenue as advanced for the Paper Mills can be expected in any case. The location with its cheap power, good water, and near-by railway, should certainly be most suitable for many industries. Judicious advertising, not only in India, but also in Europe and Canada, may bring forth some sound commercial offers. It will, however, be difficult to advertise unless the construction of the scheme is definitely sanctioned. This may be done contingent on the necessary load forthcoming.

Regarding the Textile Mill it has been pointed out previously that this load cannot be expected. However, if Government take over the water rights and deliver an equivalent amount in electric power for the same rate, it is quite possible that the mill may in time increase the consumption of power and a small increase in revenue could be expected. This has been allowed in the estimates from the third year of operation, and it is assumed that the lease for the water rights will expire by the ninth year of operation, and that Government will not renew it. For the new contract an average rate of 0·5 anna per K.W.H. is assumed. This is lower than elsewhere, but it is believed that the special conditions justify this concession.

Tuticorin.—This district possibly holds out greater promise than any of the others. Once the improvements to the port are completed, business will grow and there must be a constant increasing demand for power. With the advent of cheap power certain industries should be attracted to the port.

At present the mechanical horse-power installed is 4,031 of which 2,000 H.P. is class A* load consisting of the Mills of Messrs. A. & F. Harvey, the remainder being mainly of class B. The first year's demand has been estimated at 325 K.W., and it is assumed that Messrs. A. & F. Harvey will not be interested. It has, however, been taken that during the second, third and fourth years of operation these mills will

* Class A—Textile Mills—1,000 H.P. and above.
,, B— ,, Below 1,000 H.P.
,, C—Rice Mills, ginning factories, presses, etc.
,, D—Miscellaneous (small power and lighting).

gradually be electrified, starting first with seasonal load as an experiment. The estimated demand for the tenth year is 2,960 K.W. Increases in load from 12·5 per cent down to 8·5 per cent are allowed for during the ten-year period.

Tinnevelly.—This is a very populous district. No factories of importance are located here at present and none are expected. It should, however, prove a good market for lighting and small power—class D. The first year's demand is estimated at 170 K.W., with 484 K.W. by the tenth year. Increases in load from 20 per cent down to 8·5 per cent are allowed. The district includes Maniyachi, Kadambur, and Tachanallur. The mechanical horse-power installed at present is 559.

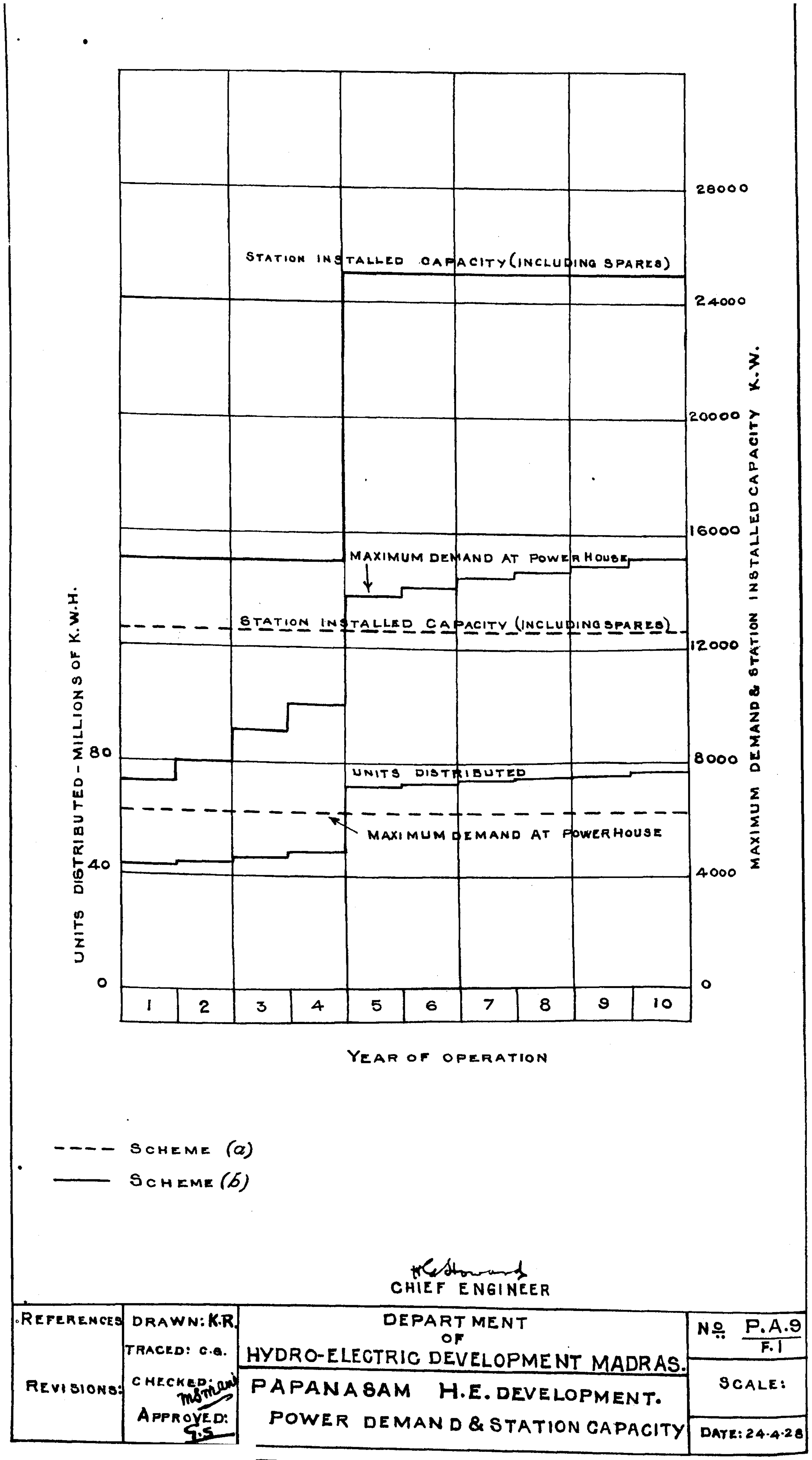
Kovilpatti (including Kalugumalai).—Some 802 H.P. is installed in this district and consists mainly of load in classes B and C. A demand of 134 K.W. is estimated for the first year, rising to 645 K.W. in the tenth year. The rates of increase allowed vary from 10 per cent to 8·5 per cent.

Sattur (including Sivakasi and Nalli).—There are numerous cotton gins and presses in this district, the total mechanical horse-power installed at present being 1,356. The estimates provide for a demand of 180 K.W. the first year, rising to 750 K.W. by the tenth year. The rates of annual increase in load are assumed to be the same as those for Kovilpatti. Additions to existing installations and new factories or industries are not considered so promising in the last two districts as in those mentioned earlier.

Seasonal load.—Returning to the question of seasonal load, there is a decided possibility of the numerous gins and presses and other seasonal consumers being persuaded to work during part of the south-west monsoon period. Such being the case, power could be offered at rates very much lower than their present costs. The procedure would be to arrange each installation so that it could be operated either by electric or mechanical power. Government would, by means of a conversion fund, bear the cost of the installation, but the rate for power would include the interest on this expenditure plus a sinking fund high enough to extinguish the investment in ten years. If, for instance, an installation of two 25 H.P. motors is to substitute the load of two 25 H P. Diesel or steam engines for the south-west monsoon months of the year, a basic rate of, say, 0·5 anna per horse-power-hour, could be quoted plus a reasonable rent for the electric motors, which would bring the total unit rate up to around 0·8 anna; for a larger installation the rate would be lower. Power taken outside the monsoon periods would be charged at double rates, while continuous power may be charged for at the normal rate. Consumers would at first tend to take power only during the monsoon months, but it is believed that the majority would soon change to a regular supply. This proposal ought to appeal especially to such important consumers as Messrs. A. & F. Harvey. If, say, for six months in the year they could obtain power at a proportion of their present running costs with no added investment in plant, it would be very strange if they did not take advantage of it, particularly as their steam plant would still act as a standby. Such an arrangement should soon lead to a contract for continuous power at the normal rate. Preliminary conversations have already been begun with representatives of Messrs. A. & F. Harvey but, until the construction of the scheme is actually authorized, it will be difficult to interest them or any other large organization, in such proposals. Other ideas might be advanced for the development of the power market, but to work out the details and get concrete results, a properly organized commercial department is necessary. It can thus be seen that there are many ways of developing the power market, and if one method does not succeed, others will be tried.

Rates.—Apart from the special rates applicable to the Paper Mills and Messrs. A. & F. Harvey's, the general rate for industrial power is as follows, being the same as for Pykara :—

Demand.	Maximum demand rate per K.V.A. per annum.	Unit rate per K.W.H.
	RS.	ANNA.
100— 500 horse-power	60	+ 0·60
500—1,000 "	60	+ 0·50
1,000—3,000 "	60	+ 0·40
3,000 and up	60	+ 0·35



To allow for development the maximum unit charge is that corresponding to a 33 per cent load factor as follows:—

Demand.	33 per cent load factor	
	Per horse-power-hour.	Per K.W. hour.
	ANNA.	ANNA.
100— 500 horse-power	0·69	0·93
500—1,000 „	0·62	0·83
1,000—3,000 „	0·55	0·73
3,000 and up	0·51	0·68

When the individual load factors further improve, a reduction in the power costs will result automatically.

Table XIII gives the amount of power which it is expected to distribute and the revenue received for the first ten years under Scheme (*b*), and drawing No. $\frac{\text{P.A. 9}}{\text{F-1}}$ shows the demand and installed capacity at the Power House.

TABLE No. XIII.

Load Details, Revenue, Return per unit, etc.

Scheme (*b*).

Year.	Demand.	Distributed K. W. H. Millions.	Average Load.	Load Factor.	Revenue.	Average return per unit sold.
	K.W.		K.W.	Per cent.	Rs.	Anna.
1	6,730	43·727	4,990	71	5,73,260	0·210
2	7,450	44·908	5,130	66	6,35,500	0·226
3	8,420	46·687	5,330	60	7,06,720	0·242
4	9,270	49·070	5,600	58	8,19,070	0·267
5	12,420	72·013	8,220	66	10,53,760	0·234
6	12,640	72·845	8,320	65	10,73,440	0 236
7	12,970	73·946	8,440	65	11,21,300	0·243
8	13,160	74·792	8,540	65	11,59,900	0·248
9	13,400	75·840	8,660	65	12,24,300	0·258
10	13,670	76·958	8,780	64	12,62,790	0·263

As in the case of the Pykara System, a mill conversion fund will have to be established to secure the rapid conversion of the existing mills to electric drive within the first years of operation. It is estimated that about Rs. 2,50,000 will be needed for this.

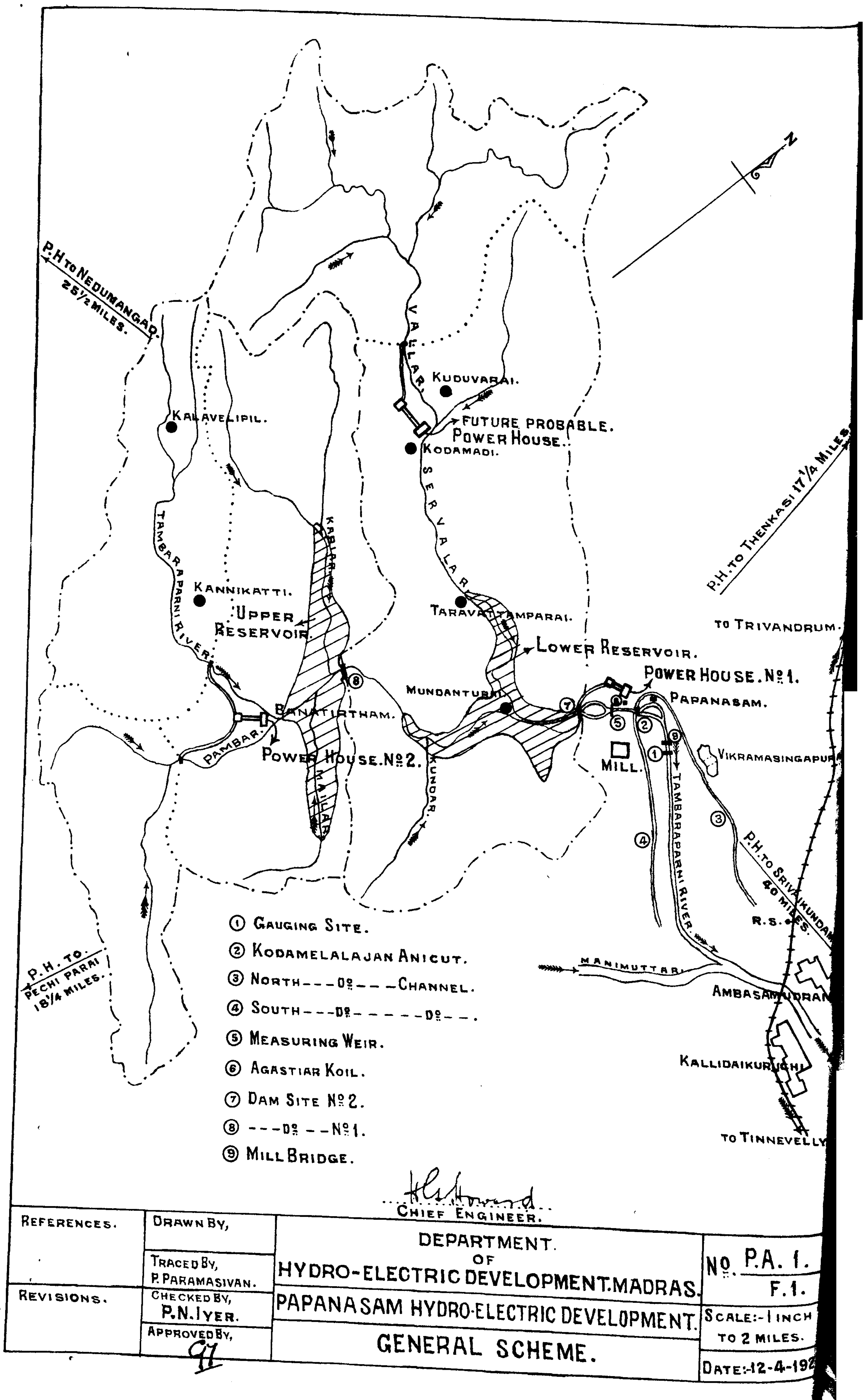
TABLE No. XI—*cont.*

Summary of power demand—*cont.*

Scheme (*b*)—cont.

District and load.	Demand at sub-station. K.W.	Load factor at sub-station.	Consumption. K.W.H.	Average rate per unit. Anna.	Revenue. Rs.	Demand at sub-station. K.W.	Load factor at sub-station.	Consumption. K.W.H.	Average rate per unit. Anna.	Revenue. Rs.
	Seventh year.					Eighth year.				
1. Tuticorin	2,520	25	5,536,000	0·68	2,35,300	2,690	25·5	6,090,000	0·68	2,58,800
2. Tinnevelly	410	24	860,000	0·83	44,600	432	25	946,000	0·83	49,100
3. Sattur	712	19	1,185,000	0·83	61,500	708	21	1,303,000	0·83	67,600
4. Kovilpatti	579	21	1,065,000	0·83	55,300	600	22	1,153,000	0·83	59,800
5. Papanasam—										
Harvey's mills	745	24	1,570,000	..	26,000	745	24	1,570,000	..	26,000
Do. extra	300	24	630,000	0·60	23,600	300	24	630,000	0·60	23,600
Paper Mills	9,000	80	63,100,000	..	6,75,000	9,000	80	63,100,000	..	6,75,000
6. Total demand	14,266	..	73,946,000	0·243	11,21,300	14,475	..	74,792,000	0·248	11,59,900
7. Demand on power house, diversity factor 1·1	12,970	..	..	..	..	13,160	..	..	..	..
POWER HOUSE.										
Average load .. K.W.	..	..	9,130	..	..	..	..	9,230	..	..
Do. factor .. Per cent.	..	..	63	..	..	..	..	63	..	..
Total generation .. K.W.H.	..	..	79,950,000	..	..	..	..	80,850,000	..	..
Peak load .. K.W.	..	..	14,410	..	..	..	..	14,620	..	..
Estimated revenue .. Rs.	..	..	11,21,300	..	..	..	..	11,59,500	..	..

District and load.	Demand at sub-station. K.W.	Load factor at sub-station.	Consumption. K.W.H.	Average rate per unit. Anna.	Revenue. Rs.	Demand at sub-station. K.W.	Load factor at sub-station.	Consumption. K.W.H.	Average rate per unit. Anna.	Revenue. Rs.
	Ninth year.					Tenth year.				
1. Tuticorin	2,850	26·5	6,607,000	0·68	2,80,800	2,960	27·5	7,158,000	0·68	3,04,200
2. Tinnevelly	457	26	1,040,000	0·83	54,000	484	27	1,145,000	0·83	59,400
3. Sattur	712	23	1,433,000	0·83	74,330	750	24	1,576,000	0·73	71,910
4. Kovilpatti	622	23	1,250,000	0·83	64,850	645	24	1,354,000	0·83	70,250
5. Papanasam—										
Harvey's mills	1,100	25	2,410,000	0·50	75,320	1,200	25	2,625,000	0·50	82,030
Do. extra	..	..	..	..	..	..	..	..	..	..
Paper Mills	9,000	80	63,100,000	..	6,75,000	9,000	80	63,100,000	..	6,75,000
6. Total demand	14,741	..	75,840,000	0·258	12,24,300	15,039	..	76,958,000	0·263	12,62,790
7. Demand on power house, diversity factor 1·1	13,400	..	..	..	..	13,670	..	..	..	..
POWER HOUSE.										
Average load .. K.W.	..	..	9,360	..	..	..	..	9,500	..	..
Do. factor .. Per cent.	..	..	63	..	..	..	..	63	..	..
Total generation .. K.W.H.	..	..	82,000,000	..	..	..	..	83,200,000	..	..
Peak load .. K.W.	..	..	14,890	..	..	..	..	15,190	..	..
Estimated revenue .. Rs.	..	..	12,24,300	..	..	..	..	12,62,790	..	..



SECTION 3—RAINFALL, RUN-OFF AND STORAGE.

The Tambraparni River proper from which it is proposed to develop power is formed by the junction of the Serval Ar and the head waters of the Tambraparni at Mundanthorai. The run-off of each stream above Mundanthorai is approximately the same although the area of their catchments is different. The total catchment area is about 127 square miles. Of this some 57 square miles are in the high ranges of the Podyamalai Hills and 70 square miles in the lower ranges. The elevation ranges from 600 feet to 5,000 feet and lies in Government reserved forest and Singampatti zamindari land. The highest peak is the Agastya Peak on the western watershed line of the catchment, and is supposed to be the source of the Tambraparni river. The higher slopes are covered with thick forest growth, and the low-lying portions with sparse jungle and a little cultivation. The catchment draining into the Tambraparni above the Papanasam falls will be termed the Papanasam basin. This basin is bounded on the west by the Kodayar and other smaller basins in Travancore territory which, however, drain into the Indian Ocean, on the north-west and north by the Punalur and Chittar basins, on the south by the Manimuttar basin which drains into the Thambraparni about 5 miles below the Papanasam falls, and on the east by the Tinnevelly plains. About 80 miles to the north lies the Periyar basin, which is referred to later.

The Podyamalais is an extension of the Cardamom Hills over the southern portion of the western ghats, and ends within 25 miles south of the Papanasam basin, some distance north of Cape Comorin. It is therefore surrounded on the west, south and east by a belt of country which is only some 40 miles from the sea.

The high range part of the catchment is therefore affected by both the south-west and north-east monsoons, while the low range catchment gets the major portion of its rainfall from the north-east monsoon. Few clouds from the south-west monsoon reach this part of the catchment, and the resulting small precipitation is called the "Saral".

In the non-monsoon months—January to May—the rainfall and weather conditions in general are similar to those of other catchments in the western ghats.

Rainfall.—Since 1910 the Forest Department has been maintaining several rain gauges in the Papanasam basin, both in the low and the high ranges.

From the records available, the average annual rainfalls are as follows :—

High ranges	..	..	..	..	121·2 inches
Low ranges	..	..	..	..	52·63 „
Average	..	..	..	..	86·92 „

Run-off.—The Tambraparni is a perennial stream, but during the dry months the flow often drops to 25 cusecs. The maximum observed flood is 70,000 cusecs, while the average flow can be considered around 1,000 cusecs.

The river has been continuously gauged since 1915. During the period of low river flow, measurements are carried out by observing the depth of water over a weir, constructed just below the Papanasam falls, and shown on Drawing No. $\frac{\text{P.A.-1}}{\text{F-1}}$; to this is added the water diverted higher up into the channel used for power supply to the Papanasam Textile Mill. At other periods of the year, when the river is too high to permit of reasonably accurate measurements being made at the weir referred to above, the flow is determined by noting the daily readings on a gauge fixed in the river near the mill bridge, about half a mile below the above weir. The actual discharges corresponding to a given height of gauge are taken from a specially prepared chart. This chart was the result of a series of careful gaugings with current meter, undertaken by the Executive Engineer of the Tinnevelly Division in 1925–26 at a specially selected site below the mill bridge. Between this bridge and the Papanasam falls, the north and south Kodamelalagian irrigation channels take off; hence, in order to arrive at the true discharge of the Tambraparni river, it is necessary to add the flows in these channels, of which fairly accurate records are available. The total flow having been determined, the result is multiplied by the ratio of the area of the Papanasam basin to that of the Tambraparni up to the mill bridge.

However, gaugings over a period of ten years are not usually considered sufficient to decide on the full possibilities of any power development. Reliable results can generally be deduced from a twenty-year period. One of the most practical methods of extending the flow of any river over a further period of years when observations have not been taken, is by determining the relationship between the measured flows available and the catchment rainfall and, provided that sufficient precipitation records have been kept, the run-offs can be deduced for any number of years by applying the ratios or differences in rainfall to the run-off already determined. If such results appear inconsistent or the necessary rainfall records have not been kept, the river can be graphically compared with another having a catchment with similar characteristics, but longer records.

In order, therefore, to obtain the flow of the Tambraparni over a period of twenty years, an endeavour was made to establish a reasonable relationship between the rainfall of the catchment and the river flow. A brief analysis showed that the average rainfall, as recorded, was less than the gauged run-off. As there was no reason to doubt the accuracy of the gauged river flows, it was concluded that the rainfall records were unreliable and not representative of the catchment rainfall. A similar method was tried by taking the average rainfall of stations, Nedumangadu, Pachiparai, Ambasamudram and Tenkasi, bordering the catchment, and a more logical relationship was established.

As a further check, the seasonal run-offs of the Papanasam basin were deduced for years prior to 1915 by correlating the run-offs of this basin with that of other catchments possessing similar topographic and climatic features. The Periyar and Kodayar basins and the discharges of the Tambraparni at the Srivaikuntam anicut were selected, records for all these being available over the twenty-year period. The method followed consisted of dividing the year up into four seasons, and taking the corresponding seasonal and annual run-offs for the Papanasam basin and for the catchment selected for correlation. From these results the usual ratio curves are drawn and the run-offs of the Papanasam basin deduced by extending the curves for periods for which figures are available for the other basin. By dividing the year into four seasons more accurate results are obtained than if the whole year is taken at one time. The relationship varies with the precipitation, and four constants are used for the yearly records instead of one.

In each of the above cases, in addition to deducing the run-offs of the Papanasam basin for years when no records were available, run-offs were deduced for the years when the river had been gauged. Comparing, therefore, the differences between the actual and deduced figures, it was found that the ratios established by correlating the run-off with the readings taken at the Srivaikuntam anicut gave the closest results, and have therefore been adopted as a basis for all designs.

Table I gives the run-off of the Papanasam basin for the years 1915—1926.

Table II is a comparative statement of the run-offs of the Papanasam basin and those measured at the Srivaikuntam anicut.

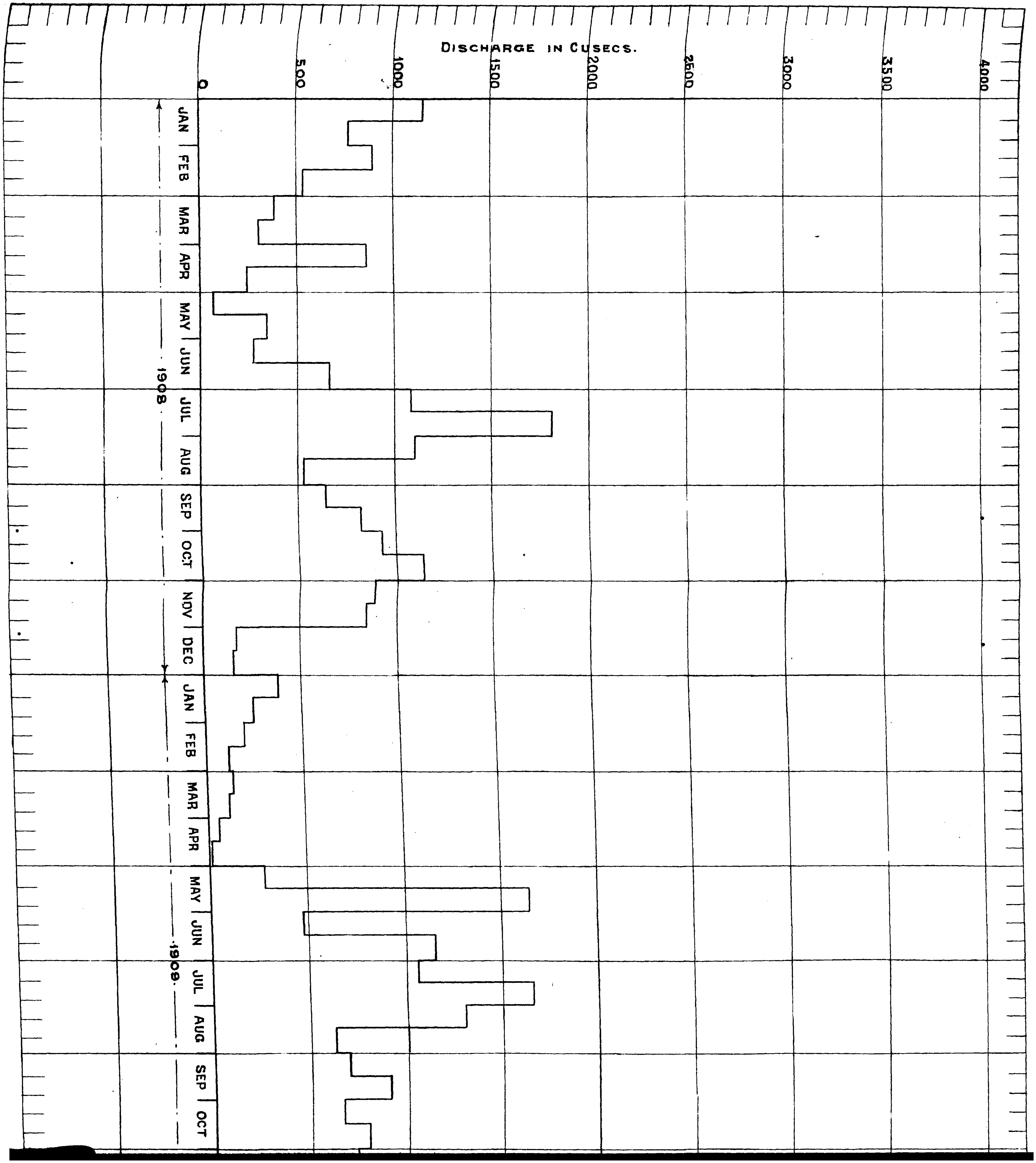
Table III shows the run-off of the Papanasam basin as deduced from the four methods already outlined, and the actual run-off.

Tables IV and IV-A give the bi-monthly discharges of the Tambraparni River, in the Papanasam catchment, since 1906, partly gauged and partly deduced from the discharges at the Srivaikuntam anicut.

Table V shows the power available from the Tambraparni for the minimum, 90 per cent and average years, as determined by the bi-monthly flows.

Other curves and tables used in the above calculations are not reproduced but are on file for reference when required.

An examination of these tables shows that 1909, with a total run-off of 19,800 million cubic feet, was the minimum year, while both 1908 and 1910 were well below the average. A hydrograph for these three years is reproduced on Drawing $\frac{\text{P.A.-2}}{\text{F-4}}$ and will form the basis of the storage calculations necessary to develop power from the whole of the run-off of the minimum year. Sometimes it is possible to design for a 90 per cent year and operate up to this limit as soon as a hydro-electric plant, in another catchment, is connected to the system. The 90 per cent year development allows for



DISCHARGE IN CUSECS.
0
500
1000
1500
2000
2500
3000
3500
4000
JAN
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MAR
APR
MAY
JUN
JUL
AUG
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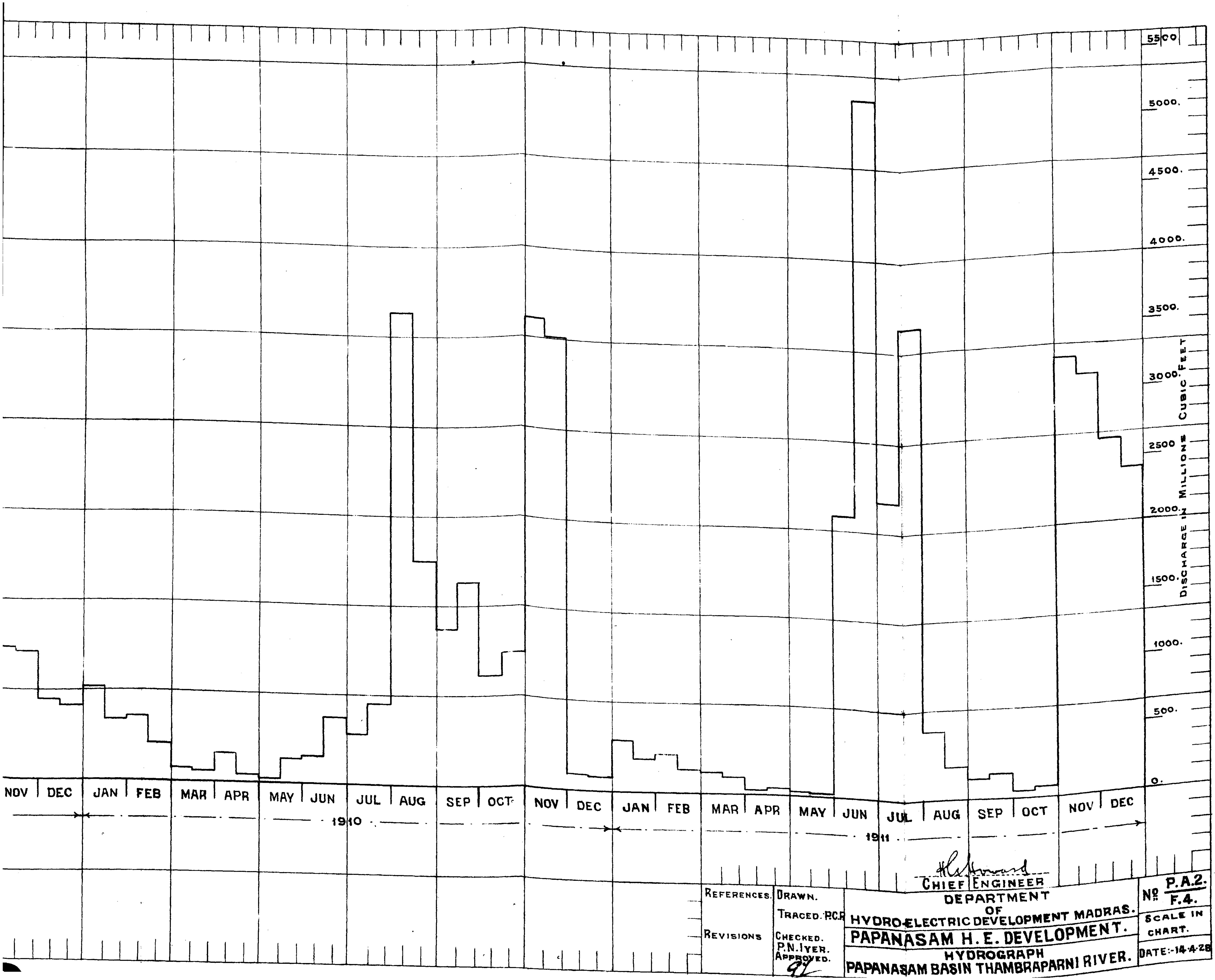
1909


5500
5000.
4500.
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2500
2000.
1500.
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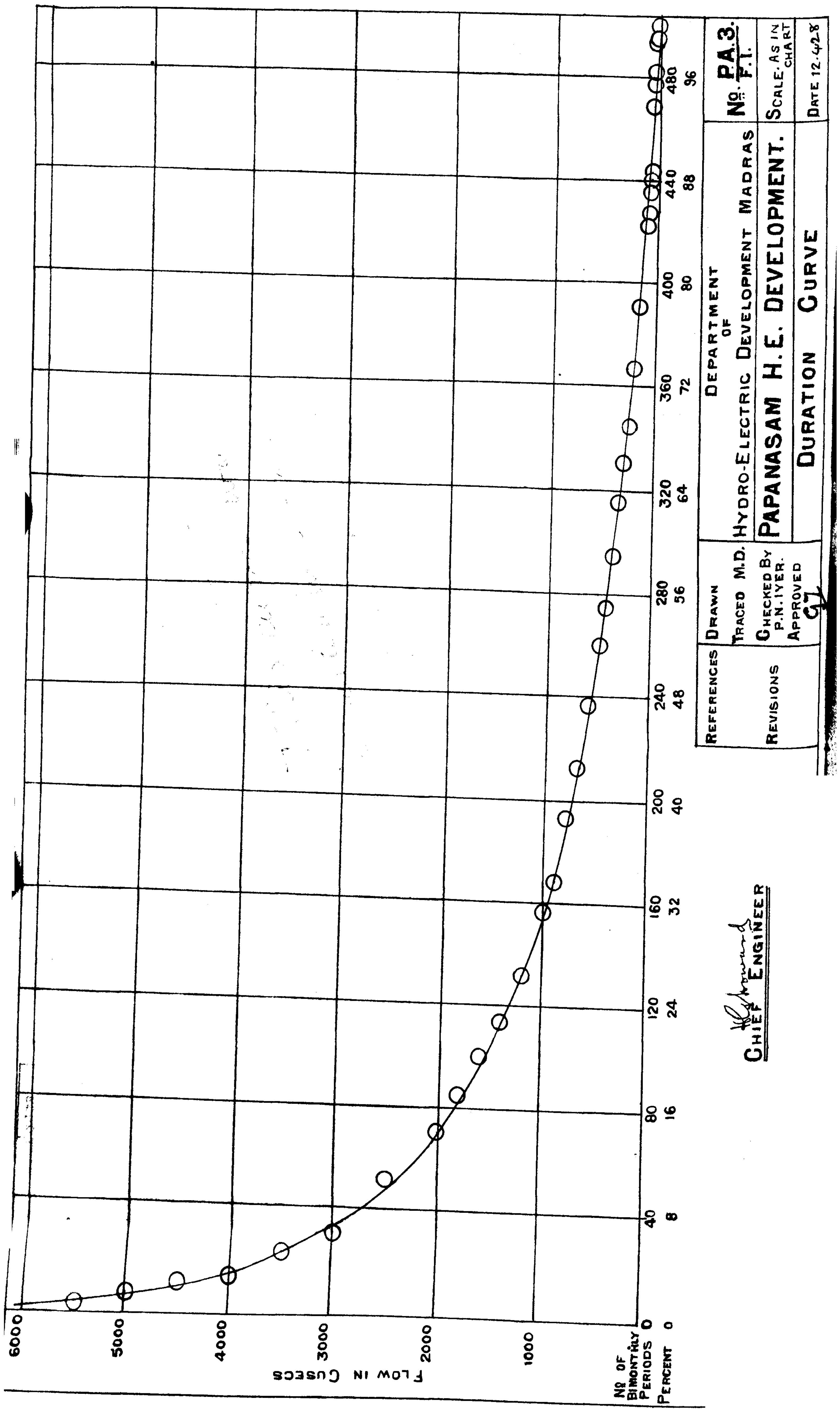
0.
Discharge in Millions Cubic Feet
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1910
1911
Chief Engineer
References. Drawn.
Traced. P.C.R.
Revisions Checked. P.N. Iyer.
Approved.
Department of Hydro-Electric Development Madras.
Papanasam H. E. Development.
Hydrograph
Papanasam Basin Thambraparni River.
Nº P.A.2. F.4.
Scale in chart.
Date:-14-4-28



a water shortage once in ten years and, owing to the diversity relationship between catchments, it is assumed that one plant could cover the shortage of the other. Development up to the limits of the minimum run-off presupposes no shortage and, although the design may be for a 90 per cent year, operation would only be within minimum year limits until another plant, as referred to above, was connected up in the system. It would be quite feasible to develop for the 80 per cent year or an even greater run-off if an auxiliary steam plant were available. This might be rendered possible in the future by purchasing, for instance, the steam plant of Messrs. A. & F. Harvey at Tuticorin. No useful purpose would, however, be served at this stage in entering into a detailed discussion of the economical advantages of such a combination. It is merely referred to as a future possibility.

The duration curve, drawing No. $\frac{\text{P. A.-3}}{\text{F-1}}$, shows that for a minimum year a river flow regulated by seasonal storage will give a continuous flow of 625 cusecs, while 690 cusecs can be expected in a 90 per cent year.

Based on the years 1908—1911, 1909 being the minimum year, reservoir working tables Nos. VI, VII and VIII have been worked out for continuous flows of 600, 625 and 650 cusecs, respectively, and a draft storage curve, No. $\frac{\text{P. A.-4}}{\text{F-1}}$, has been prepared to show the storage necessary for flows from 25 cusecs to 650 cusecs.

It will be noticed that a large increase in storage is necessary to raise the flow from 600 to 650 cusecs. This represents the dividing line between seasonal and annual storage, the actual critical flow being around 610 cusecs, corresponding to a continuous power supply of 13,100 K.W. and requiring a storage capacity of 8,800 million cubic feet.

This report will be confined to the examination of the power development involving seasonal storage only; but a brief reference will be made to the power available from annual storage.

Storage sites.—The question of suitable storage sites was studied last year by Lieutenant-Colonel M. G. Platts who submitted a very interesting report (" Notes on the discharge of the Tambraparni River and the economical storage for stages of development ") which is also referred to on other pages. He showed that only two feasible sites were available, one on the Tambraparni River about nine miles above the junction with the Serval Ar, called No. 1 site, and the other just above the Papanasam falls, referred to as No. 2 site. Curves which he had prepared, and which are reproduced on drawing No. $\frac{\text{P. A.-5}}{\text{F-2}}$, showed conclusively that the upper site was the more economical in unit cost. Table X gives the waterspread and capacity of the upper site reservoir for various levels of dam, and it will be seen t at this site is capable of storing 10,000 million cubic feet with a dam 240 feet high, but the capacity corresponding to the lowest unit cost is around 4,000 million cubic feet. The run-off into the reservoir is approximately half that of the whole catchment, so that the capacity of the reservoir, for seasonal flow, is limited to the amount of water which can be stored for the period under review, 1909—1911, for maximum draw-off. Table IX shows that the maximum draw-off available is around 440 cusecs requiring a storage, including losses, of 5,500 million cubic feet.

This storage could obviously be increased by limiting the draw-off or resorting to a variable annual carry-over.

It may be of interest to describe two methods by which the draw-off can be limited. The head waters of the Tambraparni can be utilized for five months in the year, instead of generating an equivalent amount in the main plant, thus storing additional water in the upper reservoir. A brief reconnaissance indicated that a comparatively inexpensive power development could be constructed by diverting the Tambraparni near contour 1,900 and conveying the water by an aqueduct along the right bank to a point near the junction of the Pambar River. Here a head of about 1,000 feet is available, and it should be possible to average some 10,000 K.W. over a period of seven months. The plant could be controlled from Papanasam and only a caretaker or so would be necessary. Had a storage or even pondage site been available, it would possibly have been more economical to develop this project before considering the main development. There is a similar project on the Serval Ar. Neither of these projects has been properly surveyed. They are indicated on General Scheme Map No. $\frac{\text{P. A.-1}}{\text{F-1}}$.

Another method is to develop power at the dam from the draw-off water. The cost of the necessary installation would be low per K.W. installed. It would, however, be a low head installation, and could only utilize the draw-off water within the limitations of head under which the turbine could operate. Per K.W.H. generated, this idea would not prove as attractive as the development of a seasonal flow higher up the river. At any rate, it is not intended to discuss these possibilities any further, nor to go to the expense of any other investigations. They belong to the distant future and are only mentioned to draw attention to the ultimate possibilities of the Papanasam Project.

Reservoir site No. 2 is more expensive than No. 1 for the smaller storages, but for larger storages it becomes more economical. Curves, drawing No. $\frac{\text{P A. 6.}}{\text{F-2}}$ are reproduced from the report of Lieutenant-Colonel Platts showing the relative costs of the two dams for various storage capacities. For capacities above 6,500 million cubic feet at the lower site it is necessary to raise the height of two low saddles, which increases the unit cost. To sum up, No. 1 Reservoir can be constructed more cheaply than one at the lower site, up to its normal seasonal capacity of 5,500 million cubic feet corresponding to the minimum year, and No. 2 Reservoir can be constructed up to a capacity of 6,500 million cubic feet for a reasonable figure. As long as seasonal storages only are considered, that is, the development of the whole run-off of the minimum year, a part of this storage is unnecessary. However, since the 12,000 million cubic feet of storage is available and is fairly cheap, it may be utilized some day, but even then the regulated flow will not reach 700 cusecs. For our immediate purpose, we are only concerned with providing 8,800 million cubic feet in the most economical manner, this being the maximum development considered in this report.

Storage becomes very expensive for regulation above 610 cusecs—in fact, the over-all unit cost per K.W. tends to increase.

It is also by no means certain that the Tambraparni, above Mundanthorai, provides half the total run-off of the catchment. This will have to be ascertained in future by a series of measurements extending over several seasons.

There appears, however, little doubt as to the relative unit costs already determined of the storages at the two sites.

From the information now available, it would appear that the most practical method of providing the necessary storage for a regulated flow of 610 cusecs would be the construction of a dam 170 feet high at the upper site to store 5,500 million cubic feet, and one at the lower site to store 3,300 million cubic feet. This is the most flexible arrangement and allows for any inaccuracies in the proportion of run-offs assumed in the river above Mundanthorai.

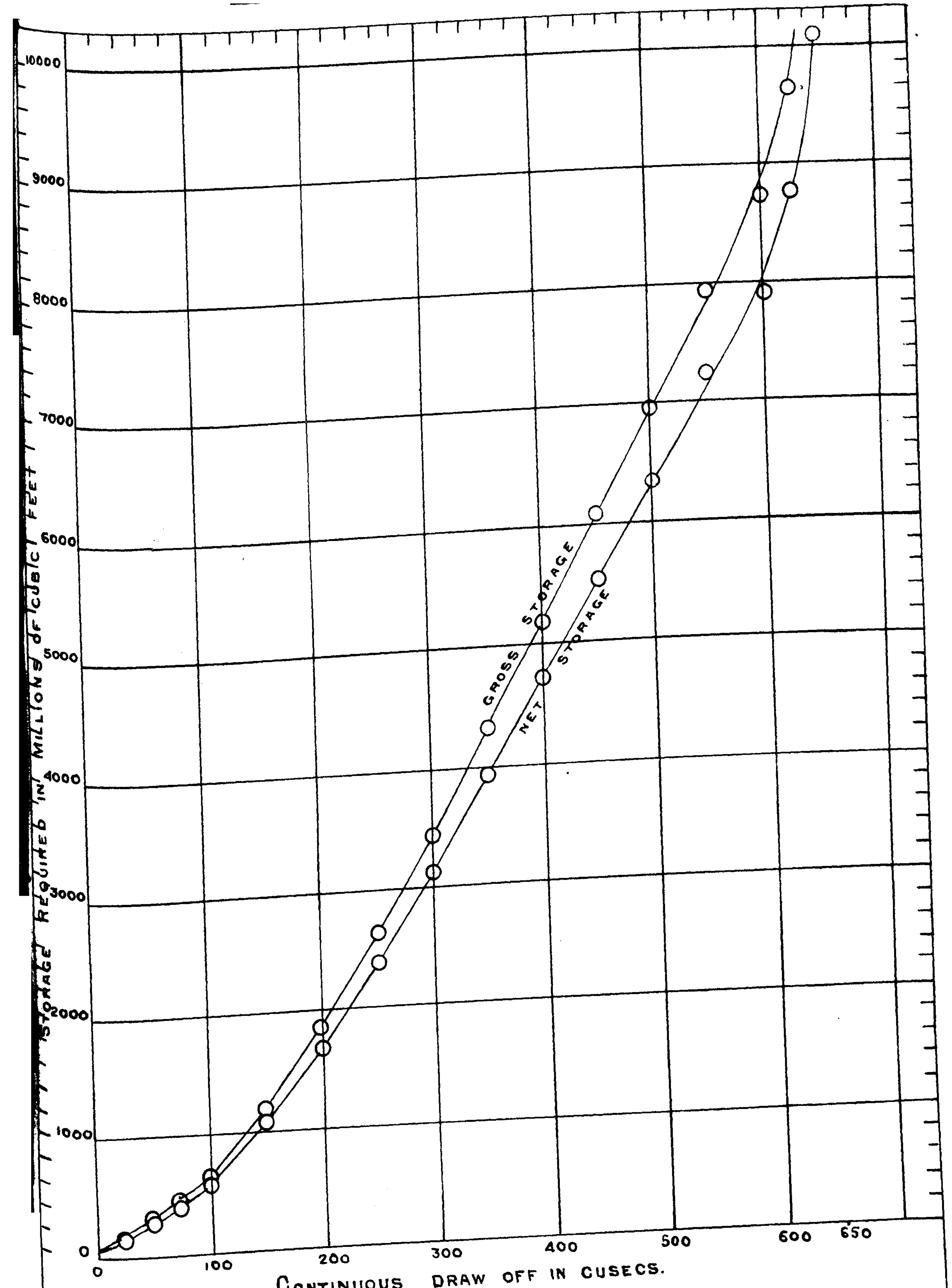
To provide all the above storage at the upper dam site involves a considerable carry-over from year to year, and although this development appears on paper to be a little less costly, it is less flexible and more dependent on the assumed run-offs. Load conditions may also justify the provision of more storage than at present allowed, in which case Dam No. 2 could be constructed for a greater height.

For the first stage of development Dam No. 1 would be constructed to a height of 140 feet for a storage of 4,000 million cubic feet giving a regulated flow of 350 cusecs or 7,400 K.W. continuous. Provision would be made for an eventual increase in the height of the structure.

The second stage would include the raising of the dam to 170 feet and storing 5,500 million cubic feet. This is equal to a seasonal storage for maximum draw-off of 440 cusecs, and represents roughly the most economical development. However, developing for a regulated flow of 610 cusecs, does not raise the unit cost to any marked degree, and the third step might be the construction of Dam No. 2 to store 3,300 million cubic feet, or more if needed.

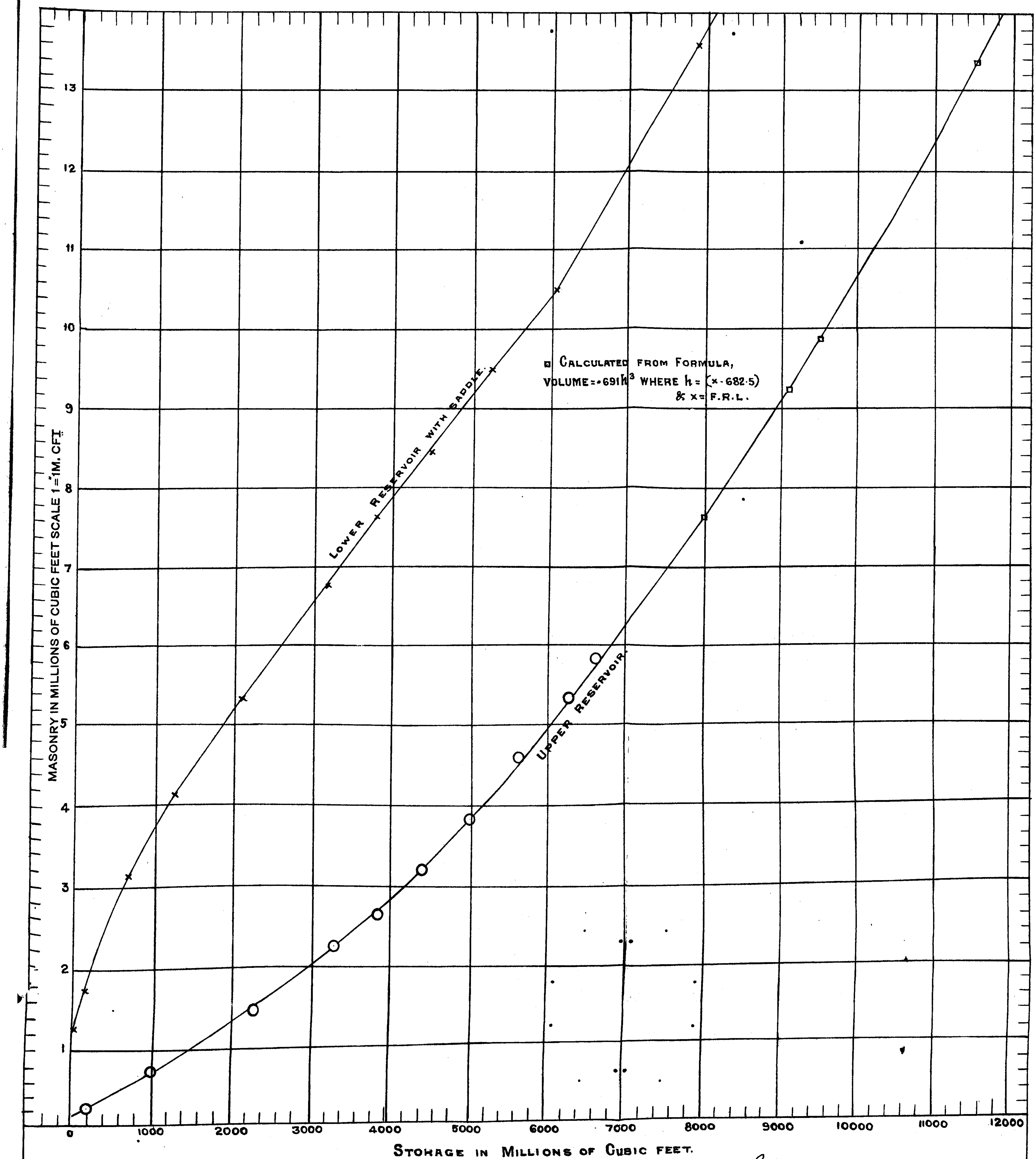
Even if it is found necessary, after more measurements have been taken, to modify the figures for run-off now assumed, it is not probable that there will be any change in the first stage of the development.

The figures for storages given above are gross and allow 10 per cent for evaporation and seepage losses.



H. Howard
CHIEF ENGINEER.

REFERENCE	DRAWN.	DEPARTMENT OF HYDRO ELECTRIC DEVELOPMENT.	No. $\frac{\text{P.A.4.}}{\text{F.I.}}$
	TRACED. M.D.		SCALE:– AS IN CHART
REVISIONS	CHECKED. P.N. IYER.	PAPANASAM H.E. DEVELOPMENT.	DATE 5.4.28
	APPROVED. GL	DRAFT STORAGE CURVE.	



Chief Engineer.

NOTE:-

REPRODUCED FROM CURVE IN COL. PLATTS REPORT DATED. 21-6-27.

REFERENCES REVISIONS	DRAWN BY, TRACED BY, M.D. NAIDU. CHECKED BY, P.N. IYER. APPROVED BY,	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT PAPANASAM H. E. DEVELOPMENT CURVES OF CORRELATION OF RESERVOIR CAPACITIES TO DAM CONTENTS	No. P.A.5. F.2. SCALE. AS IN CHART DATE:-16-4-28

Table No. I.

Statement showing the run-off of the Papanasam basin for the years 1915 to 1926 in million cubic feet.

Year.	Winter.				Summer.			South-west monsoon.					North-east monsoon.				Total of columns (5), (8), (13) and (17).
	January.	February.	March.	Total of columns (2) to (4).	April.	May.	Total of columns (6) and (7)	June.	July.	August	September.	Total of columns (9) to (12).	October.	November.	December.	Total of columns (14) to (16)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1915	1,585	504	358	2,447	156	161	317	6,297	8,014	2,841	3,425	20,577	2,013	4,325	4,918	11,256	34,597
1916	1,647	445	161	2,253	156	161	317	7,145	3,149	1,993	2,276	14,563	3,754	3,629	2,341	9,724	26,857
1917	2,274	1,221	653	4,148	357	161	518	2,478	2,682	1,762	3,913	10,835	2,784	3,307	2,481	8,572	24,073
1918	5,411	1,491	503	7,405	156	5,004	5,160	2,692	1,451	1,994	657	6,794	324	1,054	3,885	5,263	24,622
1919	2,367	732	381	3,480	420	161	581	6,979	4,429	4,371	1,610	17,389	2,783	2,150	4,254	9,187	30,637
1920	8,876	414	128	9,418	100	69	169	5,783	6,848	1,619	1,526	15,776	3,732	6,722	1,047	11,501	36,864
1921	3,896	288	105	4,289	268	73	341	907	5,795	3,220	975	10,897	2,203	2,417	5,270	9,890	25,417
1922	5,398	1,651	413	7,462	1,016	228	1,244	3,006	6,767	1,168	1,411	12,352	1,074	6,009	3,536	10,619	31,677
1923	4,127	673	277	5,077	103	75	178	4,938	7,928	9,041	1,689	23,596	2,584	1,332	10,513	14,429	43,280
1924	3,963	361	251	4,575	155	116	271	5,795	14,682	3,199	2,879	26,555	2,108	4,913	3,375	10,396	41,797
1925	2,779	1,205	1,107	5,091	883	406	1,289	3,836	3,002	2,471	676	9,985	3,010	11,955	6,543	21,508	37,873
1926	5,426	1,051	427	6,904	190	370	560	2,197	5,294	4,807	1,748	14,046	966	4,860	1,043	6,869	28,379

Table No. II.

Comparative statement of run-offs as measured at Papanasam lower dam site and at the Srivaikuntam anicut and supply channels.

Year.		January to March (winter). Discharge in m.c.ft. at Srivaikuntam.	January to March (winter). Discharge in m.c.ft. at Papanasam dam site.	April and May (summer). Discharge in m.c.ft. at Srivaikuntam.	April and May (summer). Discharge in m.c.ft. at Papanasam dam site.	June to September (south-west monsoon). Discharge in m.c.ft. at Srivaikuntam.	June to September (south-west monsoon). Discharge in m.c.ft. at Papanasam dam site.	October to December (north-east monsoon). Discharge in m.c.ft. at Srivaikuntam.	October to December (north-east monsoon). Discharge in m.c.ft. at Papanasam dam site.	Total for the year. Discharge in m.c.ft. at Srivaikuntam.	Total for the year. Discharge in m.c.ft. at Papanasam dam site.	Total as deduced from curve of figures for total year.
1905	..	..	..	1,107	**1,303**	3,675	**13,520**	16,237	**10,000**	..	..	..
1906	..	674	**1,600**	480	**500**	6,233	**16,500**	40,307	**12,700**	47,692	**31,300**	**32,750**
1907	..	2,274	**2,400**	1,968	**2,500**	8,264	**18,400**	26,264	**11,200**	38,769	**34,500**	**31,250**
1908	..	8,862	**5,300**	1,584	**2,000**	1,407	**9,250**	3,948	**5,500**	15,800	**22,050**	**24,250**
1909	..	632	**1,600**	2,132	**2,700**	2,088	**10,500**	3,679	**5,000**	8,531	**19,800**	**19,800**
1910	..	1,454	**2,000**	468	**500**	1,593	**9,600**	9,311	**8,750**	12,826	**20,850**	**22,370**
1911	..	243	**1,400**	77	..	4,197	**14,000**	28,538	**11,400**	33,055	**26,800**	**30,100**
1912	..	1,490	**2,000**	..	..	3,279	**12,750**	35,016	**12,100**	39,785	**26,850**	**31,400**
1913	..	2,275	**2,400**	651	**700**	2,251	**10,800**	42,924	**13,000**	48,098	**26,900**	**32,750**
1914	..	1,504	**2,000**	296	**270**	2,378	**11,100**	90,165	**24,500**	94,343	**37,870**	**49,750**
1915	..	2,225	2,400	530	317	14,243	20,580	24,084	11,300	41,082	34,597	..
1916	..	1,769	2,254	455	317	4,456	14,570	7,212	9,700	13,893	26,857	..
1917	..	2,545	4,148	360	518	2,247	10,800	7,779	8,600	12,931	24,073	..
1918	..	11,335	7,405	3,845	5,160	720	6,800	7,692	5,300	23,591	24,622	..
1919	..	4,667	3,480	559	581	5,792	17,400	13,739	9,400	24,757	30,637	..
1920	..	24,961	9,418	891	169	5,392	15,800	25,486	11,500	56,730	36,864	..
1921	..	6,466	4,290	652	341	3,841	10,900	15,096	9,900	26,055	25,417	..
1922	..	11,082	7,462	1,053	1,244	5,310	12,350	42,672	10,700	60,117	31,677	..
1923	..	9,698	5,077	724	178	15,894	23,600	47,897	14,429	74,213	43,280	..
1924	..	11,190	4,575	952	271	30,950	26,555	23,000	10,396	66,092	41,797	..
1925	..	9,220	5,091	..	1,289	..	9,985	..	21,508	..	37,873	..
1926	..	..	6,904	..	560	..	14,046	..	6,869	..	28,379	..

Note.—Clarendon figures are those deduced from correlation curves.

Table No. III.

Statement of run-offs computed for the years 1901—1923 for the Papanasam basin above lower dam site from the different data available such as (1) from the rainfall in the bordering stations in the plains namely Nedumangadu, Tenkasi, Ambasamudram and Pachiparai, (2) from the run-off of the Periyar basin, (3) from the run-off of the Kodayar basin and (4) from the discharges at the Srivaikuntam Anicut.

Year.		Run-off in m.c.ft. obtained for the Papanasam basin from rainfall data of four stations*. From annual total rainfall to run-off.	Run-off in m.c.ft. obtained for the Papanasam basin from rainfall data of four stations*. By adding the results obtained for the four seasons.	Run-off in m.c.ft. obtained for the Papanasam basin by correlation with the run-off of the Periyar basin. From annual total run-off.	Run-off in m.c.ft. obtained for the Papanasam basin by correlation with the run-off of the Periyar basin. By adding the results obtained for the four seasons.	Run-off in m.c.ft. obtained for the Papanasam basin by correlation with the run-off of the Kodayar basin. From annual total run-off.	Run-off in m.c.ft. obtained for the Papanasam basin by correlation with the run-off of the Kodayar basin. By adding the results obtained for the four seasons.	Run-off in m.c.ft. obtained for the Papanasam basin by correlation with the discharge at Srivaikuntam anicut across the Tambraparni river. From annual total run-off.	Run-off in m.c.ft. obtained for the Papanasam basin by correlation with the discharge at Srivaikuntam anicut across the Tambraparni river. By adding the results obtained for the four seasons.	Actual run-off from the Papanasam basin in m.c.ft.	Remarks.
1901	..	25,100	26,580	..	..	..	..	..	..	..	
1902	..	41,750	35,390	..	..	..	..	..	..	..	
1903	..	25,650	26,915	..	..	..	..	..	..	..	
1904	..	25,500	31,050	..	..	..	..	..	..	..	
1905	..	24,750	24,170	..	..	..	..	..	..	..	
1906	..	34,000	30,810	..	..	..	..	32,750	31,300	..	
1907	..	41,500	37,840	..	..	..	..	31,250	34,500	..	
1908	..	23,100	23,770	..	..	24,600	21,575	24,250	22,050	..	* Rainfall stations — 1. Ambasamudram. 2. Pachiparai. 3. Tenkasi. 4. Nedumangadu.
1909	..	23,350	22,430	30,000	30,000	27,250	..	19,800	19,800	..	
1910	..	24,100	22,945	24,400	22,720	25,750	25,050	22,370	20,850	..	
1911	..	24,300	23,975	28,000	25,450	27,600	25,280	30,100	26,800	..	
1912	..	29,150	28,860	29,800	29,070	35,000	25,855	31,400	26,850	..	
1913	..	28,000	27,560	22,750	20,080	26,500	23,825	32,750	26,900	..	
1914	..	42,750	34,220	25,800	25,130	26,500	25,700	49,750	37,870	..	
1915	..	30,400	33,380	32,800	31,690	38,100	34,970	31,750	36,010	34,597	
1916	..	23,750	24,590	27,100	25,150	32,500	29,340	23,000	24,900	26,857	
1917	..	24,000	30,055	24,100	23,130	24,250	22,870	22,130	21,950	24,073	
1918	..	26,500	30,600	23,900	27,830	24,300	17,540	27,500	23,560	24,622	
1919	..	30,300	32,340	30,800	31,310	29,400	28,130	27,880	29,861	30,637	
1920	..	40,000	35,250	30,400	32,900	29,200	29,570	34,200	37,410	36,864	
1921	..	24,900	24,620	29,400	29,570	25,700	27,470	28,300	28,590	25,417	
1922	..	34,600	31,300	37,700	40,320	31,100	33,525	34,750	35,844	31,677	
1923	..	38,500	38,820	43,800	43,028	..	..	38,900	42,810	43,280	

TABLE No. IV.

Table of bimonthly discharges of the Tambraparni River in million cubic feet in the Papanasam catchment for the years 1906—1926 partly gauged and partly deduced from the Srivaikuntam Anicut discharges in the same catchment.

Year.	Half-monthly periods.																								Total.
	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		
	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	
1906	480	320	273	160	220	175	96	27	55	320	541	1,325	751	1,185	7,487	3,553	689	891	908	1,107	3,003	2,884	2,541	2,319	31,313
1907	1,137	759	155	91	143	113	1,448	408	101	581	1,172	2,869	1,107	1,748	7,052	3,348	465	601	793	965	3,841	3,687	1,052	1,003	34,647
1908	1,541	1,027	1,193	695	512	407	1,152	325	92	461	363	888	1,452	2,420	1,472	701	855	1,104	1,252	1,524	1,177	1,131	227	208	22,179
1909	516	344	273	160	187	148	72	20	381	2,196	631	1,544	1,411	2,224	1,748	829	933	1,209	873	1,063	981	944	599	547	19,836
1910	688	459	471	273	93	75	216	61	33	193	208	509	391	616	3,521	1,675	1,172	1,616	825	1,003	3,483	3,349	124	113	21,067
1911	397	261	303	176	165	132	* 45	* 55	* 36	* 33	2,112	5,171	2,127	3,511	516	245	144	181	63	76	3,283	3,105	2,624	2,393	27,107
1912	871	581	236	137	60	119	* 45	* 55	* 36	* 33	2,237	5,476	1,027	1,620	1,305	620	268	347	1,951	2,375	2,184	2,103	1,827	1,669	27,182
1913	533	359	703	408	275	219	352	100	39	219	952	2,331	2,325	3,669	760	331	169	220	557	677	2,903	2,789	3,203	2,921	27,014
1914	764	509	176	103	253	201	216	61	* 36	* 33	469	1,151	2,524	3,985	1,365	649	397	515	2,608	3,171	2,631	2,528	7,037	6,415	37,797
1915	479	1,106	288	216	236	122	78	78	78	78	147	6,150	1,249	6,765	2,235	606	905	2,520	1,411	602	2,452	1,873	909	4,009	34,597
1916	1,128	519	247	198	78	83	78	78	78	83	4,615	2,530	1,062	2,087	1,357	636	1,460	816	517	3,237	919	2,710	1,773	568	26,857
1917	1,534	740	837	384	340	313	279	78	78	83	429	2,049	620	2,062	600	1,162	1,300	2,613	1,551	1,233	779	2,528	1,561	920	24,073
1918	1,518	3,893	911	580	281	222	78	78	252	4,752	774	1,918	1,166	285	326	1,668	515	142	154	170	477	577	1,517	2,368	24,622
1919	1,374	993	525	207	184	197	210	210	78	83	1,848	5,131	1,666	2,763	2,969	1,402	417	1,193	1,519	1,264	1,423	727	3,183	771	30,637
1920	8,294	582	311	103	79	49	45	55	36	33	133	5,650	3,470	3,378	1,058	561	491	1,035	3,034	698	1,640	5,082	487	560	36,864
1921	1,132	2,764	178	110	58	47	195	73	34	39	146	761	370	5,425	2,616	604	637	338	592	1,611	1,126	1,291	970	4,300	25,417
1922	4,780	618	837	814	292	121	436	580	48	180	1,314	1,692	5,050	1,717	435	733	604	807	273	807	2,203	3,806	3,271	265	31,677
1923	1,659	2,468	506	167	143	134	66	37	36	39	550	4,388	3,127	4,801	6,812	2,229	835	854	427	2,157	746	586	3,768	6,745	43,280
1924	3,327	636	249	112	67	184	117	38	37	79	4,022	1,773	3,879	10,803	2,037	1,162	1,242	1,637	874	1,234	4,349	564	2,009	1,366	41,797
1925	1,855	924	769	436	511	596	124	759	169	237	321	3,515	1,708	1,294	1,383	1,088	473	203	1,028	1,982	7,052	4,903	4,790	1,753	37,873
1926	802	4,624	659	392	311	116	137	53	54	316	782	1,415	2,729	2,565	3,700	1,107	1,052	696	501	465	3,721	1,139	419	624	28,379

* Where figures are not available the lowest figures of run-off recorded in 1920 for those periods are taken and used.

Note.—The figures in ordinary type indicate gauged results, and the clarendon figures deduced results.

TABLE No. IV-A.

Table of bimonthly discharges of the Tambraparni River in cusecs in the Papanasam catchment for the years 1906—1926 partly gauged and partly deduced from the Srivaikuntam Anicut discharges in the same catchment.

Year.	Half-monthly periods.																								Total.
	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		
	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	First.	Second.	
1906	360	240	205	120	165	131	72	20	41	240	406	994	583	889	5,615	2,667	517	668	681	880	2,252	2,163	1,906	1,739	23,484
1907	853	569	116	68	107	85	1,086	306	76	436	879	2,152	830	1,311	5,289	2,511	349	451	595	724	2,881	2,765	789	752	25,980
1908	1,156	770	895	521	384	305	864	244	69	346	272	666	1,089	1,815	1,104	526	641	828	939	1,143	883	848	170	156	16,634
1909	387	258	205	120	140	111	54	15	286	1,647	473	1,158	1,058	1,668	1,311	622	700	907	655	797	738	708	449	410	14,877
1910	516	344	358	205	70	56	162	46	25	145	156	382	293	432	2,641	1,256	879	1,137	619	752	2,612	2,512	93	85	15,801
1911	298	196	227	132	124	99	* 35	*42	*28	* 24	1,584	3,878	1.670	2,633	387	184	103	138	47	57	2,425	2,329	1,958	1,795	20,408
1912	653	436	177	103	45	89	* 35	*42	*28	* 24	1,678	4,107	770	1,215	979	465	201	260	1,463	1,781	1,638	1,577	1,370	1,252	20,388
1913	400	269	527	306	206	164	264	75	29	164	714	1,748	1,744	2,752	570	248	127	165	418	508	2,177	2,092	2,402	2,191	20,260
1914	573	382	132	77	190	151	162	46	*28	* 24	352	863	1,893	2,989	1,024	487	298	386	1,956	2,378	1,973	1,896	5,278	4,811	28,349
1915	370	800	238	179	182	89	60	60	60	60	114	4,745	963	4,894	1,725	439	699	1,944	1,089	435	1,892	1,445	701	2,900	26,078
1916	870	375	204	143	60	60	60	60	60	60	3,561	1,952	820	1,510	1,047	460	1,127	530	399	2,341	709	2,091	1,368	411	20,378
1917	1,184	535	692	317	262	226	215	60	60	60	331	1,581	478	1,492	463	840	1,003	2,016	1,197	892	601	1,951	1,204	666	18,326
1918	1,171	2,816	753	480	217	160	60	60	194	3,438	597	1,480	900	206	252	1,206	397	110	119	123	368	415	1,170	1,713	18,435
1919	1,060	718	434	171	142	142	162	162	60	60	1,426	3,959	1,285	1,999	2,290	1,015	322	921	1,172	914	1,098	561	2,688	558	23,319
1920	6,399	421	257	75	61	35	35	42	28	24	103	4,360	2,677	2,443	816	406	379	799	2,311	505	1,266	3,922	376	405	28,175
1921	873	1,999	147	91	45	34	150	57	26	28	113	581	286	3,924	2,019	437	492	261	456	1,165	869	996	748	3,111	18,914
1922	3,688	447	692	673	225	88	337	448	37	130	1,014	1,305	3,897	1,242	336	530	466	623	211	579	1,700	2,937	2,524	191	24,320
1923	1,280	1,785	418	138	110	97	51	29	28	28	424	3,386	2,413	3,473	5,256	1,613	644	659	329	1,560	576	452	2,908	4,880	32,537
1924	2,567	460	206	81	51	133	90	30	29	58	3,103	1,368	2,993	7,815	1,572	841	959	1,263	674	892	3,356	435	1,550	988	31,504
1925	1,431	668	636	361	395	431	96	586	130	172	248	2,712	1,318	936	1,067	787	365	156	793	1,434	5,441	3,783	3,696	1,268	28,910
1926	619	3,345	544	324	240	84	106	41	41	229	603	1,092	2,106	1,855	2,855	801	812	537	387	336	2,871	879	323	451	21,481

* Where figures are not available the lowest figures of run-off recorded in 1920 for those periods are taken and used.

NOTE.—The figures in ordinary type indicate gauged results, and the clarendon figures deduced results.

Table No. V.

Bimonthly average discharges in cusecs and equivalent available power in K.W. for a head of 320 feet.

Period.	Discharges in cusecs during			K.W. capacity. †		
	Minimum year (1911).	Ninety per cent year (1910).	Average year (1919).	Minimum year.	Ninety per cent year.	Average year.
January, 1st half	298	516	1,060	5,930	10,580	22,190
,, 2nd ,, ...	196	344	718	3,750	6,910	14,890
February, 1st ,, ...	227	353	434	4,630	7,320	9,050
,, 2nd ,, ...	132	205	171	2,600	4,160	3,440
March, 1st ,, ...	124	70	142	2,430	1,280	2,820
,, 2nd ,, ...	99	56	142	1,900	980	2,820
April, 1st ,, ...	35*	162	162	530*	3,250	[illegible]
,, 2nd ,, ...	42*	46	162	680*	770	[illegible]
May, 1st ,, ...	28*	25	60	380*	320	[illegible],070
,, 2nd ,, ...	24*	145	60	300*	2,880	[illegible],070
June, 1st ,, ...	1,584	156	1,426	33,370	2,900	30,000
,, 2nd ,, ...	3,878	382	3,959	82,310	7,720	84,080
July, 1st ,, ...	1,670	293	1,285	35,200	5,820	26,990
,, 2nd ,, ...	2,633	462	1,999	55,750	9,430	42,220
August, 1st ,, ...	387	2,641	2,290	7,830	55,920	48,430
,, 2nd ,, ...	184	1,256	1,015	3,500	26,370	21,230
September, 1st ,, ...	108	879	322	1,880	18,330	6,440
,, 2nd ,, ...	138	1,137	921	2,520	23,830	19,220
October, 1st ,, ...	47	619	1,172	580	12,780	24,580
,, 2nd ,, ...	57	752	914	790	15,620	19,070
November, 1st ,, ...	2,425	2,612	1,098	51,310	55,300	23,000
,, 2nd ,, ...	2,329	2,512	561	49,260	53,160	11,540
December, 1st ,, ...	1,968	93	2,688	41,560	1,560	56,920
,, 2nd ,, ...	1,795	85	558	37,870	1,390	11,480

* Where figures are not available the lowest figures of run-off recorded in 1920 for those periods are taken and used.

† This power is continuous, and for a ten hour working day values should be multiplied by 2·4.

Table No. VI.

Working tables for Papanasam basin for 600 cusecs continuous draw-off for the years 1908—1911.

Period.	Storage at beginning of period.	Inflow during the period.	Total.	Draw-off during the period.	Balance storage at end of period.	Remarks.
1908.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	SURPLUS.
January, 1st	..	1,156	1,156	600	0	556
,, 2nd	..	770	770	600	0	170
February, 1st	..	895	895	600	0	295
,, 2nd	..	521	521	600	— 79	..
March, 1st	— 79	384	305	600	— 295	..
,, 2nd	— 295	305	10	600	— 590	..
April, 1st	— 590	864	274	600	— 326	..
,, 2nd	— 326	244	— 82	600	— 682	..
May, 1st	— 682	69	— 613	600	— 1,213	..
,, 2nd	— 1,213	346	— 867	600	— 1,467	..
June, 1st	— 1,467	272	— 1,195	600	— 1,795	..
,, 2nd	— 1,795	666	— 1,129	600	— 1,729	..
July, 1st	— 1,729	1,089	— 640	600	— 1,240	..
,, 2nd	— 1,240	1,815	575	600	— 25	..
August, 1st	— 25	1,104	1,079	600	0	479
,, 2nd	0	526	526	600	— 74	..
September, 1st	— 74	641	567	600	— 33	..
,, 2nd	— 33	828	795	600	0	195
October, 1st	0	939	939	600	0	339
,, 2nd	0	1,143	1,143	600	0	543
November, 1st	0	883	883	600	0	283
,, 2nd	0	848	848	600	0	283
December, 1st	0	170	170	600	— 430	..
,, 2nd	— 430	156	— 274	600	— 874	..

N.B.—Multiply cusecs by 1·33 to get million cubic feet.

Table No. VI—*cont.*

Working tables for Papanasam basin for 600 cusecs continuous draw-off for the years 1908—1911—*cont.*

Period.	Storage at beginning of period.	Inflow during the period.	Total.	Draw off during the period.	Balance storage at end of period.	Remarks.
1909.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	SURPLUS.
January 1st	— 874	387	— 487	600	— 1,087	..
,, 2nd	— 1,087	258	— 829	600	— 1,429	..
February 1st	— 1,429	205	— 1,224	600	— 1,824	..
,, 2nd	— 1,824	120	— 1,704	600	— 2,304	..
March 1st	— 2,304	140	— 2,164	600	— 2,764	..
,, 2nd	— 2,764	111	— 2,653	600	— 3,253	..
April 1st	— 3,253	54	— 3,199	600	— 3,799	..
,, 2nd	— 3,799	15	— 3,784	600	— 4,384	..
May 1st	— 4,384	286	— 4,098	600	— 4,698	..
,, 2nd	— 4,698	1,647	— 3,051	600	— 3,651	..
June 1st	— 3,651	473	— 3,178	600	— 3,778	..
,, 2nd	— 3,778	1,158	— 2,620	600	— 3,220	..
July 1st	— 3,220	1,058	— 2,162	600	— 2,762	..
,, 2nd	— 2,762	1,668	— 1,094	600	— 1,694	..
August 1st	— 1,694	1,311	— 383	600	— 983	..
,, 2nd	— 983	622	— 361	600	— 961	..
September 1st	— 961	700	— 261	600	— 861	..
,, 2nd	— 861	907	46	600	— 554	..
October 1st	— 554	655	101	600	— 499	..
,, 2nd	— 499	797	298	600	— 302	..
November 1st	— 302	738	436	600	— 164	..
,, 2nd	— 164	708	544	600	— 56	..
December 1st	— 56	449	393	600	— 207	..
,, 2nd	— 207	410	203	600	— 397	..
1910.						
January 1st	— 397	516	119	600	— 481	..
,, 2nd	— 481	344	— 137	600	— 737	..
February 1st	— 737	353	— 384	600	— 984	..
,, 2nd	— 984	205	— 779	600	— 1,379	..
March 1st	— 1,379	70	— 1,309	600	— 1,909	..
,, 2nd	— 1,909	56	— 1,853	600	— 2,453	..
April 1st	— 2,453	162	— 2,291	600	— 2,891	..
,, 2nd	— 2,891	46	— 2,845	600	— 3,445	..
May 1st	— 3,445	25	— 3,420	600	— 4,020	..
,, 2nd	— 4,020	145	— 3,875	600	— 4,475	..
June 1st	— 4,475	156	— 4,319	600	— 4,919	..
,, 2nd	— 4,919	382	— 4,537	600	— 5,137	..
July 1st	— 5,137	293	— 4,844	600	— 5,444	..
,, 2nd	— 5,444	462	— 4,982	600	— 5,582	..
August 1st	— 5,582	2,641	— 2,941	600	— 3,541	..
,, 2nd	— 3,541	1,256	— 2,285	600	— 2,885	..
September 1st	— 2,885	879	— 2,006	600	— 2,606	..
,, 2nd	— 2,606	1,137	— 1,469	600	— 2,069	..
October 1st	— 2,069	619	— 1,450	600	— 2,050	..
,, 2nd	— 2,050	752	— 1,298	600	— 1,898	..
November 1st	— 1,898	2,612	714	600	0	114
,, 2nd	0	2,512	2,512	600	0	1,912
December 1st	0	93	93	600	— 507	..
,, 2nd	— 507	85	— 422	600	— 1,022	..
1911.						
January 1st	— 1,022	298	— 724	600	— 1,324	..
,, 2nd	— 1,324	196	— 1,128	600	— 1,728	..
February 1st	— 1,728	227	— 1,501	600	— 2,101	..
,, 2nd	— 2,101	132	— 1,969	600	— 2,569	..
March 1st	— 2,569	124	— 2,445	600	— 3,045	..
,, 2nd	— 3,045	99	— 2,946	600	— 3,546	..
April 1st	— 3,546	0	— 3,546	600	— 4,146	..
,, 2nd	— 4,146	0	— 4,146	600	— 4,746	..
May 1st	— 4,746	0	— 4,746	600	— 5,346	..
,, 2nd	— 5,346	0	— 5,346	600	— 5,946	..
June 1st	— 5,946	1,584	— 4,362	600	— 4,962	..
,, 2nd	— 4,962	3,878	— 1,084	600	— 1,684	..
July 1st	— 1,684	1,670	— 14	600	— 614	..
,, 2nd	— 614	2,633	2,019	600	0	1,419

N.B.—Multiply cusecs by 1·33 to get million cubic feet.

Table No. VII.

Working tables for Papanasam basin for 625 cusecs continuous draw-off for the years 1908—1911.

Period.	Storage at beginning of period.	Inflow during the period.	Total.	Draw-off during the period.	Balance storage at end of period.	Remarks.
	CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	SURPLUS.
1908.						
January 1st	..	1,156	1,156	625	0	531
,, 2nd	..	770	770	625	0	145
February 1st	..	895	895	625	0	270
,, 2nd	..	521	521	625	— 104	..
March 1st	— 104	384	280	625	— 345	..
,, 2nd	— 345	305	— 40	625	— 665	..
April 1st	— 665	864	199	625	— 426	..
,, 2nd	— 426	244	— 182	625	— 807	..
May 1st	— 807	6[illegible]	— 738	625	— 1,263	..
,, 2nd	— 1,263	346	— 917	625	— 1,542	..
June 1st	— 1,542	272	— 1,270	625	— 1,895	..
,, 2nd	— 1,895	666	— 1,229	625	— 1,854	..
July 1st	— 1,854	1,089	— 765	625	— 1,390	..
,, 2nd	— 1,390	1,815	— 425	625	— 200	..
August 1st	— 200	1,104	904	625	0	279
,, 2nd	0	526	526	625	— 99	..
September 1st	— 99	641	542	625	— 83	..
,, 2nd	— 83	828	745	625	0	120
October 1st	0	939	939	625	0	314
,, 2nd	0	1,143	1,143	625	0	518
November 1st	0	883	883	625	0	258
,, 2nd	0	848	848	625	0	223
December 1st	0	170	170	625	— 455	..
,, 2nd	— 455	156	— 299	625	— 924	..
1909						
January 1st	— 924	387	— 537	625	— 1,162	..
,, 2nd	— 1,162	258	— 904	625	— 1,529	..
February 1st	— 1,529	205	— 1,324	625	— 1,949	..
,, 2nd	— 1,949	120	— 1,829	625	— 2,454	..
March 1st	— 2,454	140	— 2,314	625	— 2,939	..
,, 2nd	— 2,939	111	— 2,828	625	— 3,453	..
April 1st	— 3,453	54	— 3,399	625	— 4,024	..
,, 2nd	— 4,024	15	— 4,009	625	— 4,634	..
May 1st	— 4,634	286	— 4,348	625	— 4,973	..
,, 2nd	— 4,973	1,647	— 3,326	625	— 3,951	..
June 1st	3,951	473	— 3,478	625	— 4,103	..
,, 2nd	— 4,103	1,158	— 2,945	625	— 3,570	..
July 1st	— 3,570	1,058	— 2,512	625	— 3,137	..
,, 2nd	— 3,137	1,668	— 1,469	625	— 2,094	..
August 1st	— 2,094	1,311	— 783	625	— 1,408	..
,, 2nd	— 1,408	622	— 786	625	— 1,411	..
September 1st	— 1,411	700	— 711	625	— 1,336	..
,, 2nd	— 1,336	907	— 429	625	— 1,054	..
October 1st	— 1,054	655	— 399	625	— 1,024	..
,, 2nd	— 1,024	797	— 227	625	— 852	..
November 1st	— 852	738	— 114	625	— 739	..
,, 2nd	— 739	708	— 31	625	— 656	..
December 1st	— 656	449	— 207	625	— 832	..
,, 2nd	— 832	410	— 422	625	— 1,047	..
1910						
January 1st	— 1,047	516	— 531	625	— 1,156	..
,, 2nd	— 1,156	344	— 812	625	— 1,437	..
February 1st	— 1,437	353	— 1,084	625	— 1,709	..
,, 2nd	— 1,709	205	— 1,504	625	— 2,129	..
March 1st	— 2,129	70	— 2,059	625	— 2,684	..
,, 2nd	— 2,684	56	— 2,628	625	— 3,253	..
April 1st	— 3,253	162	— 3,091	625	— 3,716	..
,, 2nd	— 3,716	46	— 3,670	625	— 4,295	..
May 1st	— 4,295	25	— 4,270	625	— 4,895	..
,, 2nd	— 4,895	145	— 4,750	625	— 5,375	..
June 1st	— 5,375	156	— 5,219	625	— 5,844	..
,, 2nd	— 5,844	382	— 5,462	625	— 6,087	..
July 1st	— 6,087	293	— 5,794	625	— 6,419	..
,, 2nd	— 6,419	462	— 5,957	625	— 6,582	..
August 1st	— 6,582	2,641	— 3,941	625	— 4,566	..
,, 2nd	— 4,566	1,256	— 3,310	625	— 3,935	..
September 1st	— 3,935	879	— 3,056	625	— 3,681	..
,, 2nd	— 3,681	1,137	— 2,544	625	— 3,169	..
October 1st	— 3,169	619	— 2,550	625	— 3,175	..
,, 2nd	— 3,175	752	— 2,423	625	— 3,048	..
November 1st	— 3,048	2,612	— 436	625	— 1,061	..
,, 2nd	— 1,061	2,512	— 1,451	625	0	826
December 1st	0	93	93	625	— 532	..
,, 2nd	— 532	85	— 508	625	— 1,133	..

N.B.—Multiply cusecs by 1·33 to get million cubic feet.

Table No. VII—*cont.*

Working tables for Papanasam basin for 625 cusecs continuous draw-off for the years 1908—1911—*cont.*

Period.	Storage at beginning of period.	Inflow during the period.	Total.	Draw-off during the period.	Balance storage at end of period.	Remarks.
	CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	SURPLUS.
1911.						
January 1st	— 1,133	298	— 835	625	— 1,460	..
,, 2nd	— 1,460	196	— 1,264	625	— 1,889	..
February 1st	— 1,889	227	— 1,662	625	— 2,287	..
,, 2nd	— 2,287	132	— 2,155	625	— 2,780	..
March 1st	— 2,780	124	— 2,656	625	— 3,281	..
,, 2nd	— 3,281	99	— 3,281	625	— 3,807	..
April 1st	— 3,807	0	— 3,807	625	— 4,432	..
,, 2nd	— 4,432	0	— 4,432	625	— 5,057	..
May 1st	— 5,057	0	— 5,057	625	— 5,682	..
,, 2nd	— 5,682	0	— 5,682	625	— 6,307	..
June 1st	— 6,307	1,584	— 4,723	625	— 5,348	..
,, 2nd	— 5,348	3,878	— 1,470	625	— 2,095	..
July 1st	— 2,095	1,670	— 425	625	— 1,050	..
,, 2nd	— 1,050	2,633	1,583	625	..	958

Table No. VIII.

Working tables for Papanasam basin for 650 cusecs continuous draw-off for the years 1908—1911.

Period.	Storage at beginning of period.	Inflow during the period.	Total.	Draw-off during the period.	Balance storage at end of period.	Remarks.
	CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	SURPLUS.
1908.						
January 1st	..	1,156	1,156	650	0	506
January 2nd	..	770	770	650	0	120
February 1st	..	895	895	650	0	245
February 2nd	..	521	521	650	— 129	..
March 1st	— 129	384	255	650	— 395	..
March 2nd	— 395	305	— 90	650	— 740	..
April 1st	— 740	864	124	650	— 526	..
April 2nd	— 526	244	— 282	650	— 932	..
May 1st	— 932	69	— 863	650	— 1,513	..
May 2nd	— 1,513	346	— 1,167	650	— 1,817	..
June 1st	— 1,817	272	— 1,545	650	— 2,195	..
June 2nd	— 2,195	666	— 1,529	650	— 2,179	..
July 1st	— 2,179	1,089	— 1,090	650	— 1,740	..
July 2nd	— 1,740	1,815	75	650	— 575	..
August 1st	— 575	1,104	529	650	— 121	..
August 2nd	— 121	526	405	650	— 245	..
September 1st	— 245	641	396	650	— 254	..
September 2nd	— 254	828	574	650	— 76	..
October 1st	— 76	939	863	650	0	213
October 2nd	..	1,143	1,143	650	0	493
November 1st	..	883	883	650	0	183
November 2nd	..	848	848	650	0	198
December 1st	..	170	170	650	— 480	..
December 2nd	— 480	156	— 324	650	— 974	..
1909.						
January 1st	— 974	387	— 587	650	— 1,237	..
January 2nd	— 1,237	258	— 979	650	— 1,629	..
February 1st	— 1,629	205	— 1,424	650	— 2,074	..
February 2nd	— 2,074	120	— 1,954	650	— 2,604	..
March 1st	— 2,604	140	— 2,464	650	— 3,114	..
March 2nd	— 3,114	111	— 3,003	650	— 3,653	..
April 1st	— 3,653	54	— 3,599	650	— 4,249	..
April 2nd	— 4,249	15	— 4,234	650	— 4,884	..
May 1st	— 4,884	286	— 4,598	650	— 5,248	..
May 2nd	— 5,248	1,647	— 3,601	650	— 4,251	..
June 1st	— 4,251	473	— 3,778	650	— 4,428	..
June 2nd	— 4,428	1,158	— 3,270	650	— 3,920	..
July 1st	— 3,920	1,058	— 2,862	650	— 3,512	..
July 2nd	— 3,512	1,668	— 1,844	650	— 2,494	..
August 1st	— 2,494	1,311	— 1,183	650	— 1,833	..
August 2nd	— 1,833	622	— 1,211	650	— 1,861	..
September 1st	— 1,861	700	— 1,161	650	— 1,811	..
September 2nd	— 1,811	907	— 904	650	— 1,554	..
October 1st	— 1,554	655	— 899	650	— 1,549	..
October 2nd	— 1,549	797	— 752	650	— 1,402	..
November 1st	— 1,402	738	— 664	650	— 1,314	..
November 2nd	— 1,314	708	— 606	650	— 1,256	..
December 1st	— 1,256	449	— 807	650	— 1,457	..
December 2nd	— 1,457	410	— 1,047	650	— 1,697	..

N.B.—Multiply cusecs by 1·33 to get million cubic feet.

TABLE No. VIII—*cont.*

Working tables for Papanasam basin for 650 cusecs continuous draw-off for the years 1908—1911—*cont.*

Period.		Storage at beginning of period.	Inflow during the period.	Total.	Draw off during the period.	Balance storage at end of period.	Remarks.
		CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	SURPLUS.
1910.							
January	1st	— 1,697	516	— 1,181	650	— 1,831	..
	2nd	— 1,831	344	— 1,487	650	— 2,137	..
February	1st	— 2,137	353	— 1,784	650	— 2,434	..
	2nd	— 2,434	205	— 2,229	650	— 2,879	..
March	1st	— 2,879	70	— 2,809	650	— 3,459	..
	2nd	— 3,459	56	— 3,403	650	— 4,053	..
April	1st	— 4,053	162	— 3,891	650	— 4,541	..
	2nd	— 4,541	46	— 4,495	650	— 5,145	..
May	1st	— 5,145	25	— 5,120	650	— 5,770	..
	2nd	— 5,770	145	— 5,625	650	— 6,275	..
June	1st	— 6,275	156	— 6,119	650	— 6,769	..
	2nd	— 6,769	382	— 6,387	650	— 7,037	..
July	1st	— 7,037	293	— 6,744	650	— 7,394	..
	2nd	— 7,394	462	— 6,932	650	— 7,582	..
August	1st	— 7,582	2,641	— 4,941	650	— 5,591	..
	2nd	— 5,591	1,256	— 4,335	650	— 4,985	..
September	1st	— 4,985	879	— 4,106	650	— 4,756	..
	2nd	— 4,756	1,137	— 3,619	650	— 4,269	..
October	1st	— 4,269	619	— 3,650	650	— 4,300	..
	2nd	— 4,300	752	— 3,548	650	— 4,198	..
November	1st	— 4,198	2,612	— 1,586	650	— 2,236	..
	2nd	— 2,236	2,512	276	650	— 374	..
December	1st	— 374	93	— 281	650	— 931	..
	2nd	— 931	85	— 846	650	— 1,496	..
1911.							
January	1st	— 1,496	298	— 1,198	650	— 1,848	..
	2nd	— 1,848	196	— 1,652	650	— 2,302	..
February	1st	— 2,302	227	— 2,075	650	— 2,725	..
	2nd	— 2,725	132	— 2,593	650	— 3,243	..
March	1st	— 3,243	124	— 3,119	650	— 3,769	..
	2nd	— 3,769	99	— 3,670	650	— 4,320	..
April	1st	— 4,320	0	— 4,320	650	— 4,970	..
	2nd	— 4,970	0	— 4,970	650	— 5,620	..
May	1st	— 5,620	0	— 5,620	650	— 6,270	..
	2nd	— 6,270	0	— 6,270	650	— 6,920	..
June	1st	— 6,920	1,584	— 5,336	650	— 5,986	..
	2nd	— 5,986	3,878	— 2,108	650	— 2,758	..
July	1st	— 2,758	1,670	— 1,088	650	— 1,738	..
	2nd	— 1,738	2,633	895	650	0	245

N.B.—Multiply cusecs by 1·33 to get million cubic feet.

TABLE No. IX.

Working tables for the Papanasam upper reservoir for 440 cusecs continuous draw-off for the minimum years, 1909, 1910 and 1911.

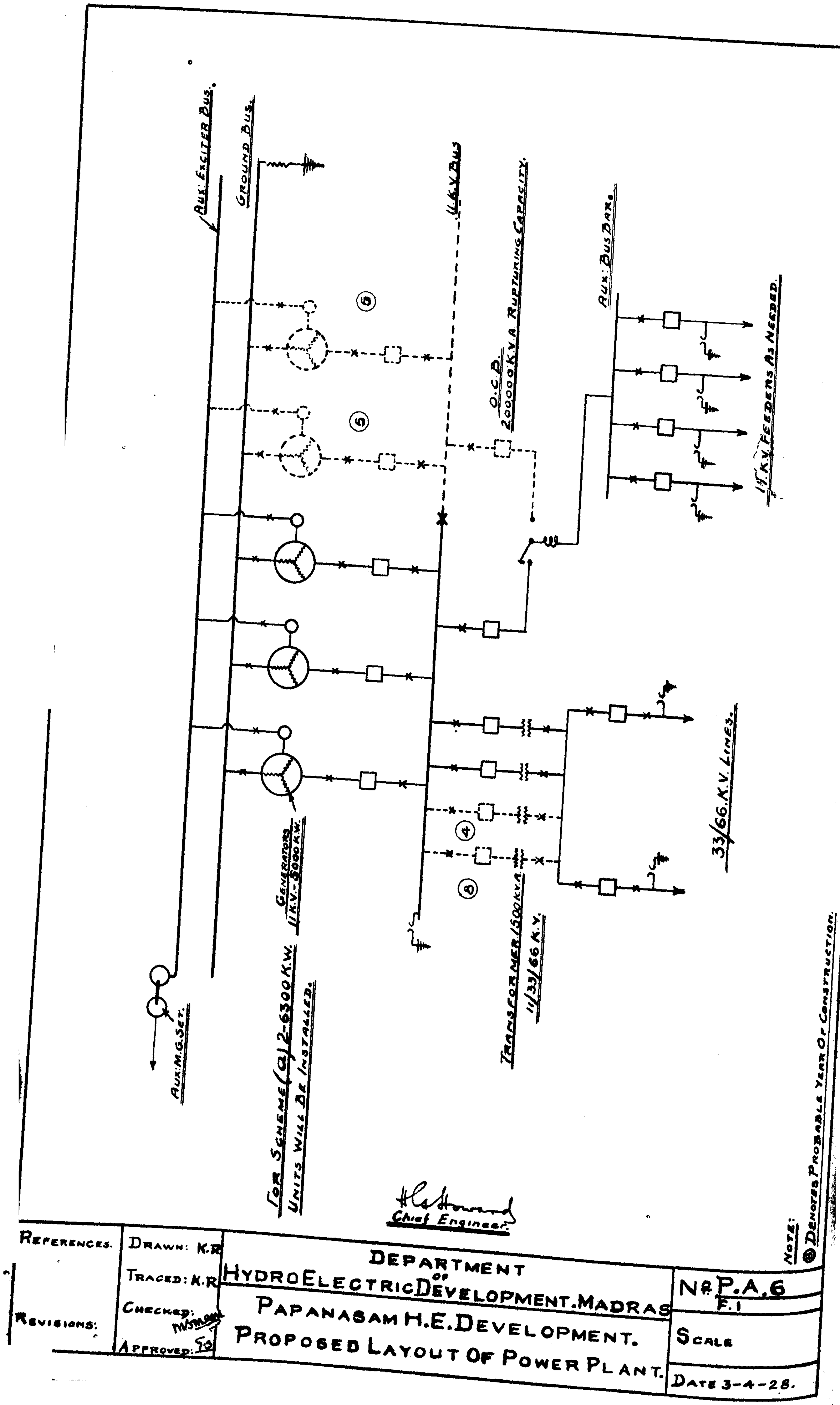
Half-months.		Run-off into Papanasam upper reservoir in minimum year.	Run-off from catchment into the Tambraparni between upper reservoir and off-take for power.	Gross draft proposed from the off-take in cusecs average.	Deficiency in the run-off in item 3 to meet the draft required.	Reservoir capacity 5,500 m.c.ft. gross and about 5,000 m.c.ft. net excluding evaporation (equivalent to).	Draw-off from storage due to deficiency during month in off-take.	Total storage in reservoir at end of bi-monthly period with 3,750 cusecs to start with.
		CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.	CUSECS.
1909.								3,750
		194	194		— 246		— 52	3,698
January	1st	129	129		— 311		— 182	3,516
	2nd	102	102		— 338		— 236	3,280
February	1st	60	60		— 380		— 320	2,960
	2nd	70	70		— 370		— 300	2,660
March	1st	56	56		— 384		— 328	2,332
	2nd	27	27		— 413		— 386	1,946
April	1st	8	8		— 432		— 424	1,522
	2nd	143	143		— 297		— 154	1,368
May	1st	824	824		0		824	2,192
	2nd	236	236		— 204		32	2,224
June	1st	579	579		0		579	2,803
	2nd	529	529		0		529	3,332
July	1st	834	834		0		834	3,750
	2nd	656	656		0		656	3,750
August	1st	311	311		— 129		182	3,750
	2nd	350	350		— 90		260	3,750
September	1st	454	454		0		454	3,750
	2nd	328	328		— 112		216	3,750
October	1st	398	398		— 42		356	3,750
	2nd	369	369		— 71		298	3,750
November	1st	354	354		— 86		268	3,750
	2nd	225	225		— 215		10	3,750
December	1st	205	205		— 235		— 30	3,720
	2nd	258	258		— 182		76	3,796
		172	172		— 268		— 96	3,790
1910.		176	176		— 264		— 88	3,702
January	1st	103	103		— 337		— 234	3,468
	2nd	35	35		— 405		— 370	3,098
February	1st	28	28		— 412		— 384	2,714
	2nd	81	81		— 359		— 278	2,436
March	1st	23	23		— 417		— 394	2,042
	2nd	12	12		— 428		— 416	1,626
April	1st	72	72		— 368		— 296	1,330
	2nd	78	78		— 362		— 284	1,046
May	1st	191	191		— 249		— 58	988
	2nd	146	146		— 294		— 148	840
June	1st	231	231		— 209		22	862
	2nd	1,320	1,320	440	0	3,750 cusecs available for a fortnight.	1,320	2,182
July	1st							
	2nd							
August	1st	628	628		0		628	2,910
	2nd	439	439		— 1		438	3,348
September	1st	568	568		0		568	3,750
	2nd	310	310		— 130		180	3,750
October	1st	376	376		— 64		312	3,750
	2nd	1,306	1,306		0		1,306	3,750
November	1st	1,256	1,256		0		1,256	3,750
	2nd	46	46		— 394		— 348	3,402
December	1st	43	43		— 397		— 354	3,048
	2nd							
1911		149	149		— 291		— 142	2,906
January	1st	98	98		— 342		— 244	2,662
	2nd	113	113		— 327		— 214	2,448
February	1st	66	66		— 374		— 308	2,140
	2nd	62	62		— 378		— 316	1,824
March	1st	50	50		— 390		— 340	1,484
	2nd	17	17		— 423		— 406	1,078
April	1st	21	21		— 419		— 398	680
	2nd	14	14		— 426		— 412	268
May	1st	12	12		— 428		— 416	— 148
	2nd	792	792		0		792	644
June	1st	1,939	1,939		0		1,939	2,583
	2nd	835	835		0		835	3,418
July	1st	1,316	1,316		0		1,316	3,750
	2nd	193	193		— 247		— 54	3,696
August	1st	92	92		— 348		— 256	3,440
	2nd	54	54		— 386		— 332	3,108
September	1st	69	69		— 371		— 302	2,806
	2nd	23	23		— 417		— 394	2,412
October	1st	28	28		— 412		— 384	2,028
	2nd	1,212	1,212		0		1,212	3,240
November	1st	1,164	1,164		0		1,164	3,750
	2nd	984	984		0		984	3,750
December	1st	897	897		0		897	3,750
	2nd							

Table No. X.

Capacity Table of the Papanasam Upper Reservoir.

Lowest bed level of river is + 701·38 above M.S.L.

Mean Sea Level.	Water spread area in million square feet.	Capacity in million cubic feet.	Mean Sea Level.	Water spread area in million square feet.	Capacity in million cubic feet.
700	..	..	830	53·06	3,309·4
710	0·16	0·8	840	55·45	3,852·0
720	1·36	13·4	850	57·85	4,418·5
730	3·98	40·1	860	60·47	5,010·1
740	8·39	101·9	870	63·00	5,627·5
750	16·25	225·1	880	65·77	6,271·[illegible]
760	24·08	426·7	890	68·24	6,9[illegible]·4
770	30·64	700·3	900	70·22	7,638·7
780	36·24	1,034·7	910	73·20	8,450·3
790	40·46	1,418·2	920	75·84	9,196·0
800	44·27	1,841·9	930	78·38	9,967·1
810	47·64	2,301·5	940	81·22	10,765·1
820	50·44	2,791·9	950	83·77	11,590·1



SECTION 4—THE DEVELOPMENT.

Scheme (*a*).—This development is primarily to generate seasonal power for the proposed paper mills. It must, however, be so designed that it may form part of a more comprehensive system for the generation, transmission, and distribution of power to the districts of Tinnevelly, Tuticorin, Kovilpatti and Sattur; it may even include Virudunagar and Madura. Provision must also be made for any new industries which may be established in the locality and any possible electrification of the railways.

No storage would be provided at the outset, provision being made only for seasonal power. The power which may be expected is shown in table V.

A diversion dam, to eventually form part of a larger structure, would be constructed at the lower dam site No. 2. This would have to be constructed up to an elevation of 650 feet giving a height of 50 feet above the level of the river-bed. It is necessary to go to this height in order to provide suitable pondage, as there is practically no storage below elevation 640 feet. At elevation 650 feet the pondage is 110 million cubic feet giving a reserve capacity corresponding to over 640,000 K.W. hours, or 6,300 K.W. continuously for about four days. Given a load factor of 34 per cent, the available power in the river mentioned in table V can be multiplied by 3 to give the maximum demand which may be relied upon. The elevation of the inlet at the diversion dam would be 635 feet. From the diversion dam the water would be conveyed by a riveted pipe line 3,680 feet long and 9 feet in diameter. This would be connected to a surge tank and header from which one riveted penstock 6 feet in diameter would take off and lead to the power house. The average static head is 645—310, or 335 feet; at maximum load, allowing for friction losses, 319 feet should be available.

In a recent report it was proposed to convey the water from the diversion dam by a flume 1,196 feet long to a forebay, formed by an earth embankment across a natural depression on the left of the road, with a masonry dam at the deepest portion at the east end. According to the estimates submitted, the forebay could be constructed for less than the pipe line. From an engineering point of view the pipe line appears the better design. With the pipe line, about 10 feet of head is gained, which is an important item on such a low head installation. About 3 per cent more power can be generated. If the lower reservoir capacity is increased to 3,300 million cubic feet, as is proposed for a later stage of Scheme (*b*), the gain in head with a pipe line will be a further 15 per cent. Also the only favourable location for the site of the projected paper mills will be saved from being submerged, as it would be by the forebay. It is further doubtful if the forebay can be constructed for the amount estimated. It is therefore considered, without going more into detail, that the pipe line is preferable to the forebay. This question will, however, be analyzed in greater detail, when actual design work is started.

At the Power House two 6,300 K.W. 11,000 volt generating units, one being spare, would be provided; this would constitute the installation for the paper mills.

Should it be found possible to develop sufficient seasonal load in the surrounding districts, another penstock would be added. Transformers, H.T. switching equipment, lines, and step-down transformer installations would be included as for Scheme (*b*).

The ultimate installation would be four 6,300 K.W. units, one of which would be spare.

Scheme (*b*).—A dam impounding 4,000 million cubic feet is to be constructed at the upper site, the diversion dam to be the same as in the previous scheme. A pipe line 7·5 feet in diameter is provided, with surge tank and header, from which two penstocks 5 feet in diameter would supply three (one spare) 5,000 K.W. generating units. Suitable transformers, high tension switching equipment, transmission lines, and sub-stations are included in the estimates. The lay-out is shown on drawing No. $\frac{\text{P.A. 6}}{\text{F. 1}}$.

In the fifth year provision is made for increasing the height of dam No. 1, and the storage capacity to 5,500 million cubic feet in order to provide for a continuous flow of 430 cusecs or 9,200 K.W. A duplicate pipe line, and two more generating units of 5,000 K.W., with the necessary penstocks, would complete the installation.

When necessary, the lower dam could be raised and an additional 3,190 million cubic feet stored. This would give the maximum continuous flow contemplated, which is 610 cusecs or 13,100 K.W. The maximum peak load would be 18,400 K.W., giving a load factor of 71·5 per cent.

Estimates and design.—Details of plant and equipment for the Schemes (*a*) and (*b*) are summarized in table XIV and the estimates are given in table XV. They must be considered preliminary, and several months' field work is necessary before final estimates and design could be submitted. However for present purposes, and to form a decision as to the feasibility of any of the schemes mentioned, the estimates can be accepted with confidence. They are believed to be fairly close, and any revision will be, as in the case of Pykara, downwards.

TABLE No. XIV.

Statement of plant and equipment.

Scheme.	—	(a)	(b)	
Year.	—	First	First	Fifth
Installed capacity (including spares).	KW.	12,600	15,000	+ 25,000
Continuous.	KW.	..	7,400	+ 9,200
			FIRST STAGE.	SECOND STAGE.
1. Upper dam site—				
Elevation at river-bed	Feet.	..	703	703
,, ,, dam crest	,,	..	843	873
Height of dam	,,	..	140	170
Storage	M.C. Ft.	..	4,000	5,500
2. Lower dam site—				
Elevation at river-bed	Feet.	600	600	..
,, ,, dam crest	,,	650	650	..
,, ,, inlet level	,,	635	635	..
Height of dam	,,	50	50 *	..
Storage	M.C. Ft.	110	110	..
3. Pipe line—				
Number	..	1	1	+ 1
Diameter	Feet	9	7·5	7·5
Length	,,	3,680	3,680	3,680
Maximum velocity	Ft./Sec.	9·5	9·8	9·8
,, flow	Cusecs.	600	430	430
4. Penstocks—				
Number	..	1 †	2	+ 2
Diameter	Feet	6	5	5
Length	,,	735	735	735
Velocity	Ft./Sec.	10·6	11·0	11·0
Flow	Cusecs.	300	215	215
5. Turbines—				
Number (including spares)	..	2 †	3	+ 2
Head (gross)	Feet.	335	335	335
Head (nett)	,,	319	315	315
Capacity	H.P.	9,200	7,000	7,000
Speed	R.P.M.	500	500	500
Elevation at tail race	Feet.	310	310	310
6. Alternators—				
Number (including spares)	,,	2 †	3	+ 2
Capacity	KW.	6,300	5,000	5,000
Voltage	Volts.	11,000	11,000	11,000
Frequency	Cycles/Sec.	50	50	50
7. Transformers—				
Number (including spares)	..	..	2	+ 2
Capacity	KVA.	..	1,500	1,500
Voltage ratio	Kilovolts.	..	11/33/66	11/33/66
8. Transmission voltage	Volts.	..	33,000	33,000 ‡
Supply voltage	,,	..	400	400

* At a later stage this will be developed to store 3,300 m.c. ft.

† A second penstock, and two more generating units will be added later on, as demand for seasonal load develops.

‡ Ultimately 66,000 volts.

Dam No. 1.—Certain test pits have been dug and the foundations are assumed to go 20 feet below the river-bed. The site is an exceptionally good one with bed rock visible in the river and on each side. In estimating the cost of this structure the quantities have been taken from the curve No. $\frac{P.A. 5}{F. 2.}$ The section assumed was the same as that at Mettur. If the construction of this structure is contemplated, further exploration will be carried out in the field, and the dam designed, in detail, to suit local conditions. From studies in connexion with the Pykara project, it would appear that a gravity section constructed with a rubble masonry facing, and cement concrete hearting, with 20 per cent plums, will prove the most suitable design. As the dam will undoubtedly be raised at a later date, it is proposed to construct for an overflow section at first, and raise it later to follow a non-overflow profile. In both cases part of the flood waters would be taken care of by the outlet sluices in the body of the dam, the remainder flowing over the crest of the structure in the first case, and over a spillway, blasted out on the right flank of the dam, when the structure was constructed for maximum height.

Diversion Dam.—For the purposes of this estimate, quantities for the diversion dam and elevations have been taken from the report of Lieutenant-Colonel M. G. Platts. It is considered that he has made a very ample provision in his figures for the masonry required, and the final design should prove less costly. A good deal of field work is necessary before final designs could be submitted. The dam could be of a simple overflow section, with inlet works similar to those designed for Pykara. It has been said that the structure would have to be scrapped, should the construction of a higher dam be contemplated. This procedure is not necessary as, properly constructed, it could very well form part of a larger structure, while the inlet tower could be designed to permit an extension of the height whenever necessary.

It has been previously mentioned that the elevation of the crest of the dam would be 650 feet, which is 50 feet above the bed of the river. This gives a pondage of 110 million cubic feet. However, below elevation 640 no appreciable storage exists. The inlet level would be about 635 feet, and the average head calculated from elevation 645 feet.

Pipe Line.—For a low head plant it is of much greater importance to avoid high friction losses, than for those operating at higher heads. Given a certain loss, the percentage is so much higher in the case of the low head plant. For this reason the velocities have been fixed so that the total loss of head will be about 5 per cent, giving an average working head of 319 feet for Scheme (*a*) and 315 feet for Scheme (*b*). For Scheme (*a*) the pipe line will have a capacity sufficient to supply two generating units of 6,300 K.W. each, and for Scheme (*b*) it will supply two of 5,000 K.W. In the first case, the water required is 600 cusecs, and in the second 430 cusecs. Each penstock will have a capacity of half these amounts. The sizes work out as follows :—

	Scheme (*a*).	Scheme (*b*).	Maximum head.
Pipe Line—			
Diameter	9 feet.	7·5 feet.	150 feet.
Velocity	9·5 ,,	9·8 ,,	
Loss of head	10 ,,	13 ,,	
Penstocks—			
Diameter	6 ,,	5 ,,	325 ,,
Velocity	10·6 ,,	11 ,,	
Loss of head	4 ,,	5 ,,	

In addition an allowance of 2·0 feet is made for velocity and entrance losses.

Surge tank and valves.—At the end of the 3,680 feet pipe line a surge tank will be provided with suitable drain. A header will be fitted between the pipe line and the two penstocks. These latter will be equipped with automatic butterfly valves and Venturi meter or Pitot tubes. At the power house a rotary or gate valve would be installed.

Piers and anchors.—These have been roughly calculated from data of other installations.

Hoist.—An inclined track from the surge tank to the power house with petrol-driven winch has been provided for in the estimates.

The main power house, as now projected, is located on a flat piece of ground near the Agastya temple at elevation 320 feet. The tail race could probably be excavated to elevation 310 feet. It has been proposed to divert the river down the right bank to a site near the present Papanasam Cotton Mills. Lieutenant-Colonel M. G. Platts in his report shows that there would be no advantage in doing this. He also suggests installing the turbines in a pit at level 280 feet and taking the discharge through a tunnel 2,000 feet long into a pool above the Kodamelalagian Anicut at elevation 270 feet. The additional cost of the installation, and the disadvantages of the long shafting and subterranean chamber more than offset, in the writer's opinion, the benefit of the additional head. This idea will, however, be given more study in the field.

Power House building.—The building on which the estimates are based is a steel structure with concrete foundations, masonry walls, and corrugated iron roof, suitable ventilation being provided.

Generating units.—For Scheme (*a*) two 6,300 K.W. 11,000 volt vertical type generators, with reaction turbines operating at 500 R.P.M. are contemplated. Scheme (*b*) includes at the outset, three (one spare) similar units, but of 5,000 K.W. capacity each, and two such units later.

Switching equipment.—The lay-out of the power house for both schemes is shown on drawing $\frac{\text{P.A. 6}}{\text{F. 1}}$ and suitable switchgear and auxiliary equipment is provided for in the estimates.

Transformers.—These would be necessary only in Scheme (*b*). Two units each of 1,500 KVA. capacity, 66/33/11 KV., would be provided, and later, two more units would be added. This allows for one complete spare unit at each stage. The transformers and H.T. switchgear will be installed outside.

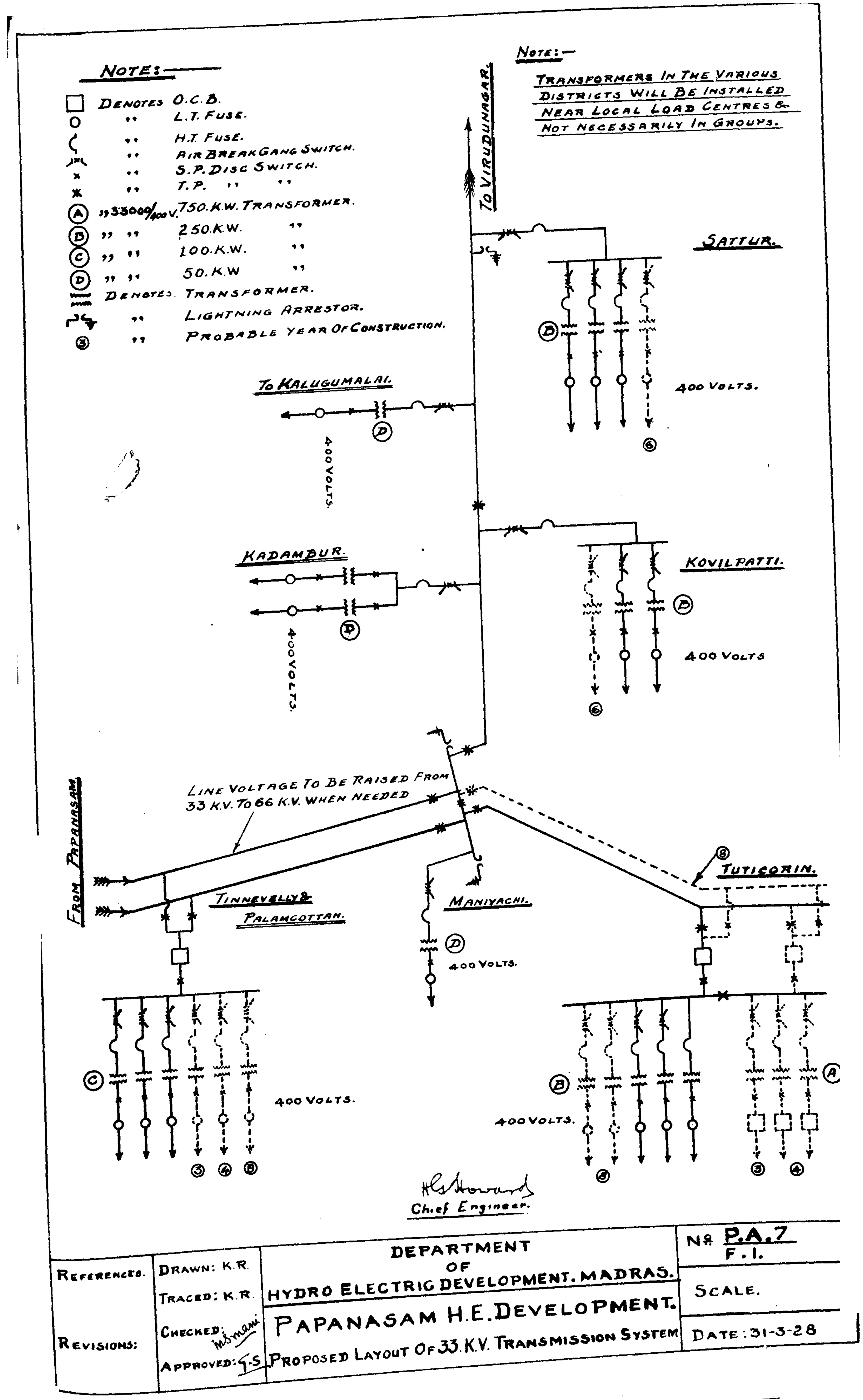
Transmission lines.—These will operate at 33,000 volts to begin with and the voltage will be raised to 66,000 when the load warrants it. The proposed lay-out is shown on drawing $\frac{\text{P.A. 7}}{\text{F. 1}}$.

A double circuit 33 KV. line is proposed as far as Maniyachi, where a sectionalizing station is contemplated. From this station single circuit lines will be constructed to Tuticorin and Sattur. These lines will be duplicated only when the revenue from the various districts warrants a more reliable service.

The transmission system differs from that advocated for Pykara. It will be essentially a design for rural conditions and particularly adapted for agricultural loads. There is no immediate prospect of railway electrification or other large loads, hence there is no necessity to construct expensive double circuit lines and instal costly H.T. oil circuit breakers. The method of distribution of power will, in general, be by means of single transformer installations which will be "hung" on the main transmission lines. Each transformer is to be placed as near the load as possible and protected by a combined H.T. air-break switch and fuse. A metering outfit will be installed on the low tension side. All L.T. feeders will also be protected with fuses, except in the case of transformers of over 250 K.W. capacity, which will be equipped with L.T. oil circuit breakers. It is expected to distribute most of the power at 400 volts.

As the revenue increases, it will be possible to gradually introduce a few refinements in design, but it is considered that the above design is best suited to the pioneer nature of the development.

Construction schedule, etc.—It is estimated that, from the date of the sanction of the construction of any of the works, nine months will be required for preliminary construction work, surveys, explorations of sites, and compiling working drawings and estimates. From then on, the works should be completed in twenty-four months for Scheme (*a*) and thirty-two months for the initial stage of Scheme (*b*). The estimates



have included certain new roads and mechanical transport. It has been assumed that all compressors, hoists, concrete mixers, etc. will be driven by petrol motors. There does not appear any possibility of developing an inexpensive power site for construction purposes. It might, however, be possible to enter into an arrangement with Messrs. A. & F. Harvey for a supply of power from Papanasam The proposal would be as follows :—Government to instal, at their own expense, two modern reaction units, at the industrial plant in place of the existing impulse wheels. Messrs. Harvey would still receive the same amount of mechanical power, while a small generator connected to each turbine would utilize the excess power. This excess would be derived from the difference in efficiencies between the new and old units and the greater amount of water diverted from the stream, for construction purposes.

The generators might be of sufficient capacity to operate as synchronous motors and drive the whole mill after the works had been constructed. Government could then supply the mills with electric power as mentioned earlier, while Messrs. A. & F. Harvey would have been put to no extra expense for electrification.

TABLE No. XV.

Estimate of costs.

Scheme.	(a).	(b).	
Year.	1	1	5
Installed capacity K.W including spares.	12,600	15,000	25,000
	RS.	RS.	RS.
Dam and reservoir	..	23,80,000	13,60,000
Diversion dam and pondage	15,00,000	15,00,000	..
Pipe lines, Penstocks, Anchors, Piers, Valves, etc., ...	7,31,600	6,05,600	6,05,600
Power House building	2,60,000	2,88,300	1,00,000
Power plant equipment	7,50,000	8,65,000	5,00,000
Transformer installation	..	70,000	70,000
Equipment for two outgoing lines	..	30,000	..
Transmission lines	..	11,00,000	50,000
Sub-stations	..	2,90,000	1,80,000
Permanent buildings	1,50,000	1,84,000	25,000
Roads and transport	2,00,000	3,20,000	1,00,000
Temporary buildings	1,01,300	1,60,000	50,000
Construction plant	3,80,000	5,50,000	2,50,000
General charges and establishment	6,00,000	7,50,000	4,50,000
Total ..	46,72,900	90,82,900	37,40,600
Interest at 5 per cent ..	3,17,600	6,44,500	2,14,400
Total ..	49,90,500	97,27,400	39,55,000
Interest at 6 per cent ..	3,80,100	7,73,400	2,57,400
Total ..	50,53,000	98,56,800	39,98,000

SECTION 5—FINANCIAL RESULTS.

Table No. XV on page 31 gives the capital costs incurred, viz., Rs. 49,90,500 for Scheme (*a*), and for Scheme (*b*) rising from Rs. 97,27,400 in the first year to Rs. 1,36,82,400 in the fifth year, with interest calculated at 5 per cent. The corresponding figures, with 6 per cent, will be Rs. 50,53,000 for Scheme (*a*), and Rs. 98,56,300 rising to Rs. 1,38,54,300 for Scheme (*b*).

Financial results are worked out in Tables XVI–A and XVI–B for two rates of interest, 5 per cent and 6 per cent respectively. Calculations for depreciation are based on the sinking fund method, while the assumed lives of the various structures and equipment are the same as those used for Pykara, viz.—

Gates and Valves—Hydraulic	25 years.
Penstocks	40 ,,
Power plant	25 ,,
Buildings	50 ,,
Transmission lines	40 ,,
Sub-stations	25 ,,

Depreciation is allowed from the first year.

Operation expenses have been worked out from a study of the staff necessary to operate the system, while maintenance costs are based on the maintenance and renewal expenses of another hydro-electric installation.

The revenue is based, generally, on the rates proposed for Pykara, except in the case of the proposed Paper Mill and the mills of Messrs. A. & F. Harvey, where owing to the special conditions prevailing, the rates have to be lower. Care has to be taken, however, not to discriminate unduly in favour of one industry against another of the same class; otherwise an undue advantage is given to one.

Scheme (*a*).—It will be seen from the Tables XVI–A and XVI–B that the gross revenues derived from the Paper Mills in Scheme (*a*) are fixed so as just to cover the operating expenses, depreciation and renewals and interest charges.

Scheme (*b*).—In the tenth year in Scheme (*b*), with 6 per cent interest rate, 7·2 per cent is the return on the capital, all arrears in interest charges will have been paid and a surplus of Rs. 58,060 will remain.

With 5 per cent rate of interest, the return is about the same, 7·21 per cent, but a surplus results even from the fourth year, ending with an accumulated total of Rs. 12,70,000 in the tenth year. After the tenth year a progressively increasing credit balance can be expected.

Owing to the high load factor of the plant and the inexpensive transmission system, the over-all cost of a K.W.H. distributed during the tenth year is lower than at Pykara for the same capacity, being about 0·23 anna. The average receipts per unit are also low, 0·26 anna; this is due to the large blocks of cheap power which are expected to be distributed at Papanasam. On the other hand, Pykara is a much larger and more flexible development and there is a gradual decrease in the cost per unit as the scheme develops.

The above revenue forecast assumes that, in the event of the proposed Paper Mills not being constructed, other industries can be attracted, and will be charged the same rate for power. As this rate is exceptionally low, it is reasonable to assume that it could be increased and an improvement in the revenue would result.

TABLE No. XVI-A.

Giving capital investment, operating expenses, revenue, surplus, etc.

(Interest charges calculated at 5 per cent.)

Year.	Capital investment.	Interest at 5 per cent on column (2).	Operation and maintenance expenses.	Depreciation and renewals.	Total expenses (4) + (5).	Gross revenue.	Net revenue (7) — (6).	Per cent return on investment $\frac{(8)}{(2)} \times 100$.	Surplus after deducting interest charges (8) — (3).	Accumulated surplus.	Average cost per K.W.H. at 11,000 volts.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Scheme (*a*).						
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	PER CENT.	RS.	RS.	ANNA.
1 to 10	49,90,500	2,49,530	1,10,000	24,700	1,34,700	3,84,230	2,49,530	5·0	Nil.	Nil.	..
					Scheme (*b*).						
1	97,27,400	4,86,370	1,40,000	42,300	1,82,300	5,73,260	3,90,960	4·02	— 95,410	— 95,410	0·24
2	97,27,400	4,86,370	1,57,000	42,300	1,99,300	6,35,500	4,36,200	4·48	— 50,170	— 1,45,580	0·24
3	97,27,400	4,86,370	1,57,000	42,300	1,99,300	7,06,720	5,07,420	5·22	+ 21,050	— 1,24,530	0·24
4	97,27,400	4,86,370	1,57,000	42,300	1,99,300	8,19,070	6,19,770	6·37	+ 1,33,400	+ 8,870	0·22
5	1,36,82,400	6,84,120	1,70,000	65,940	2,35,940	10,53,760	8,17,820	5·97	+ 1,33,700	+ 1,42,570	0·20
6	1,36,82,400	6,84,120	1,75,000	65,940	2,40,940	10,73,440	8,32,500	6·08	+ 1,48,380	+ 2,90,950	0·20
7	1,36,82,400	6,84,120	1,84,000	65,940	2,49,940	11,21,300	8,71,360	6·37	+ 1,87,240	+ 4,78,190	0·20
8	1,36,82,400	6,84,120	1,93,000	65,940	2,58,940	11,59,900	9,00,960	6·58	+ 2,16,840	+ 6,95,030	0·20
9	1,36,82,400	6,84,120	2,02,000	65,940	2,67,940	12,24,300	9,56,360	6·99	+ 2,72,240	+ 9,67,270	0·20
10	1,36,82,400	6,84,120	2,10,000	65,940	2,75,940	12,62,790	9,86,850	7·21	+ 3,02,730	+ 12,70,000	0·20

Tenth year.	K.W.H.	Per K.W.H. Average cost.	Per K.W.H. Average receipt.
		ANNA.	ANNA.
Distributed units	76,958,000	0·20	0·26
Generated ,, ...	83,200,000	0·18	0·24

TABLE No. XVI-B.

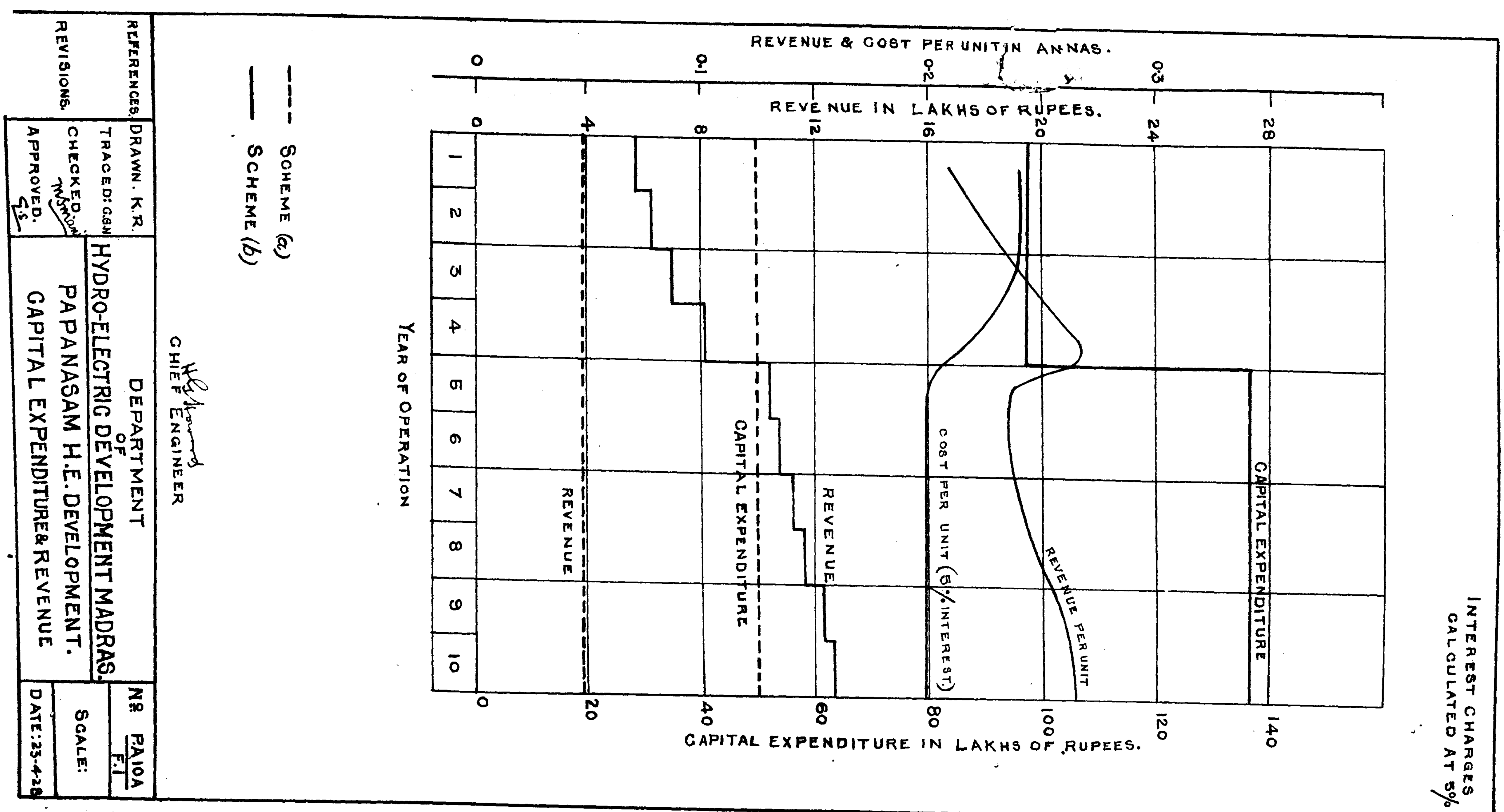
Giving capital investment, operating expenses, revenue, surplus, etc.

(Interest charges calculated at 6 per cent.)

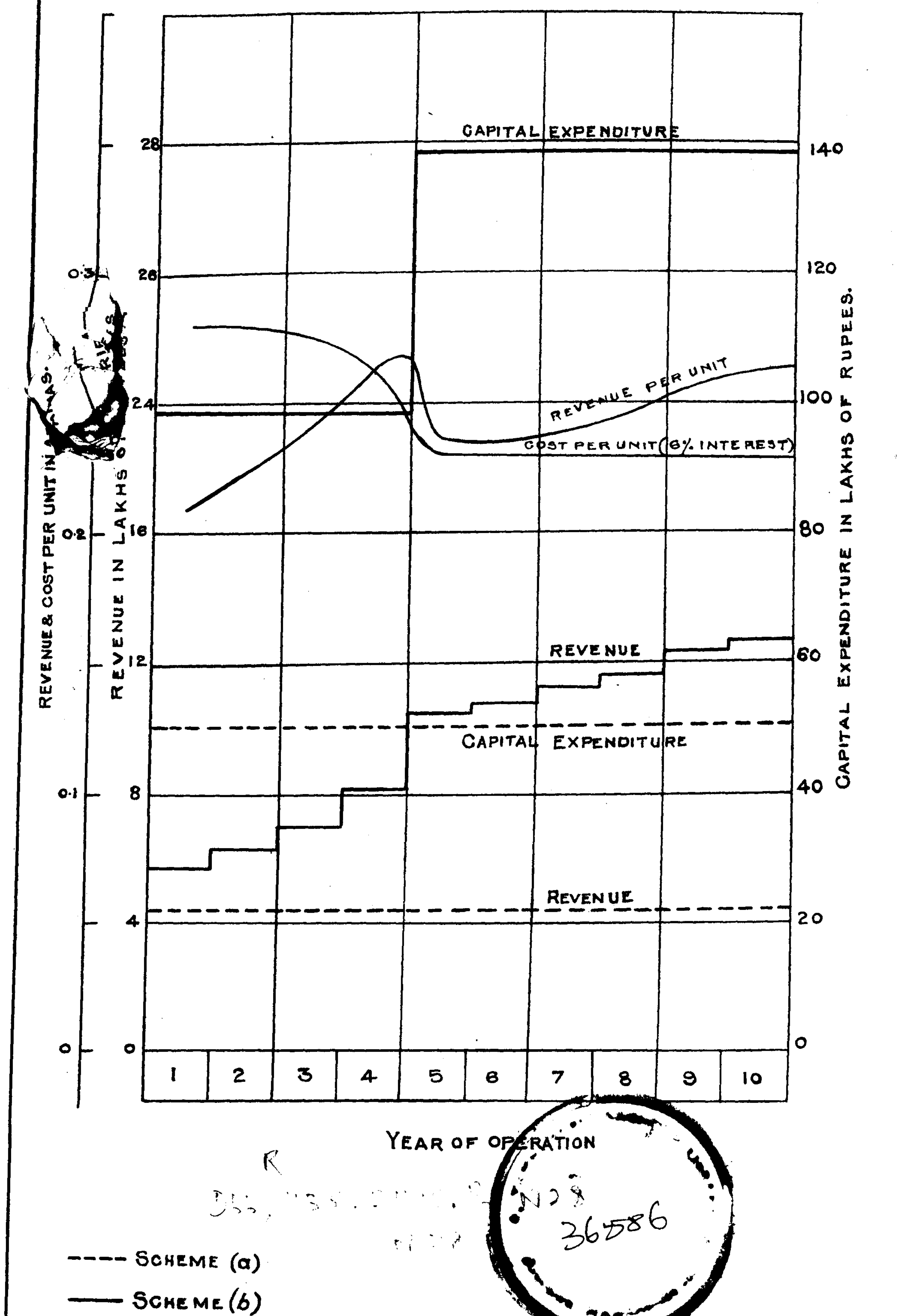
Year. (1)	Capital investment. (2)	Interest at 6 per cent on column (2). (3)	Operation and maintenance expenses. (4)	Deprecia-tion and renewals. (5)	Total expenses (4) + (5) (6)	Gross revenue. (7)	Net revenue (7) — (6). (8)	Per cent return on investment $\frac{(8)}{(2)} \times 100$. (9)	Surplus after deducting interest charges (8)—(3) (10)	Accumulated surplus (11)	Average cost per K.W.H. at 11,000 volts. (12)
					Scheme (a).						
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	PER CENT.	RS.	RS.	ANNA.
1 to 10	50,53,000	3,03,180	1,10,000	20,740	1,30,740	4,33,920	3,03,180	6·0	Nil.	Nil.	..
					Scheme (b).						
1	98,56,300	5,91,380	1,40,000	35,300	1,75,300	5,73,260	3,97,960	4·04	— 1,93,420	— 1,93,420	0·28
2	98,56,300	5,91,380	1,57,000	35,300	1,92,300	6,35,500	4,43,200	4·49	— 1,48,180	— 3,41,600	0·28
3	98,56,300	5,91,380	1,57,000	35,300	1,92,300	7,06,720	5,14,420	5·22	— 76,960	— 4,18,560	0·27
4	98,56,300	5,91,380	1,57,000	35,300	1,92,300	8,19,070	6,26,770	6·36	+ 35,390	— 3,83,170	0·26
5	1,38,54,300	8,31,260	1,70,000	55,450	2,25,450	10,53,760	8,28,310	5·98	— 2,950	— 3,86,120	0·23
6	1,38,54,300	8,31,260	1,75,000	55,450	2,30,450	10,73,440	8,42,990	6·08	+ 11,730	— 3,74,390	0·23
7	1,38,54,300	8,31,260	1,84,000	55,450	2,39,450	11,21,300	8,81,850	6·37	+ 50,590	— 3,23,800	0·23
8	1,38,54,300	8,31,260	1,93,000	55,450	2,48,450	11,59,900	9,11,450	6·58	+ 80,190	— 2,43,610	0·23
9	1,38,54,300	8,31,260	2,02,000	55,450	2,57,450	12,24,300	9,66,850	6·98	+ 1,35,590	— 1,08,020	0·23
10	1,38,54,300	8,31,260	2,10,000	55,450	2,65,450	12 62,790	9,97,340	7·20	+ 1,66,080	+ 58,060	0·23

Tenth year.

	K.W.H.	Per K.W.H. Average cost.	Per K.W.H. Average receipt.
		ANNA.	ANNA.
Distributed units	76,958,000	0·23	0·26
Generated "	83,200,000	0·21	0·24



INTEREST CHARGES
CALCULATED AT 6%



H. G. Howard
CHIEF ENGINEER

REFERENCES	DRAWN: K.R.	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT MADRAS.	No. P.A.10B F.1.
	TRACED: C.G.N.		SCALE:
REVISIONS:	CHECKED: M.S. Mani	PAPANASAM H.E DEVELOPMENT. CAPITAL EXPEDITURE& REVENUE	
	APPROVED: T.S.		DATE. 23-4-29