INTRODUCTORY REPORT

ON THE

PYKARA HYDRO-ELECTRIC DEVELOPMENT

MADRAS
PRINTED BY THE SUPERINTENDENT, GOVERNMENT PRESS
1927

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I. INTRODUCTORY REPORT.
II. APPENDIX A.—POWER DEMAND AND REVENUE FORECASTS.
III. „ B.—RAINFALL, RUN-OFF AND STORAGE.
IV. „ C.—THE SCHEME.

WITH TABLES, PLANS AND CHARTS.

MAJOR H. G. HOWARD, M.C.
Chief Engineer.

19th November 1927.

CONTENTS

I. INTRODUCTORY REPORT

II. APPENDIX A.—POWER DEMAND AND REVENUE FORECAST.

III. APPENDIX B.—RAINFALL, RUN-OFF AND STORAGE.

IV. APPENDIX C.—THE SCHEME.

PYKARA HYDRO-ELECTRIC DEVELOPMENT.

INTRODUCTORY REPORT.

1. In accordance with the instructions of Government, the Pykara Hydro-Electric Scheme has been carefully examined, and I beg to report as follows.

2. The Project presents no very difficult problems of a technical nature; there are, however, several alternatives to the original scheme, which have been investigated and are referred to elsewhere in this report.

3. The scheme now presented is for generation of power at Pykara and supply of it to Coimbatore, Pollachi, Dindigul, Trichinopoly, Madura and the neighbouring areas. The development is to be in stages dependent on the power demand. Madras is, for the present, excluded. Plan P-1-F_1 gives an idea of the power development while Plan P-2-F_3 shows the Transmission system which is proposed for the first stage of development and also indicates the future possibilities of the system.

4. The expenditure must necessarily be somewhat heavy at the outset, mainly owing to the very long penstock lines, and the extensive Transmission system necessary to secure the required load. These handicaps have been partially overcome by a carefully graded construction programme, and modifications to the original lay-out, as explained later.

5. Tables 1, 2-A, 2-B, and 3 and charts P-3-F_1, P-4-A-F_1 and P-4-B-F_1 have been prepared so that the results of the studies can be read at a glance.

6. Table 1 shows the energy which it is expected to distribute and sell during the first ten years. The estimated revenue and return per unit are also given. Attention is drawn to the fact that, while the revenue gradually increases, the return per unit tends to decrease. This is due to an improved load factor and a progressive reduction in the rates for power.

7. Table 2-A gives the estimated gross and net revenues, the capital investments, operating expenses, etc. On examining this Table it will be seen that the cost per unit steadily decreases and that all operating expenses and fixed charges can be met after the second year. By the sixth year all the back and current interest charges have been paid. On the tenth year the return on the investment is 6·70 per cent, there is a surplus of Rs. 18,51,210, and an accumulated fund for depreciation and renewals of Rs. 29,34,190. Regarding the latter fund no contributions have been made until the fifth year. From then 15 per cent of the gross revenue has been put aside annually, until such time as the accumulated fund is equal to one which would have resulted by adopting the "straight line" method from the first year of operation. This amount should be reached by the fifteenth year when the annual contribution will, instead of 15 per cent on the gross revenue, be equal to the regular amount allowed for depreciation. This method has an advantage over the conventional straight line or sinking fund arrangement in that no heavy charges are incurred during the development period, when no calls on the fund should be expected. The first few payments depend on the revenue received, which should be a fair indication of the proportionate part of the plant which is being utilized and which alone is therefore depreciating. The amounts allowed for depreciation have been arrived at by taking accepted useful lives of the plant, penstocks, transmission lines, and buildings, but not including the hydraulic works. The latter do not usually suffer from obsolescence, and the works, if properly maintained, will tend to appreciate rather than depreciate. It may be of interest to add that it is usual, in similar studies in the West, to take 1 per cent of the invested capital for annual depreciation and 1½ per cent for operation and maintenance. In this report it will be seen that the amounts provided for the two items are in excess of the conventional allowances.

A supplemental Table 2-B has been prepared to show the financial results if interest is charged at 6 per cent instead of 5 per cent allowed for in Table 2-A. But unless otherwise stated, the financial results referred to in the report are those arrived at on the basis of a 5 per cent charge for interest.

It will be seen that, with 6 per cent interest rate, the operating expenses and interest charges can be met after the sixth year of operation. The accumulated arrears of annual interest at the end of the tenth year of operation amount to Rs. 14,41,620. Following the method prescribed for Productive Irrigation Works in paragraph 560 (*a*) of the Madras Public Works Department Code, this amount is added to the capital charges incurred on the scheme up to the end of the tenth year of operation, making the capital invested up to the end of that year Rs. 3,58,36,520. The net revenue derived, Rs. 23,62,000, will represent a return of 6·6 per cent on the capital invested. The scheme is also of a class which warrants the maintenance of capital and revenue accounts. It thus satisfies the conditions of a 'Productive' public work.

In this connexion, it should be noted that the ten-year period taken into account in Table 2-B commences from the first revenue producing year as against the first year after the date of completion of the scheme which is, of course, far later. This assumption tends to be rigorous, but even then a return of 6·6 per cent is assured. Continuation of the Tables for the full ten-year period after the *completion* of the project, should show decidedly higher returns.

8. Table 3 gives the estimated capital expenditure by years, together with the demand, installed capacity and flow.

9. Charts P-3-F_1, P-4 A-F_1 and P-4 B-F_1 show some of the foregoing results in graphical form. It will be seen from chart P-4-A-F_1 that, with 5 per cent rate of interest, power is sold at a loss for the first two years, but that by the tenth year a favourable margin has been reached in spite of the fact that reductions in the rates have been allowed. Chart P-4 B-F_1 similarly shows the results with 6 per cent rate of interest. It may be of interest to add that when the whole Pykara-Moyar Scheme is finally developed, the average cost of a K.W.H. should be less than 0·3 anna. This gives a good indication of the possibility of cheap power if the load can only be sufficiently developed.

10. The history of the Pykara Project is similar to that of many other hydro-electric schemes which are now highly successful undertakings. Years were spent in preliminary investigations and surveys. Financial interests were at first somewhat shy, until a favourable decision was finally reached and construction work started.

11. During the first few years financial sacrifices have to be made in order to bring the property on to a paying basis, but after that very satisfactory profits are usually possible, which is also the case of Pykara.

12. Referring again to Table 3 doubt might be expressed as to the possibility of ever obtaining sufficient load for such large generating capacity as contemplated. It is, however, not so improbable as it may appear at first. The load and revenue forecast only takes into account the load which is actually available at present, and the resulting increases, when once electrification starts. The possibility of new industries being attracted by cheap power rates, the linking up of Madras, Cochin, Calicut and other towns, the further electrification of the railways beyond the three sections mentioned, pumping from wells for irrigation are possibilities which have not been included in the estimates, but which are almost certain to materialize and should be taken into account.

13. Regarding Madras there are no technical objections to transmitting power from Pykara to the Port; the problem is purely economic. This is being given special study, and it is believed that a practical scheme can be evolved, which would ensure the arrival of cheap hydro-electric power within a few years. It will, however, form the subject of a separate communication.

14. The outstanding advantage of Pykara is that it is a State development. The direct and indirect benefits accruing to the State from such a scheme are so well known that it is hardly necessary to discuss them here. It must, however, not

be forgotten that every pound of coal or oil imported into the Madras Presidency is an economic loss if it can be substituted by hydro-electric power at the same cost. It is also better to protect national industries by supplying cheap power and lowering the cost of production than by high import tariffs which always result in a higher cost of living. The problem of unemployment has been given a good deal of prominence lately. The initiation of the Pykara Scheme will be the means of giving employment to many, while the more extended use of electric power and consequent industrial and agricultural activity must tend to provide avenues of permanent employment that are not available at present.

15. This report has been made as concise as possible for the convenience of those who do not wish to go into much detail. For those who require more information sections have been prepared as follows:—

A. Power Demand and Revenue forecast.

B. Rainfall, Run-off and Storage.

C. The Scheme.

These sections form appendices to this report.

16. This is merely a preliminary report, and all estimates and designs are subject to revision after further investigations have been made and final surveys taken. It is, however, expected that if any changes are made, the final estimates and revenue figures will tend to be more favourable than those now submitted. A report giving detailed estimates with the necessary technical discussions and details of the scheme is now in course of preparation, but may not be ready for some months owing to the time required to carry out the final surveys and other investigations.

H. G. HOWARD,
Chief Engineer.

19th November 1927.

Table 1 giving Load Details, Revenue, Return per unit, etc.

Year.	Demand K.W.	Distributed K.W.H. (Millions).	Average load K.W.	Load factor per cent.	Revenue.	Average return per unit sold.
					RS.	ANNA.
1st	6,750	22·548	2,570	38	8,98,480	0·638
2nd	10,600	39·366	4,500	42·5	15,34,400	0·625
3rd	14,800	57·181	6,530	44	22,22,550	0·623
4th	16,300	65·995	7,540	46·5	25,19,000	0·612
5th	18,000	75·380	8,600	48	28,84,000	0·612
6th	18,600	80·200	9,150	49	30,20,000	0·602
7th	19,300	85·400	9,750	50·5	31,70,000	0·593
8th	20,100	91·000	10,390	51·5	33,30,000	0·584
9th	21,000	97·000	11,070	53	34,90,000	0·575
10th	21,900	103·315	11,800	54	36,60,000	0·567

Table 3 giving Storage, Power available and Capital expenditure.

Year.	Estimated capital expenditure.	Installed* capacity K.W.	Estimated demand at Power house K.W.	Continuous power.		Storage in millions of cubic feet.	
				K.W.	Cusecs.	Necessary.	Available.
	RS.						
1st	2,35,49,000	22,500	7,700	2,850	14·25	0	103
2nd	2,47,35,300	22,500	12,100	5,000	25·00	80	103
3rd	2,77,97,300	22,500	16,900	7,150	36·25	[illegible]	450
4th	2,95,17,300	30,000	18,600	8,350	41·75	[illegible]	450
5th	3,00,20,000	30,000	20,600	9,550	47·75	[illegible]	450
6th	3,20,70,500	30,000	21,200	10,200	51·00	460	900
7th	3,20,70,500	30,000	22,000	10,850	54·25	[illegible]	900
8th	3,28,63,200	30,000	22,900	11,550	57·75	[illegible]	900
9th	3,38,37,900	37,500†	23,900	12,300	61·50	[illegible]	900
10th	3,38,37,900	37,500†	25,000	13,100	65·50	[illegible]	900
Full capacity ..	6,72,16,600	67,500†	60,000	30,000	150·00	[illegible]	[illegible]

* All machinery is capable of a continuous overload of 15 per cent and 25 per cent for two hours.

† One spare unit of 7,500 K.W. allowed.

Table 2-A giving Capital investment, operating expenses, revenue, surplus, etc.

Interest charges calculated at 5 per cent.

Year.	Capital investment.	Interest at five per cent on column (2).	Operation and maintenance expenses.	Depreciation and renewals.	Accumulated depreciation and renewals.	Total expenses (4) + (5).	Gross revenue.	Net revenue (8) — (7).	Per cent return on investment $\frac{(9)}{(2)} \times 100$.	Surplus after deducting interest charges (9) — (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)	(13)
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.		RS.	RS.	ANNA.
1st ..	2,35,49,000	11,77,450	5,50,000	..	..	5,50,000	8,98,480	3,48,480	1·5	— 8,28,970	— 8,28,970	1·23
2nd ..	2,47,35,300	12,36,760	5,77,500	..	..	5,77,500	15,34,400	9,56,900	3·9	— 2,79,860	— 11,08,830	·74
3rd ..	2,77,97,300	13,89,870	6,06,400	..	..	6,06,400	22,22,550	16,16,150	5·8	+ 2,26,280	— 8,82,550	·560
4th ..	2,95,17,300	14,75,870	6,36,700	..	..	6,36,700	25,19,000	18,82,300	6·4	+ 4,06,430	— 4,76,120	·510
5th ..	3,00,20,000	15,01,000	6,68,500	4,32,600	4,32,600	11,01,100	28,84,000	17,82,900	5·9	+ 2,81,900	— 1,94,220	·553
6th ..	3,20,70,500	16,03,530	7,02,000	4,53,000	8,85,600	11,55,000	30,20,000	18,65,000	5·8	+ 2,61,420	+ 67,200	·550
7th ..	3,20,70,500	16,03,530	7,37,100	4,75,500	13,61,100	12,12,600	31,70,000	19,57,400	6·1	+ 3,43,870	+ 4,11,070	·527
8th ..	3,28,63,200	16,43,160	7,74,800	4,99,500	18,60,600	12,74,300	33,30,000	20,55,700	6·3	+ 4,12,540	+ 8,23,610	·513
9th ..	3,38,37,900	16,91,900	8,12,700	5,23,500	23,84,100	13,36,200	34,90,000	21,53,800	6·4	+ 4,61,900	+ 12,85,510	·50
10th ..	3,38,37,900	16,91,900	8,53,000	5,50,000	29,34,100	14,03,000	36,60,600	22,57,600	6·7	+ 5,65,700	+ 18,51,210	·48
20th * ..	6,72,16,600	33,60,830	12,00,000	8,00,000	..	20,00,000	82,12,500	62,12,500	9·2	+ 28,51,670	..	·33

* For the twentieth year of operation, it is assumed that the full capacity of Pykara will be utilized and power sold at an average rate of 0·5 anna per unit (as against the average rate in the tenth year of 0·567 anna per unit).

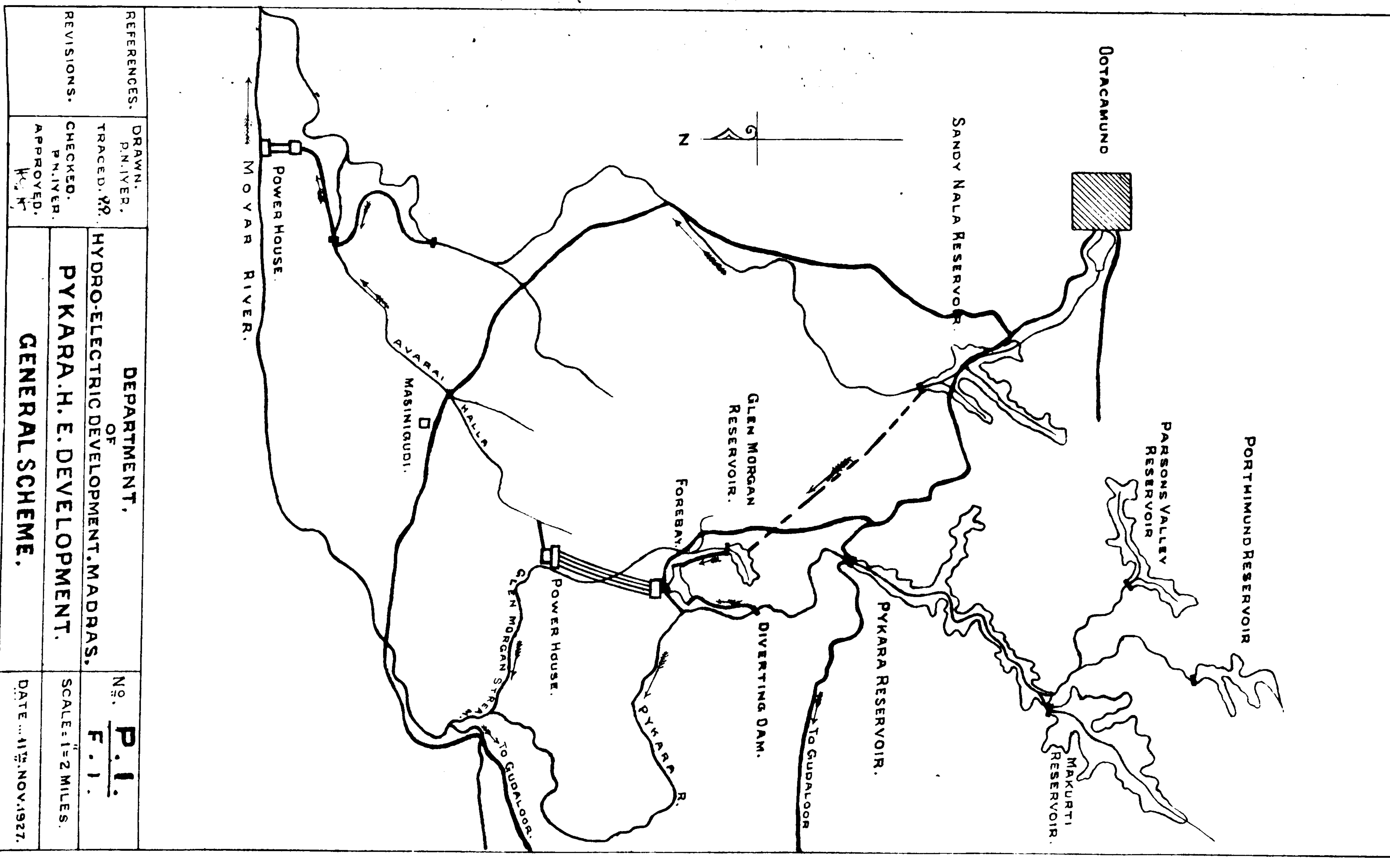
Table 2-B giving capital investment, operating expenses, revenue, surplus, etc.

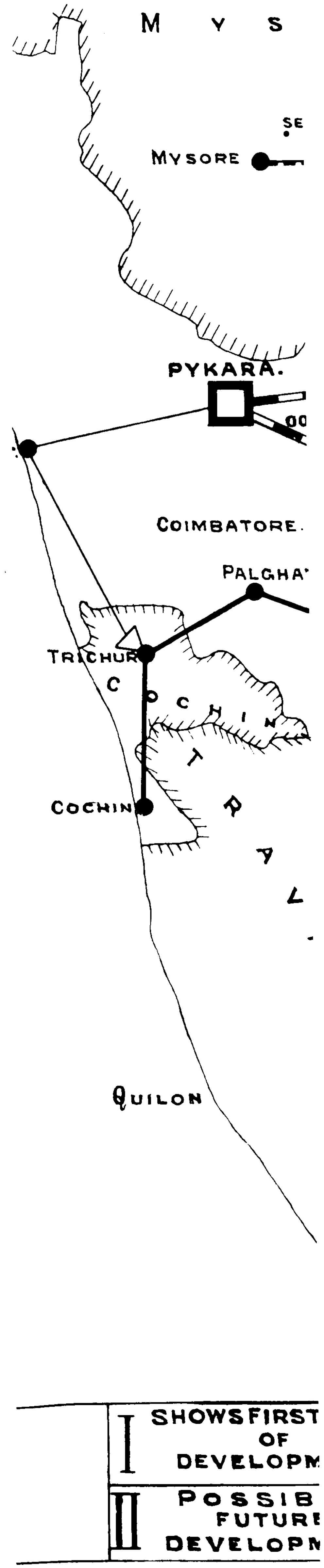
Interest charges calculated at 6 per cent.

Year of operation. (1)	Capital investment. (2)	Interest at six per cent on column (2). (3)	Operation and maintenance. (4)	Depreciation and renewals. (5)	Accumulated depreciation and renewals. (6)	Total expenses (4) + (5). (7)	Gross revenue. (8)	Net revenue (8) − (7). (9)	Per cent return on investment $\frac{(9)}{(2)} \times 100$ (10)	Surplus after deducting interest charges (9) − (3). (11)	Accumulated surplus (12)	Average cost per K.W.H. at 11,000 volts. (13)
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	PER CENT.	RS.	RS.	ANNA.
1st	2,39,54,400	14,37,260	5,50,000	..	..	5,50,000	8,98,480	3,48,480	1·5	− 10,88,780	− 10,88,780	1·41
2nd	2,51,54,600	15,09,280	5,77,500	..	..	5,77,500	15,34,400	9,56,900	3·8	− 5,52,380	− 16,41,160	0·85
3rd	2,82,65,400	16,95,920	6,06,400	..	..	6,06,400	22,22,550	16,16,150	5·7	− 79,770	− 17,20,930	0·64
4th	3,00,05,900	18,00,350	6,36,700	..	..	6,36,700	25,19,000	18,82,300	6·3	+ 81,950	− 16,38,980	0·59
5th	3,05,12,000	18,30,720	6,68,500	4,32,600	4,32,600	11,01,100	28,84,000	17,82,900	5·8	− 47,820	− 16,86,800	0·62
6th	3,26,04,000	19,56,240	7,02,000	4,53,000	8,85,600	11,55,000	30,20,000	18,65,000	5·7	− 91,240	− 17,78,040	0·62
7th	3,26,04,000	19,56,240	7,37,100	4,75,500	13,61,100	12,12,600	31,70,000	19,57,400	6·0	+ 1,160	− 17,76,880	0·59
8th	3,34,07,600	20,04,460	7,74,800	4,99,500	18,60,600	12,74,300	33,30,000	20,55,700	6·2	+ 51,240	− 17,25,640	0·58
9th	3,43,94,900	20,63,690	8,12,700	5,23,500	23,84,100	13,36,200	34,90,000	21,53,800	6·3	+ 90,110	− 16,35,530	0·56
10th	3,43,94,900	20,63,690	8,53,000	5,50,000	29,34,100	14,03,000	36,60,600	22,57,600	6·6	+ 1,93,910	− 14,41,620	0·54
11th *	3,58,36,520	21,50,190	8,93,500	5,74,500	35,08,600	14,68,000	38,30,000	23,62,000	6·6	+ 2,11,810	+ 2,11,810	0·53
20th †	6,97,64,220	41,85,850	12,00,000	8,00,000	..	20,00,000	82,12,500	62,12,500	8·9	+ 20,26,650	..	0·38

* 11th year.—Arrears in interest charges at the end of the tenth year, viz., Rs. 14,41,620, are added to the Capital and shown under column (2) for the eleventh year. For purposes of comparison only, proportionate increases have been allowed under the columns (4), (5) and (8) for the year. 6·6 per cent is the net return obtained and Rs. 2·118 lakhs is the net surplus after all charges including interest at 6 per cent are met.

† 20th year.—Capital investment under column (2) is obtained by adding the arrears of simple interest at the end of the tenth year, viz., Rs. 14,41,620 to the capital outlay at the twentieth year, viz., Rs. 6,83,22,600. For this year it is assumed that the full capacity of Pykara will be utilized and power sold at an average rate of 0·5 anna per unit (as against the average rate in the tenth year of 0·567 anna per unit).




M Y S
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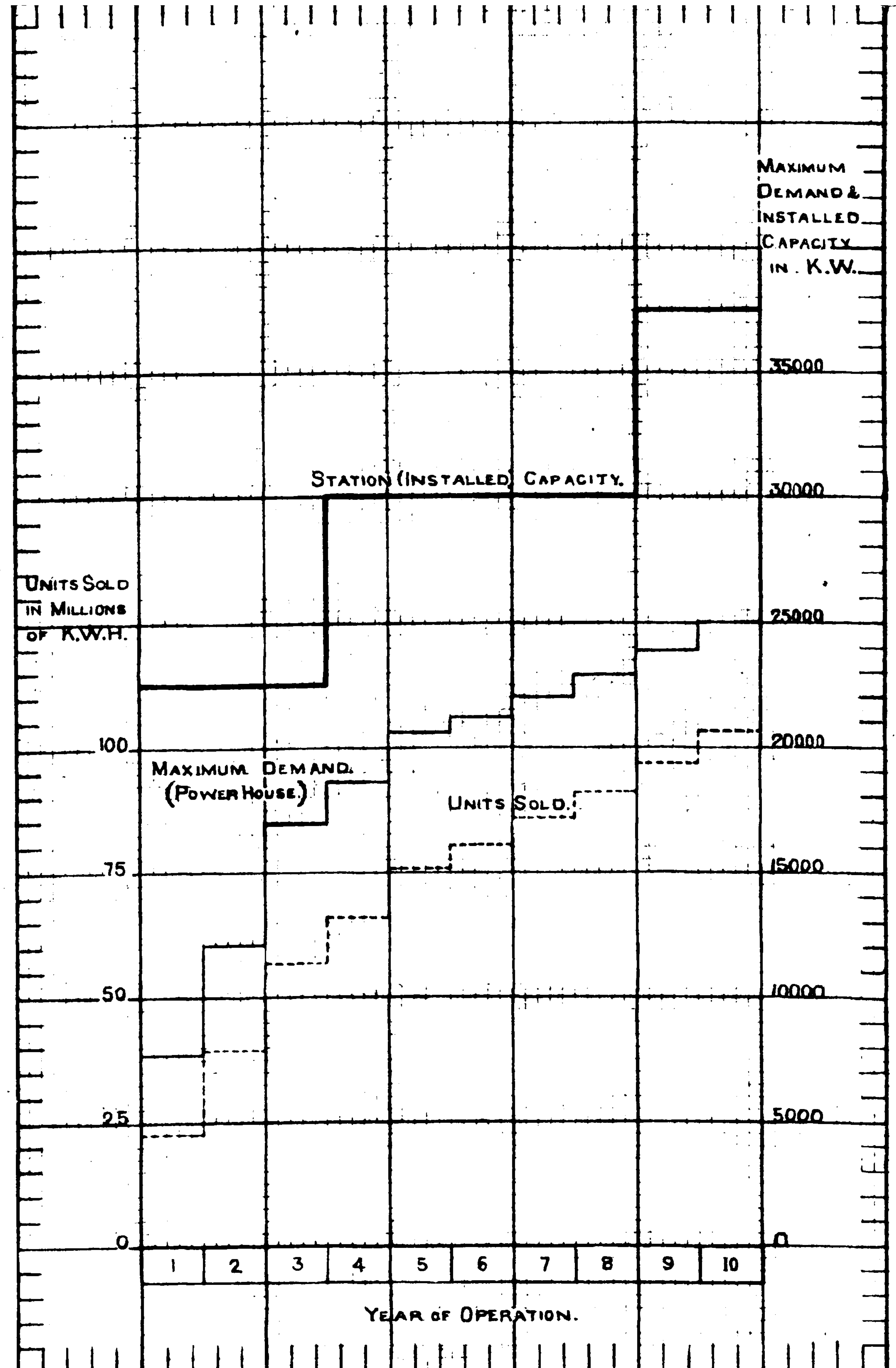
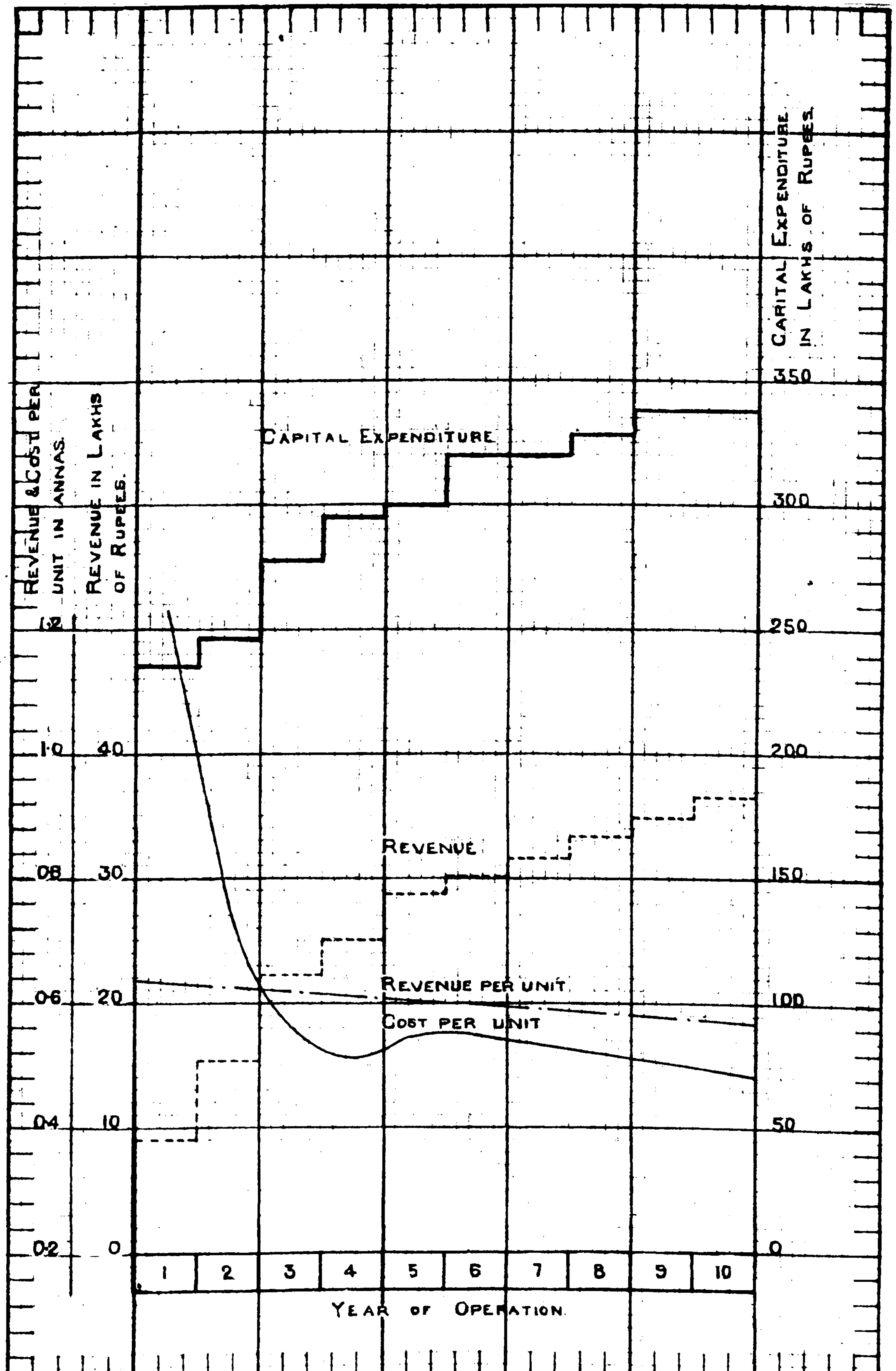
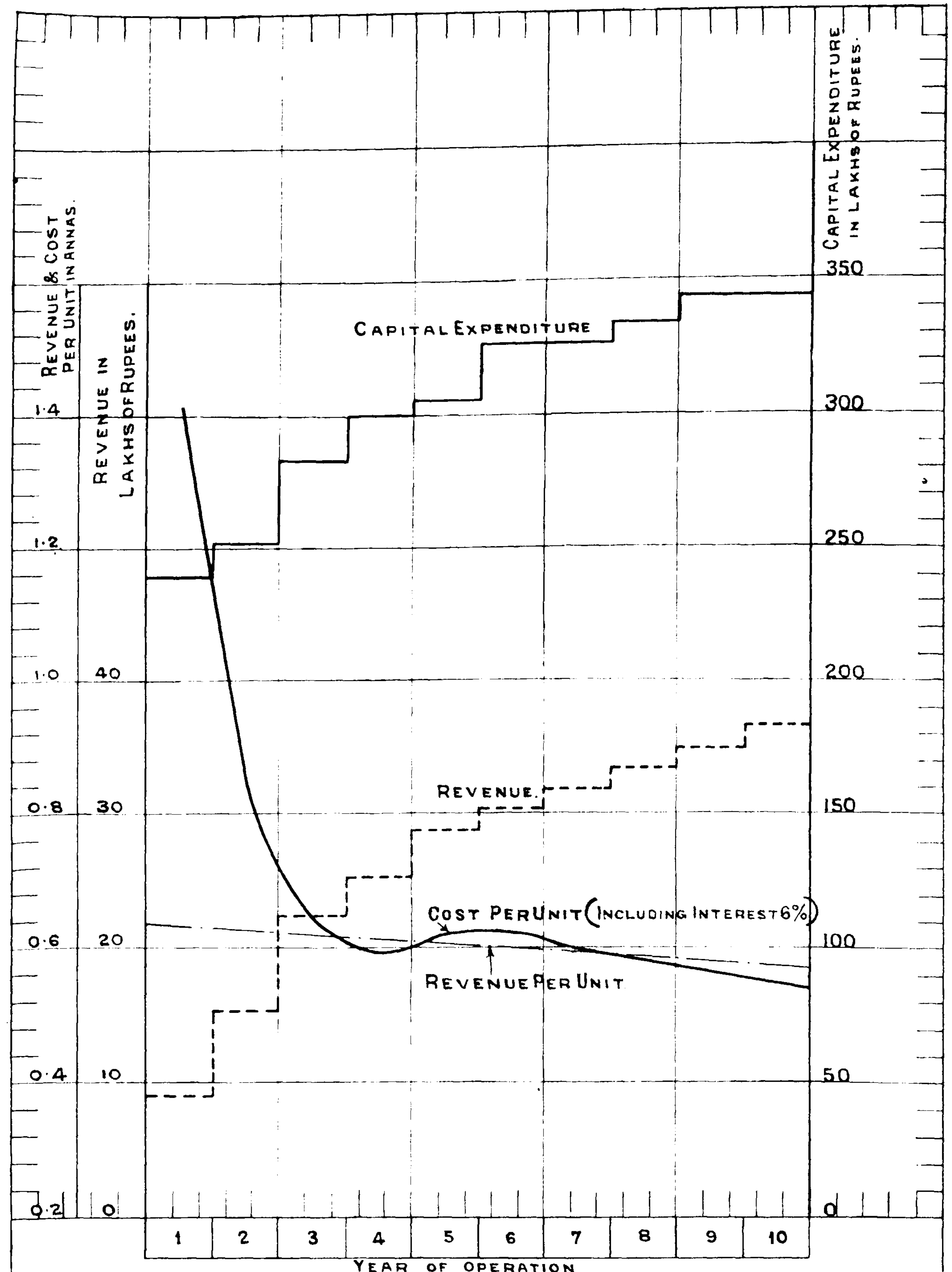


References	Drawn C.P.N.	Department of Hydro Electric Development. Madras.	No. P.3 / F.1.
	Traced. S.A.	Pykara. H.E. Development.	Scale. in chart
Revisions.	Checked P.N. Aiyer. Approved	Power Demand & Station Capacity	Date. 17-11-27.



NOTE:- INCREASE IN COST PER UNIT IN THE 5TH YEAR IS DUE TO ALLOTMENT FOR DEPRECIATION MADE FROM THAT YEAR.

References	Drawn. C.P.N	DEPARTMENT OF HYDROELECTRIC DEVELOPMENT, MADRAS.		№ P.4A / F.1.
	Traced S.A			
Revisions	Checked P.N. Aiyer	PYKARA. H.E. DEVELOPMENT.		Scale in chart
	Approved.	CAPITAL EXPENDITURE & REVENUE.		Date. 17-1-27



NOTE:- Increase in cost per unit in the 5th year of operation is due to allotment for depreciation made from that year.

References	Drawn. C.P.N.	Department of Hydro-Electric Development. Madras.	No. P.4 B. / F.1.
	Traced By, P. Paramasivam		
Revisions	Checked By, P.N. Iyer.	Pykara H.E. Development.	Scale - in Chart
	Approved	Capital Expenditure & Revenue.	Date - 3-12-27.

APPENDIX A.—POWER DEMAND AND REVENUE FORECAST.

17. Unfortunately the scheme is somewhat handicapped at the outset, by the prevailing impression that power can be delivered immediately at rates, which are far below the economic limit, and lower than it has been found possible with most schemes, of the same size, elsewhere.

18. The present cost of industrial power appears also to have been generally underestimated, and no reliable figures seem to be available.

19. The report of the Committee, formed under G.O. No. 2048 W., dated 23rd December 1926, was very complete, and contained some valuable information on the connected load in the various districts, where it is expected to distribute power.

20. This report has been carefully studied, and a tour of inspection undertaken through the more important districts.

21. The information on power costs supplied by the various industries is however, in many cases, misleading, while the estimated minimum annual consumption of power cannot be expected to be reached until the fourth year of operation.

22. Generally speaking, the cost of generating energy in mills and factories has been determined by taking an indicator card of the prime mover at certain intervals, in the case of steam and internal combustion engines, noting the fuel consumption, and from this data, arbitrarily assuming average values over the month. This is not very satisfactory and often results in very low apparent costs. However it is about the only method possible when the output cannot be measured continuously. In order to be comparable with electric drive, allowance must also be made for certain losses in the rope transmission, which may amount to 15 per cent or 20 per cent depending on the slip.

23. Fortunately a good deal of cost data is available for similar mills and factories in other parts of the world, where it has been possible to carry out very accurate tests. From these results a fairly clear idea can be formed as to the cost of power for local industries, when the cost of fuel and supplies is known.

24. The Diesel Engine Users Association of England, a technical body formed to promote the efficient operation of Diesel Engine Installations, in their Annual Report for 1926, gave as the average cost to produce a K.W.H., a figure ranging from 1·2 *d.* to 0·8 *d.* (1·07 to 0·7 anna). The cost of fuel oil was taken as 90*s.* per ton. This embraced some 34 efficiently operated plants ranging in capacity from 300 horse-power to 2,500 horse-power, but did not include capital charges, depreciation, insurance, or taxes. Fuel costs are higher in Southern India. So power costs will be higher. Steam engine costs would be higher still, with fuel of the same thermal value, on account of the lower overall efficiency of the engine, compared with an internal combustion unit. These facts have only been repeated, in order that a better idea can be formed, as to what power really costs here in the industrial world.

25. The aim in England to-day is to supply large power users with energy at a penny a unit (0·89 anna per K.W.H.). Very few are getting it now at this rate. It therefore would be quite safe to assume that no large industry in Southern India, operating under normal conditions, and where the whole plant and fuel bill is chargeable to power production, is getting usable power at an average rate, over the year, of less than one anna per electrical unit (0·75 anna per horse-power). In the smaller mills and factories the minimum cost of power will be higher.

26. Some of the commonest errors made in computing industrial power costs seem to have been as follows:—

(1) Assuming that the rated horse-power of the prime mover is the factory demand.

(2) Taking the demand, as given by the indicator card, as continuous horse-power. The "running" load factor of a factory rarely, if ever, reaches unity under normal industrial conditions.

(3) Assuming too high a figure for the "working" load factor.

(4) Allowing no diversity between individual plants.

(5) Ignoring the losses of the rope transmission, which would partially or totally disappear when an electrical drive was inaugurated.

27. It is generally known that for a mill or factory with a nominal ten-hour working day, the annual load factor will be from 15 to 28 per cent, while the demand factor may vary considerably, and even be more than unity.

28. In the absence of more definite data, the following initial factors have been assumed in the load forecast :—

	Demand factor.	Annual load factor.
Class A Textile Mills (larger)	0·6 to 0·9	24 to 28.
„ B „ (smaller)	Do.	20 to 22·5
„ C Rice Mills, Ginning Factories, Presses, etc.	Do.	15 to 17·5
„ D Miscellaneous (small power and lighting).	Do.	20 to 28.
„ E Tea estates and agricultural	Do.	18 to 20.

29. Some of these factors may even be considered high to commence with, but they will tend to gradually improve and most of them will, in time, be exceeded. On account of the seasonal nature of class C load, a certain amount of overtime is allowed for.

Diversity Factor assumed.

H.T. Feeders	1·12 to 1·15
H.T. Sub-stations	1·08
Divisional areas	1·05
Generator to bulk supply	1·27 to 1·30.

In passing, it might be noted that the diversity between individual loads tends to raise the system load factor.

30. The estimated revenue is based on the following rates for bulk supply at 11,000 volts :—

	Maximum demand rate per K.W. per annum.		Unit rate per K.W.H.
	RS.		ANNA.
100—500 horse-power	75	+	0·65
500—1,000 „	75	+	0·55
1,000—3,000 „	75	+	0·45
3,000 horse-power and up	75	+	0·35
Railway	90	+	0·2

These tariffs would give an average unit rate as follows :—

Demand.	33 per cent load factor. Per horse-power hour.	Average rate per Kilowatt hour.
	ANNA.	ANNA.
100—500 horse-power	0·79	1·06
500—1,000 „	0·72	0·96
1,000—3,000 „	0·64	0·85
3,000 horse-power and up	0·56	0·75

To allow for development, the maximum unit charge might be that corresponding to 33 per cent load factor given above. These rates have been adopted in the revenue computations.

31. When the load factor improves, there will be a reduction in the rates as shown below, where 55 per cent load factor conditions are assumed.

Demand.	55 per cent load factor. Average rate per Kilowatt hour.
	ANNA.
100—500 horse-power	0·89
500—1,000 horse-power	0·79
1,000—3,000 horse-power	0·69
3,000 horse-power and up	0·59
Railway	0·49

32. It is believed that these rates will be quite satisfactory to prospective consumers, as they will permit of a considerable saving in their present power costs. It will be shown later that at these rates, power will be delivered at a loss for the first year or so, but that after a few years, it will not only be possible to make a profit, but a general reduction in tariffs can be reasonably expected. This is most important, and should not be lost sight of by the industrialists, as the price of oil and coal will tend to increase.

33. It will be noted that the demand charges have been made high compared to the energy charges in each classification, in order to encourage consumers to improve their load factors and thus benefit by lower rates. It is very probable that after a more detailed study of the cost of power, these rates may have to be somewhat modified and the demand rate probably based on K.V.A. rather than on K.W. The equivalent unit charges should however remain substantially as indicated. Generally speaking these bulk supply rates should result in a reasonable profit for the distributors, and justify a tariff to the ultimate consumers at rates well below the prevailing average.

34. Regarding the proposed rates for the railway company it may be of interest to quote the following :—

	Average rate at 50 per cent load factor.
	ANNA.
Chilian State Railways	0·64
Transandino (between Chile and the Argentine)	0·76
Great Indian Peninsular Railway, Bombay	0·61
Paulista (Brazil)	0·56
South Indian Railway (proposed)	0·53

In Chile there are extensive coal fields, the coal having an average thermal value of 12,000 B.T.U. Yet in spite of this, a section of the State Railways has been electrified, and a considerable saving effected, with power at the rate shown above.

35. Based on the foregoing remarks and the Committee's Report (G.O. No. 678 W., dated 26th March 1927) a careful forecast of the probable load, which it is possible to develop during the first ten years of operation, is shown in Tables 4, 5, 6 and 7. For the first three years individual additions have been made, for the fourth year a general increase of 12½ per cent has been allowed, for the fifth 10 per cent, and for the last five years an overall increase of only 8·5 per cent has been assumed.

36. The figures are intended to be neither conservative nor exaggerated, but an attempt to forecast the actual load which will be available during the first few years of operation.

37. In the case of the Coimbatore district—Table 4—it is expected that, by co-operation with the Nilgiri Power Syndicate, about two-thirds of the estimated minimum demand will be available the first year; but a period of about four months before the first year of normal operation is to be allowed for testing, changes, etc., during the initial conversion work. Revenue obtained during this period has not been included in the income account.

38. At Madura—Tables 5 and 7—no provision has been made for the electrification of the larger mills the first year. In the second year 15 per cent of the plant is assumed to change over to electricity as an experiment, followed by further gradual conversion in the third and fourth years and ending in complete electrification in the fifth year.

39. The railway load is based on data furnished by the South Indian Railway Company and conferences with the Agent and the Consulting Engineer. The company are not in a position to guarantee this load at present, but the prospects of obtaining it and considerably more are distinctly favourable. The Madura-Trichinopoly section and the Workshops at Trichinopoly will be ready to take power in the first year. In the second year the Dindigul-Podanur section will come along and in the third the Podanur-Erode section. Annual increases in the load taken by these sections have been allowed on percentages varying from 2·5 to 6 depending on the sections. It will be noted that the co-operation of the Railways is essential to the success of the scheme.

40. No allowance has been made for any big new industries which may be attracted to the districts by the cheap power, nor for the possibility of connecting up Calicut and other districts. The load of the Government Cordite Factory has also not been included, although preliminary negotiations with the administration at Aravankadu were very encouraging, and it is quite probable that a rate may eventually be quoted which will be acceptable to them.

41. When this forecast had been completed a few comparisons were made with areas in the course of development elsewhere, and the following interesting figures were obtained :—

	* Average of 12 Latin American districts in Chile, Argentine and Mexico referring to 1922.	Bangalore (excluding Kolar).	* Pykara (fifth year of operation).
K.W.H. per annum per capita ...	40 to 140	120	56
Revenue per capita	Rs. 14·7 to Rs. 26	Rs. 5·7	Rs. 2·4 †

* Excluding power for electrification of railways or trams.

† For 11,000 volts; power at 400 volts would be about 80 per cent higher.

42. The above statistics tend to prove that the proposed rates for Pykara are very low, while the estimated power consumption is also on the low side. It might be of interest to note from the Committee's Report (G.O. No. 678 W., dated 26th March 1927) that the increase in the connected load of some of the districts under review since 1916 is over 200 per cent. Such figures should appeal to any business man, as there is no doubt that the estimated consumption will not only be reached, but exceeded, provided always that a consistent and energetic policy is maintained by those responsible for the development. The sale of electrical energy is now a highly specialized profession, and given a sales manager with the proper qualifications, many figures, which have been reached elsewhere, can also be attained in Southern India. The country cannot be blamed if there is no apparent immediate market for hydro-electric power; other countries appeared the same, until a start was made to develop the resources. Bangalore, as already noted, is now consuming 120 units per capita, a performance which reflects great credit on the administration. If Bangalore can do this there is no reason whatsoever why Coimbatore and Madura should not equal it, although allowance is made in the forecast for a much lower figure.

43. Tables 4 and 5 are an analysis of the load expected in the various districts during the first three years, while Tables 6 and 7 show, in less detail, the system load forecast for the first ten years. The estimated revenue and average rate per unit are also shown.

It is believed that these statements are sufficiently clear to require no further explanation.

44. For convenience some of the results may be tabulated as follows :—

Table 8—giving demand at the distributing end, revenue estimate and return per unit.

Year of operation.	Demand K.W.	Distributed K.W.H.	Estimated revenue from bulk supply.	Average return per K.W.H. sold.
			RS.	ANNA.
First	6,750	22,548,000	8,98,480	0·638
Second	10,600	39,366,000	15,34,400	0·6[illegible]
Third	14,800	57,181,000	22,22,550	0·623
Fourth	16,300	65,995,000	25,19,000	0·612
Fifth	18,000	75,380,000	28,84,600	0·612
Sixth	18,600	80,200,000	30,20,000	0·602
Seventh	19,300	85,400,000	31,70,000	0·598
Eighth	20,100	91 000,000	33,30,000	0·584
Ninth	21,000	97,000,000	34,90,000	0·575
Tenth	21,900	103,315,000	36,60,600	0·567

Table 9—giving power house load details.

Year of operation.	Demand K.W.	Generation K.W.H.	Average load. K.W.	Load factor per cent
First	7,700	25,000,000	2,850	37
Second	12,100	43,700,000	5,000	41
Third	16,900	63,500,000	7,250	43
Fourth	18,600	73,300,000	8,350	45
Fifth..	20,600	83,800,000	9,550	46·5
Sixth	21,200	89,200,000	10,200	48
Seventh	22,000	94,900,000	10,850	49·5
Eighth	22,900	101,100,000	11,550	50·5
Ninth	23,900	107,800,000	12,300	51·5
Tenth	25,000	114,800,000	13,100	52·5

45. In view of the preponderance of industrial load the peak demand will probably be in the morning, but the lighting load at night will tend to improve the system load factor.

46. This load forecast will be checked at intervals as further information becomes available. At this stage, however, it is not considered that any useful purpose would be served by going more into detail.

Methods of Developing Load.

47. As soon as the construction of the scheme is authorized, or even tentatively approved, negotiations must be entered into with the Nilgiri Power Syndicate.

48. It will be advantageous, at the outset, to co-operate fully with this organization and grant them a licence to distribute electricity in an area, which would include Gudalur, Ootacamund, and other towns in the Nilgiris, Tiruppur, Erode, Salem, Mettupalaiyam and Pollachi. It would be arranged that the construction of the distribution system and work of mill conversion be commenced the last year of the construction of the first stage of the development, so that the minimum load shown in the forecast would be assured, from the start.

49. The rates which the Nilgiri Power Syndicate would be charged for power, and the maximum permissible tariffs, would be such as to render the scheme attractive to the outside investor, yet not high enough to hamper development.

50. This arrangement should ensure that the mills of Messrs. Stanes & Co. would come in from the start, and it would be very much in the interests of the Syndicate to secure as much load as possible from the outset.

51. The Government might subscribe 51 per cent of the capital, as a good return ought to be obtained on the investment. Should it be decided to buy out the Syndicate later at a valuation plus a small percentage,—a clause to this effect may be inserted in the licence—a further profit will be made on the investment or, in other words, the purchase price will be lower. Furthermore the Government, being a majority stock-holder, could always influence the policy of the management.

52. It might be asked why the Government should not avoid the middleman's profit, and distribute and sell, power, itself. It is believed, however, that in this particular case, private enterprise, being reasonably compensated, will accomplish more in a shorter space of time, at the outset, than Government.

53. If required, Government would also be willing to act as one of the Syndicate's Consulting Engineers, and the whole endeavour should be one of assistance, rather than of obstruction by too many rules and regulations.

54. Official specifications and standards for distribution net-works may, in many cases, have to be modified to be more in accordance with Western practice, where factors of safety and consequently construction costs are often lower, but which experience has proved to answer the purpose, and reduce unproductive capital expenditure to a minimum.

55. In the case of the Madura and Trichinopoly districts, it is expected that the development of the load would depend chiefly on a central Electricity Board, which is discussed in a separate communication, or similar body.

56. Private enterprise should, however, be protected and encouraged, always provided that their systems were efficiently and progressively managed.

57. For new districts it would probably be found more convenient for the Government to start the development. After a certain stage had been reached, the area could be administered, if considered feasible, by a Syndicate or local agents appointed on a commission, based on the revenues received.

58. Their work would be facilitated by certain fixed standards and regulations. For instance standard forms of construction and costs for all classes of lines, transformer installations, etc., would be provided. Concise instructions as to conditions which would warrant an extension of existing lines, a complete set of tariffs to meet all conditions, and similar information would also be given.

59. In any case, it would appear highly desirable that those actually in charge of the sale of power, particularly in the rural districts, be men thoroughly acquainted with local conditions, and known to the leading residents.

60. As soon as it appears necessary, a commercial branch of the department will be organized, to deal exclusively with the problem of load development and power sales.

Mill Conversion Fund.

61. It is important to secure the rapid conversion of all the existing mills to electric drive within the first years of operation. To facilitate this, a Mill Conversion Fund with Rs. 12·3 lakhs is proposed.

62. The Stanes group of Mills in Coimbatore, the Harvey Mills at Madura and certain mills and factories belonging to Government and the South Indian Railway are not likely to ask for aid in converting their plant to electricity. It is assumed that all the other existing mills will seek capital from this fund and provision should be made for this. Table 10 gives the approximate capital cost of conversion under the different power groups into which the mills can be classified.

Table 10—Mill conversion costs.

Range of installed capacity.	Plant installed capacity.	Approximate rate for conversion.	Cost of conversion.
	H.P.	£ PER H.P.	£
Up to 10 h.p.	50	17	850
10 to 25 ,, ...	700	15	10,500
25 to 50 ,, ...	1,800	12	21,600
50 to 100 ,, ...	1,950	10	19,500
100 to 500 ,, ...	1,950	8	15,600
500 to 1,000 ,, ...	2,800	6	16,800
1,000 and up ,, ...	1,450	5	7,250
Total ..	10,700	..	92,100 Rs. 12,30,000

63. The total of Rs. 12·3 lakhs will be spent in three years as follows :—

	LAKHS.
	RS.
Last year of construction	6·9
First year of operation	3·45
Second year of operation	1·95
Total ...	12·30

This will ensure the complete electrification of all the existing mills before the beginning of the third year of operation.

64. *Repayment.*—The money advanced will be recovered in ten equal annual instalments which include (*a*) a sinking fund provision to discharge the debt in ten years and (*b*) annual interest charges. Interest at 6 per cent is allowed. Table 11 gives the amounts payable annually per h.p. for the different power groups.

At the end of the tenth year the payments cease and the equipment becomes the property of the mill owner.

Table 11—Repayment of conversion loan.

Period	10	years.
Interest	6	per cent.
Annual provision for sinking fund to repay capital at the end of ten years	7·587	,,

Range.	Capital cost of conversion per h.p.	Sinking fund provision at 6 per cent.	Annual interest at 6 per cent.	Annual payment per h.p.
	RS.	RS.	RS.	RS.
0 to 10 h.p.	227	17	14	31
10 to 25 ,, ...	200	15	12	27
25 to 50 ,, ...	160	12	10	22
50 to 100 ,, ...	133	10	8	18
100 to 500 ,, ...	107	8	6	14
500 to 1,000 ,, ...	80	6	5	11
1,000 and up ,, ...	67	5	4	9

The above rates are only approximate and submitted in order to give an example of the method proposed. The actual cost of the conversion of any installation will form the basis of the annual charges.

TABLE 4.

Detail of Load Forecast for the Coimbatore Division.

First three years of operation.

District.	First year. Load factor per cent.	First year. Consumption in millions of K.W.H.	First year. Demand K.W.	First year. Average rate anna.	First year. Revenue.	Second year. Load factor per cent.	Second year. Consumption in millions of K.W.H.	Second year. Demand K.W.	Second year. Average rate anna.	Second year. Revenue.	Third year. Load factor per cent.	Third year. Consumption in millions of K.W.H.	Third year. Demand K.W.	Third year. Average rate anna.	Third year. Revenue.	Remarks.
					RS.					RS.					RS.	
Coimbatore.																
Mills and Works of Messrs. Stanes & Co.	24	2·320	1,100	Bulk supply to Nilgiri Power Syndicate at 0·75 anna.	..	27	3·510	1,400	Bulk supply to Nilgiri Power Syndicate at 0·75 anna.	..	28·0	3,680	1,500	Bulk supply to Nilgiri Power Syndicate at 0·75 anna.	..	
Class B	20	1·570	900		..	21·5	2·63	1,380		..	22·5	3,450	1.750		..	
,, C	15	0·302	230		..	15	0·328	250		..	17·5	0·460	300		..	
,, D	25	0·263	120		..	25	0·394	180		..	28	0·490	200		..	
Tiruppur.																
Class C	15	0·394	300		..	15	0·590	450		.	17·5	0·920	600		..	Includes Salem and Erode from second year.
,, D	20	0·210	120		..	20	0·280	160		..	22·5	0·394	200		..	
Pollachi.																
Class C	15	0·262	200		..	15	0·394	300		..	17·5	0·615	400		..	
,, D	20	0·175	100		..	20	0·210	120		..	22·5	0·296	150		..	
Nilgiris.																
Class E	18	0·158	100		..	18	0·238	150		..	20	0·350	200		..	No allowance made for any load at Cordite Factory.
,, D	20	0·350	200		..	20	0·526	300		..	22·5	0·790	400		..	
Total for Nilgiri Power Syndicate.	..	6·004	3,370		..	..	8·900	4,690	..	..	..	11·445	5,700	..	..	
Diversity factor 1·15 ..	23·5	6·004	2,930	0·75	2,82,000	25	8·900	4,050	0·75	4,18,000	26·5	11·445	4,950	0·75	5,36,000	
Average load	..	..	686	..	..	..	..	1,010	..	..	..	..	1,310	..	..	
Railway load.																
Dindigul-Podanur ..	..	..	..	..	..	55	10·950	2,250	0·50	3,42,000	55	10·950	2,250	·50	3,42,000	
Podanur-Erode	..	..	..	..	..	..	..	..	..	..	55	10·150	2,150	·50	3,17,000	
Total, Railway ..	..	..	..	..	..	55	10,950	2,250	0·50	3,42,000	..	21·100	4,400	·50	6,59,000	
Total, Coimbatore division.	..	6·004	2,930	..	..	..	19·850	6,300	0·613	7,60,000	..	32·545	9,350	·59	11,95,000	
Diversity factor 1·08 ..	23·5	6·004	2,930	0·75	2,82,000	39	19·850	5,830	..	7,60,000	43	32·545	8,650	..	11,95,000	
Average load	..	..	686	..	..	..	..	2,260	..	..	..	..	3,720	..	..	

After third year, load forecast in the absence of more detailed information, can only be shown as a general increment, based on experience elsewhere.

Detail of Load Forecast for the Madura Division.

Table 5.

First three years of operation.

District and load.	First year.					Second year.					Third year.				
	Load factor per cent.	Consumption in millions of K.W.H.	Demand K.W.	Average rate anna.	Revenue.	Load factor per cent.	Consumption in millions of K.W.H.	Demand K.W.	Average rate anna.	Revenue.	Load factor per cent.	Consumption in millions of K.W.H	Demand K.W.	Average rate anna.	Revenue.
					RS.					RS.					RS.
Madura															
Harvey Mills A	..	..	..	..	..	24	2·100	1,000	0·85	1,11,500	28	5·400	2,200	0·75	2,53,000
Class B	20	1·110	650	0·85	60,500	21·5	1·410	750	0·85	74,500	22·5	1·670	850	0·85	88,500
,, C	15	0·263	200	1·06	17,450	15·0	0·328	250	1·06	21,750	17·5	0·460	300	1·06	30,500
,, D	25	0·655	300	1·06	43,500	25·0	0·875	400	0·96	52,500	28·0	1·100	450	0·96	67,000
Total, Madura ..	..	2·058	1,150	..	1,21,450	..	4·713	2,400	..	2,60,250	..	8·630	3,800	..	4,39,000
Trichinopoly.															
Class C	15	0·263	200	1·06	17,450	15	0·394	300	1·06	26,100	17·5	0·845	550	0·96	50,700
,, D	25	0·262	120	1·06	17,400	25	0·328	150	1·06	21,750	28·0	0·735	300	1·06	48,700
Total, Trichinopoly ..	..	0·525	320	..	34,850	..	0·722	450	..	47,850	..	1·580	850		99,400
Dindigul.															
Class C	15	0·197	150	1·06	13,050	15	0·263	200	1·06	17,450	17·5	0·460	300	1·06	30,500
,, D	25	0·164	75	1·25	12,730	25	0·218	100	1·06	14,450	28·0	0·366	150	1·06	24,250
Total, Dindigul ..	..	0·361	225	..	25,780	..	0·481	300	..	31,900	..	0·826	450	..	54,750
Total, Madura Division Load.	..	2·944	1,695	..	1,82,080	..	5·916	3,150	..	3,40,000	..	11·036	5,100	..	5,93,150
Diversity Factor 1·15 ..	23	..	1,475	..	..	24·5	..	2,710	..	..	28	..	4.440	..	..
Average Load ..	..	..	836	..	..	..	..	675	..	..	..	..	1,260	..	..
Railways.															
Workshops	48	3·700	880	0·54	1,25,000	48	3·700	880	0·54	1,25,000	48	3·700	880	0·54	1,25,000
Electrification	54	9·900	2,100	0·50	3,09,400	54	9·900	2,100	0·50	3,09,400	54	9·900	2,100	0·50	3,09,400
Total, Railways ..	..	13·600	2,980	..	4,34,400	..	13·600	2,980	..	4,34,400	..	13·600	2,980	..	4,34,400
Total, Madura Division ..	..	16·544	4,455	0·60	6,16,480	..	19·516	5,720	0·635	7,74,400	..	24·636	7,420	0·666	10,27,550
Diversity Factor, 1·08 ..	46	..	4,130	..	..	42	..	5,300	..	..	41	..	6,870	..	..
Average Load ..	..	..	1,890	..	..	..	..	2,230	..	..	..	..	2.810	..	..

After third year, load forecast in the absence of more detailed information, can only be shown as a general increment, based on experience elsewhere.

Table 6.

System Load Forecast for the first three years of operation.

Description of load.	First year.				Second year.				Third year.				Remarks.
	K.W.	K.W.H. millions.	Rate K.W.H.	Revenue.	K.W.	K.W.H. millions.	Rate K.W.H.	Revenue.	K.W.	K.W.H. millions.	Rate K.W.H.	Revenue.	
COIMBATORE DIVISION.			ANNA.	RS.			ANNA.	RS.			ANNA.	RS.	
(1) Coimbatore Commercial	2,930	6·004	0·75	2,82,000	4,050	8·900	0·75	4,18,000	4,950	11·445	0·75	5,36,000	
Railway.													
(2) Podanur-Dindigul	..	..	..	..	2,250	10·950	0·50	3,42,000	2,250	10·950	0·50	3,42,000	
(3) Podanur-Erode	..	..	..	..	..	..	..	..	2,150	10·150	0·50	3,17,000	
(4) Total Coimbatore Division ..	2,930	6·004	0·75	2,82,000	6,300	19·850	0·613	7,60,000	9,350	32·545	0·59	11,95,000	
(5) Diversity Factor 1·08	2,930	..	..	..	5,830	..	.	..	8,650	..	..	..	
MADURA DIVISION.													
(6) Madura Commercial	1,150	2·058	0·945	1,21,450	2,400	4·713	..	2,60,250	3,800	8·630	0·815	4,39,000	
(7) Trichinopoly Commercial	320	0·525	..	34,850	450	0·722	..	47,850	850	1·580	1·00	99,400	
(8) Dindigul Commercial	225	0·361	..	25,780	300	0·481	..	31,900	450	0·826	1·06	54,750	
(9) Total Demand Diversity Factor 1·15 ..	1,475	2·944	..	1,82,080	2,740	5·916	..	3,40,000	4,140	11·036	..	5,93,150	
Railway													
(10) Madura-Trichinopoly	2,100	9·900	0·50	3,09,400	2,100	9·900	0·50	3,09,400	2,100	9·900	0·50	3,09,400	
(11) Trichinopoly Shops	880	3·700	0·54	1,25,000	880	3·700	0·54	1,25,000	880	3·700	0·54	1,25,000	
(12) Total Madura Division	4,455	16·544	0·60	6,16,480	5,720	19·516	0·635	7,74,400	7,420	24·636	0·666	10,27,550	
(13) Diversity Factor 1·08	4,130	..	..	..	5,300	..	..	..	6,870	..	..	..	
(14) Total (5) + (13)	7,060	22·548	0·638	8,98,480	11,130	39·366	0·625	15,34,400	15,520	57·181	0·623	22,22,550	
(15) System Demand D.F. 1·05	6,750	22·548	..	..	10,600	39·366	..	..	14,800	57·181	..	..	
POWER HOUSE.													
(16) Average Load P.H. .. .. K.W.	2,850				5,000				7,250				
(17) Do. Load Factor P.H. Per cent.	37				41				43				
(18) Total Generation at P.H. K.W.H.	25,000,000				43,700,000				63,500,000				
(19) Peak Load at P.H. .. .. K.W.	7,700				12,100				16,900				
(20) Estimated Revenue	Rs 8,98,480				Rs. 15,34,400				Rs. 22,22,550				

Overall peak load efficiency Generator bus to H. T. Feeders 87·5 per cent.
Average load efficiency—Generator bus to H.T. Feeders 90 per cent.
Diversity Factors Generator bus to H.T. Feeders 1·30.

Table 7.

System Load Forecast for the fourth, fifth and tenth years of operation.

Description of load.	Fourth year. K.W.	Fourth year. K.W.H. millions.	Fourth year. Rate K.W.H.	Fourth year. Revenue.	Fifth year. K.W.	Fifth year. K.W.H. millions.	Fifth year. Rate K.W.H.	Fifth year. Revenue.	Tenth year. K.W.	Tenth year. K.W.H. millions.	Tenth year. Rate K.W.H.	Tenth year. Revenue.	Remarks.
COIMBATORE DIVISION.			ANNA.	RS.			ANNA.	RS.			ANNA.	RS.	
(1) Coimbatore Commercial	4,800	12·850	0·72	5,78,000	4,900	14·135	0·70	6,20,000	6,350	21·095	0·65	8,55,000	
Railways.													
(2) Podanur-Dindigul	2,500	12·000	0·50	3,75,000	2,750	13·200	0·50	4,12,000	3,100	16·150	0·48	4,85,000	
(3) Podanur-Erode	2,300	11·200	0·50	3,50,000	2,550	12·300	0·50	3,84,000	3,100	16·150	0·48	4,85,000	
(4) Total Coimbatore division	9,600	36·050	..	13,03,000	10,200	39·635	..	14,16,006	12,550	53·395	..	18,25,000	
(5) Diversity Factor 1·08	8,900	..	..	..	9,450	..	..	..	11,600	..	..	..	
MADURA DIVISION.													
(6) Madura Commercial ..	4,900	12·338	0·75	5,79,000	5,900	16·368	0·75	7,66,000	7,350	24·400	0·65	9,90,000	
(7) Trichinopoly Commercial	900	1·777	0·96	1,06,300	950	1·954	0·96	1,17,200	1,150	2·840	0·75	1,33,000	
(8) Dindigul Commercial	500	0·930	0·96	55,700	550	1·023	0·96	61,400	700	1·530	0·75	71,600	Erode and Salem are included in Coimbatore.
(9) Total Demand Diversity Factor 1·12*.	5,620	15·045	..	7,41,000	6,600	19·345	..	9,44,600	8,200	28·770	..	11,94,600	
Railways.													
(10) Madura-Trichinopoly	2,250	10·900	0·50	3,40,000	2,500	12·000	0·50	3,75,000	3,100	16·150	0·48	4,85,000	
(11) Trichinopoly Shops	1,000	4·000	0·54	1,35,000	1,050	4·400	0·54	1,49,000	1,050	5·000	0·50	1,56,000	
(12) Total Madura division	8,870	29·945	..	12,16,000	10,150	35·745	..	14,68,600	12,350	49·920	..	18,35,600	
(13) Diversity Factor 1·08	8,200	..	..	..	9,400	..	..	..	11,400	..	..	..	
Total (5) + 13 ..	17,100	65·995	0·612	25,19,000	18,850	75·380	0·612	28,84,600	23,000	103·315	0·567	36,50,600	
System demand D.F. 1·05 ..	16,300	..	..	..	18,000	..	..	..	21,900	..	..	..	
POWER HOUSE.													
Average Load P.H. .. .. .. K.W.	8,350				9,550				13,100				
Average Load Factor P.H. .. Per cent.	45				46·5				52·5				
Total generation at P.H. .. K.W.H.	73,300,000				83,800,000				114,800,000				
Peak Load at P.H. .. .. .. K.W.	18,600				20,600				25,000				
Estimated revenue	Rs. 25,19,000				Rs. 28,84,600				Rs. 36,60,600				

	PER CENT.
Assumed Peak Load Efficiency 11 K.V. Volt Feeders	97·5
Step Down Transformers	97
110 K.V. Transmission Lines	95
Step Up Transformers	97
Total	87·5
Assumed Average Load Efficiency	90

Diversity Factor Generator bus bars to H.T. Feeders 1·27.

* Diversity Factor decreased due to improved load factors.

APPENDIX B.—RAINFALL, RUN-OFF AND STORAGE.

65. The only reliable method of determining the actual run-off is by river gaugings, and any attempt at deducing run-off from rainfall must invariably result in errors to a greater or less degree. Nevertheless there are times when the run-off of a catchment must be determined from the rainfall, in which case it is better to carry out individual studies over as long a period as possible, derive independent relationships, and avoid, generally, the use of formulæ. There are a number of formulae published for different kinds of catchments, but in checking one with another very contradictory results are usually obtained.

66. Several estimates of the flow of the Pykara river have been made in the past with distinctly variable results. Three of these are quoted as follows:—

Authority.	Estimated run-off based on minimum year.	Estimated mean flow with storage.	Estimated storage.
	M.C.FT.	CUSECS.	M.C.FT.
Mr. S. G. Forbes	3,000	85	Not given.
„ P. Hawkins	860	65	3,800
„ B. D. Richards	1,750	114 to 173	6,000

67. Mr. A. W. Robert has been studying this subject for the past two years and has arrived at a figure of 4,000 millions of cubic feet for the minimum run-off. This amount appears high but has been used as a basis for present storage calculations as explained later.

68. Mr. Forbes took the rainfall records of Pykara and assumed the run-off as 50 per cent *less* 10 per cent for evaporation, etc., during storage. His results, however, were only intended to be approximate, and no attempt was made to go into detail.

69. Mr. Hawkins adopted methods outlined by Strange, but it is not clear how the results were obtained. In some years, however, no run-off was allowed for several weeks, and it is common knowledge that the Pykara river is never dry. The figures of Mr. Richards deserve careful consideration as he has had wide experience in such studies.

70. Mr. Richards came to the conclusion that due to the position of the Pykara rain gauge in the catchment area, the rainfall, as registered, during the south-west monsoon, would be lower than the average rainfall over the catchment, while for the other months it would be more or less representative. By taking the records of rain gauges established on some of the estates bordering the catchment, an average was obtained for the various months and the results plotted against the Pykara readings. The resulting curve gave an average rainfall for the catchment 58 per cent in excess of that of Pykara. For determining the run-off he used arbitrary factors of from 10 per cent to 80 per cent, depending on the rainfall.

71. Independently Mr. Robert found that a reasonable relationship existed between the rainfall of the Terrace Tea estate and the gauged run-off. From the rainfall records of Terrace since 1919, he plotted a series of monthly curves against those of Pykara, and established an average monthly relationship, so that Terrace rainfalls prior to 1919 could be deduced.

72. For the run-off, actual gaugings of the river since 1925 were plotted against the Terrace rainfall, and the average ratios thus obtained were used for deducing the run-off in years where gaugings were not available. This method should give fairly accurate results and has been used in the present estimates.

73. Fortunately river gaugings are available for the dry months over several years while since 1925 the river has been regularly gauged. The flow has been determined both by current meter and weir, the results checking within reasonable limits. As a further check the observers were changed on two or three occasions; so there is every reason to suppose that the flows, as recorded, are reasonably accurate.

74. When a power project such as Pykara forms the only source of supply to a transmission system, it is obvious that it should be developed only up to minimum water conditions, and this minimum should be determined over a period of as many years as possible; twenty is usually considered satisfactory. On a second source of power being added to the system, either a steam electric station, or a hydro-electric plant, situated in an entirely different water shed, the original plant can be safely developed to a point in excess of minimum conditions, if economically feasible.

75. Although the run-off of a catchment varies widely with the rainfall, the latter is at any rate a safe indication, as far as Pykara is concerned, as to the relative flows of the river each year.

76. Rainfall records at Pykara are available since 1882 and if these are examined, it will be seen that 1918 was the driest year. If however the years are divided up into monsoon periods and dry periods, it will be found that the dry period was more prolonged in 1926–27 (December—May) than for any other year, while the monsoon period for 1918 was the lowest on record.

77. For our immediate purpose an arbitrary minimum year is taken and a hydrograph constructed partly from the readings of 1918 and partly from 1926–27. This is shown on chart P-5-F_2. Such conditions have not existed in the forty-four years of which there are records, and probably never will. It will undoubtedly be found economical to develop the scheme beyond this arbitrary limit, once a second plant has been constructed.

78. For this hydrograph there are fortunately river gaugings available for the critical months—the dry period—but the monsoon months have to be deduced from the rainfall.

79. *Dry months, January to May.*—River gaugings are available for the dry weather 1926–27. These were checked against the dry weather readings of 1917–18, and appeared lower, having due regard to the rainfall registered at Pykara for the above years. Reference was also made to the accuracy of these gaugings in a previous paragraph.

80. *North-east monsoon months, October to December.*—Pykara rain gauge should register slightly higher than the mean catchment rainfall. The readings, deduced from curves, and used for the hydrograph, are lower than those corresponding to Pykara.

81. *South-west monsoon months.*—The rainfall and run-off figures had to be deduced according to the methods previously outlined. The deduced catchment rainfalls are usually higher than that of Terrace for heavy rains, and lower for average rains. Further investigations may show that the corresponding run-offs are too high, but this is of no great importance, unless a large proportion of the whole catchment rainfall is to be utilized.

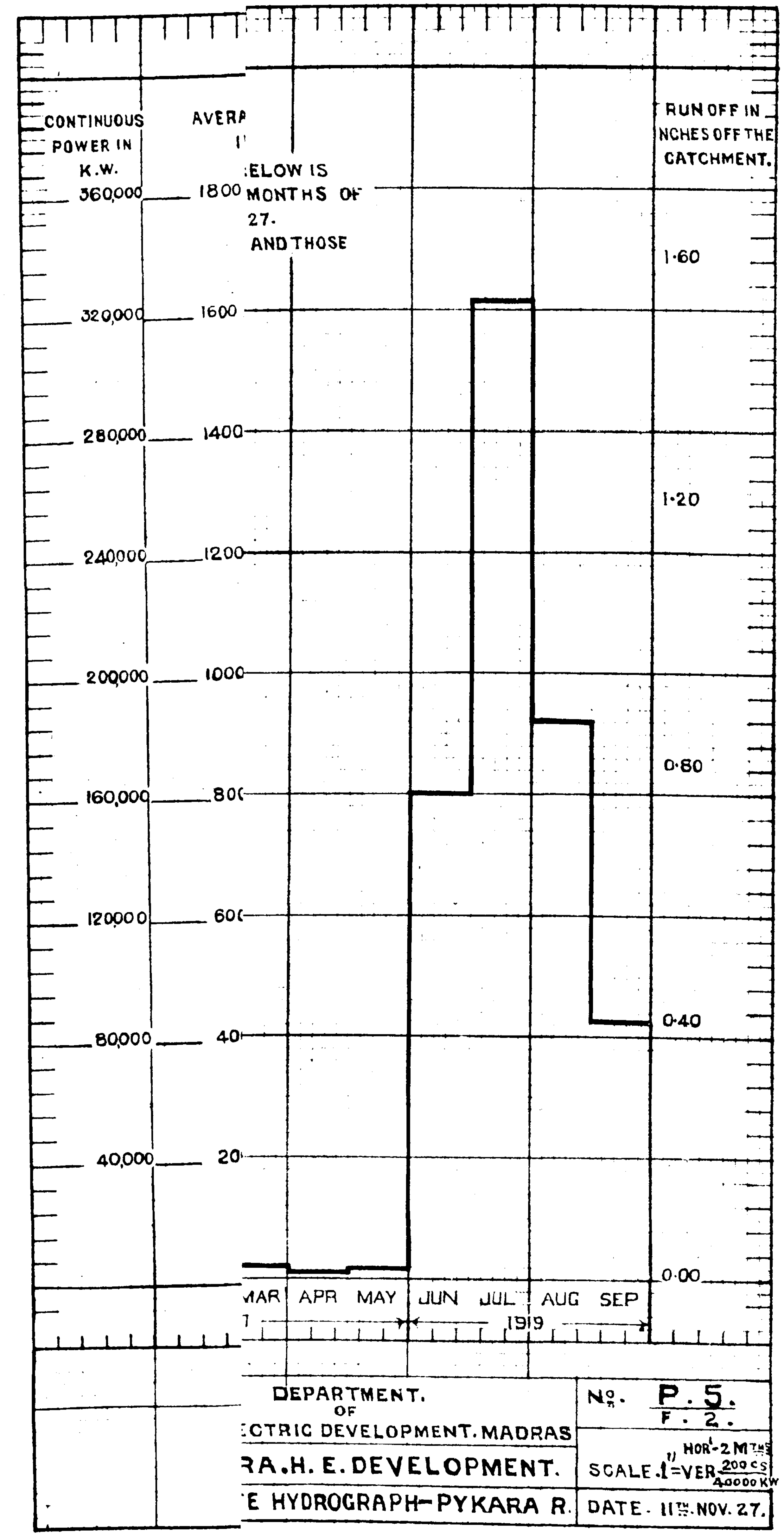
82. For such low drafts as are to be expected in the first few years of operation, it is not necessary to analyse the run-off, during the south-west monsoon months, very closely, as even the driest years will supply more water than needed. It is only when considering draw-offs of the order of 100 cusecs and above, that it becomes necessary to study the flows, for the south-west monsoon months, more closely.

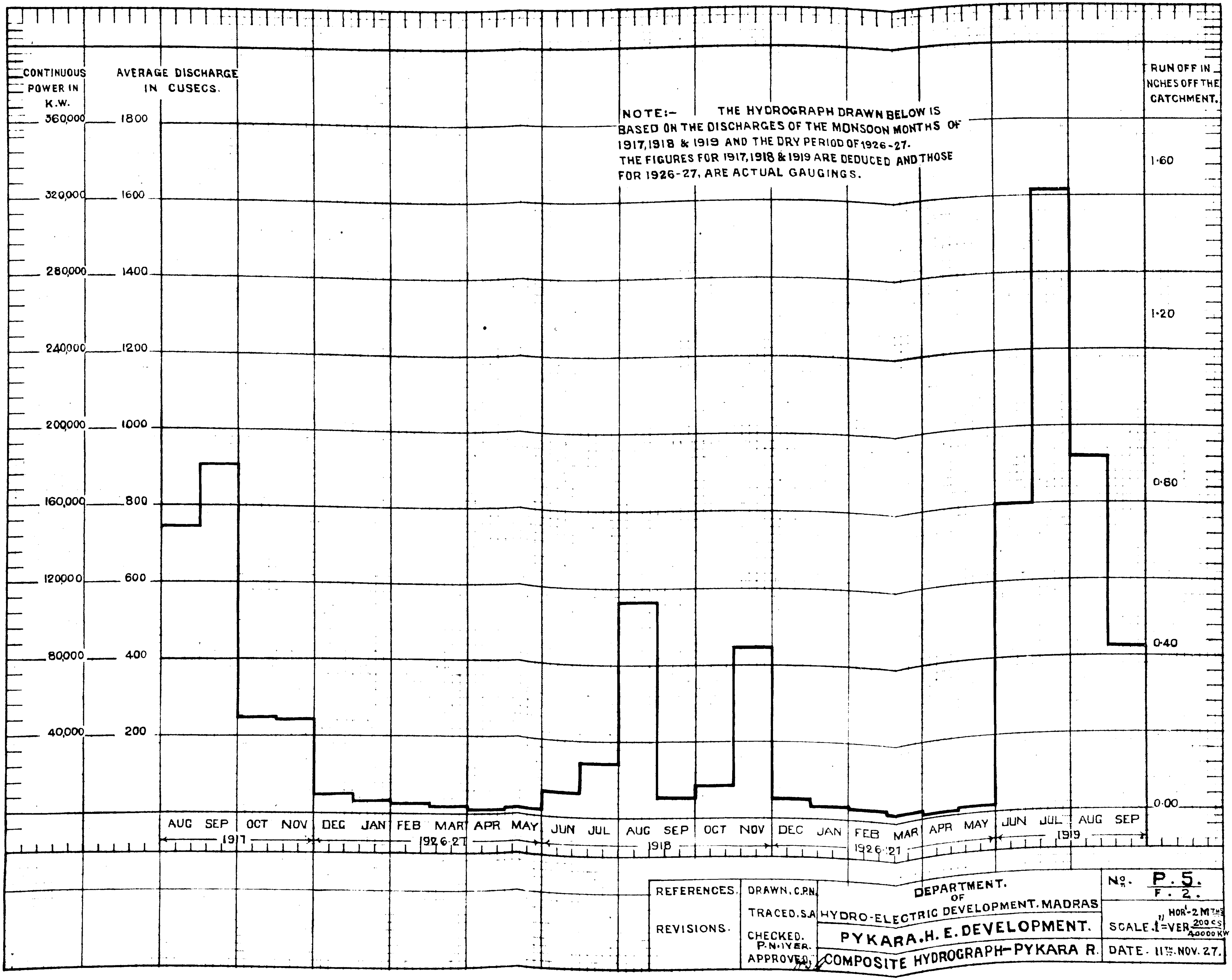
83. As it is proposed to continue and extend the gaugings of the Pykara river, construct additional weirs and establish more rainfall gauges, there will be plenty of opportunity to check any figures which may be arrived at now, and the plans, if necessary, can be accordingly modified, since it would seem that several years must elapse before the load will require very high draw-offs.

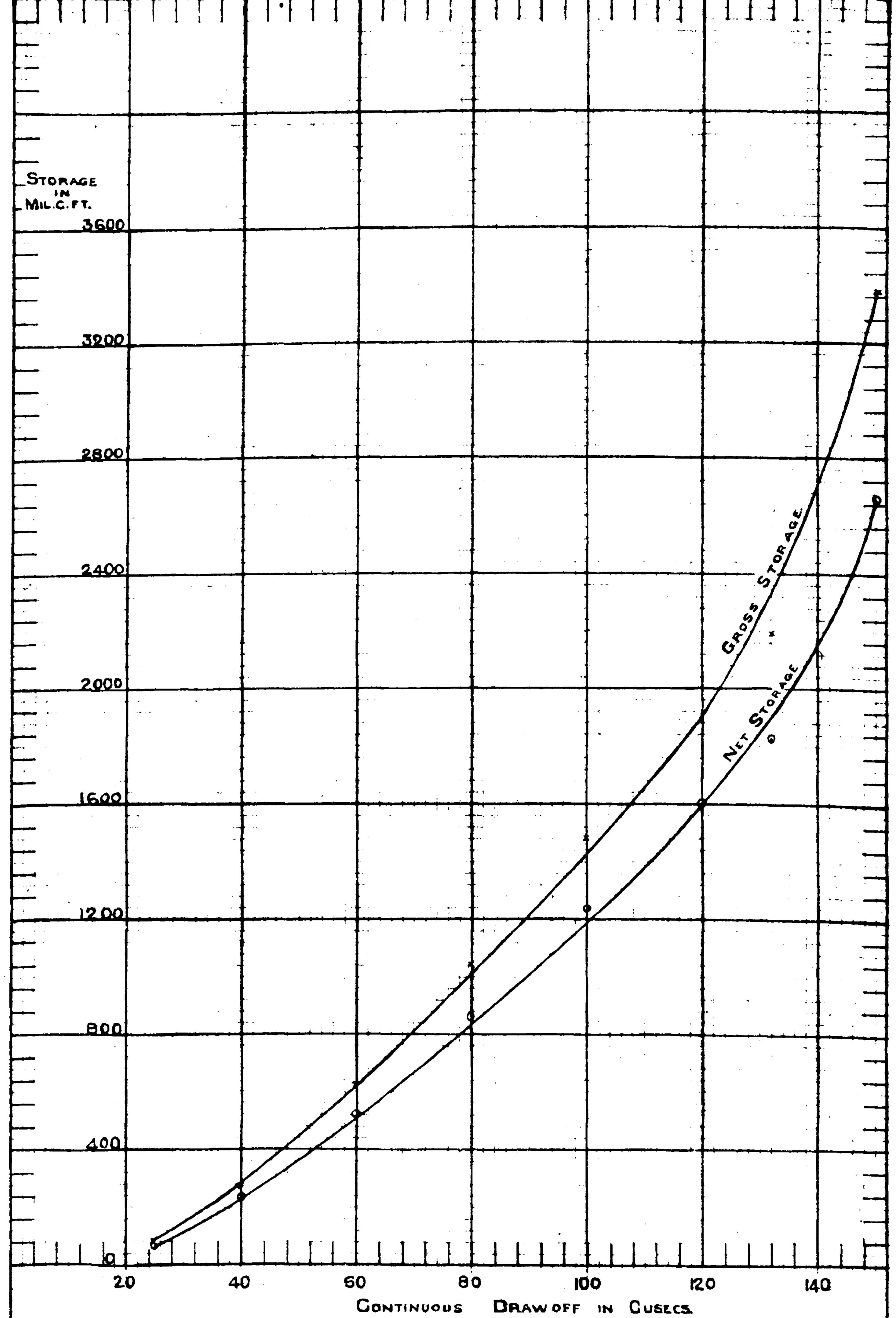
84. From the hydrograph P–5–F_2 were prepared Table 12 and chart P–6–F_1 giving the storages necessary for different power draw-offs. Table 13 below gives the storage requirements to meet the power demand in the first ten years of operation.

Table 13—giving storages required for the first ten years of operation.

Year.	Demand at Power House.	Average Load, Power House.	Average continuous draw off.	Storage required.	
				Net.	Gross.
	K.W.	K.W.	CUSECS.	M.C.FT.	M.C.FT.
First	7,700	2,850	14·25	..	..
Second	12,100	5,000	25·00	67	80
Third	16,900	7,250	36·25	185	230
Fourth	18,600	8,350	41·75	250	310
Fifth	20,600	9,550	47·75	330	410
Sixth	21,200	10,200	51·00	370	460
Seventh	22,000	10,850	54·25	420	520
Eighth	22,900	11,550	57·75	470	580
Ninth	23,900	12,300	61·50	530	650
Tenth	25,000	13,100	65·50	600	730




CONTINUOUS POWER IN K.W.
AVERAGE DISCHARGE IN CUSECS.
RUN OFF IN INCHES OFF THE CATCHMENT.
NOTE:- THE HYDROGRAPH DRAWN BELOW IS BASED ON THE DISCHARGES OF THE MONSOON MONTHS OF 1917, 1918 & 1919 AND THE DRY PERIOD OF 1926-27.
THE FIGURES FOR 1917, 1918 & 1919 ARE DEDUCED AND THOSE FOR 1926-27, ARE ACTUAL GAUGINGS.
360,000
320,000
280,000
240,000
200,000
160,000
120000
80,000
40,000
1800
1600
1400
1200
1000
800
600
400
200
1.60
1.20
0.80
0.40
0.00
AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
1917
1926-27
1918
1926-27
1919
REFERENCES.
REVISIONS.
DRAWN. C.P.N.
TRACED. S.A.
CHECKED. P.N. IYER.
APPROVED.
DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS
PYKARA. H. E. DEVELOPMENT.
COMPOSITE HYDROGRAPH—PYKARA R.
No. P. 5. F. 2.
SCALE 1" = HOR. 2 MTHS VER. 200 CS 40000 KW
DATE. 11TH NOV. 27.



Refferences	Drawn C.P.N	Department of Hydro Electric Development. Madras.	No. P.6. / F.1.
	Traced S.A.		
Revisions	Checked P.N. Aiyer.	**PYKARA. H.E. DEVELOPMENT.**	Scale 1" = 20cs Hor.; 400 M cft Vert.
	Approved	**DRAW-OFF · STORAGE CURVE.**	Date. 11-11-27

Storages required for different continuous power draw-offs—Table 12.

Year and month.	Run-off in millions of cubic feet.	25 cusecs. Draw-off in millions of cubic feet.	25 cusecs. Surplus or deficiency in millions of cubic feet.	25 cusecs. Accumulated storage required in millions of cubic feet.	40 cusecs. Draw-off in millions of cubic feet.	40 cusecs. Surplus or deficiency in millions of cubic feet.	40 cusecs. Accumulated storage required in millions of cubic feet.	60 cusecs. Draw-off in millions of cubic feet.	60 cusecs. Surplus or deficiency in millions of cubic feet.	60 cusecs. Accumulated storage required in millions of cubic feet.	80 cusecs. Draw-off in millions of cubic feet.	80 cusecs. Surplus or deficiency in millions of cubic feet.	80 cusecs. Accumulated storage required in millions of cubic feet.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1917.													
July	850	67	+ 783	..	107	+ 743	..	161	+ 689	..	214	+ 636	..
August	1,950	67	+ 1,883	..	107	+ 1,843	..	161	+ 1,789	..	214	+ 1,736	..
September ..	2,340	65	+ 2,275	..	104	+ 2,236	..	156	+ 2,184	..	207	+ 2,133	..
October	660	67	+ 593	..	107	+ 553	..	161	+ 499	..	214	+ 446	..
November	632	65	+ 567	..	104	+ 528	..	156	+ 476	..	207	+ 425	..
December	134	67	+ 67	..	107	+ 27	..	161	— 27	27	214	— 80	80
1918.													
January	88	67	+ 21	..	107	— 19	19	161	— 73	100	214	— 126	206
February	70	63	+ 7	..	97	— 27	46	145	— 75	175	194	— 124	330
March	53	67	— 14	14	107	— 54	100	161	— 108	283	214	— 161	491
April	32	65	— 33	47	104	— 72	172	156	— 124	407	207	— 175	666
May	47	67	— 20	67	107	— 60	232	161	— 114	521	214	— 167	833
June	171	65	+ 106	..	104	+ 67	..	156	+ 15	..	207	— 36	869
July	380	67	+ 313	..	107	+ 273	..	161	+ 219	..	214	+ 166	..
August	1,520	67	+ 1,453	..	107	+ 1,413	..	161	+ 1,359	..	214	+ 1,306	..
September	135	65	+ 70	..	104	+ 31	..	156	— 21	21	207	— 72	72
October	225	67	+ 58	..	107	+ 118	..	161	+ 64	..	214	+ 11	..
November	1,155	65	+ 1,090	..	104	+ 1,051	..	156	+ 994	..	207	+ 948	..
December	134	67	+ 67	..	107	+ 27	..	161	— 27	27	214	— 80	80
1919.													
January	88	67	+ 21	..	107	— 19	19	161	— 73	100	214	— 126	206
February	70	63	+ 7	..	97	— 27	46	145	— 75	175	194	— 124	330
March	53	67	— 14	14	107	— 54	100	161	— 108	283	214	— 161	491
April	32	65	— 33	47	104	— 72	172	156	— 124	407	207	— 175	666
May	47	67	— 20	67	107	— 60	232	161	— 114	521	214	— 167	833
June	2,065	65	+ 2,000	..	104	+ 1,961	..	156	+ 1,909	..	207	+ 1,858	..
July	4,340	67	+ 4,273	..	107	+ 4,233	..	161	+ 4,179	..	214	+ 4,126	..
	Net storage required. 67 millions of cubic feet. Evaporation and seepage—20 per cent. 13 millions of cubic feet.				232 millions of cubic feet. 46 ,, ,,			521 millions of cubic feet. 104 ,, ,,			869 millions of cubic feet. 174 ,, ,,		
Total storage ..	80 millions of cubic feet.				278 millions of cubic feet			625 millions of cubic feet.			1,043 millions of cubic feet.		

Storage required for different continuous power draw-offs—Table 12—*cont.*

Year and month.	100 cusecs. Draw off in millions of cubic feet.	100 cusecs. Surplus or deficiency in millions of cubic feet.	100 cusecs. Accumulated storage required in millions of cubic feet.	120 cusecs. Draw off in millions of cubic feet.	120 cusecs. Surplus or deficiency in millions of cubic feet.	120 cusecs. Accumulated storage required in millions of cubic feet.	132 cusecs. Draw-off in millions of cubic feet.	132 cusecs. Surplus or deficiency in millions of cubic feet.	132 cusecs. Accumulated storage required in millions of cubic feet.	150 cusecs. Draw-off in millions of cubic feet.	150 cusecs. Surplus or deficiency in millions of cubic feet.	150 cusecs. Accumulated storage required in millions of cubic feet.	Balance in reservoir with net storage of 2,660 millions of cubic feet.
	15	16	17	18	19	20	21	22	23	24	25	26	(27)
1917.													
July	268	+ 582	..	321	+ 529	..	..	..	..	402	+ 448	..	..
August	268	+ 1,682	..	321	+ 1,629	..	..	..	..	402	+ 1,548	..	..
September	259	+ 2,081	..	311	+ 2,029	..	..	..	..	389	+ 1,951	..	2,660
October	268	+ 392	..	321	+ 339	..	..	..	..	402	+ 258	..	2,660
November	259	+ 373	..	311	+ 321	..	..	..	..	389	+ 248	..	2,660
December	268	− 134	134	321	− 187	187	354	− 220	220	402	− 268	268	2,392
1918.													
January	268	− 180	314	321	− 233	420	354	− 266	486	402	− 314	582	2,078
February	242	− 172	486	290	− 220	640	320	− 250	736	363	− 298	875	1,785
March	268	− 215	701	321	− 268	908	354	− 301	1,037	402	− 349	1,224	1,436
April	259	− 227	928	311	− 279	1,187	342	− 310	1,347	389	− 357	1,581	1,079
May	268	− 221	1,149	321	− 274	1,461	354	− 307	1,654	402	− 355	1,936	724
June	259	− 88	1,237	311	− 140	1,601	342	− 171	1,825	389	− 218	2,154	506
July	268	+ 112	..	321	+ 59	..	354	+ 26	..	402	− 22	2,176	484
August	268	+ 1,252	..	321	+ 1,199	..	354	+ 1,166	..	402	+ 1,118	..	1,602
September	259	− 124	124	311	− 176	176	342	− 207	207	389	− 254	254	1,848
October	268	− 43	167	321	− 96	272	354	− 129	336	402	− 177	431	1,171
November	259	+ 896	..	311	+ 844	..	342	+ 813	..	389	+ 766	..	1,937
December	268	− 134	134	321	− 187	187	354	− 220	220	402	− 268	268	1,669
1919.													
January	268	− 180	314	321	− 233	420	354	− 266	486	402	− 314	582	1,355
February	242	− 172	486	290	− 220	640	320	− 250	786	363	− 293	875	1,062
March	268	− 215	701	321	− 268	908	354	− 301	1,037	402	− 349	1,224	713
April	259	− 227	928	311	− 279	1,187	342	− 310	1,347	389	− 357	1,581	356
May	268	− 221	1,149	321	− 274	1,461	354	− 307	1,654	402	− 355	1,936	1
June	259	+ 1,806	..	311	+ 1,754	..	342	+ 1,723	..	389	+ 1,676	..	1,677
July	268	+ 4,072	..	321	+ 4,019	..	354	+ 3,986	..	402	+ 3,938	..	2,660
	1,237 millions of cubic feet. 247 ,, ,,			1,601 millions of cubic feet. 320 ,, ,,			1,825 millions of cubic feet. 365 ,, ,,			Net storage		Millions of cubic feet. 2,660	.
										Evaporation and seepage ..		721	..
Total ..	1,484 millions of cubic feet.			1,921 millions of cubic feet.			2,190 millions of cubic feet.					3,381	..

APPENDIX C—THE SCHEME.

85. Assuming that the load and water estimates are accepted, the method of developing the Project can now be decided.

86. It is apparent that Pykara must be developed for such capacity as will involve the least initial expenditure, and reduce the immediate unproductive part of the installation to a minimum. The fixed charges are thus kept down.

87. Bearing this in mind, the possibility of abandoning the original scheme, and developing the power in three stages over the falls, was examined. A brief study sufficed, however to show that this method would not be as attractive as the scheme now recommended.

88. Efforts were then made to devise more economical alternatives ,to the various parts of the original scheme.

89. The results of these studies indicated that, in general, owing to the nature of the ground in the Pykara catchment high dams could only be constructed at a very high cost, whereas conditions were much more favourable for lower structures, and the required amount of water could still be stored.

When it is realized that, given equal conditions, two 50 feet masonry dams of the gravity type can be constructed for a much lower cost than one of 100 feet, the economical advantage is obvious. It was also recognized that the storage requirements could be considerably reduced during the first few years of operation. Estimates for the Power House are lower, due to a modification in the lay-out, while the initial expenditure for sub-stations has been reduced, due to the postponement of the installation of the majority of the synchronous condensers, and the adoption of a very simple design.

90. The estimates for many of the items under Hydraulic Works have unfortunately had to be increased so that the overall cost does not differ very much from some of the estimates recently submitted. The capacity has, however, been nearly doubled and the unit cost is lower.

Table 14 gives the cost of the scheme for various capacities.

Table 14—Estimate of costs.

For various stages of development.

—	Stage.	A	B	C	D	E
Hydraulic Works	Rupees in lakhs.	55·827	84·436	119·436	153·436	369·023
Power House	,,	70·653	91·950	125·732	155·587	
Transmission lines	,,	93·580	121·503	222·503	302·503	310·923
Sub-stations and bulk supply connections.	,,	15·400	40·490	53·000	60·640	65·640
Total ..	..	235·490	338·379	520·671	672·166	745·586
Installed capacity	K.W.	22,500	37,500	52,500	67,500	87,500
Continuous	..	5,200	15,000	26,000	30,000	50,000
Flow	Cusecs.	26	75	130	150	150
Average cost per unit at Power House if full capacity is utilized.	Anna.	0·83	0·412	0·366	0·410 *	0·272
Unit cost per K.W. installed ..	Rupees.	1,045	905	993	995	855

After completing A and B stages it may be found desirable to develop another project before proceeding with C, D and E.

* The average cost per unit rises at this stage due to the heavy expenditure in connexion with the Madras Lines. Stage E includes Moyar for which a tentative estimate of Rs. 60 lakhs has been allowed.

91. A brief description of each part of the work is as follows :—

Dam and Reservoir.—On referring to Table 13, it will be seen that our storage requirements are comparatively low for some years ; hence the consideration of high dams and large storages must be avoided where possible ; otherwise there will be fixed charges to be met annually on unproductive works.

92. A careful study was made of all the feasible storage schemes, both large and small, in the Pykara and adjoining catchments. It is unnecessary to enumerate them all, nor the combinations which are possible, but the conclusions arrived at were that subject to the results of detailed surveys and a further study of the run-off, the most economical developments and

those best suited to our needs, based on the load data and hydrograph shown in another part of this report, were in the following order :—

Year.	Reservoir.	Storage in millions of cubic feet.	Equivalent flow cusecs.
First ...	... Forebay and Glen Morgan.	105	26
Third ...	... Parson's Valley.	350	50
Sixth ...	... Porthumund.	450	75
When needed	... Makurti.	1,050	120
Do.	... Sandy nalla.	450	130
Do.	... Pykara.	1,200	150

93. If the load factor of the system improves at a greater rate than anticipated it will be found economical to develop Moyar at an earlier stage, as it is essentially a base load plant.

94. This programme can always be speeded up or may be modified, should load conditions and further investigations in the field warrant it.

95. It will be seen that there is a total storage possible of 3,600 million cubic feet which is sufficient for a continuous flow of over 150 cusecs.

96. However to ensure continuous flows in excess of 130 cusecs, based on the minimum year, requires storage to be carried over from one year to another, and this is not always economical, since the water may only be required once in a period extending over several years, i.e., at periods of extreme drought.

97. For the present only the development of storages up to a total of 2,400 million cubic feet is being considered, as this will ensure that the whole of the run-off in a minimum year can be utilized. The possibilities of the additional storage must not however be lost sight of.

98. If the plan of the general scheme P1—F1 is referred to, it will be seen that the Glen Morgan and Sandy nalla Reservoirs are fed from entirely different watersheds to that of Pykara. This is obviously an advantage, and ensures that the Forebay can be supplied from two independent sources.

99. If the Sigur river can be diverted into the Moyar Forebay, Sandy nalla Reservoir will possess the additional advantage of allowing Moyar to carry a variable load, independent of the Pykara tail race water, should it ever be necessary.

100. The capacities of the various reservoirs have been determined from the estimated minimum run-off of each catchment area. All figures have, however, to be confirmed by final surveys and observations.

101. For the first two years of operation, the necessary storage will be derived from the Glen Morgan Reservoir and the Forebay. A water-supply, both for the construction and permanent buildings, is absolutely necessary, also some means of regulating the flow of the Pykara River, during the dry months, for the Auxiliary Power Scheme. If the Glen Morgan basin is closed by a 50-ft. dam the run off of the minimum year, about 43·5 million cubic feet, can be stored, and a water-supply and regulating reservoir provided, which will be of value both during the construction period, and afterwards for regular operation.

102. The water from the Glen Morgan Reservoir will be conveyed to the Forebay by a short aqueduct 3,000 feet long having a capacity of 100 cusecs. Provision will also be made to supply water to those people who now depend on this stream for their water-supply. Preliminary enquiries indicate that this should be less than 1 cusec during the dry months. This reservoir will not, however, be used normally for power generation, after the first two years, except for an emergency.

103. The Forebay will be constructed for a capacity of 60 million cubic feet making, with the Glen Morgan Reservoir, a total available storage of 105 million cubic feet. This will suffice for the first two years of operation. By the third year the Parson's Valley Reservoir must be completed, adding 350 million cubic feet to the total. No further provision need be made until the sixth year, when either the Porthumund or Makurti dam, depending on load conditions, should be finished.

104. To provide sufficient storage to ensure a continuous flow of 130 cusecs, and thus utilize the whole run-off of the minimum year, both of the above Porthumund and Makurti dams and the Sandy nalla one have to be constructed. An aqueduct from the Sandy nalla Reservoir communicating with the Glen Morgan basin is also necessary. The total storage then available will be 2,400 million cubic feet.

105. At this stage it will probably be found feasible to develop another power project, and return to Pykara at a later date, when the maximum capacity might be developed.

106. The writer has not yet investigated the Moyar Project in the field, but, assuming that it is a practical scheme, the Pykara-Moyar combination would appear to give an ultimate capacity of 107,000 horse-power or 80,000 K.W.

107. The hydraulic development, by stages, might be conveniently set out as follows :—

Table 15—Hydraulic development by stages.

Stages.	Continuous power.		Peak Load	
	K.W.	Cusecs.	K.W.	cusecs.
First	5,200	26	22,500	112·5
Second	10,000	50	30,000	150
Third	15,000	75	30,000	150
Fourth	26,000	130	45,000	225
Fifth	30,000	150	60,000	300
Sixth (Moyar) ..	50,000	150	80,000	300

108. *Diversion dam (Pykara).*—This is to be of a design which has proved satisfactory under similar conditions elsewhere, and will ensure that the intake is kept clear at all water levels, and that the course of the river can be controlled.

109. *Pykara aqueduct.*—The intake will be redesigned, so that floods will affect it as little as possible. A section of the aqueduct will have to be lined, and a short tunnel driven, in order to make a safer flow line.

110. *Forebay.*—This is substantially as previously laid out. The water level and the earth bunds will, however, be 10 feet lower. The extra capacity is not needed, and the lower elevation will ensure a less costly basin ; it will also tend to reduce the seepage, although a certain amount is to be expected, owing to the nature of the ground.

111. *Headworks.*—This structure is to be of conventional design with gates and racks. The water will then be conveyed through a tunnel to the valve house and surge chamber. In the tunnel two 60″ riveted pipes will be laid to a header at the valve house. Only one 60″ pipe is necessary for the first few years.

112. *Penstocks.*—From the header two penstocks eventually four—will convey the water to the power house. They will be equipped with automatic butterfly valves and venturi meters. The capacity of each penstock will be 75 cusecs, the diameter varying from about 37″ to 26″, and the velocity from 10 to 20 feet per second. The profile of the penstock line is somewhat disappointing, involving a large number of bends, while the ratio of length to head is high. It is also unfortunate that the slope is more gradual when nearing the power house, where the thickest and most expensive pipes are to be laid. It is hoped to partially overcome these disadvantages by adopting a high velocity for the last few sections. This subject will be fully discussed later in the technical report. At the power house each line will feed two 7,500 K.W. units, while a selective feed, from either line, will furnish water for a spare unit. Alternative locations for the penstocks were considered, particularly with a view to obtaining a sharper gradient for the sections near the power house ; the original or Richard's line, however, still appears the best. Further investigations are being made.

113. *Power house.*—This has not yet been definitely located ; but the ground, in the vicinity of a possible site, has been cleared and exploration work can now proceed at a quicker rate. No difficulty is anticipated in finding a suitable site. The building will be a steel structure with masonry filling and concrete foundations.

114. *Power house equipment.*—Provision has been tentatively made for five (one spare) 7,500 K.W. generating units for the first ten years, to be followed by two 15,000 K.W. sets when the load warrants it. The generators would be wound for 11,000 volts and be capable of operating at 0·85 P.F. They would also be suitably designed for stability at high leading currents, and be equipped with special excitation systems. On account of the small load demand during the first few years, it is necessary to have comparatively small units at first, otherwise the machines would be underloaded and be operating very inefficiently most of the time. In order to provide sufficient spare unit capacity economically, the size of the machines must also be limited. In this connexion it should be remembered that the load, at certain hours of the night, during the first two years of operation, may be less than 1,000 K.W., and a large generator operating under these conditions will always tend to instability. On the other hand, for such an extensive transmission system, the units must be as large as possible, in order to take care of the charging K.V.A. It is considered that 7,500 K.W. is a compromise, and will be more suitable for the earlier stages, and 15,000 K.W. when the scheme has reached a more advanced stage of development. The power house lay-out on which estimates are worked out is shown in chart P-7-F1.

115. *Transformers.*—These will be three phase units, installed outside with H. T. circuit breakers. A suitable steel structure for mounting the H. T. bus bars and disconnecting switches will be erected.

116. *Permanent buildings, transport and power.*—It is proposed to locate the buildings near the forebay and at the head of the falls. Three small houses may be constructed near the power house, for temporary occupation as occasion demands, but the staff will ordinarily live near the headworks. The estimate is based on buildings which have been found necessary

on similar projects elsewhere. It is proposed, however, to enlist the assistance of the Department of Roads and Buildings to draw up final plans and estimates for the houses. The questions of transportation and power for construction purposes have also been studied, and will be discussed in a future report.

TRANSMISSION SYSTEM.

117. *Voltage.*—110 K.V. has been adopted for the main transmission voltage. The load, for the first few years may not appear to warrant such a high voltage, but the distances are great enough to require very heavy conductors at a lower voltage. For the branch lines, 66 K.V. has been chosen and 11 K.V. for the feeders. The towers on the 110 K.V. lines between Pykara and Coimbatore may be designed for 132 K.V. It is fully expected that it will be found economical, after Pykara has been operating some years, to change the voltage of part of the system to 132 K.V. It is also highly probable that Madras and the Malabar coasts will eventually be connected to the H.T. system. Sketch No. P-2-F₂ shows how the transmission system should develop in a few years and also indicates the present or minimum programme.

118. *Routes.*—The routes of the lines which are to be constructed in the immediate future are substantially the same as described in other reports. A reconnaisance survey did not indicate that those routes could be improved upon. The Madras lines, when constructed, will probably go along Moyar valley to Satyamangalam, and thence to Salem and Madras.

119. *Regulation.*—This will be fully discussed in the Technical Report, but reactances will not be necessary at the power house, and it is doubtful if synchronous condensers will be needed at the outset. The estimates have, however, allowed for one 5,000 K V A. condenser unit.

Substations.

120. These have been tentatively decided on at the following places:—

Coimbatore.	Trichinopoly.	Tiruppur.
Dindigul.	Pollachi.	Erode.
Madura.		

121. Coimbatore and Dindigul will be the only 110 K.V. substations and will transform down to 66 K.V. and 11 K.V. Secondary transmission lines at 66 K.V. and distribution feeders at 11 K.V. will radiate from these stations. Coimbatore is also to be equipped as a H.T. sectionalizing station, while all necessary condenser capacity will be installed at Dindigul for some years to come. The remaining stations will serve the railways at 66 K.V. and transform down to 11 K.V. for local distribution.

122. The Nilgiri district may be fed for some time by 11 K.V. feeders from the Pykara power house, unless the Government Cordite Factory decides to take a substantial block of power. To ensure continuity of service it is highly desirable that the main transmission lines be tapped as little as possible, and then only at large load centres.

123. Efforts are to be made to standardise where possible on transformer sizes, so that the cost of spare units can be kept low.

The estimates have provided for all 110 K.V. units to be of 3,000 K.V.A. capacity. The 66 K.V./11 K.V. units will, however, be in three sizes, 3,000 K.V.A., 1,000 K.V.A. and 500 K.V.A. Certain distribution feeders have been included in the estimates, but it is expected that much of this work will be undertaken by the local power syndicates, with or without Government assistance.

124. The preliminary estimates are given in more detail at the end of the report (Tables 16, 17 and 18) and as mentioned before, the final estimates and designs will not be ready for some time.

125. It will be noted that the contractors' fee of $12\frac{1}{2}$ per cent has been included. If the work is not done by contract, it is quite possible that the general expense account would have to be increased by this amount. Certain additions would have to be made in any case to all items which include machinery and equipment purchased abroad, in order to cover purchasing fees and inspection charges.

126. The contractors' fee includes all expenses in connexion with purchases and inspection, general administration, legal and engineering charges, also the working plans and drawings, from Government designs and specifications.

127. The main items included under local general expenses may be cited as follows:—

Transportation.
Construction Power costs.
Light and Telephone service.
Engineering.
Temporary camp expenses.
Special and Travelling allowances.
Office expenses (Time-keeping, costs, audit, etc.)
General Administration charges.
Insurance, Taxes, Hospital, etc., etc.

128. It may probably be found convenient to devise, with the co-operation of the Accountant-General, a new system of construction accounting.

129. *Construction programme.*—If the scheme is tentatively approved, and while the final surveys are being carried out and the plans and estimates drawn up, negotiations may be started with the Nilgiri Power Syndicate, and the South Indian Railway with an idea of coming to a provisional agreement regarding the future supply of power. Communications with the Power Securities Corporation may also be established.

130. In the field, a start must be made on the buildings and roads, the acquisition of lands, the provisional power-supply, temporary camp, water-supply, etc., while orders for machinery, construction tools and equipment will be placed, subject to the final approval of the scheme.

131. If official sanction to the scheme is obtained by July 1928, it will probably be another year before all the preliminary work can be completed, and serious construction work started. This being the case, the plant should be in operation by August 1931. Care must be taken that no part of the work is unduly rushed, and costly structures or installations allowed to stand idle for any length of time, due to some other part of the works not being ready. This only piles up the interest charges, and makes a more costly job in the end. A detailed construction schedule will be compiled after consultation with the Railway Engineers and Power Securities Corporation, and once approved, it must be strictly adhered to.

132. At this stage, it would be somewhat premature to make any recommendations as to whether the hydraulic works should be constructed by the Hydro-Electric Department or by contract.

133. Owing to the agreement with the Power Securities Corporation, the power plant, transmission lines and sub-stations must be constructed by them, and the writer has satisfied himself that this Corporation possesses the facilities for undertaking the work satisfactorily.

134. The Hydro-Electric Department will, in any case, undertake much of the preliminary work, draw up the plans, specifications, and estimates for the whole scheme, and carry out the usual inspection work.

TABLE 16.

Estimates for Hydraulic Works.

Year	1st	3rd	6th	
Installed capacity K.W.	22,500	22,500	30,000	When needed.
Continuous K.W.	5,200	10,000	15,000	
	RS.	RS.	RS.	RS.
Parson's Valley dam, 250 m.c.ft.	..	6,50,000	..	..
Porthimund River dam, 450 m.c.ft.	..	..	10,00,000	..
Makurti ,, ,, 1,050 ,, ...	..	..	..	20,00,000*
Sandy nalla ,, ,, 450 ,, ...	..	..	..	15,00,000*
Pykara ,, ,, 1,200 ,, ...	..	..	..	34,00,000*
Diverting dam and intake	2,[illegible]0,000	..	..	..
Flume	2,47,000	..	..	..
Upper dam at forebay	1,26,000	..	..	..
Glen Morgan dam and flume	5,80,000	..	..	..
Lower dam at forebay	1,90,000	..	..	..
Spillway	[illegible]0,000	..	..	..
Headworks and Penstock tunnel	1,50,000	..	..	..
Permanent buildings and services	7,00,000	..	..	..
Sub-total ..	20,73,000	6,50,000	10,00,000	
Contingencies, 5 per cent	1,03,700	32,500	50,000	..
Construction plant and tools	4,10,000	50,000	50,000	..
Temporary camp	2,50,000	60,000	60,000	..
Local general expenses	3,81,000	1,58,500	2,32,000	..
Sub-total ..	32,17,700	9,51,000	13,92,000	
Contractors commission, $12\frac{1}{2}$ per cent	4,02,200			..
Sub-total ..	36,19,900	9,51,000	13,92,000	
Auxiliary power scheme	4,32,800	..	..	..
Roads and bridges	6,50,000	50,000	50,000	
Land and preliminary work	3,00,000	50,000	50,000	..
Sub-total ..	50,02,700	10,51,000	14,92,000	
Interest at 5 per cent	5,80,000	1,31,400	1,86,500	..
Grand total ..	55,82,700	11,82,100	16,78,500	69,00,000

* Estimated total cost.

TABLE 17.

Estimates for Pen-stocks and Power-house.

Year	1st	4th	9th	When needed.	
Installed capacity K.W.	22,500	30,000	37,500	52,500	67,500
Continuous K.W.	5,200	10,000	15,000	26,000	30,000
	RS.	RS.	RS.	RS.	RS.
Pen-stocks	22,80,000	..	..	14,00,000	11,00,000
Incline Railway	1,60,000	..	..	..	..
Building and Tail race	4,00,000	2,00,000	1,00,000	2,00,000	2,00,000
Turbines and Governors	3,56,000	1,30,000	1,20,000	1,41,000	1,11,000
Generators and Exciters	4,23,000	1,15,000	1,35,000	2,31,000	2,31,000
L.T. Switchgear and accessories ..	1,25,000	40,000	40,000	46,500	46,500
Auxiliaries and feeders	1,20,000	25,000	25,000	29,600	29,600
Crane, piping, repair shop, etc. ..	1,30,000	30,000	30,000	30,000	30,000
H. T. Switchgear and accessories ..	2,95,000	55,000	55,000	89,800	89,800
Transformers	2,25,000	85,000	85,000	1,29,000	1,29,000
Outdoor structure	87,000	15,000	15,000	16,500	16,500
Contingencies—5 per cent	2,31,000	36,300	30,300	1,16,700	1,06,700
Sub-total ..	48,32,000	7,61,300	6,35,300	24,50,100	21,20,100
Construction plant and tools	2,00,000	50,000	50,000	75,000	75,000
Temporary camp	1,00,000	25,000	25,000	40,000	40,000
Local general expenses	5,02,000	1,20,000	1,00,000	2,50,000	2,50,000
Sub-total ..	56,34,000	9,56,300	8,10,300	28,15,000	24,85,100
Contractors' commission 12½ per cent ..	7,04,300	1,19,600	1,01,300	3,52,000	3,10,600
Total ..	63,38,300	10,75,900	9,11,600	31,67,000	27,95,700
Interest at 5 per cent	7,30,000	76,300	63,100	2,11,000	1,89,800
Total ..	70,68,300	11,52,200	9,74,700	33,78,000	29,85,500

Note.—1. The machinery would be capable of a 15 per cent continuous overload and 25 per cent for two hours.

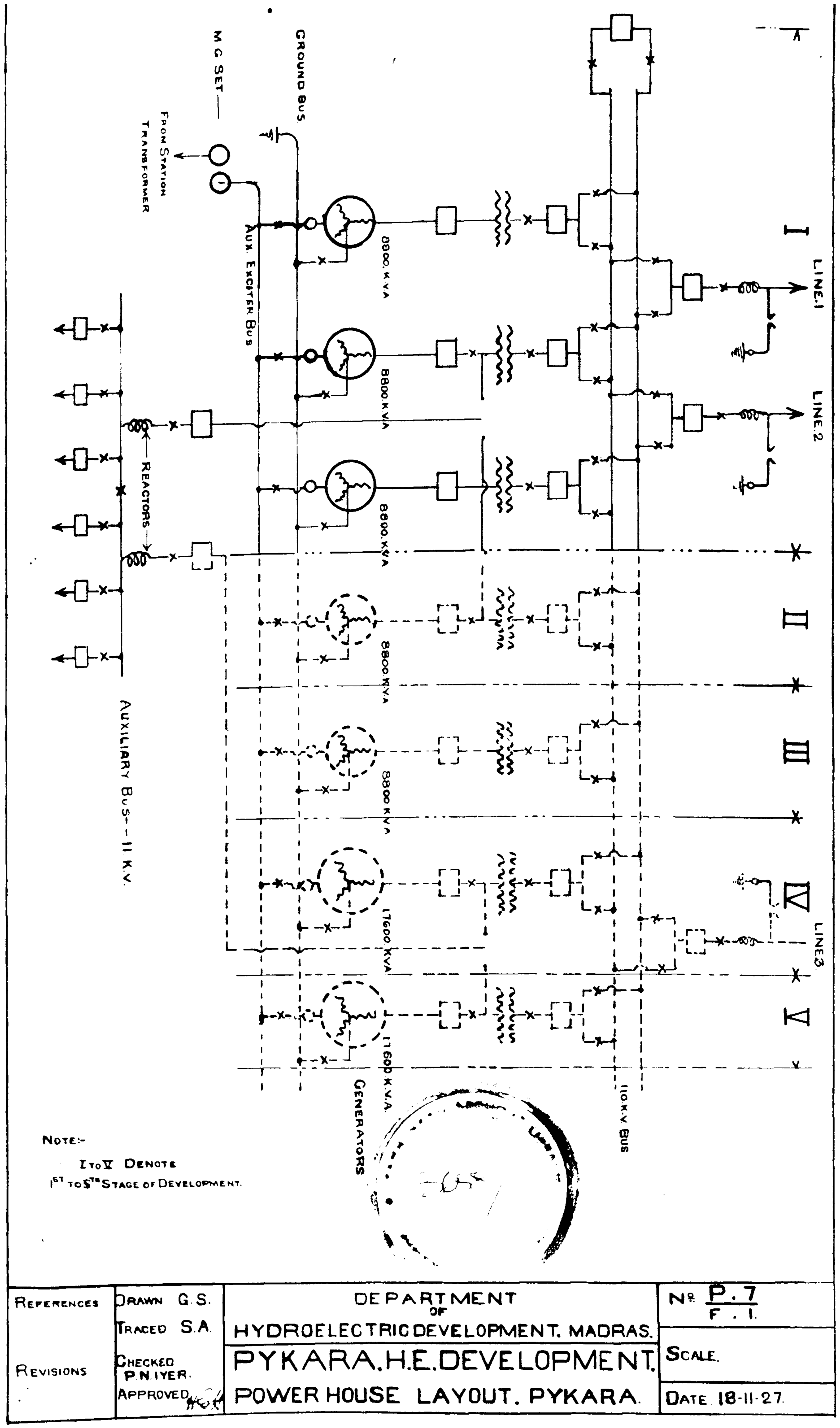
2. The cost of the Moyar scheme for 20,000 K.W. has been tentatively estimated at Rs. 60,00,000.

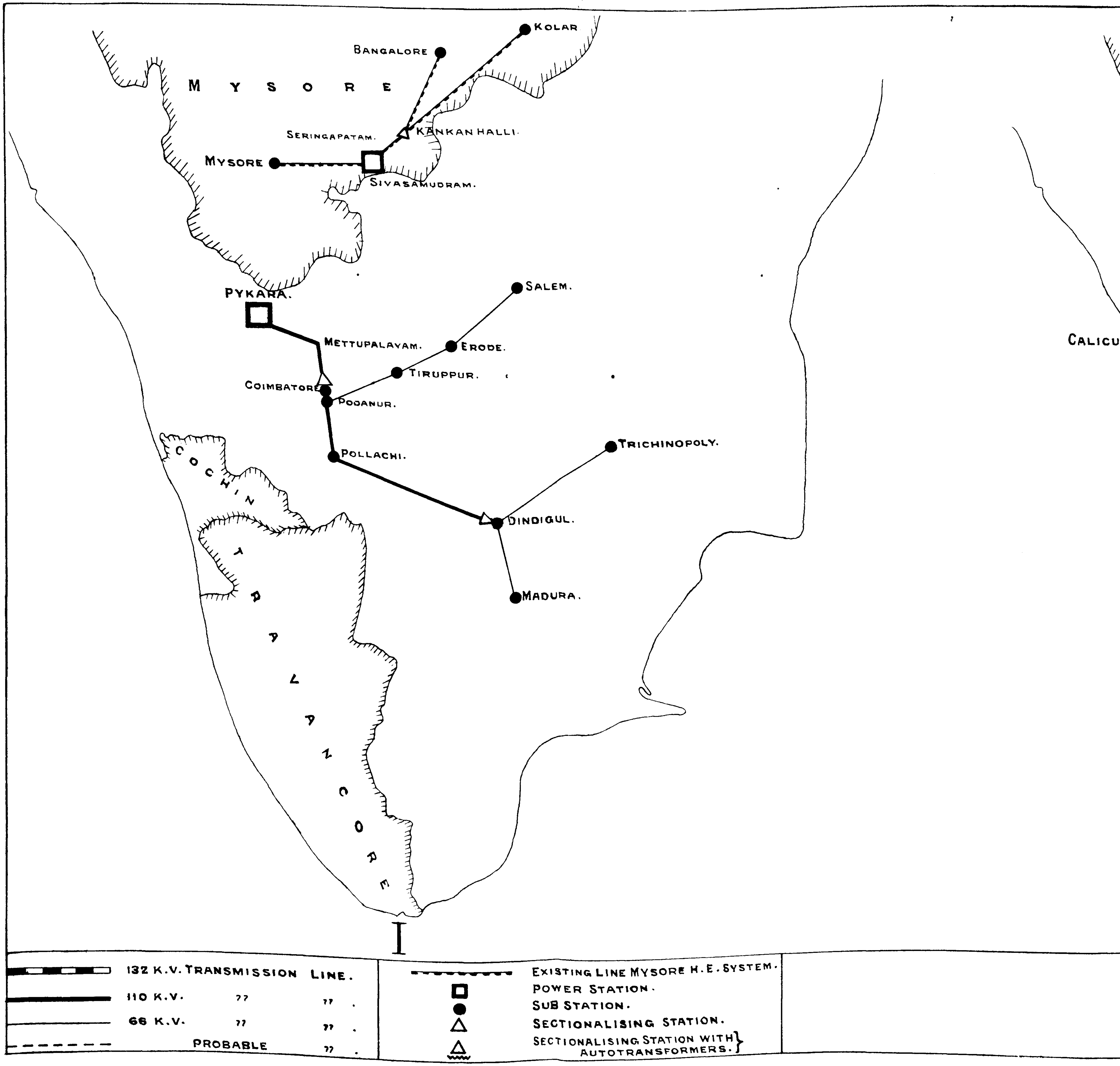
TABLE 18.

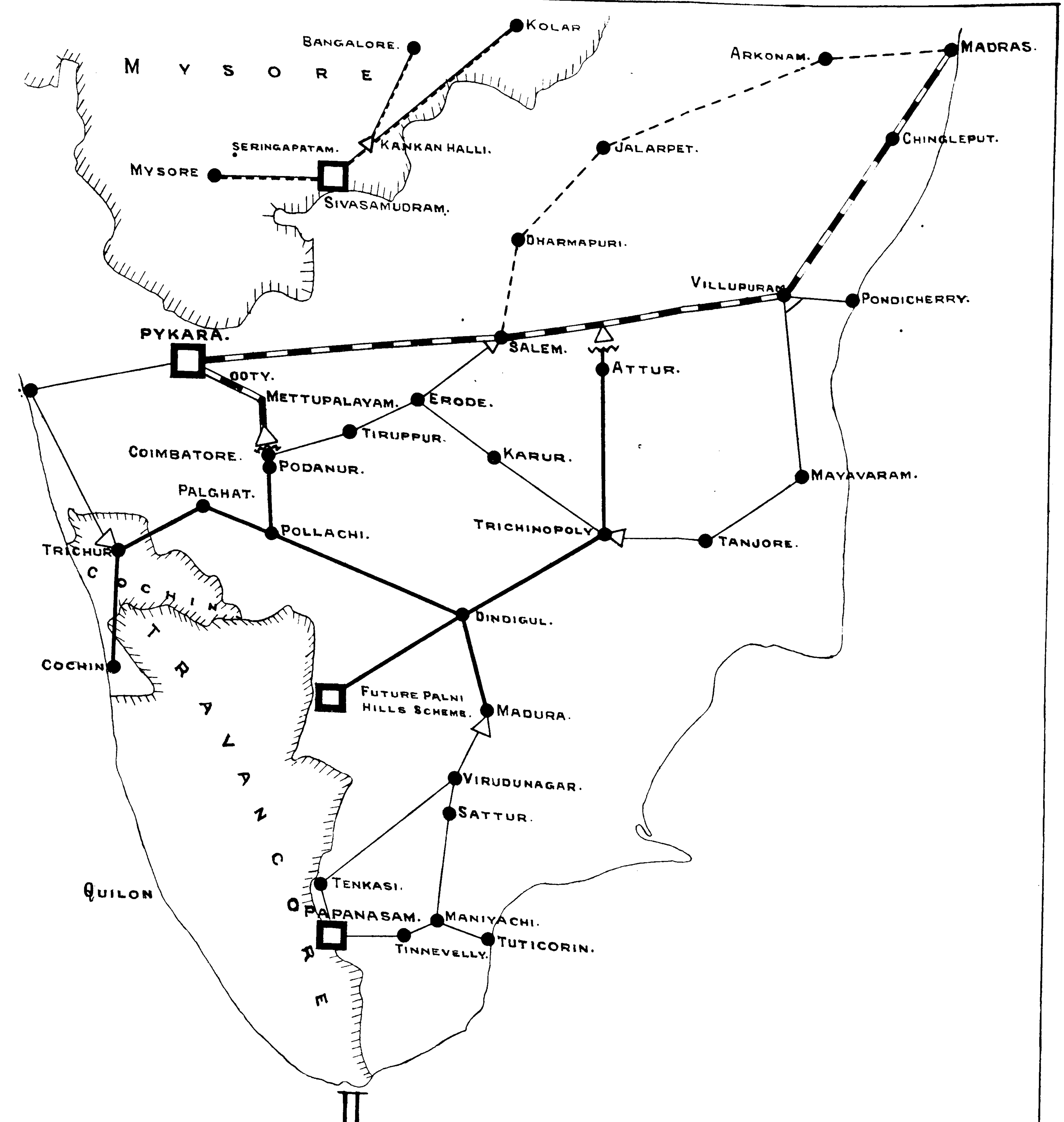
Estimates for Transmission lines, Sub-stations and Distribution lines.

Year.	1	2	3	4	5	6	8	After the tenth.
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.
Transmission lines.	93,58,000	6,77,300	15,63,600	..	2,75,700	..	2,75,700	1,89,42,000
Sub-stations and bulk supply connections.	15,40,000	5,09,000	3,16,000	5,68,000	2,27,000	3,72,000	5,17,000	25,65,000
Total ..	1,08,98,000	11,86,300	18,79,600	5,68,000	5,02,700	3,72,000	7,92,700	2,15,07,000

Note.—It is assumed that most of the distribution lines and feeders will be constructed by distributing bodies. If undertaken by Government the increased rate for the smaller blocks of power should cover the cost of local development.




MYSORE
KOLAR
BANGALORE
SERINGAPATAM.
KANKAN HALLI.
MYSORE
SIVASAMUDRAM.
PYKARA.
SALEM.
METTUPALAYAM.
ERODE.
TIRUPPUR.
COIMBATORE
PODANUR.
POLLACHI.
TRICHINOPOLY.
DINDIGUL.
MADURA.
COCHIN
TRAVANCORE
CALICU
132 K.V. TRANSMISSION LINE.
110 K.V. " " .
66 K.V. " " .
PROBABLE " .
EXISTING LINE MYSORE H.E. SYSTEM.
POWER STATION.
SUB STATION.
SECTIONALISING STATION.
SECTIONALISING STATION WITH AUTOTRANSFORMERS.



I SHOWS FIRST STAGE OF DEVELOPMENT.	REFERENCES	DRAWN. G.S. TRACED. P. PARAMASIVA	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS.	Nº. P.2. F.3.	
II POSSIBLE FUTURE DEVELOPMENT.	REVISIONS.	CHECKED. P.N. IYER	HYDRO-ELECTRIC POWER SYSTEM.	SCALE 1" = 32 MILES.	
		APPROVED.	SOUTHERN AREA – MADRAS PRESIDENCY.	DATE. 17-11-1927.	