1937.

VICTORIA

REPORT

OF

STATE ELECTRICITY COMMISSION OF VICTORIA

ON

Extension of State Electricity Generating System for Requirements of System Load after 1940

PRESENTED TO BOTH HOUSES OF PARLIAMENT BY HIS EXCELLENCY'S COMMAND.

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STATE ELECTRICITY COMMISSION OF VICTORIA.

The Hon. the Minister In Charge, Electrical Undertakings,
Melbourne.

SIR,

EXTENSION OF STATE ELECTRICITY GENERATING SYSTEM.

1. An essential duty devolving upon the Commission is the necessity to forecast and provide for the growing demands upon the State Power System. As it is estimated that the capacity of the Commission's generating plants, including extensions now in progress, will be overtaken in 1940, and as preparations for installing new plant must necessarily be made as much in advance as possible, the time has arrived for the Commission to submit to the Government definite proposals for major extensions to the generating capacity of the State system.

2. The Commission's considered recommendations in this respect, supported by a comprehensive survey of the position and an analysis of all factors bearing thereon, are set forth in this Report, which is submitted pursuant to the requirements of section 13 of the State Electricity Commission Act No. 3776 of 1929.

3. Appended hereto are the following:—

(*a*) Report of May, 1937, of the Chief Engineer, Power Production (Mr. E. Bate), setting out particulars of the technicalities and economics of a hydro-electric scheme utilizing as a major development the waters of the Kiewa River (North Eastern Victoria). (Appendix " B ").

(*b*) Report dated 11th June, 1937, of the Chief Engineer, Power Production, as to the necessity for also adding to the existing metropolitan steam-generating stations. (Appendix " B ").

(*c*) Report of Rendel, Palmer, and Tritton, Consulting Engineers, 55 Broadway, Westminster, London, S.W.1, who were appointed, in association with Messrs. Vattenbyggnadsbyran (VBB) of Stockholm, Sweden, to investigate and report on the Kiewa hydro-electric project. (Appendix " A ").

4. The several technical questions involved have been treated exhaustively in the above-quoted annexures, which the Commission, after full consideration, has approved and adopted. In this overriding report, therefore, the Commission deals only with the economic comparisons which are involved, and the policy and financial aspects of its recommendations to the Government.

PART I.—BASIC CONSIDERATIONS.

5. When the fundamentals of a large-scale electricity generating system have been established, as is the case with the Commission—with its large heat-power station at Yallourn, based on brown coal, its peak load metropolitan stations based on black coal and brown coal briquettes, and its water-power development based on the resources of Sugarloaf-Rubicon—certain important considerations present themselves immediately major extensions to such a system become necessary. These considerations must be especially directed towards securing the most economical overall unit cost of generation at all times, having regard to the fluctuations in demand which necessarily occur throughout the day and from month to month throughout the year. Consequently, any review must centre in a careful study as to when each instalment of new plant in the extended system should come into operation, so that as the system is progressively enlarged, each part of it shall take its proper place in and economic share of the total load to be supplied. It is necessary, therefore, that attention be given both to the increase in the peak load (measured in kilowatts) and to the additional energy (measured in kilowatt-hours) which the system will be called upon to supply.

6. **Growth of Demand.**—The Commission has at its disposal statistical material and experience covering many years upon which to base estimates as to the future, and upon which to make forecasts of the probable load on the system for a series of years to come. There must always be an element of uncertainty in such forecasts, due to unforeseen circumstances, but, on the outlook at present, it is necessary that the generating system should be prepared to deal with the following anticipated requirements over the next few years :—

Year.	Kilowatts.	Kilowatt Hours.
1938	166,000	815 millions.
1939	179,000	875 ,,
1940	194,000	950 ,,
1941	210,000	1,030 ,,
1942	227,000	1,115 ,,
1943	244,000	1,200 ,,
1944	265,000	1,300 ,,
1945	286,000	1,400 ,,

7. The total generating capacity, including spare plant, which will be available when the extensions at Yallourn and Newport "B" Power Stations are completed in 1939 will comprise :—

Yallourn Power Station	136,000 kw.
Briquetting Factory	8,000 ,,
Sugarloaf–Rubicon Power Stations	11,000 ,,
Newport "B" Power Station	48,000 ,,
Richmond Power Station	15,000 ,,
Geelong Power Station	7,500 ,,
Total	225,500 ,,

8. To avoid the possibility of demand overtaking net capacity, it is necessary that preparations be made immediately for still further plant to be in operation in the winter of 1941. At the present rate of increase in the demand, the deficiency in plant, unless timely provision be made, will, by 1945, exceed 50,000 kw.

9. The following comment, which was made by the Commission in 1928, when submitting its recommendations in regard to the last major extension of the generating system, is reiterated for the purpose of emphasizing the obligation which rests upon the Commission to keep abreast of public requirements :—

> "Lest it may be thought that large further investments in generating plant can be obviated or postponed, it should be explained, in general terms, that the growth of demand is beyond the control of an electricity supply authority. Every tenement and every factory is free to draw current and to increase its consuming devices at its own will and pleasure. Consequently, when an existing system of supply has reached full load conditions, the inevitable further increase of consumption cannot be prevented, with the result that the system becomes overloaded. The effect of sustained overload—apart from the risk of serious breakdowns of essential plant—is to render the service, in its entirety, irregular and unreliable, to the disadvantage and inconvenience of the whole body of consumers. It is, therefore, the paramount duty of every supply authority to ensure that its plant capacity is, at all times, available *in advance* of public requirements."

10. In every form of generation of electricity, the ultimate cost to the public is divisible into two parts, viz., that depending upon capital and other fixed costs (called "demand component"), and that depending on operating cost (called "energy component"). The most economic generating system is obtained when the total of these two parts is at a minimum.

11. The constitution of the Commission's generating system to-day (and as, of course, it still will be when the extensions at present proceeding are completed) is such that by far the greater part of the total generating cost is represented by capital cost. This is because most of the total plant capacity is located at Yallourn and at Sugarloaf–Rubicon, thus involving long transmission lines for delivering electricity to the main load centres. At Yallourn the operating cost is low due to the relatively low cost of brown coal fuel for steam raising, while the operating cost of the Sugarloaf–Rubicon hydro-electric scheme is very small in relation to the fixed charges, this feature being characteristic of all hydro-electric schemes. In order then to achieve the most economic generating costs the capital charges must be spread over the largest possible number of kilowatt hours.

As a consequence, the Yallourn and Sugarloaf–Rubicon Stations of the existing system operate most economically when supplying a load as uniformly distributed as possible throughout the 24 hours of the day—that is, these stations should be operated at the highest possible load factor by supplying the base portion of the system load.

12. The base or high load factor portion of the system load having been allotted to the Yallourn and Sugarloaf–Rubicon Stations, it is economical to deal with the remaining load of lower load factor through generating plants of low capital cost, even if a more expensive fuel must be used in such stations.

Combined with the low charges upon capital, even the higher cost of fuel may result in a lower overall cost per kw. hr. for energy generated in such stations than would be the case in a plant of higher first cost when operated at the same load factor.

It will be possible, for some years to come, to increase the utilization factor, and therefore the load factor of the Yallourn Power Station, but it will be necessary progressively to make provision for the installation of plant to deal with the increment of load, and for a few years the plant thus provided will be required to operate at a relatively low load factor.

It is shown in this Report, however, that after 1941 there will be a portion of the system load, after the requirements of economical operation of Yallourn and Sugarloaf–Rubicon have been satisfied, which will have such a load factor as to carry economically the charges associated with schemes of comparatively high capital cost without adversely influencing the overall unit generating cost of the system. The method of operation under these circumstances will be that the plant provided for dealing with the peak load will continue to meet that portion of the load, and the subsequent addition to the generating plant will be allocated to the moderate load factor portion of the load.

By pursuing a policy of extending the generating system generally in accordance with these principles, the lowest possible generating costs will be obtained at all times.

PART II.—STUDY OF ALTERNATIVE PROPOSALS.

13. The reports of the Chief Engineer, Power Production, on the Kiewa hydro-electric scheme, and on the metropolitan steam stations, set out in full detail the considerations described in paragraph 5 *supra*. As the reliability of the data employed in the conclusions arrived at is of paramount importance, the data and all source material have been included by the Chief Engineer in his reports, which form Appendix "B."

14. These investigations were directed towards designing a long range programme for augmenting the State's resources of power plant, and they have clearly established that the characteristics of the anticipated increments of system loading are such that the lowest possible generating costs will be secured by the combination of a large-scale water power scheme with the installation of additional plant at a heat power station in Melbourne, both installations to be developed in stages according to the rate of growth in the class of demand which each project is designed to serve.

WATER POWER SCHEME.

15. This Report embodies a recommendation by the Commission that, for such portion of the anticipated additional loading as will have a load factor approximating 48 per cent. in an average year, generating plant be provided to utilize the power resources of the Kiewa River. This conclusion has been reached after exhaustive examination of the other competing alternatives, viz., extension at Yallourn and the establishment of a metropolitan plant.

For the purpose of this examination, all three alternatives are reduced to a common basis, which requires delivery of 92,500 kw. to the system at equivalent load points. The alternatives compare as follows :—

Costs of providing 92,500 kw. delivered to the System at Equivalent Load Centres.

Alternative.	Estimated Capital Cost.	Estimated Annual Expenditure.
	£	£
1. Extension of Yallourn Power Station	4,981,000	620,000
2. Establishment of Metropolitan Station	3,598,800	694,000
3. Kiewa Project	6,136,000	433,000

16. Analysis of the annual costs of delivering 92,500 kw.—390,000,000 kwh.—at load centres gives the following conclusions :—

(*a*) The Kiewa project is economically superior to the Yallourn extension at all load factors of which the former is capable.

(*b*) The Yallourn extension and the metropolitan station are economically equivalent at about 30 per cent. load factor, above which load factor, on the basis of present costs of black coal and raw brown coal respectively, the Yallourn extension is the more economical.

(*c*) The Kiewa and the metropolitan station are economically equivalent at about 10 per cent. load factor, above which load factor Kiewa is economically superior to the metropolitan station.

(*d*) At the time when the Kiewa plant is fully developed the range of load allotted to the plants of this scheme would be between 34 per cent. and 62 per cent. of the system load, and for this particular band of loading there is no portion of the Kiewa load which could economically be taken by metropolitan plants, and it follows that no combination of metropolitan and Yallourn plants could give more economical production of energy for this portion of the loading than the Kiewa plants.

17. The lengthy investigations made have resulted in the design of a scheme which can be applied economically to that part of the load which will be available to it within a few years from this date. Although the capital cost of the whole scheme is estimated to reach the comparatively high figure of £66·33 per kw. of output at load centres, the capital outlay can be limited to amounts

from which benefit can be derived within short periods and the hydraulic works will be of such a permanent nature that they will be subject to a very low rate of depreciation, with the result that the overall annual charges will amount to only 7 per cent. of the capital cost, corresponding to the satisfactory figure, for the completed scheme, of £4·68 per annum per kw. of output at load centres.

Kiewa, as designed, will not be capable of operating at the same high load factors which are the function of the Yallourn plant, but despite the fact that its capital cost is higher than that of the available alternatives its economic superiority over such alternatives is very marked. The Commission's Consulting Engineers—Messrs. Rendel, Palmer and Tritton—have endorsed this conclusion in the following terms :—

> "We share the opinion expressed by the Chief Engineer of the Commission that an analysis of basic annual costs of power clearly demonstrates the economic superiority of the Kiewa project, and that the Kiewa scheme is technically and economically to be preferred to major extensions of the steam stations. It is reasonable to assume that power from the Kiewa scheme when fully developed can be delivered at load centres at a cost of approximately two-thirds of the cost of power generated by coal from such major extensions.
>
> As a conclusion we would say that in our opinion the Kiewa project contains all the elements of a successful hydro-electric power undertaking, which, operated in conjunction with other sources of supply considered, would meet the growing demand on the Commission's electric supply system in a suitable and economical way."

18. While it is thus clear that economically Kiewa possesses very real advantages over the competing alternatives, there is another equally important consideration which bears on its selection, particularly as it will be some years before the extension is fully loaded. As designed, the scheme will be constructed and operated in stages of moderate capacity, and thus avoid charges on unproductive capital that would arise should the scheme be of such a nature that expenditure on assets would not at once be utilized to the full. A further advantage over other available alternatives is that, from the standpoint of reliability, Kiewa will be a highly favorable source of supply, giving the same splendid service which the smaller Sugarloaf–Rubicon hydro-electric scheme has afforded during the ten years of its existence, for operation will be largely automatic, requiring but a small staff. This is a very marked advantage, as the operation of the stations will have almost complete immunity from industrial dislocations.

19. In the form proposed, the Kiewa scheme is the culmination of investigations carried out by the Commission since 1919, coupled with a close study of the hydrological and meteorological data available from the year 1865 in respect of rivers and localities situated close to the Kiewa watershed. As part of the investigations, discharge of the Kiewa River itself has been gauged accurately for the last ten years. Over the period for which records are available, some very dry years have occurred, particularly the years 1902 and 1914. The most severe drought since the year 1865 was that during the period from December, 1913, to July, 1915, but this was not taken as giving the most extreme conditions which might occur, and the water storage capacity in the design has been based on the actual drought period mentioned, plus an assumed additional drought period of one year immediately following. Such storage capacity avoids the necessity for providing standby steam plant at load centres to tide over the periods of minimum water flow. On the advice received and the information available, the Commission has no doubts as to the adequacy of the water available, and of the arrangements proposed to maintain the designed output from the scheme.

20. Due to the fact that some portions of the scheme are situated at altitudes which are within the region of heavy and regular winter snow fall, one or two features unusual to water power schemes in Australia are introduced. Investigations have shown that the conditions at the higher elevations are so severe that open water races at these levels would be inoperative in the winter months, owing to blockage by snow and ice. Hence, it is proposed to convey water almost entirely in tunnels driven in solid rock. The good quality of the rock permits of unlined tunnels, excepting for short lengths where the geological conditions will necessitate concrete lining. Similar unlined tunnels have been constructed and operated successfully in Sweden and other countries for a number of years, and the advice of authorities in Australia who have gained experience of mining in rock is reassuring. The opinion of the Consulting Engineers is that, provided care is exercised in locating the tunnels in the best rock available, lining of the tunnels will be needed only in those places where broken rock or faults are known to exist. No insurmountable difficulties of construction are anticipated.

21. The Commission believes that it should again call attention to statements in its earlier reports that a development based on Kiewa does not permit of serious consideration for any objective that excludes the metropolitan load. The engineering studies make it clear that the

scheme could not be developed for small outputs, except at prohibitive costs. For instance, the north-eastern district of Victoria, in which the Kiewa River is located, at present is supplied from the State power system, but the load of this area alone is altogether too small to justify the Kiewa project. The establishment of the designed scheme as part of the main interconnected State power system is made possible only by anticipated major loading in the metropolitan area. The development of Kiewa is advantageous to all territories capable of being served from the State system, for its addition to the main generating system will result in ultimate lower overall unit generating costs.

22. Earlier reports of the Commission have mentioned the Mitta River and the outflow from the Hume Reservoir as alternative sources of hydro-electric power, which, at an appropriate stage, would need to receive consideration in comparison with a development based on Kiewa. The Commission endorses the recommendation of the Chief Engineer, Power Production, in preferring Kiewa to the other sources of water power.

The grounds for this conclusion are disclosed in detail in the Chief Engineer's Report, (pages 47–8); briefly, they are as follow:—

Concurrently with its work on the Kiewa River, investigations have been made into the possibilities of utilizing the Mitta River and the Hume Reservoir, and it would seem that the cost of electricity from these sources would approximate to that estimated for the Kiewa. But the Mitta River is one of the main sources of water for the Hume Reservoir, and storages on that river such as would be involved in any power scheme are believed by the River Murray Commission as likely detrimentally to affect irrigation interests, and at this stage it has been unable to signify its concurrence in such a project. More important still, the geological conditions on the Mitta River are less favorable than those on Kiewa.

Despite the view that Kiewa is the best source of water-power available in the State for the conditions of load which the project is designed to meet, it is the Commission's intention to continue investigations into the Mitta, Hume, and other hydraulic potential power sources within the State, as their possibilities may be such as to place them ultimately in the list of adjuncts to the State's ever-expanding generating system.

Transmission Line and Terminal Station.

23. An integral part of the project above selected and forming part of the estimated capital cost is a transmission line from Kiewa to Melbourne—a distance of 158 miles. This line is estimated to cost £975,500 (including Kiewa step-up station), and will consist ultimately of two circuits operating at 165,000 volts. This operating pressure, which is higher than that of the 132,000-volt Yallourn–Melbourne transmission, is warranted by the long transmission distance. It is not a feature which calls for special consideration, since many systems in U.S.A. and Europe have been operating for several years with complete success at a pressure substantially in excess of 165,000 volts.

24. There is also included in the recommended scheme provision for a third main delivery (or terminal) station in the metropolitan area. The existing stations are located at Yarraville (capacity, 60,000 kw.), at Richmond (ultimate capacity, 90,000 kw.), and at Thomastown (capacity 20,000 kw.). The new station, with a plant capacity of 92,500 kw., will be located at Brunswick in conformity with the needs of the main Melbourne distributing system, and of the main country feeders radiating therefrom. This new station is estimated to cost £408,000, and would need to be established whichever alternative were chosen for the next major installation of generating plant.

Independent Examinations of the Kiewa Project.

25. The Commission desires to place on record the extent to which it has secured outside advice in respect of Kiewa since the examination and possible development of the State's power resources were committed to its charge in 1919.

26. **Investigation in 1920 by A. G. M. Michell, M.C.E.**—In September, 1920, the Commission (then the Electricity Commissioners) submitted to the Government a report on the possibility of developing the Kiewa resources, such examination being undertaken pursuant to Section 13 (*c*) of Act No. 3776, which requires the Commission "to carry out investigations, surveys, explorations, and borings to ascertain the existence, nature, and extent of coal deposits or of water power suitable for use in connexion with the generation of electricity and to ascertain suitable sites for generating stations."

The hydraulic and electrical engineering investigations were undertaken by the Commission's then consulting hydraulic engineer, Mr. A. G. M. Michell, M.C.E., who, on appointment in June, 1919, undertook the conduct of detailed investigations into the topographical and climatic conditions, involving the preparation of an outline scheme of works and the framing of estimates for bringing such a scheme into existence at that time. Mr. Michell's report was adopted by the Commissioners as a reliable guide to the determination of the policy questions then involved. These questions concerned the relation of such a hydro-electric project, on the one hand, to the works already being undertaken in the power production development at the Yallourn brown coal fields, with supplementary generating provision at Newport, and, on the other hand, to the problem of meeting the electrical needs of the provincial areas comprised in the north-eastern district.

The Commission arrived at the quite definite conclusions that the Kiewa development as then propounded, particularly as to that part based on the hydro works located on the Kiewa, did not permit of its serious consideration for any other objective than supply to the metropolis, and that, having regard to the nature and extent of the generating plant which the State was to install at Yallourn and Newport, there was no justification at that stage for embarking on a scheme of the magnitude and nature of Kiewa.

A Select Committee of Parliament endorsed this conclusion.

As part of the 1920 scheme, Mr. Michell put forward the development of the Sugarloaf–Rubicon resources. This smaller scheme, having striking advantages over any other proposal for the combined purpose of serving both the north-eastern district and the metropolitan market, was reported on again by the Commission in 1922, and on its recommendation Parliament later authorized the construction of such project, at a cost of approximately £1,000,000.

Although it is only after seventeen years have elapsed that the Commission finds itself in a position to recommend a major development based on Kiewa, it desires here to acknowledge the most valuable work of Mr. Michell in his 1919–20 investigations. Notwithstanding that these investigations were directed towards meeting conditions of demand essentially different from the part that the 1937 Kiewa scheme, as now contemplated, is designed to fulfil in meeting conditions of load of 1941 and after, the earlier investigations undertaken under Mr. Michell's direction have provided the Commission's engineering staff with a substantial contribution towards the design of any scheme based on Kiewa, and the fullest advantage has been taken of Mr. Michell's work in the project now submitted in this present Report.

27. **Examination in 1936-1937 by Messrs. Rendel, Palmer and Tritton.**—During his visit abroad in 1936, the then Chief Engineer of the Commission, Mr. H. R. Harper, knowing that the Kiewa alternative would call for serious consideration when the final decision as to the nature and location of the next major installation of power plant had to be made, paid particular attention to hydro-electric works in European countries, especially those located in mountainous country similar to that of the Kiewa.

The hydraulic side of the Kiewa project, as conceived by the Commission's staff, includes features which are by no means novel in Europe, but concerning which no Australian experience is available. Of these, the large scale tunnelling for the conveyance of water in territory subject to heavy snowfall is the most important.

As the civil and hydraulic works in the Kiewa project are estimated to involve an expenditure of over £4,000,000, or approximately two-thirds of the total estimated cost of the complete project, it was the Commission's desire, before submission of any recommendation to the Government, that the proposal should be made the subject of critical examination by an acknowledged outside authority versed in the actual design and construction of schemes similar to the Kiewa. There was chosen for this purpose the well-known consulting firm of Messrs. Rendel, Palmer, and Tritton, of London, which, in alliance with Messrs. Vattenbyggnadsbyran (VBB) of Stockholm, Sweden, has been associated with many recent important hydro-electric projects in various parts of the world. For this examination, the consulting engineers sent to Victoria Mr. B. Hellstrom, M.Inst.C.E., M.Am.Soc.C.E., and Dr. A. F. Samsioe, M.I.V.A. The terms of reference to the consultants required them to undertake the following work:—

1. Inspection of sites of proposed civil engineering works.
2. Consideration of these civil engineering proposals, so as to give independent opinion in regard to—
   - (*a*) Reliability and accuracy of the methods used in determining the fundamental hydrological data and the conclusions drawn therefrom for the Kiewa catchment, particularly the areas contributing water to the storages and diversions proposed.
   - (*b*) Reliability of the conclusions formed as to the energy which can be furnished over a period of years, including drought periods.

(*c*) Suitability and adequacy of the proposals with regard to storages, dams, tunnels, diversion pipe lines, and hydraulic machinery for the purposes proposed.

(*d*) General adequacy of cost estimates for storages, dams, tunnels, diversions, and hydraulic machinery.

The Commission has been impressed with the evident care and thoroughness with which the consultants' representatives applied themselves to the investigation, and it believes that the high degree of technical ability which they brought to bear in their study of the many problems of design and construction must ensure that the State has been well served by the special review of the scheme which they have made. Their report forms Appendix " A."

HEAT POWER STATION.

28. This Report also contains a recommendation that, for the peak load portion of the demand estimated to arise between 1939 and 1948, progressive extensions be made in the Newport " B " power station. Engineering investigations for meeting this section of the system demand are greatly simplified by the availability at Newport of power plant in which the State of Victoria already has invested approximately £2,000,000. Erected, in the first instance, by the Victorian Railways for the electrification of the suburban railway system, the station was extended in 1920 by the installation of plant, in the ownership of the State Electricity Commission, for serving the Melbourne peak load of the State power system. Extensions now in course will, by 1939, bring the expenditure on this plant on account of the State Electricity Commission to £1,398,000.

The plants, which are known respectively as Newport " A " (Victorian Railways Commissioners) and Newport " B " (State Electricity Commission) stations, utilize all facilities for power production, including site works, circulating water arrangements, &c., which are common to both, and are operated by the Victorian Railways Commissioners, who are reimbursed by the Commission the cost of operating the " B " station.

From every standpoint, there is no more favourable site in the metropolitan area for the progressive provision of the Commission's peak load plant. The important question of location thus not being at issue, the engineering investigations have been confined to the nature, extent and time of installation of the plant additions. This aspect, having been completely traversed in the report of the Chief Engineer—Power Production, does not call for special comment by the Commission, except to declare in the following table the advantages that will accrue from the greater utilization of the existing assets of the Commission at this location :—

EXISTING AND CONTEMPLATED INVESTMENT AT NEWPORT " B " POWER STATION.

Stage.	Progressive Capital Cost.	Effective Capacity in kw.	Capital Cost per kw. of Effective Capacity.
	£		£
1. At present	835,000	19,000	43.9
2. At completion of extensions already planned	1,203,000	30,000	40.1
3. At completion of extensions proposed before 1939	1,398,000	48,000	29.1
4. At completion of extensions proposed from 1939–1941 ..	2,118,000	75,000	28.3
5. At completion of extensions proposed from 1943–1945 ..	2,838,000	100,000	28.3
6. At completion of extensions proposed from 1946–1948 ..	3,558,000	120,000	29.6

PART III.—FINANCIAL.

29. **Capital Cost.**—It is estimated that the complete combined scheme covered by this Report will cost £8,296,000, of which sum £6,136,000 is on account of Kiewa and £2,160,000 for Newport " B." These figures are based on present-day price levels, and include interest that will accrue during the construction period. Distribution of the total sum over the various works comprised in the scheme is as follows :—

KIEWA.

	£	£
Hydraulic Works and Power Stations—		
1. Land, clearing, roads, buildings, &c.	429,000	
2. Dams and offtakes	1,037,000	
3. Tunnels, conduits, offtakes, surge tanks, and diversion races ..	992,000	
4. Pressure pipe lines complete	318,000	
5. Turbo-generator plant	476,500	
6. Switchgear and transformers	210,500	
7. General equipment	340,000	
8. Engineering	221,000	
9. Interest during construction	264,000	
10. Contingencies	341,000	
		4,629,000
Transmission, &c.—		
1. Main transmission line	760,000	
2. Kiewa " A " and other substations	286,000	
3. Melbourne Terminal Station	408,000	
4. Interest during construction	53,000	
		1,507,000
Total		6,136,000

NEWPORT " B."

1. Site works, land, buildings	400,000
2. Machinery and plant	1,370,000
3. Switchgear and transformers	170,000
4. General, including overheads, engineering and inspection	140,000
5. Interest during construction	80,000
Total	2,160,000

A more detailed distribution of the above items will be found in the report of the Chief Engineer—Appendix " B."

30. **Time Programme.**—The following table shows the segregation of the expenditure into the periods in which the funds will be required as the works proceed :—

Period.	Kiewa.				Newport " B."	Grand Total.
	Hydraulic Works and Power Stations.	Transmission Line.	Terminal Station and Substations.	Total.		
	£	£	£	£	£	£
1938–1942	872,500	454,500	81,000	1,408,000	720,000	2,128,000
1942–1945	903,750	272,500	281,750	1,458,000	720,000	2,178,000
1945–1947	935,000	61,500	65,500	1,062,000	..	1,062,000
1947–1948	690,750	..	211,250	902,000	720,000	1,622,000
1948–1949	272,000	..	79,000	351,000	..	351,000
1949–1951	955,000	..	..	955,000	..	955,000
Totals	4,629,000	788,500	718,500	6,136,000	2,160,000	8,296,000

31. Under the above programme, power from Kiewa will become available to the extent and at the times shown below :—

Year.	Total available power at Kiewa Generators.
1942	20,000 kw.
1945	37,000 „
1947	50,000 „
1948	76,000 „
1949	83,000 „
1951	104,000 „

The balance between the above-stated increases in capacity and estimated load requirements will be provided by the proposed installation of plant at Newport " B."

32. **Economics of the Extended Generating System.**—The estimated effect of the above proposal on the overall cost of generating and delivering to the load centres the energy corresponding to the figures set out in Part I., is shown in the following table. These estimates are based on existing costs and on the distribution of load between the existing and proposed sections of the generating system as described herein :—

Year Ending June—	Estimated Overall Cost of Electricity Delivered at Load Centres.	
	Total.	Per Kilowatt Hour.
	£	Pence.
1939	1,530,000	0·472
1940	1,605,000	0·455
1941	1,680,000	0·441
1942	1,830,000	0·443
1943	1,965,000	0·442
1944	2,055,000	0·427
1945	2,150,000	0·414
1946	2,390,000	0·424
With Kiewa fully loaded (around 1950)	2,595,000	0·407

As previously stated, higher costs would have resulted from any alternative proposal and under the most favorable of the discarded alternatives (extensions at Yallourn and Newport " B ") the excess cost would have amounted to some £200,000 per annum when the fully loaded stage of the extension was reached.

33. **Provision of Funds to meet Expenditure.**—Commencing with the year 1940, capital expenditure on Kiewa will range from £400,000 to £800,000 in each year until 1949. When to this is added the yearly expenditure necessary for augmenting the metropolitan power plants as herein proposed, as well as the ordinary capital requirements of the Commission which at present are met from the Commission's own funds, it is clear that the existing borrowing powers of the Commission will need to be increased if the requisite funds are not obtained by State borrowings. This action is not immediately necessary, for the unexercised borrowing powers of the Commission amount to £1,160,000, but a general survey of probable capital expenditure during the next 10 to 12 years indicates that an additional borrowing authority of approximately £6-7,000,000 should become available in 1939 for the works programme for the next decade.

PART IV.—RECOMMENDATIONS.

34. In view of the rapidly expanding requirements for electrical energy throughout the State, and of the most favorable means for meeting such as exhaustively discussed in this our Report and the important technical Reports thereto annexed, we now have the honour to recommend to the Government :—

(*a*) That early approval be given to a long range programme designed to increase the existing generating plant of the State Electricity Scheme by approximately 200,000 kilowatts of installed capacity, such, subject to Government approval, to be made available progressively over the next 14 or 15 years to meet the expanding demand. The total expenditure on such increased plant capacity including transmission and terminal transformation, is estimated at £8,296,000.

(*b*) That the additional generating plant be installed at two locations—at Kiewa utilizing the waters of the Kiewa River and at Newport " B " heat-power station, such works including provision for delivery of energy to load centres.

(*c*) That immediate authority be given for the preparation of detailed designs and specifications, and calling of tenders for the whole of the works embraced in the first stage of the Kiewa Scheme, estimated to cost £1,408,000, and to be in operation for the winter of 1942 ; and for the installation of the first additional generating unit at Newport " B," which is estimated to cost £720,000 and will be required for the winter of 1941.

In submitting these recommendations, it is desired to emphasize that the contemplated future distribution of generating capacity amongst power stations at widely separated locations will enhance the overall reliability of the Commission's generating system, and in particular assure a desirable change from the now obtaining position, wherein more than 70 per cent. of the State's effective generating capacity is concentrated at one power-station (Yallourn).

APPRECIATION.

35. The Commission desires to place on record its appreciation of the valuable work done by its former Chief Engineer, Mr. H. R. Harper, in the prosecution of the Kiewa investigations, which were practically complete at the date of his retirement. His successor, Mr. E. Bate, as Electrical Engineer, was also closely associated with the work, and his reports (Appendix " B ") afford striking evidence of the thoroughness of the investigations, and the skill and unremitting zeal with which they have been conducted over a long period of years, to the end of perfecting a scheme which will reliably and economically exploit the full resources of the Kiewa catchment. The examination of alternatives and the preparation of a project for substantial expansion of a metropolitan heat power station, although not so prolonged, have been no less important, and the combined development of water and heat power which has been evolved has called for the fullest co-operation of the Civil, Electrical and Mechanical Engineering Staffs associated with the Power Production Department, as well as of the Construction Engineer's Department. It is extremely gratifying to the Commission, as it must be to the staffs concerned, that the hydro-electric proposals put forward have been completely endorsed by Consulting Engineers of the highest standing from abroad, after an analysis of all factors, combined with inspection of the Kiewa terrain and a careful study of its geological, hydrological and meteorological characteristics.

We have the honour to be, Sir, your obedient servants,

F. W. CLEMENTS, Chairman.

D. J. McCLELLAND, Commissioner.

C. A. NORRIS, Commissioner.

ANDREW W. FAIRLEY, Commissioner.

W. J. PRICE, Secretary.

12th June, 1937.

APPENDIX "A"

REPORT

of

RENDEL, PALMER, and TRITTON,

Consulting Engineers,

of

55 Broadway, Westminster, London,

on the

KIEWA HYDRO-ELECTRIC SCHEME

CONTENTS.

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RENDEL, PALMER & TRITTON.
CONSULTING ENGINEERS.

Sir Seymour B. Tritton, K.B.E., M. Inst. C.E.
Sir Robert R. Gales, M. Inst. C.E.
H. J. Fereday, M. Inst. C.E.
E. J. Buckton, M. Inst. C.E., M. I. Mech. E.
J. S. Tritton, M. Inst. C.E., M. I. Mech. E.

CHARTERED CIVIL ENGINEERS.

55, Broadway,
Westminster,
London, S.W.1.

The Chairman,
The State Electricity Commission of Victoria,
Melbourne.

Sir,

Having studied the report, dated 7th March, 1936, prepared by the Acting Chief Engineer and the Civil Engineer, as well as data subsequently supplied to us, and having inspected the sites of the proposed works, we have much pleasure in submitting herewith our report on the Kiewa Hydro-Electric Scheme.

2. In the terms of reference we were asked to give independent opinion in regard to the civil engineering proposals put forward by the Engineers of the Commission. Our views may be summarized as follows :—

The methods used in determining the fundamental hydrological data for the Kiewa catchment, and the conclusions drawn therefrom regarding the areas contributing water to the storages and diversions proposed, are reliable and accurate.

The conclusions formed as to the energy which can be furnished over a period of years, including drought periods, are correct.

The general layout of the proposed scheme, particularly with regard to storages, dams, tunnels, diversion pipe lines and hydraulic machinery, is well conceived and suitably adapted to the general topography of the country.

Taking into account the modifications introduced to the scheme, the results of additional surveys carried out, and the recent increase in cost of turbines and other equipment, our estimate of cost agrees well with the cost as estimated by the engineers of the Commission.

3. The investigations and surveys of the sites of the proposed works have continued after the report by the engineers of the Commission was submitted, and detail geological and aerial surveys were proceeded with after our first visit to the sites. Consequently it has been possible to locate the works with more complete allowance for the geological conditions than was previously possible. This has been done in close co-operation with the engineers of the Commission and has led to certain modifications of the details of the suggested layout, particularly with reference to the alignment of tunnels, and the position of the power stations. Further exploration work is required, especially for Power Plants Nos. 2 and 4 and for West Kiewa tunnel, and this may lead to further adjustments of the details of the layout. As comparative estimates of cost showed that it will be more economical to place the power stations overground, this alternative has been adopted.

4. The modified scheme consists of two storage basins, the Pretty Valley and the Rocky Valley Reservoirs, and four power plants designated as Nos. 1, 2, 3 and 4.

5. A special study has been made of the storage required, and we have arrived at the conclusion that with 95,000 acre-feet in Pretty Valley Reservoir and 13,000 acre-feet in Rocky Valley, the working capacity of the scheme can be somewhat increased.

6. The main data for the power stations considered in our report are given in the following table :—

Power Station Number.	Average Net Head in Feet.	Number of Units.	Capacity in Kilowatts.			
			Per Unit.	Total Installed.	Working.	Spare.
1	1,444	2	10,500	21,000	21,000	..
2H	1,454	2	13,000	26,000	26,000	..
2L	350	1	7,000	7,000	7,000	..
3	355	3	8,000	24,000	} 50,000	13,000
4	603	3	13,000	39,000		
Total		..	..	117,000	104,000	13,000

To allow for any one unit in any station to be out of commission at any time the working capacity is fixed at 104,000 kw., i.e., 13,000 kw. less than the installed capacity.

7. Whether the installation and working capacity should be still further increased over and above the figures given in the table, has, for certain reasons, been left for consideration at a later date.

8. The scheme lends itself favourably to development by stages. The power available can be made to follow closely the growing demand on the Commission's system, and the capital outlay can be limited to amounts from which benefit can be derived within short periods.

The most suitable main stages of development are considered to be the following :—

First development stage :—

Access road from Tawonga.
Pretty Valley Reservoir.
Power Plant No. 3.
Power Plant No. 4.

Second development stage—

Diversion of West Kiewa River to Pretty Valley Branch by means of West Kiewa tunnel.

Third development stage—

Rocky Valley Dam.
Power Plant No. 1.
Power Plant No. 2.

9. It is estimated that the total power and energy output for the three development stages will be as follows :—

—	First Development Stage.	Second Development Stage.	Third Development Stage.	Total Development.
Working capacity at Kiewa in kw.	50,000	..	54,000	104,000
Million kwh. generated at Kiewa	145	59	236	440
Working capacity at load centres in kw. ..	45,000	..	47,500	92,500
Million kwh. at load centres	130	53	207	390

10. The capital cost of the scheme, including turbines, generators, low tension switchgear, and interest during construction, but excluding transmission, has been estimated as follows :—

	£
First development stage	2,350,000
Second development stage	300,000
Third development stage	1,890,000
Total	4,540,000

11. The annual cost, including $4\frac{1}{2}$ per cent. interest on capital, has been estimated as follows :—

	£
First development stage	163,000
Second development stage	16,000
Third development stage	129,000
Total	308,000

The depreciation charges included in the annual cost amount, on an average, to 1·32 per cent. of the capital cost.

12. At the Hume Dam on the Murray River, provisions have been made for utilizing for power generation the head created by the impounding of the water. The dam has been built for irrigation purposes and, with the amount of storage provided at present, hydro-electric power must be considered as a by-product only. Until full use can be made of the water for irrigation, power will be available all the year round, whilst later on no power may be obtainable for several months of the year when the water is being impounded. It is obvious that under such conditions a power station at the Hume Dam cannot be considered as a permanent and independent source of power supply.

On the other hand, a power station at the Hume Dam can be built in a short time, the cost of construction will be low, and the energy output will be considerable. Provided that the Kiewa Scheme is proceeded with, and that thus energy from the Hume Power Station is transmitted over the same high tension lines as that from the Kiewa Scheme, the cost of transmission will be very low. If no charge be made for using the water, and no contribution be required towards the cost of the dam, it seems to us that this possibility should be economical, and we recommend it to be investigated in detail.

13. The estimated capital cost of the Kiewa Scheme up to generating station bus bars is £39 per kw. of installed capacity, and £44 per kw. of working capacity at Kiewa ; and the estimated annual cost is £3 per kw. of the working capacity at a load factor of about 48 per cent. This corresponds to 0·17 pence per kwh. generated at Kiewa.

We share the opinion expressed by the Chief Engineer of the Commission that an analysis of basic annual costs of power clearly demonstrates the economic superiority of the Kiewa project, and that the Kiewa Scheme is technically and economically to be preferred to major extensions of the steam stations. It is reasonable to assume that power from the Kiewa Scheme when fully developed can be delivered at load centres at a cost of approximately two-thirds of the cost of power generated by coal from such major extensions.

14. As a conclusion we would say that in our opinion the Kiewa project contains all the elements of a successful hydro-electric power undertaking, which, operated in conjunction with other sources of supply considered, would meet the growing demand on the Commission's electric supply system in a suitable and economical way.

Yours faithfully,

(Sgd.) RENDEL, PALMER AND TRITTON.

Melbourne,
16th March, 1937.

REPORT OF CONSULTING ENGINEERS, MESSRS. RENDEL, PALMER AND TRITTON, ON THE KIEWA HYDRO-ELECTRIC SCHEME.

INTRODUCTORY.

Previous investigation. The feasibility of utilizing the water power of the Kiewa River, situated about 145 miles north-east of Melbourne, for generation of electricity, has been considered on several occasions. Preliminary investigations for such a project were carried out in 1914 by Mr. A. G. M. Michell, M.C.E., for the Victorian Hydro-Electric Company, and a somewhat more detailed examination was commenced in 1919 by Mr. Michell for the State Electricity Commission of Victoria (hereinafter referred to as the Commission). His report was submitted in 1920, but no further work was carried out until 1923, when the Commission's own staff started a detail study of the possibilities of hydro-electric developments, including survey and hydraulic observations. Based on these investigations reports were prepared in 1929 and 1933, and after further detail survey and diamond drilling, a comprehensive report, dated 7th March, 1936, was submitted by the Acting Chief Engineer and the Civil Engineer to the Commission. The investigations and proposed developments as set out in their report are the subjects of the present inquiry.

Appointment. In May, 1936, the Commission appointed Messrs. Rendel, Palmer and Tritton, of Westminster, in association with Messrs. Vattenbyggnadsbyran (VBB), of Stockholm, to investigate and submit a report on the Kiewa Hydro-Electric Scheme. The work of the Consulting Engineers was to cover the following matters, viz. :—

1. Inspection of sites of proposed civil engineering works.
2. Consideration of these civil engineering proposals, so as to give independent opinion in regard to—
   - (*a*) Reliability and accuracy of the methods used in determining the fundamental hydrological data and the conclusions drawn therefrom for the Kiewa catchment, particularly the areas contributing water to the storages and diversions proposed.
   - (*b*) Reliability of the conclusions formed as to the energy which can be furnished over a period of years, including drought periods.
   - (*c*) Suitability and adequacy of the proposals with regard to storages, dams, tunnels, diversion pipe lines and hydraulic machinery for the purposes proposed.
   - (*d*) General adequacy of cost estimates for storages, dams, tunnels, diversions and hydraulic machinery.

For the execution of this commission Mr. B. Hellstrom, M.Inst. C.E., M.Am.Soc., C.E., and Dr. A. F. Samsioe, M.I.V.A., proceeded to Victoria for carrying out the investigations necessary for submitting this Report. These investigations started in November, 1936, and were completed in March, 1937.

The Consulting Engineers desire to express their appreciation of the hearty co-operation of the Chairman of the Commission, Mr. F. W. Clements. They are also greatly indebted to the Chief Engineer, Mr. E. Bate, for the valuable service which he rendered, and to the Civil Engineer, Mr. A. L. Galbraith, and the assistant to the Civil Engineer, Mr. L. T. Guy, for their assistance

PRESENT SYSTEM OF ELECTRIC SUPPLY.

Supply system. By far the greater part of the electric power used in the State of Victoria is generated and distributed by the Commission. Exceptions are the State Railways (which have a separate system of supply operated by the Victorian Railways Commissioners), the Melbourne City Council, and a few private companies generating electric power for their own use or for distribution within limited areas. The frequency of the current on the Commission's system is 50 cycles, and on the Railways' system, 25 cycles.

The Commission's main supply system comprises generating stations at Yallourn, Sugarloaf, the Rubicon–Royston system of stations (referred to as the Mountain Stream Stations), Newport, Richmond, Geelong, and Bendigo; main terminal stations at Yarraville, Richmond, and Thomastown; and transmission lines connecting the generating stations with the terminals. From this main supply system electricity is delivered to the Melbourne metropolitan area, including the various suburbs of Melbourne, and to the South-western, Castlemaine, North-eastern, Eastern Metropolitan, and Gippsland districts. From Melbourne this network of transmission lines reaches about 150 miles to the west, 130 miles to the north, and 160 miles to the east. The demand of the Melbourne metropolitan area, with a population of somewhat over a million, is over 80 per cent. of the total load on the main supply system.

At Ballarat and Euroa the Commission operates small power stations and supply systems independently of the main system.

The general lay-out of the supply system is given on Plate No. 1.

Load. The general trend of the daily and weekly variation of load on the system can be gathered from the actual load diagrams shown on Plate No. 2 for four weeks at different seasons of the year. The highest peak generally occurs in May and June (22nd to 26th week), and the lowest daily peak at the end of the year.

In the load diagrams for the first five working days three peaks can generally be observed all the year round. The first two of these which occur during the usual working hours of the day, i.e., between 8 a.m. and 5 p.m., have a flat top, and are sharply separated by a drop in load between noon and 1 p.m. The third peak is due to lighting load, which culminates as dusk passes into darkness. In summer time the drop in load between the second and third peak has a duration of some three hours. As the season advances the gap becomes of shorter duration and less pronounced, and disappears nearly altogether at the end of May, when the lighting peak encroaches upon the second peak. On dark days the two peaks are merged together and create a resultant peak at the end of the working day, which may become the maximum peak of the year. At the end of August the lighting peak is again well detached from the second peak, and remains so until the following winter.

On dark mornings, in the middle of the winter, the first part of the first peak is accentuated by a lighting load superimposed upon the working day load. This combined load may sometimes be so high as to give the maximum peak of the year.

On Saturdays the second peak is non-existent and the remaining peaks much smaller than on the other working days. On Sundays and holidays only the lighting peak occurs.

The daily load factor for an ordinary week day (Monday to Friday) averages about 70 per cent.

The weekly load factor varies irregularly during the year, and its average value has slowly increased from 57 per cent. in 1929 to 61 per cent. in 1936. The highest value reached in 1929 was 60, and in 1936, 64 per cent.

The annual load factor has also grown slightly during the past years, and it was 53.6 per cent. in 1936.

The growth of the maximum demand on the system, represented by the simultaneous weekly quarter-hour maximum load on the generators in Yallourn, Sugarloaf, the Mountain Stream Stations, Newport and Richmond, is shown on Plate No. 3 for the period 1929 to 1936. In 1929 the maximum load was 103,160 kw. (kilowatts); in 1935 it had risen to 132,000 kw. and in 1936 the peak was no less than 147,900 kw. The energy output generated in 1929 was 432 million kwh. (kilowatt-hours) and in 1936 697 million kwh. The figures mentioned are exclusive of the load on, and the output from Geelong and Bendigo power stations, which have only recently been linked up with the main system. In 1936 32 million kwh. were generated at Geelong and 5.7 million kwh. at Bendigo, the peak load in that year being 7,940 kw. and 1,760 kw. respectively.

To eliminate the annual variation 52-week moving averages have been formed of the weekly peak loads, and the moving average thus obtained is shown in Fig. 1, Plate No. 3.

By plotting the weekly maximum load as a percentage of the moving average, the annual variation of the weekly peak load has been determined and is shown in Fig. 2, Plate No. 3. It will be seen that the probable annual peak load is about 108 per cent. of the moving average, and that occasionally it may reach 112 per cent. of the moving average.

The increase of load during the last three years or so has been about 8 per cent. per annum. If the demand should continue to increase at the same rate, a peak load of 350,000 kw. would be reached in about eleven years. Although the present rate of increase may not be maintained throughout a long period of years, a substantial rise in the demand will undoubtedly take place, and steps should be taken to meet a growing demand during the next few years corresponding at least to the present rate of increase.

Power generation. As previously mentioned, the electric supply from the Commission's main system is generated at Yallourn, Sugarloaf, the Mountain Stream Stations, Newport "B," Richmond, Geelong and Bendigo.

In emergency cases, power can also be obtained from the State Railways' generating plant at Newport "A." In our opinion, however, this emergency arrangement should be disregarded when considering the means of meeting the load on the Commission's supply system in the future.

The bulk of the electric power is generated at the Yallourn steam power station in the Latrobe Valley, about 80 miles east of Melbourne. The fuel used is low-grade brown coal (lignite) won by open-cut method from an extensive coal deposit. In the large mine worked at present the depth of coal is no less than 180 feet, and the overburden about 30 feet only.

The original boiler house contains twelve boilers, each of a normal capacity of somewhat over 75,000 lb. of steam per hour. These were put into operation in 1924 to 1928. After the erection of boilers now on order, the new boiler house will contain ten boilers, each of a normal rating of 100,000 lb. The capacity of the total boiler installation will thus be about 2,000,000 lb. The steam pressure is 260 to 290 lb. per square inch, and the steam temperature 650° to 700° F.

After the erection of two turbo-alternators now on order, the machine installation will consist of (*a*) six units, each of a normal rating of 12,500 kw., which started operation in 1924 to 1929; (*b*) two units, each of a normal capacity of 25,000 kw., put into service in 1932 and 1935; and (*c*) two units, now on order, of a normal rating of 25,000 kw. The total capacity of the steam turbines will thus shortly have been brought up to 175,000 kw.

In the Briquette Factory at Yallourn, owned and operated by the Commission, there are two turbo-alternators, each of a normal rating of 10,000 kw., one of which is a spare, and, in addition, one unit of 1,500 kw. Part of the power generated is used for the briquetting process and the remaining power of 8,000 kw. is normally supplied to the Commission's main system for distribution.

From Yallourn power is transmitted to the Yarraville Terminal Station by a double circuit line, and by a single circuit line to the Richmond Terminal Station, a second circuit now being erected on the same towers. The voltage at Yallourn is 132,000 and in Melbourne, 120,000. From Yallourn, power is also transmitted to the Gippsland district at 22,000 volts.

Having made due allowance for auxiliaries and standby purposes, the Chief Engineer estimates that during week days 136,000 kw. can always be counted upon as available at Yallourn corresponding to 120,000 kw. at load centres. Due to necessary overhaul the power available on Sundays is reduced to 100,000 kw. at Yallourn, corresponding to 88,000 kw. at load centres.

The Sugarloaf Hydro-Electric Station, situated on the Goulburn River about 90 miles north-east of Melbourne, is located immediately downstream of the Sugarloaf Dam, or Eildon Weir, built and maintained for irrigation purposes by the State Rivers and Water Supply Commission of Victoria. The installation in the power station consists of two turbines and alternators of a total capacity of 13,500 kw. The head varies between 55 and 115 feet, and the storage capacity of the reservoir is about 300,000 acre-feet. In dry years the station operates during the irrigation period only and may be shut down during three to six months for the impounding of water in the reservoir.

The daily output from this station is estimated as follows :—

DAILY OUTPUT IN THOUSANDS OF KILOWATT-HOURS.

Month.	Normal Year.	1914–1915.		Very Dry Year.	
	During 24 Hours.	During Daytime.	During 24 Hours.	During Daytime.	During 24 Hours.
April	140	95	120	0	0
May	25*	0	0	0	0
June	80*	0	0	0	0
July	200*	0	0	0	0
August	260*	0	0	0	0
September	290	0	0	0	0
October	290	0	0	0	0
November	290	130	160	85	140
December	290	105	150	70	105
January	290	90	140	0	0
February	290	90	120	0	0
March	260	70	85	0	0

* Output varies between 290,000 kwh. and nil.

The Mountain Stream Stations, which are located about 8 miles from Sugarloaf, consist of four high head hydro-electric stations utilizing the waters of the Royston and Rubicon Rivers. The main data for these stations are given in the following table :—

Station.	Gross Head in Feet.	Maximum Flow in Cusecs.	Pondage in Acre-feet.	Number of Machine Units.	Generator Capacity in Kw. (Total).
Royston	266	45	23	1	840
Rubicon Falls	300	15	9	1	275
Rubicon	1,455	90	16	2	9,100
Lower Rubicon	278	140	0	1	2,700
Total	..	..	..	..	12,915

The output available from these stations depends entirely upon the natural run-off, small pondage basins only being available for daily regulation of the flow.

The daily output from the four stations is estimated as follows :—

DAILY OUTPUT IN THOUSANDS OF KILOWATT-HOURS.

Month.	Normal Year.	Dry Year.*	
	During 24 Hours.	During Daytime.	During 24 Hours.
April	135	55	55
May	175	55	55
June	215	90	90
July	290	110	110
August	290	130	130
September	290	130	185
October	290	130	175
November	290	110	175
December	215	95	160
January	175	75	75
February	120	50	50
March	125	45	45

* Practically the same as during 1914–1915.

Utilizing the pondage available, the operation of these stations, which has to be scheduled beforehand, can be arranged so as to obtain 11,000 kw. on the station bus bars when the highest peaks of the year occur on the main system.

The power from Sugarloaf and the Mountain Stream Stations is transmitted to the Rubicon " A " Sub-station, from which point all five stations are under supervisory operation. At this sub-station the power is stepped up to 70,000 volts and transmitted by a double circuit transmission line to the Thomastown Terminal Station in Melbourne. From the Rubicon " A " Sub-station power is also supplied to the North-East district.

The Newport steam station in Melbourne is divided into two sections, " A " and " B."

Newport " A " Station, which is owned and operated by the Victorian Railways Commissioners, commenced operation in 1918, the construction being completed in 1923. It contains four turbo-generators, each of 12,500 kw., and two turbo-generators, each of 14,000 kw. the current generated being of 25 cycles. There are 24 boilers of a steaming capacity sufficient to generate 60,000 kw. sustained.

Newport " B " Station is owned by the Commission, on whose behalf it is operated by the Railways Commissioners, the power being fed into the Commission's main system. The station was completed in 1923, and the installation consists of two turbo-generators, each of 15,000 kw., of a frequency of 50 cycles. There are five boilers capable of giving steam for a maximum load of 18,000 kw.

In case of emergency, power up to a maximum of 17,000 kw. can be interchanged in either direction between the Railways' system and the Commission's system by means of frequency changers at the Yarraville Terminal Station, which convert the frequency from 25 to 50 cycles or vice versa.

One of the first steam stations in Melbourne was built at Richmond about 1900. The generating machinery was designed for one phase current and is now obsolete. In 1929 a turbo-generator of a capacity of 15,000 kw. was installed and is driven by steam from the old boilers.

The present installation of the station at Geelong, completed in 1920, consists of six boilers and four turbo-alternators of a total capacity of 10,500 kw.

The station at Bendigo is of a capacity of about 1,400 kw. only and will, in future, be kept as a standby or may be shut down altogether.

The Melbourne City Council's steam station has an installation of seventeen boilers and six turbo-alternators of a total rating of 27,800 kw.

The load despatching office is located at Yarraville Terminal Station whence directions are given to the power stations about the load to be provided for and taken up. The frequency control is effected at Yallourn and the momentary variations of the load are met there.

After making due allowances for spare plant to meet the peak load during a dry year, the generating capacity of the stations normally operated for the main system will be as follows when the installations now on order at Yallourn have been completed :—

Station.	Rating in Kilowatt (Dry Year).
Yallourn	136,000
Sugarloaf	0
The Mountain Streams	11,000
Newport " B "	18,000
Richmond	15,000
Geelong	7,500
Total	187,500

As it is possible that the peak load may reach or exceed 187,500 kw. in, say, three years, a decision has soon to be made as to the most suitable and economical development of power generation to meet future demand. One of the schemes considered for this purpose by the Commission is based on the utilization of the water power on the Kiewa River.

KIEWA HYDRO-ELECTRIC SCHEME.

Kiewa River. The Kiewa River is a tributary of the Murray River, which for most of its course forms the boundary between the States of Victoria and New South Wales. The upper catchment of the Kiewa River is in mountainous country, the higher parts of which reach an altitude of between 5,000 and 6,000 feet on the Bogong High Plains, and is drained by the East and the West Kiewa Rivers, which join at the Tawonga flats at an altitude of about 1,200 feet, some 14 miles from the High Plains. The East Kiewa River has two branches the Rocky Valley branch and the Pretty Valley branch. They unite at the Junction at an altitude of about 2,200 feet. The catchment area at this point is 53·5 square miles.

On the Murray, some 7 miles east of the town of Albury, the River Murray Commission has constructed the Hume Dam, by which, for the present, 1,250,000 acre-feet of water can be impounded in the Murray and Mitta Mitta Valleys for irrigation and other purposes. The catchment area above the dam is 6,000 square miles.

The Kiewa joins the Murray a few miles downstream of the Hume Dam. The catchment, area of the Kiewa River at this point is 435 square miles.

General layout of proposed scheme. The hydro-electric scheme, as proposed by the engineers of the Commission consists of five-power plants served by two storage reservoirs. The general layout of the works is indicated on Plate No. 4.

The main reservoir is located in Pretty Valley, where 95,000 acre-feet of water can be impounded by means of a rock-fill dam. Another reservoir of a capacity of 13,000 acre-feet is provided in Rocky Valley.

From Pretty Valley Storage the water is led by means of a head race tunnel to an underground power station "P", whence the water is discharged into Rocky Valley Reservoir. The capacity of the power station is 2,600 kw., and the machine unit is equipped with a pump for transferring water from Rocky Valley to Pretty Valley Reservoir, if and when required.

From Rocky Valley Reservoir the water is led by means of a head-race tunnel and a steel pipe line to an overground power Station, No. 1, from which the water flows through a tail-race tunnel discharging into Rocky Valley branch at Rocky Valley offtake No. 2H.

The gross head at Power Station No. 1 is about 1,540 feet, and the generating unit has a rating of 21,000 kw.

To augment the water supply at Power Station No. 2, there is an offtake on Pretty Valley branch, referred to as Pretty Valley offtake No. 2H, to divert the run-off below Pretty Valley Dam through a tunnel discharging into the tail-race tunnel at Power Station No. 1, where also the run-off from McKay Creek is diverted into the tunnel.

From Rocky Valley offtake No. 2H, the water is led by means of a wood stave pipe line (or, conditions permitting, by a tunnel), and a steel pipe line to an underground Power Station No. 2, whence it is discharged into the Junction pond by a tail-race tunnel.

The gross head is about 1,480 feet, and the installation consists of a turbine and generator of a capacity of 21,000 kw. This unit is referred to as No. 2H.

The flow of the West Kiewa River is diverted by means of a tunnel to Pretty Valley branch at Pretty Valley offtake No. 2L, whence the water, augmented by the run-off from the watershed downstream of Pretty Valley offtake No. 2H, is conveyed through a pressure tunnel to Power Station No. 2, where a head of about 365 feet is utilized by a turbine and generator of a capacity of 7,000 kw. This unit is referred to as No. 2L.

At the Junction a fairly large pondage is created by an arch dam and the water diverted by means of a tunnel continued by two steel pipe lines, to an overground Power Station No. 3 The water from the station discharges into the river through a short tail-race canal. The gross head is about 360 feet, and the installation consists of three turbines and generators each of a capacity of 8,000 kw. One of these units is intended for standby purposes.

Downstream of Power Station No. 3, the water is again diverted, by means of a tunnel continued by two steel pipe lines, to an underground Power Station No. 4, whence the water is finally discharged through a tail-race tunnel to the end of the rapids on the East Kiewa River at Tawonga flats.

The gross head at Power Station No. 4 is about 630 feet, and the installation consists of three turbines and generators, each of a capacity of 13,000 kw. One of these machines is a standby unit.

The engineers of the Commission have also considered and suggested certain alternatives, including a layout with all power stations above ground. This alternative has been found more favourable, and Plate No. 5 shows the scheme adopted for the purpose of estimating available power, and capital and recurring costs.

The power will be stepped up to 165,000 volts at an outdoor sub-station at Tawonga and transmitted to Melbourne by a double circuit transmission line on steel towers. This line, 158 miles long, will deliver power to a terminal station located at an appropriate load centre in the Melbourne Metropolitan area, where it will be stepped down to 22,000 volts for transmission to distributing centres.

In the early part of the first stage the power from Kiewa will be fed to the system by means of a 66,000 volt line to Wangaratta, having a capacity of 15,000 kw., and this line will remain in use when the direct lines to Melbourne are built.

The operation of all stations will be effected by supervisory control from Tawonga sub-station.

Feasibility of proposed scheme. Having carefully studied the report prepared by the Acting Chief Engineer and the Civil Engineer, as well as data subsequently supplied to us, and having inspected the sites of the proposed works, we are of the opinion that the project contains all the elements of a successful hydro-electric power undertaking which, operated in conjunction with other sources of supply considered, will meet the growing demand on the Commission's electric supply system in a suitable and economical way.

The methods used in determining the fundamental hydrological data for the Kiewa catchment, and the conclusions drawn therefrom regarding the areas contributing water to the storages and diversions proposed, are reliable and accurate.

The conclusions formed as to the energy which can be furnished over a period of years, including drought periods, are correct and this matter will be dealt with in some detail later in this Report.

The general layout of the proposed scheme, particularly with regard to storages, dams, tunnels, diversion pipe lines and hydraulic machinery, is well conceived and suitably adapted to the general topography of the country.

The engineers of the Commission are to be commended for the thorough exploration work carried out. After the preparation of their report, the investigation work has been continued and was somewhat extended at our first visit to the sites. Consequently, it has been possible to locate the works with more complete allowance for the geological conditions than was previously possible. This has led to certain modifications of the details of the layout, particularly with reference to the alignment of tunnels, and to the position of the power stations, and further adjustments may be required as the exploration work proceeds.

By Power Station "P," a pump storage plant with a comparatively small capacity (2,600 kw. as proposed by the engineers of the Commission) is introduced into the scheme. Provided arrangements as to transmission of power, &c., are made so as to ensure that the capacity of the plant is available when the annual maximum peak load occurs, the plant may be justified, although it will somewhat complicate the operation of the scheme.

As the influence of Power Station "P" on the Kiewa Scheme as a whole is very small, it is considered advisable in this Report not to enter into the details of this pump storage plant, its suitable capacity, available output, &c., but to disregard it altogether. The matters relating to this station should preferably be investigated and considered at a later stage in conjunction with the construction of Power Stations No. 1 and No. 2.

In the modified scheme, as set out in the following, it is therefore assumed that the water is diverted from Pretty Valley Reservoir to Rocky Valley Reservoir by a tunnel cutting through the narrowest ridge between the two valleys, and neither power generation nor pumping is provided at this place.

A study of the operation of the scheme in conjunction with other sources of electric supply considered has shown that the capacity of the scheme can be somewhat increased, and modifications of the installed machinery at Power Stations No. 1 and No. 2 are suggested.

In collaboration with the engineers of the Commission we have gone into the capital and recurring costs of the scheme. Taking into account the modifications introduced, the results of additional surveys carried out, and the recent increase in cost of turbines and other equipment, our estimate of cost agrees well with the cost as estimated by the engineers of the Commission.

The latter part of this Report is devoted to a detail study of the scheme. This investigation, which has been carried out in close co-operation with the engineers of the Commission, will also deal with the modifications mentioned as well as with other adjustments found suitable or desirable.

Other power resources. Our commission being limited to the investigation of the Kiewa Scheme, we have not studied in detail any other possibility of augmenting the power production within the State. It is felt, however, that this Report would not be complete without some thoughts being given to a comparison between the Kiewa Scheme and other power resources.

With reference to power generation by steam, the Acting Chief Engineer, in his report, makes a comparison between the Kiewa Scheme and major extensions of the Yallourn station, and the metropolitan stations, respectively. Having analysed the basic annual costs of power, the Acting Chief Engineer states that the comparison clearly demonstrates the economic superiority of the Kiewa project, and also makes readily appreciable the economic place of the scheme in the Commission's generating system as it grows.

We share the opinion thus expressed, and an independent comparison has led us to the opinion that the Kiewa Scheme is technically and economically to be preferred to major extensions of the steam stations.

The possibilities of power development on the Mitta Mitta River have formed the subject of lengthy investigations by the staff of the Commission, indicating that a substantial amount of power may be obtained from that river. The Mitta Mitta River is one of the main sources of water for the Hume Reservoir, and storages on that river, as required for a power scheme, could only be developed with the approval of the River Murray Commission. The Murray Commission, however, considers that, as far as it can see at present, the construction of a storage on the Mitta Mitta River might prejudice the irrigation interests of one or more of the States, and it has, therefore, been unable to signify its acquiescence in such a project.

We are informed that the cost of power generation on the Mitta Mitta River would be about the same as on the Kiewa River, and there seems therefore to be no particular reason to prefer, at the present stage, a development of water power on the Mitta Mitta River.

At the Hume Dam, provisions have been made for utilizing for power generation the head created by the impounding of the water. For this purpose a power station can be constructed immediately downstream of the dam on the right bank, where three penstocks have been embedded in the concrete to be connected to generating units.

The dam has been built for irrigation purposes and, with the amount of storage provided at present, hydro-electric power must be considered as a by-product only. Until full use can be made of the water for irrigation, power will be available all the year round, whilst later on, no power may be obtainable for several months of the year, when the water is being impounded.

It is obvious that under such conditions a power station at the Hume Dam cannot be considered as a permanent and independent source of power supply. On the other hand, a power station at the Hume Dam can be built in a short time, the cost of construction will be low, and the energy output will be considerable. Provided that the Kiewa Scheme be proceeded with, and that energy from the Hume Power Station be transmitted over the same high tension line as that from the Kiewa Scheme, the cost of transmission would be very low. If no charge be made for using the water, and no contribution be required towards the cost of the dam, it seems to us that this possibility should be economical, and we recommend it to be investigated in detail.

As it has but little influence on the Kiewa Scheme whether or not power from a station at the Hume Dam will be fed into the Commission's system, the Kiewa Scheme is dealt with in this Report without cognizance being taken of such power generation.

HYDROLOGY OF KIEWA RIVER.

Run-off. In general, the Australian climate is characterized by sharp changes, rainfalls are unevenly distributed, and heavy downpours are frequent. It is often maintained that the occurrence of long spells of dry years is another characteristic, but actual records of rainfall and run-off show nothing peculiar to Australia in this respect. In the high land where Kiewa is situated, westerly winds prevail. The precipitation is distributed over all seasons of the year and has a maximum during the winter and a minimum during the summer.

The drainage area above the Junction is 53.5 square miles, of which about 45 square miles are snow covered continuously each winter, and the remaining area at intervals only. The average annual precipitation exceeds 80 inches and the average annual run-off 60 inches.

The discharge of the Kiewa River has been accurately gauged for the last ten years, at the following four important places:—

1. Pretty Valley branch at Pretty Valley Dam site.
2. Rocky Valley branch at Rocky Valley Dam site.
3. The junction below the confluence of Pretty and Rocky Valley branches of East Kiewa River.
4. West Kiewa River at the offtake for the diversion tunnel to East Kiewa River.

At these places records of the water level have been obtained by automatic gauges, and rating curves have been established by a great number of discharge measurements at different water levels.

In an Appendix to this Report, the average run-off at these gauging stations is given as calculated by the staff of the Commission for each month of the last ten years, and the average values for the ten-year period are as follow:—

AVERAGE ANNUAL RUN-OFF DURING 1926 TO 1935.

Number.	Gauging Station.	Catchment Area. Square Miles.	Cusecs.	Inches.
1	Pretty Valley Dam site	7·7	34·9	61·6
2	Rocky Valley Dam site	6·9	32·4	64·1
3	The Junction	53·5	250·3	63·8
4	West Kiewa River downstream of the offtake	33·5	141·4*	56·6*

* For period 1927–1935.

The methods of gauging used by the engineers of the Commission are entirely satisfactory, in accordance with the best engineering practice, and the figures given in the above table and in the Appendix may be considered as correct as can be.

For the period 1865 to 1925, certain data are available of run-off from adjacent rivers and of rainfall at meteorological stations situated close to the Kiewa watershed. These records have been carefully examined by the engineers of the Commission and, as far as can be judged, the average run-off from the Kiewa catchment during the whole period 1865 to 1935 is a few per cent. higher than during the ten-year period. As, however, the distribution of flow during the latter period is slightly more favorable than during the longer period, the period 1926 to 1935 may be considered to represent average conditions for power generation.

During the period 1896 to 1925 some very dry years have occurred, e.g., 1902 and 1914, and these will have to be taken into account when considering the storage needed for the scheme.

The catchment area of the Kiewa River is proposed to be slightly increased by the diversion of a few small creeks, at present draining to the Mitta Mitta River.

The catchment areas at the various points will then be as follows:—

Gaugging Station.	Offtake for Power Station.	Catchment Area.		
		Present. Square Miles.	Future. Square Miles.	Increase. Percentage.
Pretty Valley Dam	..	7·7	9·4	22
Rocky Valley Dam	..	6·9	6·9	..
	No. 1	..	16·9	..
	No. 2H	..	38·7	..
	No. 2L	..	41·2	..
Junction (exclusive of West Kiewa) ..	..	53·5	57·6	8
West Kiewa at offtake	..	31·5	33·5	6
	No. 3	..	92·4	..
	No. 4	..	96·5	..

Taking the size and location of the additional catchment areas into consideration, the flow available for power production at the proposed power stations can be calculated by interpolation from the records of the discharge at the four gauging stations mentioned.

Floods. Arrangements for discharging floods at the storage dams have been based on a maximum run-off of about 2,000 cusecs per square mile, and at the Junction Dam of about 500 cusecs per square mile.

Hydrogen-ion concentration. The water in the Kiewa River is generally very clear and carries silt on rare occasions only. The hydrogen-ion concentration in January, 1937, varied between 6.3 and 6.8. Tests carried out show that the action on cement of the Kiewa water when percolating through concrete is severe and almost as bad as that of distilled water. Utmost care, should therefore be taken to make the dams and other water retaining structures watertight and the concrete used should be rich in cement.

GEOLOGY OF EAST KIEWA AREA.

Exploration work. One of the main features of the Kiewa Scheme is water conveying tunnels excavated in rock, and, for certain alternative layouts, underground power stations. To find the most suitable alignment of tunnels and the best position of power stations, an extensive exploration of the ground has been carried out during the past few years by means of diamond drilling. On an average the bores have been taken down to about 75 feet below ground level, and in many instances they penetrate over 100 feet into the rock. Detail record of every bore is kept and the cores are stored for inspection.

In addition to diamond drilling, trenches and test pits have been opened up at places of importance, and at Junction Dam site, two exploration tunnels, each of an area of about 50 square feet and (on the occasion of our visit) of a length of 35 and 106 feet, have been excavated into the rock of the left and right banks, respectively.

Preliminary geological reconnaissance was made in 1929 and 1930 by Mr. J. P. L. Kenny, B.C.E., Senior Field Geologist of the Mines Department.

Having studied the results obtained so far and inspected the various sites, together with Mr. Kenny, we are satisfied that the geological conditions generally of the Kiewa area are favourable for the rock excavation works as proposed. Before the location of the works can be recommended, faults, dykes, veins, and landslips have to be surveyed and studied. For this purpose a detail geological survey was suggested, comprising:—

(*a*) a detail geological study on the ground of the dam sites and other areas of tunnels, pipe lines, power stations, &c., and

(*b*) an aerial photographic survey of the East Kiewa River and adjacent ground for the purpose of studying the topography by means of the stereoscope, this method being of greatest assistance in locating the fault lines.

The aerial survey of the major portion of the area involved has now been successfully completed, and the detail geological study on the ground has been carried out by the geologists for Power Plant No. 3, and part of Power Plant No. 4.

Based on a study of the aerial photographs and on inspections on the ground, a map showing our findings so far with reference to faults, lines of weakness, landslips, &c., has been handed to the Chief Engineer for further investigation and corroboration in the field by engineers and geologists.

Rock varieties. The Kiewa area forms part of the extensive belt of metamorphic rocks of north-eastern Victoria. A series of sedimentary strata, possibly with some igneous rocks, has been penetrated by granite intrusions which have altered the original rocks to crystalline gneisses and foliated schists. The Bogong High Plains consist of coarse gneisses and schists with some granite, and a small area is covered with basalt. Towards the north, in the deeply-cut East Kiewa valleys, fine-grained gneisses and schists occur with large areas of granite, and at the northern end of the Kiewa area, at Mount Beauty near the Tawonga flats, the rocks are schistose.

The foliated rocks, i.e., the gneisses and schists, occur in many varieties and generally they are hard and resistant to weathering and decomposition.

The granite is mainly found in two varieties, of which one is fine grained, dense and uniform in texture, and the other is coarse grained and somewhat porous. Most of the granite in the East Kiewa area is of the first type, and the latter kind occurs in a few isolated places only. The granite formations consist of outcrops over large areas and also of dykes and pipes of varying thickness in the gneiss and the schistose rocks.

The rocks of the area are traversed by vertical joint planes running in two directions, and also by more or less horizontal joints.

The question of decomposition of the rock is important. Generally speaking, in the course of geological periods decomposition begins along the joint planes, ultimately leaving in places outstanding rock tors of resistant material, while elsewhere boulders are left set in a granitic sand. As the depth increases the boulders increase in size and the sand decreases in amount until finally the apparently solid granite is reached. The fine grained variety has a good resistance to weathering, while in the coarse-grained granite disintegration is particularly marked and deserves attention.

In the Kiewa area there are few and limited places only of deteriorated coarse-grained granite, but during a visit to Mount Buffalo (about 25 miles west of the Kiewa area) which consists of coarse-grained granite, we had an opportunity of inspecting the decomposition process of such granite in all its stages.

As a result of this investigation we would say that, in our opinion, there will be no serious decomposition of really sound coarse-grained granite if left unprotected in the works. The deterioration, however, penetrates deeply into the apparently solid granite, and it is difficult to determine the soundness of this kind of rock until the actual excavation is available for inspection.

With reference to sound rock of the common fine-grained variety of granite, there is no risk of decomposition of any practical consequences taking place within periods of time considered in civil engineering. This also applies to sound gneiss and schist.

Of other rocks to be found in the East Kiewa area, quartz, diorite, eurite, and porphyrite, occurring in dykes and pipes, may be mentioned. Some of these rocks, and particularly the porphyrite, are liable to cause trouble and should be specially considered. In places they are badly fractured and water may easily penetrate into them to a great depth. Several landslides, some of which extended over fairly large areas, were most likely caused by water pressure created within porphyrite seams discovered to exist at the places of these slides.

Hill sides traversed by porphyrite and eurite seams should, if possible, be avoided for pipe lines, and wherever tunnels have to be taken through these rocks they should be lined with concrete, and preferably be located more or less at right angles to the seam, so as to make the transit as short as possible.

Faults. For the correct location of tunnels and power stations it is of great importance to determine the position of existing fault lines and of areas of rock that may have become broken up during movements in the earth's crust.

There are several marked faults traversing the East Kiewa area, and evidence was obtained during our visits of at least three systems of fault lines striking approximately 30°, 70° and 100°, respectively.

As a continuation, more or less, of the two creeks running westward from Mount Nelson, there is a trough fault extending over Homan's Gap and continuing along two tributaries flowing westward to Pretty Valley branch. The distance across the trough, which is bounded towards the south by a succession of faults, is some 3,000 feet, and in the enclosed area the country consists of broken rock. Due to this the tunnel from Pretty Valley offtake No. 2H to Rocky Valley offtake No. 2H has been partly replaced by an open channel.

Another fault line can be traced for about 5 miles from the West Kiewa River near West Kiewa offtake to the Junction. The western portion of the West Kiewa tunnel is proposed to be located between 1,000 and 2,000 feet south of, and practically parallel to, this fault line.

A marked fault line is also to be found through Simmond's Gap, Young's Gap and the gap just south of Mount Beauty. The West Kiewa River follows this line for some 2 miles in a gorge considerably steeper than the upper part of the valley. On the Mount Beauty Spur this fault line appears to be the boundary line between some varieties of gneiss and schistose rocks.

It is likely that there is a major fault line striking at right angles to the last-mentioned fault and following up the valley of the East Kiewa River in a south-easterly direction, possibly continuing up Rocky Valley. More definite evidence as to this fault is likely to be obtained when additional aerial surveys are available.

A number of minor fault lines have been examined and due regard has been taken to these when locating the works.

Tunnel lining. It is an important question whether the rock is of such quality that the tunnels can be expected to stand without the support of concrete lining.

It is evident that concrete lining will be required wherever a tunnel has to be taken through rock that has been subjected to earth movement and broken up, for instance by faulting, or if a tunnel has to pass a seam of decomposed rock or soft material. In the layout of the scheme such areas and places should be avoided as far as possible, and the tunnels should be located in the best rock available.

After having carefully investigated and studied the rocks in the East Kiewa area, and having compared them with similar rocks in Sweden and in other countries where unlined tunnels have been constructed and successfully used for many years, we have arrived at the conclusion that tunnels through solid gneisses, schists and fine-grained granite will not generally require supporting concrete lining. Experience has shown, however, that even in rock of the very best quality there will be places where a limited amount of concrete work will be required to obviate too sudden changes in the cross section, or to avoid unnecessary maintenance, or for other reasons, and this has to be provided for. As regards coarse-grained granite, the question whether concrete lining will be required will depend upon the soundness of the rock exposed by the excavation.

A thorough inspection has been made of the two trial tunnels at the Junction dam site excavated in fine-grained granite. The quality of the rock is good, the fissures and cracks in the rock walls and the roof are of ordinary character and no lining will be required in such rock.

A visit has also been paid to Omeo, where unlined tunnels were excavated in gneiss and schist between 50 and 80 years ago for gold mining purposes. Our conclusions regarding tunnels in the Kiewa area have been confirmed by the condition of these tunnels at Omeo.

In the estimate of cost, full supporting concrete lining has been provided at the places where broken rock or faults are known to exist. In addition, for tunnels passing through rock that is expected to be sound and solid, 12 to 20 per cent. of the cost of excavation has been added to provide for lining.

The preceding statements refer to tunnels subjected to low-water pressure as contemplated in the scheme. If high pressure tunnels be used, they should be provided with steel sheet lining supported by concrete (the lining being designed to take full-water pressure), or the water should be led through ordinary pipe lines located in the tunnels.

STORAGE AND SPARE PLANT.

General. As previously mentioned, the amount of water available for power production on the Kiewa River varies considerably. During periods of abundant water supply, the power stations will run at or nearly at full capacity day and night, taking the base load on the system. During periods of drought, economy will have to be exercised with the water, the power stations taking the peak load and operating during the daytime only. Under average conditions, the power stations will run principally during daytime, using the water for the purpose of meeting the demand on the system and of relieving the load on the coal-fired stations in the metropolitan area, so as to effect the greatest possible saving of coal at these stations.

Under the varying conditions of operation the hydro-electric power obtained from the Kiewa Scheme can be considered as technically equivalent to steam power installed in Melbourne provided that, at any time at short notice, the Kiewa plant, together with the Mountain Stream Stations, is able to deal with the load on the system over and above the capacity of the steam stations, and that adequate spare plant is installed.

Demand storage. As can be gathered from the tables in the Appendix, dry spells may occur at almost any time of the year. During such periods, the unregulated flow available at the power stations would not be sufficient to maintain the minimum output required, i.e., the output when the hydro-electric plants take the peak of the load only, and therefore storage reservoirs are provided which can be drawn upon on these occasions. The amount of storage assigned for the above purpose, being intended to satisfy the demand for the minimum output required, will in the following be called the " demand storage," as distinguished from the other part of the storage referred to later. The demand storage, when drawn upon, should be replenished as soon as. and to the extent that the power demand will allow.

In order to make it possible for the power stations to follow the required variation in load during the day and the week, pondage basins are also provided at each of the stations, with the exception of Power Station No. 1, which draws its water directly from Rocky Valley Reservoir. As the pondage basins at the various offtakes for Power Station No. 2 are situated in narrow gorges, the dams are comparatively high, and consequently the cost per unit volume of pondage becomes high. Therefore, the volume of these pondage basins is limited to that required during week days only. At the Junction Dam the natural water level will be raised some 100 feet, principally for utilizing the head, and a large basin will thus be created which will provide weekly pondage for Power Stations No. 3 and No. 4. At the diversion dam for Power Station No. 4, the natural water level will be raised some 50 feet for utilizing the head, and the large basin created can serve as pondage for Power Station No. 4 at times when the flow of water through that station differs from that at Power Station No. 3.

Day-power storage. As the total amount of storage provided in the scheme exceeds the volume required for demand storage, the balance can be used for additional storing of water when the natural run-off is high and the demand storage full. This upper part is in the following called " day-power storage," as during periods of relatively low natural flow water can be obtained from this part of the storage during the busy hours of the week day when the power requirements are heavy. This will result in a higher output than that obtainable from the natural flow, even if this latter output be higher than the minimum required. In such a case, the Kiewa plant would be able to cover a lower portion of the load diagram than when the plant is using the natural flow or is being operated to satisfy demand with the minimum energy output.

The pondage basins are sufficiently large to allow the power stations, during periods of moderate flow, to operate at full capacity during busy hours of the week days.

Capacity of sources of electric supply. The amount of storage which will have to be reserved as demand storage will depend on the estimated load of the year and on the capacity of other sources of supply to the system.

The Chief Engineer of the Commission has proposed to increase the capacity of the steam stations in Melbourne so as to make the capacity of the generating plant within the metropolitan area keep step with the increase of power supplied by long transmission lines. The desirable proportion between the capacity of the two sources of supply will principally depend on the appreciation of emergency requirements, and the proposal by the Chief Engineer that the metropolitan plant should be able to deal with about 30 per cent. of the system load at load centres seems to be very appropriate.

As previously mentioned it is suggested that the total capacity of the Kiewa Scheme be increased somewhat over and above that proposed by the engineers of the Commission. To investigate to what extent such an increase will affect the storage volume required, two capacities will be considered, viz., 91,000 kw., being the capacity proposed by the engineers of the Commission, and 104,000 kw., being a tentative capacity of the modified scheme. When the capacity of the Kiewa Scheme is fully utilized, it can be forecast that the yearly peak load on the generating plants will have to be divided between the various sources of supply as follows :—

Yallourn Steam Station	136,000 kw.	136,000 kw.
Sugarloaf and Mountain Stream Stations	11,000 ,,	11,000 ,,
Metropolitan Steam Stations	90,000 ,,	100,000 ,,
Kiewa Hydro-electric Plant	91,000 ,,	104,000 ,,
Total	328,000 ,,	351,000 ,,

Load curve. It is, of course, difficult to forecast the shape of the daily load curve at that future time when the maximum load shall have risen to 328,000 or 351,000 kw. A study of the daily load curves for the last five years shows no material changes except, as mentioned before, a slight increase in the load factor. As no reasons, based on known facts, can be given for a material change in the future it has been assumed that the load curves at the future time considered will have the same shape as the present ones and could therefore be taken to be as those shown on Plate No. 2, but with scales as indicated at the right side of the plate.

As a closer comparison between the load curves of the different years reveals that the peaks during 1935 are slightly broader than for other years, load curves of the same shape as for that year have been used for estimating the minimum output required under drought conditions when the utmost economy has to be exercised with the water stored.

Load to be taken by Kiewa plant. If, on the load diagrams designed for peaks of 328,000 and 351,000 kw., respectively, a line be drawn at the capacity of the combined steam plants, the area included by this line and the top portion of the load curve shows the minimum output which has to be generated at the hydro-electric station during each day. Summating the outputs required from the hydro-electric plants for all full working days in any calendar month, and adding 20,000 kwh. daily for overlapping, we arrive at the amounts of energy required from these plants during that month. Subtracting the output during peak hours from Sugarloaf and the Mountain Stream Stations, the required output from the Kiewa plant is obtained. This output has to be supplied from river flow and from storage.

In the calculations of the demand storage required, Saturdays and Sundays, and other days with similar load, are disregarded. The load curves for these days have small and narrow peaks, and these can be taken by the combined steam plants and the natural river flow, and no draw on storage is necessary during such days.

Efficiency of machinery. For the purpose of estimating the power output a turbo-generator efficiency of 80 per cent. has been assumed throughout. Considering the type of load to be met, the assumed efficiency is low when the turbines are new, and may be considered as a fair average for the life-time of the machinery.

Drought period. As previously mentioned, records and calculations of the discharge are available from 1865. The most severe drought period during this time occurred from December, 1913, to July, 1915. This cannot, however, be considered as giving the most extreme conditions which might occur. To design a period representing the worst drought which reasonably may be imagined, we have taken the actual period from December, 1913, to March, 1915, and assumed the drought to continue for another year by adding a " synthetic " year composed of such calendar months, picked out from the whole period from 1896, as have a run-off giving the minimum output for Kiewa, Sugarloaf and the Mountain Stream Stations combined.

Volume of demand storage. The calculations and deliberations show that a storage volume of 25,000 acre-feet of water would be sufficient to provide for the necessary supply of power during the assumed hypothetic drought period if the maximum scheduled load be 328,000 kw., including 91,000 kw. on the Kiewa generators. Allowing, say, 10,000 acre-feet of water, corresponding to about 30 million kilowatt-hours at load centres supplied from the Kiewa plant, as an emergency reserve, it may be concluded that an amount of 35,000 acre-feet would be adequate for demand storage at the maximum load mentioned.

If the scheduled maximum load be 351,000 kw., including 104,000 kw. on the Kiewa generators, the adequate amount of demand storage including 10,000 acre-feet as an emergency reserve would be 50,000 acre-feet of water.

Volume of day-power storage. The volume to be provided for day-power storage is determined principally by economic considerations. The annual cost of a storage of 1,000 acre-feet averages some £350 in the top portion of Pretty Valley Reservoir, and some £1,000 in the top portion of Rocky Valley Reservoir. The value of the day-time power obtained from a storage of this size, less the value of the amount of power which would have been obtained if the water had not been stored, amounts to some £1,300 every time that particular volume is utilized.

It follows that the day-power storage should not be made larger than is necessary to cause the top portion of Pretty Valley Reservoir to be utilized on an average not less than once in four years, and that of Rocky Valley Reservoir on an average not less than three times in four years. With due regard to evaporation, the appropriate volume of day-power storage has been estimated at some 40,000 acre-feet in Pretty Valley and some 10,000 acre-feet in Rocky Valley.

As the demand storage is suitably provided for in Pretty Valley, the appropriate total storage in this reservoir would be 75,000 acre-feet if the generating capacity be 91,000 kw., and 90,000 acre-feet if the generating capacity be 104,000 kw. In both cases it would be appropriate to provide for a storage of 10,000 acre-feet of water in Rocky Valley.

Spare plant. Due to the topography of the East Kiewa Valley and the general layout of the scheme, Power Stations No. 3 and No. 4 command large pondage basins from which any necessary amount of water for operation can be obtained at any moment without interference with the operation of the other plants. Therefore, Power Stations No. 3 and No. 4 are indicated as the appropriate places for the installation of spare plant for the whole scheme.

Experience has shown that first-class hydro-electric machinery is so reliable in operation and requires so few stoppages for inspection and maintenance, that the necessary provision for spare plant can be made very small.

In the scheme, Power Stations No. 3 and No. 4 are each equipped with three generating units, the ratings of which are tentatively fixed at 8,000 kw. in Power Station No. 3, and at 13,000 kw. in Power Station No. 4. Provided that Power Stations No. 1 and No. 2 are each equipped with two units of a rating not exceeding those in Power Station No. 4, the consideration of spares would call for a normal rating of the whole plant 13,000 kw. short of the total installed capacity, so as to allow for one of the biggest units to be out of commission at any one time.

CAPACITY OF SCHEME AND ENERGY OUTPUT.

Machinery installation. As can be gathered from the preceding section, the volume of storage provided in the scheme, i.e., 95,000 acre-feet in Pretty Valley and 13,000 acre-feet in Rocky Valley, is ample for a working capacity of 104,000 kw. In accordance with the views expressed in the same section regarding spare plant, a suitable installation with this working capacity would be as follows :—

Power Station Number.	Number of Units.	Capacity in Kilowatt.			
		Per Unit.	Total Installed.	Working.	Spare.
1	2	10,500	21,000	21,000	. .
2H	2	13,000	26,000	26,000	. .
2L	1	7,000	7,000	7,000	. .
3	3	8,000	24,000	} 50,000	13,000
4	3	13,000	39,000		
Total	. .	. .	117,000	104,000	13,000

This installation and working capacity is, in our opinion, well justified. With economical advantage the installation and working capacity could be slightly increased without increasing the volume of the storage, and further increased if a larger volume of storage were created.

On the other hand, difficulties in handling the storage would arise and increase as the working capacity is raised. It should be borne in mind that the estimate of the necessary volume of demand storage is based on the assumption that the future load curves will be similar to the present ones, and that the capacity of the steam stations in the metropolitan area will be increased as previously mentioned. These assumptions introduce in the calculations an element of uncertainty which becomes appreciable if the capacity is substantially increased.

Our investigations have shown that if Power Stations No. 1 and No. 2 are considered as one group, and Power Stations No. 3 and No. 4 as another group, within reasonable limits the installations in these two groups are independent of one another, and the same economical benefit is derived by increasing the capacity of either group. If, therefore, Power Stations No. 3 and No. 4 are constructed as the first development stage, a decision regarding the capacity of Power Stations No. 1 and No. 2, and thereby regarding the ultimate capacity of the scheme, can advantageously be postponed until the future time when work has to commence on these two stations. At that time a more precise judgment on the matter of capacity can be formed.

Without prejudicing the eventual choice of the working capacity, the estimates of energy output and of the capital and annual costs of the scheme have been based on the installation as set out in the above table.

Operation of storage. As previously mentioned, the volume of the reservoir in Pretty Valley is considered to consist of two parts, which are divided at a certain predetermined level in the following called " the mark." The volume below this level is the demand storage and above it the day-power storage.

When the water level in Pretty Valley Reservoir stands above the mark, the operation policy would be to use the water stored above the mark and in Rocky Valley Reservoir so as to effect the greatest possible saving of coal in the metropolitan steam stations. The energy output from the Kiewa Scheme which will effect such saving is the output fed into the system for taking the load over and above that which can be met by Yallourn and the Mountain Stream stations. Such output will in the following be called " energy, class A," and all other output, which will only lessen the load on Yallourn, will be called " energy, class B."

The result aimed at can be obtained by applying to the operation of storage the following rules :—

Rule (*a*). When the water level is above the mark, such quantity of water shall be supplied from the storages as will give, out of this water, the greatest possible amount of energy, class A, but no energy, class B, with the exception as stated in Rule (*b*.)

If the exception to this rule, given in Rule (*b*), is disregarded, it will result in a fair amount of water being wasted when the reservoirs become full, and it is profitable to increase the water discharge through the plants over and above the draw given by Rule (*a*) when the reservoirs are nearly full. This can be effected by establishing an " upper limit " near the full reservoir level and applying the following :—

Rule (*b*). If at any time from the beginning of April to the end of August the volume of water in the storages exceeds the upper limit, the net inflow to the storages shall be discharged through the plants.

To these two rules will have to be added the two following in order to make the set of rules complete :—

Rule (*c*). When the reservoirs are full the net inflow shall be discharged.

Rule (*d*). When the water level is at the mark or below it, the strictest possible economy with the water shall be exercised and water drawn only so as to satisfy the demand on the supply system with the minimum of energy output for the hydro-electric stations.

For a scheme with the installation and working capacity set out in the previous table, the mark would be at El. 5,517 feet in Pretty Valley Reservoir, corresponding to a demand storage of 50,000 acre-feet of water, and the upper limit would be at a volume of 90,000 acre-feet stored in the two reservoirs.

Energy output. Detail investigations carried out show that on adopting the rules and marks as stated above, and with the working capacity considered, the following energy output would have been obtained during the period 1926 to 1935 :—

Year.	Output Generated in Millions of Kilowatt-hours.	
	Energy, Class A.	Energy, Class B.
1926	403	67
1927	395	33
1928	406	50
1929	393	27
1930	331	43
1931	431	92
1932	410	51
1933	392	37
1934	417	71
1935	409	49
Mean	399	52

As previously mentioned, the period, 1926 to 1935, can be considered to represent average conditions of water supply for energy production. The figures given in the above table are based upon a possible but almost ideal operation. In practice some water will, by necessity, be wasted or not used to the best advantage. Making due allowances for this, the average yearly output generated for a number of years, including drought periods, is estimated at :—

Output of energy, class A—390,000,000 kwh. per annum.
Output of energy, class B— 50,000,000 kwh. per annum.

Total .. .. 440,000,000 kwh. per annum.

DEVELOPMENT IN STAGES.

The Kiewa Scheme lends itself favorably to development by stages, and the power available can be made to follow closely the growing demand on the Commission's system.

The most suitable main stages of development are considered to be the following :—

First development stage—
- Access road from Tawonga.
- Pretty Valley Reservoir.
- Power Plant No. 3.
- Power Plant No. 4.

Second development stage—
- Diversion of West Kiewa River to Pretty Valley branch by means of West Kiewa tunnel.

Third development stage—
- Rocky Valley Dam.
- Power Plant No. 1.
- Power Plant No. 2.

During the period of construction a subdivision of the first and third stages will be introduced to suit the load on the system, and to make the best possible use of the construction plant.

Power Plants No. 3 and No. 4 are particularly suitable for the first development as the sites are readily accessible and the spare plant of the scheme is installed in these stations.

At the completion of the first stage, 50,000 kw. would be available. When this capacity is fully utilized, it can be foreseen that the yearly peak load on the Commission's generating plant will be divided between the various sources of supply as follows :—

Yallourn Steam Station	136,000 kw.
Sugarloaf and Mountain Stream Stations	11,000 ,,
Metropolitan Steam Stations	75,000 ,,
Kiewa Hydro-Electric Plant—First Development Stage	50,000 ,,
Total	272,000 ,,

A demand storage of 35,000 acre-feet (including an emergency reserve of 12,000 acre-feet) would be required to bridge over the drought period previously considered, and another 15,000 acre-feet would be appropriate as day-power storage. The storage volume provided in the Pretty Valley for the ultimate scheme is therefore ample for this development stage.

The energy from the first development stage has been estimated, on an average as follows :—

Output of energy, class A—105,000,000 kwh. per annum.
Output of energy, class B— 22,000,000 kwh. per annum.

Total .. .. 127,000,000 kwh. per annum.

The construction of the West Kiewa Tunnel and appertaining offtake included in the second development stage can be built so that the works will be finished at any time after the completion of the first development stage, and no installation of machinery will be required. Benefit of the diversion will be obtained immediately upon its completion as an increase in the energy output from Power Stations No. 3 and No. 4.

This increase in energy has been estimated, on an average, as follows :—

Output of energy, class A—30,000,000 kwh. per annum.
Output of energy, class B—22,000,000 kwh. per annum.

Total .. .. 52,000,000 kwh. per annum.

The third development stage comprises the completion of the scheme.

The estimate of cost is divided into the same main stages as given above.

GENERAL LAYOUT OF SCHEME RECOMMENDED.

The scheme proposed by us in co-operation with the engineers of the Commission consists of two storage basins and four power stations. The general layout of the works is indicated on Plate No. 5.

Reservoirs. The main reservoir is located in Pretty Valley, where 95,000 acre-feet of water can be impounded between full reservoir level, El. 5,545, and low water level, El. 5,467, by building a rock-fill dam about 125 feet in height. Floods are discharged over a spillway dam constructed in a gap half-a-mile south-east of the main dam. At the south end of the basin there is an earth dam, referred to as Mount Cope Dam, to prevent water escaping over a low gap.

Another reservoir has been provided in Rocky Valley with a capacity of 13,000 acre-feet, and 10,000 acre-feet are available between full reservoir level, El. 5,310, and water level at El. 5,285. The dam is constructed of earth fill with a clayey core and a core wall of concrete, and the maximum height of the dam above river bed is about 75 feet. A spillway channel is located on the left bank, and the rock excavated from this channel is used in the dam.

From Pretty Valley storage the water is led by means of a tunnel, about 1·4 miles long, to Rocky Valley Reservoir, cutting through a narrow ridge between the two valleys.

Power Plant No. 1. From Rocky Valley Reservoir, the water is led by means of a head race tunnel, about 2·8 miles in length, and a steel pressure pipe line, about 3,800 feet long, to an overground Power Station No. 1, located on McKay Creek. The average net head is 1,444 feet, and the installation consists of two Pelton turbines with direct coupled generators, each of a capacity of 10,500 kw.

Power Plant No. 2 and West Kiewa diversion. On Pretty Valley branch there is an offtake, referred to as Pretty Valley Offtake No. 2H, to divert the run-off downstream from Pretty Valley Dam to Power Plant No. 2H.

From the offtake the water flows through an open race line, about 2·5 miles in length, and through a tunnel, about 0·7 mile long, leading to Rocky Valley branch, upstream of Rocky Valley Offtake No. 2H. About 0·7 mile from Pretty Valley Offtake No. 2H the race line passes Power Station No. 1, and the water from this station, as well as water from McKay Creek, is discharged into the race line.

At Rocky Valley Offtake No. 2H, there is a single arch dam of a maximum height above river bed of about 70 feet. The top level of the flashboards on the spillway is at El. 3,770, and at a draw-off to W.L. El. 3,730, the pondage is 115 acre-feet.

At the offtake, the natural run-off is collected from the catchment area downstream of Rocky Valley Reservoir. This water and the water from Pretty Valley Offtake No. 2H and Power Station No. 1 is conveyed by means of a tunnel, about 1·0 mile in length, and by a steel pipe line, about 2,800 feet in length, thence by a pressure pipe line, about 5,500 feet long, to an overground Power Station No. 2, located near the Junction.

From this station the water flows through a short tail race excavated in the river bed, discharging into the Junction Pond.

The head is utilized by two Pelton turbines, with direct coupled generators, each of a capacity of 13,000 kw. These units are referred to as No. 2H, and the average net head utilized is 1,454 feet.

The flow of the West Kiewa River is diverted by a tunnel, about 4·0 miles long, to Pretty Valley branch from an offtake located in the West Kiewa, immediately downstream of Bogong Jack's Creek. The dam is of Ambursen type of a maximum height of about 30 feet above river bed. The level of the crest of the spillway is El. 2,607, and the pondage is 50 acre-feet at a draw-off to W.L. El. 2,592. The tunnel discharges into a pondage on Pretty Valley branch upstream of an offtake, referred to as Pretty Valley Offtake No. 2L. At this offtake there is a single arch dam, the maximum height of which is about 60 feet above river bed. The top level of the flashboards of the spillway is El. 2,607, and the pondage is 70 acre-feet at a draw-off to W.L. El. 2,570.

The water from the West Kiewa, augmented by the run-off downstream of Pretty Valley Offtake No. 2H, is conveyed by means of a tunnel, about 1 mile in length, and by a pressure pipe line, about 1,300 feet long, to Power Station No. 2. After passing the turbine the water discharges into the tail race, previously mentioned, to the Junction Pond.

The head between Pretty Valley Offtake No. 2L and the Junction Pond is utilized by a vertical shaft turbine with direct coupled generator of a capacity of 7,000 kw. This unit is referred to as No. 2L, and the average net head utilized is 350 feet.

Power Plant No. 3.

Due to favorable topographical conditions at the Junction, a fairly large pondage is created by means of a single arch dam of a maximum height of about 100 feet above river bed. The top level of the flashboards of the spillway is El. 2,235, and at a draw-off to W.L. El. 2,180, the pondage is 1,900 acre-feet.

At the Junction Dam the water is diverted by means of a head race tunnel, about 0·8 mile in length, continued by three steel pipe lines, each of a length of about 950 feet, to an overground Power Station No. 3. The water from the station discharges into the river through a short tail race canal. The average net head is 355 feet, and the installation consists of three vertical shaft turbines with direct coupled generators, each of a capacity of 8,000 kw.

Power Plant No. 4.

About 0·4 mile downstream of Power Station No. 3 there is an Offtake No. 4 where the water is impounded to El. 1,870 by a single arch dam of a maximum height of 55 feet above river bed. At a draw-off to W.L. El. 1,840 a pondage of 460 acre-feet is obtained. The water is diverted by means of a head race tunnel of a length of about 2·4 miles, and by a steel pipe line, about 1·3 miles in length, continued by three pressure pipe lines, each 1,400 feet long, to an overground Power Station No. 4 situated at the end of the rapids on the West Kiewa River.

The average net head is 603 feet, and the installation consists of three turbines with direct coupled generators, each of a capacity of 13,000 kw.

General arrangement of works for transmission of power remains as in the description of the scheme proposed by the engineers of the Commission.

ESTIMATES OF COST.

Estimate of capital cost.

The capital cost of the works as described in the previous section is estimated as follows :—

	£
A. First development stage—	
Land resumption, easements and clearing for works	50,000
Access road from Tawonga, including maintenance during first development stage	103,000
Pretty Valley Reservoir	411,000
Power Plant No. 3, including turbines, generators and low tension switchgear	486,000
Power plant No. 4, including turbines, generators and low tension switchgear	651,000
Diversion races	2,000
Permanent offices and quarters for operation staff	27,000
Local administration, including staff, offices, temporary quarters, social arrangements, store facilities and other general charges	175,000
Engineering	125,000
Contingencies	190,000
Interest during construction	130,000
First development stage, total	2,350,000
B. Second development stage—	
Diversion dam at West Kiewa offtake, tunnel intake and tunnel through the ridge between West and East Kiewa Rivers	£ 210,000
Local administration and other general charges	25,000
Engineering	15,500
Contingencies	25,500
Interest during construction	24,000
Second development stage, total	300,000
C. Third development stage—	
Maintenance of access roads	10,000
Tunnel from Pretty Valley Reservoir to Rocky Valley Reservoir	70,000
Rocky Valley Reservoir	269,000
Power Plant No. 1, including turbines, generators and low tension switchgear	327,000
Power Plant No. 2, including turbines, generators and low tension switchgear	689,000
Diversion races	2,000
Permanent offices and quarters for operation staff	17,000
Local administration, including staff, offices, temporary quarters, social arrangements, store facilities and other general charges	140,000
Engineering	100,000
Contingencies	156,000
Interest during construction	110,000
Third development stage, total	1,890,000

SUMMARY OF ESTIMATE OF CAPITAL COST.

	£
First development stage	2,350,000
Second development stage	300,000
Third development stage	1,890,000
Grand Total	4,540,000

The estimate of capital cost includes all cost of material and labour necessary for the completion of the works at present (February, 1937) market prices, including overhead charges and contingencies. The estimate has been based on quantities taken from sketch designs. It has been assumed that the works will be carried out departmentally, using the most efficient methods of work, with sufficient and most modern plant. The quantities and unit prices have been worked out in collaboration with the engineers of the Commission.

Estimate of annual cost. The annual cost of the scheme is estimated as follows:—

	£
A. First development stage—	
Interest on capital, 4½ per cent. on £2,350,000	105,750
Depreciation	33,000
Maintenance and operation	22,000
Contingencies	2,250
First development stage, total	163,000
B. Second development stage—	£
Interest on capital, 4½ per cent. on £300,000	13,500
Depreciation	1,350
Maintenance, operation and contingencies	1,150
Second development stage, total	16,000
C. Third development stage—	
Interest on capital, 4½ per cent. on £1,890,000	85,050
Depreciation	25,850
Maintenance and operation	16,500
Contingencies	1,600
Third development stage, total	129,000

SUMMARY OF ESTIMATE OF ANNUAL COST.

First development stage	163,000
Second development stage	16,000
Third development stage	129,000
Grand Total	308,000

The depreciation charges included in the estimate are based upon the following rates:—

One quarter per cent. per annum for tunnels and other main rock excavations, land resumption and easements, roads, and interest during construction.

One per cent. per annum for dams, power station buildings, and other concrete work,
Three per cent. for steel structures in pipe lines, turbines, travelling cranes, other mechanical equipment, and generators and low tension switchgear.

On an average the depreciation charges correspond to 1·32 per cent. of the capital cost.

Concluding Remarks. The estimated capital cost of the scheme up to generating station-bus bars is £39 per kw. of installed capacity, and £44 per kw. of working capacity at Kiewa; and the estimated annual cost is £3 per kilowatt of the working capacity at a load factor of about 48 per cent. This corresponds to 0·17 pence per kwh. generated at Kiewa.

It is reasonable to assume that power from the Kiewa Scheme when fully developed can be delivered at load centres at a cost of approximately two-thirds of the cost of power generated by coal from major extensions of existing steam stations.

(Sgd.) RENDEL, PALMER AND TRITTON.

Melbourne,
16th March, 1937.

APPENDIX TO CONSULTING ENGINEER'S REPORT.

AVERAGE MONTHLY RUN-OFF IN CUSECS AT GAUGING STATION No. K.7 ON PRETTY VALLEY BRANCH AT PRETTY VALLEY DAM SITE.

Drainage Area: 7·7 square miles.
Catchment heavily snow covered for some five months of each year.
Altitude 5,500 to 6,000 feet.

Year.	Average Run-off.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1926	2	2	7	32	47	40	36	45	94	96	37	9	37
1927	7	3	2	2	7	8	14	9	44	171	51	11	27
1928	6	16	26	26	25	44	23	33	67	125	34	9	36
1929	4	3	2	12	27	26	10	22	96	95	29	22	29
1930	9	4·7	2·8	5·1	29·1	28·7	14·6	19·8	71·3	149·5	45·1	36·8	34·7
1931	16	7	31	24.6	76	72	39	43	66·6	142	61·3	12·3	49·2
1932	3·5	3·9	10	42	16·7	24·2	13	56·5	100·4	63·2	26·3	10·9	31
1933	4·3	2	1·7	3·1	11·8	15	37	30·8	126	80·5	19·3	28·9	30
1934	25·4	14	12	32	14·6	9·5	27·7	36	92·8	124	71·8	23·7	40·3
1935	7·9	9·8	8·4	38	28·6	23·4	12·2	20·4	70	136·5	35·1	17·7	34
Mean ..	8·5	6·5	10·3	21·7	28·3	29·1	22·6	31·5	82·8	118·3	41·0	18·1	34·8

In some months of this period, interruptions occurred due to climatic conditions. During such times flows are deduced from adjacent gauges.

AVERAGE MONTHLY RUN-OFF IN CUSECS AT GAUGING STATION No. K.4 ON ROCKY VALLEY BRANCH AT ROCKY VALLEY DAM SITE.

Drainage Area: 6·9 sqaure miles.
Catchment heavily snow covered for some five months of each year.
Altitude 5,300 to 6,000 feet.

Year.	Average Run-off.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1926	2	2	7	33	47	40	36	45	94	96	43	14	38
1927	8	3	2·5	2·4	7·5	8	14	9	44	170	51	10·6	28
1928	6	20	26	26	23	51	23	33	67	116	37	9	36
1929	4	3·6	2	16	27	26	11	31	77	97	27	20	28·4
1930	8·7	4	2·2	3·5	17·4	21·8	13	19	54	137·4	39	29·7	29·1
1931	16·4	6·4	25·4	18·1	59·7	72	39	40·2	65·5	128·2	67·6	15·3	46
1932	4	4·4	10	38	15	24	13	43	87·5	70	32	10·7	29·3
1933	4·5	2	1·5	2	11	13	33	30·6	106	79·3	19	22·9	27·1
1934	22	9	9·5	27·8	10·9	6·1	25·5	30	74	99·7	59	22	32·9
1935	7·3	7·4	6·5	27·3	25·5	20·7	11·3	24·7	55·1	118	35	17·1	29·6
Mean ..	8·3	6·2	9·3	19·4	24·4	28·3	21·9	30·6	72·4	111·2	41·0	17·1	32·4

In some few months of this period, interruptions occurred due to climatic conditions. During such times flows are deduced from adjacent gauges.

AVERAGE MONTHLY RUN-OFF IN CUSECS AT GAUGING STATION No. K.5 AT THE JUNCTION BELOW THE CONFLUENCE OF PRETTY AND ROCKY VALLEY BRANCHES OF EAST KIEWA RIVER.

Drainage Area : 53·4 square miles.

Year.	Average Run-off.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1926	35	27	54.6	192·7	333	287	265	343	667	694·5	305·2	123·5	277·3
1927	86.5	64·4	48·9	41·7	67·4	91·5	133·2	108·7	295·9	1,035·8	316·7	100	199·2
1928	67·4	182	203·3	193·5	184	401·6	205·8	235	469	528	293·4	106·6	255·8
1929	54·4	49·4	32·4	116	149·9	170	104	189·5	496·2	674·3	204·1	167·4	200·6
1930	91·9	50·5	34·8	43·3	164·8	151·5	135	186·7	399·9	1,002·5	318·9	260·5	236·7
1931	140·2	74·9	216·3	183·7	490	536	308	360	400	865	441	117·2	344·4
1932	58	54	135·7	376·7	144·6	222·4	170·4	354·5	666·5	471·2	218·8	103·8	248·1
1933	57·3	37·1	36·2	41·1	87·5	129·5	331·5	214·8	670·3	566·1	159·5	201·2	211·0
1934	173·9	105·1	124·2	217·0	114·2	75·8	267·2	275·5	545·9	834·8	554·9	260·0	295·7
1935	101	80·7	67·3	194·5	196·1	177·4	147·2	252	445·8	752	256·5	136·5	234
Mean ..	86·5	72·5	95·4	160·0	193·1	224·3	206·7	252·0	505·7	742·4	306·9	157·7	250·3

Figures for May–October, 1931, are deduced.
For a few periods of a few days each, interruptions occurred and flows are deduced from adjacent gauges.

AVERAGE MONTHLY RUN-OFF IN CUSECS AT GAUGING STATION No. K.6 ON WEST KIEWA RIVER DOWNSTREAM OF THE OFFTAKE FOR THE DIVERSION TUNNEL TO EAST KIEWA RIVER.

Drainage Area : 33·5 square miles.

Year.	Average Run-off.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1926	..	..	..	..	..	177	162	256	285	284	102	48	..
1927	31	21	16	15	39	71	147	122	251	370	113	37	103
1928	25	77	93	93	116	202	134	128	223	473	135	52	146
1929	30	26	23	57	120	135	78	155	262	250	89	88	109
1930	52	27	18	21	83	74	115	179	224	418	155	151	126
1931	77	39	82	79	259	402	325	321	371	309	160	65	207
1932	37	28	81	217	80	158	161	266	323	191	108	60	142
1933	36	24	19	20	57	122	244	150	385	248	79	130	126
1934	118	62	70	129	78	48	218	203	256	449	273	154	172
1935	54	47	41	130	136	131	152	258·5	272·2	282·3	131·1	71·8	142
Mean ..	51	39	49	85	108	152	174	204	285	327	135	86	141

PLATE 1

GENERAL LAY-OUT OF ELECTRIC SUPPLY SYSTEM OF THE STATE ELECTRICITY COMMISSION OF VICTORIA

(*See* PLATE 1 of Report of Chief Engineer, Power Production)

PLATE 2

LOAD DIAGRAMS

TO REPORT OF MARCH 1937 BY MESS
RENDEL, PALMER AND TRITTON ON TH
KIEWA HYDRO ELECTRIC SCHEME.

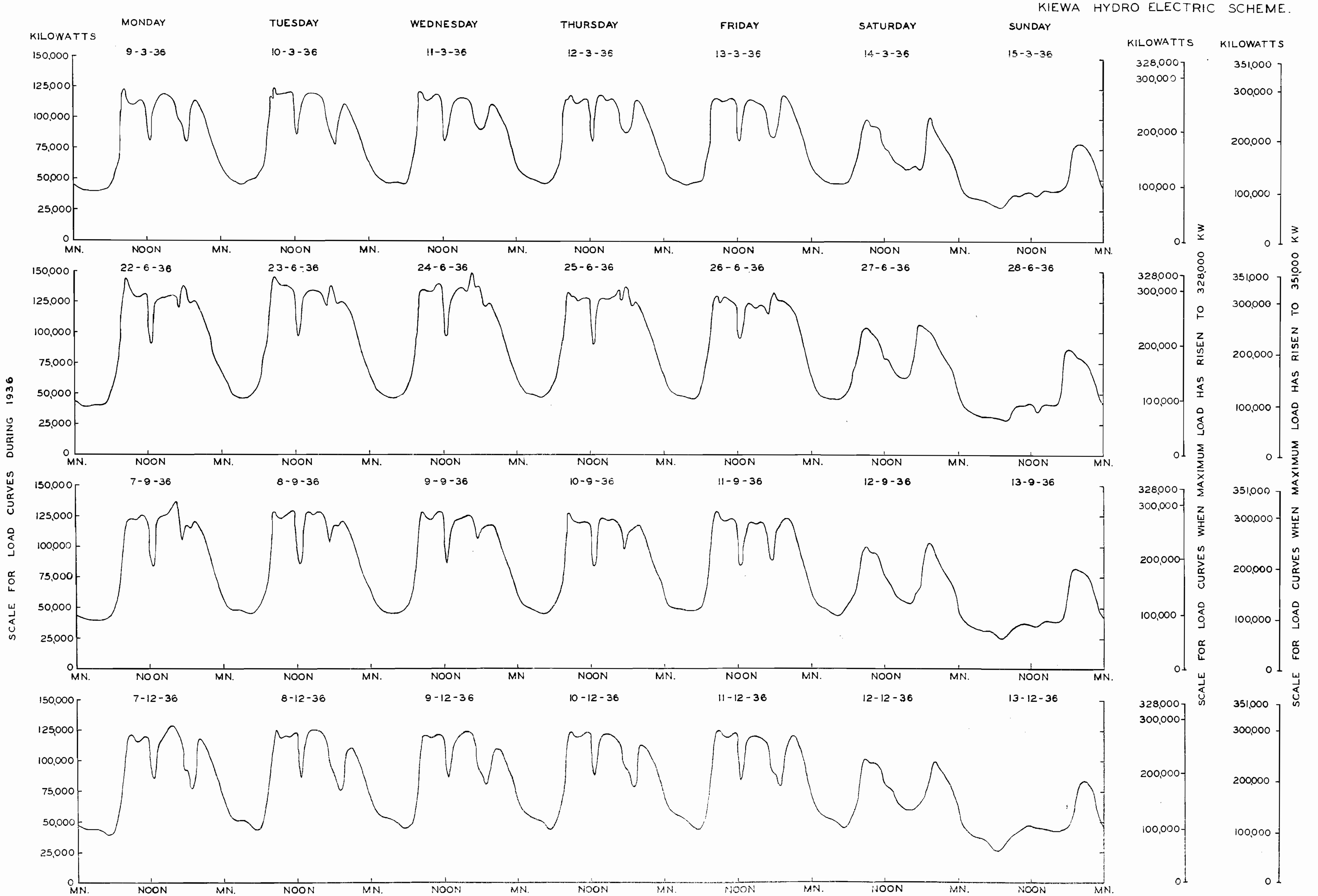
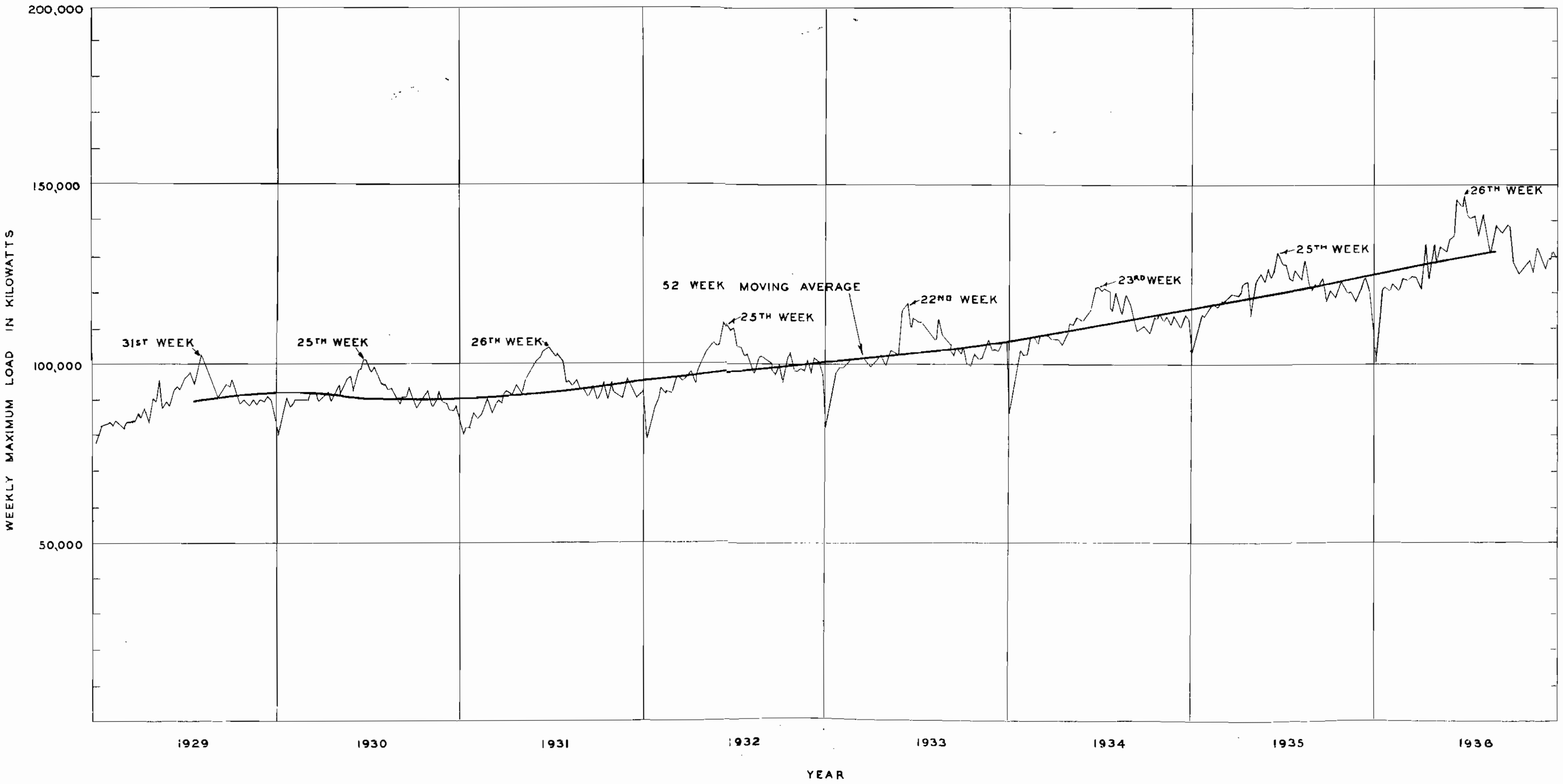


PLATE 3

TO REPORT OF MARCH 1937 BY MESSRS RENDEL PALMER AND TRITTON ON THE KIEWA HYDRO-ELECTRIC SCHEME

WEEKLY MAXIMUM LOAD IN KILOWATTS

ON THE GENERATORS IN YALLOURN, SUGARLOAF, MOUNTAIN STREAM STATIONS, NEWPORT AND RICHMOND



WEEKLY MAXIMUM LOAD IN PER CENT OF 52 WEEK MOVING AVERAGE

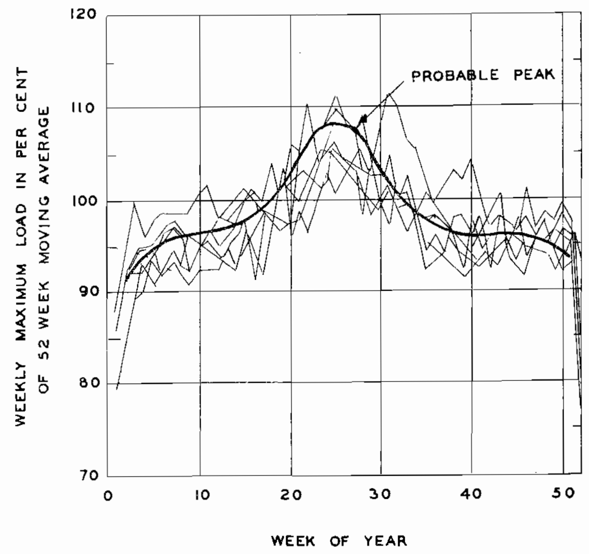


FIG. 2

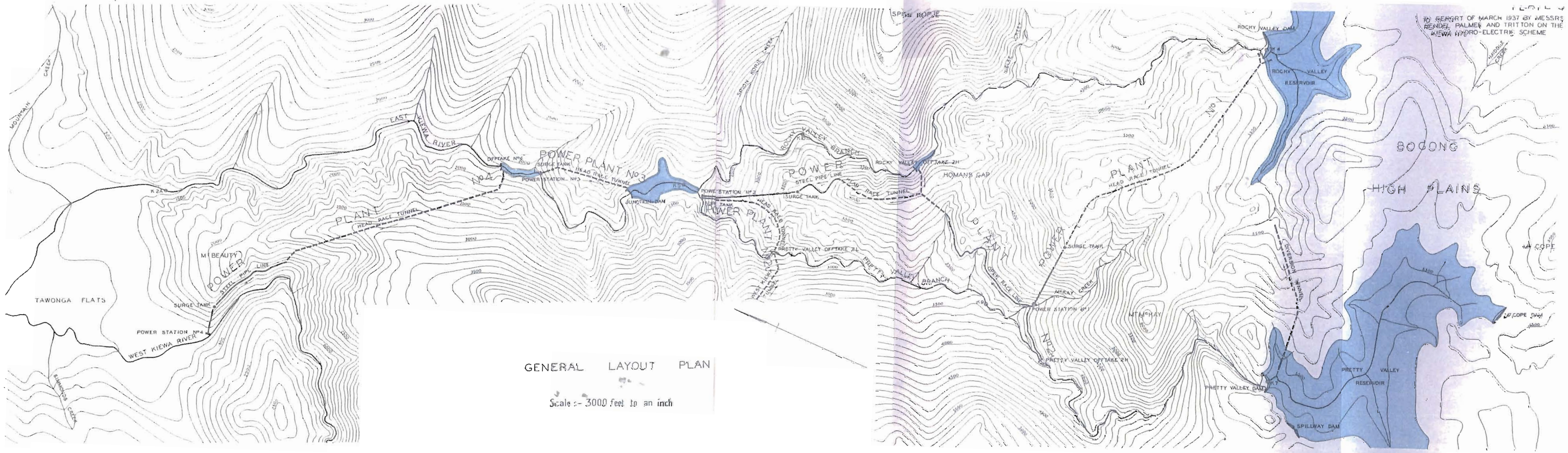
PLATE 4

TO REPORT OF MARCH 1937 BY MESSRS RENDEL PALMER AND TRITTON ON THE KIEWA HYDRO-ELECTRIC SCHEME

GENERAL LAYOUT

AS PROPOSED BY THE ENGINEERS OF THE COMMISSION

TO REPORT OF MARCH 1937 BY MESSRS RENDEL PALMER AND TRITTON ON THE KIEWA HYDRO-ELECTRIC SCHEME



GENERAL LAYOUT PLAN

Scale :- 3000 feet to an inch

APPENDIX "B"

REPORTS

of

CHIEF ENGINEER, POWER PRODUCTION

(Mr. E. BATE, B.Sc., Wh. Sch., A.M.I.E.A.),

on the

KIEWA HYDRO-ELECTRIC SCHEME

and an

EXTENSION OF NEWPORT "B" STEAM STATION

For the purpose of meeting the requirements of the State Power System after 1940, with an Examination of Alternatives

CONTENTS.

PLATES.

REPORT OF CHIEF ENGINEER, POWER PRODUCTION (MR. E. BATE, B.Sc., Wh.Sch., A.M.I.E.A.), ON KIEWA HYDRO-ELECTRIC SCHEME.

INTRODUCTION.

In this Report are submitted proposals for the construction of hydro-electric works in the Kiewa Valley to generate approximately 104,000 kw. associated with an energy output of 440,000,000 kw. hrs. in an average year, and for the transmission works to deliver this energy to the Commission's main system. The bulk of the energy would be absorbed into the system at Melbourne by transmission to a terminal station situated on the Merri Creek in the Brunswick area, the remainder being transmitted to Wangaratta for the Commission's North-east transmission system, to which the Kiewa Valley is adjacent.

These proposals have matured over a considerable number of years, during which period very comprehensive hydrological and meteorological observations have been made, so that the characteristics of flow and run-off in the various portions of the Kiewa catchment have been determined with great precision, and form a very sound basis for the scheme which will be unfolded herein.

From time to time during years over which investigations into the Kiewa Scheme have spread, progress reports have been made by the Chief Engineer, embodying the views of the Commission's officers in regard to the development, the latest of these reports being presented in March, 1936, by the undersigned. Since that date, we have had the advantage of consultation and collaboration with Messrs. Hellstrom and Samsioe, representing Messrs. Rendel, Palmer, and Tritton, Consulting Engineers of London, and the scheme which is now presented embodies some modifications on that of March, 1936, which have resulted after close consideration and intensive survey and investigation, especially on the geological side, which has taken place since the date of the previous report, especially during the period of Messrs. Hellstrom and Samsioe's visit to Melbourne.

As the report of these engineers is in the hands of the Commission, it will be unnecessary for me in this report to detail those modifications which were decided upon as a result of this collaboration, but I would like to say that the engineering and economic features of the Kiewa scheme were very thoroughly discussed and analysed by Messrs. Hellstrom and Samsioe with the Commission's engineering staff, to obtain the very best proposals which engineering knowledge and skill could produce.

I would like to point out, before proceeding to the particular details of the scheme now proposed for the Kiewa Valley, that for many years the possibilities of power development on the Murray River at the Hume Dam, and also on the Mitta River were the subject of lengthy investigations, which indicated that these sources could jointly give about 140,000 kw. of electric energy at a cost per kilowatt approximately the same as that for which the Kiewa scheme could be developed.

Although it appeared some years ago that the Hume-Mitta might have claims to priority over the Kiewa scheme in the order of construction on account of the low cost of plant installation at the Hume Dam, at the present time these claims have lost most of their weight for several reasons, which are as follow:—

1. The halt in the system requirements which occurred during the years of the financial depression reacted unfavorably upon proposals for generating at the Hume Dam owing to the fact that the prospective requirements of water for irrigation were increasing, with the consequent reduction in the availability, at certain periods of the year, of water for purposes of electric generation. In October, 1935, the River Murray Commission stated its expectation:—

   "That an amount of approximately 190,000 acre-feet per month (including the flow of the Kiewa River) could be made available at the Albury gauge for twelve months in the year for five years from the present date, and during the following five years an amount gradually increasing to 263,000 acre-feet per month for the nine irrigation months in the year."

   The provision of the greater outflow during the irrigation months after 1940 will involve progressive curtailment of the outflow during the winter months, so that by 1945 the discharge from the reservoir will cease for about three months in each year, as is liable to be the case at the Sugarloaf Reservoir.

2. Since the Mitta River is one of the main sources of water for storage in the Hume Reservoir, independent storages on that river, which would be required for any scheme of energy production, could only be developed with the approval of the River Murray Commission. Our engineering studies indicate that the power scheme could be efficiently operated without any detriment to the function of the Hume storage in respect of water conservation. The River Murray Commission, however, being the controlling authority, has taken the view that it is not possible to encourage the retention of water by storage on the Mitta catchment to the extent which would be necessary in any plans formulated by us. The River Murray Commission considers that so far as can be seen at present, such storage would prejudice irrigation interests in one or more of the States, and it is, therefore, unable to acquiesce in such independent storages.
3. Investigation by diamond drilling of the sites for dams on the Mitta River has proved that rock, which appears on the surface to be quite sound, is broken and fissured to considerable depths. This is a very discouraging fact as affecting large storages on the Mitta River, and it would be impossible to make or recommend proposals in any case until suitable sites for the construction of the storage walls could be proved.

   It may be remarked that the geological formations on the Kiewa River are much more favorable, and, in fact, there is no reason to anticipate any difficulty in regard to foundations in the storages which are proposed on the Kiewa River.
4. While formerly it was thought that proposals for utilizing the Hume storage for generation of electricity offered a suitable preliminary and productive stage in the development of the Kiewa, this idea has been affected and made unattractive, firstly, by the change in outlook of the Hume scheme which has been mentioned above, and secondly by the careful planning of the Kiewa scheme for construction and utilization in suitable stages.

Having regard to these considerations, the Kiewa proposals are the more suitable for early development, though the undoubtedly considerable potentialities on the Mitta River can be studied at leisure, and may possibly be utilized in years to come.

I would like to remark that the Kiewa project has now been so comprehensively studied and investigated, that the proposals are stable and definite in the sense that no technical modifications in the design stage will so affect the final economic results as to justify postponing a decision on the question of adopting the proposals, or deciding on the probable dates when the scheme should be in operation in its various stages.

Before concluding these introductory remarks, I would like to say that in the course of evolving the scheme which is now presented, it has been necessary to consider very carefully from time to time the characteristics desired of the scheme, from the point of view of utilization factor or load factor. While it would be possible to design a scheme which should furnish a base load for the Commission's system, that is, a system of plants which would operate at 100 per cent. load factor, and in fact such a proposal was contemplated in the very early stages of the investigations, it has become evident as the investigations proceeded that the more favorable and suitable development would be one working at a lower load factor. The proposals now being presented provide for the production of power up to 104,000 kw. at Kiewa, with an average utilization factor of 48 per cent., giving an average of about 390,000,000 kw. hrs. per annum available at load centres on the Commission's system from the Kiewa.

In accordance with this fundamental conception of design, the upper storages in Pretty Valley and Rocky Valley are in the scheme now presented relatively extensive, and provide for the storage of 95,000 acre-feet in Pretty Valley, and 13,000 acre-feet in Rocky Valley. Since the bulk of this water will be stored at roughly 5,500 feet (R.L.), the effect of these storages upon the operation of the whole scheme will be vital, as will be shown later in discussing the hydrological proposals in detail.

During the considerable period since the commencement of these investigations, the growth of the Commission's system (see Plate No. 1) has influenced to some degree proposals for transmission of energy.

By the time that the early stages of construction are reached, it seems probable that the Commission's North-east district will have developed to the extent that about 15,000 kw. from Kiewa may be absorbed at Wangaratta for use in that district, thus reducing somewhat the load to be transmitted to Melbourne, and at the same time increasing the security of supply to the Northern area very appreciably.

PROPOSED ENGINEERING WORKS.

A. CIVIL AND HYDRAULIC.

1. Location and General Topography. The Kiewa River, whose native name appropriately means "cold water," has its source on the Bogong High Plains, an extensive plateau some 5,500 feet above sea level, lying between Mounts Bogong and Hotham, in the highest mountain system in Victoria. The East Kiewa River drains the greater portion of this plateau, although the eastern and southern slopes provide the main source of the Mitta River. For several months of the year the whole of the high plateau is covered, to a depth of some feet, with snow which disappears during the rains and warmer weather in the spring, although it is not uncommon for drifts to remain as late as the end of December.

The vegetation on the Bogong High Plains reflects the unusual meteorological conditions, and, as a result of the area being above the elevation where timber thrives, the plateau in summer presents the spectacle of wide open valleys luxuriantly grassed, interspersed with patches of granite rock, and here and there, clumps of snow gums, with their typical gnarled and stunted appearance. The whole area is Crown land, but is held under annual grazing leases, the pastures being used extensively for the summer grazing of cattle and sheep.

This portion of the East Kiewa catchment takes the form of two main valleys, Pretty Valley and Rocky Valley, each with a narrow outlet through the mountain ranges by which they are surrounded, and the grade on the streams, whilst very flat through this area, is very steep after leaving the high plains.

The two branches of the East Kiewa River which rise in these two valleys unite at the Junction, at about 2,200 feet elevation, some 7 miles after leaving the plateau, but the grade of the river remains steep until the flats above Tawonga are reached some 14 miles from the plateau, in which distance the stream has descended from about 5,500 feet to about 1,200 feet elevation.

At Tawonga, the East Kiewa River is joined by the West Kiewa River, which has its source neat Mount Hotham and drains the deep valley between Mount Feathertop and Mount Fainter.

On the slopes below the High Plains, snow-gum scrub is very plentiful, while on the portions below about 4,000 feet elevation, there are several fine areas of woolly-butt timber. Areas suitable for milling timber for construction purposes can be located, but the timber available is of poor quality for permanent construction. The catchment has a comparatively good yield of water from springs which are in evidence particularly down-stream from the Junction, and this has an important bearing on the flow during drought seasons.

From Tawonga, the Kiewa River flows in a northerly direction to join the Murray River a short distance up-stream from Wodonga, and just down-stream from the Hume Dam constructed by the River Murray Commission.

The hydro-electric developments which are proposed herein are limited to that section of the Kiewa River up-stream from Tawonga.

2. General Layout of project. The general layout of the works is indicated on Plates Nos. 2 and 3.

The main storage reservoir is located in Pretty Valley, at an altitude of about 5,500 feet, where some 95,000 acre-feet of water will be impounded by means of a rock-fill dam. Another storage reservoir with a capacity of 13,000 acre-feet is provided in Rocky Valley at about 5,300 feet altitude.

From Pretty Valley storage the water is discharged to Rocky Valley Reservoir by means of a diversion tunnel, all draw from these two storages being through the Rocky Valley outlet.

In the scheme now submitted, no provision is made for power generation at the outlet of this tunnel, but further consideration will be given at a later date to the desirability of constructing a small power station with a turbine of 2,500 kw. capacity to utilize the head available between these storages, together with a pump for transferring water from Rocky Valley to Pretty Valley.

Power Plant No. 1. From Rocky Valley the water is led by means of a head race tunnel about 2·8 miles in length, and a steel pressure pipe line about 3,800 feet long, to Power Station No. 1, where the turbine installation consists of two pelton wheels, each of 10,500 kw. capacity under an average net head of 1,444 feet.

Power Plant No. 2. The tail-water from No. 1 Power Station is led by a flow-line conduit to the Rocky Valley Branch, the same conduit serving also to convey the flow diverted from an offtake on Pretty Valley Branch. It consists of an open race line about 2·5 miles in length from Pretty Valley Branch, followed by a tunnel 0·7 mile long, discharging into the pondage formed by a dam known as Rocky Valley Offtake No. 2H, a single arch dam in height about 70 feet above the river bed. This dam collects the natural run-off of the catchment area down-stream from Rocky Valley Reservoir.

This water, and the water from Pretty Valley Offtake No. 2H, is conveyed by means of a tunnel about 1·0 mile in length, to a steel pipe line about 2,800 feet long, and thence by a steel pressure pipe line 5,500 feet in length to Power Station No. 2, located near the Junction, where the average net head of 1,454 feet is utilized in two pelton wheel turbines with direct coupled generators, each with a capacity of 13,000 kw., the tail-water discharging into the junction pondage by means of a short tail-water canal.

On the West Kiewa River a reinforced concrete slab dam 30 feet high is located immediately down-stream of Bogong Jack's Creek to form a diversion by means of a tunnel about 4 miles in length, to the Pretty Valley branch of the East Kiewa River, discharging into a pondage known as Pretty Valley Offtake No. 2L. This pondage is formed by a single arch dam 60 feet in height.

The water diverted from the West Kiewa, augmented by the run-off down-stream from Pretty Valley Offtake No. 2H, is conveyed by means of a tunnel about 1 mile long, and by a pressure pipe line, to Power Station No. 2, where it is utilized under an average net head of 350 feet by a vertical shaft turbine with direct coupled generator of 7,000 kw. capacity. The tail-water from this unit discharges to the Junction pondage by the tail race canal previously mentioned.

Power Plant No. 3. Down-stream from the Junction a pondage of about 1,900 acre-feet is provided by means of a single arch dam 100 feet in height, and from this pondage water is diverted by means of a head race tunnel about 0·8 mile in length, leading to three steel pipe lines, each about 950 feet long, to Power Station No. 3, where three vertical shaft turbines with direct coupled generators are installed, each of 8,000 kw. capacity under an average net head of 355 feet.

The water from this station discharges into the river through a short tail race canal.

Power Plant No. 4. The tail-water from Power Station No. 3 discharges into the head of a pondage formed by No. 4 Offtake, which consists of a single arch dam 55 feet high, located nearly half a mile down-stream from No. 3 station.

From this pondage water is again diverted by means of a head race tunnel 2·4 miles long, continued by a steel pipe line about 1·3 miles long, and finally to three steel pressure pipe lines, each 1,400 feet long, to Power Station No. 4, situated at the end of the rapids on the West Kiewa River. At Power Station No. 4 the average net head is 603 feet and the installation consists of three turbines with direct coupled generators, each of 13,000 kw. capacity.

3. Surveys. The investigation of hydro-electric resources in the Kiewa Valley was undertaken by the Commission's staff in 1923. Previous to 1923 some records of river flow at Tawonga were made for the Victorian Hydro-Electric Company.

In order to ensure that all essential stream flow data would be available during the progress of the investigations, which clearly would last for several years, arrangements were made early in 1925 to install automatic recording gauges. At the same time, a commencement was made with the preliminary surveys and reconnaissances for the purpose of facilitating the preparation of proposals.

During the summer 1925–26 preliminary proposals were thoroughly investigated by surveys, which indicated the possibility of developing a much greater output than had been anticipated previously. These surveys were limited to the upper portions of the scheme. The necessary additional surveys required on the lower portions of the scheme were delayed until the summer of 1928–29, and this portion of the scheme was greatly modified as compared with earlier proposals, with the idea of obtaining simplicity and economy in the arrangement of the power stations.

Between 1933 and October, 1935, when a comprehensive review of the proposals was submitted, further detailed surveys were carried out, together with an extensive programme of diamond drilling on dam sites and tunnel locations, but this did not result in any major alterations in the layout. Further work of this nature is still necessary and is proceeding. The results achieved by the later investigations into this scheme provide a striking example of the benefits of, and the necessity for, very complete investigations of such schemes.

The time available since investigations were originally commenced has enabled these surveys to be unusually complete and comprehensive, and several alternative layouts have been thoroughly investigated by survey. Each party has been under the direction of a competent surveyor, experienced in this work, and the efficiency and direction of the work have been further ensured by frequent visits of the responsible engineers.

All surveys were carried out by tacheometer, and bench marks have since been checked by accurate levelling, and any necessary adjustments made. The catchment areas have been adequately surveyed so that discharge measurements may be correctly deduced at different points.

Detailed contour surveys have been carried over all the areas in which it is proposed to locate works of any kind, and these have been sufficiently extensive to render possible the construction of an accurate model, a photograph of which is attached hereto (Plate No. 4).

4. Hydrological Data. Catchment areas. Reference to Plate No. 2 will indicate the main features of the catchment in relation to the works proposed and the sites at which gaugings have been obtained.

The catchment area of the East Kiewa River may be divided into two sections:—

1. An area of 14·6 square miles of the Bogong High Plains, located in Pretty Valley and Rocky Valley, at elevations of 5,250 feet to 6,100 feet above sea level.

   This area is supplemented by a further 2 square miles of catchment obtained by small diversion channels, and the flow from this total area will be regulated by the storages which are proposed in these two valleys.
2. An area of approximately 41 square miles down-stream from the Pretty Valley and Rocky Valley dam sites, including all the area contributing to the Junction. This includes country ranging from 2,200 feet to over 6,000 feet in elevation.

Below the junction on the East Kiewa River, a few small creeks may perhaps be picked up by the tunnel, but there is no considerable addition of water from this area.

The catchment area on the West Kiewa comprises about 32 square miles of country ranging up to more than 6,000 feet in elevation. This catchment, however, is confined throughout to a deep narrow valley, and, unlike the East Kiewa, contains no areas of any magnitude at the higher elevations.

It is proposed to add to this catchment by diversion from about 2 square miles which, at present, form the headwaters of the Cobungra River.

Stream Flow Records. Discharge records for the East and West branches of the Kiewa River at Tawonga for the years 1914–16 are available, and cover a period which is the critical one in the gauging history of Victoria. For the period 1916 to 1919 no gaugings are available. Gaugings are available for a short period in 1919, but consistent gauging of the East Kiewa River did not re-commence until 1923, and is still being maintained.

Stream flow records at Tawonga, however, do not give much indication of the flows from the upper portions of the catchment, where meteorological conditions are quite different. When hydro-electric investigations were taken over by the Commission in 1923, the necessity for more reliable stream flow records at the vital points of the scheme led to the installation, early in 1925, of automatic recording gauges at four positions on the Kiewa:—

1. Pretty Valley Dam Site.
2. Rocky Valley Dam Site.
3. Junction of right and left hand branches of East Kiewa.
4. Offtake site on West Kiewa.

During the winter the streams at Pretty Valley and Rocky Valley are usually completely covered with ice and snow, which caused considerable difficulty in obtaining reliable winter records. The erection of special weir controls, together with various improvements to the gauges and gauge shelters, has overcome practically all these difficulties, and these gauges have since given reliable service. The automatic gauges at the lower elevations have proved very reliable.

Owing to interruptions due to severe weather, winter records were not obtained in a few cases at Pretty and Rocky Valleys, but these gauges have now been in operation for a sufficient period to enable a reliable comparison to be obtained between the flows at the various gauging stations. It is thus possible to make deductions of these winter flows from the records at the junction and West Kiewa Offtake.

River gauging records are now, therefore, available for the following periods:—

Pretty Valley Dam Site	1925 to date.
Rocky Valley Dam Site	1925 to date.
Junction of right and left hand branches of East Kiewa ..	1925 to date.
West Kiewa Offtake Site	1925 to date.
West Kiewa at Tawonga	1914 to 1916 and 1921 to 1928.
East Kiewa at Tawonga	1914 to 1916, 1921 to 1928, and 1933 to date.
Pretty Valley Branch (near offtake 2H)	1936 to date.
Rocky Valley Branch (near offtake 2H)	1936 to date.

From the above tabulation it will be noted that actual gaugings are available at the main offtake sites from 1925 to the present date, and on the Kiewa at Tawonga for the period 1914 to 1916.

For a scheme of this nature, involving storage over long periods, this information was considered insufficient, particularly as some slight doubt was felt regarding the accuracy of records for the period 1914 to 1916, and as this latter included the worst drought in the history of Victoria, it was essential that accurate information should be obtained regarding the flow of the Kiewa for this period.

Earlier investigations were based largely on flows deduced from gaugings of the Mitta River at Tallangatta, but unfortunately this station had to be abandoned in 1934 owing to flooding from the backwater curve of the Hume Dam. There are thus only five or six years of records available for correlation between the Kiewa and Mitta flows.

A longer period of correlation, now about ten years, is available between the flows on the Kiewa and on the Murray at Jingellic, and as these latter records are available since 1891, they have now been used in preference to the Tallangatta figures.

Although the catchment of the Kiewa is not entirely similar to that of the upper Murray, a fair relationship is obtained between the two flows, and reasonable accuracy may be expected in deducing Kiewa flows from Jingellic. During exceptional drought periods the relationships deduced from normal years cannot be expected to hold, but it has been found possible to confirm the actual records at Tawonga by means of meteorological data, including rainfall, temperature, &c.

As part of this investigation a comprehensive programme of snow research was initiated in December, 1932, when equipment was installed on the high plains and a cottage erected, where an engineer has since been continuously in residence to carry out field researches, which include a continuous record of all meteorological data, such as precipitation, evaporation, temperature, winds, &c., whilst other special researches are also carried out.

As a result of this work a method has been developed for the deduction of Kiewa flows from meteorological observations taken at surrounding stations during the period from 1926, which gave very close agreement with the flows actually recorded.

Flows deduced by this method for the drought period, 1914 to 1915, were almost identical with those actually recorded, which substantially corroborates the accuracy of the records.

A further investigation was also carried out to ascertain whether it was reasonable to expect that the two drought periods of 1902–3 and 1914–15 would ever be exceeded in severity. This investigation led to a study of cycles in river flows and climatic conditions from which the existence of such cycles appears well established. As a result, it appears extremely likely that these two drought periods are the most critical since 1825, but that more severe periods may have occurred between 1810 and 1825. It appears probable, however, that no period of such severity as 1902–3 or 1914–15 will occur within the next 50 years.

The manner in which provision is made for the possibility of a drought, more severe than any yet recorded, is set out in paragraph 6 hereinafter.

Floods. Records during several floods are available, and the maximum run-off at the main storage dams recorded to date is about 180 cusecs per square mile of catchment.

In the case of dams such as those at Pretty Valley and Rocky Valley, provision must be made for an extraordinary flood, and the dams which are proposed will safely withstand a maximum run-off of about 2,000 cusecs per square mile.

At the Junction Dam where the catchment area is much greater, and the conditions much less severe, provision against a maximum run-off of about 500 cusecs per square mile is considered to be ample.

Hydrogen-ion Concentration. The water in the Kiewa River is generally very clear and only rarely carries silt. The hydrogen-ion concentration appears to vary between 6·3 and 6·8, and tests show that the action of Kiewa water on cement when percolating through concrete is practically the same as that of distilled water, which is severe. Special care will, therefore, be required to ensure watertightness in all concrete used for structures retaining water.

Regular records of hydrogen-ion concentration are being obtained.

5. Geological Formations. The formation over the whole area is metamorphic and igneous, the various rocks being gneiss, schist, and granite. In addition, some areas of the older basalt still remain on the higher points.

In view of the extensive tunnelling proposed in the scheme, for which sound rock is required, the rock formations are of the utmost importance, and a programme of diamond drilling has been actively pursued for the past few years. This has followed geological investigation and reports, and geological advice has been obtained at several stages of the work.

Dam sites and tunnel locations have now all been tested with the diamond drill, and although further work of this nature is still required, it is now apparent that, in general, all tunnels can be located in satisfactory rock formations.

In addition to diamond drilling, trenches and test pits have been opened up at important sites, and at the Junction dam site three exploration tunnels have been excavated in the rock, two of which are over 100 feet in length in sound rock.

It will be noted that one of the features of these proposals is the use of long tunnels in rock *without concrete lining*. This practice, though not common elsewhere, is used in Sweden and Norway with great success.

Unlined tunnels are very much less expensive than lined tunnels, and as the tunnels in this scheme are not under great head, and as sound rock is indicated by the diamond drill, there appears to be every justification for their use.

Inspection of unlined mining tunnels, 50 to 80 years old, in gneiss and schist formations near Omeo, confirms the conclusion that lining will not be generally required for tunnels in the Kiewa area, where these are driven through the solid rock.

Concrete lining will be required wherever a tunnel has to be taken through rock which has been broken up by earth movement, for instance, by faulting, or where a tunnel passes through decomposed or soft material, since it is not possible entirely to avoid such areas. Where a fault line must be crossed it is desirable to cross as nearly as possible at right angles in order to minimize the length of tunnel in broken country.

To assist in the location of faults, slips, &c., an aerial survey was recommended by Mr. B. Hellstrom and Dr. Samsioe, and the major part of this was carried out during the past few months. The stereoscopic examination of these aerial photographs will be of great value in carrying out the thorough geological surveys which will be necessary when finalizing the location of the various tunnels.

It should be mentioned that in the estimates of cost, full supporting concrete lining has been provided for at those places where broken rocks or faults are definitely indicated, whilst, for tunnels passing through what is expected to be sound and solid rock, 12 to 20 per cent. of the cost of excavation has been added to provide for lining.

6. Storage Capacity. A hydro-electric scheme of this nature, designed to operate in conjunction with a large steam generating system, should operate under a variable utilization factor. Thus, at times when flows are high, full use should be made of the water available by operating at a high utilization factor, whereas during periods of low flow, the scheme should be operated at a lower utilization factor and retain a sufficient margin to ensure that all power demands can be met.

As an illustration, Plate No. 5 indicates the mode of operation for a typical day during normal periods, of high and low flow respectively.

To determine the correct capacity for the design of this scheme it has been necessary to consider all factors, such as the shape of the load curve, capacity of steam stations, cost and limitations of storage, cost of power, coal, &c., but further, and for reasons which will be explained later, it has been determined that the capacity of the metropolitan steam stations, which form part of the generating system of the State, should be increased from time to time so as to be able to generate about 30 per cent. of the system load.

On this basis, when the generating capacity of the Kiewa scheme, which is now taken as 104,000 kw., is fully developed, the load by the various sources of supply, under critical winter conditions, would be as follows :—

Yallourn Steam Station	136,000 kw.
Sugarloaf and Mountain Stream Stations	11,000 ,,
Metropolitan Steam Stations	100,000 ,,
Kiewa Hydro-electric Scheme	104,000 ,,
	351,000 ,,

During the last five years no very material change has taken place in the typical shape of the daily load curve, and as there appears to be no reason to anticipate any considerable change in the future, it has been assumed that the load curve will retain its present shape when the maximum demand has risen to 351,000 kw.

For the purpose of estimating power output the turbo-generator efficiency at the Kiewa stations has been taken as 80 per cent.

Drought Period. As previously mentioned, flow records, either observed or deduced, are available since 1865, and during that time the most severe drought period occurred from December, 1913, to July, 1915, although another period in 1902–3 was nearly as severe. Statistical treatment of these records since 1865, as shown on Plate No. 6, indicates that drought periods of such severity are of very rare occurrence, and although two such periods have occurred during the last 70 years, it is probable that such periods will not occur more frequently than, say, once in 100 years.

Nevertheless, it cannot be safely assumed that the drought periods on record are the most severe which can possibly occur, and to provide for a possible period of greater severity, it has been assumed that the actual drought period from December, 1913, to March, 1915, would be followed by a further "synthetic" year composed of such calendar months, picked out from the period from 1896, as have a run-off giving the minimum output for Kiewa, Sugarloaf, and the Mountain Stream Stations combined, and it is on this basis that the storage capacity for the scheme has been calculated.

In calculating the storage necessary two different requirements have to be met :—

(*a*) Storage capacity to enable the scheme to cover its demand capacity, when operated at the minimum load factor permissible.

(*b*) Storage to provide additional output in kilowatt-hours to such extent as is economical having regard to the relative costs of energy from this source and from other sources of power.

With a peak capacity of 104,000 kw. generated at Kiewa, and a maximum system demand of 351,000 kw., the storage capacity necessary to meet the first of these requirements—known as the "demand" storage—would be 50,000 acre-feet, including 10,000 acre-feet as emergency reserve.

The second storage requirement, which may be termed "day-power" storage, is determined as above-mentioned by economic considerations.

Taking all factors into consideration and allowing for evaporation, it is estimated that the appropriate capacity of storage for this latter purpose is about 40,000 acre-feet in Pretty Valley and about 10,000 acre-feet in Rocky Valley.

As the "demand" storage is best provided in Pretty Valley, the total storage capacities required for a scheme of 104,000 kw. are estimated to be as follow :—

Pretty Valley	90,000 acre-feet.
Rocky Valley	10,000 ,,

The storage capacities actually proposed allow for a slight margin on these figures, being *95,000 acre-feet* in Pretty Valley, and *13,000 acre-feet* in Rocky Valley.

7. Plant Capacity. The operation of the scheme has been worked out for several different plant capacities, and consideration given to all factors such as physical limitations and cost of storage and other works, difficulties of operating storages, possibility of future changes in shape of load curve, and possible modifications in the general supply system.

The allocation to power stations of the appropriate total capacity of the scheme is shown hereunder :—

Power Station No.	No. of Units.	Capacity in Kilowatts.			
		Per Unit.	Total Installed.	Working.	Spare.
1	2	10,500	21,000	21,000	..
2H	2	13,000	26,000	26,000	..
2L	1	7,000	7,000	7,000	..
3	3	8,000	24,000 }	50,000	13,000
4	3	13,000	39,000 }		
	Total ..	.. ..	117,000	104,000	13,000

The spare capacity located in Power Stations Nos. 3 and 4 will be always available, and will allow for one of the largest machines on the Kiewa system being out of commission.

In considering the subdivision of the total capacity of 104,000 kw., the design is such that if Power Stations upstream from the Junction (Nos. 1 and 2) be regarded as one group, and those downstream therefrom (Nos. 3 and 4) as another group, within reasonable limits the installations in these two groups are independent of one another, and the same economic effect is obtained by an alteration in the capacity of either group. If then, as proposed in a later section of this Report, Power Stations Nos. 3 and 4 be constructed during the first development stages, Power Stations Nos. 1 and 2, which may be constructed later, can be varied in size and output, if so desired at a later date.

Thus whilst, as far as can at present be determined, the correct capacity for the scheme is 104,000 kw., should circumstances at a later date make it desirable to alter this proposed capacity, this will be possible without detriment to the scheme, and after completion of Power Stations Nos. 3 and 4, by varying the capacity of Power Stations Nos. 1 and 2.

8. Operation of Storages. In the use of the storage capacity as "demand" or "day-power" storage as may be required, it will be necessary for the draw from storages to follow definite rules.

The whole of the capacity in Rocky Valley storage is "day-power" storage, whilst Pretty Valley storage is considered to be divided into two parts at a predetermined level, the upper portion being "day-power" storage, and the lower portion "demand" storage. "Day-power" storage capacity will be drawn upon so as to effect the greatest possible saving of coal in the metropolitan steam stations, but it is not economical to draw upon storage to save coal at Yallourn by reducing the energy output of that station, except in cases where water and unregulated natural flow, which would otherwise be wasted, are available, when it may be used for this purpose.

When the water level is below El. 5,517 feet in Pretty Valley, which is the elevation determined as the top level of the "demand" storage, the utmost economy of water will be observed and water drawn only to satisfy the demand on the supply system with the minimum of energy output from the hydro-electric stations.

9. Power Output. Operated on the above basis and to satisfy a demand of 104,000 kw. at Kiewa, the average annual output of energy over a long period of years, including drought periods, is estimated at 440,000,000 kwh., of which 50,000,000 kwh. is energy, class B, or energy which could have been supplied from Yallourn, and serves only to save coal at that station.

This demand capacity is available in all years, including the worst drought periods.

10. Elasticity of Operation. A special effort has been made to make the scheme as elastic as possible in regard to operation, particularly as regards the ease with which load may be picked up or rejected. Reference to Plate No. 3 will show the manner in which this has been accomplished.

It will be noted that all power stations are connected directly by closed conduits to the storages, so that load may be picked up during the short time necessary to open a valve and bring the turbine up to speed. Similarly, rejection of load involves practically no by-passing or waste of water.

At any time in an emergency the whole capacity of the scheme will be almost immediately available, and this capacity can be maintained at 100 per cent. load factor, for some days, if necessary, to meet special system requirements.

The storage below the Junction is, of course, an important factor in the operation of Power Stations Nos. 3 and 4, and renders possible some diversity in the manner of loading the different stations without loss of water. It also provides an essential feature in the initial stage of development, as later described, and provides water for over 24 hours at full load on No. 3 Power Station, making the full station capacity immediately available.

11. Access Roads. A glance at the map of Victoria will indicate that the site of the Kiewa works is rather isolated, and remote from any large centre of population. All the proposed works are located on the northern slopes of the ranges, and as the railheads are much closer on this side, it is certain that the main access route will pass through or near Tawonga. The most favorable means of transport for construction purposes appears to be road transport by motor trucks from the railhead at Bright—in the Ovens River Valley, some 18 miles from Tawonga—but this outlet is complicated somewhat by the high range which is crossed by the existing road between Tawonga and Bright. The road is quite passable, and with some improvement and maintenance will probably form the main route for the transport by trucks of bulk loading, such as cement, &c.

For the transport of heavy equipment the route along the Kiewa Valley will probably be utilized on account of the easier grades, although some bridges will require strengthening, and the distance to the railway siding at Huon is over 40 miles.

From a point near Tawonga, a new road will be constructed, the route proposed crossing the West Kiewa River near Power Station No. 4, thence to the East Kiewa River, up the side of which valley the road will be graded, first to the Junction Dam, and ultimately past Rocky Valley Dam to Pretty Valley Dam. Detailed surveys are available and reasonable grades can be obtained.

In the first stage of development some 12 miles of new and reconstructed road will be required, and as much of this is of fairly heavy construction, this work will have to be commenced well in advance of construction on the scheme proper.

12. Storage works in the Upper Plateau.

A. Pretty Valley Dam. This dam, which is located, as shown on the plan, at the outlet from Pretty Valley, provides the greater part of the storage for the scheme, and is designed to store water to a level of R.L. 5,545, impounding 95,000 acre-feet of water. The manner in which this storage will be drawn upon has been described already.

There are two saddles on the watershed of Pretty Valley which for a short distance are a few feet below the top water level. One of these will be dammed by means of an earth bank, whilst the other provides an excellent location for the spillway, well removed from the main structure.

The foundations at the dam site have been fully tested by diamond drill and are good solid rock, gneiss, and schist. The junction plane between these two classes of rock occurs at the dam site on the west bank, but the junction is thoroughly fused together. There is also evidence of an old fault plane on the west bank, but careful consideration and examination by an expert geologist leads to the conclusion that this is not likely to cause any trouble.

The total height of the dam from stream-bed being about 124 feet, consideration has been given to various types of construction, resulting in the adoption of the rock-fill type of dam which will require about 380,000 cubic yards of rock (see Plate No. 7). This appears to be the most suitable type of dam having regard to the high cost of transporting cement and sand, and the large quantities of rock available for quarrying practically on the site.

As the foundations for this dam are practically all solid rock, no fears of serious subsidence need be entertained, whilst the concrete cut-out wall is carried well into the solid rock. Watertightness will be obtained by an impervious up-stream facing, the exact nature of which is still under consideration.

B. Outlet from Pretty Valley Storage. The water from Pretty Valley storage will pass through an outlet structure remote from the dam structure itself, to a tunnel 1·4 miles in length, leading into the Rocky Valley Reservoir and cutting through the narrow ridge between these two valleys where sound rock suitable for an unlined tunnel is expected. The cross sectional area of this tunnel will be about 50 square feet.

As previously mentioned, the desirability of developing the head between these two valleys will receive further consideration at a later date.

At Pretty Valley Dam a bypass tunnel with control valve will be provided by which water may be passed to the Pretty Valley branch down-stream of the dam. This will be in regular operation during the earlier stages of construction, prior to the completion of Power Station No. 1.

C. Rocky Valley Dam. As the design of this dam is determined largely by the nature of the foundations, these have been the subject of considerable investigation by surveys, test shafts, and diamond drilling, as well as geological reports and chemical examination of the decomposed material.

The formation is decomposed granite with large granite boulders outcropping, but solid bed-rock is in parts at a considerable depth.

The nature of this foundation, together with the remoteness of the location, indicates that an earth fill dam with a concrete core wall is the best type to adopt (see Plate No. 8). Water will be stored to a depth of 60 feet with full water level at R.L. 5,310, the spillway being located adjacent to the west end of the dam.

13. Head Works, No. 1 Power Station. Water from Rocky Valley storage will be led to No. 1 pipe head by means of an unlined tunnel excavated in the solid rock with a cross sectional area of about 60 square feet.

A. Head Race Tunnel No. 1. This tunnel is nearly 3 miles in length to No. 1 pipe head and crosses the main plateau at an elevation of over 5,000 feet above sea level. The use of a tunnel at this elevation avoids all the difficulties of snow slides, &c., which occur in this locality.

B. Surge Tank No. 1. At the head of No. 1 pipe line it is necessary to use a surge tank to provide for sudden variations in load on the turbines.

This tank will be a shaft about 25 feet in diameter cut out of the rock and connected to the pipe by means of a tunnel 9 feet in diameter. The shaft, which will be concrete lined and roofed over, will be extended to about 12 feet above top water level in Rocky Valley storage.

14. Head Works, No. 2 Power Station. The conduit conveying water from the Offtake No. 2H on Pretty Valley Branch to the corresponding Offtake No. 2H on Rocky Valley Branch will be a concrete lined open race for the greater part of its length.

Open channel is here preferred to tunnel, as the country in this region has been disturbed by a series of fault movements adjacent to the steep slope leading off the high plains and the broken country is geologically unfavorable for the economical construction of tunnels.

The offtake dam in Rocky Valley Branch, which is located in a narrow gorge and is of single arch type about 70 feet in height, and the adjacent tunnel, appear to be clear of the disturbed region.

Further drilling and geological investigations are required for the conduit from Rocky Valley Branch to Pipe Head No. 2H, but to date sound rock has not been found at the northern end of this conduit, and consequently steel pipe on a flow line grade is proposed for this portion.

Water for Plant No. 2L is diverted from Pretty Valley Branch near the outlet from the West Kiewa Tunnel at a pondage formed by a concrete arch dam about 60 feet in height. The conduit takes the form of a tunnel located so as to avoid broken country and is about one mile in length with a cross sectional area of about 75 square feet.

15. Junction Dam. For about three quarters of a mile down-stream from the Junction of the Pretty Valley and Rocky Valley branches of the East Kiewa there are river flats which provide good pondage, and at the lower end the banks narrow to a rock-bound gorge where the dam will be located. The foundations at this site have been very thoroughly tested by drilling, test pits, and exploration tunnels, and work of this nature is still proceeding.

The dam proposed is a single arch, nearly 100 feet in height, with special abutments, for which type of dam the site is excellent, with the exception that the upper portion of the right bank is disturbed country which will require special treatment, for which the estimates provide (see Plate No. 9).

Flood provision is made for a flow of at least 20,000 cusecs.

16. Tunnels to Nos. 3 and 4 Power Stations. These tunnels are identical in design, the capacity required being in both cases normally 780 cusecs, but at times when the spare units are in operation 980 cusecs. The cross sectional area proposed is 200 square feet.

Diamond drilling indicates that these tunnels will be in sound rock, and lining is not proposed except for short lengths where bad conditions may be encountered. It will be noted that No 4 Tunnel is continued in steel pipe line to avoid tunnelling through the disturbed region just south of Mount Beauty.

17. No. 4 Offtake Dam. This dam is located nearly half a mile down-stream from Power Station No. 3, the tail water from that station discharging into the up-stream end of the pondage.

The dam is generally similar in type to that at the Junction and is about 60 feet in height above stream bed, and foundations at this site appear to be good.

18. West Kiewa Offtake. This offtake is located immediately below the junction of Bogong Jack's Creek with the West Kiewa River. At this point there is a dam site just downstream from some small river flats which afford pondage.

It is proposed to build a concrete slab and buttress dam at this point impounding water to a height of about 30 feet above stream bed. The level of the spillway crest is R.L. 2,607 and a pondage of 50 acre-feet is obtained by a draw down of 15 feet.

19. West Kiewa Tunnel. At the abovementioned offtake, the water will be diverted to the East Kiewa Valley by means of a tunnel about 75 square feet in cross sectional area and about 4 miles in length under the main ridge between the East and West Kiewa Rivers. This tunnel discharges into the pondage on Pretty Valley Branch, known as Pretty Valley 2L, from which it is drawn for the operation of the small unit of 7,000 kw. in Power Station No. 2 as previously described in paragraph No. 14.

The tunnel will probably be attacked from one heading only and the construction period will be long, but this work can proceed as may be required without affecting the demand output of the scheme.

20. Tunnels—General. As previously mentioned, the upper portions of this scheme above No. 1 Power Station are within the region of heavy regular winter snow fall.

The original proposals put forward in 1920 for the Kiewa scheme contemplated the construction of a very long race line at this elevation, through very precipitous and difficult country.

Careful investigations of snow and ice conditions carried out during the past years have shown the impracticability of operating an open race line at these levels during the winter months, for it would be impossible to prevent the race from becoming completely blocked by snow and ice.

It will be noted that in the proposals now put forward the only open race lines at these levels are a few short lengths of small unlined race which are used to supplement the High Plains catchment, and which do not operate during the winter time.

At the higher altitudes it is imperative that all conduits should be closed, and that they should be of such design as to avoid damage or destruction by the large snow slides which occur on the hillsides, in places.

Tunnels meet these conditions in the best manner, and furthermore provide excellently for elasticity of operation. Owing to the good rock conditions, these tunnels can be located in solid rock and can be unlined, except for short sections. This feature, together with the fact that the most direct route may be adopted, also renders tunnels no more costly than other types of conduit.

These latter considerations have led to the adoption of tunnels throughout the scheme, even at the lower altitudes, where no trouble from snow or ice can occur.

The length and sizes of the tunnels proposed are set out in the following tabulation :—

—	Length. (Feet).	Area. (Square Feet).
Pretty Valley to Rocky Valley	7,500	50
No. 1 head race tunnel	14,700	60
Tunnel from open channel to Rocky Valley Offtake 2H	3,500	65
No. 2 head race tunnel (to steel pipe)	5,000	80
Head race tunnel No. 2L	5,000	75
West Kiewa tunnel	21,000	75
No. 3 head race tunnel	4,200	200
No. 4 head race tunnel	12,500	200

21. Pressure Pipe Lines. Owing to the high heads developed in this scheme, the pressure pipe lines form one of the most important portions of the scheme, although, with the layout now proposed, the highest head at any station is little greater than that at the Commission's present Rubicon Power Station.

Considerable development has occurred in recent years in the practice of electric welding for pressure pipes, and in any proposals now put forward welding would be used to a great extent.

The general characteristics of the pipe lines are tabulated herewith :—

Pipe Line. Number.	Full Load Capacity. (Cusecs).	Maximum Gross Head. (Feet).	Approximate Net Head at Full Load (Feet).	Number of Pipe Lines.	Diameter of Pipes. Inches).
1	215	1,503	1,444	1	60-54-51-48
2H ..	265	1,509	1,454	1	63-60-57-54
2L	295	362	350	1	66-64-62
3	780	366	355	3	66-64-62
4	780	637	603	3	65-62-59

The arrangement of the pipe lines with concrete anchors and piers will be generally similar to that adopted at Rubicon. Pipe line profiles are shown on Plate No. 10.

22. Power Stations. Until the last few months our proposals contemplated locating several power stations underground in rock excavations. Later investigations indicated that in one case the power station site could be altered so as to locate the station above ground without increasing the length and thus the cost of the pressure pipe line. In the two other cases where underground stations were proposed, further geological investigation indicated difficulties in the construction of both the underground power station and the necessary tail water tunnels.

These difficulties involved such considerable increase in the estimated cost of underground power stations that in the proposals now submitted all power stations are located overground.

The estimates of cost provide for the construction of substantial ferro concrete buildings.

23. Turbines. Main turbines for Power Stations Nos. 1 and 2 will be of the vertical shaft impulse or pelton wheel type.

Main turbines for Power Stations Nos. 3 and 4 will be vertical reaction wheels, whilst the smaller unit at Station No. 2 will also be of this type.

The probable general particulars are set out hereunder :—

Power Station Number.	Net Head at Full Load. (Load feet).	Maximum Power Available (kw.)	Number and Capacity of Units.		Type of Turbine.	Probable Speed. r.p.m.
			Total Installed.	Spare.		
1 ..	1,444	21,000	2/10,500	..	Vertical Pelton 4-jet	500
2 ..	1,454	26,000	2/13,000	..	,, ,,	500
	350	7,000	1/7,000	..	Vertical Reaction	428
3 ..	355	24,000	3/8,000	13,000	Vertical Reaction	428
4 ..	603	39,000	3/13,000			500

It will be noted that the spare plant for the whole scheme is housed in Power Stations Nos. 3 and 4, where water can be made available from the Junction.

24. Effect of proposed works on hydraulic regime. All water stored or diverted is ultimately returned to the streams upstream of the confluence of the East and West Kiewa Rivers.

Upstream of this confluence there is sparse settlement for about 2 miles to the foot of Mount Beauty, but beyond this point the country is forest land without any settlement.

The effect upon land holders of any alteration in the hydraulic regime due to the works of this scheme would, therefore, be of importance mainly down-stream of this confluence, where the main effect on the stream would be due to the storage of water on the high plains, and its subsequent release.

The effect of these storage operations would be beneficial to the stream in that it would increase the flow during dry periods, and in some cases reduce the magnitude of floods.

With the works proposed the diurnal variations of flow in this portion of the river will be small, and should have no appreciable effect.

The effect on the streams of the very small diversions proposed from the Mitta catchment are negligible, both as regards the increase of flow in the Kiewa and the reduction of flow in the Mitta.

Up-stream from the confluence of the East and West Kiewa Rivers only those portions of the streams north of Mount Beauty need be considered, as although portions of the rivers between the various power stations and dams would be considerably affected by the operation of the scheme, the whole of this area is forest country and no outside interests are concerned.

North of Mount Beauty the flow in the West Kiewa River would be considerably augmented by water diverted from the East Kiewa River, but this should not have any serious effect and there is not much settlement on this portion of the stream.

The flow in the East Kiewa River below No. 4 offtake will, generally, be considerably reduced, particularly during dry flow periods, when the flow near Mount Beauty will probably be only one-fourth of its natural flow. Some flow, however, is always maintained by small tributaries below the offtake.

25. Construction Power. There is no outstanding local possibility for the development of hydro-electric power for construction purposes, and it is proposed that this should be provided by transmission line from the Commission's existing system, this line later being used for transmitting outgoing power.

26. Local Construction Materials. Fair concrete sand has been located in the Kiewa River at Tawonga, about 5 miles down-stream from No. 4 Power Station site, in quantities ample for all requirements. This sand, which is mixed with gravel, will require washing, but ample water is available, and after crushing and screening, the gravel will be suitable for road surfacing, &c.

On account of the high cost of transporting sand to the high plains a special endeavour was made to locate sand at these elevations, but the only sand located is a rather poor quality sand and gravel which exists in limited quantities in Rocky Valley and is not suitable for first class concrete.

Ample deposits of stone are available at all parts of the scheme, of excellent quality for concrete and all other purposes, and tests have indicated that satisfactory sand also can be obtained by crushing this rock.

Timber suitable for milling is available between Tawonga and No. 1 Power Station site, but the quality is not suitable for permanent construction purposes. No timber is available above No. 1 Power Station site.

27. Investigations still in hand. Although investigations to date have been fairly complete, a continuance of certain work now in hand is essential.

Field investigations may be grouped as follows:—

1. Hydrological.
2. Sub-surface Explorations.
3. Surveys and Geological Investigations.

1. Hydrological.

Continuous river gaugings are being maintained.

As previously mentioned, the importance of obtaining some check on the flows for the period 1914–16, and the desirability of a more complete understanding of the volume and effect of precipitation on the high plains led, at the beginning of 1933, to the establishment of a meteorological station on the high plains. This station has now demonstrated its value, and in order to obtain the full value of this work, its continuance for a few years at least is essential.

2. Sub-surface Explorations.

These have been in hand for some time, but are by no means complete over the whole scheme. The self evident value of this work needs no stressing.

3. Surveys and Geological Investigations.

Further survey work is still required, largely in conjunction with diamond drilling for the most economical location of various portions of the scheme. Detail geological survey assisted by the aerial survey is required over the proposed sites of all works.

PROPOSED ENGINEERING WORKS.

B. ELECTRICAL AND TRANSMISSION.

The electrical works in connexion with the Kiewa scheme comprehend the generators to be coupled to turbine shafts, the switchgear and control apparatus for the proper control of the turbines and generators, transformers stepping up from the generator pressure to the eventual transmission pressure, transmission lines to the Melbourne Terminal Station, together with a minor transmission to Wangaratta, and the works of stepping down, regulating and switching at the Melbourne Terminal Station.

1. General description of the proposed electrical works. It is proposed that at all four generating stations, the generating pressure shall be 11,000 volts and that at Stations Nos. 1, 2, and 3 the generated energy be transformed in pressure from 11,000 volts to 66,000 volts for transmission down the Kiewa Valley to Power Station No. 4 at Mount Beauty where transformation of the bulk of the energy from all stations to 165,000 volts for transmission to Melbourne will be effected.

A portion of the output from the stations will be absorbed by transmission to Wangaratta at 66,000 volts and utilized in the North-east system. The two circuit 165,000 volt transmission line from Tawonga to Melbourne will terminate at a station on the Merri Creek in the Brunswick area, where the received energy will be transformed from the receiving pressure on the high pressure line of 154 kv. to 22,000 volts for transmission to the central system of the metropolitan area.

2. Generating Stations—electrical control. It is not anticipated, in respect of the electrical machines installed in the power station, there will be any features which do not form a part of current practice. In the control of the stations, full advantage will be taken of the most modern developments.

With regard to the control and supervision of the power stations from a central point, the latter will be the transmitting station at Tawonga.

The principle of remote supervision of hydro stations on a major scale was first adopted in 1925 by this Commission in connexion with the Sugarloaf–Rubicon plants, and while the system has been extremely satisfactory in facilitating the control of the five power stations of that group, there have in the years since that time, been such great improvements in the technique and apparatus concerned with distant control and distant metering, that its adoption for the much larger Kiewa installation can be contemplated with complete confidence.

Allied with the design of the Kiewa system on the hydraulic side, the result will undoubtedly be a system of power stations under very complete control, entirely and rapidly responsive to the requirements of the major system.

3. Transmission from Tawonga to Melbourne. The route chosen for the transmission line from Tawonga to Melbourne is approximately 158 miles long. A number of flying surveys has been made of the proposed route which follows very closely the following line—(see Plate No. 11):—

> From Tawonga over the Tawonga Gap and down German Creek past Bright, along the Buckland Valley to a point just south of the Horn at Buffalo, through Dondangadale direct west to the King River Valley, striking this river at a point just south of Whitfield, thence up the King River and over the Tolmie Plateau to a point a few miles east of Mansfield, and then direct to Darlingford, crossing the Sugarloaf Weir on the way. From the vicinity of Rubicon "A" the line will follow the easement of the existing Rubicon "A"—Thomastown transmission, and penetrates Melbourne roughly by the course of the Merri Creek.

There are no inherent difficulties to be anticipated in this transmission which are greater than those which have already been encountered by the Commission's Engineers in the present extensive transmission works of the State system.

The length and high voltage of the line will introduce requirements in regard to the charging of the transmission line which will be met by suitable arrangements of the generators at Power Station No. 4 and the synchronous condenser plant at the Melbourne Terminal.

4. Melbourne Terminal Station. The Melbourne Terminal Station will be equipped for receiving and transforming for a normal capacity of 92,500 kw. (at 22 kv.), the pressure regulation being accomplished, as is the case in the existing terminal stations of the Commission, by rotating condensers.

The site for this station has been chosen in a suitable location for effectively dealing with the anticipated loading in the metropolitan area, with due regard to economy in secondary transmission, and there will be no difficulty in bringing the high voltage line into the terminal station.

5. Progressive Construction of Electrical Works. To make power available for construction purposes, the present intention is to construct a transmission line from Wangaratta to Mount Beauty which, while serving construction purposes during the first few years, can be used for the purpose of supplying energy through Wangaratta to the North-east District as soon as energy is actually produced at Kiewa. It will be possible in this way to absorb about 15,000 kw. into the system via Wangaratta, of which a great deal will be used in the north-east, thus appreciably relieving major transmission to Melbourne.

At the stage when 20,000 kw. becomes available from Kiewa, the transmission structures from Tawonga to Sugarloaf will have been erected, admitting of the transmission over the existing Sugarloaf–Thomastown route and transmission circuits to Thomastown Terminal Station of that part of the Sugarloaf–Rubicon and Kiewa output which is not absorbed in the North-east District.

As the stages of development proceed, the transmission of the increasing power to Melbourne will include a stage involving the absorption of part of the energy at Rubicon " A," together with the transmission of the remainder direct to Melbourne by a single 165-kv. circuit.

At the stage when rather more than 50,000 kw. will be generated at Kiewa, two 165-kv. circuits will be available to deliver power from Kiewa to the Melbourne Terminal Station, but operating for a stage at 66,000 volts.

Operation at the ultimate transmission voltage of 165 kv. will be initiated at the stage when Kiewa's capacity has reached 76,000 kw.

ESTIMATES OF THE TOTAL CAPITAL COST OF THE COMPLETED KIEWA SCHEME, INCLUDING TRANSMISSION TO MELBOURNE AND TO NORTH-EAST DISTRICT AT WANGARATTA.

ASSEMBLED UNDER GENERAL WORKS CLASSIFICATIONS.

Civil and Hydraulic Engineering Works—	£
Land, clearing, surveys, &c.	50,000
Transport works, including roads and pipeline haulages	157,000
Tunnels, conduits, offtakes, surge tanks and diversion races	992,000
Dams and offtakes	1,037,000
Pressure pipelines complete	318,000
Turbine equipment in power stations	247,000
Power station buildings, including cranes	178,000
Permanent buildings, residences, &c.	44,000
General equipment	340,000
Contingencies	341,000
Engineering	221,000
Interest during construction	248,000
Total	4,173,000
Electrical Works, including Transmission to Melbourne and Transformation at Terminal Station—	£
Power Station generators, control gear, switch gear, and transformers—	
No. 1	82,500
No. 2	122,250
No. 3	110,500
No. 4	92,250
Main transmission to Melbourne Terminal Station and Wangaratta	760,000
Melbourne Terminal Station	408,000
Kiewa " A " Transmitting Station	215,500
Power Station interconnecting transmission lines	32,500
Wangaratta Substation	54,000
Rubicon " A " and construction substations	16,500
Interest during construction	69,000
Total	1,963,000
Grand total	6,136,000

ESTIMATED TOTAL OUTPUT OF THE KIEWA SCHEME.

Generated at Kiewa Stations—
- 104,000 kw.
- 440,000,000 kw. hrs.

Delivered at load centres for distribution Melbourne and Wangaratta—
- 92,500 kw.
- 390,000,000 kw. hrs.

Energy output in kw. hrs. per annum are average figures over a number of years.

ESTIMATED ANNUAL CHARGES ON THE COMPLETED KIEWA SCHEME INCLUDING TRANSMISSION TO MELBOURNE AND THE NORTH-EAST DISTRICT AT WANGARATTA.

	£
Civil and Hydraulic Works—	
Interest, 4½ per cent. on £4,173,000	187,785
Depreciation—1·18 per cent. on £4,173,000 (on sinking fund basis 3½ per cent. per annum)	49,239
Superintendence and maintenance	18,000
Total	255,024
Electrical and Transmission Works—	
Interest, 4½ per cent. on £1,963,000	88,335
Depreciation—2·28 per cent. on £1,963,000 (on sinking fund basis 3½ per cent. per annum)	44.756
Superintendence, operation, and maintenance of Kiewa group	20,000
Superintendence, patrol, and maintenance of transmission lines	14,000
Superintendence, operation, and maintenance of terminal stations	11,000
Total	178,091

Total annual charges on Kiewa energy delivered at load centres	£433,000
Annual charges per kw. delivered to load centres	£4·68 per kw. p.a.
Average cost of energy delivered from Kiewa group to load centres per kw. hr.	0·267d.

ERRATUM.

The amount, "£4·63," in the ninth line from the bottom of page 65, should be "£4·68."

COMPARISON OF THE KIEWA PROPOSALS WITH ALTERNATIVE GENERATING STATIONS.

There are at present two alternative or competing proposals which are worth examining as generating schemes in comparison with the Kiewa :—

(*a*) An extension of the Yallourn Power Station.

(*b*) A major extension of plant at a location close to Melbourne, such as Newport.

When the plant at present authorized at Yallourn comes to completion in what are known as the " A " and " B " Stations at Yallourn, there will be a total plant installation of 175,000 kw., able to produce a total of about 136,000 kw. at the station busbars. It will be possible to provide another extension on the same site of sufficient capacity to deliver in Melbourne the same load at load centres as that proposed to be delivered under the Kiewa scheme. The total load delivered to station busbars at Yallourn in the " A," " B," and " C " Stations would then be about 240,000 kw.

This extension " C " at Yallourn would involve special consideration of the arrangements for circulating water, and provision for additional storage on the Latrobe River, to safeguard the operation of the plant over periods of low river flow. The energy generated by this extension station would be brought into the Melbourne area at the same point as that determined upon for a terminal station in connexion with the Kiewa scheme.

In the metropolitan area there is no doubt that the most favorable site for the location of a major plant would be Newport, where, in addition to the Newport " A " plant of the Victorian Railways, the State Electricity Commission has at present a considerable installation in Newport " B."

The original project of Newport " B " in 1921 provided, as far as concerns site plan and circulating water, provision for a station very much greater than the existing Newport " B " Station, and there is no doubt that, apart from this present consideration of alternatives to the Kiewa scheme, *the Newport site will be progressively utilized for increased metropolitan plant installation.*

In comparing Kiewa with the metropolitan station, therefore, it will be assumed that this plant will be developed at Newport.

For the purpose of the present comparison, estimates have been prepared for stations at Yallourn and Newport respectively, assuming in each case that 92,500 kw. is to be delivered at equivalent load points on the Commission's system, and the results of these estimates are summarized hereunder, the details following :—

Capital cost of providing for 92,500 kw. delivered to the system at load centres :—

1. Extension of Yallourn Power Station	£4,981,000
2. Metropolitan Station	3,598,800
3. Kiewa project	6,136,000

Under 1, Yallourn Extension, provision has been made for the capital necessary to augment the coal winning operations in order to deal with the supply of coal to the new station.

Annual costs of energy at load centres from the respective sources :—

The annual costs of energy at load centres from these various sources, set out on the basis of " demand " plus " energy " cost, are as follow :—

1. Extension, Yallourn Power Station—£5 per kw. p.a., plus 0·1d. per kw. hr.
2. Metropolitan Station—£4 per kw. p.a., plus 0·195d. per kw. hr.
3. Kiewa project—£4·63 per kw. p.a., at an average load factor of 48 per cent.

These calculations of annual costs are based on the assumption of price levels, interest rates, fuel costs, &c., as at present, thus :—

Interest	4½ per cent.
Raw brown coal in bunkers at Yallourn	2s. per ton.
Newcastle coal, Newport at conveyors	27s.

Depreciation has been allowed in all cases in accordance with the Commission's standard practice and with interest on depreciation funds compounded at 3½ per cent. per annum.

Analysing the basic annual costs of energy in the three cases stated above, it will be found that:—

(*a*) The Kiewa project is economically superior to the Yallourn extension at all load factors of which the former is capable.

(*b*) The Yallourn extension and the metropolitan station are economically equivalent at about 30 per cent. load factor, above which load factor, on the basis of present costs of black coal and raw brown coal respectively, the Yallourn extension is the more economical.

(*c*) The Kiewa and the metropolitan station are economically equivalent at about 10 per cent. load factor, above which load factor Kiewa is economically superior to the metropolitan station.

(*d*) A study of the system load duration curve will show that, at the time when the Kiewa project is fully developed, the range of load allotted to the plants of this scheme would be between 34 per cent. and 62 per cent. of the system load, and for this particular band of loading there is no portion of the Kiewa load which could economically be taken by metropolitan plants, and it follows that no combination of metropolitan and Yallourn plants could give more economical production of energy for this portion of the loading than the Kiewa plants.

Stated in terms of total annual cost for delivery of 92,500 kw., 390,000,000 kw. hrs., at load centres, the respective total annual costs under the three alternatives are estimated to be:—

Yallourn	£620,000
Newport	694,000
Kiewa	433,000

It must be repeated that the Kiewa scheme as designed is fitted to take a definite portion of the system load, and is not capable of operating at the high load factors which are the duty of the Yallourn plants.

The above comparisons demonstrate clearly that, while the capital cost of the Kiewa project is higher than that of available alternatives, its economic superiority, as designed, to alternative proposals, is very marked, and also makes readily appreciable the economic place of the Kiewa project in the Commission's generating system as it grows.

ESTIMATES OF CAPITAL AND OPERATING COSTS OF GENERATING PLANTS AT YALLOURN AND MELBOURNE FOR THE PURPOSE OF DELIVERING 92,500 KW. (390 MILLION KW. HRS.) TO LOAD CENTRES.

A. Yallourn—

Estimates provide for plant to deliver—

107,000 kw. at generator terminals.
101,000 kw. to transmission line at Yallourn.
92,500 kw. at Melbourne Terminal Station.

The plant will consist of—

12 boiler units each generating from 130,000 to 156,000 lb. of steam per hour.
5 turbo-alternators each 30,000 kw.

Steam conditions—

290 lb. per square inch boiler pressure.
750° Fahr.

Estimated Capital Costs—

	£
Power Station—	
Land and preparation of site	12,000
Buildings	584,000
Coal handling plant and storage	110,000
Ash handling plant	33,000
Boiler plant and chimneys	1,356,000
Turbo-alternator and condensing plant	578,000
Feed water plant, piping, &c.	205,000
Circulating water system and storage basin	200,000
Electrical auxiliaries and cables	70,000
General equipment	16,000
Switchgear for generators, transformers, and transmission lines, main and auxiliary transformers and controls	325,000
Interest during construction	178,000
Overheads, including engineering and inspection	236,000
Total	3,903,000

	£
Electrical Works—	
Transmission line to Melbourne Terminal, 86 miles	370,000
Melbourne Terminal Station, buildings and equipment, excluding 22 kv. switchgear for secondary transmission	422,000
Interest during construction	36,000
Progressive total	4,731,000
Provision for extension of coal winning operations	250,000
Grand total	4,981,000

B. Newport—

Estimates provide for plant to deliver—

104,000 kw. at generator terminals.
99,000 kw. to outgoing feeders.
92,500 kw. to Melbourne load centres.

The plant will consist of—

10 boiler units each generating from 160,000 to 190,000 lb. of steam per hour.
5 turbo-alternators each 30,000 kw.

Estimated Capital Costs—

Power Station—

	£
Land and preparation of site	20,000
Buildings	500,000
Coal handling plant and storage	90,000
Ash handling plant	40,000
Boiler plant and chimneys	1,305,000
Turbo-alternators and condensing plant	568,000
Feed water plant, piping, &c.	201,000
Circulating water system	35,000
Electrical auxiliaries and cables	70,000
General equipment	24,000
Switchgear for generators, transformers, and feeders, main and auxiliary transformers and controls	210,800
Interest during construction	135,000
Overheads, including engineering and inspection	212,000
Total	3,410,800

Electrical Works—

	£
Transmission	40,000
Terminal station buildings and equipment, excluding 22 kv. switchgear for secondary transmission	140,000
Interest during construction	8,000
	188,000
Grand Total	3,598,800

ANNUAL CHARGES—

A. Yallourn—

	£
Operation—	
Superintendence	9,934
Labour	28,142
Fuel	147,000
Water	400
Sundry supplies	3,000
Miscellaneous station expense	1,400
Maintenance—	
Land and buildings	2,000
Coal and ash handling	8,460
Boiler equipment	26,400
Turbo-generator equipment and circulating water system	9,100
Switchgear and transformers and general equipment	6,000
Fixed Charges and Overheads—	
Interest, 4½ per cent. on £3,903,000	175,635
Depreciation, 2·28 per cent. on £3,903,000	88,988
Insurance and workers' compensation	1,025
Administration, local and Melbourne, and superintendence	35,000
Transmission and Terminal Station fixed charges	77,330
Total annual charges	619,814

The toal annual charges can be divided into—

	£
Total fixed charges	459,298
Variable charges	160,516

Approximate annual charges on energy delivered to load centres—
£5 per kw. per annum, plus 0·1d. per kw. hr.

B. Newport—

	£
Operation—	
Superintendence	9,934
Labour	22,616
Fuel at 27s. per ton	329,400
Water	750
Sundry supplies and miscellaneous station expense	4,400
Maintenance-	
Land and buildings	2,000
Coal and ash handling	4,115
Boiler equipment	20,000
Turbo-generator and condensing equipment	9,100
Switchgear, transformers, and general equipment	6,000
Fixed Charges and Overheads—	
Interest, 4½ per cent. on £3,410,000	153,450
Depreciation, 2·28 per cent. on £3,410,000	77,748
Insurance, workers' compensation	1,025
Administration, local and Melbourne, and superintendence	35,000
Fixed charges on transmission and terminal stations	18,460
Total annual charges	693,998

The total annual charges can be divided into—

	£
Total fixed charges	376,610
Total variable	317,388

Approximate annual charges on energy delivered to load centres—
£4 per kw. per annum, plus 0·195d. per kw. hr.

THE FUNCTIONS IN THE COMMISSION'S GENERATING SYSTEM OF THE YALLOURN, METROPOLITAN, AND KIEWA GENERATING PLANTS.

Characteristics of the system loading. The characteristics of the system load on the Commission's plants can be appreciated very clearly by a study of the load duration curve which is attached to this Report, and of the typical daily loading curves which are also appended (see Plate Nos. 12 and 5).

The statistics which are available over a considerable number of years since the system commenced operation show that, while there is a steady increase in the weekly load factor of the system, there is no such definite trend with regard to annual load factor, and there is nothing to justify the assumption of an annual load factor, over a considerable number of years, greater than 53 per cent. Similarly, there is no reason to assume that the annual load duration curve for the system is likely to vary seriously in its characteristics over a considerable period of years, so that the application of this typical duration curve to the questions involved in the economic relation between generating sources is justified.

A study of the rate of load increase upon the Commission's system has been made by plotting the " moving average " of the weekly maximum load, a study of which shows that for some years past the increase in the moving average has been at the rate of about 8 per cent. per annum. There is also a fairly definite relation between the moving average and the annual " one hour maximum load " which must be met by the Commission's generating system.

Although it might not be justifiable to assume an increase at the rate of 8 per cent. per annum over a very long period of years. it would not, on the contrary, be justifiable in providing for meeting the demands of the system for a period of, say ten years, to assume a lower rate of increase.

It is possible, therefore, to estimate for some years ahead the anticipated maximum load on the system, and assuming no significant variation in load factor or the shape of the duration curve, plant requirements can be fairly definitely forecast (see Plate No. 13) for a number of years, but beyond 1944–45 I would regard this forecast as distinctly speculative.

The full development of the Kiewa plants can be utilized satisfactorily when the total system load becomes 350,000 kw., which may be the case some time between 1948 and 1952, at which period the load distribution between stations would be approximately as follows:—

Yallourn Steam Station	136,000 kw.
Sugarloaf and Mountain Stream Stations	11,000 ,,
Metropolitan Steam Station	100,000 ,,
Kiewa Hydro-electric Scheme	104,000 ,,
Total	351,000 ,,

The division of loading between the several sources under these conditions is shown on the attached graph, which is a typical duration curve (Plate No. 12).

In view of the principles which have been adopted in the design and operation of the Kiewa scheme, it is necessary at this assumed loading and condition of plant installation to apportion to the Kiewa scheme a definite position in the load duration curve, roughly in the centre third of the curve under the loading conditions above defined. The high load factor portion of the load would be taken by the Yallourn plant, and the low load factor, or upper portion of the load, by the metropolitan plant, the latter at the stage contemplated generating from one-third to one-fourth of the total load.

It has been shown in a previous paragraph of this Report that the Yallourn plant and the metropolitan plant at Newport are equal, in respect of the cost per kilowatt hour at which energy can be delivered to load centres, at a load factor of about 30 per cent. under existing prices for fuel at the respective stations. Generally speaking, therefore, it will be economical to give to the metropolitan stations any of the system load which is below 30 per cent. load factor.

In addition to the purely economic consideration, *it is necessary that a reserve of plant to cover emergency requirements should be held in the metropolitan area*, and the present condition is that, in this respect, the existing installation of plants in the metropolitan area is below the requirements dictated by both economic and emergency considerations.

It is possible that a total system load of 350,000 kw. may be reached in 1948, and it will be necessary therefore to provide not only that the Kiewa plants, if their construction be authorized, be brought into commission within a few years of that date, but also that the necessary development of metropolitan plant be provided so that the due balance in the economic arrangement of the generating system can be preserved.

Looking to the functioning of the Kiewa scheme in years well beyond 1948, there will be no difficulty in assigning to the Kiewa installation the utilization factor for which it will have been designed because, so far as can be reasonably anticipated, the typical shape of the daily load curves will not seriously vary. As far as the duration curve is concerned, the band occupied by the Kiewa plants will steadily become narrower with the progressive growth of the Commission's system. Thus, while upon completion the plants may be called upon to operate on the duration curve between the limits of 34 per cent. and 62 per cent. load factor, these limits will have a tendency to contract closer to 48 per cent. as years pass. As time goes on the metropolitan plant may either take a larger proportion of the system load, or, alternatively, if proved to be economical, the Yallourn plant may extend into the upper portion of the duration curve.

At stages in the development of the Kiewa plants, should they be approved, it will be necessary to provide for augmentation of the metropolitan generating plant in order to maintain the desirable proportions in the various plant capacities to satisfy the requirements above stated.

It must be pointed out that, in the comparison which has been presented above, the assumption made as to the cost of Newcastle coal, or equivalent fuel in Melbourne, is the only one which can be made at the present time, although this cost is somewhat uncertain and may not be reasonably stabilized at the present time.

In the case of the Yallourn and Kiewa plants, the costs which have been determined should be more definite and controllable.

CONSTRUCTION OF THE WORKS INCLUDED IN THE KIEWA PROPOSALS.

As a basis for calculation of the progressive financial requirements for the purpose of construction of the Kiewa works, if approved, a programme of construction has been prepared and in graph form is attached to this Report. (See Plate No. 14).

If it be assumed that towards the end of 1937 a start were made with the essential preliminaries, it is considered that the whole of the works could be completed by the year 1951, a period of about thirteen years. The average expenditure spread over thirteen years would then be about £470,000 per annum, but the capital requirements in individual years would not be uniform.

Constructed in six main stages of development, the flow of capital into the construction works is estimated to be :—

	£
1937–42	1,408,000
1942–45	1,458,000
1945–47	1,062,000
1947–48	802,000
1948–49	351,000
1949–51	1,055,000
Total	6,136,000

The capital expenditure is shown in detail in the tabulation hereunder. (See Table 1).

Power and energy would become available in 1942, and in progressively increasing amounts, culminating in the full development in 1951 of the generated output of 104,000 kw. (440,000,000 kw. hrs.).

The duration of the complete construction period has been determined as that which is reasonably capable of achievement having regard to working conditions in the mountain country and the extent of local resources of every kind.

It has been pointed out elsewhere in this Report that during the period of construction and progressive availability of power, increments of power from the Kiewa scheme will not meet the estimated increments of system loading, and that simultaneous with the progressive availability of plant in the Kiewa group, there must be developed increments of generating plant at the steam stations, preferably in the metropolitan area.

Table 1.

SUMMARY OF ESTIMATED PROGRESSIVE CAPITAL COST OF THE DEVELOPMENT OF THE KIEWA SCHEME IN STAGES.

Generated output	Stage 1. 20,000 kw.	Stage 2. 37,000 kw.	Stage 3. 50,000 kw.	Stage 4. 76,000 kw.	Stage 5. 83,000 kw.	Stage 6 (Final). 104,000 kw.
Civil and Hydraulic Works.	£	£	£	£	£	£
Land resumptions, clearing, &c.	50,000	50,000	50,000	50,000	50,000	50,000
Roads	50,000	50,000	105,000	105,000	115,000	115,000
Dams and offtakes	145,000	189,000	647,000	698,000	768,000	1,037,000
Tunnels and conduits	81,000	383,000	546,000	729,000	794,000	992,000
Pressure pipes (including haulages)	83,000	149,000	149,000	259,000	278,000	360,000
Turbine plant	52,000	155,000	155,000	193,000	215,000	247,000
Power stations	47,000	94,000	94,000	141,000	141,000	178,000
	508,000	1,070,000	1,746,000	2,175,000	2,361,000	2,979,000
Permanent buildings	15,000	27,000	27,000	34,000	34,000	44,000
General Equipment	61,000	131,000	200,000	246,000	265,000	340,000
Contingencies	60,000	115,000	198,000	250,000	266,000	341,000
Engineering	40,000	80,000	130,000	165,000	180,000	221,000
Interest during construction	40,000	88,000	145,000	186,000	200,000	248,000
Progressive total capital cost of Civil and Hydraulic Works	724,000	1,511,000	2,446,000	3,056,000	3,306,000	4,173,000
Electrical Works.						
Power stations	116,000	228,250	228,250	303,750	325,000	407,500
Main transmission	438,000	700,000	760,000	760,000	760,000	760,000
Melbourne Terminal Station	..	206,000	269,000	332,000	408,000	408,000
Kiewa "A"	14,500	73,500	73,500	215,500	215,500	215,500
Power station interconnectors	27,000	27,000	27,000	30,000	30,000	32,500
Wangaratta Substation	54,000	54,000	54,000	54,000	54,000	54,000
Rubicon "A" and construction substations and lines	9,500	15,500	16,500	16,500	16,500	16,500
Interest during construction	25,000	50,750	53,750	62,250	66,000	69,000
Progressive total capital cost of Electrical and Transmission Works	684,000	1,355,000	1,482,000	1,774,000	1,875,000	1,963,000
Progressive total capital cost of Civil, Hydraulic, and Electrical Works	1,408,000	2,866,000	3,928,000	4,830,000	5,181,000	6,136,000

SUMMARY OF PROGRESSIVE ANNUAL CHARGES.

—	Stage 1.	Stage 2.	Stage 3.	Stage 4.	Stage 5.	Stage 6 (Final)
	£	£	£	£	£	£
Civil and hydraulic works	45,000	95,000	149,000	187,000	203,000	255,000
Electrical and transmission works	60,000	121,000	132,000	160,000	169,000	178,000
Total progressive annual charges	105,000	216,000	281,000	347,000	371,000	433,000
Total progressive kilowatts delivered to load centres	17,800	33,500	45,000	68,000	74,000	92,500
Annual cost per kw. delivered to load centres	£5·9	£6·45	£6·25	£5·10	£5·00	£4·68
Average kw. hrs. delivered to load centres per annum	$43{\cdot}8 \times 10^6$	$102{\cdot}5 \times 10^6$	189×10^6	..	..	390×10^6
Average cost per kw. hr. delivered to load centres, pence	0·575d.	0·505d.	0·357d.	..	..	0·267d.

CONCLUSION.

I would like to express my conclusion, after a long study of this project from every aspect, that the proposals now presented are thoroughly sound, both technically and economically. The capital expenditure which will be necessary for the complete scheme is large, but a considerable proportion of this expenditure will be on works of a highly permanent nature, subject to a very low rate of depreciation or obsolescence, and therefore, a very secure investment.

In undertaking these works as a major portion of its future generating system, the Commission would not be undertaking any liability for heavy expenditure near the power station sites which would not be directly reproductive, since the staff required for operation of the plants will be few in number.

The technical bases and design features of the scheme upon the civil engineering and hydrological sides have been very thoroughly investigated over a considerable number of years, and in the last few months have been completely discussed, criticized and revised with the co-operation of Mr. B. Hellstrom and Dr. A. F. Samsioe, whose very cordial, courteous and able co-operation I desire to acknowledge. Further, I desire to acknowledge the very able and thorough work of the members of the staff who have been particularly concerned with the investigations, proposals and estimates of this scheme, and especially Mr. A. L. Galbraith, Civil Engineer; Mr. L. T. Guy, Assistant to the Civil Engineer; Mr. T. Olsen of the Civil Engineer's staff for thorough hydrological work; Mr. W. A. Potts, the Electrical Engineer, and Mr. C. H. Kernot, the Construction Engineer.

E. BATE,

Chief Engineer, Power Production.

22nd May, 1937.

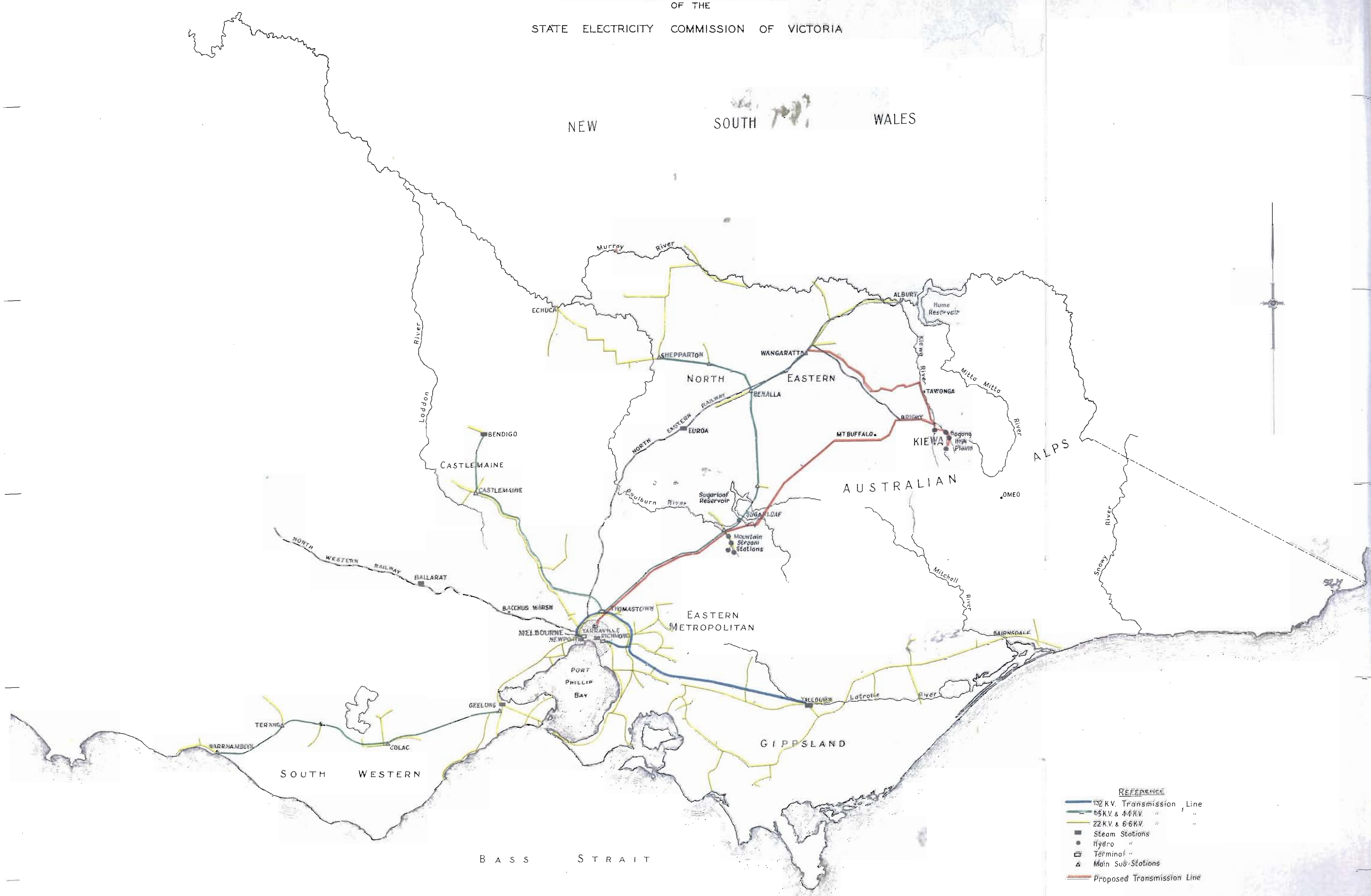
Plates 7 to 10 show sketches of the designs adopted for estimating purposes after collaboration with Mr. B. Hellstrom and Dr. A. F. Samsioe, of Messrs. Rendel, Palmer and Tritton.

GENERAL LAY-OUT OF ELECTRIC SUPPLY SYSTEM

OF THE

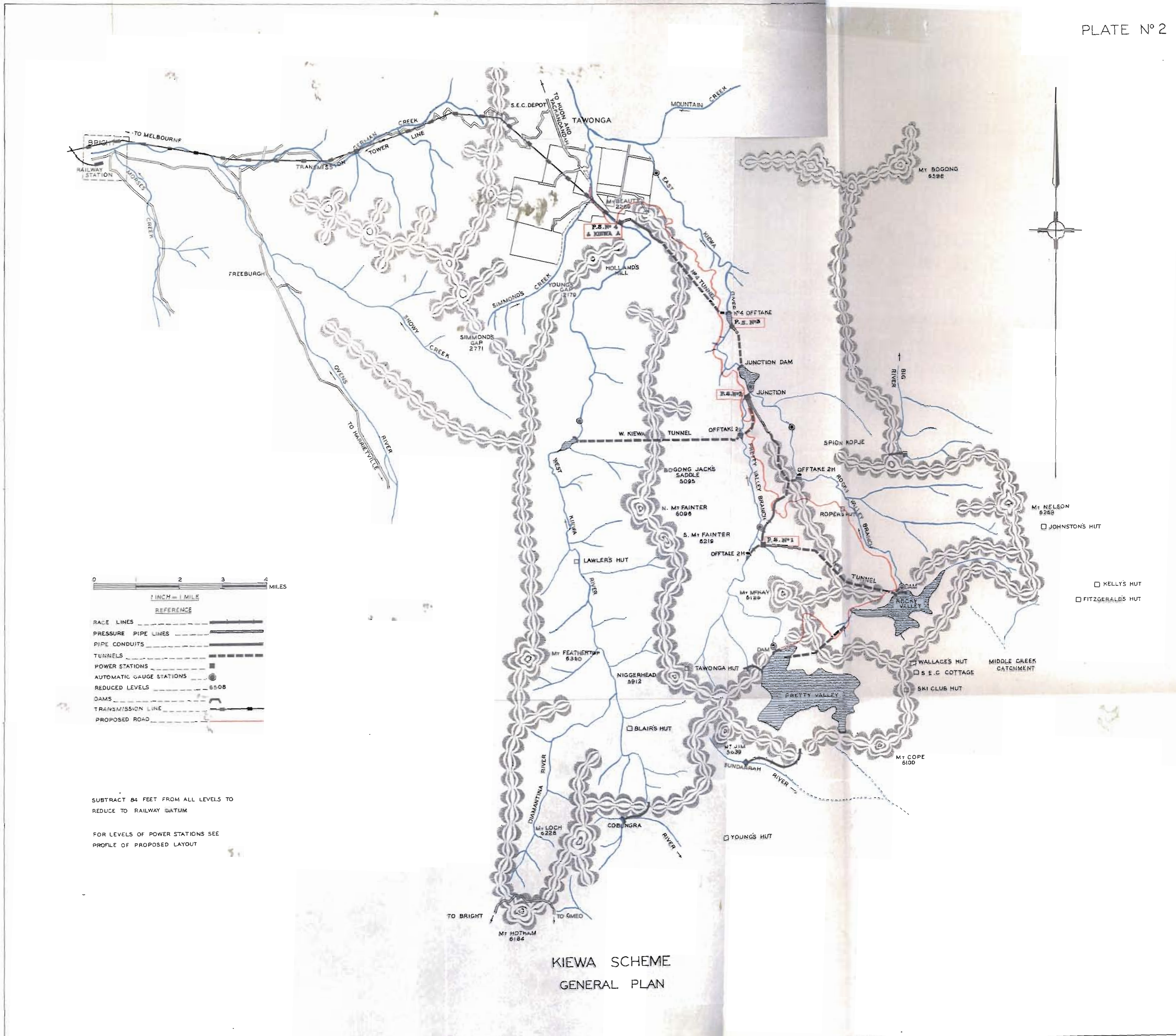
STATE ELECTRICITY COMMISSION OF VICTORIA

PLATE Nº I



STATE ELECTRICITY COMMISSION OF VICTORIA

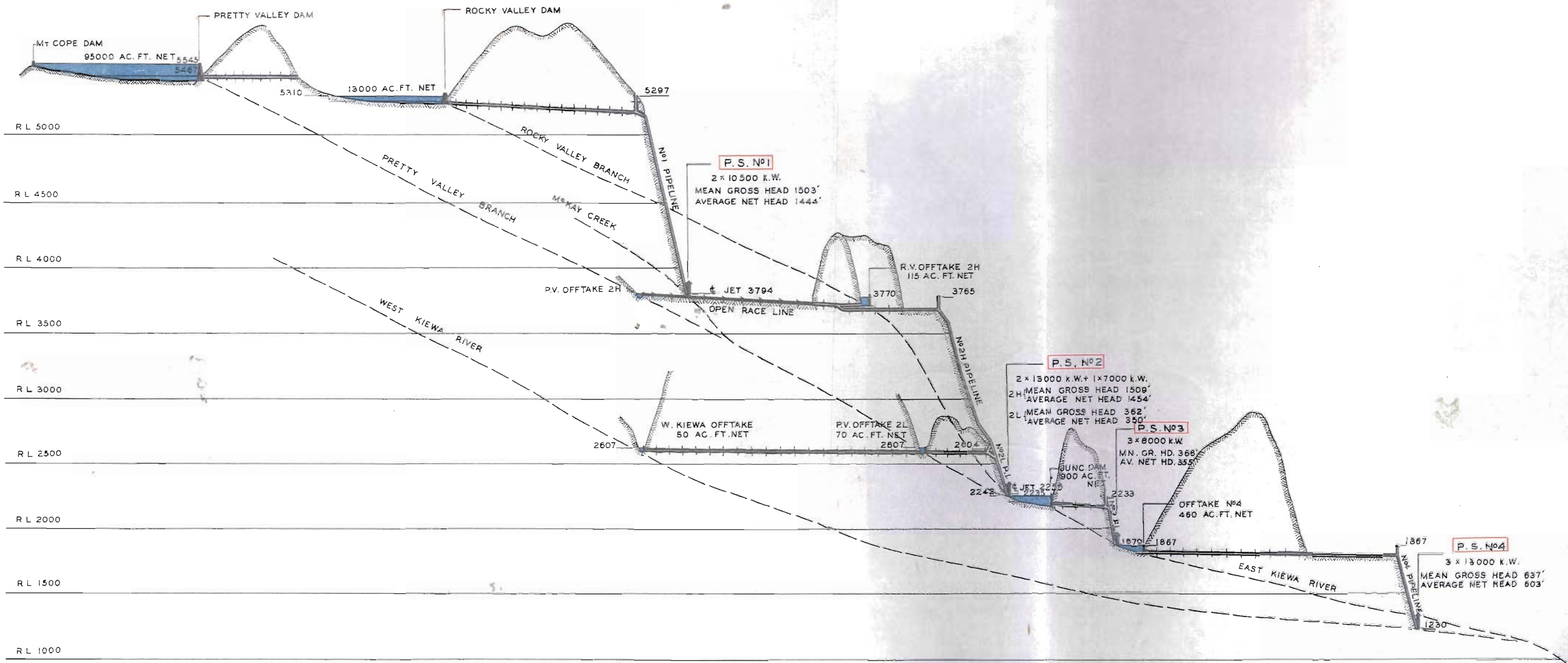
PLATE Nº 2



KIEWA SCHEME
GENERAL PLAN

STATE ELECTRICITY COMMISSION OF VICTORIA

PLATE Nº 3



KIEWA SCHEME

PROFILE OF LAYOUT

SCALES: HORIZONTAL 1" = 6000'
VERTICAL 1" = 600'

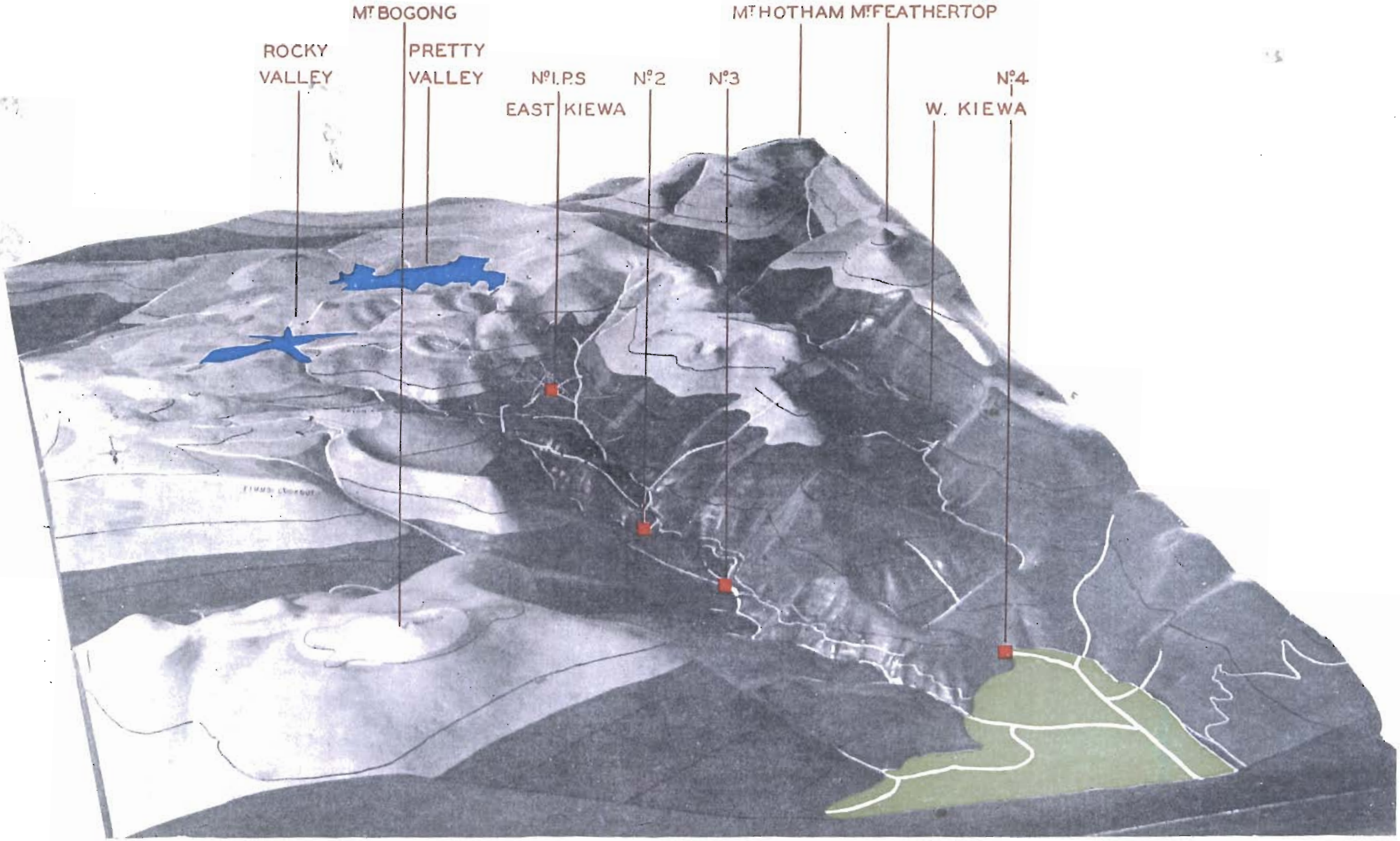

MT BOGONG
ROCKY VALLEY
PRETTY VALLEY
No.1 P.S EAST KIEWA
No.2
No.3
MT HOTHAM
MT FEATHERTOP
No.4 W. KIEWA

PLATE 4.

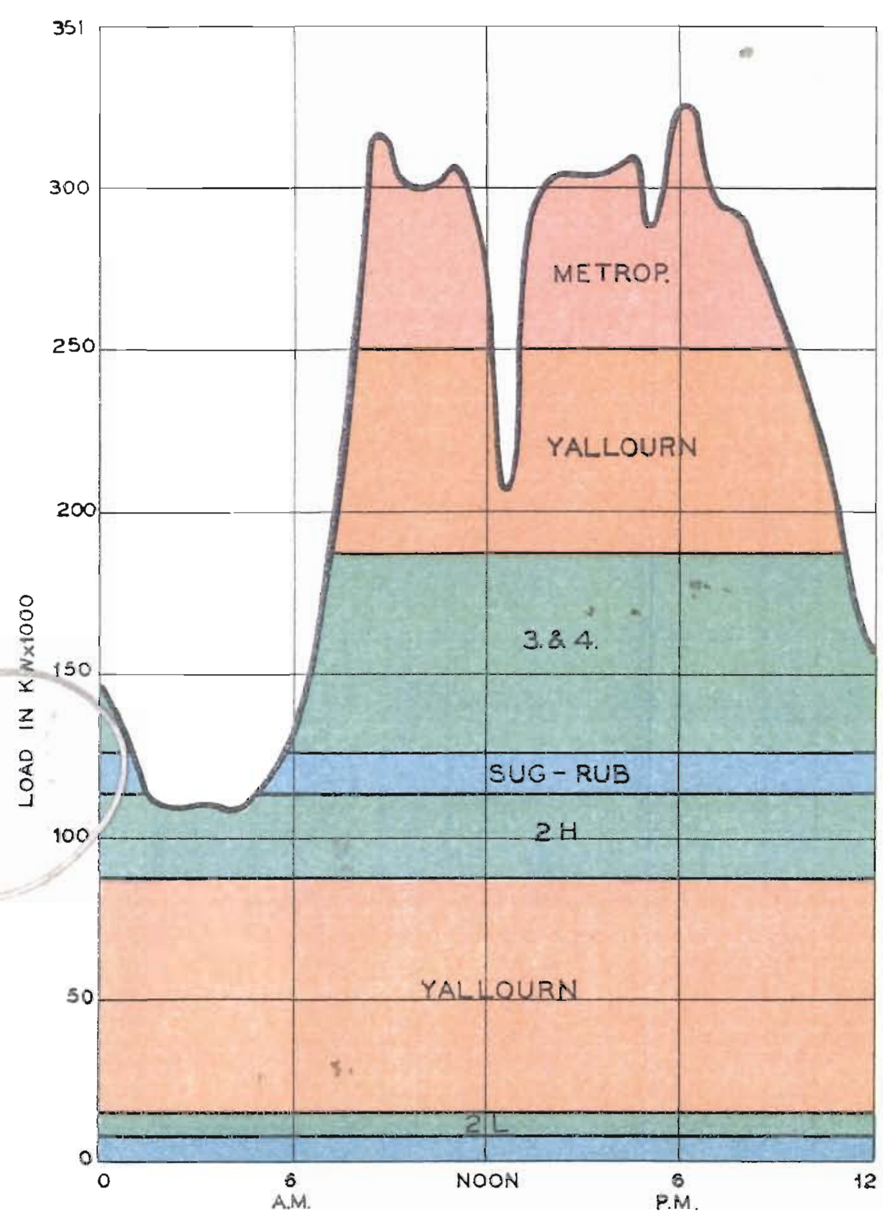
STATE ELECTRICITY COMMISSION OF VICTORIA

PLATE No. 5.

TYPICAL SYSTEM LOAD CURVES WHEN SYSTEM MAX. DEMAND IS 351,000 K.W. SHOWING OPERATION OF KIEWA SCHEME DURING NORMAL PERIODS IN JUNE (KIEWA SCHEME SHOWN IN GREEN)

(A) WET PERIOD

(FLOWS AS IN 1931)

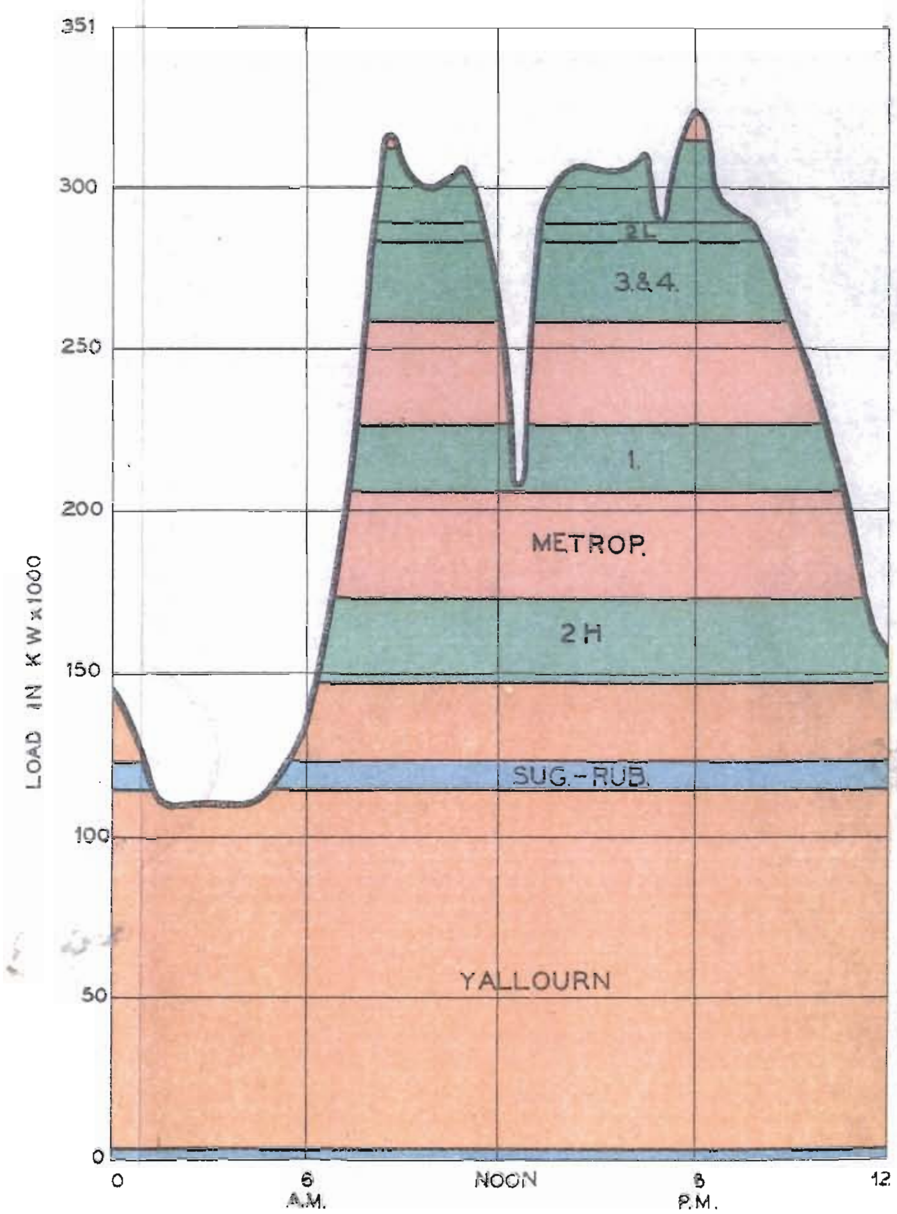


AMPLE FLOW FOR OPERATION OF ALL UNITS (INCLUDING SPARES) IN POWER STATIONS NOS. 3 & 4

POWER STATION NO. 1. NOT IN OPERATION TO CONSERVE STORAGE.

(B) DRY PERIOD

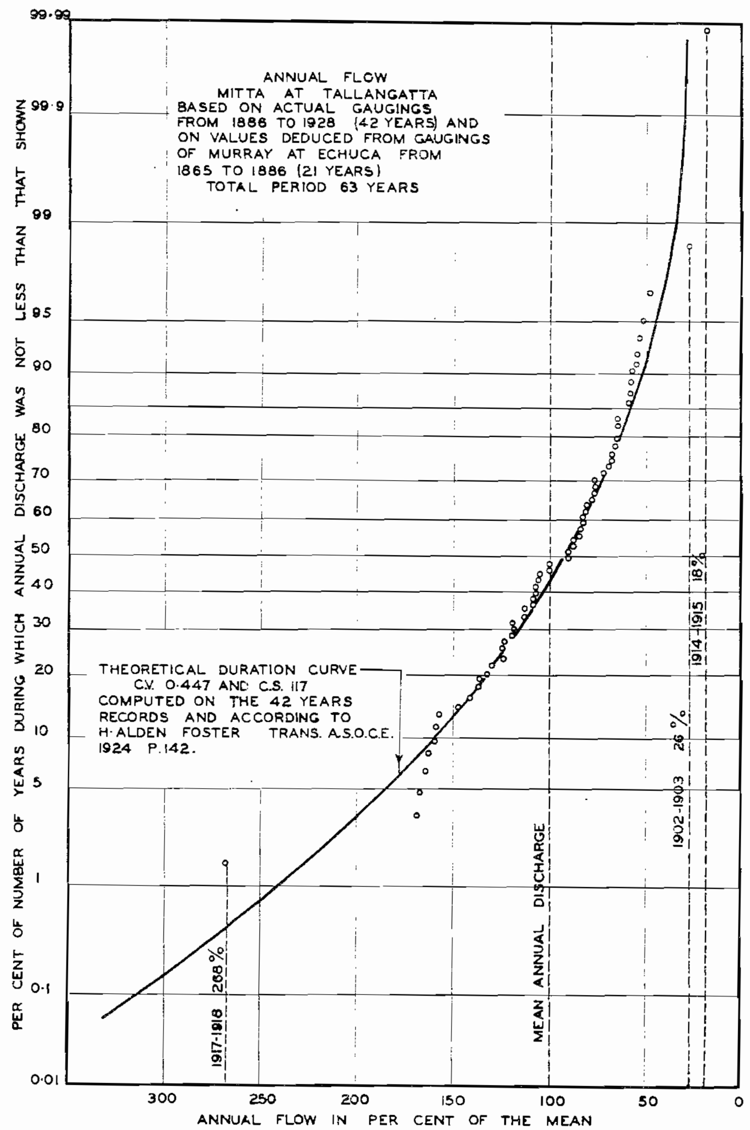
(FLOWS AS IN 1929)

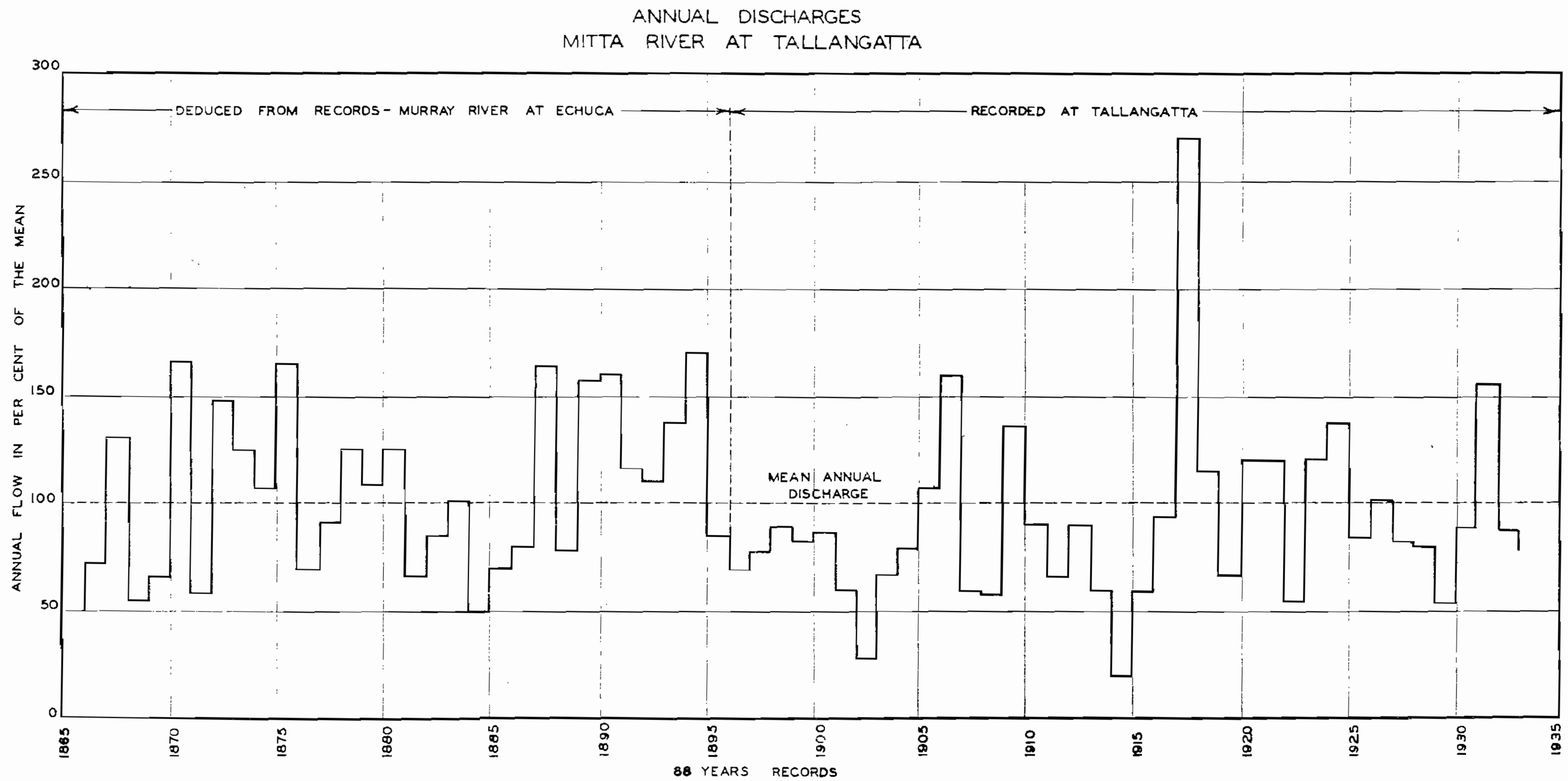


WATER BEING DRAWN FROM STORAGES.
ALL POWER STATIONS IN OPERATION.

STATE ELECTRICITY COMMISSION OF VICTORIA

PLATE No. 6.





RIVER DISCHARGE RECORDS

1865 - 1933

STATE ELECTRICITY COMMISSION OF VICTORIA

PLATE No. 7.

KIEWA SCHEME
PRETTY VALLEY DAM

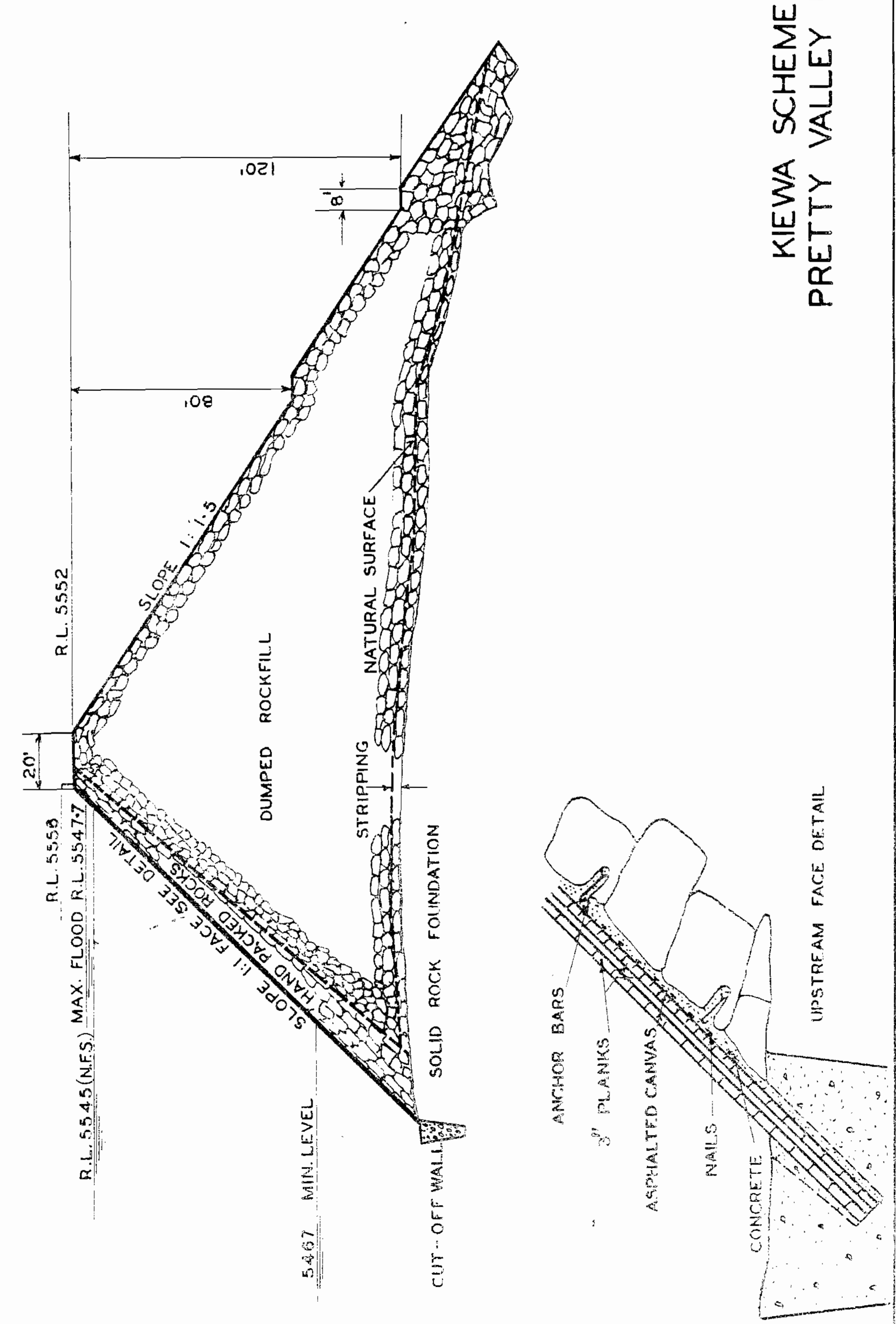
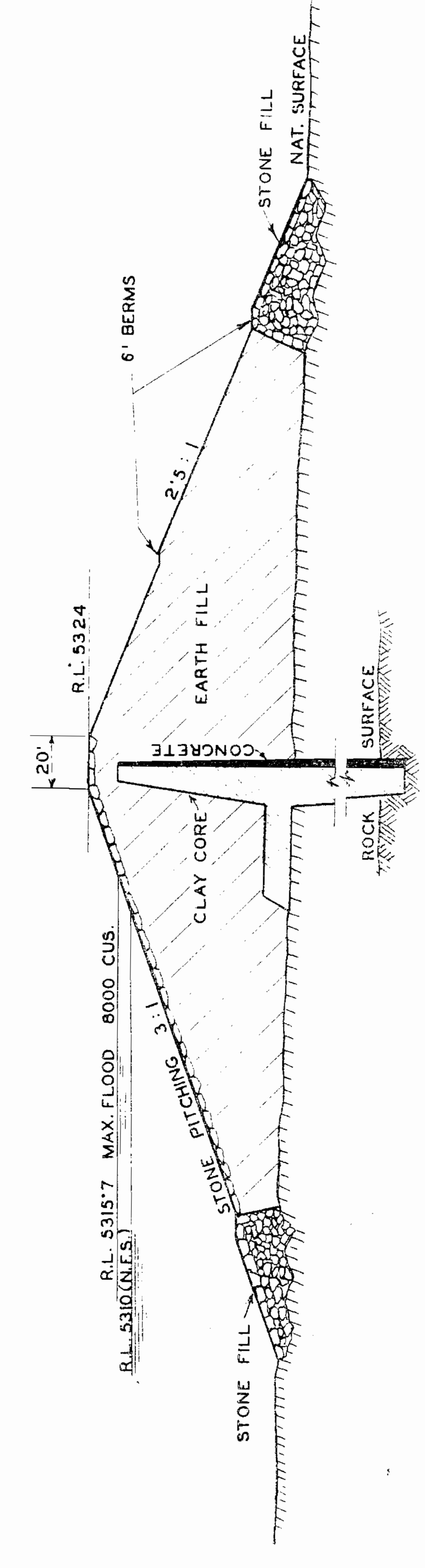


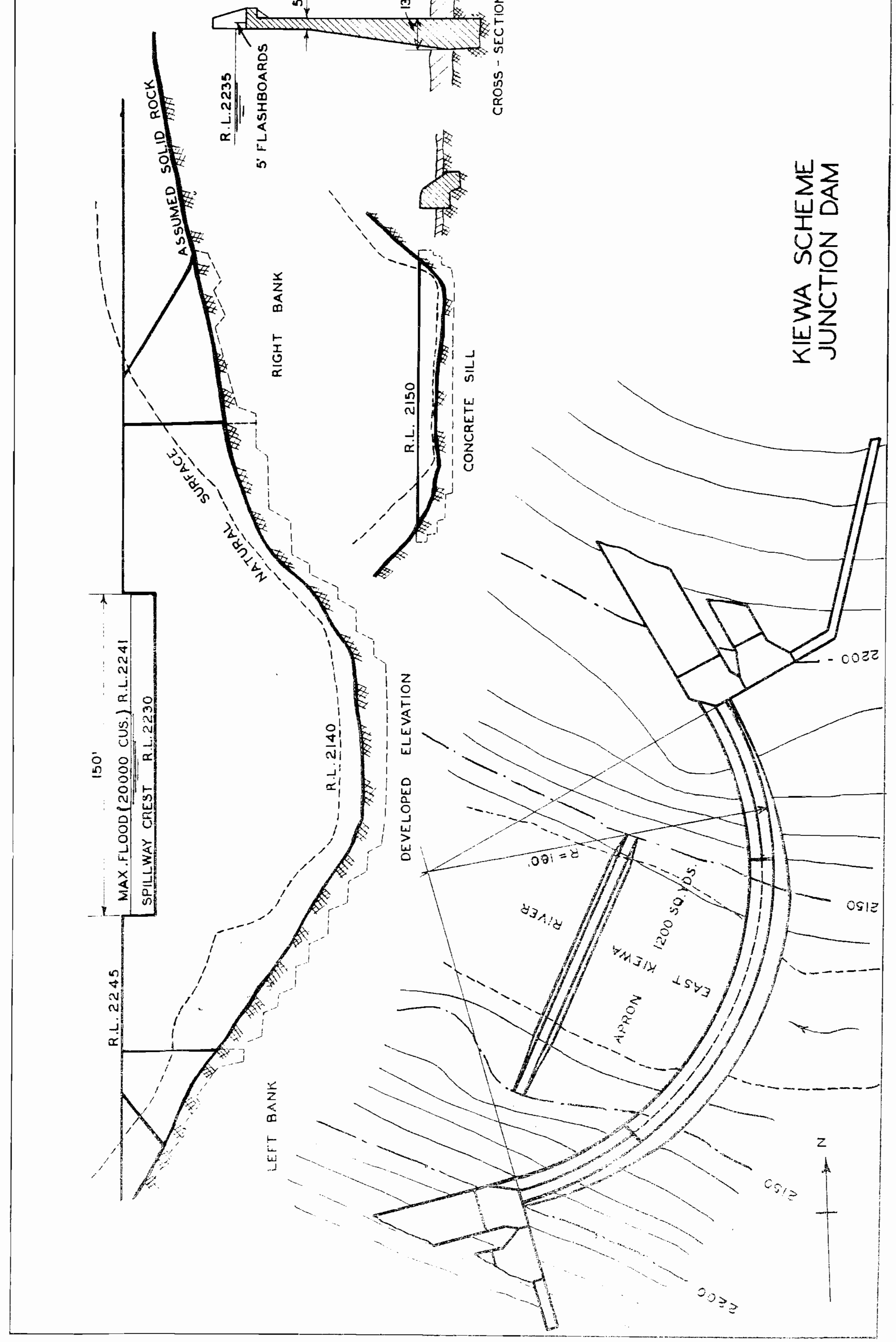
PLATE No. 8.

KIEWA SCHEME
ROCKY VALLEY DAM



STATE ELECTRICITY COMMISSION OF VICTORIA

PLATE No. 9.



STATE ELECTRICITY COMMISSION OF VICTORIA

PLATE No. 10.

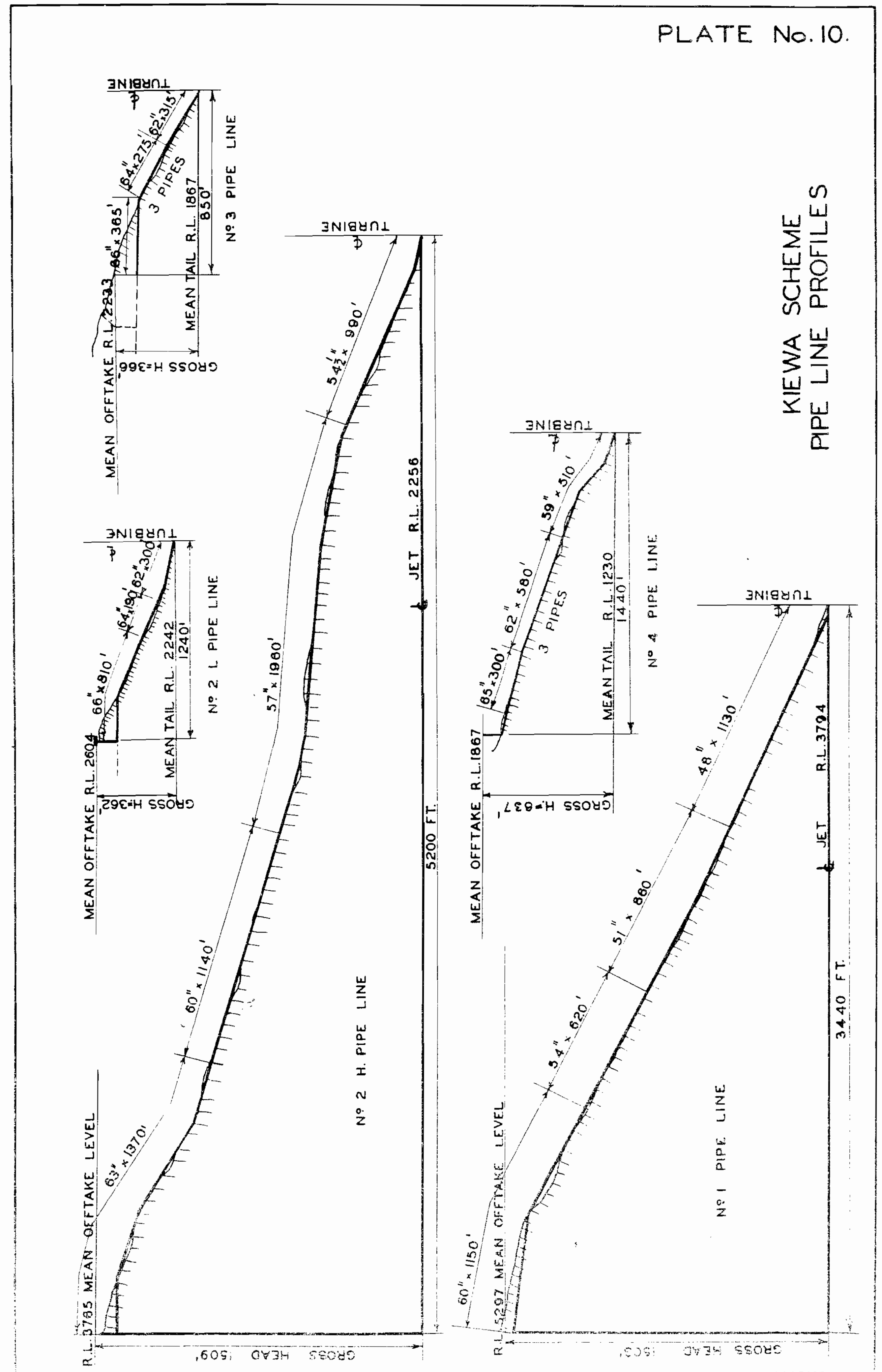
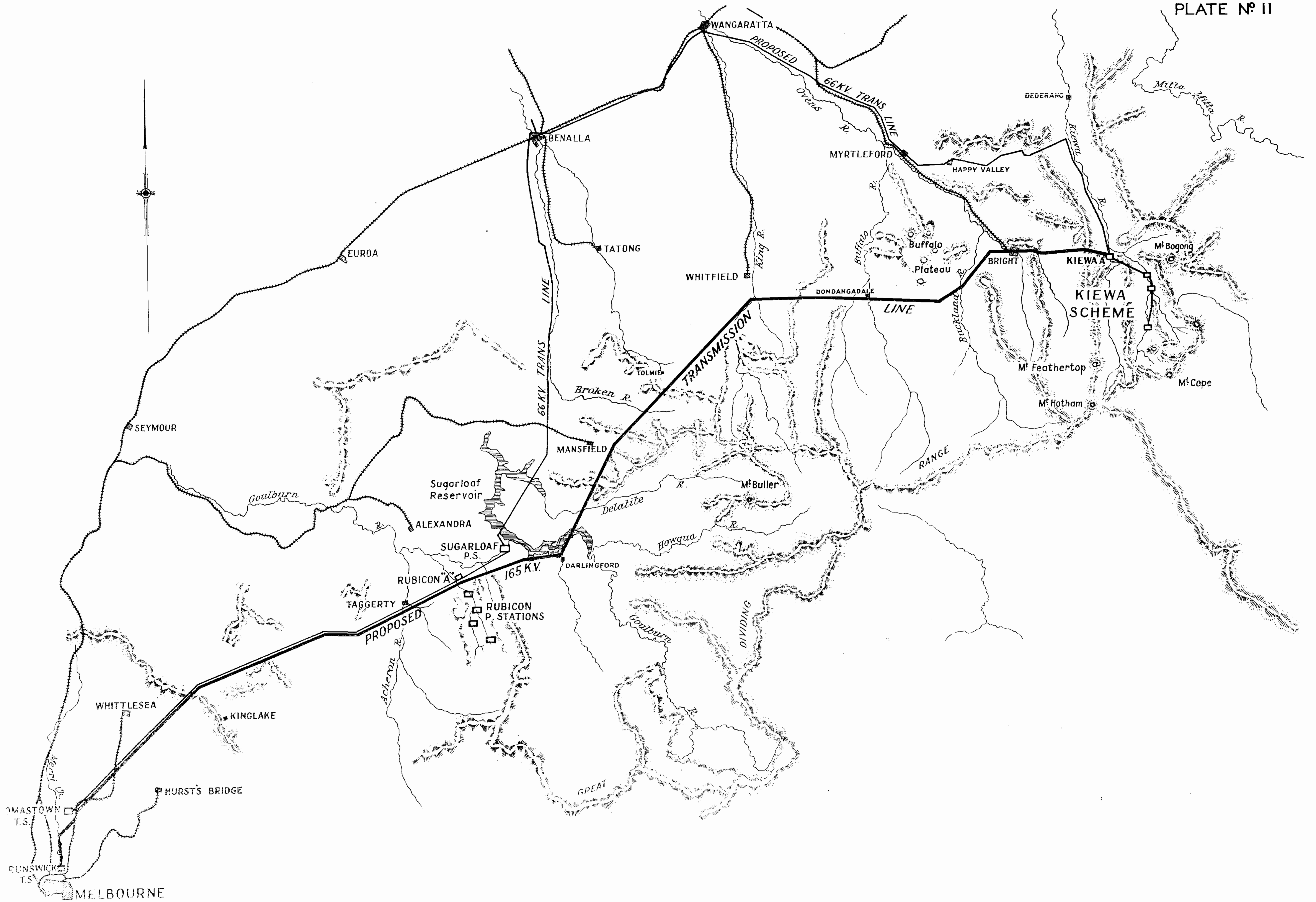


PLATE Nº 11


WANGARATTA
PROPOSED 66 K.V. TRANS LINE
Ovens R.
DEDERANG
Mitta Mitta R.
Kiewa R.
MYRTLEFORD
HAPPY VALLEY
BENALLA
TATONG
WHITFIELD
King R.
Buffalo
Buffalo Plateau
BRIGHT
KIEWA 'A'
Mt Bogong
KIEWA SCHEME
DONDANGADALE
LINE
Buckland R.
Mt Feathertop
Mt Cope
Mt Hotham
EUROA
66 K.V. TRANS LINE
TRANSMISSION
TOLMIE
Broken R.
SEYMOUR
MANSFIELD
RANGE
Mt Buller
Sugarloaf Reservoir
Goulburn R.
Delatite R.
ALEXANDRA
Howqua R.
SUGARLOAF P.S.
DARLINGFORD
165 K.V.
RUBICON "A"
TAGGERTY
RUBICON P. STATIONS
PROPOSED
DIVIDING
Goulburn R.
Acheron R.
WHITTLESEA
KINGLAKE
Merri Ck.
HURST'S BRIDGE
GREAT
MELBOURNE

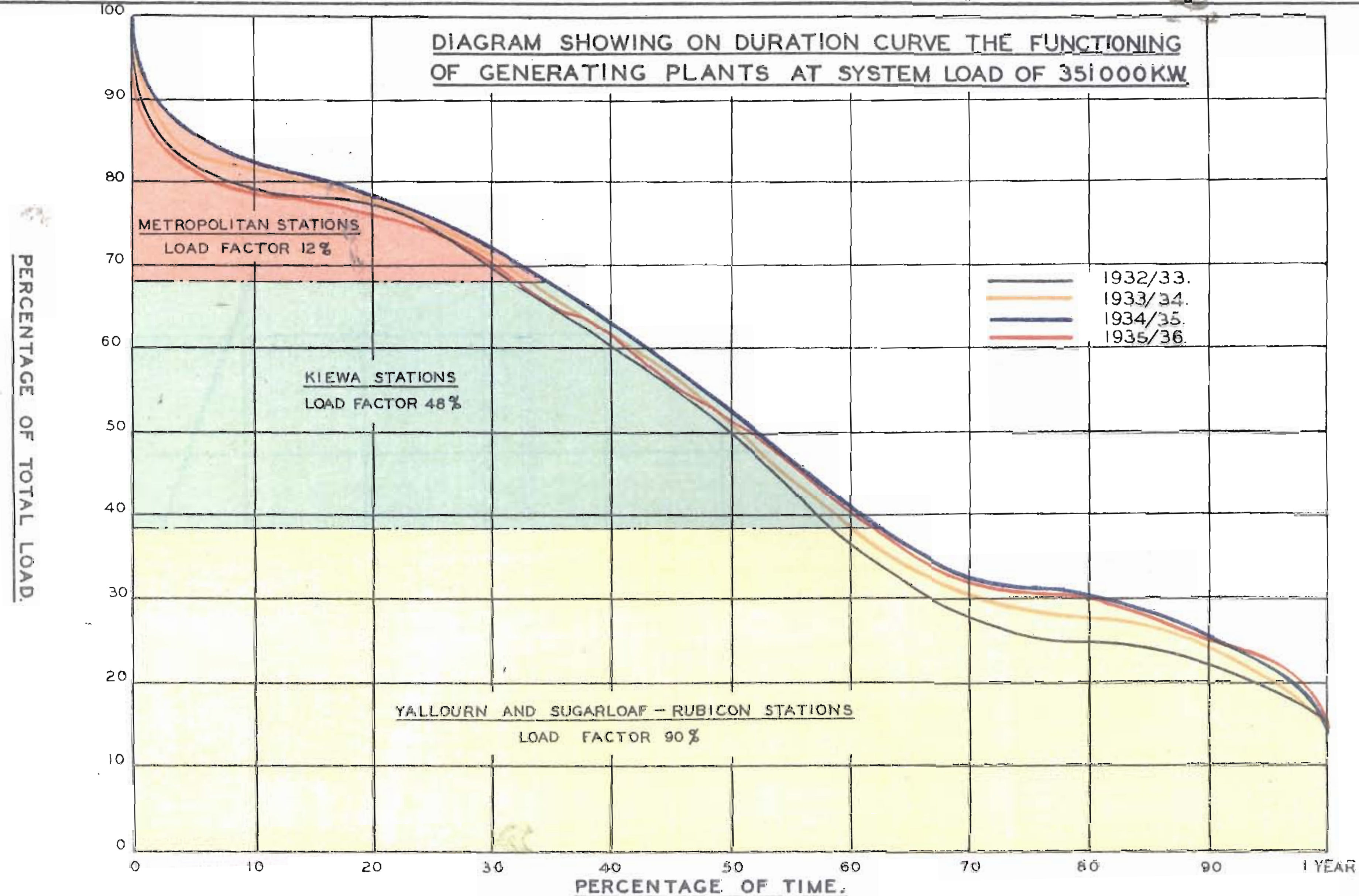


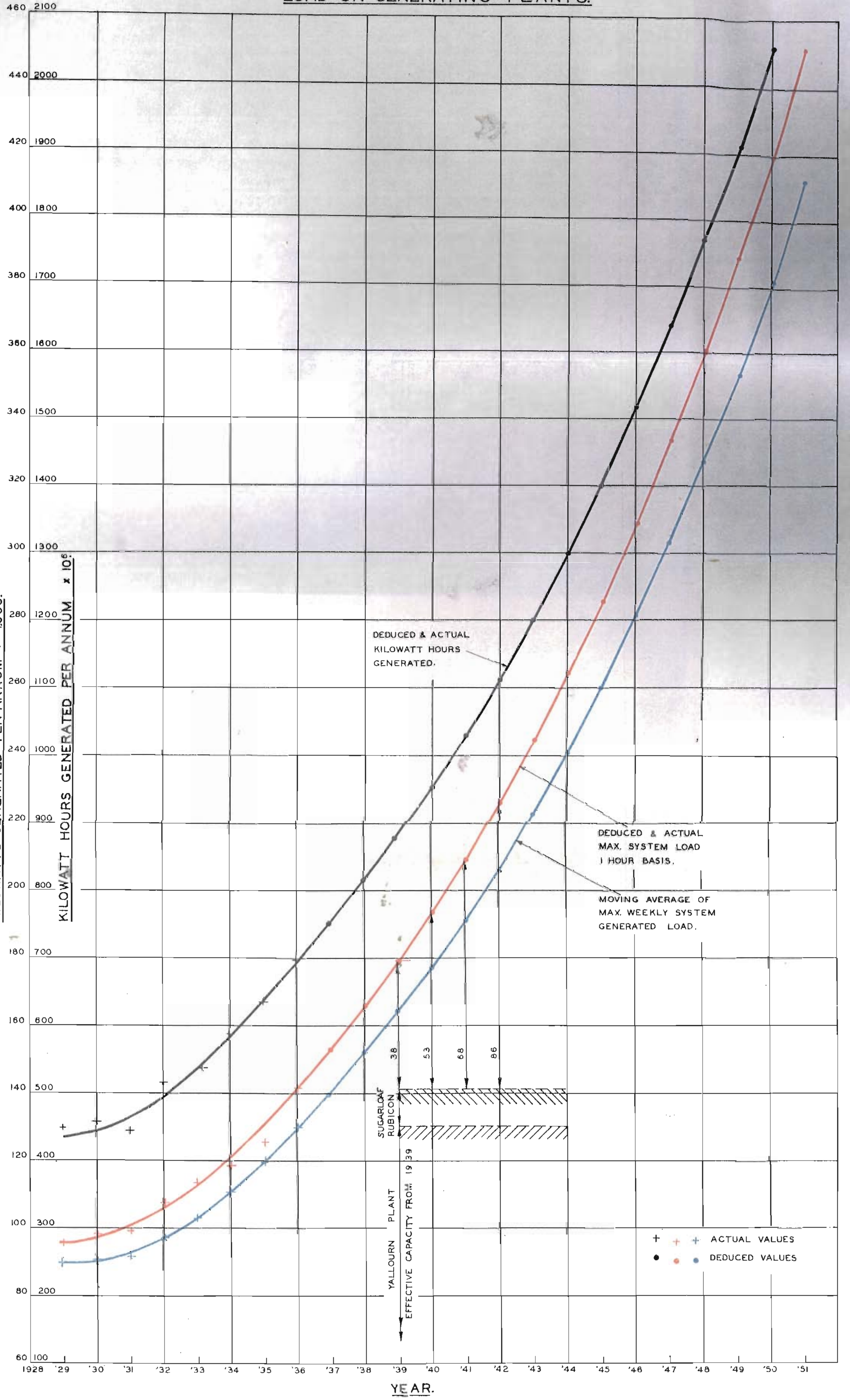
DIAGRAM SHOWING ON DURATION CURVE THE FUNCTIONING OF GENERATING PLANTS AT SYSTEM LOAD OF 351 000 K.W.
METROPOLITAN STATIONS
LOAD FACTOR 12%
KIEWA STATIONS
LOAD FACTOR 48%
YALLOURN AND SUGARLOAF – RUBICON STATIONS
LOAD FACTOR 90%
1932/33.
1933/34.
1934/35.
1935/36.
PERCENTAGE OF TOTAL LOAD.
PERCENTAGE OF TIME.
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
1 YEAR

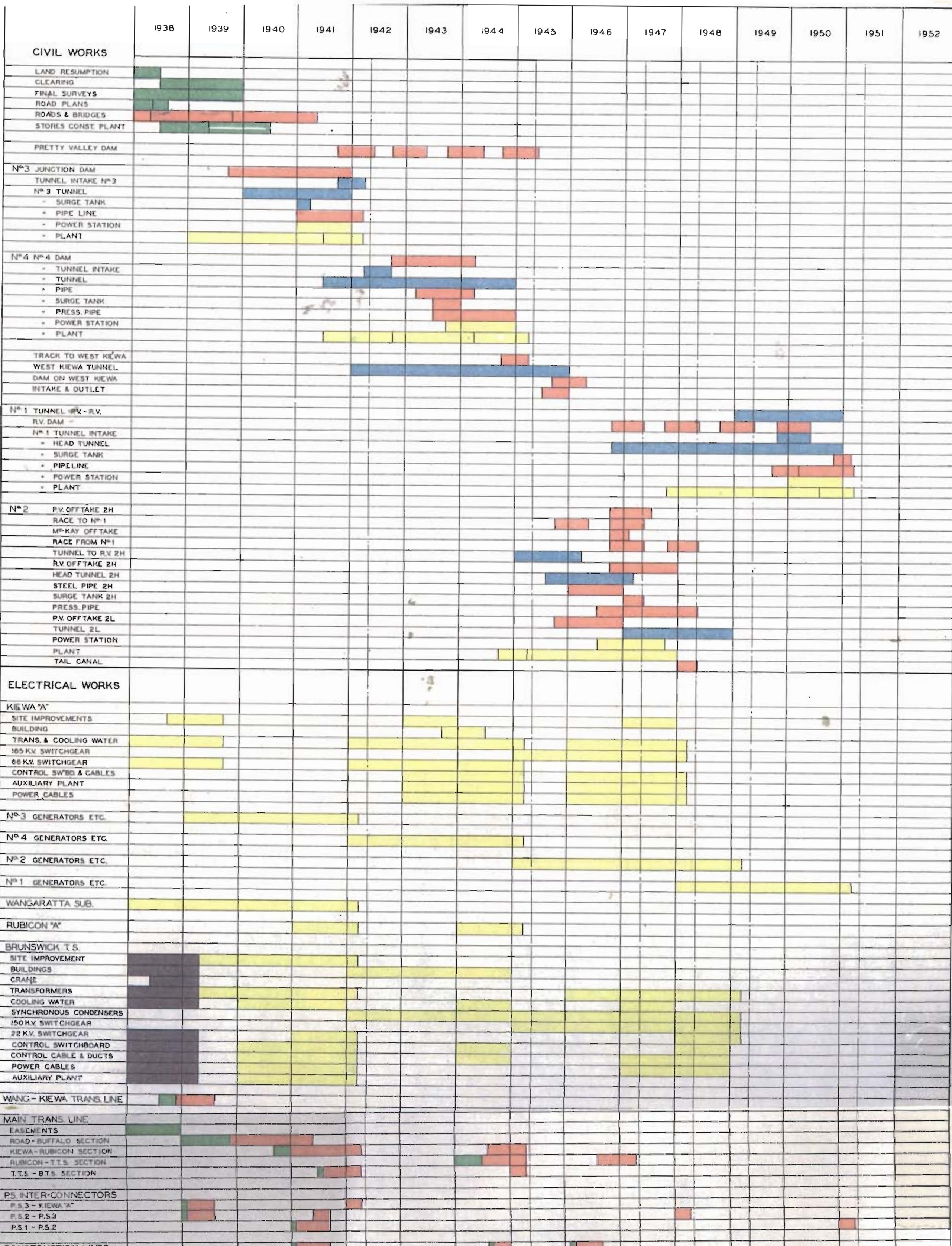
PLATE No 12

PLATE Nº 13.

STATE ELECTRICITY COMMISSION OF VICTORIA

MOVEMENT OF SYSTEM LOADING
LOAD ON GENERATING PLANTS.





EXPENDITURE	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	TOTALS
CIVIL WORKS £	55,000	90,000	203,000	363,000	366,000	480,000	480,000	347,000	420,000	460,000	308,000	216,000	300,000	45,000	CIVIL WORKS 4,173,000
ELECTRICAL WORKS £	106,000	112,000	55,000	447,000	117,000	67,000	312,000	153,000	144,000	271,000	91,000	25,000	60,000	3,000	ELEC. WORKS 1,963,000
ANNUAL TOTALS £	161,000	202,000	258,000	830,000	503,000	547,000	792,000	500,000	564,000	731,000	399,000	241,000	360,000	48,000	GRAND TOTAL 6,136,000
PROGRESSIVE TOTALS £	161,000	363,000	621,000	1,451,000	1,954,000	2,501,000	3,293,000	3,793,000	4,357,000	5,088,000	5,487,000	5,728,000	6,088,000	6,136,000	

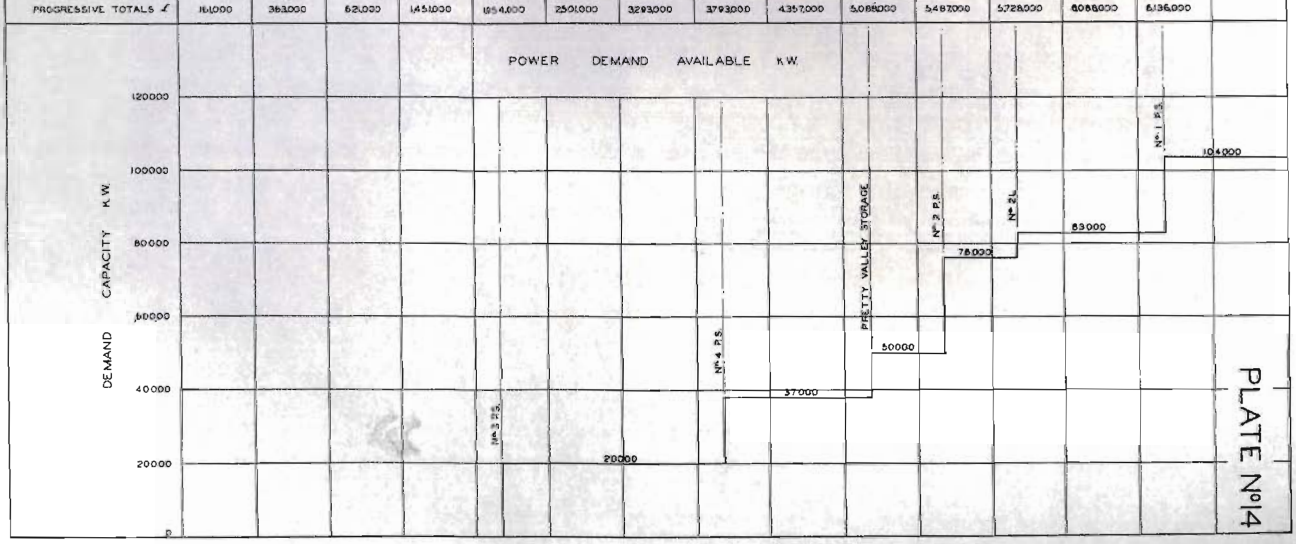


PLATE No.14

KIEWA CONSTRUCTION PROGRAMME.

SUPPLEMENTARY REPORT OF CHIEF ENGINEER, POWER PRODUCTION, ON METROPOLITAN HEAT POWER STATION.

My report on the Kiewa scheme, which has been forwarded separately, is essentially an analysis of the Kiewa proposals, together with an explanation of the economic functioning of the Kiewa scheme as part of the major system, which involves a comparison of the Kiewa scheme with alternatives of identical functional capacity. Although in the course of the discussion in my report I have, I think, dealt fully with the necessity for the extension of metropolitan plant in step with the construction of the Kiewa plants, I would like to deal with the extension which I recommend, and which has been outlined in the report on the Kiewa, in some detail in this Supplementary Report.

It has been made sufficiently clear that at the time when the system generated load is 350,000 kw., which may be at some date between 1948 and 1952, and assuming that the Kiewa plants have come into operation at that time, an amount of 100,000 kw. of the system load should be contributed by the metropolitan plant at Newport. It will be necessary for increments of plant to become available in the metropolitan area from the end of 1938 onwards so that the total effective capacity from metropolitan plants shall reach 100,000 kw. in 1948 or thereabouts, according to the development of system load.

It will be necessary for development of the metropolitan plant to proceed after this date as a continual process of keeping pace with the system demand in an economical fashion, the requirements of which have been fully dealt with in my main report.

It is intended that the complete extension described in my report shall be realized in approximately five steps, the first of which should become effective between 1939 and 1941, the others following at intervals of about three years, so that the completion of the third stage of this extension, when the installed capacity of the extension will be 90,000 kw., should be reached in 1948, by which date the effective capacity of metropolitan plant, including the existing Newport "B" plant, will be 120,000 kw. This programme, together with the simultaneous development of the Kiewa plants will, I consider, adequately provide for system load development between the present time and the date mentioned.

By the time the third stage of the Newport extension will have been realized in 1948, I estimate the expenditure on this extension will be approximately as follows :—

Newport Plant Extension—	
Installed capacity	90,000 kw.
Estimated Capital Cost of Power Station—	£
Land and preparation of site	20,000
Buildings	380,000
Coal handling plant and storage	50,000
Ash handling plant	25,000
Boiler plant and chimneys	800,000
Turbo-alternators and condensing plant	345,000
Feed water plant, piping, &c.	120,000
Circulating water system	30,000
Switchgear and transformers	170,000
General equipment	20,000
Interest during construction	80,000
Overheads, including engineering and inspection	120,000
Total	2,160,000

I anticipate that the capital cost of each complete 30,000 kw. installation in the individual stages of construction of the above plant will be approximately £720,000, and that the incidence of capital expenditure up to 1948 will be approximately as follows :—

	£
1940	250,000
1941	470,000
1944	250,000
1945	470,000
1947	250,000
1948	470,000

Operation of the Newport Plant Extension—

Costs have been presented in my main report covering the operation of the Newport extension, upon the basis of a 48 per cent. load factor to compare with the proposed Kiewa plants, and it has been shown herein that energy from this major extension at Newport could be delivered to load centres at the following basic cost:—£4 per kw. per annum plus 0·195d. per kwh., the relevant cost at generating station busbars being :—

£3·6 per kw. per annum, plus 0·183d. per kwh.

The extension to be operated in conjunction with the Kiewa plants and the Yallourn Power Station will, however, operate on a different basis, reaching its maximum load for relatively short periods, mainly during the winter, and allowing the existing metropolitan installation to take up the duty of reserve and emergency which comes into operation for very short periods during the year.

The cost has therefore been estimated for operating the Newport plant extension, of an installed capacity of 90,000 kw. to a maximum generated output of 84,000 kw., on the basis of a 20 per cent. load factor, and these annual costs are tabulated hereunder :—

Newport Plant Extension—	
Installed capacity	90,000 kw.
Annual operating cost of Power Station—	
Operation—	£
Superintendence	6,000
Labour	10,740
Fuel—90,300 tons at 27s. per ton	121,800
Water	450
Sundry supplies and miscellaneous station expense	2,700
Maintenance—	
Land and buildings	1,200
Coal and ash handling	2,460
Boiler equipment	12,000
Turbo-generator and condensing plant	5,520
Switchgear and transformers and general equipment	3,600
Fixed Charges and Overheads—	
Interest, 4½ per cent. on £2,160,000	97,200
Depreciation, 2·28 per cent. on £2,160,000	49,200
Insurance, workers' compensation, &c.	615
Administration, local and Melbourne and superintendence	21,000
	334,485

Total annual charges can be divided into—	
Total fixed charges	£212,805
Total variable charges	£121,680
Maximum kw. sent out from station busbars	79,800 kw.
Kwh. sent out from station busbars	135,000,000
Approximate annual charges on energy sent out from station busbars	£2·67 per kw. per annum, plus 0·216d. per kwh.

The above estimate does not allow for any of the extension contemplated acting as spare: which accounts for the relatively low annual charge per kilowatt at station busbars, and I must, therefore, point out that further extensions of this plant could not be considered as operating to the same effective proportion of the installed plant, and it will be necessary to take account of this fact in the installation of further plant, and in the calculation of the annual charges upon the same.

I strongly recommend that authority for the further extension of Newport "B", in a manner and in the steps which I have proposed, be given, so that adequate preparations and consideration of all relevant data may be given in good time before the actual design work is due to commence.

E. BATE,
Chief Engineer, Power Production.

11th June, 1937.

By Authority: H. J. Green, Government Printer, Melbourne.