

BOMBAY ELECTRIC GRID



REPORT

ON THE

HYDRO ELECTRIC RESOURCES

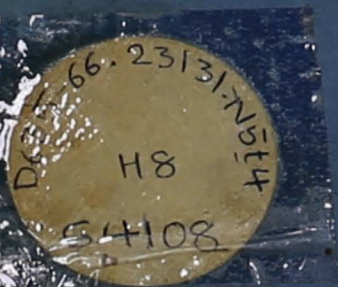
OF THE

KALINADI BASIN

BOMBAY PRESIDENCY

BY

ASSOCIATED CONSULTING ENGINEERS (INDIA)

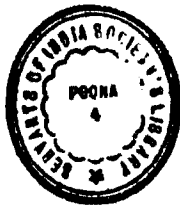


DECEMBER, 1948.

BOMBAY & LONDON



NAGJHRI PIPE-LINE & POWER STATION



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Hydro-Electric Resources
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KALINADI RIVER BASIN

TABLE OF CONTENTS.

	<u>Page.</u>
<u>Covering Report.</u>	1 - 18
<u>Engineering Report.</u>	1
Chapter I. - General Description of the Kalinadi River Basin.	1
II. - Geology.	4
III. - Site Investigations.	10
IV. - Hydrology.	12
V. - Storage.	23
VI. - Scheme of Development.	31
VII. - Method of Operation.	46
VIII. - Development in Stages.	54
IX. - Communications.	61
X. - Types and Outputs of Turbines.	66
XI. - General Description of Electrical and Mechanical Works.	71
XII. - Local Interconnecting Transmission System.	74
XIII. - Estimated Cost of Project.	78
XIV. - Annual Cost of Operation.	82
XV. - Cost of Energy.	84
XVI. - Effect on Local Economy.	86

KALINADI REPORT.

APPENDICES.

- No.
- I Boring Programme - Summary of Results.
 - II Rainfall Statistics - Sources of Information.
 - III Silt Sampling - Summary of Tests made.
 - IV Annual Cost of H. E. Schemes.
 - V Explanatory Memorandum on the Cost Estimates.
 - VI Variation of Cost of Energy with Load Factor.
 - VII Bibliography.

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31st December, 1948.

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Electrical Commissioner
with the Government of Bombay,
Bombay Electric Grid,
Bombay.

Dear Sir,

HYDRO-ELECTRIC RESOURCES
of the
KALINADI RIVER BASIN

1. We refer to your letter of the 11th January, 1947, No. Elg. 12-A/251, in which you instructed us to prepare a Report on the hydro-electric resources of the Kalinadi river basin.
2. Our Terms of Reference were embodied in our letter to you of 16th December, 1946 and in your letter to us of 11th January, 1947. Briefly, we undertook to :-
 - (a) Examine and correlate all existing data relating to rainfall, runoff and available power, and to study similar data from other catchment areas where climatological conditions possessed characteristics in common with those of the areas under examination.
 - (b) Collect and examine any additional data considered necessary for the formulation of reliable estimates of available power.

- (c) Prepare economic studies of alternative storage sites based upon the cost of constructing reservoirs and a consideration of the varying flow of the streams at different seasons of the year.
- (d) Study alternative methods of utilising the power resources of the area and the extent to which development could be justified on economic grounds.
- (e) Prepare a general scheme of development together with plans and drawings showing the location of the proposed works, the areas to be flooded by the reservoirs and such other information as might be necessary to a proper appreciation of the scheme.
- (f) Study the designs of the proposed works, prepare estimates of the cost of carrying out the scheme of development and submit recommendations as to the stages in which the works should be executed in order to meet an expanding demand for electric power.
- (g) Study the plant capacities which should be installed in the various power stations forming part of the ultimate scheme of development.
- (h) Prepare estimates of the annual operating charges and total cost of producing power at various load factors.

3. In considering the utilisation of the power resources of the area we were not required to take account of the possible needs of irrigation or the use to which the power could be put; nor were we required to deal with

the problem of electrical transmission. While passing reference has been made to the effect of our proposals on the general economy of the district and to the necessity for improvements in communications, we have, in the main, confined ourselves to the engineering problems arising from the exploitation of the area as a source of power.

4. In examining the matters which have been referred to us, we have had the advantage of studying the plans and records relating to the early investigations of the area which were made by Mr. P. L. Bowers in 1921. After studying these plans, which were placed at our disposal by your Department, we formed the opinion that the ultimate power resources of the Kalinadi river basin were much greater than had hitherto been appreciated. We pointed out that the partial development proposed by Mr. Bowers was without doubt conceived against a background of industrial development materially different from that obtaining to-day. We therefore suggested that before attempting to reach any decision as to how immediate power requirements might be met, a complete re-examination of the whole area drained by the Kalinadi and its tributaries should be undertaken. In making this suggestion we were conscious of the importance of planning the development of the regional resources as a co-ordinated whole, as opposed to piece-meal development: and we pointed out that it was only by taking such a broad view that it would be possible to ensure orderly development and the avoidance of the wasteful expenditure which must inevitably arise from an attempt to satisfy immediate needs without an overall plan.

5. On receipt of your instructions to prepare a Report we took immediate steps to organise the site investigations. Our survey party established themselves in the field on February 11th, 1947 and, except for one member who remained behind to supervise the boring work, the party was withdrawn on May 28th shortly before the anticipated break of the monsoon.

Before going on to describe the results of our investigations and the conclusions reached, it will be appropriate if we give a brief account of the work undertaken in the field. The latter may be conveniently considered under the following headings :-

- (a) Topographical surveys.
- (b) Hydrological surveys.
- (c) Geological surveys.

6. Since the majority of the available maps of the district were uncountoured and generally unsuitable for our purposes, we arranged for the Survey of India to take aerial photographs of the whole area to be covered by our investigations - some 1,650 sq. miles. As it was known that the Department was heavily loaded with urgent air survey work on behalf of other Government Departments you very kindly offered to secure special priority for the Kalinadi work and, by accepting countoured mosaics in place of finished countoured maps, it was hoped that the necessary aerial surveys would be in our hands by September, 1947. The air photography was completed expeditiously in February 1947, but unfortunately, the increasing pressure of high priority work and the limited resources of the Air Survey Department resulted in serious delays in the production of the countoured mosaics and it was not until August, 1948 that the last of these mosaics was made available to us.

7. Concurrently with the air survey work we undertook the detailed surveys of the sites selected for certain of the dams and other important structures. These surveys were made by our field party using conventional methods and were afterwards used to supplement the information obtained by aerial photography. The work covered by the ground surveys related mainly to the sites proposed for the Supa dam, the Bomanhalli diversion weir and a number of alternative sites for the Kaneri dam.

8. As a result of the investigations initiated by Mr. Bowers a number of measurements of the discharge of the Kalinadi river were made at intervals between February 1921 and July 1932. Apart from some of the early dry weather gaugings at Kheda, the measurements were made by surface float, and the records have unfortunately been left in a somewhat fragmentary state. For this reason they have proved of only limited value, and in estimating the available runoff we have been guided to a large extent by experience gained from other catchment areas in the Western Ghats from which more complete records are available: due allowance being made for differences in geological, climatological and other factors.

During the course of our investigations in 1947 we took steps to establish water level gauges on the Kalinadi and one of its tributaries, the Kaneri. These gauges were in use before the commencement of the monsoon and continuous water level observations have been maintained ever since. The records so obtained have since been related to actual runoff by a series of river gauging operations undertaken during the 1948 monsoon. The results

of these gaugings have been embodied in a separate Report which has already been submitted to you. They provide ample confirmation of the validity of the indirect methods of computation which we had previously adopted in estimating the runoff.

9. Since the geology of the district had not previously been studied we considered it essential to supplement our surface examination by a number of trial borings. The extent of this work was restricted to certain of the sites selected for some of the principal dams and tunnels and was directed to obtaining sufficient information with regard to the character of the rock to satisfy ourselves as to the general practicability of the sites for the proposed works. The work was entrusted to a firm of boring contractors who commenced operations on site towards the end of May 1947. Boring work was carried on during the ensuing monsoon and the limited programme undertaken was completed early in 1948.

10. In addition to the work described above we considered it advisable, having in mind the very important and extensive character of the project, to seek an independent opinion on certain of the principal sites from the Geological Survey of India. With your approval we accordingly arranged for Dr. J. B. Auden, Superintendent of the Engineering Geology Department, to inspect some of the sites which had been selected. Dr. Auden submitted his Report in April, 1947. Subsequently, after the completion of some of the preliminary boring work we arranged for a further visit to be paid by a member of the India Geological Survey, Dr. B. C. Roy, Superintending Geologist, Western

Circle, who submitted his Report in June 1948. Since you are already in possession of copies of both these Reports we need not refer to them in detail but an appreciation of the general geology of the area and of certain of the sites selected will be found in the Engineering Report which is attached hereto.

11. When in the summer of 1947 it became apparent that the continued postponement of the production of the contoured mosaics would seriously delay the issue of our Report, we undertook the preparation of an Interim Report for the purpose of affording you advance information on the potential resources of the area. This Interim Report, which was necessarily based on incomplete topographical information, was issued in August 1947, and it will be found that the more detailed proposals now submitted follow very closely those which we outlined more than a year ago.

Amongst the numerous schemes examined during the course of our investigations were independent developments on the Tattihalla and the Baginkatte rivers. Detailed study, however, disclosed that none of these schemes were attractive, mainly owing to the impossibility of obtaining satisfactory and economical reservoir sites. They have therefore been discarded and no separate developments on these rivers have been incorporated as part of our proposals. Special attention was also given to the possibility of developing a large block of power by diverting the river by means of a tunnel driven through the escarpment overlooking the coastal plain. We found, however, that it was possible to secure much greater use of the potential resources of the Kalinadi by developing the river in a series of stages, and it is this broad principle which forms the basis of the scheme described hereafter.

12. The principal factors affecting the development of power from the Kalinadi River basin are discussed in detail in the attached Engineering Report and supporting Appendices. Here, for your convenience, we set out a summary of the conclusions we have reached as a result of our studies.

- I. The potential water power represented by the high monsoon rainfall which obtains over the greater part of the catchment area, taken in conjunction with the difference in elevation between the plateau and the coastal plain, is theoretically very great.
- II. The total rainfall varies considerably from year to year, the minimum recorded by the gauge which has been maintained at Supa over a period of 71 years being only 55.5 per cent. of the annual average, while the maximum recorded over the same period represents 168 per cent. of the average. Variations in the annual runoff may be expected to be even wider than those recorded in the annual rainfall although not necessarily wider than the variations recorded by an individual rain gauge station.
- III. Over 90 per cent. of the annual runoff takes place in 25 per cent. of the year and since the area is devoid of natural lakes or extensive underground storage the flow of the Kalinadi and its tributaries is subject to very wide variations, the discharge of some of the lesser tributaries falling to negligible values during the dry weather. The efficient use of the potential water power resources represented by the features referred

to in I. above is therefore dependent upon the possibility of creating a large reservoir capable of storing the heavy monsoon runoff for use during the dry weather.

- IV. A favourable site for such a reservoir is to be found in the neighbourhood of the village of Supa where the broad valley contracts to a narrow gorge permitting the economical construction of a high dam and the creation of a reservoir of sufficient magnitude to store more than one year's runoff from a catchment area of 400 sq. miles.
- V. It is proposed that this reservoir, which would cover an area of 46 sq. miles should have a maximum elevation above sea level of 1,825 ft., such a reservoir would be amongst the largest in India and would provide a gross storage of 128,000 million cu. ft., sufficient to afford in an average year, a steady regulated flow of 2,855 cusecs.
- VI. The Supa reservoir provides the key to the ultimate development of the water power resources of the whole of the Kalinadi River basin. That these resources are impressive may be judged from the fact that they are capable of producing even in the driest year some 30 per cent. more electrical energy than was generated by all the hydro-electric power stations in the whole of the Indian Dominion in 1947, the last year for which returns are available.

VII. The general scheme of development proposed is shown on the accompanying key plan, Figure No. 1, while Figure No. 2 shows a schematic diagram indicating the relationship between the various sections of the scheme. A flow diagram is also attached indicating how it is proposed to deal with the available water, the flow available for power production in an average year, and the estimated spillage and other losses.

VIII. The complete development is based upon the construction of four separate power stations, of which three, those built at Supa, Nagjhiri and the Lower Kalinadi, are in series on the main river. The fourth station utilises an independent catchment area, the Kaneri, the waters of which subsequently join the Kalinadi and thence pass through the Lower Kalinadi station. The four stations taken together will be capable of producing in a dry year 2,840 million kilowatt-hours of firm power, equivalent to a continuous output of 325,000 kilowatts. In a year of average rainfall the output will exceed this figure by about 26 per cent.

IX. The total amount of generating capacity to be ultimately installed will be governed by the use to which the power will be put and the manner in which the Kalinadi Group of stations will be interconnected to present and future sources of power, both hydro and thermal. While some flexibility in planning is afforded by the fact that the execution of the scheme

can be carried out in stages, it is very desirable, before determining the total amount of plant to be provided in any one of the four power stations, that some attempt should be made to decide the role to be ultimately assumed by the Kalinadi Group in the general build up of the power supply industry, not only in the Bombay Presidency itself but also in adjacent territories.

- X. In order to present the estimates in as complete a form as possible we have had to make some assumptions with regard to the annual load factor on which the Group will ultimately operate. For this purpose we have assumed that, based upon the firm output available in a dry year, the annual load factor will be 60 per cent., corresponding to an effective plant capacity of 540,000 kilowatts. The estimates which accompany the Report have been worked out on this basis.

As a further guide we have made estimates based on assumed annual load factors of 40 per cent. and 80 per cent. respectively.

- XI. On the assumption that the greater part of the output of the Kalinadi Group will be transmitted to distant load centres, we recommend that the power from the individual stations should be collected at one central point by a local 110 kV. transmission system. At this central point the energy would be transformed to the voltage required for long distance transmission, and the accompanying estimates include the cost of the

necessary step up transformers and associated switchgear which we have assumed would operate at 220 kV. If the whole of the output from the Group were dealt with in this way the net output available in a dry year at the 220 kV. busbars would be 2,800 million kilowatt-hours.

- XII. After making reasonable allowances for reserve plant we consider that a maximum demand of 540,000 kilowatts could normally be sustained by a total plant installation of 590,000 kilowatts. We have estimated that at present day prices the total cost of the Kalinadi scheme, based upon a plant installation of 590,000 kilowatts, would be Rs. 39.28 crores - corresponding to an annual cost of Rs. 226.98 lakhs.

From this it follows that at an annual load factor of 60 per cent. the firm output from the Group would be available at the 220 kV. busbars at a total cost of 0.130 annas per kilowatt-hour.

The corresponding costs at the alternative annual load factors referred to under X. above would be as follows :-

40 per cent. load factor 0.163 annas per kilowatt-hour.

80 per cent. load factor 0.117 annas per kilowatt-hour.

- XIII. In the year 1947 the total electrical energy generated from all sources in the Dominion of India amounted to 4,073 million kilowatt-hours, of which 2,194 million kilowatt-hours were produced by hydro-electric stations.

While it is true that electrical development in India has been artificially retarded in recent years as the result of the disturbed conditions in the world and the difficulties which have arisen in obtaining new capital equipment; it is evident that the absorption of a great block of new power on the scale represented by the Kalinadi development cannot take place very rapidly unless a major outlet can be found in new heavy power consuming industries. For this reason we have given special consideration to the possibility of providing for a gradual increase in the output of the Kalinadi scheme by carrying out the works in stages over a period of years.

- XIV. In the event of it being possible to foresee the rapid growth of a large scale demand, it is clear that the first stage of the works to be undertaken should be that associated with the creation of the Supa reservoir. The control of the main river flow which would thus be achieved would permit the Nagjhiri development to be carried out and would result in the production of a very large block of power at an exceptionally low cost. The next stage in the utilisation of the Kalinadi resources would logically be the lower Kalinadi section since it would benefit directly from the regulation already afforded by the Supa reservoir. Finally the independent Kaneri section would be put in hand.

XV. Should it be found difficult to justify the early execution of the very large Nagjhiri station the position is somewhat different. If it were anticipated that for some years it would prove difficult to dispose of an annual output much in excess of 500 million kilowatt-hours, two alternatives are possible :-

- (1) The Supa scheme followed by either the Kaneri or the Lower Kalinadi scheme.
- (2) The Kaneri scheme followed by the Supa scheme.

It will be seen that selection of the Supa scheme for initial development leaves two alternative courses open for the second limited stage. Selection of the Kaneri scheme, however, leaves no alternative but to follow with the Supa scheme when extension becomes necessary.

From the cost point of view there is little to choose between the two schemes but a final decision must await the results of further site investigations into the foundation conditions. While, therefore, we can merely indicate the existence of these alternatives without making a definite recommendation, we would say that on general grounds there are advantages in the selection of the Supa scheme as the first stage, particularly if it is thought that the demand for power might develop more rapidly than at present seems likely.

XVI. If the Supa scheme were to be selected as the first stage of development, the total capital expenditure, based upon an installation of 60,000 kilowatts would amount to Rs. 8.40 crores-equivalent to an annual cost of Rs. 47.76 lakhs. The firm output available from the Supa station would be 250 million kilowatt-hours at a cost of 0.305 annas per kilowatt-hour.

Alternatively, if the Kaneri scheme were to be selected as the first stage, the total capital expenditure would amount to Rs. 7.95 crores for a total plant installation of 75,000 kilowatts. The total annual charges on this expenditure would amount to Rs. 44.30 lakhs and, since the firm annual output has been estimated at 240 million kilowatt-hours, the cost would be 0.296 annas per kilowatt-hour.

It should be noted that the foregoing figures include, in both cases, the cost of transmission between the power station and the proposed collecting station at Nagjhiri, together with the cost of transformation to 220 kV. If, during the early years of development, the output from either of the power stations were transmitted at a lower voltage than 220 kV., the cost per kilowatt-hour sent out would be correspondingly reduced.

XVII. When the Supa and Kaneri schemes are combined, the total firm output will for reasons explained in the Engineering Report, exceed the sum of the individual outputs from the two power stations

when considered independently, and further benefits will be secured from the pooling of reserve plant. Thus, while the total capital expenditure on the combined Supa and Kaneri schemes will amount to Rs. 16.35 crores - equivalent to an annual cost of Rs. 92.06 lakhs - the total firm output will be increased to 540 million kilowatt-hours per year. The overall cost per kilowatt-hour will thus be reduced to 0.273 annas.

The combined power stations would be capable of meeting a firm maximum demand in excess of 100,000 kilowatts.

XVIII. It will be observed that the estimated costs of electrical energy as given above have in all cases been related to the firm output which would be available under the most unfavourable conditions following a seriously deficient monsoon. In a year of average rainfall we estimate, taking the Kalinadi scheme as a whole, that the output available would exceed this minimum by about 26 per cent. It would, however, be difficult to utilise such secondary energy unless the hydro stations forming the Kalinadi Group were interconnected either to thermal power stations or to other hydro stations in those parts of India where differences in climatic conditions would permit the benefits of diversity to be secured.

From studies we have made of the incidence of the south west monsoon in the Western Ghats, we have come to the conclusion that, at least so far as the Bombay Presidency is concerned, little

benefit to the Kalinadi scheme is likely to accrue from interconnection with other hydro-electric systems which depend for their water supply upon the south west monsoon. Bearing in mind the very great power potential represented by the many water power schemes now being studied along the western sea board of India, it seems unlikely that thermal power is destined to play a very important part in the development of the electric supply industry in the Bombay Presidency. Whilst, therefore, we have not entirely excluded the possibility that a use may be found for the very considerable secondary power which will normally be available from the Kalinadi scheme, we have attached no value to it in estimating the cost of the firm power output.

13. This concludes our brief summary of the work we have undertaken and the conclusions we have reached. A more complete discussion of our proposals will be found in the accompanying Engineering Report. We trust it will be found that we have dealt adequately with the matters which have been referred to us. Should you feel, however, that any further elaboration would assist you in coming to a decision as to the action which should be taken on our Report, we shall be very glad to furnish you with such additional information as may be within our power.

14. In conclusion, we would like to acknowledge the valuable assistance which we have received in connection with our site investigations, not only from the officers of your Department but also from local Government officers and representatives of the Forestry Department. We are also

- 18 -

greatly indebted to the Director of the Department of Agriculture who has provided us with valuable rainfall records, and to the officers of the Meteorological Department for the interpretation of the records which we have received from a variety of sources, including the Customs Department, and the Madras and Southern Mahratta Railway. In addition we have received valuable help from the Directors of the Tata Power Company who have placed their rainfall and other records at our disposal.

Yours faithfully,

For ASSOCIATED CONSULTING ENGINEERS (INDIA).

(Signed) R. L. Fitt
Bryan Donkin

ENGINEERING REPORT.

CHAPTER I.

GENERAL DESCRIPTION

of the

KALINADI RIVER BASIN.

1. The drainage basin of the Kalinadi river (see Figure No. 1) lies in the extreme south of the Bombay Presidency and covers a total area of some 1870 sq. miles. It takes the form of a broken plateau deeply dissected by river courses, particularly in the southern portion of the area which is traversed by deep gorges.

2. After rising on the escarpment of the Western Ghats the river first flows in an easterly direction for some 40 miles to Bomanhalli where it takes a south westerly course for a further 30 miles and finally swings round in a westerly direction and enters the Arabian Sea near the port of Karwar after having traversed a total distance of rather over 100 miles. The main tributaries of the Kalinadi are :-

- (a) The Pandri river draining 260 sq. miles of high ground in the north of the catchment area in the neighbourhood of Castle Rock and Londa. It joins the Kalinadi at Supa.
- (b) The Tattihalla river which drains 460 sq. miles on the eastern side of the catchment area and enters the main river 6 miles below Bomanhalli.

(c) The Kaneri river which drains 170 sq. miles of high ground lying to the south west within the main loop formed by the Kalinadi river. It joins the latter about 10 miles north east of Bogrigadde.

3. Except for the narrow corridor through the Western Ghats by which the river enters the sea, the Kalinadi basin lies to the east of the escarpment, being bounded on the north by the Pandri-Malprabha water shed; on the east by the water shed between the Tattihalla and Bedti rivers, the latter a tributary of the Gangavali; and on the south by the Kalinadi-Gangavali water shed.

4. The Kalinadi differs markedly from the majority of the rivers draining the plateau which falls away on the eastern side of the Ghat escarpment. Instead of continuing its eastern course and eventually flowing into the Bay of Bengal, the Kalinadi turns south and then west to flow into the Arabian Sea through a gap in the Western Ghats. It is this characteristic which makes possible the utilisation for power purposes a much greater proportion of the catchment area than would be the case if the river had continued its eastern course.

5. Except in the eastern districts the catchment area is thickly forested, mainly with teak and bamboo, and there is little cultivation except in the catchment of the Dogi river. A large part of the forest is reserved as a game sanctuary and is under the control of the Forestry Department which has in operation a long term programme of cutting and planting. Having regard to the control which is

- 3 -

already exercised through the Forestry Department, it may be assumed that appropriate steps will be taken to preserve the forest cover and prevent the heavy soil erosion which would at once arise if indiscriminate clearing were allowed to take place.

CHAPTER II.

G E O L O G Y.

Introduction.

1. The Kalinadi basin falls within a tract of country which has not been examined in detail by the Geological Survey of India. On the maps issued by the Department the area is coloured pink, signifying "unclassified crystalline gneiss etc.", a phrase covering all the Archaen formations, not only gneisses and granites, but the metamorphic schists of the Dharwar system, including mica-schists, hornblende-schists, phyllites, quartzites and limestone.

2. In view of the scanty information available, we communicated with Sir Lewis Fermor, late Director of the Indian Geological Survey Department, who had some years previously visited the regions lying both to the north and south of the tract occupied by the Kalinadi basin. Although not personally familiar with the tract in question, Sir Lewis was able, by deduction, to describe it as consisting of :-

"gneisses and granites, with bands of Dharwar schists, including limestone, quartzite and phyllite, and probably some mica-schist. These rocks are folded together and the regional strike is probably N.N.W., so that the rock bands must have this as their average strike, though there may be wide local variations. The dip of the sheets or beds of rock will often be steep, though in the crests of

anticlines and the troughs of synclines the dips will, of course, be gentle locally. Such beds or sheets of rock as exist will plunge to the deep and so continue until they are either brought up again by a fold or faulted out".

Subsequent examination of the region confirmed that this description gave a very fair general picture of the geological structure.

3. Bearing in mind the very great importance of a detailed knowledge of the geology, particularly in relation to the construction of storage dams and reservoirs, we arranged for Dr. J. B. Auden, Superintendent of the Engineering Geology Department, to inspect the more important sites. Dr. Auden's Report was submitted in April 1947 and was made prior to the commencement of the limited boring programme which is referred to in Chapter III. Later in February 1948, we arranged for Dr. B. C. Roy, Superintending Geologist, Western Circle, to pay a visit to the district to examine the results of some of the boring work and to inspect some of the sites which had not been covered by the earlier visit of Dr. Auden. Dr. Roy's Report was made in June 1948.

Regional Geology.

4. The projected works lie within the area occupied by the Dharwar metamorphic series of which the following are the main rock types :-

- (i) Banded Magnetite-Haematite-Quartzites.
- (ii) Hornblende-Schists.
- (iii) Banded Silicified rocks.

(iv) Mica-Schists and Phyllites.

(v) A calcareous suite of banded marmors
(fine - grain sugary marbles with
bands of calc-phyllite).

5. The area is in general covered by thick forest, and, except along the river section, the outcrops are not conspicuously developed. The thickness of the laterite varies considerably, many areas on the plateau showing outcrops of almost fresh rock while in other areas the laterite cover is thick.

The main features of the local geology of the more important sites are detailed below :-

Supa Dam.

6. The site of the dam lies at the upper end of a gorge which has been cut by the Kalinadi through a ridge running transversely across the line of the river in a north and south direction. The rocks in the vicinity are of igneous and metamorphic origin and are well cemented by processes of crystallisation. They are, except where weathered or open jointed, impermeable to water.

The river bed, which is clear of gravel deposits, is some 200 ft. wide and at low water exhibits extensive rock outcrops. For the most part, the rocks belong to the banded haematite-quartzite series (B.H.Q.) dipping in a downstream direction; although showing conspicuous joints the latter appear to be tight. A vertical dolerite dyke, about 55 ft. thick, crosses the river slightly obliquely to the dip of the B.H.Q. rocks but little distortion of the strata on either side is apparent. The sides of the gorge

rise steeply from the bed of the river at an angle of about 40° on the right bank and at about 50° on the left bank, frequent outcrops of weathered B.H.Q. rock being exposed on both flanks.

The site as a whole may be considered as reasonably satisfactory for the construction of a high dam of the magnitude contemplated, and it is unlikely that any serious trouble will be encountered in securing water tightness of the foundations in depth. It is considered that the depth of excavation necessary to reach sound rock in the river bed will not be great, although fairly heavy stripping of weathered and jointed rock will be necessary on the abutments. An extensive programme of cement grouting under pressure will have to be undertaken as an essential part of the work of preparing the dam foundations.

Bomanhalli Weir.

7. The rocks in the river bed consist of massive hornblende schists interbedded with phyllites, dipping at 50° to 65° . They are exposed over a distance of about $\frac{1}{4}$ mile along the river bed and offer a sound foundation for the spillway portion of the weir. On the left bank the rocks rise to a height of about 15 ft. above the river bed and are overlain by alluvium to a depth of 20 to 30 ft., bed rock being about 20 ft. below the proposed top water level of the Bomanhalli headpond. On the right bank there is a similar cover of alluvium although here the bed rock rises sharply to above top water level.

Nagjhiri Tunnel.

8. Over the greater part of its length the tunnel would pierce a suite of steeply dipping, highly foliated chlorite-phyllite rocks. Rock outcrops are to be seen at intervals along the tunnel alignment while test bores which have been put down indicate that the depth of laterisation is not great and is generally of the order of 20 ft. to 40 ft. Except near the intake end the cover over the tunnel would be considerable, generally varying between 200 and 400 ft. and the driving operations would, therefore, be carried out under favourable conditions, well below the zone of weathered rock.

Although the presence of faults, bands of clay or ankeritic limestone cannot be ruled out, it is not likely that serious troubles with water will be encountered during construction. On the other hand the line of the tunnel cuts across the general strike of the rocks at a small angle and this may lead to rather heavy over breakage.

Kaneri Dam.

9. At the site selected for the main dam (see Chapter VI) the river bed is about 60 ft. wide, the sides of the gorge rising steeply at angles of about 35° and 45° from the north and south banks respectively.

The rocks in the neighbourhood consist essentially of a series of banded haematite-quartzites, the bedding thickness varying from a few inches to several feet. At the site of the dam, rock is exposed over the river bed while the higher slopes are covered by talus, debris and soil creep with only occasional outcrops of weathered rock. The general dip of the rocks is in a downstream direction.

The depth of excavation required for the foundations over the river bed section is not likely to be great but on the flanks fairly heavy stripping of the overburden and weathered material will probably be necessary before sound rock is exposed. Since the local geological structure consists of compact and well cemented metamorphic rocks formed by a process of re-crystallisation it is not anticipated that serious difficulty will be encountered in securing a water tight reservoir. Proper precautions will have, however, to be taken by means of cement pressure grouting to seal up any open joints and fissures which may underlie the dam foundations.

Lower Kalinadi Dam.

10. The geological structure is generally similar to that already described for the Kaneri dam. Sound banded haematite-quartzite rocks are exposed at the bottom of the gorge and in the river bed, while weathered outcrops occur at higher levels on the flanks. The strike of the rocks runs obliquely across the axis of the gorge, the bedding planes dipping in an upstream direction at angles varying from 20° to 35°.

CHAPTER III.

SITE INVESTIGATIONS.

1. A general account of the site investigations has already been given in the Covering Report, and various aspects are also referred to in other sections of the Engineering Report. The boring programme remains to be described.
2. During Dr. Auden's visit to the site in March 1947 a tentative programme of preliminary boring was discussed, and arrangements for its execution were made. As a result a contract for the work was made on March 24th of that year with the firm of Alladin Virjee Nathani, Bombay. The Contractors reached the site at the end of May, and started work on percussion borings for locating the levels of rock at two alternative sites proposed for the Bomanhalli weir. This work continued during the monsoon until early September.
3. At the beginning of 1948 boring work was resumed, and a small amount of percussion drilling was undertaken on the suggested tunnel line between the Dandeli headpond and the Nagjhiri Power Station in order to establish the rock cover over the tunnel. At the same time a limited programme of core drilling was put in hand at the Supa dam site, to establish the feasibility of the suggested location. This core drilling while based on the programme suggested by Dr. Auden was not intended to do more than confirm the general conclusions previously arrived at by visual inspection. A further and much more extensive programme of drilling will be necessary before it will be possible to proceed with detailed designs.

- 11 -

The boring programme was completed in May 1948.
A summary of the results is set out in Appendix I.
attached to this Report.

CHAPTER IV.

H Y D R O L O G Y.

RAINFALL.

General Considerations.

1. The general pattern of rainfall distribution in the Kalinadi basin is determined by the incidence of the south west monsoon on the escarpment of the Western Ghats, and is extremely variable both as to location and time. To a small extent only the north east monsoon slightly affects the rainfall distribution, particularly over the eastern parts of the catchment.

The south west monsoon normally reaches the Kalinadi district towards the middle of June and persists until October, the maximum intensity usually occurring in July. Except for the effect of an occasional early arrival of the monsoon in May and its prolongation into November, the remainder of the year is generally dry with only an occasional shower of low intensity.

The monsoon rainfall increases steadily from the coast to the summit of the Ghat escarpment where it may reach locally an average of 300 inches per year. Beyond the summit the rainfall diminishes rapidly until, at the eastern limit of the catchment area, it does not average more than about 40 inches per year.

Distribution of Rainfall.

2. Figure No. 3 is an isohyetal map of the Kalinadi basin which we have prepared from a study of the rainfall statistics collected from a variety of sources. (see Appendix II.).

The statistical information has been submitted to the Deputy Director of Observatories, Poona, whose Department has prepared an independent isohyetal map. The latter has not been reproduced in this Report since comparison showed that there was little disparity between the two maps except in the southern part of the area where there is a difference of interpretation of the effect of the Kalinadi and Gangavali valleys. The latter, by cutting through the Ghats, break the mountain barrier presented to the south west monsoon by the escarpment and undoubtedly lead to a discontinuity in the isohyetal lines which, in general, run approximately north and south parallel to the coast. Unfortunately, the rainfall records covering the southern portion of the Kalinadi and Gangavali valleys are not sufficient to give a clear indication of the extent of this discontinuity and we have adopted our own interpretation as shown in Figure No. 3 since it leads to a more conservative estimate of the rainfall over the area with which we are concerned.

Variation of Annual rainfall.

3. The total rainfall in any single year is subject to wide fluctuation. Figure No. 4 shows the variation, expressed as a percentage of the mean over a long period, of the annual rainfall recorded at three selected rain gauges in or near the catchment. For the period covered by the records the maximum and minimum values of the annual rainfall are given in the following Table.

TABLE 1.

<u>Gauge.</u>	<u>Maximum.</u>	<u>Minimum.</u>
Castle Rock.	143.5 %	53.5 %
Supa.	168 %	55.5 %
Yellapur.	145 %	62 %

It will be observed from the diagram that in many years the rainfall, in terms of the average for the station, shows considerable diversity between the three gauges; a feature which is not uncommon in areas of intense rainfall. While it is not to be expected that the total rainfall over an area would show such extremes of variation as would be recorded by individual gauges, the irregular distribution of the heavy monsoon precipitation makes it difficult, in the absence of a large number of gauges, to evaluate accurately the overall diversity effect.

The annual rainfall records relating to Supa and Yellapur which cover the longest period are shown on Figure 5 in the form of a rainfall-duration curve. This curve gives the percentage of the years in which the annual rainfall is greater or less than any given percentage of the mean. It will be observed that in 50 per cent. of the years, the rainfall was within 10% of the long average for the whole period.

Variation of Monthly Rainfall.

4. The 71 year record of the Supa gauge has been used to produce a diagram (Figure No. 6, left hand side) showing the average rainfall in each month of the year. It will be seen that over 93 per cent. of the mean annual rainfall

occurs during the period June to October, the month of July alone accounting for about 40 per cent. of the years total. This diagram also shows the monthly rainfall for the driest recorded year, 1899, and for the wettest year, 1882, and indicates that although exceptions do occur, the monthly distribution of the rainfall is not greatly affected by variations in the annual total.

A second diagram (Figure No. 6, right hand side) shows the monthly distribution in two exceptional years, 1904 and 1918. In the first mentioned the monsoon arrived early although the total rainfall was not widely different from that for an average year. The year 1918 was one in which the monsoon was a failure, although rainfall of a relatively low intensity was distributed fairly evenly over a period of 7 months.

RUNOFF.

General Considerations.

5. River gauging operations on the Kalinadi and some of its tributaries were initiated by Mr. Bowers during his investigations in 1921 and were carried on at intervals until July 1932 when they were finally discontinued. The records which have been preserved relate to measurements made on the Kalinadi, at Kheda, about 2 miles upstream from Supa, and at Bomanhalli; in addition there are some records which cover gaugings on the river Pandri at Apeli taken during the years 1925, 1930 and 1931. Apart from a series of dry weather flows taken at Kheda prior to June 7th 1921, for which a V notch weir was employed, all measurements appear to have been made by means of surface floats and the discharges deduced from them must necessarily be accepted with caution.

6. In view of the uncertainty which must now surround these old and somewhat fragmentary records, we have attached great importance to studies of the runoff from other catchment areas in the Western Ghats and, particularly, the work carried out by Mr. (now Sir Claude) Inglis in association with Mr. A. J. De Souza, and published in 1930 by the Public Works Department of the Bombay Government - Technical Paper No. 30. We have also referred to the "Annual Reports of Supplies of Water Available for Irrigation", published up to 1926 by the Public Works Department of the Government of Bombay, and to the 1922 "Triennial Report of the Hydro-Electric Survey of India" by J. W. Meares. And we have had the advantage of consultations with Sir Claude Inglis in London.

7. The succession of coastal plain, steep escarpment and high level plateau gently falling away to the east persist throughout the Bombay Presidency and is everywhere under the influence of the south west monsoon. By making appropriate allowances for variations in geological structure, forest cover and other factors, the records relating to other rivers afford a logical basis on which to assess the runoff from the Kalinadi basin.

Relationship between Rainfall and Runoff.

8. An important part of Technical Paper No. 30 is devoted to a consideration of the relationship between annual rainfall and runoff from catchment areas in the Western Ghats. The authors show that in the majority of cases examined this relationship can be conveniently expressed by the simple straight line formula :-

$$\text{Runoff (Inches)} = 0.85 \times \text{rainfall (Inches)} - 12 \text{ inches.}$$

This formula is a similar type to those which have been found to fit the observed facts in other parts of the world, the constants depending upon the local climatological geological and other factors which determine the losses represented by the ratio between rainfall and runoff.

It was observed by the authors of this Paper that some of the southern rivers of the Bombay Presidency appeared to give yields which exhibited a markedly smaller ratio of runoff to rainfall than that given by the above formula. This was attributed to increased losses arising from the greater absorptive capacity of the substratum.

9. Although the Kalinadi was not included among the rivers to which specific reference was made in the Paper, it lies in the southern part of the Presidency and it has, therefore, been necessary to pay special attention to any local factors which might abnormally influence the runoff characteristics. In this connection it may be observed that experience has shown that it is by no means easy to arrive at a reliable estimate of the losses which take place from a catchment area. The determination of the total quantity of rain which falls in the course of the year is, in the absence of a large number of carefully placed rain-gauges, difficult to assess, particularly if the catchment is mountainous and subject to wide local variations in the amount of rain received from a particular storm. Again, estimates of the quantity of water which runs off a catchment area are fundamentally difficult to measure accurately, particularly at high stages of the river when direct gauging operations may be impracticable.

10. The most reliable estimates of losses are usually to be found in relation to those catchment areas which have been reservoiried for a number of years and for which adequate rainfall records, combined with direct measurements of the water utilised and discharged over the waste weirs, have been maintained. Such records are to be found among the statistics relating to some of the irrigation reservoirs in the Bombay Presidency such as that at Dhupdal on the Ghatprabha river, 70 miles north of Supa. In a somewhat different category fall the records which have been maintained by the Tata Hydro-Electric Company, which we have been given an opportunity of studying through the courtesy of the Directors.

11. The principal causes of rainfall losses are direct evaporation from the wetted surface of the ground and from the surfaces of vegetation, transpiration of moisture by vegetation, and deep seepage of water through joints, solution channels and bedding planes in the rock which may allow a portion of the rainfall to by-pass the gauging point on the river where discharges are measured and re-appear at some point outside the catchment area on which the rain originally fell. The first two causes are greatly influenced by temperature, humidity and wind; the latter by the geological structure of the district.

12. Climatological factors are not likely to influence greatly the losses from the Kalinadi basin in relation to other river basins situated on the Western Ghats, although the dense forest cover which characterises the western portion undoubtedly offers greater opportunity for evaporation and transpiration.

Geologically, however, the Kalinadi lies outside the Deccan trap area to the rivers of which the majority of the existing records relate, and for this reason it is necessary to consider whether the structure of the catchment is likely to give rise to excessive losses. Although the regional geology is little known the general character of the rocks may be described broadly as consisting of crystalline gneisses and schists and there is little evidence of the existence of stratified or cavernous rocks which might lead to the subterranean diversion of water into other drainage systems. Moreover, we have seen no evidence of underground losses of water within the area with which we are concerned and in our opinion such losses as may occur are likely to be negligible.

13. After a careful study of all the available evidence we consider that the following modified formula for the runoff from the Kalinadi basin will lead to a conservative assessment of the water available for power development :-

$$\text{Runoff (inches)} = 0.80 \times \text{rainfall (inches)} - 15 \text{ inches.}$$

14. In the interests of long term planning it is important that steps should be taken to record by direct measurement the runoff from those rivers which are scheduled for future development. This work has already been initiated in the case of the Kalinadi at Dandeli and in the case of the Kaneri at the Gund causeway. Continuous daily water level records have been maintained at these points since June 1948 by the Forest Department staff while a series of gauging operations was undertaken on these rivers during the 1948 monsoon. In addition water level records of a temporary gauge at Bomanhalli have been kept since June 1947 although this gauge will be discontinued in future now that sufficient correlation with the Dandeli gauge has been obtained. The

results of the river gauging work, which form the subject of a separate Report, were submitted in October 1948 and tend to confirm that the runoff recorded over the period June 1947 to July 1948 was in accord with the values calculated from the above formula.

Variation of Annual Runoff.

15. The rainfall records at Supa (1876 - 1946) and at Castle Rock (1916 - 1946) have been used to estimate the annual runoff available year by year at the site of the Supa dam over the period 1876 - 1946. The data so obtained have been plotted on Figure No. 8 which also shows the runoff from the Ghatprabha river as measured at the Dhupdal weir during the years 1897 - 1926.

It will be observed that while the annual variations in the runoff from the two rivers follow generally similar trends, an exceptionally large difference, amounting to 45 per cent., occurred in 1914 when the discharge at Dhupdal exceeded 189 per cent. of the recorded mean.

Variations of Monthly Runoff.

16. Figure No. 9 shows a comparison between the mean monthly rainfall at Supa and the mean monthly runoff of the Ghatprabha river at the Dhupdal weir. It will be seen that the pre-monsoon showers of March and April have a negligible effect on the river flow. The early monsoon rainfall soaks the catchment area and in July, when the ground is saturated, the runoff reaches its maximum intensity with the maximum precipitation of the monsoon rain. In August and September, due to the natural retentive effect of the subsoil, the river flow does not decrease as rapidly as the rainfall. Later in the year, as the catchment area gradually dries up, the flow of the river falls to a steady low value which, continually diminishing, is maintained during the dry season.

Maximum Flood Flows.

17. The reliable estimation of maximum floods is a matter of supreme importance in considering the design of the dams which form part of the scheme of development to be described hereafter. The size of the floods for which provision has to be made not only affects the design of the spillway but may also profoundly influence the type and even the location of the dam itself.

No records exist of unusual flood flows in the Kalinadi basin and until such time as a considerable mass of data on the subject has been accumulated it is necessary to rely upon the guidance which can be obtained from studies of flood records relating to other rivers of broadly similar character.

18. Of the various empirical formulae which have been suggested from time to time for the estimation of floods in Indian rivers, we are of the opinion that the Inglis formula for fan catchments, as proposed in Technical Paper No. 30 previously referred to, is the most reliable for use in connection with the Kalinadi.

This formula is as follows :-

$$Q = \frac{7000 A}{\sqrt{A + 4}}$$

Q = Maximum flood flow in cusecs.

A = Area of catchment in sq. miles.

We consider that whilst this formula will give a reasonable estimate of the maximum flood flows which may be expected to occur, the importance of the Kalinadi works justifies the adoption of a cautious attitude towards the

designs of the spillways and we have, therefore, allowed a margin of 25 per cent. over and above the figures as determined by the Inglis formula.

This has led to the peak values of the maximum floods which might occur from the unreservoired catchment areas given in the following Table.

TABLE 2.

Name of Reservoir.	Catchment area sq. miles.	Maximum Flood Flows. cusecs.
Supa	400	174,000
Bomanhalli	647	222,000
Kaneri	114	93,000
Lower Kalinadi	1,439	330,000

CHAPTER V.

S T O R A G E .

1. Since no continuous records of the discharge of the Kalinadi river were available prior to the commencement of our investigations in 1947, it has been necessary to study the effect of storage by using the monthly rainfall figures relating to the gauges which have been maintained at Supa and Castle Rock. These figures in conjunction with the isohyetal map (Figure No. 3) have been used to produce a mass runoff diagram covering the 71 year period 1876 to 1946. From this mass diagram it has been possible to produce a curve which expresses, in terms of the amount of storage provided, the uniform flow which can be maintained by the reservoir. The diagram obtained in this way has been compared with similar diagrams prepared from the runoff records for the Dhupdal weir on the Ghatprabha river.

2. The capacities of the reservoirs which form part of the scheme of development described in Chapter VI are set out in Table 3. below. The sizes have been determined from considerations of overall economy; that is to say, the cost of providing the storage has been balanced against the benefits to be derived therefrom in the form of revenue from the sale of electricity.

TABLE 3.

Name of Reservoir.	Millions of cubic feet.	
	Gross Storage.	Net Storage.
Supa	128,000	118,000
Kaneri	7,600	6,900
Lower Kalinadi	11,900	10,100

3. The Supa reservoir offers the opportunity of providing effective regulation of the runoff from 400 sq. miles of catchment draining the high rainfall belt. The stored water would be utilised through three power stations in series which would make use of a total head of 1,462 ft. During the monsoon water would be held back in the Supa reservoir and the power stations situated lower downstream would be operated to the maximum extent on the runoff from the unreservoired areas. A large part of the firm output from the Kalinadi scheme would thus be dependent on the storage afforded by the Supa reservoir which would be sufficiently large to provide over-year regulation and make up deficiencies in flow arising from a series of light monsoons.

4. The Kaneri reservoir would provide a measure of regulation of the runoff from an independent catchment area which is also subject to high rainfall. Unfortunately, the topography of the site does not lend itself to the creation of a reservoir sufficiently large to make full use of the monsoon runoff and, as explained in Chapter VII, considerable water would at times be lost over the spillways of the dam.

5. The Lower Kalinadi reservoir would result from the construction of a dam on the lower reaches of the river. Its main function would be the concentration, for the production of power, of the head represented by the natural gradient of the river over a stretch of some 12 miles below the Nagjhiri power station.

6. A discussion of the manner in which the operation of the reservoirs would be interlocked will be found in Chapter VII.

Silting of Reservoirs.

7. We have paid special attention to the possibility that the economic life of the reservoirs might be seriously affected by loss of storage resulting from the deposition of the large volumes of silt carried down by the rivers during the monsoon months.
8. A great deal of research work has been done on this problem both in India and elsewhere and much useful information has been published. We felt it desirable, however, to obtain some direct evidence of the amount of silt which the Kalinadi carries under monsoon conditions and we, therefore, arranged for a number of samples to be taken during the course of our field investigations: the results will be found tabulated in Appendix III. Whilst the work accomplished is useful as a general guide to the conditions likely to be met, it should be pointed out that the number of samples obtained is far too few to offer a reliable guide to the rate of silting which may be expected. The silt load carried by a river, particularly when in flood, varies even over a short period of time within the widest limits and it is doubtful whether anything less than an elaborate series of records taken over a number of years will lead to a closer approximation than can be obtained from a careful comparison of the actual rate of silt deposition measured in reservoirs possessing similar characteristics.
9. In order to obtain some guidance as to the probable effective life of the Kalinadi reservoirs, we have attempted to estimate the rate of siltation of the Supa Reservoir by three alternative methods.

- (a) By use of the following formula suggested in the 1941 Annual Report (Technical) of the Central Board of Irrigation, India.

$$S = KA^{\frac{3}{4}}$$

where S = Annual siltation rate in acre feet.

A = Catchment area in square miles.

K = 0.5; 1.7; 5.5; for rock, normal and soil catchments respectively.

N.B. In Table 4 below, the value of K applying to a normal catchment has been used.

- (b) By comparison with a similar catchment for which a silt survey has been made. For this purpose the catchment of Lake Fife reservoir, near Poona, has been selected as giving a reasonably close analogy.

The 1941 Report, quoted above, gives the annual siltation rate for this reservoir as 144 acre feet per 100 square miles of catchment area over a period of 70 years. In view of the rather sparse vegetation cover of the Lake Fife catchment it is to be expected that the siltation rate would be greater than would be the case for a reservoir situated in the Kalinadi Basin.

- (c) By deduction from silt samples taken at Supa and at Bomanhalli on the Kalinadi River.

Comparative rates of siltation as indicated by the foregoing methods are shown in Table 4. below.

TABLE 4.

	Siltation rate - acre feet per year.		
	(a)	(b)	(c)
	Supa.	152	483

10. It is probable that the actual siltation rates would lie within the extremes given above and, for purposes of this Report, we have adopted a rate of 300 acre feet per year, corresponding to a coefficient of 3.4 in the formula quoted above. Using this coefficient for assessing the siltation rate in the other reservoirs which form part of the Kalinadi scheme we have arrived at the following results.

TABLE 5.

Reservoir	Silt storage Capacity - acre feet.	Estimated siltation rate		Life Years.
		Acre feet per year	Acre feet per 100 sq. miles of catchment	
Supa.	206,000	300	75	690
Kaneri	16,100	122	103	132
Lower Kalinadi	33,300	450	67	74

11. In the foregoing Table the silt storage capacity has been taken as represented by the dead storage provided below the lowest draw down level of the reservoir. The figures given for the Supa and Kaneri reservoirs indicate that no reduction in effective storage capacity is to be expected over the assumed amortisation period (100 years).

The figure of 74 years computed for the Lower Kalinadi reservoir makes no allowance for the considerable quantity of heavy silt which could be passed through the reservoir during the early stages of the monsoon by opening the culverts provided through the base of the dam. Further assistance in the same direction would be afforded by the monsoon floods containing fine silt in suspension which would be discharged over the crest of the dam. It may reasonably be assumed, therefore, that over the first 100 years no reduction in the effective storage capacity would in fact take place. Moreover, since the lower storage levels of the reservoir would not be utilised except under exceptional conditions there would, in effect, be no serious interference with the use of the power station until long after the expiration of the amortisation period.

12. Extending the foregoing basis of computation to the Dandeli headpond it may be shown that theoretically the latter would be completely silted up after about 80 years. It is proposed, however, that the weir at Dandeli should incorporate a number of deep sluice gates in addition to the crest gate and by their judicious use at periods of high flood, particularly during the early part of the monsoon when the silt load will be at its maximum, it would be possible to keep the pond comparatively clear of deposits and indefinitely prolong its effective usefulness.

13. It should be stressed that from the point of view of reducing the siltation of the reservoirs to a minimum, it is important that the existing forest conservation

programme should be maintained and in addition steps should, if possible, be taken to exercise some control over the grazing lands which constitute part of the catchment area, particularly in the eastern districts.

Evaporation Losses from Reservoirs.

14. In the absence of experimental data on evaporation losses within the Kalinadi basin, we have examined the published results of investigations which have been made in similar regions in the Western Ghats. We consider the most reliable data to be that given by Messrs. P. K. Raman and V. Satokopan in the "Scientific Notes" of the Government of India Meteorological Department (Vol. VI. No. 61.).

The figures given for Belgaum, some 40 miles north of Supa, have been used in estimating the mean evaporation rate to be expected from the proposed reservoirs. The figures relate to losses from an evaporation pan and, after applying a correction for scale so as to make the data applicable to the large water surface of a reservoir, we have adopted a rate of 5 feet per year for the mean annual evaporation. In assessing the volume of water lost annually we have assumed that evaporation at this rate will occur from the water surface of the reservoir when it is half full. The estimated evaporation losses for each section are given on the Flow Diagram (Figure No. 7.).

It is probable that there will be appreciable variations in evaporation losses, both between the individual reservoirs in any year and for the whole scheme from year to year. Such variations would, however, have little effect on the total quantity of water available for power production.

Compensation Water.

15. Since the areas immediately affected are sparsely populated the construction of the proposed works should not introduce any serious compensation water problems. The main centres of population, where such problems might be expected to arise, are at Supa, Dandeli and Bomanhalli. Of these areas Supa will be inundated by the proposed reservoir while at Dandeli any requirements would be amply met by a combination of the regulated discharge from the Supa reservoir and the unregulated flow from the catchment between Supa and Dandeli.

Below the Bomanhalli weir the bed of the Kalinadi will, except during the monsoon, be completely dried out down to the Nagjhiri power station at the head of the Lower Kalinadi reservoir. Since there are some village settlements in the neighbourhood of Bomanhalli a piped water supply will ultimately have to be given to such of the communities as may be affected. The problems of drainage and sanitation will also require attention.

CHAPTER VI.

SCHEME OF DEVELOPMENT.

General Description.

1. Apart from the small Baginkatte project which has now been omitted, it will be found that the scheme shown on Figures Nos. 1 and 2 closely follows the proposals outlined in our Interim Report of August 1947. It comprises four distinct but interlocked sections, the principal features of which are described below.

It should be noted that where dimensions of tunnels and pipelines, and the capacity of turbo-generator units, are given, they relate to those corresponding to an overall system load factor of 60 per cent - based upon the firm output available in a dry year. The firm annual outputs given for the individual power stations are those which are capable of attainment as the result of integrated operation and relate to the output at the station busbars.

Supa Scheme.

2. The essential feature of this section is the large reservoir which would provide the main storage for the whole scheme of development. With the dam would be incorporated a power station having a total installed capacity of 90 MW, in three sets of 30 MW each.

The principal technical details relating to the Supa section are as follows:-

Catchment area	400 sq. miles.
Mean annual rainfall	144 in.
Mean annual runoff	100 in.
	or 2,940 cusecs.

Mean flow for power in an average year	2,855 cusecs.
Mean flow for power in a dry year	2,480 cusecs.
Output in an average year	400 million kWh.
Output in a dry year (firm)	265 million kWh.
Plant installation 3 x 30 MW	= 90 MW.

Nagjhiri Scheme.

3. The principal works would comprise a headpond between Dandeli and Bomanhalli from which the water would be diverted through a pressure tunnel and pipeline to a power station situated near the confluence of the Nagjhiri nullah and the Kalinadi river. The power station would have an installed capacity of 350 MW, in 7 sets of 50 MW each.

The principal technical details relating to the Nagjhiri section are as follows:-

Total Catchment area	647 sq.miles.
Mean annual rainfall	116 in.
Mean annual runoff	78 in.
	or 3,700 cusecs.
Mean flow for power in an average year	3,540 cusecs.
Mean flow for power in a dry year	2,820 cusecs.
Maximum net head on full load	1,005 ft.
Output in an average year	2,300 million kWh
Output in a dry year (firm)	1,830 million kWh
Plant installation 7 x 50 MW	= 350 MW.

Kaneri Scheme.

4. This section would include a dam on the Kaneri river from which a pressure tunnel and pipeline would convey the water to a generating station located about two miles upstream of the Kaneri-Kalinadi confluence. The power station would have an installed capacity of 75 MW, in three sets of 25 MW each.

The principal technical details relating to the Kaneri section are as follows:-

Total Catchment area	114 sq. miles.
Mean annual rainfall	154 in.
Mean annual runoff	108 in. or 905 cusecs.
Mean flow for power in an average year	525 cusecs.
Mean flow for power in a dry year	450 cusecs.
Maximum net head on full load	1,170 ft.
Output in an average year	390 million kWh.
Output in a dry year (firm)	325 million kWh.
Plant installation	3 x 25 MW = 75 MW.

Lower Kalinadi Scheme.

5. This would form the lowest of the three schemes in series on the main river and would consist of a combined dam and power station located about 1½ miles upstream of the confluence of the Baginkatte and Kalinadi rivers. The power station would have an installed capacity of 75 MW in three sets of 25 MW each.

The principal technical details relating to the Lower Kalinadi Section are as follows:-

Total Catchment area	1,439 sq.miles.
Mean annual rainfall	93 in.
Mean annual runoff	59.5 in.
	or 6,280 cusecs.
Mean flow for power in an average year	4,645 cusecs.
Mean flow for power in a dry year	4,090 cusecs.
Maximum net head on full load	185 ft.
Output in an average year	500 million kWh.
Output in a dry year (firm)	420 million kWh.
Plant installation	3 x 25 MW = 75 MW.

Below, we describe some of the more important characteristics of the foregoing schemes.

Supa Scheme.

6. The site selected for the dam lies about $1\frac{1}{4}$ miles downstream of the Supa causeway (see Figure No.10) at the head of a gorge where the configuration of the ground favours the economical construction of a high dam. Moreover, the wide valley which opens out upstream of the dam site offers a very favourable reservoir site, particularly so as the Kalinadi is joined a short distance above Supa by two major tributaries, the Pandri and the Nagi, both of which drain areas of high rainfall. These natural features afford the opportunity of creating a reservoir large enough to provide a very high degree of regulation of the head waters of the Kalinadi river.

7. Of the many potential reservoir sites examined in the Kalinadi basin that at Supa offers by far the most economical storage and, moreover, provides the means of exercising effective control of the flow to the other

sections of the scheme. As will be seen from the flow diagram (Figure No. 7) the regulated discharge from the Supa reservoir will, in an average year, represent nearly 80% of the total flow at Bomanhalli. In consequence of this control the amount of water which will be lost to the Nagjhiri power station as the result of spillage at the Bomanhalli weir will be very small.

8. Because of the vital part played by the Supa reservoir in the development of the Kalinadi basin as a whole, the determination of the height of the dam is a matter for very careful investigation. Our present studies indicate that the maximum economical height would correspond to a top water level of 1825 ft. above M.S.L. Under these conditions the dam would rise some 275 ft. above the river bed and would provide 118,000 million cu. ft. of effective storage; equivalent to nearly 130 per cent of the mean annual runoff from the catchment area of 400 sq. miles. When the reservoir is filled the water area will extend to 46 sq. miles.

9. The site of the dam is very restricted and the construction of the power station at its foot makes the provision of an over fall spillway a somewhat difficult technical problem. For this reason we consider the most satisfactory method of dealing with flood water would lie in the adoption of an independent spillway channel cut through the low saddle which lies to the north of the main dam and separates the reservoir from the nullah which leads back into the Kalinadi river. The release of flood water would be controlled by a weir, the crest of which would be surmounted by gates of the sector or

vertical lift type. The moveable crest so provided would permit the maximum use to be made of the reservoir for storage purposes and no additional land beyond the normal margins of the lake would be inundated during periods of high flood.

10. The head concentrated at the dam would be considerable and, although subject to wide seasonal fluctuation, would permit the generation of a very considerable block of power at the low incremental cost represented by the expenditure on the power station and its equipment.

11. Subject to a more thorough geological examination of the rock abutments it is likely that an arch dam would prove the most economical type for the site conditions. In order to be conservative, however, we have assumed in preparing the accompanying estimates that a mass concrete gravity dam would be adopted. The general features of such a dam are shown in figure No.11, while on Plate No.2 will be found an artist's impression of the complete dam and power station as at present visualised.

12. The creation of the reservoir would inundate the small town of Supa together with nearly six sq. miles of forest clearing, a part of which is under cultivation. In addition, about 8 miles of the Londa-Karwar road would be flooded and would be replaced by a new road which, after passing over both the main dam and the spillway, would follow the eastern edge of the reservoir and would provide an uninterrupted crossing of the Kalinadi river during the monsoon.

Nagjhiri Scheme.

13. Between Bomanhalli and the confluence of the Kalinadi with the Nagjhiri nullah the main river makes a great loop, some 15 miles in length, over the middle portion of which it drops rapidly over a series of cataracts through at total height of 1080 ft. By diverting the river through a tunnel and short circuiting this loop it would be possible to carry out a very economical development (See Figure No.12).

14. The power station at Nagjhiri would produce about two thirds of the total output available from the whole Kalinadi scheme and it would therefore be by far the most important member of the Group. The great size of the station is rendered possible by the construction of the Supa reservoir which is capable of producing, even under the most unfavourable conditions, a steady discharge of not less than 2480 cusecs. In addition to the regulated water provided by the Supa reservoir, the Nagjhiri station would utilise a part of the unregulated runoff from an additional catchment area extending to 247 sq. miles.

15. Water for power generation would be stored in a head pond which would be created below Dandeli by the construction of a diversion weir about $\frac{3}{4}$ mile upstream of the Bomanhalli causeway. The weir would be surmounted by a series of automatically controlled crest gates which would permit the fullest use to be made of the storage for purposes of taking up variations in the daily load on the Nagjhiri power station. The crest gates would be designed to permit the passage of the largest floods without

producing any objectionable rise in the normal top water level of the headpond, which we suggest should be fixed at 1400 ft. above M.S.L. The back water created by the weir would not affect the river levels at Dandeli where the community would benefit greatly from the very full control of the main river exercised by the Supa reservoir.

16. Two alternative sites for the weir have been investigated, at Don Shigur and Bomanhalli respectively; it is considered that on balance the latter or lower site offers the greatest advantages and it has been adopted for purposes of our Report. Both sites have been examined by means of a series of trial bores and the geological conditions have been described by Dr. Auden in his report of April 1947. Before taking a final decision, however, we would recommend that some further borings should be undertaken, particularly on the left bank at Bomanhalli.

17. The proposed pressure tunnel (see Figure No.13) which would have an equivalent diameter of approximately 21 ft., would be concrete lined and would have an overall length of about 30,000 ft. A surge shaft would be provided at the downstream end of the tunnel which would terminate at a valve house from which the high pressure pipes would descend to the power station at the bottom of the gorge (see Plate 1).

By locating the intake opposite Don Shigur the shortest length of tunnel would be secured. At this point the ground rises slightly and to obtain the necessary cover as quickly as possible the intake shaft would be set

back some distance from the bed of the Kalinadi and would be connected to the head pond by a short length of open channel. From the intake the tunnel would run in a south south westerly direction to a construction adit located approximately half way along its length; beyond this point it would run in a south westerly direction towards the surge shaft. This alignment has been chosen in order to obtain the best driving conditions by ensuring that the tunnel is located well below the zone of weathered surface rock. Should it be necessary to open up driving operations at additional faces there will be no difficulty in locating further working shafts or adits.

18. The possibility of affecting a substantial economy in the amount of steel required for the pipeline by adopting underground construction should not be lost sight of. Apart from the possibility of securing a substantial saving in capital expenditure such an arrangement would possess obvious advantages from the point of view of national security. Its practicability is however dependent upon more detailed geological examination of the rock in depth and, for purposes of the attached estimates, we have assumed that the design of the pipeline would follow conventional practice and be carried wholly over the surface of the ground between the portal valve house and the power station.

Kaneri Scheme.

19. This scheme which is shown in outline in Figures Nos. 14 and 15 would utilise the waters of the Kaneri river, one of the main tributaries of the Kalinadi. It can, if

desired, be operated initially as an independent and self contained development but, as explained in Chapter VII, it will benefit materially from the storage provided by the Supa reservoir when the full scheme is in operation.

20. In the 12 mile stretch between the sites selected for the dam and the power station respectively the river falls at a fairly uniform gradient through almost 1000 ft. Above the dam site, however, the gradient of the river within the reservoir area is much flatter.

21. During the course of our field investigations three separate sites for the main storage dam were examined. The upper of these three sites, originally proposed by Mr. Bowers in 1921, is about $\frac{1}{2}$ mile upstream of the Gund causeway which carries the Dandeli-Bogrigadde road across the Kaneri river, while the two lower sites lie 1 mile and $1\frac{3}{4}$ miles respectively downstream of the causeway.

Preliminary studies of the available topographical maps had indicated that one of the lower sites would prove attractive from the point of view of economical dam construction. Moreover, they both possessed the further advantage of leading to an appreciable reduction in the length of the pressure tunnel which would be required to supply the power station. Subsequent examination of the aerial surveys, however, disclosed that the reservoir area was, as a whole, less favourable than had been anticipated and a comparison between the three sites led to the conclusion that the upper site would afford the greatest overall economy in spite of the fact that it would entail some 6000 ft. of additional tunnelling.

22. The maximum permissible size of the Kaneri reservoir is limited to some extent by the local topography which renders it impracticable to obtain regulation of the river discharge on a scale comparable with that afforded by the Supa reservoir in respect of the Kalinadi. But apart from these limitations the economic size of the reservoir is dependent upon the method of operating the power station and the extent to which the Kaneri storage can be assisted by the Supa reservoir.

The final determination of the top water level of the reservoir and the type of dam best suited to the site must await further detailed topographical and geological investigations. Provisionally, however, we have adopted a level of 1570 ft. above M.S.L. although it is possible that it may later prove economical to increase somewhat the height of the dam. A top water level of 1570 ft. would entail the construction of a cut off dam across the low saddle which lies about a mile to the north of the main dam. It is proposed that this cut off dam should be utilised as a flood spillway in preference to the discharge water over the crest of the main dam in the gorge.

23. The dam as described would have a total height of 250 ft. above river bed level. It would create a reservoir with a surface area extending to 4 sq. miles and would provide an effective storage capacity of nearly 7000 million cu. ft. above the lowest drawdown level which has been fixed at 1450 ft. above M.S.L. This storage is equivalent to not more than 25 per cent of the mean annual

runoff and so long as the Kaneri station is operated as an independent unit the loss of water by spillage during the monsoon would in an average year be considerable and would, based upon firm output, amount to about 64 per cent of the total runoff. Integration of the operation of the Kaneri station with the other members of the Group would lead to a substantial reduction in the loss of water arising from spillage during the monsoon, (see Chapter VII)

24. The accompanying estimates are based on the use of a mass concrete gravity section for both the main dam and the secondary spillway dam. It seems possible that the use of a rock fill for the main dam will offer some economy in capital cost although this is a matter which must await more detailed investigation.

25. An intake tower with a sluice gate to control the admission of water to the pressure tunnel would be located immediately upstream of the main dam. The tunnel, which would be concrete lined, would have an equivalent diameter of 10 ft., an overall length of 20,000 ft. and would lead the water to a valve house situated on the upper slopes of the Kaneri gorge. The alignment selected for the tunnel provides ample cover except for two short lengths near the intake where the lining would require to be reinforced (see Figure No.15). Construction would be carried out from the two ends and in addition a working shaft would be sunk near the village of Gund below which the tunnel line would pass. At the surge shaft the tunnel would change direction in order to bring the portal out at a point which offers the advantage of a favourable alignment for the high pressure pipeline.

26. For estimating purposes we have assumed that the tunnel would trifurcate at the portal and that from this point three separate high pressure pipes would be taken down to the power house. As in the case of the Nagjhiri scheme, there is the possibility of obtaining some overall economy in capital expenditure by substituting for the three separate pipes a single steel lined sloping tunnel, and this should be studied when the time comes to prepare detailed designs.

Lower Kalinadi Scheme.

27. This is the lowest of the chain of three power stations situated on the main river and, in addition to utilising the controlled water discharged by the Nagjhiri and Kaneri power stations, would benefit from the unregulated runoff from a further 678 sq. miles of catchment area.

28. The site selected for the dam is shown on Figure No. 16. It lies about $1\frac{1}{2}$ miles upstream of the confluence of the Baginkatte and Kalinadi rivers on a reach where the main stream runs almost due south. The river here is comparatively wide and deep, flowing through a deep gorge, the steep sides of which rise abruptly from the river bed at an angle approaching 45° .

29. The accompanying estimates have been based on the adoption of a site at the narrowest part of the gorge where the river channel is about 300 ft. wide. Soundings taken over the river bed indicate that under conditions of average dry weather flow the maximum depth of water is

about 45 ft. Upstream of the selected site the river is even deeper and soundings up to 77 ft. have been recorded. It is possible that more extensive investigations may reveal the existence of a site a little further downstream where the depth of water is shallower and where, although accompanied by a somewhat greater width between the sides of the gorge, some economy in overall cost may prove possible.

30. The rocks in the vicinity of the dam site consist of massive quartzite, dipping obliquely across the line of the river in an upstream direction at an angle varying from 20° to 35° . Although the rocks are somewhat laterised on the flanks of the gorge they are fresh and sound over the river bed where they have been subject to the scouring action of the water and it is not anticipated that deep excavation will be necessary for the foundations, except on the flanks where fairly heavy stripping of weathered rock may be necessary.

31. The site lends itself to the adoption of an arch dam but pending more detailed geological exploration of the sub-surface conditions we have, as in the case of the Supa and Kaneri dams, based our estimates upon the use of a mass concrete gravity section. The crest of the dam would be surmounted by deep, sector type gates which would control the discharge of flood water, while close to the base of the dam a pair of draw off culverts would be provided for the purpose of drawing down the level of the reservoir in order to dewater the turbine intakes, which would be sited close to the western flank of the gorge.

32. The dam as proposed would provide a top water level of 320 ft. above M.S.L. corresponding to the normal tailrace level of the Nagjhiri power station and would rise 205 ft. above the river. The surface of the reservoir thus created would extend to about 4 sq. miles and by using a total draw down of 120 ft. would provide an effective storage of 10,100 million cu.ft. - equivalent to 19 per cent of the mean annual runoff from the residual catchment area below the Nagjhiri and Kaneri schemes.

33. During the greater part of the year the discharge through the power station would be adjusted to suit the flow of water released by the upper power stations, supplemented by the residual runoff from the unreservoired areas and the water level in the Lower Kalinadi reservoir would be maintained as high as possible consistent with the provision of the daily pondage necessary to take up variations in the output from the upper stations. In this way the maximum energy output would be obtained from the Lower Kalinadi station and only in an emergency would full use be made of the storage represented by the possible draw down of 120 ft.

34. The creation of the reservoir would have little effect upon existing settlements, but it would entail the relocation of some $2\frac{1}{2}$ miles of road between Gund and Bogrigadde. The new road would be carried over the crest of the dam and would greatly improve communications between the districts lying on either side of the Kalinadi river which are now virtually isolated from one another by the gorge.

CHAPTER VII.

METHOD OF OPERATION.

Flow Diagram.

1. Figure No. 7 is a Flow Diagram which shows for a year of average rainfall the mean flows available for the production of power from the four sections into which the scheme is divided. The runoff figures have been derived from the isohyetal map (Figure No.3) by using the formula for annual runoff recommended in Chapter IV, while the figures for estimated losses due to spillage and evaporation from the reservoirs represent the mean equivalent flows for the year.
2. The great size of the Supa reservoir will be sufficient to prevent any spillage in an average year, the only loss of water being that due to evaporation from the surface of the reservoir which will represent about 3% of the inflow. Consequently some 97% of the water reaching the reservoir will be available for power development at the dam.
3. At the Dandeli headpond the water discharged from the Supa generating station will be augmented by the unregulated flow from the catchment area below Supa dam. As the storage provided by the headpond is not large the flood flows from this unreservoired area are likely, in an average year, to exceed the capacity of the plant installed in the Nagjhiri Station and spillage at the Bomanhalli weir will occur. It is estimated that this

spillage, which will be equivalent to a continuous discharge of 75 cusecs, will normally occur over a period of a few weeks only. Owing to its small surface area the evaporation losses from the Dandeli headpond will be negligible. It will be observed that no compensation discharge has been allowed for in the diagram, and any such allowance as may ultimately be made will represent a reduction of energy from the Nagjhiri power station.

The diagram shows that in an average year about 98% of the water reaching the headpond will be available for power production. This high rate of utilisation can only be achieved by the correct operation of the Supa reservoir and is based on the assumption that the whole output available from the Nagjhiri station can be absorbed by the interconnected electrical network.

4. The situation at Kaneri differs from that relating to the Supa and Nagjhiri stations, which are heavily reservoirised. The storage provided by the Kaneri reservoir is insufficient to regulate fully the runoff in an average year. Consequently, in addition to the small evaporation loss equivalent to a continuous flow of 10 cusecs, there will be a considerable spillage loss. Under the conditions described in this Report the total losses are estimated as equivalent to a continuous flow of 380 cusecs, the whole of which, apart from evaporation, is lost during the monsoon period. In an average year the water which will be available for use at the Kaneri power station will not exceed 58% of the total reaching the reservoir.

5. That part of the Flow Diagram relating to the Lower Kalinadi development again shows the influence of a large unregulated catchment. The regulated discharges from Nagjhiri and Kaneri power stations provide a controlled dry season flow to the Lower Kalinadi reservoir. The reservoir level will normally be kept as high as possible to provide the maximum head on the power station. During the monsoon period the heavy unregulated runoff from the residual catchment enters the reservoir together with spillage from Kaneri and Dandeli and is largely wasted. The evaporation loss from the reservoir will be negligible compared with the spillage which is estimated to be equivalent to a mean flow of 1515 cusecs. The water available for power development at the Lower Kalinadi power station is estimated at 75% of the total reaching the reservoir.

Integration of Operational Programmes of Individual Stations.

6. In order to obtain the maximum combined output from the group of power stations the utilisation of the water stored in the various reservoirs will demand careful and continuous study by the operating staff. At the end of each monsoon it will be possible to assess the amount of water available for power production and to plan the dry weather working of each station so that the group output will be evenly distributed over the entire year.

7. Figure No. 17 shows two typical operating programmes, the one for a complete year of average rainfall and the other for a complete year of minimum rainfall.

The underlying principle of operation is that on those sections of the scheme from which the spillage losses are likely to be greatest, that is to say the Kaneri and Lower Kalinadi sections, the power house plant would, during the monsoon, be maintained on continuous full load for so long as this could be done without drawing on stored water. At such times the Kaneri and Lower Kalinadi power stations would operate on a steady block load in order to utilise as far as possible water which would otherwise be wasted over the spillways. The additional output thus obtained from these two stations during the monsoon months would be compensated by correspondingly reducing the output both from the Supa station and to a lesser extent from the Nagjhiri station.

This method of integrated operation is rendered possible by the very large storage afforded by the Supa reservoir and, by carefully planning the release of water it would be possible, as Figure No. 17 shows, to secure a uniform output from the whole Group. For short periods, totalling perhaps 4 to 8 weeks in an average year, spillage would occur from the Dandeli headpond unless a suitable outlet could be found for the secondary power available from the Nagjhiri station.

8. If reference be made to the operating diagram representing conditions in an average year it will be seen that the Kaneri station would normally operate at a mean load of 33 MW, using water stored in the reservoir to augment the dry season runoff. At the start of the monsoon the output would be gradually stepped up to take

advantage of the increased runoff and, when the plant was operating at its full capacity, the reservoir would be allowed to fill. To avoid unnecessary spillage the plant would be maintained at full capacity as long as possible and then, as the natural runoff into the reservoir decreased, the load would be gradually reduced in order to avoid making any demand on storage. As soon as it became necessary to call on storage, the Kaneri station would revert to the steady mean output normally maintained during the dry season.

In this way the co-ordinated operation of the Supa and Kaneri reservoirs would lead to a greater output of firm power than would be possible with independent working, and a block of what would otherwise be secondary power would be turned to good account.

9. The Lower Kalinadi station would operate in a rather similar manner except that its water supply during the dry season would be obtained from the Kaneri and Nagjhiri power stations instead of from its own storage. The monsoon flow would be utilised as far as possible by bringing the plant up to continuous full load in the manner described for the Kaneri station. As soon as spillage ceased the output would be gradually reduced to correspond with the reduction in the unregulated runoff until, eventually the dry season output would again be reached. The latter would then be maintained by the regulated discharge from the upper stations.

10. In the case of the Nagjhiri station, the water used for power generation would consist partly of the stored water released from the Supa reservoir and partly of the natural runoff from the unreservoired area. The release of stored water would be gradually reduced as the natural runoff increased until finally it was withheld altogether. In this manner the additional output available from the Kaneri and the Lower Kalinadi generating stations during the monsoon could, to a large extent, be offset by a reduction of output from the Nagjhiri station. In an average year, however, there would be times during the monsoon when the unregulated flow to the Nagjhiri station would be greater than that necessary to maintain the normal output from the Group. Under these conditions the plant would either produce secondary power as shown in Figure No. 17 or, alternatively, if there were no market for such a block of secondary power, it would be necessary to spill the surplus water as already explained.

11. The operation of the Supa power station would be conditioned by the operation of the other three members of the Group. The large available storage would be used to reverse the general conditions elsewhere and compensate as far as possible for the excess of water available to the other stations during the monsoon. The Supa station would thus supply its greatest output in the dry season and a reduced output during the monsoon. When the Nagjhiri station had more water than it could use no water would be released from the Supa reservoir and the station would be shut down.

The variation of head due to the fluctuating levels in the Supa reservoir would mean that a varying amount of water would have to be passed through the turbines for a given power output. This accounts for the gradual changes, apparent from the diagram, in the electrical output from the Supa, Nagjhiri and Lower Kalinadi stations during the dry season.

12. It should be noted that the diagram represents mean outputs for weekly periods throughout the year and that the use of daily pondage will enable the full capacity of the plant to be used as necessary to meet peak demands. Should the availability of plant at the power stations belonging to the other members of the Group, make it necessary to utilise the Supa plant during those few weeks of the year when it would normally be shut down, the operating programme of the Supa station would be temporarily modified and the plant run for a few hours each day to carry the peak load.

13. The operating diagram relating to a dry year (Figure No. 17) is based upon the extreme condition in which, as the result of a monsoon failure, the total runoff is only 50% of the average and, as a consequence, the Supa reservoir is drawn down to its lowest level at the end of the dry season. Under these conditions the method of operating the group of power stations would be generally similar to that described for a normal year. The Kaneri reservoir would, however, spill considerably less water and the power station would be kept on full

load for a correspondingly shorter period. In consequence the dry season output from the Kaneri station would be reduced since the stored water would have to be utilised over a longer period.

14. For similar reasons the dry season output from the Lower Kalinadi station would also be reduced as the result of restriction in the regulated flow. Since the unregulated flow to the Nagjhiri station would be much less than that available in a normal year, the demand on the Supa reservoir would have to be maintained for a longer period, the general reduction in the total flow resulting in a reduced output from the Nagjhiri station.

15. The Supa station would also operate much as in an average year, and, by drawing upon the reserve storage, the mean flow would be maintained at a value much in excess of that corresponding to the natural runoff available from a poor monsoon. The heavy draft on storage would, however, lead to a reduced head on the Supa station with consequent reduction in the output of electrical energy.

16. By careful manipulation of the storage reservoirs it would be possible, apart from occasional brief periods during the monsoon, to maintain a uniform output from the Group over the entire year. During these brief periods there would be however, as the diagram indicates, a surplus of power available from the Nagjhiri station.

CHAPTER VIII.

DEVELOPMENT IN STAGES.

1. We have considered in some detail the methods by which the great power resources of the Kalinadi basin could best be developed. There are a number of possibilities depending upon the rate at which it is considered necessary to plan the development of electricity supplies in the Bombay Presidency and adjacent territories.

2. If it is assumed that it is necessary to provide power in large increments over a comparatively short period then it would be desirable to develop the main Nagjhiri station as soon as possible. This station would be of little use without the Supa storage reservoir and consequently the Supa development would be required first to establish control of the river, followed by the Nagjhiri works. These two stations would provide between them 440,000 kW. of installed plant, or about 75% of the ultimate development.

The Lower Kalinadi would then follow, to take advantage of the regulation already obtained, and finally development would be completed by the construction of the Kaneri section of the works.

3. If on the other hand power is not required in large increments, at least in the early stages of development, then the construction of the Nagjhiri section should be delayed, since it would be costly to develop it for small increments of installed plant capacity.

We have considered a limited objective defined by the following conditions:-

- (a) An initial annual demand of about 250 million firm kWh combined with a firm maximum demand of 50 MW.
- (b) Provision for extension to meet a firm demand of upwards of 500 million kWh. combined with a firm maximum demand of 100 MW.

4. We have investigated a number of alternative methods of meeting the proposals set out above including the following:-

- (i) Combination of the Supa and Kaneri Schemes.
- (ii) Partial development of the Nagjhiri scheme in combination with partial storage at Supa.
- (iii) Combination of the Kaneri and Lower Kalinadi schemes.
- (iv) Combination of the Supa and Lower Kalinadi schemes.

5. We find that, owing to inadequate storage, alternative (iii) would be incapable of meeting a firm demand of 500 million kWh. when associated with a maximum demand of 100 MW.

Partial development of the Nagjhiri scheme in combination with partial storage at Supa would not produce firm energy during the first phase of development at a rate which would show any advantage over that resulting from the full but independent development of either the Supa or Kaneri schemes. When extended to

meet a maximum demand of 100 MW, however, some saving in the overall cost of energy, as compared with the combination of Supa and Kaneri, could be obtained. Such a proposal to provide limited storage at Supa would, however, involve serious technical difficulties in the subsequent raising of the dam and its incorporation with the power station which would ultimately form part of the completed scheme. For these reasons we have come to the conclusion that the best solution lies in a combination of the Supa and Kaneri schemes.

6. An initial demand of 250 million kWh. could be met by the Supa development. Two machines of 30 MW each would be able to provide a firm power output of 50 MW except on those rare occasions when the reservoir was heavily depleted after a series of dry years. A third machine would later be installed when it became necessary to meet this contingency and provide reserve generating capacity.

The firm kilowatt output at the Supa dam is dependent on the minimum head created by the dead storage. If this dead storage is reduced then the firm kilowatts fall off rapidly owing to the reduction in the minimum head on the turbines. In effect, the firm power development at Supa is a consequence of the provision of this dead storage and without it Supa could only produce secondary power.

7. Providing the demand for firm energy did not exceed 250 million kWh. it would be possible to lower the top water level proposed for the Supa reservoir by 60 ft. and still maintain both the firm output and the dead

storage. Such a reduction in the Supa storage would, however, react unfavourably on the ability of this reservoir to make good, in the future, deficiencies in the storage available on other sections of the scheme.

Apart from this objection, any appreciable reduction in the height of the Supa dam would introduce serious engineering difficulties. The proposed top water level (1825 ft.) would permit the discharge of flood water over a separate saddle to the north of the dam, thus bypassing the power station. If this level were reduced by 60 ft. it would then be necessary to deal with the flood water by discharging it over the dam itself. It will be seen from the accompanying perspective of the dam (Plate 2) that this would introduce difficult technical problems in the disposal of flood water. A further objection to reducing the height of the dam is to be found in the increase in the frequency with which excessively low water levels in the reservoir would cause difficulty in maintaining the kilowatt output. It would become a regular seasonal condition instead of only a rare condition arising from a series of dry years.

We are of the opinion therefore that when the Supa dam is built it should be constructed to the full height necessary for the ultimate scheme of development.

8. The development of the Kaneri scheme would provide an alternative method of meeting an initial demand for 50 MW. The scheme proposed calls for a dam 240 ft. high above river bed level and would, if considered as an independent development, provide a firm

annual output of 240 million kWh. This firm output is dependent upon the amount of storage provided and could be increased to 260 million kWh. by raising the dam to a relatively small extent.

9. Before it would be possible to fix definitely the height of the Kaneri dam, extensive sub-surface investigations would have to be carried out. Pending such further investigations we have provisionally adopted a top water level of 1570 for the Kaneri reservoir and on this basis we have estimated that the cost of producing 240 million units of firm energy would be 0.296 annas per unit equivalent to a capital expenditure of Rs.7.95 crores. These estimates include the cost of the considerable programme of road construction which would be necessary if the Kaneri scheme were to be undertaken as the first stage development, and which must initially be carried by the Kaneri scheme alone.

10. If the Supa scheme were to be selected as the first stage development the total capital expenditure would amount to Rs.8.40 crores, equivalent, on the basis of a firm annual output of 250 million kWh, to 0.305 annas per kWh. In comparing these figures it should, however, be remembered that owing to reduction in head, the initial installation of 60 MW at Supa will, in an exceptionally dry year, only meet a demand of 33 MW, and to this extent the value of the Supa station will be more restricted than would be the case if Kaneri were selected as the first stage.

11. A combination of the Supa and Kaneri schemes would, for the reasons explained in the previous Chapter, result in a greater output than would be possible if they were operated separately, the combined output amounting to not less than 540 million firm kWh per year at an overall cost of 0.273 annas per kWh. The two power stations would together be capable of meeting a maximum demand in excess of 100 MW.

It should be noted that the foregoing estimates include, in both cases, the cost of transmission between the power stations and the proposed switching station at Nagjhiri, together with the cost of transformation to 220 kV. If during the early years of development the output from either of the power stations were transmitted at a lower voltage than 220 kV, the cost per kilowatt-hour sent out would be correspondingly reduced and there would be a slight increase in output due to the elimination of the transformer losses associated with the Nagjhiri switching station.

12. The combination of the Supa and Lower Kalinadi schemes would again offer possibilities for meeting a demand limited to about 100 MW. We consider it would be possible to obtain the necessary firm output from Supa and Lower Kalinadi in combination at approximately the same cost as from Supa and Kaneri in combination. Such a proposal is however dependent on the large storage provided by the Supa reservoir. For this reason a combination of Kaneri and Lower Kalinadi would not achieve the same results.

13. Setting aside the partial development of the Nagjhiri, there are therefore two alternatives for limited development.

1. The Supa scheme followed by either the Kaneri or the Lower Kalinadi scheme.
2. The Kaneri scheme followed by the Supa scheme.

It will be seen that selecting Supa for the initial development would leave two further courses open for a second limited stage, which would be subject to further investigation. Selecting Kaneri, however, would leave no alternative but to follow with Supa when extension became necessary.

14. It will be noted that the relative economy of the two possibilities for the first stage of development is slightly in favour of Kaneri as compared with Supa. The difference is, however, marginal, and before taking any definite decision to proceed with the Kaneri works it would be advisable to initiate further investigations of both the Kaneri and Supa schemes.

15. It is apparent therefore, that at whatever rate the power demand increased, the Supa scheme should be developed at an early stage. In view of the difficulty of forecasting how the demand for power will grow once a new and important source of energy becomes available, careful consideration should be given to the advantages of starting the Supa scheme first in spite of a slightly adverse economic comparison with Kaneri.

Details of the estimated capital and annual costs will be found in Chapters XIII and XIV.

CHAPTER IX.

COMMUNICATIONS

General Considerations.

1. Up to the present there has been little development within the Kalinadi basin of either railways or all-weather roads. The existing facilities, shown on Figure No. 18, are generally remote from the works proposed in this Report. An all-weather road system connecting the various parts of the development is essential for the efficient operation of this scheme. A good road system is also very necessary for construction purposes to allow rapid and economic haulage of the large quantities of materials required. It is probable also that the improved road works necessary for the power development would assist in the general economic development of the region.

Ports.

2. It has been assumed that all imported plant and materials would be brought by rail from Bombay, since the facilities at Karwar are very limited and Marmagao is in Portuguese territory.

Railways.

3. The only main line railway in the Kalinadi Basin is the metre gauge line, operated by the Madras and Southern Mahratta Railway, passing through Londa and Alnavar, with a branch running westwards from Londa through Castle Rock into Portuguese territory. These lines traverse the northern edge of the Kalinadi basin. There are junctions at Londa, from which the metre gauge main

line runs northwards to connect with the broad gauge line of the Great Indian Peninsula Railway at Poona, and at Alnavar whence a branch line runs south to Dandeli, which is the nearest railhead to the proposed works.

Studies we have made lead us to believe it would be uneconomical to undertake any extension of the railway system solely to assist in the construction of the various works described in this Report.

Existing Roads.

4. Two main all-weather roads cross the catchment area. One runs from east to west, via Alnavar and Londa into Goa. The other runs south from Belgaum down the eastern side of the Kalinadi basin via Alnavar, Haliyal and Yellapur to Karwar at the mouth of the Kalinadi River. A second north-south road runs from Khanapur to Karwar via Londa and Supa, but south of Supa this road is not negotiable by vehicles when the rivers are in flood.

The area is traversed by a network of secondary roads and tracks which at present facilitate forestry operations and serve the scattered population. Many of these are negotiable by light vehicles during dry weather only, but would not be suitable for heavy construction traffic without considerable improvements.

Proposed Road Works.

5. It has been assumed that all imported materials and plant would be brought by rail to Dandeli and then transported by road to the individual sites, although for the Supa scheme it is possible that Londa might be an equally convenient point for the transshipment of freight from rail to road.

The permanent roads which we consider will be necessary for the construction and operation of the development are described below on the assumption that the projects are constructed in the order given. There would in addition be temporary roads to tunnel adits, quarries and the like.

(a) Supa Project (Figure No. 10):

The main works required would be a bridge over the Kalinadi near the railhead at Dandeli and the re-location of the inundated section of the Londa-Karwar road to run over Supa dam and alongside the eastern shore of the reservoir. The existing road running south from Dandeli to Gund, improved as necessary, would be linked to the latter by a short connecting road. An access road would lead from the southern end of the spillway bridge down to the generating station at the base of the dam. The road running west from Samjoda would be replaced by a new road to the west of the reservoir.

(b) Kaneri Project (Figure No. 14):

Improvement of the Dandeli-Gund road would be continued from the point reached in (a) as far as Gund. A short length of this road would be re-located to pass over the spillway and the Kaneri dam. An access road would be constructed from Gund to the generating station on the right bank of the Kaneri River. The Gund-Amboli road would be re-located to run along the southern side of the reservoir.

(c) Nagjhiri Project (Figure No. 12):

The road from Dandeli to Bomanhalli via Kulgi would be improved and the short section inundated by the Dandeli headpond would be re-located to run alongside the latter and over the diversion weir at Bomanhalli. The road running south from Kulgi would be improved and extended to provide access to the generating station on the right bank of the Kalinadi river.

(d) Lower Kalinadi Project (Figure No. 16):

Improvements would be made to the existing roads from Yellapur to Ganesh Gudi and from Gund to Bogrigadde. The latter road would need re-location to pass around an arm of the reservoir. A new road would be constructed from Ganesh Gudi to the dam. Access to the power station would be obtained from the Bogrigadde road.

6. The mileage of the proposed road works is tabulated below :

TABLE 6.

Mileage of Proposed Road Works.

Project.	New Roads.	Improvement of existing roads.
Supa	23	5
Keneri	11	12
Nagjhiri	7	16
Lower Kalinadi	12	18
TOTAL DEVELOPMENT	53 miles	51 miles

The cost of the foregoing road works together with their associated bridges, has been included in the estimates of capital expenditure to be found in Chapter XIII.

Telegraph.

7. At present there are public telegraph offices at Supa and Yellapur in addition to which the Government Forest Department maintain a telegraph system in the area. The Madras and Southern Mahratta Railway telegraph system extends to Dandeli.

Extension of the existing facilities to give direct communication to the main sites would assist in the expeditious construction of the proposed works.

CHAPTER X.

TYPES AND OUTPUTS OF TURBINES.

1. No technical difficulties arise in choosing suitable types of turbines and associated plant for the four power stations described in our Report. The Supa and Lower Kalinadi stations will be combined with their associated dam and will form an integral part of the structure. The water intakes to the turbines are therefore relatively short and problems of difficult regulation and hydraulic stability, sometimes associated with long intakes at relatively low heads, do not arise. The lengths and dimensions of the pipelines downstream of the surge chambers at Kaneri and Nagjhiri are such that stability conditions can be met without difficulty, although it will be necessary to provide deflector gear on the former machines and relief valves on the latter in order to ensure reasonable speed regulation under conditions of load rejection.

2. The head characteristics of the four stations are summarised in Table 7 below.

TABLE 7.
POWER STATION HEAD CHARACTERISTICS.

STATION	<u>HEAD CHARACTERISTICS</u>	
	Maximum Net Head on Full load--Ft.	Net Head for Rated Output Ft.
SUPA	272	170
NAGJHIRI	1005	990
KANERI	1170	1050
LOWER KALINADI	185	170

3. Vertical shaft turbines with direct coupled alternators can be used under the hydraulic conditions obtaining at the stations. The types of turbine recommended are as shown in Table 8.

TABLE 8.

RECOMMENDED TYPES OF TURBINE.

STATION	TYPE OF TURBINE
SUPA	FRANCIS
NAGJHIRI	FRANCIS
KANERI	MULTIPLE JET PELTONS
LOWER KALINADI	FRANCIS

4. Tests made on the water of the Kalinadi River show that erosive material in suspension is present during a large proportion of the year and, although the setting of the turbines has been chosen to limit damage due to cavitation, it is recommended that runners and other components liable to erosion should be constructed of stainless steel to ensure a long and trouble-free life for the machines.

5. The size of the individual power station units as recommended below has been selected with due regard to the ultimate installed capacity of the Group, account being taken of the limitations likely to be imposed by transportation problems, provision of a reasonable investment in reserve plant, and the maintenance of satisfactory operating conditions during the early years of load development.

The outputs of the power station units are summarised in Table 9 below.

TABLE 9.

RECOMMENDED INSTALLED PLANT CAPACITIES.

STATION	RECOMMENDED PLANT INSTALLATION		
	No.Units.	Unit Capacity MW.	Total Installed MW.
SUPA	3	30	90 *
NAGJHIRI	7	50	350
KANERI	3	25	75
LOWER KALINADI	3	25	75
TOTAL.....	16	-	590

* Note Initial Development
2 - 30 MW. Units.

6. Units of the types recommended, with considerably larger outputs than those proposed above, have been operating satisfactorily for a number of years under more onerous hydraulic conditions than those likely to be encountered on the Kalinadi scheme. The choice appears, therefore, to be fully justified and in accordance with modern hydro-electric practice on both technical and economic grounds.

7. Whilst the adoption at the Nagjhiri power station of a larger number of smaller units than the 7 - 50 MW. machines proposed would result in less expenditure being

invested in standby plant during the early stages of development, the restricted site available for the power house would make it difficult to accommodate the longer building which would be entailed and it would not, in our opinion, taking the scheme as a whole, result in any overall economy. In the event of a very large demand being available in the immediate future, we would recommend that serious consideration be given to the installation of units with a larger output than 50 MW as now recommended.

8. In view of the somewhat isolated character of the power stations and the frequency of lightning storms, it is recommended that the auxiliaries at Supa and Nagjhiri should be supplied from auxiliary house service generators, the supplies from which will be kept completely separate from those exported by the main units. Accordingly provision has been made in the initial development for the installation of 1 - 750 kW. house unit at Supa and 2 - 1500 kW. house sets at Nagjhiri. In the latter station one of the house sets would act as a standby to the other. These house service units are included in the accompanying estimates of capital cost.

9. It has been necessary to give some consideration to the amount of reserve plant carried by the project as a whole. It is our usual practice to allow spare capacity equal to either 10% of the probable maximum load or to the largest machine on the system. In this connection it is necessary to take into account the

reliability of the local transmission interconnections referred to in Chapter XII since it is proposed that the three subsidiary generating stations should ultimately be connected to the Nagjhiri 220 kV. busbars by single circuit overhead lines. From the point of view of reserve generating plant the availability and utilisation of the subsidiary stations would permit one of these circuits being out of service either because of fault conditions or because of line maintenance.

CHAPTER XI.

GENERAL DESCRIPTION OF ELECTRICAL AND
MECHANICAL WORKS.

1. The general electrical and mechanical design and layout of the plant proposed for each of the power stations do not give rise to any major difficulties. The arrangement of machines and ancillary equipment would therefore be generally similar to that normally adopted in modern hydro-electric stations of the type under consideration.
2. The ultimate development of more than 500 MW. of hydro-electric power in the Kalinadi basin and industrial development in the Presidency will be accompanied by the necessity to transmit energy over long distances. For the purposes of this Report, therefore, it has been assumed that this will be effected at a voltage of 220 kv.
3. After careful consideration of the various possible arrangements of transforming stations for stepping up the voltage of generation (11 kv) to the transmission voltage of (220 kv), it is recommended that, at Nagjhiri, each generator should be connected separately to its own main unit transformer, as shown in the single line diagram (Figure No. 19) attached. All main switching would be done at the transmission voltage (220 kv) and it is proposed to locate both switchgear and step-up transformers at an outdoor

substation in the immediate vicinity of the generating station. The generators would be connected to the transformers by means of underground cables. At the subsidiary stations each generator would be provided with its own 11 kV. circuit breaker and the output would be stepped up through a single transformer to the voltage required for transmission to Nagjhiri.

4. The three smaller stations at Supa, Kaneri and Lower Kalinadi would be designed in accordance with modern practice for non-attended operation and remote control from the major station at Nagjhiri, which would be fully attended and responsible for the general control and operation of the subsidiary stations and of the lines connecting the remote stations with Nagjhiri. In the initial stages of development the Supa station would be operated on an attended basis but when Nagjhiri comes into operation, remote control would be the most effective and economic method of supervision. On this basis the Supa station would serve as a training ground for station operators required for the major station at Nagjhiri.

5. In laying out the Nagjhiri power station and switching station, provision would be made for self-contained control and relay rooms, designed in accordance with modern practice. These rooms would accommodate all control, indicating, metering and communication equipment essential for properly supervising the operation of the three subsidiary stations. Provision would be made to enable visitors to inspect the station without interfering with the duties of the

operating staff. The station would contain its own laboratory and workshop for over-hauling the plant, and space would be provided in each of the subsidiary stations for erection and dismantling of the machines. The cost of all these services has been included in the estimates contained in this Report.

CHAPTER XII.

LOCAL INTERCONNECTING TRANSMISSION SYSTEM.

1. In view of the relative location of the unattended power stations at Supa, Kaneri and Lower Kalinadi, it is desirable that the aggregate output should be collected at one central point for ultimate transmission to distant load centres. It is suggested that Nagjhiri is the most suitable location and the single line diagram, Figure No. 19 attached to this Report, indicates the character of the transmission system proposed for collection of the power generated by the four stations.

2. The distance of the smaller power stations from Nagjhiri is shown in Table 10 which follows, and it will be seen that the total length of transmission lines required for power collection is approximately 40 miles.

TABLE 10.

MILEAGES OF LOCAL TRANSMISSION CIRCUITS.

ROUTE	LENGTH OF LINE MILES
NAGJHIRI - SUPA	20 Miles
NAGJHIRI - KANERI	7 Miles
NAGJHIRI - LOWER KALINADI	<u>13 Miles</u>
TOTAL	40 Miles

3. From calculations which we have made relating to alternative transmission systems for the whole project, we consider that a voltage of 110 kV. would be the most economical and reliable. We therefore propose that the output from Supa, Kaneri and Lower Kalinadi should be transmitted to Nagjhiri over single circuit lines supported on steel towers. In our view the reliability of a single circuit as opposed to double circuit lines for the interconnections with the subsidiary stations would not, for the outputs involved, justify the additional capital expenditure required for their duplication, especially as adequate provision would be made at Nagjhiri for standby plant.

4. The estimates include the necessary step-up transformers and the associated 220 kV. switchgear.

5. The losses in the transformers, cables and transmission lines between each of the stations referred to have been calculated on the basis of the station plant capacities indicated on the diagram and the appropriate annual load factors. The total number of firm units delivered from the various power stations to the 220 kV. busbars of the Nagjhiri Switching station would amount to approximately 2800 million kWh. per annum, and this output would be available for transmission to near or distant load centres. Table 11 gives details of the firm outputs attributed to each of the four power stations.

TABLE 11.

FIRM ENERGY GENERATED AND DELIVERED.

STATION	MILLIONS OF kWh PER YEAR	
	Firm kWh Generated	Firm kWh delivered to Nagjhiri
SUPA	265	250
NAGJHIRI	1830	1820
KANERI	325	320
LOWER KALINADI	420	410
TOTAL	2840	2800

6. It is difficult to draw a line of demarcation separating generating station from transmission plant. In the estimates which follow we have debited the generating stations with the cost of all equipment and transmission lines necessary to collect the output and deliver it to the 220 kv. busbars. No provision has been made for switchgear or other equipment for connecting the 220 kv. busbars to the transmission system proper, since this is considered to be outside the scope of this Report.

7. For the first stage development based on either the Supa or Kaneri power stations, it will no doubt be more convenient to dispose of the output at Dandeli at 66 kV. or 110 kV. and subsequently to loop these circuits into the switching station at Nagjhiri.

CHAPTER XIII.

ESTIMATED COST OF PROJECT.

1. On the assumption that the necessary plant, labour and materials could be made available in sufficient quantities, we estimate that the first stage of the works (i.e. either the Supa or Kaneri schemes) could be carried out in about 5 years after completion of all necessary site investigations.
2. It may be assumed that should it be necessary to carry the whole of the Kalinadi scheme through to completion in the shortest possible time, a total period of not less than 10 years would be required. Such a vast programme of constructional work would, however, make very heavy demands upon both the material and human resources of the country, and it could only be accomplished in the time suggested provided the work were accorded a high priority in relation to other demands on the national resources.
3. Under the present unsettled conditions it is necessarily difficult to make an accurate forecast of the ultimate cost of the scheme, the construction of which is likely to be spread over a considerable period of time and the programming of which is so intimately bound up with the future growth in the demand for electric power. It is believed, however, that the estimates of cost, given in Tables 12, 13 and 14 which follow, will be found sufficiently reliable for the purposes of this Report.

4. The estimates are based upon prices ruling in mid 1948 and take due account of local conditions. The estimates include appropriate allowances for contingent and temporary works, engineering costs and interest during construction.

No allowance has been made for the cost of land and compensation.

TABLE 12.

ESTIMATED CAPITAL COST OF WORKS
ASSOCIATED WITH THE FOUR MAIN SECTIONS OF THE
SCHEME

Total Plant Installation
590 MW.

Item No.	Item	Cost in Lakhs of Rupees			
		Supa 3-30 MW Units	Nagjhiri 7-50 MW. Units	Kaneri 3-25 MW. Units	Lower Kalinadi 3-25 MW. Units
	<u>Civil Engin- eering Work.</u>				
1	Roads and Bridges	35	24	31	27
2	Dams	511	93	363	285
3	Tunnels	-	559	129	-
4	Pipelines	25	193	75	25
5	Generating Stations	60	49	20	65
6	Total cost of Civil Engin- eering Works	631	918	618	402
7	Hydro-Electric & Mechanical Plant	223	370	117	200
8	Electrical Plant	29	120	28	25
9	Local Trans- mission System	49	128	32	38
10	TOTAL ESTIMATED COST	932	1536	795	665
	Capital Cost per MW. of in- stalled Plant	10.36	4.39	10.60	8.87

TABLE 13.

ESTIMATED CAPITAL COST OF COMPLETE
SCHEME

Total Plant Installation
590 MW.

Item No.	Item	Cost in Lakhs of Rupees.
1	Roads and Bridges	117
2	Dams	1252
3	Tunnels	688
4	Pipelines	318
5	Generating Stations	194
6	Total Cost of Civil Engineering Work	2569
7	Hydro-Electric and Mechanical Plant	910
8	Electrical Plant	202
9	Local Transmission System	247
10	TOTAL ESTIMATED COST	3928
	Capital Cost per MW. of Installed Plant.	6.66

TABLE 14.

ESTIMATED CAPITAL COST OF SUPA AND KANERI
SCHEMES AS INDEPENDENT DEVELOPMENTS.

Item No.	Item.	Cost in Lakhs of Rupees.		
		Supa 2-30 MW Units.	Kaneri 3-25 MW. Units.	Supa - Kaneri Combined 135 MW Total
1	Roads and Bridges	35	31	66
2	Dams	511	363	874
3	Tunnels	-	129	129
4	Pipelines	25	75	100
5	Generating Stations	55	20	75
6	Total Cost of Civil Engineering Work	626	618	1244
7	Hydro-Electric and Mechanical Plant	150	117	267
8	Electrical Plant	20	28	48
9	Local Transmission System	44	32	76
10	TOTAL ESTIMATED COST	840	795	1635
	Capital Cost per MW. of Installed Plant	14.00	10.60	12.10

CHAPTER XIV.

ANNUAL COST OF OPERATION.

1. In Appendix IV will be found a detailed study of the annual cost of operating the four power stations and the associated interconnecting transmission system. A summary of the annual costs is given in the following Tables: 15, 16 and 17.

TABLE 15.

ESTIMATED ANNUAL COST OF THE
FOUR MAIN SECTIONS OF THE SCHEME.

Total Plant Installation
590 MW.

Item No.	Item	Annual Cost in Lakhs of Rupees			
		Supa 3-30 MW. Units.	Nagjhiri 7-50 MW. Units.	Kaneri 3-25 MW. Units.	Lower Kalinadi 3-25 MW.
1	Interest at 3½%	32.62	53.68	27.83	23.28
2	Sinking Fund	7.84	17.36	6.79	6.95
3	Total Fixed Charges	40.46	71.04	34.62	30.23
4	Operating Expenses, Maintenance and Management	11.52	21.24	9.68	8.19
5	TOTAL ANNUAL COST	51.98	92.28	44.30	38.42

TABLE 16.
ESTIMATED ANNUAL COST OF THE
COMPLETE SCHEME

Total Plant Installation
590 MW.

Item No.	Item	Annual Cost in Lakhs of Rupees.
1	Interest at $3\frac{1}{2}\%$	137.41
2	Sinking Fund	38.94
3	Total Fixed Charges	176.35
4	Operating Expenses, Maintenance & Management	50.63
5	TOTAL ANNUAL COST	226.98

TABLE 17.

ESTIMATED ANNUAL COST OF THE SUPA
AND KANERI SCHEMES AS INDEPENDENT
DEVELOPMENTS.

Item No.	Item	Annual Cost in Lakhs of Rupees		
		Supa 2-30 MW Units	Kaneri 3-25 MW. Units	Supa-Kaneri Combined 135 MW. Total
1	Interest at $3\frac{1}{2}\%$	29.40	27.83	57.23
2	Sinking Fund	6.29	6.79	13.08
3	Total Fixed Charges	35.69	34.62	70.31
4	Operating Expenses, Maintenance & Management	12.07	9.68	21.75
5	TOTAL ANNUAL COST	47.76	44.30	92.06

CHAPTER XV.

COST OF ENERGY.

1. In Table 18 below is given the estimated cost of delivering firm energy from the completed scheme at the 220 kV busbars of the Nagjhiri switching station.
2. In Table 19 is given the corresponding costs of delivering firm energy at the 220 kV busbars from the Supa and Kaneri stations, both individually and from the combined Supa and Kaneri stations.
3. In arriving at these estimates we have taken no account of any additional revenue which may be obtained should it be found possible to dispose of the considerable surplus energy which would be available in a year of normal rainfall.

TABLE 18.

COST OF FIRM ENERGY DELIVERED
FROM THE COMPLETE SCHEME.

Item No.	Item.	Complete Scheme.
1.	Maximum Installed Capacity - MW.	590
2.	Annual cost of operation Lakhs of Rupees.	226.98
3.	Firm output available at 220 kV at Nagjhiri collecting station - Million kWh.	2800
4.	Cost per kWh. at the 220 kV busbars of Nagjhiri collecting station - annas	0.130

TABLE 19.

COST OF FIRM ENERGY DELIVERED FROM
THE SUPA AND KANERI STATIONS.

Item No.	Item	Supa 2-30 MW Units	Kaneri 3-25 MW Units	Supa-Kaneri Combined
1.	Maximum Installed Capacity - MW.	60	75	135
2.	Annual cost of operation Lakhs of Rupees.	47.76	44.30	92.06
3.	Firm output available at Nagjhiri collecting station. Million kWh.	250	240	540
4.	Cost per kWh. at the 220 kV busbars of Nagjhiri collecting station. Annas.	0.305	0.296	0.273

CHAPTER XVI.

EFFECT ON LOCAL ECONOMY.

1. The Kalinadi basin may be considered as divided into two distinct regions of which the western portion comprises a forest belt while the eastern portion consists mainly of agricultural land. The latter will not be directly affected by the works described in this Report.
2. The forest region is at present being carefully developed by the Forestry Department under a long term policy designed to increase the output of high quality timber and maintain its existence as a forest. It is largely scheduled as a game reserve. Within the forest area there is a certain amount of local industry such as the ply wood factory at Dandeli; manganese ore is also mined in the district on a limited scale.
3. The local population of the forest is dispersed in a number of small villages with some concentration at Supa. The villages are supported by small patches of cultivation which have been reclaimed from the jungle. There is a considerable seasonal influx of labour for forestry work.
4. Apart from the temporary disturbance necessarily associated with the execution of any large scale engineering works, the project which we have described will have considerable effect on the economy of the forest belt.

The creation of the Supa storage reservoir will inundate considerable tracts of jungle together with the town of Supa and will entail the resettlement of the population affected. The Kaneri and Lower Kalinadi reservoirs will, however, not have much effect upon existing settlements as the areas in question are largely uninhabited. The Dandeli headpond will flood some of the land belonging to the villages of Don Shigur and Bada Shigur, and the diversion of water from below the Bomanhalli weir will affect the communities of Bomanhalli and Vincholi which are at present dependent on the river for their water supply.

5. We have already referred to the necessity for opening up communications and providing an extensive system of new roads and bridges. The improved communications which will result from the construction of the works will greatly facilitate the general development of the area and will make possible the establishment of new communities and local industries which are bound to affect favourably the life of the people.

6. As explained in Chapter IX. we have examined the relative costs of road and rail construction and we have come to the conclusion that the execution of the works described in our Report will afford no economic justification for extending the existing railway system. There is, however, the possibility that the general development of the area will give rise to the exploitation of the mineral deposits which are known to exist. Among the most valuable of these may be mentioned the manganese

deposits in the high forest areas both to the east of the Kalinadi between Dandeli and Bomanhalli, and in the hills both north and south of Supa. Kaolin is also known to exist in the vicinity of Castle Rock and should these and other valuable minerals be worked in the future, heavy freight traffics are likely to develop which may well alter the economic balance between road and rail transport. In the absence of such heavy mineral traffics we believe the adoption of road transport will prove the most economical method of handling the products of both the forests and such light industries as may arise.

7. The regulation of the flow of the Kalinadi will have a considerable effect on the use of the river generally. The wide seasonal fluctuations in the level of the Supa reservoir will introduce certain difficulties but, generally, the reservoir will provide convenient access to the westerly portion of the forest belt and afford a means of collecting timber to a central point.

8. The flow in the stretch between the Supa dam and the Dandeli headpond will be closely controlled and there will be ample opportunity for using this stretch of the river for water borne transport. From the Bomanhalli weir to the Nagjhiri power station the river will, during the dry season, carry only such compensation flow as may be necessary to maintain any communities retained on this stretch of the river. During the monsoon, however, the inconvenience arising from floods in the river will be greatly reduced as the result of the abstraction of the water from the upper reaches into storage reservoirs.

9. The Lower Kalinadi reservoir with a normally high water level will provide access to the thickly wooded slopes of the valley at present worked from the plateau above, while the provision of a log chute at the dam would enable timber to pass right down to Karwar on the regulated flow. The stretch to Karwar would be generally the best controlled reach of the river and would offer the possibility of water borne transport working upstream from Karwar. The latter has been suggested as the site of an all weather port and should this proposal ever be carried out considerable benefits will accrue, not only from the reduction in the floods to which the river is now subject during the monsoon months, but also from the greatly reduced silt load which will be carried by the river as the result of the creation of large storage reservoirs on its upper reaches.

10. The Kaneri reservoir although subject to large fluctuations in level would also open up the higher reaches of the river and it would be possible to pass timber down the river during the monsoon when the reservoir was spilling.

It will thus be seen that the regulation of the river may have far reaching effects on the methods of extracting timber from this important forest area.

APPENDIX I.

RESULTS OF PRELIMINARY BORING PROGRAMME

MAY 1947 TO MAY 1948.

A. Supa Dam Site.

Three core borings were drilled, a total of 156 feet. The borings revealed sound foundation conditions in the bed of the river and on the right bank near a cavernous lenticle of sideritic quartzite.

B. Bomanhalli Weir Sites.

Fiftyeight percussion bores were sunk, a total boring length of 1810 feet. Of these bores fourteen did not reach rockhead either because of the limited depth to which the rigs could bore, or else they landed on a boulder which could not be broken. Of the remaining bores, there are five doubtful cases where it cannot be stated with any certainty that rock was reached and not a boulder.

These borings reveal that particular care will be required in the final selection of the weir site and a considerable depth of overburden must be allowed for in its design.

C. Nagghiri Tunnel Site.

Four percussion bores were sunk along the preliminary tunnel line, a total of 110 feet of boring. Although rock was not reached in one bore at a depth of 40 feet, no undue difficulty is expected on this tunnel line due to lack of sufficient rock cover. The tunnel proper would be approached by open cut at the intake and as far as necessary to provide a satisfactory rock face from which driving operations could be undertaken.

APPENDIX II.

RAINFALL RECORDS USED FOR PREPARATION OF THE
ISOHYETAL MAP - FIGURE No. 3.

A. Department of Agriculture - Poona.

Supa - Monthly Rainfall	1876 - 1946
Haliyal - Monthly Rainfall	1875 - 1946
Karwar - Monthly Rainfall	1875 - 1946

These gauges are in the Kalinadi Basin. There are also long term monthly records from 9 gauges in adjacent catchment areas.

B. Customs.

Castle Rock - Annual Rainfall	1921 - 1946
Daily Rainfall	1940 - 1946

C. Madras and Southern Mahratta Railway.

Castle Rock - Daily Rainfall	1933 - 1946
Monthly Rainfall	1916 - 1920
Londa Monthly Rainfall	1939 - 1941
Daily Rainfall	1942 - 1946

D. Bombay Electric Grid.

Monthly rainfall at 30 gauges in the Kalinadi Basin. These records vary in duration from one to seven years and were taken only during the period from June to November.

E. Forest Department.

Dandeli - Daily Rainfall	1946
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APPENDIX III.SILT SAMPLES TAKEN AT SUPA AND BOMANHALLI.

SUPA.

Date	Location		Total Depth D Ft.	Dry silt - Grammes per litre	
				at Depth 1'0" below Surface	at Depth 0.6 D Ft.
1.9.47	500 yds. upstream of con- fluence	I	32'	0.180'	0.177
		II	28'	0.190	0.180
		III	40'	0.170	0.183
4.9.47	½ mile upstream of con- fluence	I	25'	0.176	0.190
		II	20'	0.176	0.189
		III	30'	0.181	0.179
6.9.47	At con- fluence of Pandri and Kalinadi Rivers	I	18'	0.176	0.178
		II	20'	0.163	0.168
		III	22'	0.174	0.181
AVERAGE				0.176	0.180

LOCATION of samples.

I ... 15 feet from right bank
 II ... 5 feet from left bank
 III ... 10 feet from left bank

BOMANHALLI.

Date	Location	Dry silt - Grammes per litre at Depth 1'0" below surface.
30.8.47	Near Temporary River Gauge	0.062
31.8.47		0.072
1.9.47		0.072
2.9.47		0.074
3.9.47		0.070
4.9.47		0.072
5.9.47		0.065
6.9.47		0.071
AVERAGE		0.070

APPENDIX IV.

DETAILED STUDY OF ANNUAL COSTS
OF OPERATING THE HYDRO ELECTRIC STATIONS
AND ASSOCIATED LOCAL TRANSMISSION SYSTEM.

1. The annual cost of operating the hydro-electric stations and associated local transmission system may be broadly divided under the following headings :-

- (a) Interest on Capital.
- (b) Sinking Fund.
- (c) Rates and Taxes.
- (d) Operating Costs including Salaries and Wages.
- (e) Maintenance and Repairs.
- (f) Management.
- (g) Wayleaves for Transmission Line Right of Way.

2. An estimate of the operating costs under each of these headings is given below.

(a) Interest

It has been assumed that a loan will be obtained for the project and that interest will be payable thereon at the rate of $3\frac{1}{2}$ per cent. per annum. The total capital cost of the works, including interest during construction and other charges, is estimated at Rs. 39.28 crores for the ultimate development. The annual interest payment on the estimated capital expenditure for ultimate stage of development amount to Rs. 137.41 lakhs.

TABLE 18.

SUMMARY OF INTEREST CHARGES.

S T A T I O N	Lakhs of Rupees	
	CAPITAL COST	ANNUAL INTEREST CHARGES at 3.5%
Supa	932	32.62
Nagjhiri	1536	53.68
Kaneri	795	27.83
Lower Kalinadi	665	23.28
TOTAL	3928	137.41

(b) Sinking Fund

In calculating the annual cost of contribution to sinking fund, the following assumptions have been made, based on the provisions of Section 68 of the 7th Schedule of the Indian Electricity Supply Bill, 1948.

- (i) Loan Charges are based on annual repayment by the fixed annuity method with interest compounded at 3 per cent. per annum.
- (ii) Loans are repaid within the period applicable to the asset concerned, the period dating from the year in which the scheme commences operation.
- (iii) That the loan periods would be as follows :-
 - (a) Hydro-Electric Work.
 - (i) Dams, Tunnels etc. 100 years.
 - (ii) Pipelines, Hydraulic Valves Gates and Control Equipment. 40 years.
 - (iii) Hydro-Electric and Mechanical Plant, including foundations and power station building. 35 years.
 - (b) Electrical Plant and Transmission System.
 - (i) Switchgear. 20 years.
 - (ii) Transformers. 35 years.
 - (iii) Underground Cables. 40 years.
 - (iv) Overhead Lines. 30 years.
- (iv) That loan repayments are made on the total estimated capital cost including interest during construction.
- (v) An allowance of 10 per cent. of the original value has been made for the residual value of the assets at the end of the amortisation period.

The following Table 19 shows that the total annual contribution to sinking fund is estimated at 7.84 Lakhs for the initial development of the Supa Power Station and Rs. 38.94 Lakhs for the ultimate development of the complete scheme.

TABLE 19.

SUMMARY OF SINKING FUND CHARGES.

STATION	CAPITAL COST Lakhs of Rupees.	SINKING FUND CHARGES
		Lakhs of Rupees.
Supa	932	7.84
Nagjhiri	1536	17.36
Kaneri	795	6.79
Lower Kalinadi	665	6.95
TOTAL	3928	38.94

It may be considered desirable during the early stages of development to suspend sinking fund payments until revenue is built up and to make a correspondingly increased contribution over a shorter period later on. The estimates in this Report, however, take no account of such a policy.

(c) Rates and Taxes

It is assumed that being in the nature of a Government Scheme, local rates would not be chargeable on land, buildings, civil engineering works, or plant. It is also assumed that no income tax would be chargeable on the interest earned by investment of sinking fund accumulation.

(d) Salaries and Wages,
Maintenance and Management.(1) Hydro-Electric Stations

Reference to the costs of operating fully attended stations similar to those described in this Report in various parts of the world indicates that the total of the annual costs under the above three headings amounts on an average to 1.25 per cent. of the total capital expenditure. At the Supa

station, however, we consider that it would be wise to assume that the cost of salaries and wages and maintenance may be higher than average in the early stages of development.

With the development of the major station at Nagjhiri the three subsidiary generating stations would be remote controlled and would not therefore be normally attended.

With large stations such as Nagjhiri, the total cost of salaries, wages, maintenance and management usually falls below the average figure of 1.25 per cent. and taking all these factors into account in conjunction with available statistics for actual station operation at similar load factors, the allowances which should be made for items c, d, e and f (salaries and wages, maintenance and management) as percentages of capital expenditure work out approximately as follows :-

SUPA Initial Development (Attended)	1.35%
Unattended Subsidiary Stations	1.10% - 1.15%
NAGJHIRI Development	1.235%

(ii) Local Interconnecting
Transmission System

The total annual expenditure in the United Kingdom for operating the British Electricity Authority transmission system under the foregoing headings is approximately 2.5 per cent. of the total capital cost.

For the conditions in the area it would be appropriate to increase the annual percentage in the case of the system under consideration. Since climatic conditions would have the effect of increasing maintenance costs beyond those experienced in more temperate climates.

We therefore are of the opinion that it would be wise to assume that the cost of repairs and maintenance, management and other expenses on the system under consideration would amount to not more than 3 per cent. per annum on the total capital expenditure involved.

(e) Wayleaves

Since the transmission lines associated with the subsidiary power stations would run through jungle and forest country we have made no allowance for the payment of wayleave rentals. Table 20 which follows, gives annual operating costs of the proposed transmission system on the basis of the above remarks.

The percentages given above have accordingly been used in Table 20 from which it will be seen that the total annual cost of salaries, wages and maintenance of management is estimated at Rs. 50.63 lakhs for the ultimate development of the complete project.

TABLE 20.

SALARIES AND WAGES, MAINTENANCE AND MANAGEMENT,
GENERATING STATIONS AND TRANSMISSION SYSTEM.

STATION	ANNUAL OPERATING CHARGES Lakhs of Rupees
Supa	11.52
Nagjhiri	21.24
Kaneri	9.68
Lower Kalinadi	8.19
TOTAL	50.63

APPENDIX V.

EXPLANATORY MEMORANDUM ON THE COST ESTIMATES

INCLUDED IN TABLES 12, 13 AND 14.

(A) SUMMARY OF WORKS IN EACH SECTION.

1. Roads and Bridges.

Under this section is included the cost of improving and re-surfacing the forest and country roads to make them fit to carry the heavy traffic which will arise during construction. Also included are the new roads and bridges necessary to provide permanent access to the works and the road diversions which will result from the inundation by the reservoirs of existing means of communication.

2. Dams.

This section includes the cost of dams, spillways, flood gates, drawoff valves and culverts, and the necessary protection works associated therewith.

3. Tunnels.

Included under this section are the necessary tunnel intakes and intake shafts together with gates, screens and appurtenant works. Also included are the surge shafts and chambers, tunnel portal works and construction shafts and adits.

4. Pipelines.

This section comprises the portal valves and valve house at the head of the pipeline, the cost of preparing the pipe track and providing a permanent inclined railway alongside the pipes for service and maintenance. It also includes the cost of all pipe foundations and anchorages.

5. Generating Stations.

Included under the heading are the power house buildings, offices, workshops, stores and garages together with any excavation or protection works for the tailrace.

6. Hydro-Electric & Mechanical Plant.

This section includes the main turbines and alternators, auxiliary turbines and alternators, and machine tool equipment but not the generator protection which is included in Section 7.

This section also includes the turbine house cranes, auxiliary cranes, machine tools and plant required for the workshops, station dewatering pumps and pipework, water supply and conditioning plant, generator, transformer and station fire fighting equipment, and the station compressed air services. It also includes oil and water storage tanks, miscellaneous pumping plant and pipework, and laboratory and testing equipment.

7. Electrical Plant.

This section comprises the power station cables for interconnecting the generators with the transmission system, 11 kV. switchgear and the various auxiliary transformers required. It also includes electrical protective equipment for the main and auxiliary generators, the station low voltage auxiliary switchgear with all the necessary remote and local control equipment, as well as the alarm and relay equipment required.

This section also provides for station batteries and charging equipment, all auxiliary cables required in the station as well as lighting, heating, power and air conditioning installations and the telephone and inter-communication system.

8. Local Transmission System.

This section includes the 11/110, 110/220 and 11/220 kV. step-up transformers associated with each power station, the 220 kV. switchgear and transmission lines required for connecting the subsidiary power stations to the 220 kV. busbars at Nagjhiri and also for the switchgear required to connect the 7 machines at Nagjhiri to the same busbars.

(B) SOME FACTORS AFFECTING
THE ESTIMATES OF CAPITAL COSTS.

INTEREST DURING CONSTRUCTION.

1. The estimates given in Tables 12, 13 and 14, Chapter XIII. include interest during construction. The amount has been calculated on the basis that idle money is reinvested at $3\frac{1}{2}$ per cent. per annum. As the amount involved is substantial and in view of the nature of the scheme it is suggested that if possible short term borrowing should be advanced at a low rate of interest during the construction period.

2. Customs Duties.

It is assumed that for a scheme of this nature no Customs Duties would be levied by the Government on plant for the permanent installations or on the contractors plant required during construction. No allowance has accordingly been made for Customs Duties in the estimates.

3. Contingencies and Engineering Charges.

Suitable allowances have been included in the estimates to cover reasonable contingencies and the cost of engineering services during construction.

4. Transport of Plant and Material to Site.

The four stations forming the Kalinadi scheme are close to the road and rail system connected to the Port of Bombay. In view of the distances involved and the loads to be carried, transport, handling and haulage charges constitute an important factor in the total erected cost of the plant required. The estimates in the Report include for

- (a) The cost of sea transport to Bombay.
- (b) The cost of rail and road haulage between Bombay and the power station sites, including the provision of suitable vehicles.
- (c) Suitable sidings with lifting facilities for off loading plant at the rail terminals.

Estimates of transport costs have been based on information available concerning transport conditions and the recommended size of the individual main generator units has been fixed as far as possible to meet the limitations imposed by :-

- (i) Handling and off loading facilities at the Port of Bombay.
- (ii) Weight and dimensional limitations for rail and road transport between Bombay and the sites, assuming that suitable access facilities will become available with the construction of the scheme.

5. Labour During Construction.

In order to restrict the amount of skilled labour required during construction of the Project, it has been assumed that as much of the plant as possible should be prefabricated so as to reduce work on site to a minimum and that the contractors would provide skilled labour and supervision. It has also been assumed that the civil engineering work would be mechanised to the greatest extent practicable.

The stations have been designed so that erection, maintenance and operation of the plant will be as simple as possible and on the assumption that permanent operating staff will ultimately be required only at the major station at Nagjhiri.

6. Current Prices and Delivery.

The estimates of costs and deliveries assumed in this Report are based on prices for electrical and mechanical plant and civil engineering work ruling in mid 1949, but it is not possible to forecast with certainty what may be the future price levels with the present day unsettled industrial and social conditions obtaining throughout the world. We would emphasize that no allowance has been made in our estimates for any increased costs which may take place between now and the time when it is decided to proceed with the construction of the Scheme.

7. Power During Construction.

It is recommended that the power required during the construction period be obtained by provision of independent diesel engine generating plant to be erected on the site of the works. It would no doubt be possible to obtain a supply from the existing system or direct from Jog Falls, which is about 75 miles from the site of the Supa Dam, but we consider the independent diesel plant to be preferable in this instance.

APPENDIX VI.VARIATION OF COST OF ENERGY WITH LOAD
FACTOR.

In the Covering Report we have referred to the variations in the cost of firm energy when the load factor is altered.

The following table shows the relative plant installations and costs for the complete development on which the figures given in the Report are based.

TABLE 21.Variation of Cost of Energy with Load
Factor.

Load Factor	40%	60%	80%
Firm annual output millions of kWh	2,800	2,800	2,800
Firm plant capacity kilowatts	800,000	540,000	400,000
Installed plant capacity kilowatts	890,000	590,000	440,000
Capital Cost of Development Crores of Rupees	49.6	39.28	35.4
Annual Cost of Operation Lakhs of Rupees	285	226.98	205.0
Cost per kWh of firm energy delivered to the 220 kV. busbars.	0.163 annas	0.130 annas	0.117 annas

It should be noted that in the above analysis we have assumed that the firm annual output remains constant. The method of operating the four stations as a co-ordinated Group would depend on the manner in which the total installed plant is distributed among the individual stations. As the load factor decreased and the installed plant capacity increased, there would

be greater opportunity for utilising water which would otherwise be spilt during the monsoon, while the regulation afforded by the Supa reservoir would permit some of the additional energy obtained in this way to be converted into firm output. Conversely an increase of load factor would tend to reduce the firm annual output.

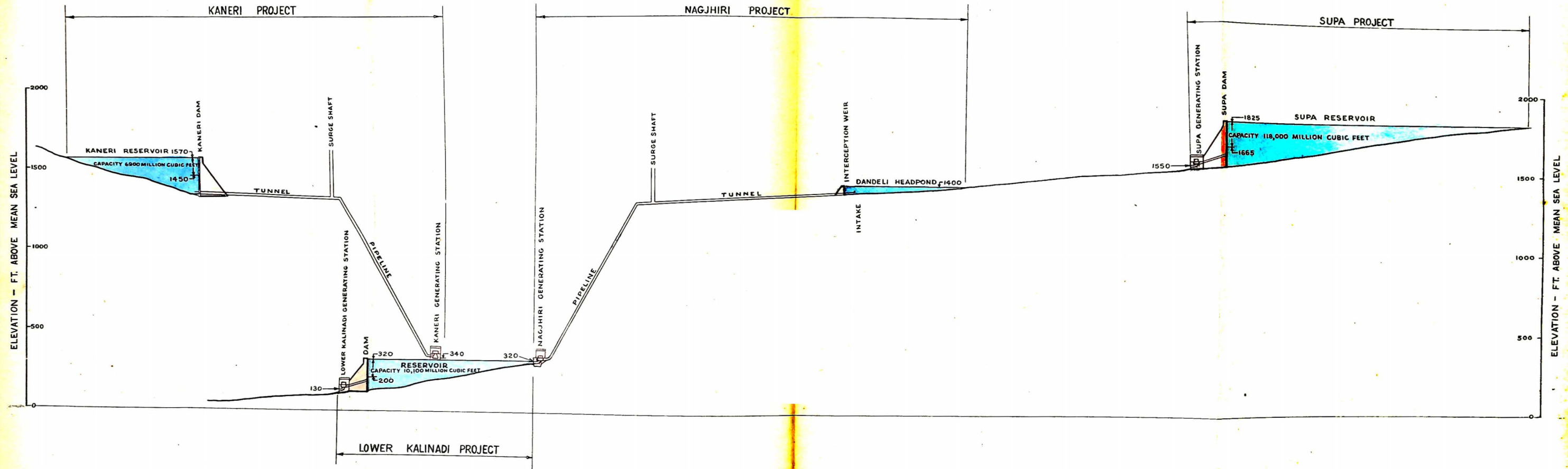
We have discounted the probability of any great benefit accruing to the Kalinadi scheme from interconnection with other sources of supply, but it may be observed here that such interconnection could result in an increase in the firm output. Such an increase would occur, for instance, if it should prove possible to operate the Group in such a way that the average output required during the monsoon months was greater than that given during the dry season, that is to say if the annual load factor was made subject to a favourable seasonal variation.

For the above reasons, the costs given for load factors other than 60% must be regarded as approximate only, but they nevertheless show the general trend in the cost of energy with varying load factor.

APPENDIX VII.

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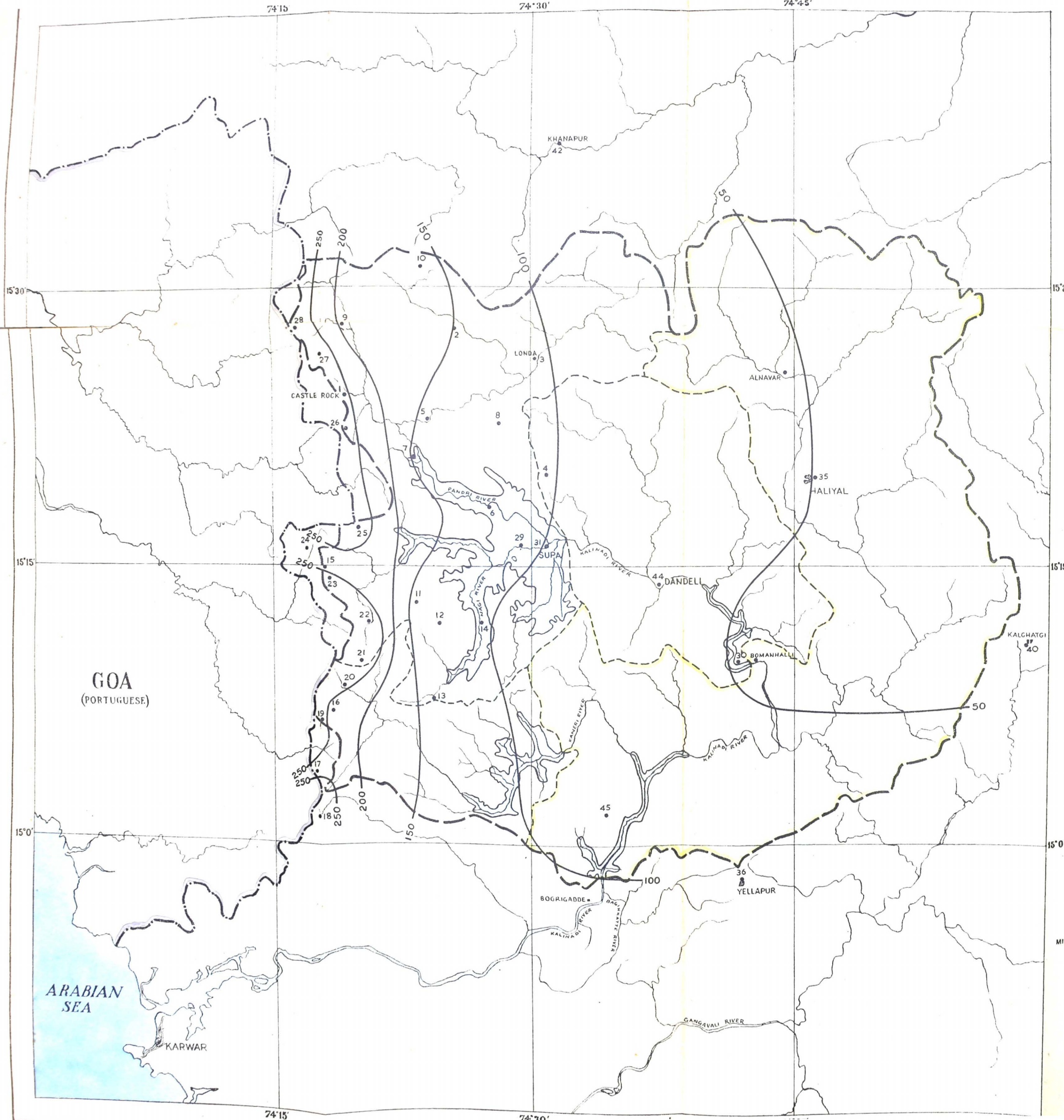


NOTES ON LEVELS INDICATED.
 STORAGE AREAS...PROPOSED TOP WATER LEVEL AND THE LOWEST DRAWDOWN LEVEL
 FOR POWER ARE SHOWN TOGETHER WITH THE STORAGE CAPACITY
 AVAILABLE BETWEEN THESE LEVELS.
 GENERATING STATIONS...THE NORMAL TAIL RACE LEVEL IS SHOWN.

KALINADI HYDRO-ELECTRIC SCHEME
 DIAGRAMMATIC SECTION SHOWING
 PROPOSED METHOD OF DEVELOPMENT

DECEMBER 1948

FIGURE No. 2

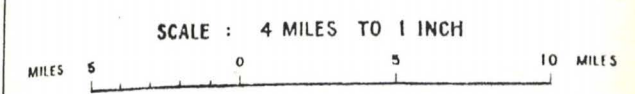


REF. No.	LOCATION	PERIOD OF RECORD	MEAN ANNUAL RAINFALL	REF. GAUGE
A - GAUGES AT PRESENT IN EXISTENCE				
1	CASTLE ROCK	1916-1946	255.9	
31	SUPA	1876-1947	91.52	
35	HALIYAL	1875-1946	48.45	
36	YELLAPUR	1876-1947	98.04	
40	KALGHATGI	1875-1946	35.28	
42	KHANAPUR	1876-1946	66.50	
44	DANDELI	1946-1947	62	S.
45	NANDIGADDA	1946		
B - GAUGES ABANDONED				
2	TINAI GHAT	1921-1927	150	C.R.
3	LONDA	" - "	105	C.R.
4	JAGALBAT	" - "	103	S.
5	CHANDVADI	" - "	134	S.C.R.
6	APELI	" - "	124	S.
7	AVEDA	" - "	140	C.R.
8	ASU	" - "	113	S.C.R.
9	AKETIDUDEGALI	" - "	195	C.R.
10	HEMADGA	" - "	156	S.C.R.
11	KALPA	" - "	130	S.C.R.
12	GURAVADI	" - "	118	S.C.R.
13	KAMBHARWADI	" - "	143	S.C.R.
14	PALLI	" - "	103	S.
15	DIGGI	1920-1921	245	C.R.
16	KUNDAL	" - "	225	C.R.
17	DHOKARPA	" - "	245	C.R.
18	JAMBOADA (LANDHA)	1921 ONLY	300	C.R.
19	POY	" - "	275	C.R.
20	KELOLI	" - "	270	C.R.
21	KUSAVLI	" - "	280	C.R.
22	BUMNIA	" - "	290	C.R.
23	DUDHMALA	" - "	275	C.R.
24	KADNA	" - "	245	C.R.
25	SOLIYA	" - "	285	C.R.
26	DHANGARWADI (ALU)	" - "	265	C.R.
27	ANMOD	" - "	275	C.R.
28	KASKARWADI (KARJAL)	" - "	275	C.R.
29	KHEDA	1921-1927	119	S.
30	BOMANHALLI	" - "	42.5	H.

NOTES.

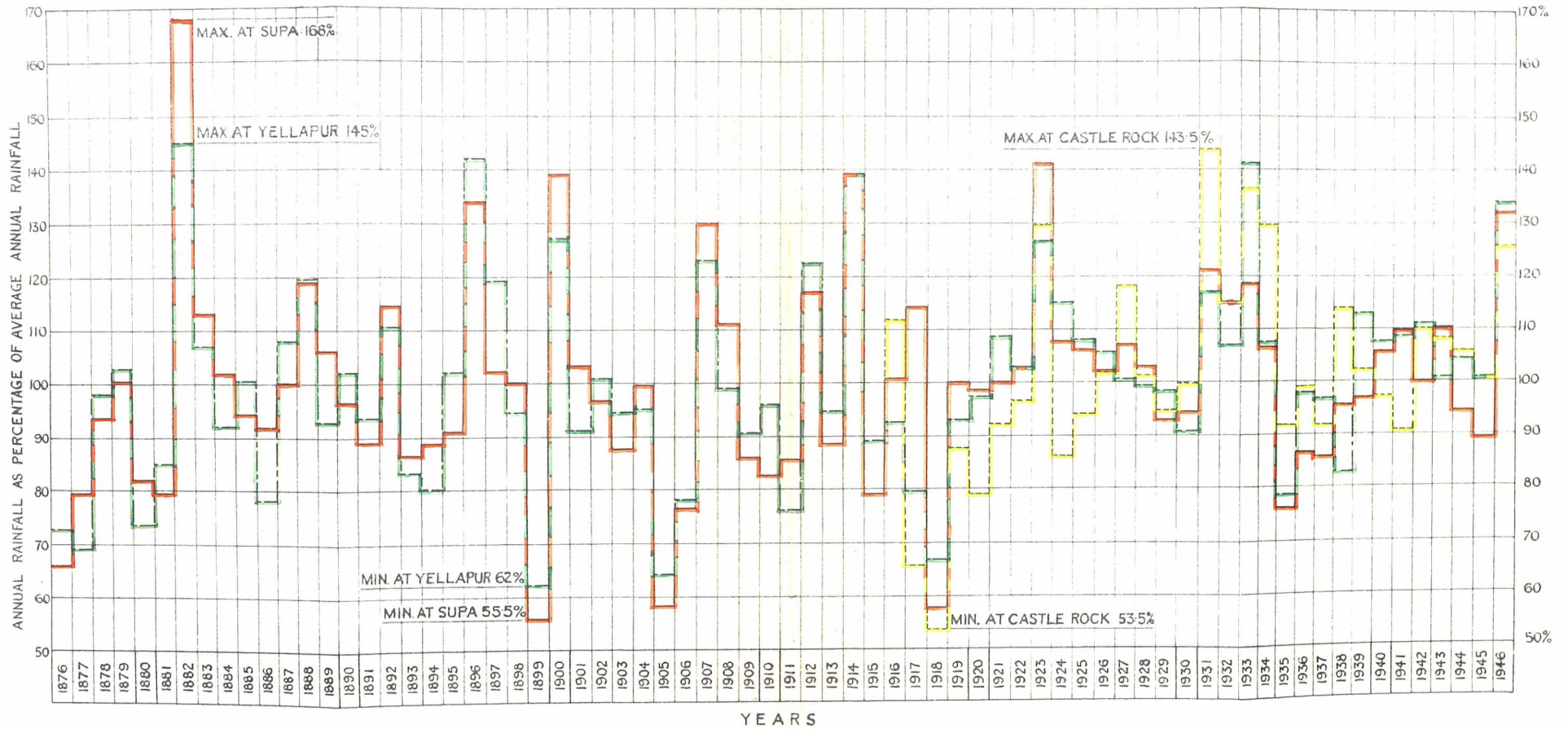
- REFERENCE NUMBERS.
A AND B. REFERENCES GIVEN BY A.C.E(1) TO EXISTING AND ABANDONED GAUGES.
- MEAN ANNUAL RAINFALL.
FOR SHORT TERM RECORDS, THE MEAN ANNUAL RAINFALL HAS BEEN ESTIMATED BY COMPARISON WITH A GAUGE WHICH HAS A LONG RECORD.
- REFERENCE GAUGE.
THE LONG PERIOD GAUGE WHICH HAS BEEN USED FOR ESTIMATION OF THE MEAN ANNUAL RAINFALL IS INDICATED:-
C.R. CASTLE ROCK.
S. SUPA.
H. HALIYAL.
S.C.R. SUPA AND CASTLE ROCK.
- VALUES OF ISOHYETAL LINES GIVEN IN INCHES.

SCHEME CATCHMENT AREA BOUNDARY SHOWN THUS PROJECT



KALINADI HYDRO-ELECTRIC SCHEME
PLAN OF CATCHMENT AREA
SHOWING ISOHYETALS

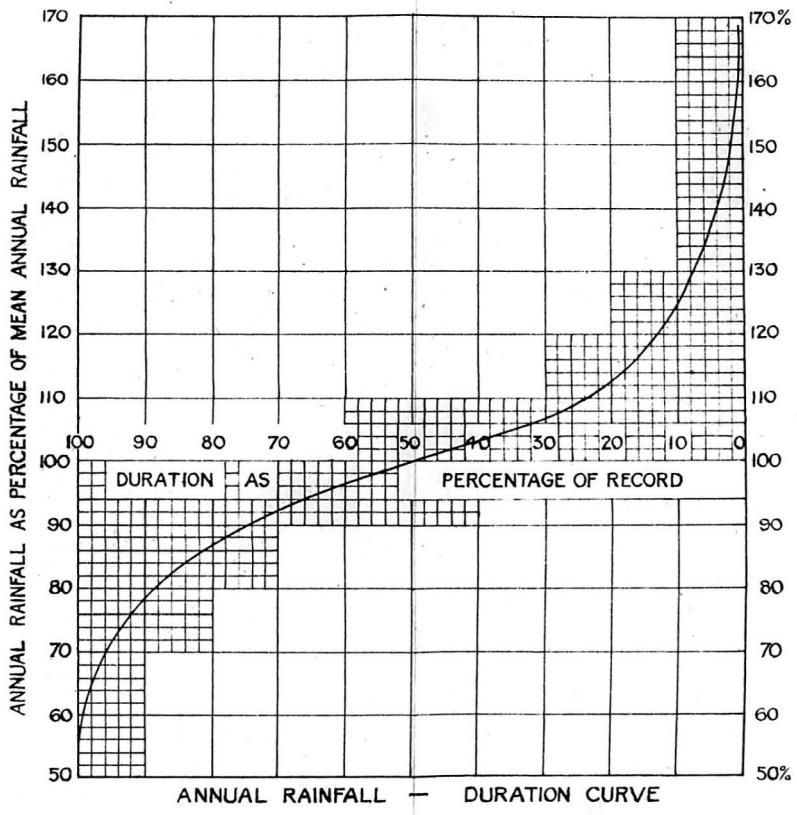
SUPA RAINGAUGE 1876-1946
 YELLAPUR RAINGAUGE . . . 1876-1946
 CASTLE ROCK RAINGAUGE . 1916-1946



VARIATION OF ANNUAL RAINFALL
 SUPA RAINGAUGE, 1876-1946. SHOWN THUS: ————
 YELLAPUR RAINGAUGE, 1876-1946 SHOWN THUS: - - - -
 CASTLE ROCK RAINGAUGE, 1916-1946 SHOWN THUS: - - - -

AVERAGE ANNUAL RAINFALL
 SUPA : 91.7 ins.
 YELLAPUR : 98.3 ins.
 CASTLE ROCK : 250.3 ins.

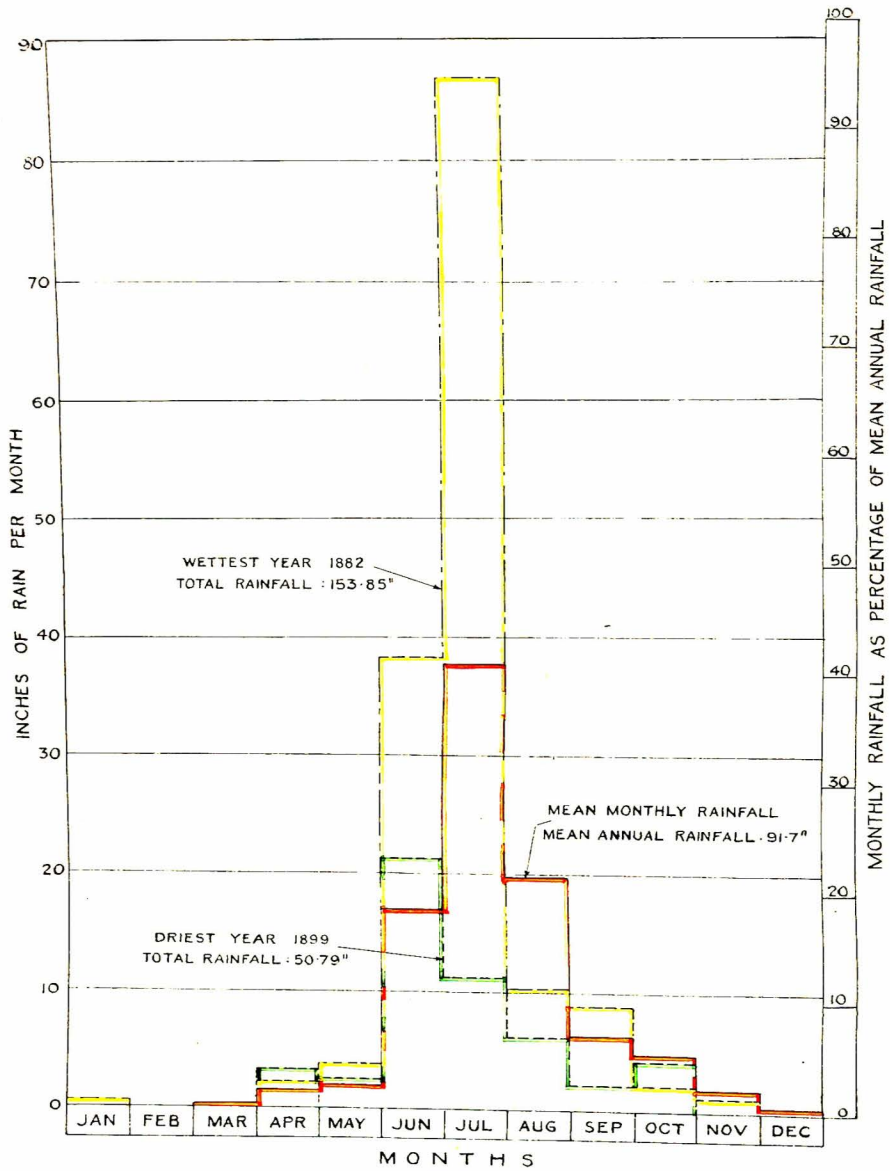
KALINADI HYDRO-ELECTRIC SCHEME
 VARIATION OF ANNUAL RAINFALL,
 COMPARISON OF SUPA, YELLAPUR
 AND CASTLE ROCK



ANNUAL RAINFALL — DURATION CURVE

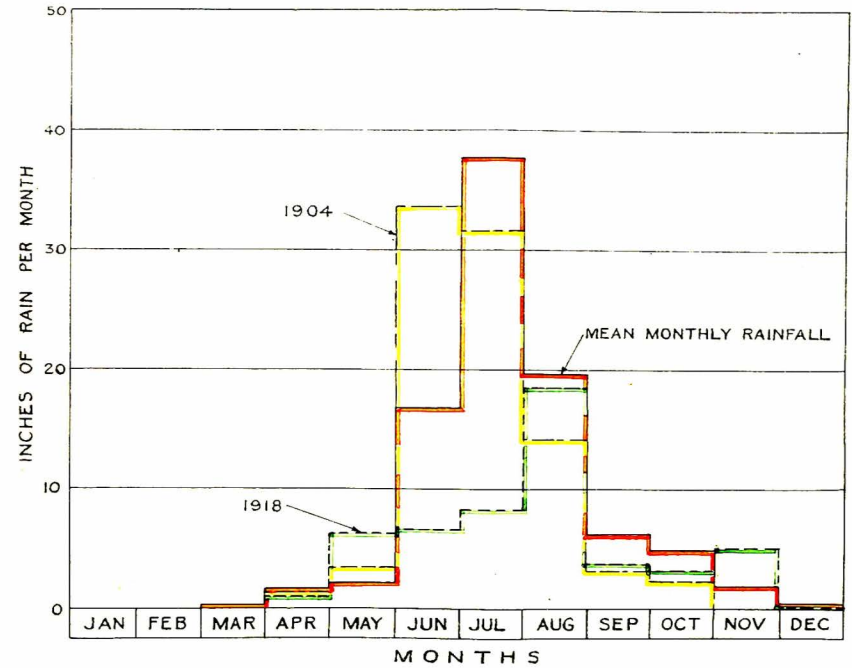
BASED ON ANNUAL RECORDS FROM SUPÁ AND YELLAPUR 1876-1946.
 THIS CURVE SHOWS THE PERCENTAGE OF TIME (YEARS) IN WHICH
 THE ANNUAL RAINFALL IS GREATER THAN A GIVEN PERCENTAGE OF
 THE MEAN ANNUAL RAINFALL.

KÁLINADI HYDRO-ELECTRIC SCHEME
 ANNUAL RAINFALL DURATION CURVE



MONTHLY DISTRIBUTION OF RAINFALL

MEAN MONTHLY DISTRIBUTION SHOWN THUS:
 MONTHLY DISTRIBUTION IN 1882 (WETTEST RECORDED YEAR) SHOWN THUS:
 MONTHLY DISTRIBUTION IN 1899 (DRIEST RECORDED YEAR) SHOWN THUS:

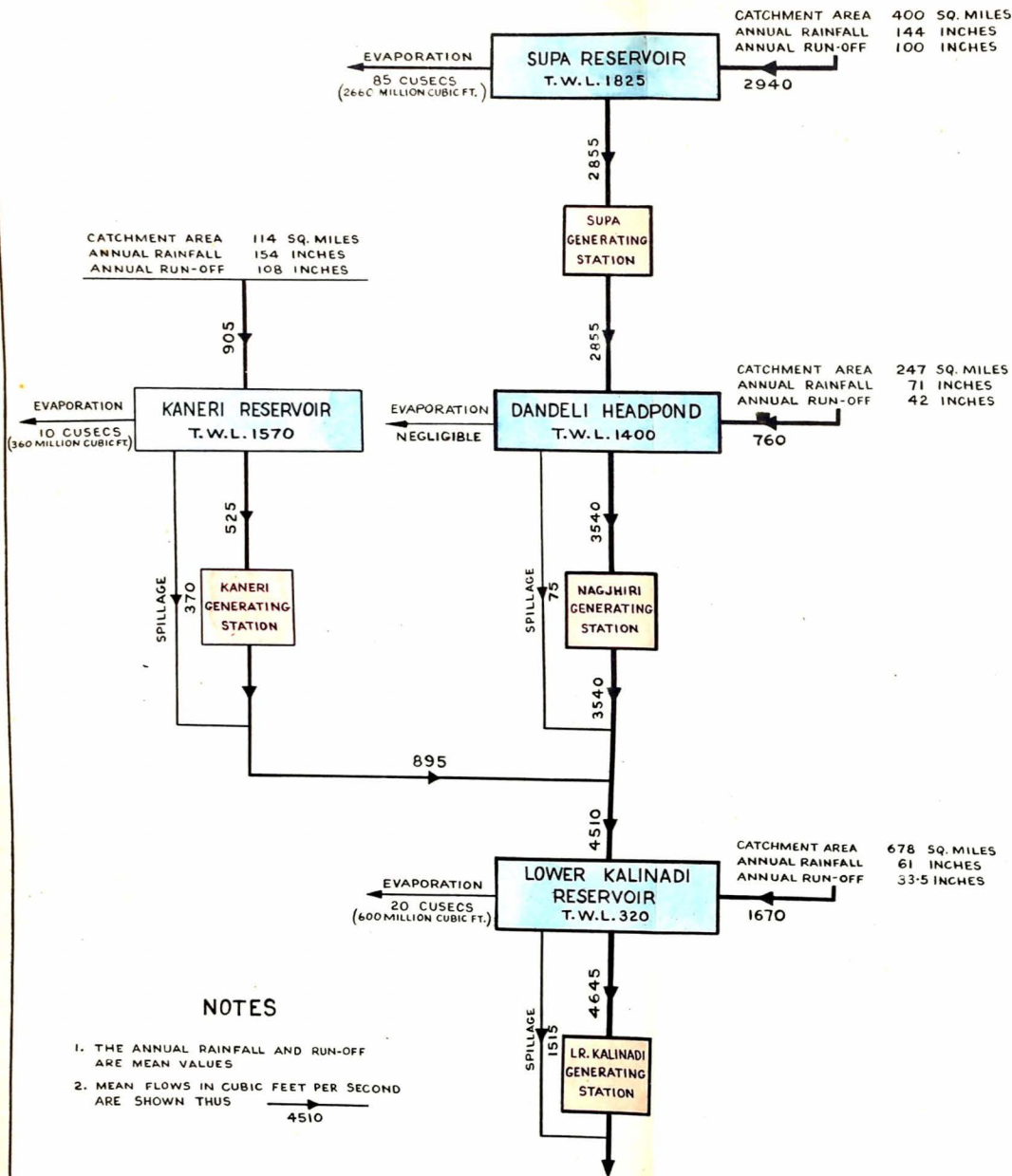


MONTHLY DISTRIBUTION OF RAINFALL

MEAN MONTHLY DISTRIBUTION SHOWN THUS:
 1904 (EARLY MONSOON OF NORMAL INTENSITY) SHOWN THUS:
 1918 (FAILURE OF MONSOON & LONG RAINY PERIOD) SHOWN THUS:

KALINAJI HYDRO-ELECTRIC SCHEME

MONTHLY RAINFALL DISTRIBUTION AT SUPA

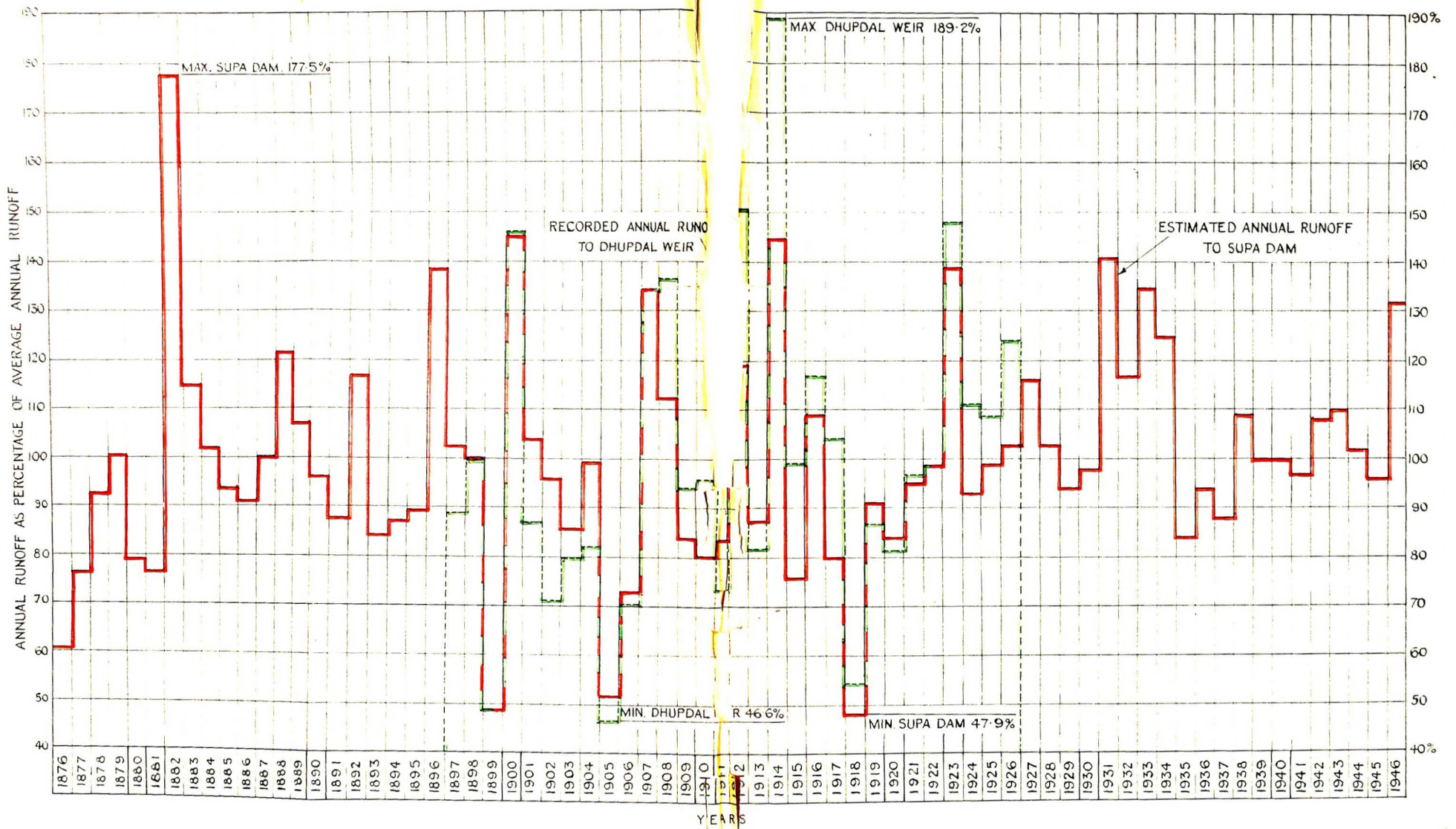


NOTES

1. THE ANNUAL RAINFALL AND RUN-OFF ARE MEAN VALUES
2. MEAN FLOWS IN CUBIC FEET PER SECOND ARE SHOWN THUS $\rightarrow 4510$

KALINADI HYDRO-ELECTRIC SCHEME

FLOW DIAGRAM
FOR AVERAGE YEAR



VARIATION OF ANNUAL RUNOFF

ESTIMATED RUNOFF TO SUPA DAM 1876-1946 SHOWN THUS: —

RECORDED RUNOFF TO DHUPDAL WEIR 1897-1926 SHOWN THUS: - - -

(SEE ANNUAL REPORTS OF THE SUPPLIES OF WATER AVAILABLE FOR IRRIGATION WORKS AND THE DISCHARGE FROM CATCHMENT AREAS IN THE BOMBAY PRESIDENCY. GOVT. OF BOMBAY P.W.D.)

AVERAGE ANNUAL RUNOFF

SUPA DAM (ESTIMATED) 93,300 MILLION CU. FT.

DHUPDAL WEIR (MEASURED) 114,000 MILLION CU. FT.

KALINADI HYDRO-ELECTRIC SCHEME

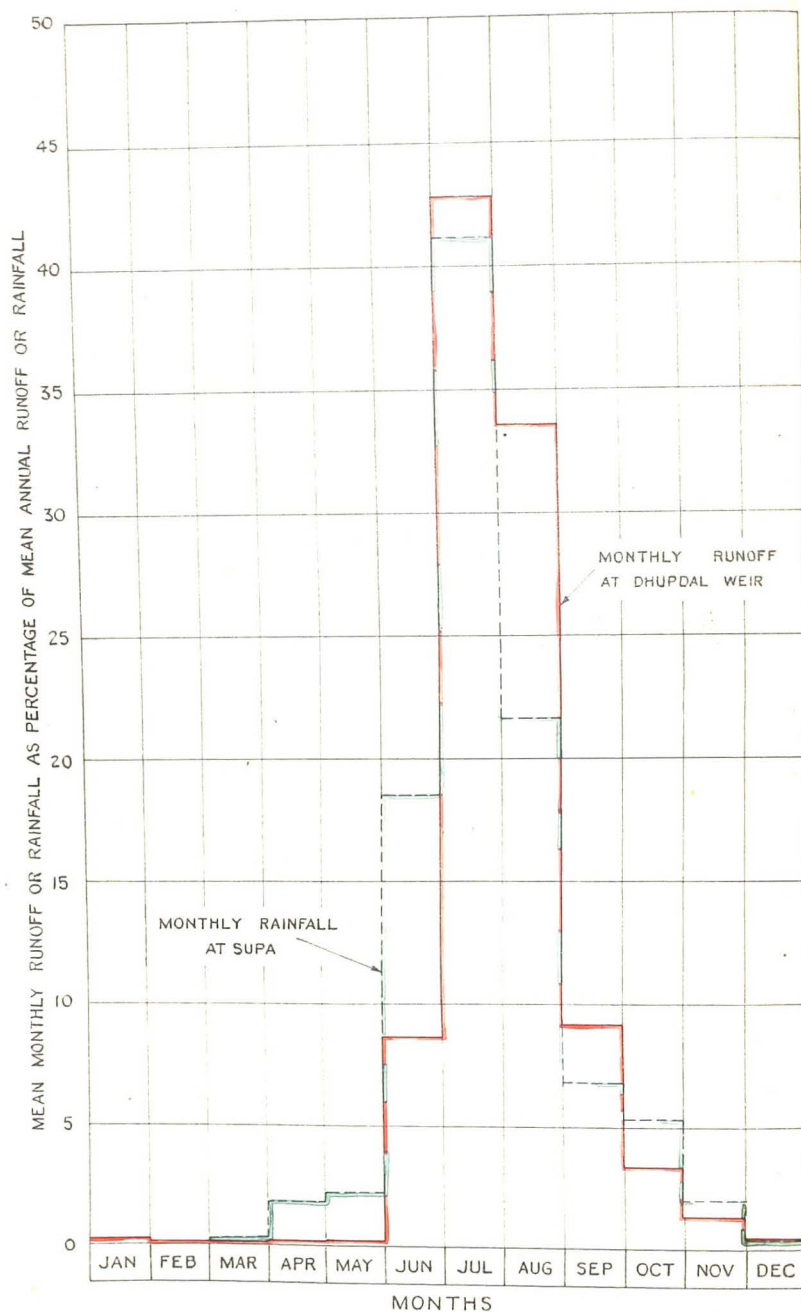
ANNUAL RUNOFF TO SUPA DAM

COMPARED WITH

ANNUAL RUNOFF TO DHUPDAL WEIR

DECEMBER 1948

FIGURE NO 8



MONTHLY VARIATION OF RUNOFF AT DHUPDAL WEIR
 COMPARED WITH MONTHLY VARIATION OF RAINFALL AT SUPA

MEAN MONTHLY RAINFALL AT SUPA
 DEPARTMENT OF AGRICULTURE RECORDS. 1876-1946

MEAN MONTHLY RUNOFF AT DHUPDAL WEIR

DHUPDAL WEIR ON R. GHATPRABHA NEAR GOKAK, BELGAUM DISTRICT.
 RECORDS FROM "ANNUAL REPORT OF THE SUPPLIES OF WATER
 AVAILABE FOR IRRIGATION WORKS AND OF THE DISCHARGE FROM
 CATCHMENT AREAS IN THE BOMBAY PRESIDENCY" 1896-1927.

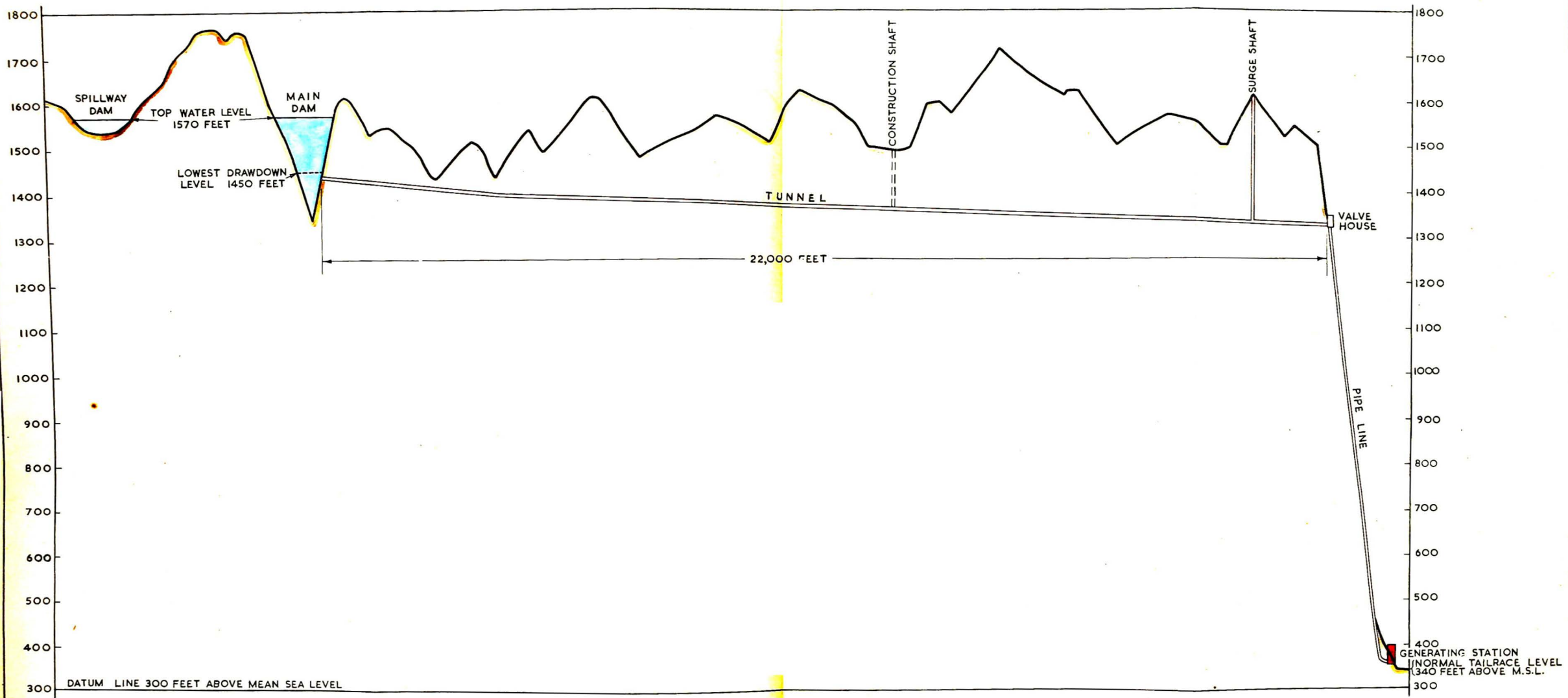
MONTHS	RAINFALL AT SUPA		RUNOFF AT DHUPDAL WEIR	
	MEAN RAINFALL IN INCHES	RAINFALL AS % OF ANNUAL	MEAN RUNOFF IN CUSEC. DAYS	MONTHS RUNOFF AS% OF ANNUAL
JAN	0.04	0.0%	3,295	0.2%
FEB	0.05	0.0%	2,195	0.2%
MAR	0.29	0.3%	1,848	0.1%
APR	1.64	1.8%	2,125	0.2%
MAY	2.04	2.2%	2,815	0.2%
JUN	16.94	18.5%	116,648	8.6%
JUL	37.68	41.1%	576,608	42.7%
AUG	19.74	21.6%	452,327	33.6%
SEP	6.24	6.8%	123,694	9.2%
OCT	4.86	5.3%	44,574	3.3%
NOV	1.82	2.0%	17,651	1.3%
DEC	0.35	0.4%	5,961	0.4%
MEAN ANN. TOTAL	91.69 INS.	100.0%	1,349,696 CUSEC. DAYS	100.0%

KALINADI HYDRO-ELECTRIC SCHEME

MONTHLY DISTRIBUTION OF RAINFALL AT SUPA
 COMPARED WITH MONTHLY RUN-OFF AT DHUPDAL

DECEMBER 1948

FIGURE No 9



HORIZONTAL SCALE:- 3 INCHES TO 1 MILE



VERTICAL SCALE:- 30 INCHES TO 1 MILE

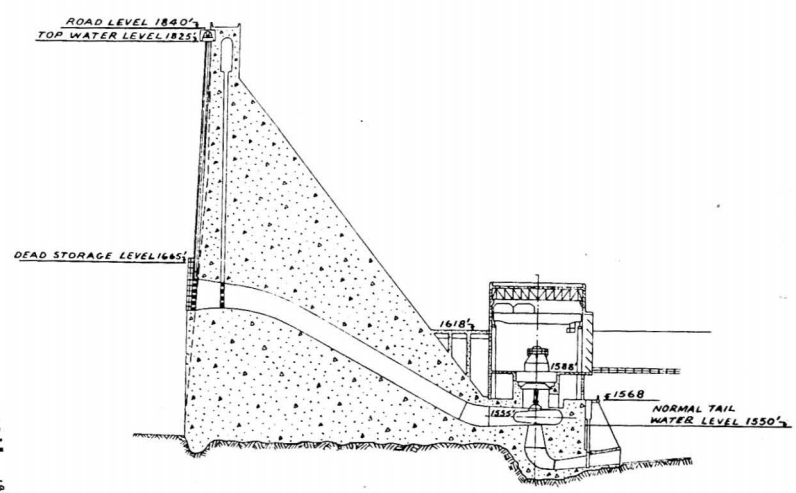
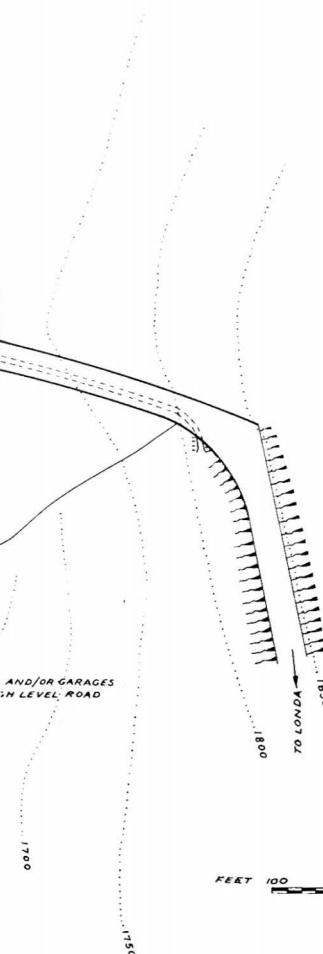


KALINADI HYDRO-ELECTRIC SCHEME

KANERI PROJECT - SECTION THROUGH PROPOSED WORKS

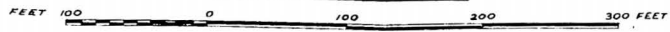
DECEMBER 1948

FIGURE No 15



SECTION THROUGH PENSTOCK

SCALE - 88 FEET TO 1 INCH

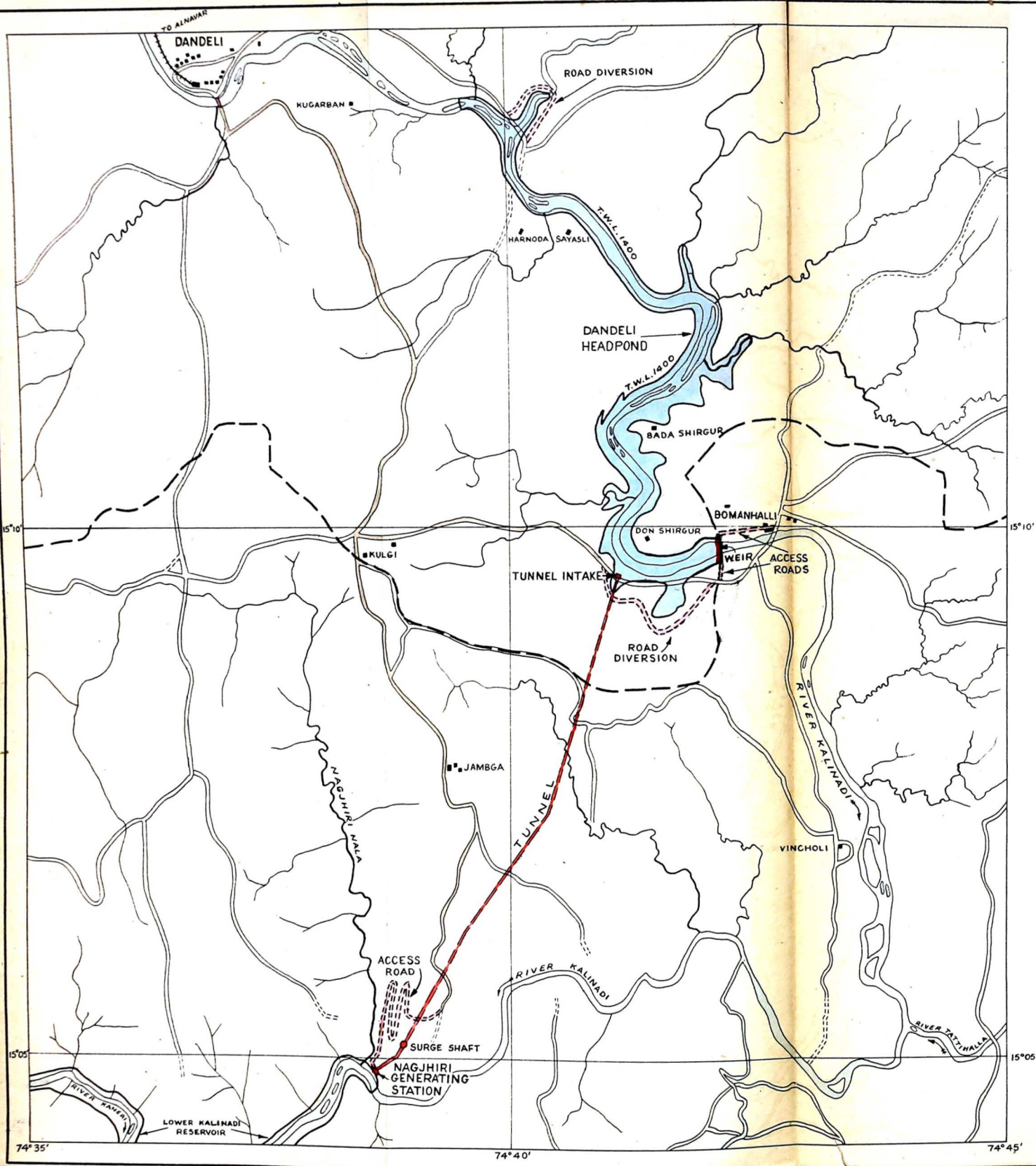


KALINADI HYDRO-ELECTRIC SCHEME

SUPA DAM AND POWER STATION

DECEMBER 1948

FIGURE NO. 11



NOTE.

CATCHMENT AREA BOUNDARY SHOWN THUS. — — —

SCALE:- 1 INCH TO 1 MILE.

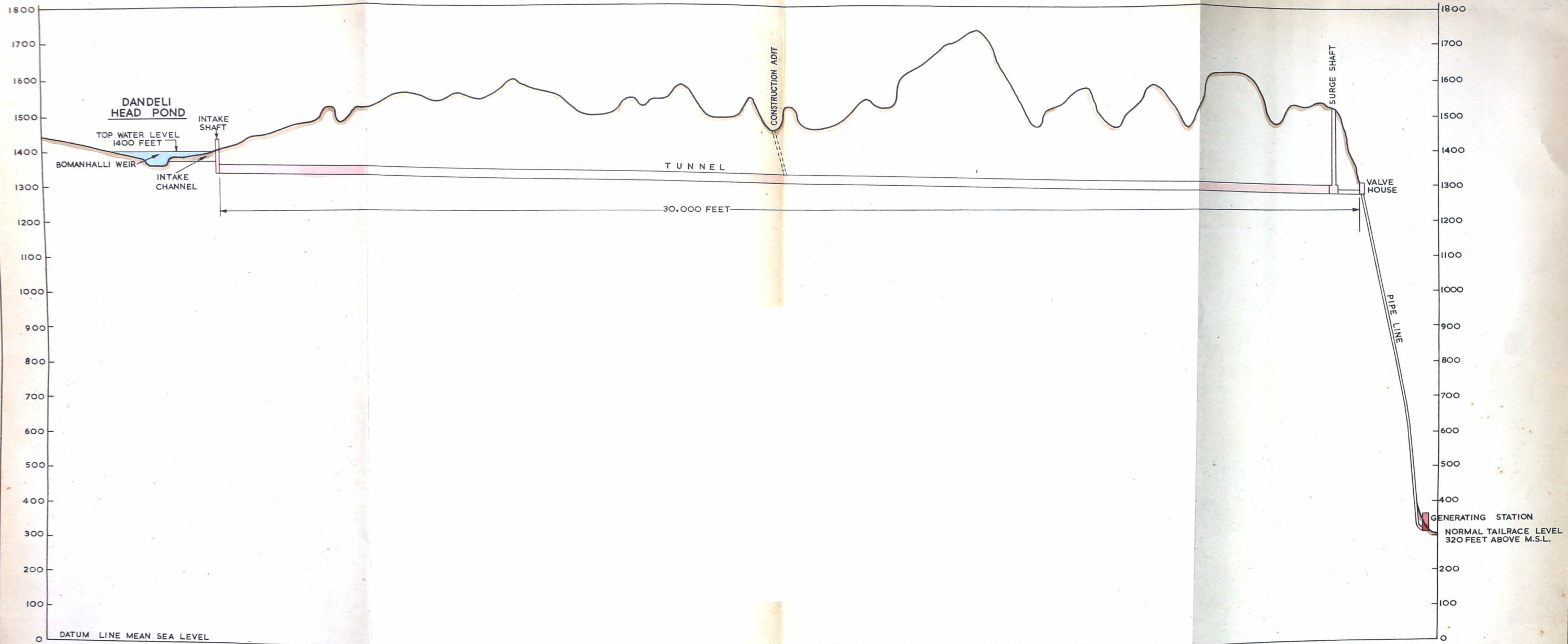


KALINADI HYDRO-ELECTRIC SCHEME

PLAN SHOWING NAGJHIRI PROJECT

DECEMBER 1948

FIGURE No 12

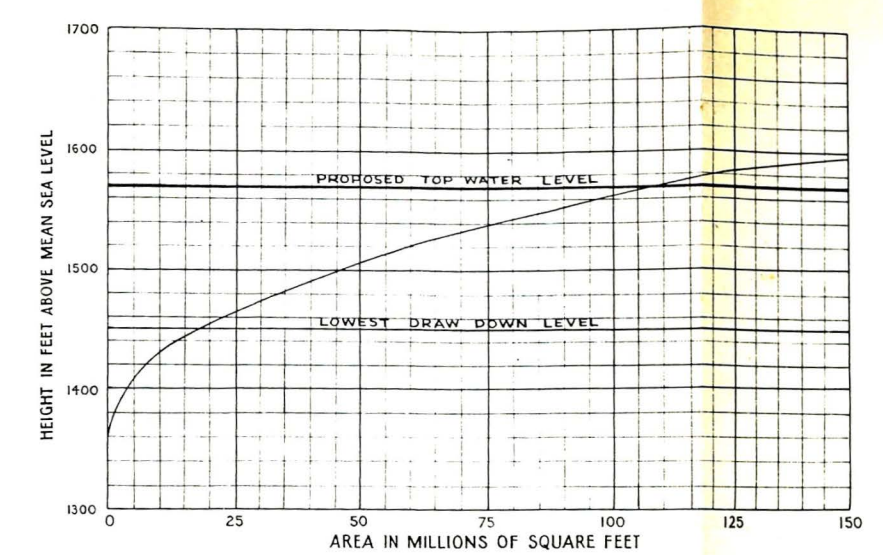
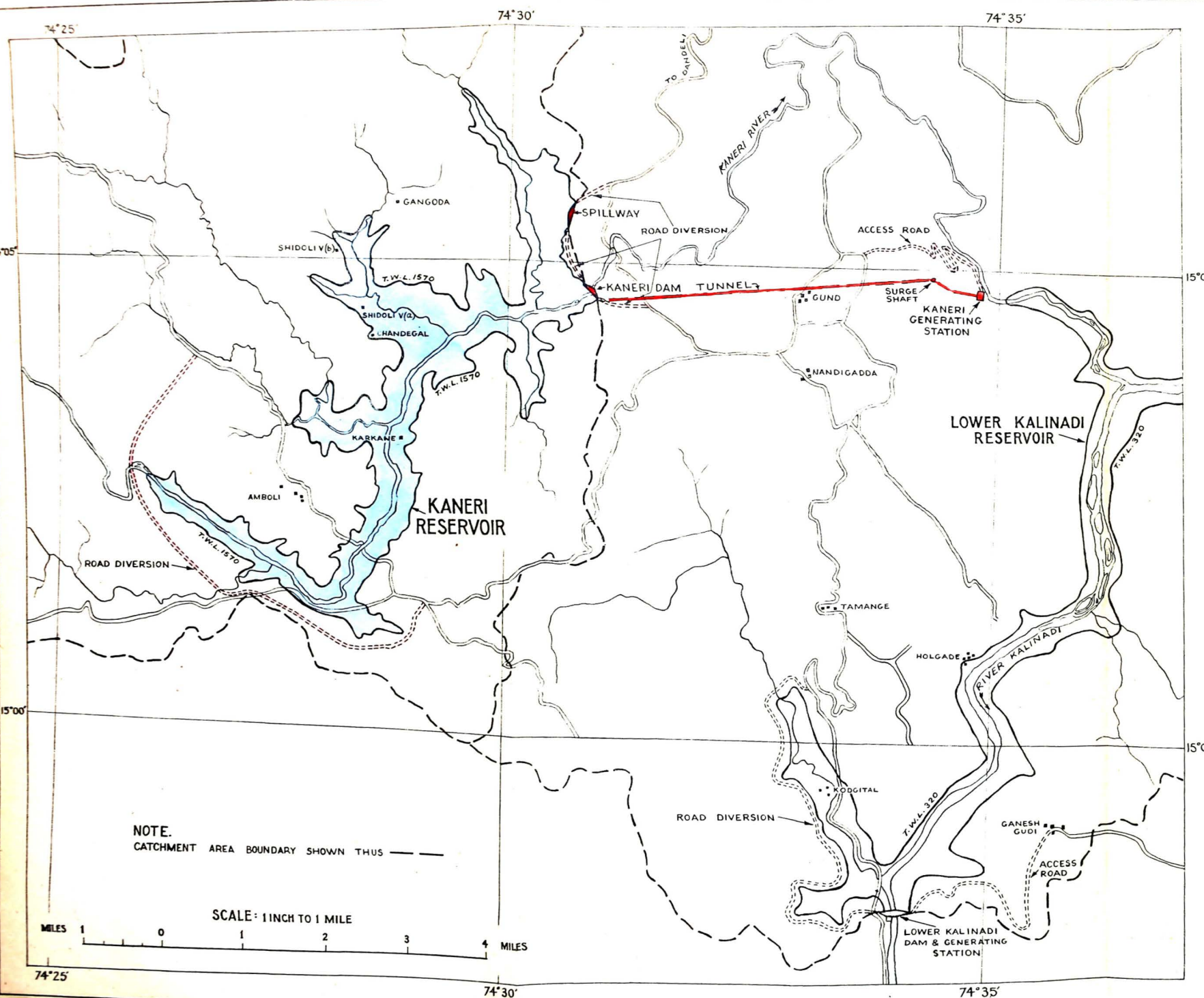


HORIZONTAL SCALE:- 3 INCHES TO 1 MILE
 FEET 1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

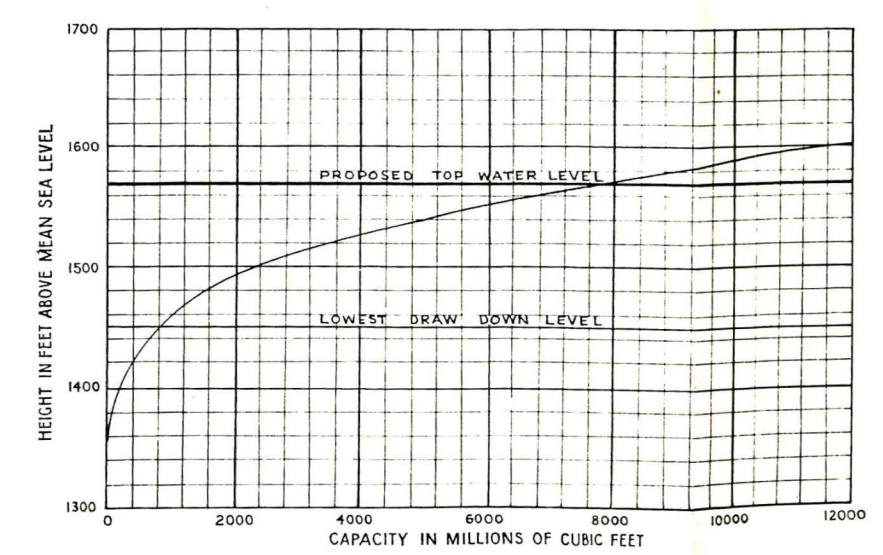
VERTICAL SCALE:- 30 INCHES TO 1 MILE
 FEET 100 0 100 200 300 400 500 600 700 FEET

KALINADI HYDRO-ELECTRIC SCHEME

NAGJHIRI PROJECT - SECTION THROUGH PROPOSED WORKS

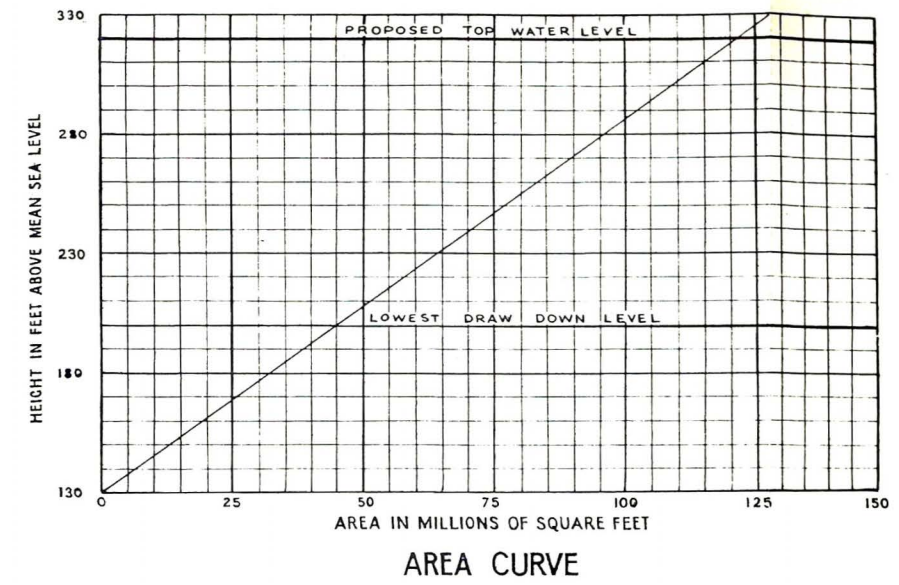
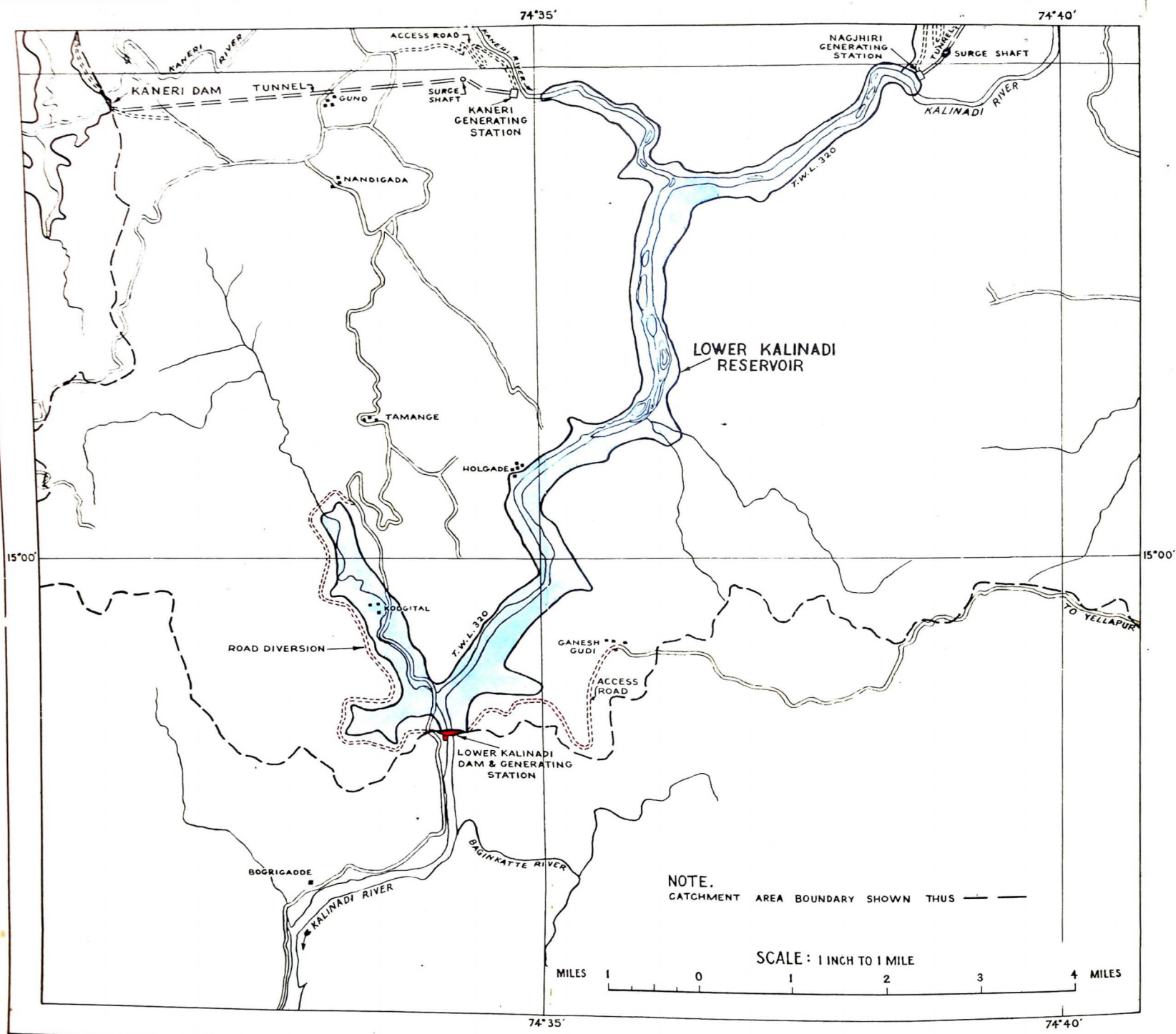


AREA CURVE
KANERI RESERVOIR

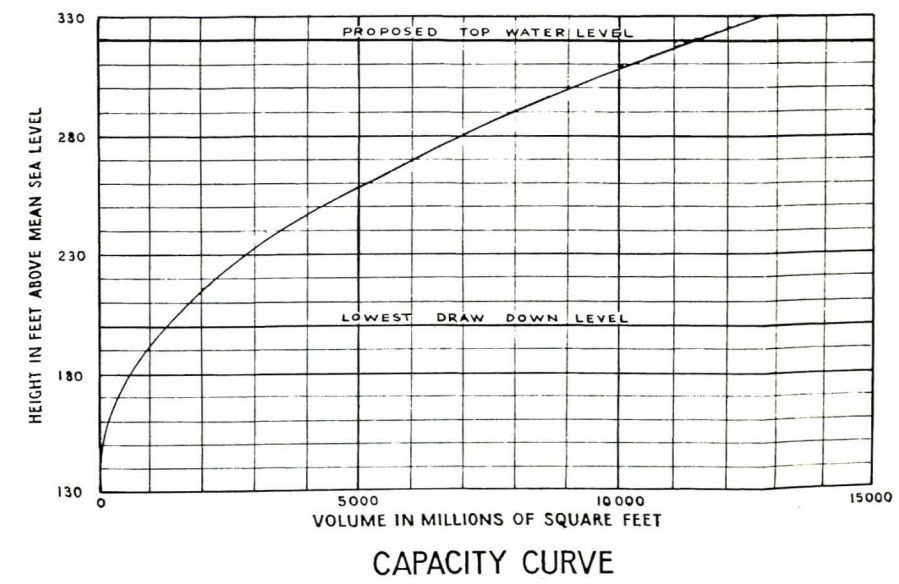


CAPACITY CURVE

KALINADI HYDRO-ELECTRIC SCHEME
PLAN SHOWING KANERI PROJECT

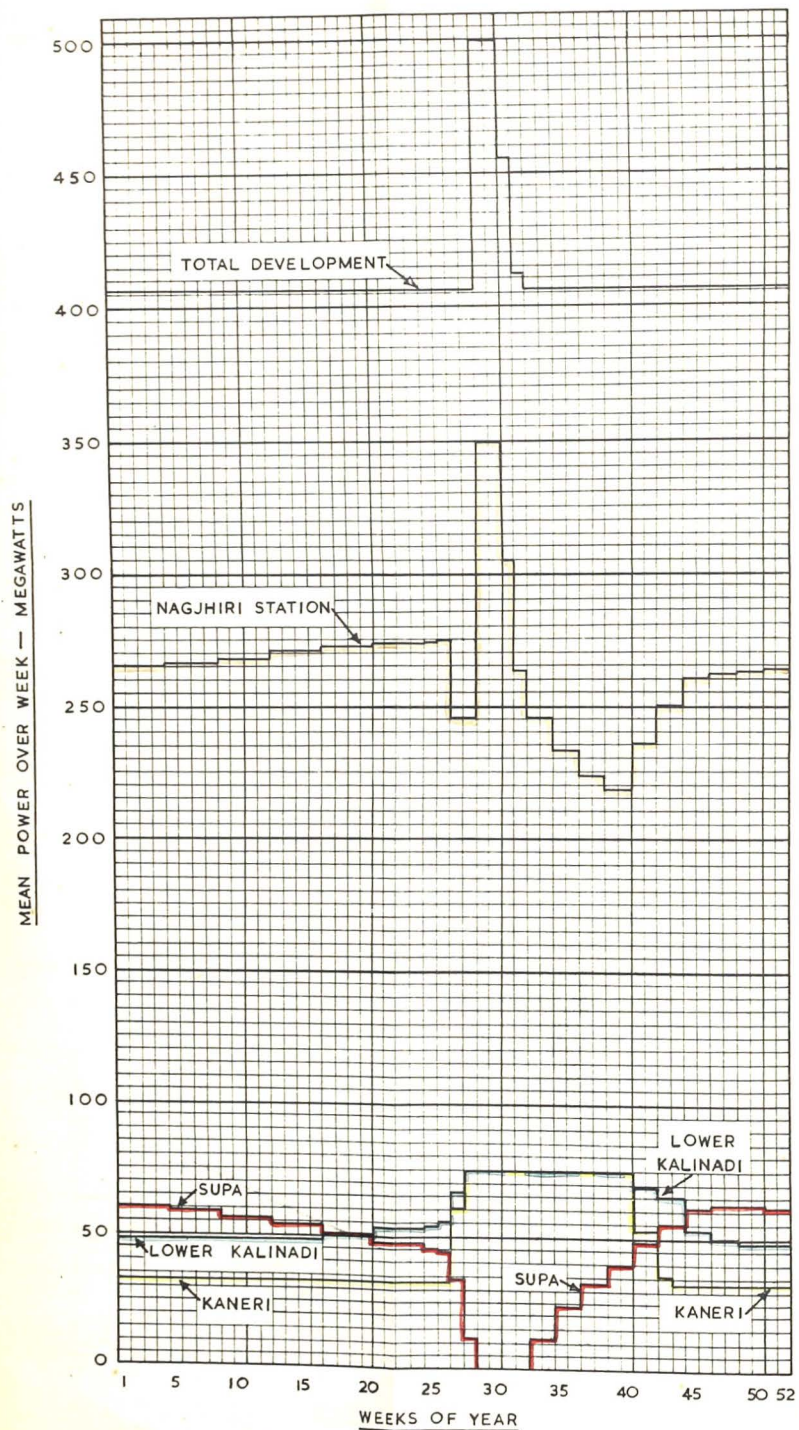


AREA CURVE
LOWER KALINADI RESERVOIR

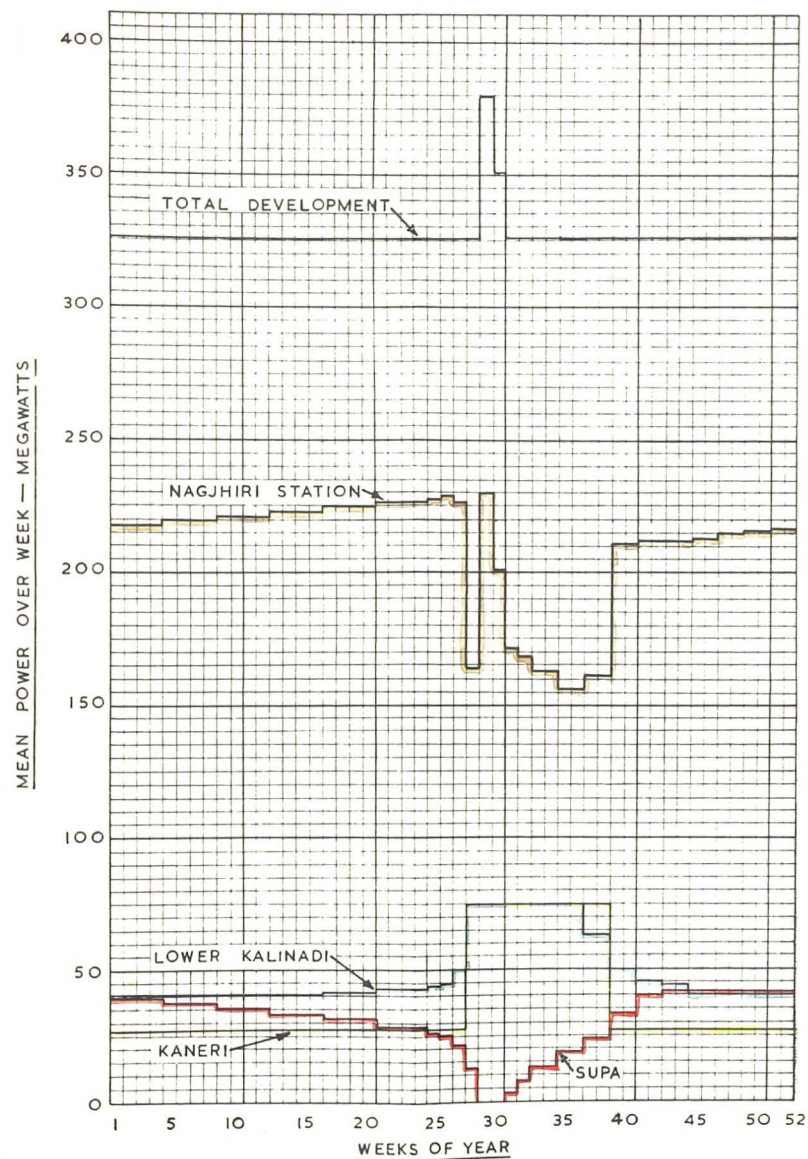


CAPACITY CURVE

KALINADI HYDRO-ELECTRIC SCHEME
PLAN SHOWING
LOWER KALINADI PROJECT



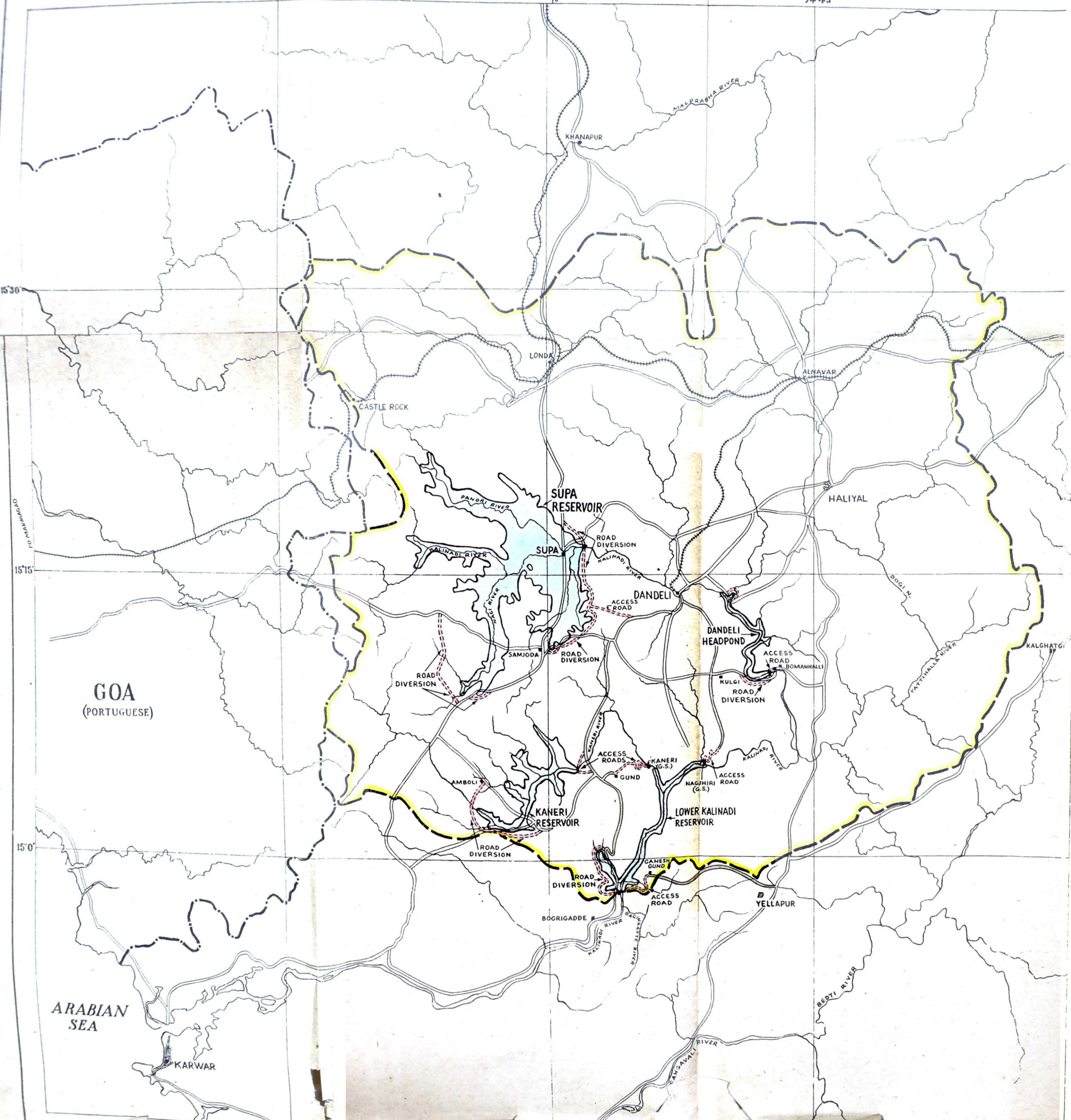
AVERAGE YEAR OPERATION OF KALINADI DEVELOPMENT

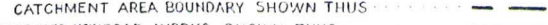
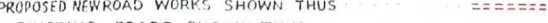




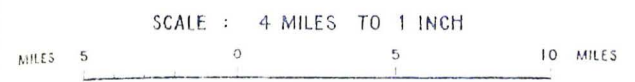
DRY YEAR OPERATION OF KALINADI DEVELOPMENT

KALINADI HYDRO-ELECTRIC SCHEME

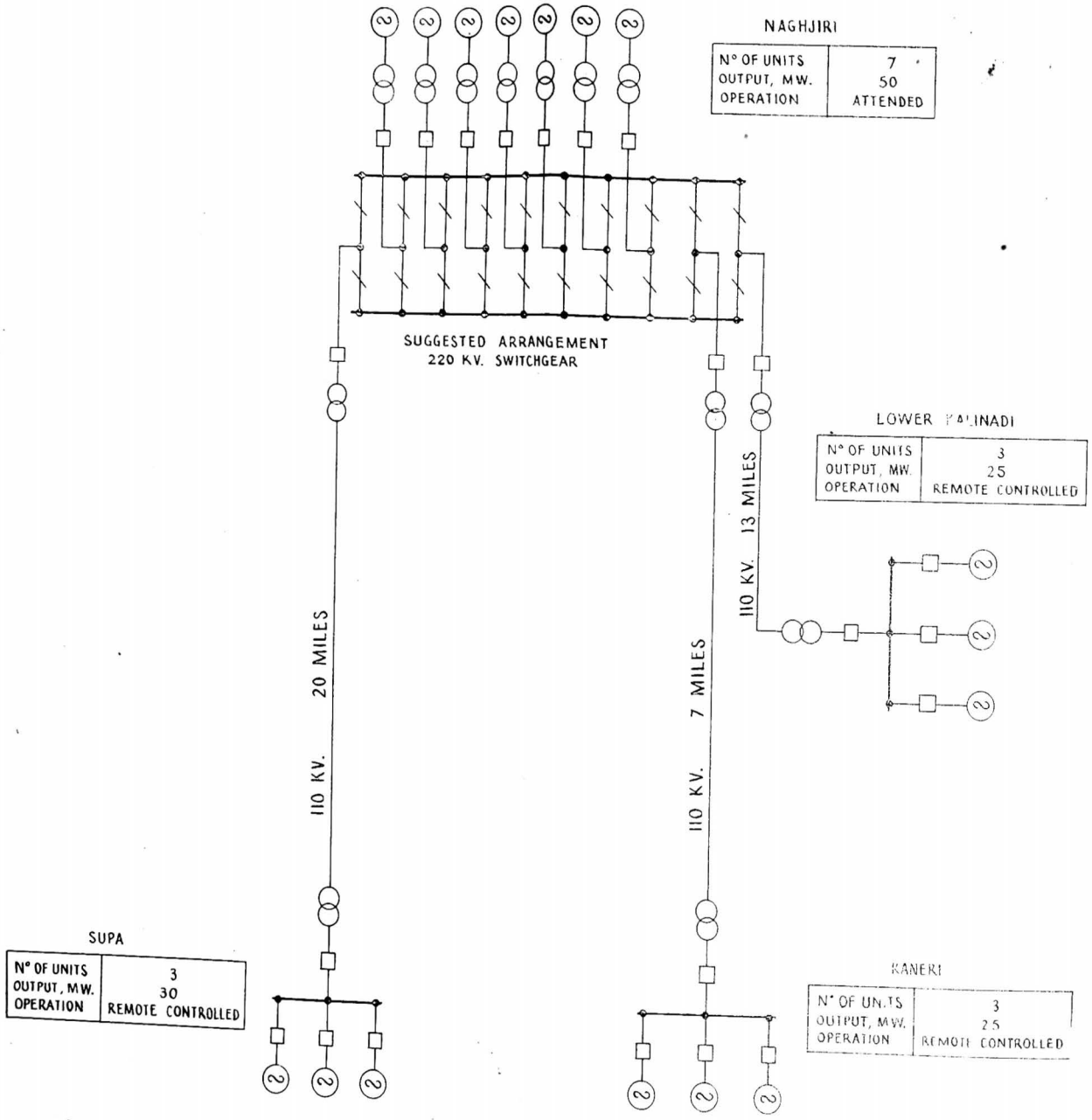
OPERATION DIAGRAM FOR
COMPLETE DEVELOPMENT



NOTES.
 CATCHMENT AREA BOUNDARY SHOWN THUS 
 PROPOSED NEW ROAD WORKS SHOWN THUS 
 EXISTING ROADS SHOWN THUS 
 IMPROVEMENTS TO EXISTING ROADS SHOWN THUS 



KALINADI HYDRO-ELECTRIC SCHEME
 PLAN OF CATCHMENT AREA
 SHOWING COMMUNICATIONS



NAGHJIRI	
N° OF UNITS	7
OUTPUT, MW.	50
OPERATION	ATTENDED

LOWER PALINADI	
N° OF UNITS	3
OUTPUT, MW.	25
OPERATION	REMOTE CONTROLLED

SUPA	
N° OF UNITS	3
OUTPUT, MW.	30
OPERATION	REMOTE CONTROLLED

KANERI	
N° OF UNITS	3
OUTPUT, MW.	25
OPERATION	REMOTE CONTROLLED

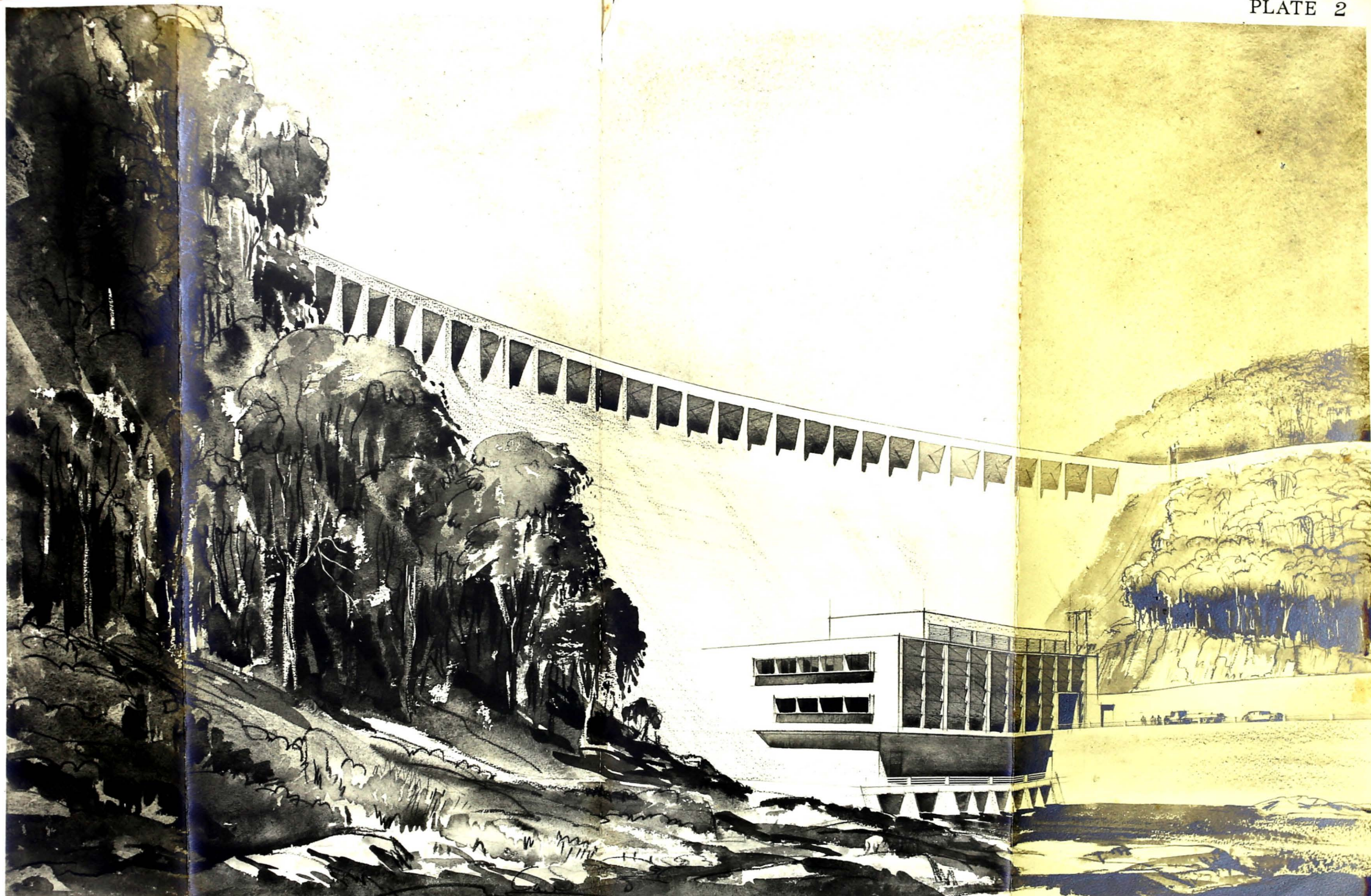
- KEY TO SYMBOLS
- GENERATOR
 - SWITCH
 - TRANSFORMER
 - ISOLATOR

KALINADI HYDRO-ELECTRIC SCHEME

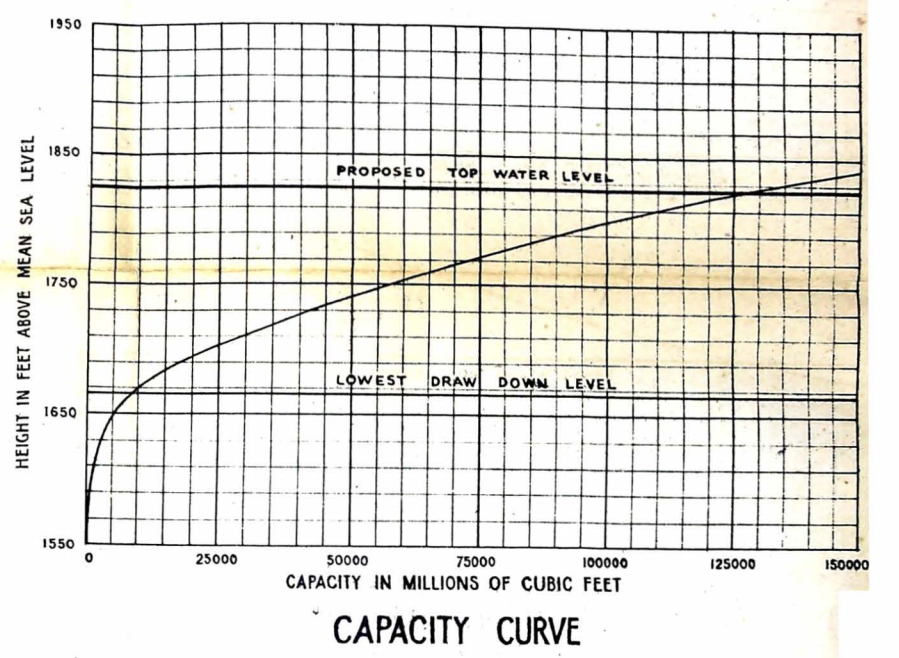
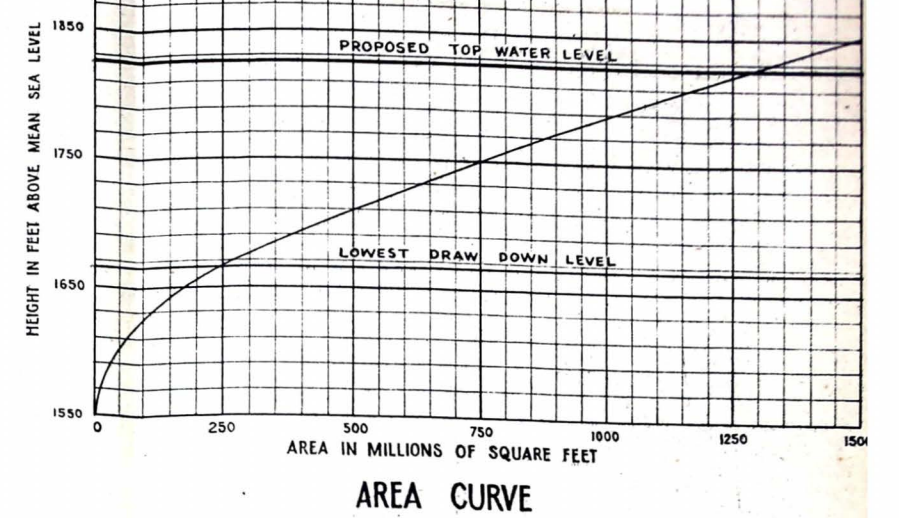
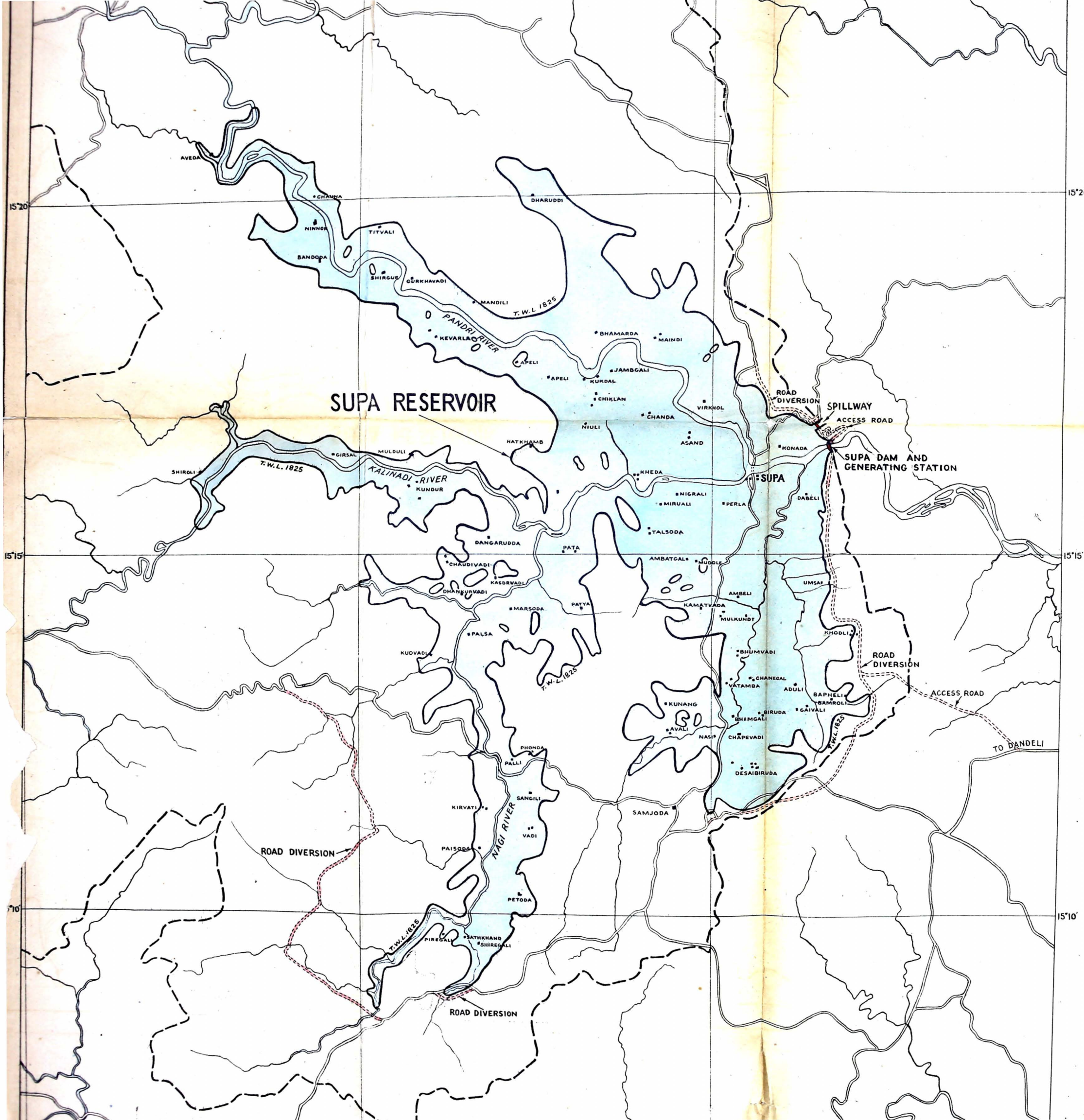
PROPOSED ARRANGEMENTS OF LOCAL INTERCONNECTING TRANSMISSION SYSTEM

DECEMBER 1948

FIGURE N°19



S U P A D A M & P O W E R S T A T I O N



NOTES.
 VILLAGES SHOWN IN STORAGE AREA ARE TAKEN FROM 1" TO 1 MILE SURVEY OF INDIA MAPS AND ARE NOT NECESSARILY IN OCCUPATION AT PRESENT.
 CATCHMENT AREA BOUNDARY SHOWN THUS ———

