1904.
NEW ZEALAND.

NEW ZEALAND WATER-POWERS, ETC.

REPORT ON) BY MR. P. S. HAY, M.A., M. INST. C.E., SUPERINTENDING ENGINEER OF THE PUBLIC WORKS DEPARTMENT.

Presented to both Houses of the General Assembly by Command of His Excellency.

Public Works Department, Wellington, 16th September, 1904.

Memorandum for the Hon. the Minister for Public Works.

I HAVE the honor to submit the following report embodying all the information collected to date regarding the water-power available in the colony.

Some of the larger schemes outlined may at present appear to be of speculative interest only, as industries of magnitude sufficient to utilise the power available in these schemes may not seem likely to be develope deven in the near future; but I think it is worth while to make the list of schemes, as at present known, from the largest possible to the smaller ones, as complete as the information now available allows, so that further investigation and discussion may result, and the probable magnitude, cost, and economic value of each scheme or any of its alternatives be more accurately determined, and an outline at least be got of the total amount of water-power available in the colony.

In formulating schemes and estimating their costs there appears at once the question of the probable number of shifts per day of twenty-four hours which will be worked in the industries of the future that may use electric power. In general the cost for hydraulic works, hydraulic and electric plant, &c., will be much greater for any scheme working eight hours or sixteen hours per day than for one working twenty-four hours per day; in each case all the water available for the scheme being supposed to be used. The conduits require to be larger to deliver the same quantity of water in the shorter time each day; the water-motors, the electric generating plant, also the transmission-lines, must be of increased capacity. The gross revenue will be approximately the same in each case (all the energy being sold); but in the shorter-time schemes the interest, and perhaps the renewal charges, will be greater. This question only affects lake schemes or others where adequate storage is possible. Where rivers or streams are utilised, and no storage is possible, then the plant has to be worked continuously, or water must run to waste. Full power for twelve hours per day, or, better, eighty-four hours per week, may, for a preliminary investigation such as this, be taken as equivalent to working at variable power extending over two or three shifts per day each of eight hours.

Throughout this report 80 per cent. efficiency is taken for all water-motors, and the power given is brake horse-power (b.h.p.) on the turbine-shafts. Probable losses of head in races or conduits and pipes have been deducted before computing the horse-power.

In schemes where storage is obtainable, a large part, and in many cases all of the Sunday and holiday surplus flow would be available for increasing the average power during working-days. No notice of this has been taken in estimating the power in any scheme. When complete information is available for any proposed scheme, designs for actual working would probably be based on a flow greater than the mean annual flow taken herein. For this reason many of the lake schemes might for actual working-days be greater than stated by a considerable percentage.

All the schemes put forward in this report are taken to be of an efficiency sufficient to pay interest on first cost taken at 4 per cent. per annum, and all charges for renewals, sinking fund, costs of staff, and management. The revenue has been computed on the assumption that power paid for is 60 per cent. of the b.h.p. on the turbine-shafts, £12 a year per b.h.p. being charged for continuous working. As a matter of fact the tariff would vary with the cost of the scheme within certain limits, and should vary with the time per day for which power is used, also with amount of power taken for any industry. In one large French power-installation the tariff varies for various reasons from £10 to £30 a year per horse-power.

The above conditions impose a limit at which any scheme can be developed under present conditions, and worked as a national undertaking without loss to the State. In the future lower rates of interest and other altered conditions may render it practicable to develop more costly schemes than would at present be justifiable.

NORTH ISLAND.

Wairua Falls.

These falls are situated on the Wairua River, about two and a half miles above the landing at the head of the navigable section of the river. The drainage-area above the falls is about 266 square miles. There are no rainfall-records available within this drainage-area, but at a rain-gauge station (Pakaraka) about twenty miles from the centre of the area the records show an annual rainfall varying from 60·7 in. to 38 in., a maximum fall of 5 in. in twenty-four hours, and a monthly rainfall ranging from 16·7 in. to 0·23 in. There is every probability of corresponding variations in the rainfall on the Wairua basin. A rainfall on the Wairua basin (equal to the lowest of the Pakaraka years) at 70 per cent. run off, would give a mean flow of 520 cubic feet per second. This is probably too high and would only be obtainable by perfect lake-regulation of the flow. The gauging of this river in February last gave a flow of 285 cubic feet per second, but this was not minimum flow. From information given as to the height of the river at its lowest, it is not probable that the minimum flow is more than two-thirds of the above-measured flow. The rainfall-records at Pakaraka and at Parua, one north and one south of Wairua basin, each show two successive months with less than 1 in. of rainfall. Under such conditions the flow in the Wairua would probably fall very low. There are no very high hills in the Wairua basin to catch a higher rainfall than observed on the low ground. Just above the falls the river flows in a channel about 15 ft. deep below the level of the valley-bottom. Below the falls it has cut a canyon 45 ft. to over 100 ft. deep, this depth being attained about a mile from the falls. The height of the falls is given as 45½ ft., but below the falls there are rapids. About a mile below the falls the ordinary water-level is 108 ft. below the water-level at the top of the falls, and, at about a mile and a half, 133 ft. The high-tide level at the landing is 141 ft. below the top of the falls.

Taking the ordinary low summer flow as about two-thirds of the gauging, the power obtainable just below the falls would be about 720 b.h.p., and at a power-station a mile and a half below the falls about 1,600 b.h.p. At about this point the best results will be attained ; fall being lost by going further down the river. A race can easily be constructed between the falls and this point—on the flats along the right bank of the river.

Immediately above the falls the best location for a storage-reservoir requires a dam 1,100 yards long. The cost of a masonry dam of a sufficient height is too great to warrant consideration : an earth dam would cost less. But the necessity of providing for flood-water overflow would involve expensive works. The cost of an earth dam would be £240,000 to hold the water to a height of 50 ft.

To test the probable value of a work of this size the mean run-off due to 38 in. of rainfall, the lowest year recorded at Pakaraka, would be 520 cubic feet per second if all water were conserved by the dam. The maximum power obtainable at a power-station one and a half miles from the falls would be 5,000 b.h.p. for continuous working. As a matter of fact much flood-water would be lost and not nearly the maximum power would be obtained. The cost would be too great for the probable benefit, and the question of constructing a large reservoir just above the fall may be abandoned.

It is possible that dams could be built elsewhere in the river-basin at much less cost. This is a matter for further search : if found, any proposed scheme would be modified to suit the conditions.

The only schemes worth considering at Wairua Falls are : (*a*) the construction of a power-station one and a half miles below the falls to use only the low-water flow of the river. This would give about 1,500 b.h.p. for continuous working. Or (*b*) build a dam costing, say, £25,000 to store surplus water for one week, and instal a plant of 3,000 b.h.p. for intermittent working equal to eighty-four hours full power per week for ordinary low-water flow of, say, 180 cubic feet per second. If future observations show the figure to be too high, as possibly they may, the above estimates of power obtainable would have to be modified to suit the final results.

Rotoiti–Kaituna.

The Kaituna River drains Rotorua and Rotoiti Lakes. Just below the outlet there are a series of falls and rapids. An accurate survey has been made for a distance of two miles, and the total fall has been found to be 177 ft. The fall in the first 62 chains is 101 ft. Aneroid heights give a fall of 325 ft. below lake-level at a point on the river three miles from the lake.

The flow in the river was gauged approximately in October last and found to be 500 cubic feet per second. By putting the tunnel at a proper level below the present low-water level a somewhat larger average flow might be taken to be available. After comparing the measured flow with the rainfall I think 600 cubic feet per second may be taken in view of the storage obtainable.

The drainage-area of the two lakes is 248 square miles: the area of Lake Rotorua is $31\frac{1}{2}$ square miles, and of Rotoiti $13\frac{3}{4}$ square miles. The range of level in Rotorua Lake is given as 3.3 ft. That in Rotoiti Lake cannot be very great in view of the depth of the river at the outlet and the small range in Rotorua.

Rainfall-records have been kept at Rotorua for a period of eighteen years. The mean rainfall in that period has been 56·49 in., the lowest year 45·33 in., and the highest 93·72 in. in 1893; but this appears to have been quite an exceptional year and may be disregarded. The next highest year is 70·27 in.

The highest recorded level of Lake Rotorua is given as 0·87 ft. above the best level for the working of the baths, and the lowest recorded level of the lake is given as 2.43 ft. below the same level. This small natural range of level seriously curtails the capacity of Rotorua as a storage-reservoir for power purposes. The highest level at which the baths can be worked satisfactorily fixes the highest lake-level in Rotorua and also in Rotoiti, which must be at such a lower level as is required for the flow of water between the two lakes. The present difference of level is given as 2 ft.

It would appear at present that storage can only be got by putting a draw-off tunnel at a suitable level below the present low-water level of Rotoiti, and to utilise the volume between that level and what may be termed the bath-level for storage. This level also conserves the settlement interest on the lake-shores. Had there been no interests to be taken into account a dam could have been built at relatively small cost at the Kaituna outlet to conserve all the water from the drainage-area; but this would appear from present data to involve a fluctuation in lake-levels of from 15 ft. to 20 ft. above the present low-water level in order to conserve the water in an extreme year such as 1893, but only about 6 ft. to 8 ft. for the next-highest year.

To get full advantage of the possible storage it would be necessary to dredge a deep channel between the lakes to draw off the water from Rotorua to a depth of 10 ft. or 12 ft. or more, if it were found that no interference with the actions of the springs causing injury thereto were likely to result. Regulating-sluices might also be required on the canal between the lakes if it was ultimately found advisable at times to retain the water in Rotorua at a higher level than in Rotoiti.

The determination of the correct level at which a draw-off tunnel should be put below the present low-water level of Rotoiti will involve very careful investigation, and requires a continuous record of lake-levels with frequent measurements of flow in the Kaituna and Ohura for as long a period as possible before any works are undertaken. If the relation between one or more years' rainfall and flow-off were determined, the flow-off for past years might thence be inferred with some degree of probable accuracy, and also the amount of power likely to be available could be estimated.

A power-scheme on the Kaituna requires careful investigation, being more favourably situated than any of the upper Waikato schemes for the supply of power to the Auckland District where steam and other plants aggregating about 51,000 indicated horse-power are now in use. Also a scheme which contemplated the capture of a large part or the whole of this power-supply would have to be one of some magnitude at first, and be designed to be easily extended as required by the increasing demand for power that may reasonably be expected to arise with the continued increase of industries in the district. A power scheme can also be got in the Kaituna without destroying any scenic assets, as would be the case if Huka Falls or Aratiatia Rapids were utilised, perhaps a not unimportant consideration.

At present I will assume that by storage 600 cubic feet per second can be got, and that the highest point in the draw-off tunnel will be 15 ft. below the present low-water level of Lake Rotoiti.

Taking the three points in the Kaituna River where the fall from the lake has been determined as 101 ft., 177 ft., and 325 ft. at distances of 62 chains, two miles, and three miles respectively, from the lake; the power obtainable after deducting loss of height for storage, range of level, fall in conduit, &c., would be approximately 4,400 b.h.p., 8,100 b.h.p., and 15,800 b.h.p. continuously for twenty-four hours each day. If it be assumed that all the water is to be used in twelve instead of twenty-four hours, or at the rate of 1,200 cubic feet per second for twelve hours, then installations of 8,800 b.h.p., 16,200 b.h.p., or 31,600 b.h.p. could be adopted. As an approximate indication of the relative values of these schemes the following table is given:—

Power at station	8,800 b.h.p.	16,200 b.h.p.	31,600 b.h.p.
Cost	£340,000	£550,000	£880,000
Power delivered	5,280 b.h.p.	9,720 b.h.p.	18,960 b.h.p.
Probable revenue	£31,680	£58,320	£113,760

The Kaituna Valley has not yet been exhaustively examined. There is the ascertained fall of over 300 ft. in the first three miles, but in a further distance of about nine miles there is an additional fall of about 400 ft. The conduit should be taken as far as the ground will carry it, or, perhaps, some distance further by ferro-concrete pipes and then by steel pipes. I think an exhaustive investigation would be likely to show that this is the proper course. From the lake-outlet it is about nineteen miles to the sea in a direct line, while at the south end of the lake it is only sixteen miles. Search might show that it would be easier to get a high fall by diverting the water from Rotoiti into, say, the Waitahunui Stream, or into any of the streams between it and the Kaituna. The country is covered with scrub and it will take some time to examine it thoroughly.

Lake Rotoiti is 904 ft. above the sea-level, and it may be possible to get 40,000 to 45,000 b.h.p. for continuous working by developing it to the utmost, or 80,000 to 90,000 b.h.p. for a plant using all available water in twelve hours each day. A power-station on the Kaituna would be about thirty miles nearer Auckland than the Huka Falls or Aratiatia, and a good transmission-line should be obtainable by way of Katikati, Waihi, Paeroa, and Mercer, to Auckland, the distance being about a hundred and twenty miles. This line would in time deliver a considerable amount of power along its route and would pass through a good mining district where some power may reasonably be expected to be used.

Waikato River.

Huka Falls.

The places in the river where it is possible to get power-installations, so far as ascertained, are Huka Falls, Aratiatia Rapids, Orakeikorako Rapids, the gorge between Orakeikorako and Aniwhaniwha, the Aniwhaniwha Falls, Atiamuri Rapids, also the lower Aniwhaniwha Rapids near Cambridge.

The flow of water in the Waikato was measured in October last and found to be 6,378 cubic feet per second. Taking the relative high- and low-water levels of the lake as given by Taupo residents the corresponding flow of the river at these levels would be 7,300 cubic feet and 5,200 cubic feet per second. Adverse winds interfere with the flow by heaping the waters on the Tokaanu shore. For this and other reasons the minimum flow for water-power purposes must be taken at no more than 5,000 cubic feet per second, or perhaps somewhat less, unless the outflow is regulated by a dam of suitable height.

The mean flow from Taupo appears from the data obtained to be about 5 cubic feet per second per square mile of drainage-area. This, as might be expected, is much lower than the flow from the southern lakes. Rainfall-records are available for a station at Taupo Township, but only for a period of two years and a half previous to the gaugings. The mean fall for this period was 49·5 in. per annum. With a run-off equal to 100 per cent. this rainfall over the lake-basin would give only 3·6 cubic feet per second running off. Taking note of evaporation from land and lake it appears clear that the rainfall on the mountainous portions of the lake-basin must be very great, as on the lake itself and along the lake-margin there is no reason for supposing that the average rainfall differs much from that at Taupo Township.

The top of the rapids at Huka Falls was 13·8 ft. below the lake-level at the time the levels were taken; the drop from the top of the rapids to the pool below the falls was 50·8 ft. The low-water flow of the river would give about 22,000 b.h.p. for this fall. A weir would have to be built across the race forming the rapids either at the upper end or any lower point that full investigation shows to be best, and the water would be taken to the power-house by canal and pipes. There would be somewhat heavy works involved in the weir, canal, and power-house excavations, and subsidiary works.

If a dam were built just above the falls to hold up the lake-water to a sufficient height to get the mean flow of the river all the year, the power obtainable would be about 38,000 b.h.p. The dam would be about 18 ft. to 20 ft. high above the water-level at the top of the rapids, and at least 540 ft. long, and should be as near the falls as possible to diminish the length of pipes. The works required in this case would be a dam, pipes, excavations for power-house, and subsidiary works. In both cases there would likely be some troublesome work involved in closing the "race" as the rock may be deeply fissured and also decayed, as is sometimes found in such cases. Damming the river in this way would submerge some of the geysers on the river-bank at the Spa, but this would not likely be injurious in any way, as there are supposed to be some submerged hot springs under the river; at least some deep dark pools are pointed out as such.

Assuming the power at the Huka Falls developed to give the various amounts of power stated in the table below, the probable relative total cost for each scheme and the probable annual revenue would be as given, the energy being distributed to various points north of the falls up to a distance of 150 miles, and, of course, assumed to be all sold.

Brake Horse Power.	Hours per Day.	Cost. £	Revenue. £
10,000	24	300,000	72,000
22,000	24	550,000	158,000
38,000	24	1,030,000	273,000
76,000	12	1,900,000	273,000

These figures may be taken as an approximate indication of the potential value of the Huka Falls for power purposes, and of the magnitude of the works likely to be required for their development.

As the utilisation of the Huka Falls involves dealing with a large volume of water with a relatively small fall, it may be of interest to compare the figures given for the schemes above merely outlined with some similar figures for an installation to utilise the water from the Rhone at Lyons, now working and known as the "Jonage." The information is from the "Annales des Ponts et Chaussées."

Feeder canal, 329 ft. wide at bottom, 9·8 miles long.

Draw-off canal, 329 ft. wide at bottom, 1·9 miles long.

Fall, variable with state of river, 27·88 ft. to 39·36 ft.

Power, 12,100 b.h.p., supplemented by 7,800 b.h.p. during periods of four to nine hours each day.

Cost of canals, 22,015,000 francs—say £880,000.

Electrical installation, £364,000.

Capital at start, 40,000,000 francs—say £1,600,000—subsequently increased to 50,000,000 francs—£2,000,000. (Extra capital taken up wholly by first shareholders.)

Works begun in 1894, finished 1898. Network of distribution has a total length of 330 kilometres (204 miles).

In 1901, 7,000-horse power and 100,000 lamps supplied.

Receipts: 1898, 170,350 francs—£6,814; 1899, 566,377 francs—£22,655; 1900, 1,490,450 francs—£59,618. Expected to rise to 2,500,000 francs—£100,000.

Tariff varies from 720 francs to 250 francs per horse-power per annum. Mean taken to be about 500 francs—about £20 a year.

There is a compensation-reservoir of 395 acres area to store surplus water from slack working-hours.

The figures do not appear to show that the "Jonage" is yet a commercial success, but it is an indication of the amount of capital that may be spent on the development of hydraulic power in a locality possessing industries enough to utilise it. Under equal conditions it will be shown further on that some immense schemes may be possible in New Zealand in the future, but while much larger, they will be relatively less costly, in many cases much less costly than the "Jonage."

Aratiatia Rapids.

When levels were taken the top of these rapids was at a level of 74·7 ft. below Lake Taupo level (this height will no doubt vary with the state of the lake and river), and just less than 10 ft. below the bottom of the Huka Falls. The river below the rapids at the first good site for a power-station to utilise all the fall was almost 100 ft. below the top of the rapids, the direct distance between the two points being a little over three-quarters of a mile.

To use all the water it would be necessary to build a weir in the river-channel. Only approximate data are available, but the weir would not apparently be a very large work, though it might prove to be somewhat more difficult than it looks, if the river-bottom consists of fissured and decaying rocks. This weir would only be a little above the water-level at the top of the rapids, and its cost might be £60,000 or more, according to the difficulties met with. The power available, supposing the lake-outlet not controlled, may be taken to be 47,000 b.h.p., and if the lake is controlled, 59,500 b.h.p. The terraces on either side of the river did not appear to me to be very favourable for the construction of canals or tunnel conduits, and for the present it may be taken that the water would have to be conveyed most if not all the distance required in pipes. The cost of these, with all necessary works, would be over £500,000, but a complete survey of the terraces is required before more than a very rough approximation can be made of the cost of the works required for the utilisation of the Aratiatia Rapids.

It would be possible to cut a short intake from the river, and draw off part of the water for a partial scheme, to give, say, 10,000 or 15,000 b.h.p. I think this may perhaps be possible without a weir at the top of the rapids, but until Huka was overtaxed, no scheme at the Aratiatia would be justifiable on account of the distance the water has to be carried in pipes.

It would be possible to build a dam at the top of the Aratiatia to dam the water up to lake-level. This would give the maximum amount of power obtainable from the Waikato down to the foot of the Aratiatia Rapids. The cost would be over £300,000, or somewhat over £800,000 for dam and pipes alone. The power obtainable would be over 92,000 b.h.p.—somewhat more than the Aratiatia and Huka, as above outlined, combined; but the increase is not great enough to justify the extra cost, and it is likely the water would be dammed back over the Wairakei geysers, the Huka Falls lost, and the valley flooded.

Orakeikorako.

There is a rapid in the Waikato River at Orakeikorako. The fall, in a relatively short distance, is about 35 ft. This might be utilised at a considerable cost by a dam and conduit of sufficient length. Some distance further down there is a narrow gorge where the river could be dammed a considerable height and power got, but the water would be dammed back over the Orakeikorako rapids, so only one of the two schemes is possible. The lower one would likely be the better one. This site is about half-way between Orakeikorako and Aniwhaniwha.

Aniwhaniwha Falls.

These falls are about 20 ft. high. The terraces on both sides of the river are about 60 ft. to 70 ft. high, and by a dam this height above water-level above the falls about 80 ft. of fall could be obtained, giving, say, 35,000 to 45,000 b.h.p., according as the flow from Taupo is regulated or not. A dam at these falls would interfere with the dam at the gorge mentioned in the preceding paragraph.

Atiamuri.

There is a rapid at Atiamuri having a fall of about 25 ft. in a relatively short distance. No great height of dam could be built except at some cost. If high, the length would be considerable. The collection of the necessary data would require some survey-work, but this site does not seem a very favourable one for developing power. A dam here, even if not very high, would interfere with a scheme at the Aniwhaniwha Falls. There are only three or four miles between the places, and the rate of fall in the river is not very great in this reach.

The Huka and Aratiatia schemes should be almost free from flood-rise, except the rise and fall due to variations in the level of Lake Taupo. At the lower sites flood-rise would begin to be felt, and some loss in efficiency might result, and some extra cost in works be necessary.

The lower Aniwhaniwha Rapids near Cambridge should give some power, but I have no data regarding them.

Rotoaira.

This lake is part of the Lake Taupo drainage-area. It is situated between Tongariro and Pihanga Mountains. Its drainage-area is forty-eight square miles, and the area of the lake is six square miles. The lake-level could very easily be increased 45 ft. by a dam, the Poutu flowing through a narrow gully which could be closed by a timber or earth dam. The lake-level is about 520 ft. above the junction of the Poutu with the Waikato, and the slopes of Pihanga Mountain appear to be quite favourable for the construction of a flume or concrete channel. The distance from the lake to the Waikato River is about six miles, and there would be this length of conduit to construct. The volume of flow in the Poutu was not gauged. Taking it as proportional to the Taupo outflow, its mean value should be about 260 cubic feet per second, but when I saw it there was not this volume of water flowing. There may be local conditions here, as at Coleridge, which cause an abnormally low flow.

Taking the mean flow as above, and allowing for loss of head in race, there should be about 11,000 b.h.p. obtainable for continuous working in a power-station at the junction of the Poutu and upper Waikato, and as the water can be stored, a much larger power—22,000 b.h.p.—for full power twelve hours each day. It should be possible to greatly augment the power from the lake by leading water from the nearest streams flowing from Tongariro or from Ngauruhoe, or perhaps from the upper Waikato itself, into the lake.

Waikaremoana Lake.

This lake is situated at an elevation of 2,015 ft. above the sea-level, as determined by triangulation. Its drainage-area is 143 square miles, and the area of the lake a little over twenty-one square miles. It is surrounded by high mountainous country. In addition to the area of Waikaremoana, Waikareiti Lake has an area of 2·72 square miles, the combined lake-area being nearly twenty-four square miles. The rainfall at the lake-outlet at Onepoto for six years averages 53½ in. The flow measured in the Waikaretahaki River, which flows from the lake, was 772 cubic feet per second, giving about 5·4 cubic feet per second per square mile. This flow would require a mean rainfall of about 73 in., all running off. It is probable, therefore, allowing for evaporation and other losses, that the mean rainfall on the lake-basin is somewhere about 90 in., more or less. The flow is a little greater than the flow per second per square mile from Taupo. This may be due to rainfall-variations merely, or it may arise from a relatively greater proportion of mountainous country in the drainage-area. If allowance be made for the loss of water through the overflow-channel, the mean flow from Waikaremoana is likely to be between 7 and 8 cubic feet per second per square mile.

The lake has numerous underground outlets. The three principal ones are estimated to discharge over 60 per cent. of the whole flow: there is also a fourth outlet of some size. The lake rises and overflows through a small channel for some months, more or less, during wet winters. At the time the river was gauged the lake-surface was level with the bottom of the overflow-channel, and it is said to fall about 3 ft. below this level. It is not likely the low-water flow will vary by more than a few per. cent. from the volume of flow measured. Also the flow from the underground outlets should only be a few per cent. greater when the lake is at its highest level, but of course the flow will then be increased by the discharge through the channel, which, however, can never be very great except in exceptional cases.

The three principal outlets issue from the ground at depths of 55 ft., 58 ft., and 85 ft. below the lake-level. All the streams unite about 37 chains from the lake, and at a depth of about 400 ft. below the lake-surface. At a distance of a mile and a half from the lake the stream is 760 ft. below the lake; at two miles, 1,070 ft.; and at four miles, 1,420 ft. below the lake-level.

The proper point to take the water from the river appears to be the common junction of the streams, rather than from the three principal outlets, though a greater fall is obtained. More power could be got at the first of the above points (a mile and a half from the lake) by taking the water from the outlets, but less at the second (two miles from the lake), and much less at the third (four miles from the lake).

At the three points where altitudes of the Waikaretahaki were taken, at distances of, say, a mile, a mile and a half, and three miles and a half from the junctions of the streams, the power obtainable would be, say, 24,200 b.h.p., 44,900 b.h.p., and 67,500 b.h.p. respectively. The country has not been closely examined to determine how a conduit could best be constructed, but assuming the most expensive plan of carrying the water the whole distance in pipes had to be adopted, the costs of conduits for the three schemes may be taken to be £105,000, £264,000, and £480,000, and there would be in addition considerable expenditure required for excavations, trestles over creeks, &c., which can only be determined after a careful survey has been made.

A tunnel conduit parallel to the stream, or as nearly so as circumstances would permit, should not cost more than £20,000 per mile if in sandstone or papa. With a fairly straight tunnel conduit, and on certain assumptions as to the length of pipes required from the end of the tunnel to the power-house in each case, the cost for conduits by tunnel and pipes should be, say, £70,000, £210,000, and £340,000 as against the corresponding costs for pipes alone. Even if a tunnel conduit should depart considerably from the straight, and its length be increased, it would still be cheaper than pipes in view of the subsidiary works required for the latter in addition to the costs given above. There would, besides, be greatly diminished maintenance charges. A tunnel conduit carrying lake-water should be practically everlasting, while pipes rust in a comparatively short time.

Considering the relatively advantageous conditions of the lake, as regards fall obtainable in a short distance, it is interesting to compare the probable amounts of energy that could be got if the lake were successfully dammed with the similar amounts obtainable by taking the water from the junction of the streams to the points A, B, and C on the plan, a mile and a half, two, and four miles from the lake.

At least one fill of the space between the low- and high-water levels of the lake, 12 ft. in height, may be reckoned on as available in each year. This would give over 250 cubic feet per second over the whole year. Adding a small quantity for increased flow through underground channels when the lake is high,,and for flow through overflow-channels, the flow per second for the lake if dammed may safely be put at 1,100 cubic feet per second. The relative amounts of power obtainable would be as under :—

Station.	Distance from Lake.	Water taken from Junction of Streams.		Water taken fom Lake.	
		Total Fall.	Total Power, b.h.p.	Total Fall.	Power, b.h.p.
	Miles.	Ft.		Ft.	
A	1½	360	24,200	760	75,000
B	2	670	44,900	1,070	105,000
C	4	1,020	67,700	1,420	134,000

In view of the large additional amount of power to be gained, it would be necessary to fully investigate the possibility of closing the underground outlets to the lake, before any scheme for the utilisation of Waikaremoana could be undertaken. The three main outlets may have their feeder-channels at a less depth than the outlets themselves, or they may not. Assuming that the lake-rim is not shattered to a greater depth than 85 ft., the cost of building a concrete watertight wall should not be excessive. The length should not be great, for the width of the arm of the lake leading up to the outlets is only 600 ft., but the outlets are 1,100 ft. apart. The length of the wall would likely lie between these limits. Probably £100,000 to £150,000 would close the outlets if not deeper than say 80 ft. to 90 ft. That the water flows out of the lake either through numerous openings or at a considerable depth may be inferred from the absence of whirlpools in the lake; also there are numerous small outlets issuing at a lower level than the main streams. This may mean that fissures exist at much greater depths than the main streams; but all these small and lower outlets may also only mean that the water is flowing down hill through numerous fissures in shattered rock overlying a sloping solid lake-rim, the upper edge of this solid rim not being at any great depth below the lake-surface.

The value of the lake as a source of power will be greatly enhanced—about doubled—should it prove possible to close the underground outlets.

Waikareiti Lake lies north-east of the lower end of Waikaremoana Lake, and drains into it. The area of the lakelet is 2·72 square miles, and its drainage-area is just under ten square miles. Its height above Waikaremoana is given as 700 ft. If this is correct, at the same rate of flow as from Waikaremoana, the power obtainable should be about 4,800 b.h.p. for continuous working. The distance between the two lakes is less than a mile, so that the combined length of flume or drive and pipe should not be much more than a mile.

Nearer to a centre of population, Waikareiti would be most valuable as a cheaply developable power scheme. As it stands it is worth some further preliminary investigation to ascertain its value more exactly, and if a scheme for its utilisation could be reinforced by the diversion of other streams into it.

The proximity of Mokau and Aniwhaniwha Streams suggests the possibility of diverting all the water from them into Waikareiti. If this could be done at reasonable cost, the drainage-area of the lake would be increased to nearly twenty-three square miles. Assuming the mean Waikaremoana flow to hold for this area, the power obtainable would be 11,500 b.h.p. for continuous working. The two diversion races or drives would probably not have a combined length of more than about two miles.

From the small quantity of water to be handled, and the short distance it has to be conveyed, this would be a good scheme to develop for working shorter hours per day, the extra cost for hydraulic works being relatively not so great as in some other schemes.

A power-station below Waikaremoana would be somewhat inaccessible for transport of heavy machinery, and, of course, Waikareiti is more unfavourably situated; also there would be much rough country to cross with the necessary transmission-lines.

Te Reinga Falls.

These falls are situated just below the junction of the Ruakituri and Hangaroa Rivers. The drainage-area above the falls is 531 square miles. When gauged the flow of water was 2,088 cubic feet per second, but this was much above the low-water flow, which is estimated to be only about one-fourth of that measured. About 125 ft. fall is obtainable by about 20 chains of drive or pipes, and about 6,000 b.h.p. could be got for continuous working, or about 12,000 b.h.p. for all the water half-time. The distance of the falls from Wairoa is twenty miles by road. There is at present no local use for the power. The cost of development should not be great. In addition to the quarter-mile of conduit, there would be two weirs to build—one across the Ruakituri, and one across the Hangaroa. This would likely be cheaper than a single dam across the river below the junction, where the water appears to be very deep. Or a weir could be built almost wholly on the sandstone reef on which the road now runs. This would probably be the cheaper plan. Some storage and perhaps some additional height could be got in this way.

Whakapapa.

The Whakapapa River rises from Tongariro, and flows to join the Wanganui River above the crossing of the North Island Main Trunk Railway. There is a considerable quantity of water flowing in it, and the fall is given as about 3 ft. to 4 ft. per chain. If it were found practicable to carry the water any distance along the valley, a considerable amount of power could be got. It is too far away from any industrial settlement at present to make it of any value. Possibly it might be used in the event of the North Island Main Trunk Railway being worked by electricity.

Mangawhero.

The Raukawa Falls on this river would give a small power scheme of about 2,400 b.h.p. at very small cost, if the flow in the stream is as great as has been given—viz., 300 cubic feet per second—a fall of about 90 ft. in a few chains can be obtained. A much lower estimate of the flow has been given, but I think it is too low. The drainage-area above the Raukawa Falls is 212 square miles, which would give a result somewhat nearer the higher estimate, in view of the situation of the river-basin and the fact that it rises in Ruapehu. The Wangaehu has been gauged when very low; the flow was 333 cubic feet per second; its drainage-area is 291 square miles. The proportional flow of the Mangawhero would be 243 cubic feet per second. The Wangaehu, however, drains more of Ruapehu, and perhaps its flow per second per square mile of drainage-area should be somewhat greater than that of the Mangawhero.

The Raukawa Falls are given as 1,050 ft. above sea-level, also as being 950 ft. The Wanganui River opposite the falls at Koriniti is 48 ft. above sea-level, with a flood-rise of about 52 ft. Between the two rivers there is a range near the Mangawhero, with spurs leading to the Wanganui. The range would be pierced by a drive, and a conduit could be taken along a spur to a point about three-quarters of a mile above Koriniti. Allowing for fall in the conduit, if Raukawa is 1,050 ft. above sea-level, about 900 ft. of fall should be obtainable.

Probably it would be best to take the water from the Mangawhero at a point some four miles above the falls, where the river is nearest the Wanganui—about five and a half miles distant. The conduit would in this case be taken to near Galatea. The Wanganui does not rise much in the extra distance, but the Mangawhero rises rapidly up to Raetihi. Probably a greater fall could be obtained by this alternative.

So far as I can learn at present there seems every probability, from information supplied by the Surveyor-General, that a conduit can be got from the Mangawhero to the Wanganui. The length of conduit would likely be seven or eight miles. Along the spurs it would be drive, flume, or race, as the ground required. The power obtainable should be 20,000 to 24,000 b.h.p., unless the flow is much less than given above. If dams could be built to store a sufficient quantity of water, still better results could be got by increasing the water available over the minimum flow and by enabling a plant to work part time in a week, while all the weekly flow is conserved.

The power-station would be in a fairly central position. It would be near to one large centre—Wanganui—which would be distant by river about thirty-seven miles, and more directly by land about twenty-four miles. The scheme would conveniently command all the country from New Plymouth to Palmerston North, the distance to New Plymouth, *viâ* the river and railway being, say 125 miles, but shorter if a transmission-line can be taken across country by Waitotara. The distance to Palmerston North would be, say eighty-four miles, but only about sixty miles if a cross-country route is possible. It would be conveniently placed for electric traction on the Wellington–New Plymouth Railway should this ever be adopted.

This scheme is worthy of close examination, first to determine the possibility of getting a conduit from Mangawhero to the Wanganui, and, if that is possible, the Mangawhero Valley should be examined to ascertain if a storage-reservoir could be got at reasonable cost, and also to determine if water can be easily diverted from any of the branches of the Wangaehu into the Mangawhero, and a large scheme be thereby obtained.

The power-station would only be about twenty-five miles distant from the ironsand deposits at Nukumaru, where a large part of the energy could be used for electric smelting.

Manganui-a-te-ao.

This river has been suggested as one from which a considerable amount of power could be got. The flow of water should be fairly good. The water would be taken from the river at about the junction of the Ruatiti Stream. This would give about 180 square miles of drainage-area. At the Pakenga junction, a little way above this point, the river is about 1,000 ft. above sea-level, and about 850 ft. above the Wanganui at the Manganui-a-te-ao junction. The distance from the Ruatiti junction to the Wanganui would be between ten and eleven miles, and perhaps 650 ft. to 700 ft. of fall could be got. At a power-station on the banks of the Wanganui perhaps 10,000 b.h.p. or more could be got, depending on the flow of water in the river. The works for a race would likely be heavy in this country.

Wangaehu.

This river might be available for power purposes but that it carries acids or other chemical constitutents from the volcanoes which quickly corrode iron. If used, the hydraulic motors would require renewing more frequently than in pure streams. A low-water flow has been measured, amounting to 333 cubic feet per second. No systematic examination has been made so far, but in one section of the river, three miles long, the fall is given as 70 ft. A race of this length on this reach of the river would give, say, 1,500 b.h.p. A power-installation here would be somewhat costly, but probably better schemes would be found on search. The impurity of the water is likely to prevent the use of the river for power purposes, unless machinery could be got of non-corrosive metal as cheaply as of iron.

Turakina.

There are two falls—Otaemata, 20 ft., and Rerepapa, 80 ft., about a mile and a quarter apart—on this river. The drainage-area of the river above the falls is seventy-three square miles, but the Wangaehu cuts off the Turakina from Ruapehu on the one side, and the Hautapu cuts it off from the Kaimanawas on the other. The low-water flow is likely to be small, and perhaps variable. A small scheme could be got by taking the water from the upper fall to any convenient point below the lower fall, either by race or pipe-line—perhaps at most 500 to 600 b.h.p. This may be of use for some local purpose in the future.

Taranaki.

No suggestion of value has yet been made for a power scheme likely to be of any great use. The largest scheme at present known of, near New Plymouth, appears to be at falls on the Waitara River, 30 ft. high. The drainage-area above these falls is 433 square miles, and the rainfall on some parts of this area is very high. Probably there would be as a rule a good flow of water, but the flood-rise would be likely to give some trouble. Merely from these falls it is not likely that more than 1,500 to 2,000 b.h.p. could be got, but it may be possible to get more power by carrying the water some distance in a race. A survey would be required to determine what could be done. The distance of the falls from New Plymouth is about twelve miles, and about five and a half miles from Waitara. The Mohakatino River has been suggested as likely to yield some power. A preliminary survey is required to determine fall in river, possibility of constructing water-races, and getting storage for water. The drainage-area is not large, and the rapid fall in the river does not offer much prospect of getting a storage-reservoir.

Some minor schemes have been suggested for using streams from Mount Egmont. The only one apparently of any size, and it is very small, is that for using Bell's Falls. The stream and falls by themselves would perhaps not be of much value, but it is stated that some swamp land, about 400 acres in extent, could be utilised as a reservoir. If this could be done cheaply, and water stored to some depth, the value of the stream might be considerably increased. As the quantity of water would be small, a pipe might be taken some distance down the mountain-side and a fair amount of power got at perhaps no great expense. The rainfall is high just below Bell's Falls, and will likely be more nearer the mountain-top. At best, however, only a few hundred horse-power could be got. The drainage-area is only three and a half square miles, and the height of the falls 60 ft.

With so many streams running from Mount Egmont, it is probable that if water were taken from some of the larger ones, or the water from several streams diverted to one power-station, a much larger scheme could be got than at Bell's Falls.

Mokau.

The Wairere Falls on the Mokau River have been suggested as a source of power. The drainage-area above these falls is 240 square miles. As the country is relatively low, the minimum flow of the stream is not likely to be great. The height of the falls is about 40 ft. Further data are required, but it is likely that the falls will only be of value for local requirements in the future. The Mokau can be easily diverted into the Waipa, but the drainage-area is small above the point of diversion.

Rangitikei.

This river has been examined from the junction of the Hautapu to Vinegar Hill bridge. In this distance there is a fall of 400 ft., but the Makohine ravine is a serious obstacle to carry a river across.

In view of the fierce floods that may occur in this river, and the wholesale cutting-away of flats in the bottom of the canyon, either the Makohine flat, or the flat just below Ohingaiti, seems to be a very suitable location for a power-station; and of these the Makohine flat seems the best, so far as safety from flood-attack is concerned, also the flood-rise should be fairly low.

Just below the Kawhatau junction is a good point to take the water from the river. The extra height at the Hautapu junction would not compensate for the loss of the Kawhatau water, while below the Kawhatau there are no streams joining to compensate for the loss of head. Water could be taken, of course, at points lower down the river, for schemes giving less power, but there is no need to discuss any such schemes at present.

The river was gauged at Mangaweka in October last, and gave over 2,100 cubic feet per second, from a drainage-area of 1,060 square miles, but it was stated that the water had been lower by a certain height. Allowing for this, and for a slight reduction in drainage-area, the low-water flow at the Kawhatau junction may be taken to be 1,500 cubic feet per second under the existing conditions of the river-basin. These conditions may yet, however, be much modified by destruction of the forests increasing the flood flow and diminishing the low-water flow.

A gauging supplied by the Surveyor-General for the Rangitikei above the Hautapu junction at Omatane ford gave only 606 cubic feet per second. Allowing for the Hautapu, Kawhatau, and other streams, the result would give a little over half of the above flow as the low-water flow at Kawhatau. This illustrates the uncertainty of formulating a scheme for any river merely on solitary gaugings, combined with statements as to the lowest known level of the river.

The river does not at first sight appear very favourably conditioned for development of power, but though the works would be costly, yet if the power could be sold up to the quantities given in the schemes below, it appears that any of them would be successful.

The papa country along the banks of the Rangitikei is not favourable for the construction of canals carrying water, being too liable to slip. I have therefore assumed that the conduit would be wholly in tunnel. If it was found safe to construct it in canal or flume, some reduction in first cost might result.

Assuming the water taken out of the river at the Kawhatau and carried to the Makohine—the distance is about nine and a half miles by the probable conduit-route—the total fall obtainable is just over 300 ft. Water can be taken at about the river-level by a suitable weir, or at levels of say 50 ft., 100 ft., or 150 ft. above the ordinary low-water level by dams. The dams could be used to store some days' supply, or merely to store the overnight low-water flow, and use the height to give extra head. This is probably the best alternative, as giving the greatest amount of power. The tunnel would be on a grade of about 6 ft. per mile to a point as near the power-station as possible, then in tunnel on a steeper grade, lined with armoured concrete as required, and the last length would be of steel pipes.

For the low-water flow of 1,500 cubic feet per second, various schemes can be formulated. Some are given in the table below. The energy is supposed to be distributed to the districts around the power-station south to Palmerston North, and north to say Wanganui.

Kawhatau to Makohine Flat.

——	Power, b.h.p.	Cost.	Revenue.
		£	£
No dam (24 hours)	30,000	1,060,000	216,000
50 ft. dam—			
24 hours	36,800	1,230,000	265,000
12 hours	73,600	2,030,000	265,000
100 ft. dam—			
24 hours	43,600	1,440,000	314,000
12 hours	87,200	2,450,000	314,000
150 ft. dam—			
24 hours	50,500	1,770,000	363,000
12 hours	101,000	2,800,000	363,000

The above table outlines what results might be got from the river, and the cost. One great trouble with a large scheme like this would be the intermittent use of a large portion of the power. In a large power-installation in Berlin, up to a certain period of its history, the largest amount of power actually taken at one time was 60,000 kilowatts out of a possible output of 84,000 kilowatts. Business, if offering, could of course be undertaken beyond the actual capacity of the plant to such an extent that the probable maximum power likely to be used would not exceed the capacity of the plant. This difficulty will apply to all schemes, except, perhaps, some specially favourable ones supplying special industries.

The lake above a dam would act as a settling-reservoir for a long time, depending on the activity of denudation in the river-basin. After a time this reservoir would fill up, and the passage of shingle over the dam would tend to wear it. Then the question would arise as to cost of repairs to dam, as against dredging the shingle over to prevent excessive cutting. This would mean an increase of cost of working, but by how much could only be determined by actual experience for each river.

Silt-laden water would in time have an effect on tunnel-lining. This would begin to be felt after a time in the case of a scheme taking water at ordinary level, but with a high dam it would not arise till after a considerable period. Ultimately it would have to be met by tunnel-repairs, dredging of deposits above the dam, or otherwise, as might seem best.

The construction of works of the magnitude above outlined for the utilisation of the Rangitikei is evidently for the distant future. In a district without mineral resources, and without present manufacturing industries, there appears to be no prospect whatever of finding uses for the large amount of energy obtainable from this river, though if the energy could be utilised, any of the schemes would be a success. If a smaller scheme were required for the Rangitikei, the proper course is to utilise the river further up the valley and transmit energy from a greater distance. No very definite information is available for the Rangitikei above the Hautapu junction, but no doubt many schemes are possible on the Rangitikei and on the Moawhanga, and probably they would be less costly per horse-power for the hydraulic part of the schemes than those I have outlined, but the cost for transmission-lines would be relatively greater.

Manawatu River, etc.

The Manawatu Gorge has attracted some attention as a possible power-scheme location. The fall in the river is not great enough in the four miles of gorge to justify any attempt being made to construct a power-station here, and the several roads, the railway, the bridges, also the flat agricultural land above the gorge do not allow of any attempts at damming.

Schemes to supply local industries of the future could possibly be got in the Oroua and Pohangina. These would be located near the mountains, and be of no great size.

The rivers rising from the east slopes of the Ruahine Range would probably yield some schemes also in their upper reaches. No information is available about any of them. The head-waters of the Tukituki and Waipawa might furnish some small schemes, also those of the Ngaruroro should give some schemes if sufficient fall is obtainable in reasonable distances. The Mohaka is a stream that might also yield some power.

Waihi Falls, Weber.

These falls are situated on the Waihi River, seventeen miles from Dannevirke, and five and a quarter miles from Weber in a straight line. The drainage-area of the river above the falls is forty-six square miles, and a considerable portion is of fairly high elevation. The Puketoi Range, forming the western boundary for a distance of eight miles, is from 2,200 ft. to 2,630 ft. in height. There is probably a considerable rainfall over the river-basin, and, if the water could be cheaply stored, a considerable amount of power could be obtained. Without considerable survey-work it is not possible to say how much of the flood-water could be stored. The appearance of the valley above the falls is, however, not such as to give hopes of good results if a dam were built.

I gauged the river at the suspension bridge above the falls. The flow was about 45 cubic feet per second, and this was not the low-water flow—being I think somewhat above it.

There is a slight rapid above the fall and a rapid below the fall. The total height for power purposes, making no allowance for flood back-water, would be, say, 90 ft. A turbine might be placed to get this head by using a draught-tube and noting that the flood would likely be higher in the channel above than below the falls, or could be made so at trifling expense. The power obtainable from the flow I measured would not be more than about 360 b.h.p. on the turbine-shaft. I think it is probable that the extreme low-water flow would give considerably less than the above amount of power, say 250 to 300 b.h.p. A power-station would best be placed just below the rapid below the fall, on the left bank. The distance the water need be taken is very short. The fall in the river above and below the falls is not sufficient to justify the cutting of any length of race. Starting, say, from the suspension footbridge and going a mile or more below the falls, the additional height to be got is not great enough to compensate for cost of work, risk of interruptions by the failure of the race, &c.

The width of river-channel above the fall is about 120 ft. The banks are very steep, and 40 ft. to 50 ft. deep. If a curved dam, say, 45 ft. high, were built, extra head would be got, also some storage, which would last for a considerable time until the river silted up the reservoir so formed. Taking the upper 10 ft. for storage, and taking a plant working full power twelve hours a day, or its equivalent spread over two shifts of sixteen hours a day, I think a plant of 800 to 900 b.h.p. could be worked without any great risk of the failure of the water-supply.

If a favourable site just above the falls could be got for a curved dam—*i.e.*, with solid papa to butt the ends of the dam against, it should not cost more than about £7,000, and perhaps be worth this amount in the event of any power scheme being installed at these falls.

At the time of my visit the flow in the Akitio River just below Weber was 20 cubic feet per second, from a drainage-area of forty-seven square miles. This is a small result, and if the flow in the Waihi fell so low as this, the above estimates for probable amounts of power would be much too high. The hills forming the western and northern boundaries of the Akitio are about 1,000 ft. to 1,200 ft. lower than those on the western boundary of the Waihi; also there is a considerable extent of open country as well, so that a lower rate of flow per square mile may reasonably be expected from the Akitio than from the Waihi basin. The destruction of forest on the Puketois will tend, however, to lower the low-water flow of the Waihi.

Makuri.

There is a fall of about 330 ft. in about two and a quarter miles in the Makuri Gorge, starting from the ford below the township. The water could be taken from the river a little below the ford. The drainage-area of the river-basin above this point is about thirty-eight square miles. The hill-peaks encircling the river-basin range in height from 1,867 ft. to 2,634 ft. A fairly good and reliable rainfall may therefore be expected to prevail. The flow of the stream at the time of my visit was slightly over 40 cubic feet per second, but the stream was probably somewhat above its lowest level. The flow I measured in the stream would give, at a power-station at the sheep-pens, about two and a quarter miles below the ford, a little over 1,100 b.h.p. continuously, but for low-water flow I would not at present put the power available at more than 600 to 700 b.h.p. until reliable data as to low-water flow is obtained. With a small reservoir sufficient to store surplus water when a plant was not working, perhaps 1,300 b.h.p. could be got for about twelve hours each day. The water would be carried along the side of the gorge by drives in the rock, race, flume, or pipes, as deemed best. If a large reservoir were made by building a sufficiently high dam just below the ford, and all the water stored, I should expect to get a power-station to give 3,000 b.h.p. continuously, or 6,000 b.h.p. for twelve hours each day. A considerable volume for storing water could be got in the valley above the ford. Whether it would be sufficient to store all the rainfall running off could only be determined by survey, and by the collection of reliable data as to the flow of the stream. A large reservoir would mean making new roads up the gorge, and about Makuri the loss of some houses and land. This, with the cost of the dam, might make the scheme somewhat costly; nevertheless it seems probable that a power scheme of the above character, if all the flow of the Makuri could be conserved, would be a success. One objection to the building of a dam is that fissures may exist in the limestone rock and cause leakage.

If the water were carried further down stream, more power would be got. The river appears to fall about 20 ft. per mile from the sheep-pens to its junction with the Tiraumea, and the fall seems much greater near the gorge. I think about half to three-quarters of a mile longer race would give a considerable increase in power.

The stream is a good one for a small power scheme, even if only a small reservoir is built.

Wellington.

For the supply of power to Wellington City and surrounding districts, there is first to be ascertained whether any power schemes are to be obtained in any of the rivers rising in the high peaks of the southern Tararuas, where there is undoubtedly a heavy annual rainfall. These rivers are the Hutt, Otaki, Tauherenikau, and Waiohine, and further north there are the Waingawa, Ruamahunga, Mangahao, and Ohau. No information has yet been obtained about these latter rivers.

The rainfall at the Summit Railway-station for a period of nine years is given on a diagram attached. There is every indication that the rainfall on the mountains around Mount Hector is much heavier than at the Summit. As one proof of this, practically simultaneous gaugings of the streams gave for the Tauherenikau a flow-off equal to 5·6 cubic feet per second per square mile, and for the Pakuratahi barely 2 cubic feet per second per square mile, while the previous weather-conditions were more favourable for the latter stream than the Tauherenikau, for on its watershed and on a neighbouring one heavy rains about ten days before had caused high floods, while the Tauherenikau had scarcely been affected by the storm, which, though severe, had been local, as observed by the Working Railways maintenance staff. Notwithstanding this special case, it may for the present be assumed that generally the variations in the rainfall over the Tauherenikau will follow those at the Summit.

A considerable sum extra per brake horse-power could be spent on power schemes on these rivers to avoid, for the Wellington supply, the cost of a long transmission to, say, Waikaremoana or Mangawhero, and the cost of the extra machinery required to give power to cover the line losses—a considerable item in a line up to 250 miles long, while the distance to Mungaroa is only twenty-five miles, and to Featherston forty miles, by probable transmission-line routes. All conditions being on the average equal, the longer line is more liable to interruptions and serious breakdowns, and a line to Waikaremoana or Mangawhero would cross much papa country, where the liability to slip is greater than in the slate country between Featherston and Wellington.

The conditions for these rivers would be most materially affected by the destruction of the existing forests on the mountain-slopes in the various watersheds.

An examination should be made of the Mangahao, Ruamahunga, Waingawa, Ohau, and perhaps Waikanae Rivers. A good power scheme may be obtainable from one or more of these rivers.

Waiohine.

This river above the junction of the two branches, Waiohine and Waiohine-iti-iti, has a drainage-area of forty-six square miles. The Waiohine branch rises in Mount Hector, and the Waiohine-iti-iti runs in a valley about eleven miles long, flanked by high mountains, spurs from Mounts Hector, Crawford, and Holdsworth—all very high ground. The area should be an excellent catchment one. The greater portion is at present bush-clad. There must be a considerable flow in both these streams—at the time I saw them about 400 cubic feet per second, but from the information I got as to lower states of the river and otherwise, the lowest flow is not likely to be much over half the above quantity. The height above sea-level of the junction of the streams is about 820 ft. There is a fall of 135 ft. in about a mile and a quarter below the junction, but from this point downwards the fall in the river is less rapid. The total fall from the junction to the railway-crossing is 520 ft., and to about the mouth of the gorge, say, 500 ft. The distance to this latter point is about ten miles. Taking a station just below the Goose Neck, after deducting fall in race, probably about 400 ft. of fall would be available. On a probable minimum flow this would give about 7,000 b.h.p. continuously. Some minor creeks could be led into the race in its course.

From the view I had of the country just at and above the junction, there does not appear to be any suitable site for a storage-reservoir. The gorges at the junction are too narrow, and the streams rise too steeply. Perhaps a storage-reservoir might be got further up the Waiohine-iti-iti. Considerable drainage-area might be lost, but some benefit might be got. It is probable that the Waiohine Valley is too steep to provide any sites for a large reservoir, but only search would show in both cases.

A regular survey of the river would show whether a power scheme could be got by taking the water from the river at a suitable point four or five miles or more above the Goose Neck. The water-level could be raised by a dam to give some overnight storage or more. The drainage-area would be about seventy square miles. Of this the portion above the junction of the two main streams would yield by far the largest proportion of water. Perhaps about 200 ft. fall could be obtained, but of this I am not sure, as the conditions were unfavourable for aneroid work when I was at this part of the river. Probably up to 7,000 or 8,000 b.h.p. could be got in this way for intermittent working during two shifts per day.

As a comparison with the Waiohine River, the works on the conduit of the Kern River Company, Los Angeles, California, are of interest. The minimum discharge of this river is 200 cubic feet per second. The conduit is 11½ miles long; the effective fall obtained is 260 ft.; the average annual discharge is about four times the minimum flow. The canal is designed to carry 600 cubic feet of water per second. At minimum flow only about 4,500 b.h.p. would be available in the above scheme, and about 13,500 when the conduit is running full. No mention is made of storage in the description available, so the plant may be intended to utilise the ordinary flow regardless of the extreme minimum flow. The works on the conduit—in addition to a timber diversion-weir with sluice-gates—are a settling-basin, 3,200 ft. long, 400 ft. wide, and 10 ft. deep, formed by an embankment; four tunnels of an aggregate length of 1,922 ft.; the tunnels are lined with cement concrete; the waterway in the tunnels is 10 ft. wide and 8 ft. deep. There are fourteen flumes of an aggregate length of 5,572 ft.; 1,371 ft. of flume is required to cross the Kern River. In this length there are four spans of 121 ft. The height of the flume above water-level at the highest point is 72 ft. The flumes are 16 ft. wide and 8 ft. deep. There are eight miles of canal, on a grade of 1 in 5,000. In earth the width at bottom is 22 ft., at top 49 ft., and the depth is 9 ft. The depth of water is designed to be 7½ ft. In rock a different section is adopted. Two miles of this canal are on a grade of 1 in 2,500, with a bottom width of 15 ft. In sandy soil, or where leakage is likely to occur, the canal is lined with cement concrete. These works are of considerable magnitude.

The Waiohine would give about 50 per cent. more power at its probable minimum flow than the Kern River at its minimum flow, but not so much at its ordinary flow. The ground along which the Kern River canal is cut is much easier than the hillsides along the Waiohine Valley.

Otaki.

The maximum drainage-area of this river available for power purposes is 112 square miles. It drains the western slopes of Mounts Crawford, Hector, and Alpha, and the flow of water should generally be considerable. The river would probably be best utilised by building a dam in the best site in the canyon about a mile or more below the Waitapia junction. Some additional height would thus be got; and some storage, sufficient probably to store two or three weeks' minimum flow, should be obtainable. I think 4,000 b.h.p. for continuous working is the limit of the power that could be got from this scheme. The race would be three and a half or four miles long, and would be on the right bank of the river. The sides of the gorge are rough, and a race would be expensive, and a part of its length would be likely to be in drive. Some approximate sections of the canyon in the gorge were taken, and show that the cost for a dam would be relatively high per brake horse-power. Further search might disclose a better dam-site. No gaugings of the minimum flow of water in the river have been made.

Another scheme would be to put a power-station at the junction of the Waiotauru with the Otaki and bring races to this point to take water from the Otaki and Waiotauru. I have not been able to get sufficient data to formulate a scheme for this alternative. About eighty square miles of the best part of the drainage-area would be available for this scheme, water being taken from the Otaki below the Denan Creek, and from the Waiotauru at about a corresponding height, or higher if thought best.

Though they do not promise very well I think these Otaki schemes are worth investigating further to ascertain definitely their worth. A power-station on the Otaki would be valuable for various reasons.

Tauherenikau.

This river rises in the ridge between Mount Alpha and Mount Hector, 4,400 ft. to 5,000 ft. high. The upper valley is encircled by hills from 2,000 ft. to 5,000 ft. high. There are no intervening mountains to screen these peaks from the moisture-laden winds coming from either of the prevailing directions in this district. The rainfall at the Summit Railway-station has averaged 93½ in. for the past nine years, and there is certainly a greater rainfall in the Upper Tauherenikau Valley.

For power purposes the water would be taken from the Tauherenikau at the junction of Smith's Creek. The drainage-area above this point is twenty-seven square miles, and the actual fall to the railway-crossing of Abbot Creek, near Featherston, is nearly 500 ft. The effective fall obtainable should be about 440 ft. It is possible to take the water by race from the above point to a suitable point on Abbott Creek near the railway-crossing, the direct distance being just under five miles. The race would be longer than this. A drive would be required at the head of Boar Bush Gully to get the water on to the ridge between this gully and Abbott Creek, whence it would be taken down the hill in armoured concrete and in steel pipes to the power-station.

A concrete dam could be built across the Tauherenikau Gorge at Smith's Creek junction to store water. Above this point there is a narrow flat in the valley-bottom about 50 chains long. The gorge is rather wide to allow full advantage to be taken of this flat so as to give a reservoir large enough to store all surplus water for power purposes.

At the time I inspected the river the flow at Smith's Creek was slightly over 150 cubic feet per second, and from all the information I could get and having seen the stream at this point on previous occasions, it was at about its ordinary level, as it was also said to be at the railway-bridge by the Railway Maintenance staff. This quantity of water would give at a power-station at Featherston about 6,000 b.h.p. continuously. With storage to average the ordinary flow over several weeks, there should be no difficulty in getting, say, 10,000 or 11,000 b.h.p. for continuous full power working for eighty-four hours or more a week. This would be a very serviceable scheme.

It is likely the low-water flow may be less than the above quantity, but by how much and for how long it lasts it is not possible to say. The rainfall records at the Summit show a continuous period of about four months of low rainfall during the nine years for which the records are available, and, of course, a longer period than this might also occur. There might be a similarly long period of low rainfall in the Tauherenikau, and there might not. The higher elevation would tend to more frequent rainfall.

The question of storage in a river-valley such as this cannot be discussed without somewhat extensive surveys. A small reservoir at Smith's Creek junction, supplemented by several rock-fill dams at successive points of vantage up the valley, might give much better results than a single expensive dam at Smith's Creek. Rock-fill dams with the interstices filled with small rock, clay, &c., to stop leakage could be built for much less than concrete dams, and might be found to give much better results for a given expenditure. The materials for such dams are on the ground, and little else but plant and materials for draw-off pipe and its fittings would have to be taken up the valley. If all the water could be stored it would, I feel certain, be possible to get much more power than I have given above.

A smaller scheme is possible by taking the race down the left bank of the Tauherenikau to Tait's Creek, near the mouth of the gorge. This would give only about 60 per cent. of the power obtainable at Featherston.

The cost of the scheme outlined above, for 11,000 b.h.p. may be taken at £400,000, and the probable gross revenue at £40,000 per annum. The cost of a scheme to give 5,000 b.h.p. continuously would be cheaper—say, £225,000, giving a gross revenue of £36,000.

A power-installation very similar to this was under construction lately at Utah, U.S.A. The leading features may be summarised here for comparison. The principal difference between the two schemes is that the Utah one has a much larger drainage-area, but a much less rainfall, and likely a much less percentage of rainfall running off. Dam, 100 ft. high; foundation to crest, 400 ft. long; depth of water in reservoir, 60 ft.; storage-capacity, 2,400,000,000 cubic feet. Conduit nearly six miles long, 27,000 ft. being wooden-stave pipe in trench, and 4,600 ft. steel pipe; both pipes 6 ft. internal diameter. Quantity of water delivered, 250 cubic feet per second. Effective fall, 440 ft. Gross power given as 12,500 (equal to about 10,000 b.h.p.). Length of transmission-line, thirty-eight miles. On the conduit there were eight tunnels (the longest 667 ft.), eight steel bridges of a total length of 560 ft., and one timber trestle.

A dam to contain as much water as in the above scheme is not possible on the Tauherenikau, nor is it absolutely necessary.

It remains to test the value of the river by gauging to determine the flow throughout the year, and to ascertain by survey the storage available at reasonable cost.

Hutt.

The Hutt Gorge a short distance below the junction of the Pakuratahi Stream is very narrow, and can be dammed with comparative ease, the breadth of the river being under 50 ft.; the slopes of the gorge steep and showing rock-outcrops, so that probably good foundations can be got without much excavation. A dam 125 ft. high above low-water level would store a very large quantity of water —how much could only be determined by a contour-survey, as the water-level lines would be very irregular. The water would reach over two miles above the dam and above the road-bridge over the Pakuratahi.

The drainage-area above the dam would be fifty-seven square miles. Of these thirty square miles would belong to the Hutt River, and the remainder to the Pakuratahi. The Hutt portion of the basin is bush-clad. A large portion of the bush on the Pakuratahi is now cleared.

Apparently there must be a considerable rainfall over the area in question. For the years a rain-gauge was kept at the Upper Hutt the average rainfall was 65·7 in. The rainfall at the Summit has averaged for nine years 93½ in. The rainfall on the higher portions of the basin which reach heights of 2,800 ft. to 4,400 ft. is no doubt much greater than at the Summit, where the height is 1,144 ft. only.

The junction of the Pakuratahi is 583 ft. above sea-level, as determined by levelling. The best place for a power-station is probably just above the junction of the Mungaroa with the Hutt. The conduit would consist of about 146 chains of drive, and about two miles of fluming or ditch, with a length of steel pipes from the end of the flume to the power-station. An effective head of about 275 ft. would be obtainable.

I think investigation will show that water enough can be got to give a power plant of at least 5,000 b.h.p. at Mungaroa for continuous working, a dam 125 ft. high being built. The cost of this scheme would be, say, £225,000. The gross revenue derivable therefrom would be, say, £40,000 a year, the line losses being small for the short distance.

To meet the present-day conditions of hours of working, a plant of greater capacity would be required to use all the water in a shorter time, working at varying power during, say, sixteen hours or more per day. Supposing a plant of 12,000 b.h.p. installed for this purpose, the cost would be, say, £340,000, the gross revenue being £50,000. The dam for this scheme would be 150 ft. high.

The dam, if built, should be 150 ft. to 160 ft. high. This would give a great increase in the amount of water stored, and a consequent increase in available power; but this is a point to settle when the total annual flow of the river is known.

The distance of the power-station from Wellington would be a little over twenty-four miles. The Hutt and Petone districts would take a large amount of power, so that the transmission losses would not be so great in this scheme as in others. The transmission-line should be comparatively very safe from risks of breakdown. Though relatively expensive per horse-power, this scheme is, I think, worthy of very full investigation if ever any proposal is considered for supplying electric energy to Wellington. The low-water flow of the Hutt is likely to be much too small to justify any attempt to utilise it alone for the generation of power. Storage of all the water flowing from the upper areas of the river-basin is necessary to make any such scheme a success.

The Akatarawa River joins the Hutt just above the Upper Hutt Station. Its drainage-area is fifty square miles above the junction of the little Akatarawa. The fall from this point to the Hutt is 133 ft. A race starting about a mile above the junction of the two Akatarawas, and taking the water of both to the Hutt would give, say, 1,000 b.h.p. continuous working for probable ordinary low-water flow. Small dams for overnight storage could be got, but the valley does not present conditions favourable for the construction of a large storage-reservoir to equalise the annual flow.

The Whakataki joins the Hutt River just below the Upper Hutt. It has a drainage-area of twenty-three square miles to the junction of the two streams at Birch Spur. The stream here is nearly 160 ft. above its junction with the Hutt; the distance is about two miles. A reservoir of some size could be got here. If most of the water could be stored, 700 or 800 b.h.p. could be got from this stream for continuous working, and about twice this for intermittent working. The cost of a dam would be too great to justify much storage, and the scheme is only of value for some small local industry.

The Mungaroa Stream has a drainage-area of twenty-two square miles above the swamp behind Wallaceville. The area of the swamp is 2·2 square miles. The fall from the centre of the swamp to Wallaceville is given as over 260 ft., and the distance about a mile. The lower end of the swamp can be closed by a dam, and a lakelet formed, but the dam would be over three-quarters of a mile long and the cost too great to warrant consideration of the scheme at the present time. The cost would probably be about £70 per brake horse-power. At some future time the Mungaroa may be used with profit for some local industry using water-power direct.

Minor Schemes, North Island.

A number of minor schemes have been suggested for the North Island. Those not dealt with in the report are given in the lists below:—

Auckland.

	Drainage-area. Sq. m.	Height of Falls. Ft.
Waipapa Falls	10½	40
Kirikiri	36	100
Waitangi	105	30
Waitakerei	5½	440
Bridal Veil	12½	100
Wairere	3½	400
Table Mount	4	300
Waireinga	7	170
Ariki	3	320
Mauku	15½	66
Wairoa	28½	96
Mangatawhiri	11½	70
Whirinaki	18½	300

The above are all falls on streams in Auckland Province. The flow is available for Wairoa, and it would only give about 160 b.h.p. Only three of the others are likely to be above this power for a proportional rate of flow. These are Kirikiri, Waitangi, and Whirinaki. The remainder are about 100 b.h.p. or under.

Napier and Gisborne.

	Drainage-area. Sq. m.	Height of Falls. Ft.
Motu	94	40
Wharekopau	44	..
Waihiere	11	..
Mokau*	26½	..
Aniwhaniwha*	26½	..
Double Waterfall, Mohaka River, Tongoio East	1	..
Mangapuaka	1¼	..
Taranaki.		
Kiri	1	..
Dawson's Falls	1	65
Wellington Provincial District.		
Wanganui Rapids	..	..
Retaruke†	..	..
Waimarino	..	..
Makaretu	..	..
Piopiotea	..	..
Pukerimu	..	..
Tauranga Taupo	..	..
Waihi Falls, Tokaanu	..	..
Waitangi Fall‡	..	20
Ohura§	..	20
Otuiti Falls‖	..	20
Tikirere, Moawhango¶	..	20
Pongo, Moawhango	..	25
Te Paunga, Moawhango	..	17
Papakore, Moawhango	..	20

In addition to the above falls, and streams with rapid fall, the following have also been suggested: Waihohone, Mangatoetoenui, Rangitikei above Napier Road, Mangahowhi, Tunanui, Turangarere Falls, Hautapu, Makatote, Mangaturuturu, Matakereputu, Makotutu, and some others of no apparent value. Some of these streams would yield small amounts of power in many cases by cutting a race for some distance. Good schemes for merely local use could be got as required. A complete examination of all and the collection of data regarding them would involve a considerable amount of work. Hardly any would likely be large enough for a transmission scheme.

* May be used to reinforce Waikareiti. † 1,000 ft. fall in four miles. ‡ Near Karioi. § Near Wanganui River, and probably flood-water will dam it back in floods, and power-station probably impossible. ‖ Probably same as above. ¶ Tributary stream.

SOUTH ISLAND.

Marlborough.

The rivers suggested as sources of power in this district are the Pelorus and Rai, Wakamarina, Wairau, Waihopai, Awatere, Clarence, and Conway. In all cases the works required to utilise these rivers would be of the same general character, consisting of weirs, settling-tanks, and races along the hills to convey the water to selected points, to get as great an altitude as possible. No detailed examination has been made of any of the rivers to determine the best location or possible magnitude of any scheme to utilise any of them. The Surveyor-General has supplied information regarding the fall obtainable in the Clarence, Awatere, and Wairau. This information is given in the sections for these rivers attached hereto; also the drainage-areas above each of the points named for each river. No low-water or any gaugings have been obtained for any of the rivers in this district, and the low-water flow is only a matter of surmise. It will be generally relatively low, as there are no lakes to equalise the flow, nor bush to any extent on the large rivers—the Clarence, Awatere, and Wairau.

The Waihopai, a tributary of the Wairau, is worth investigating. It is possible that it might be found sufficient for all industrial purposes for Blenheim and surrounding district. If not, an investigation of the upper reaches of the Wairau or Awatere should be made.

Clarence River.

The head-waters of the Clarence River could be diverted by a tunnel under Jollie's Pass, and taken to a point in the valley of the Waiau-ua just below the Jollie's Pass Hotel. The difference in level between the probable intake and the power-station would be 1,160 ft. Probably about 1,100 ft. of effective head would be got. The distance between the two points is about three miles, but a conduit would be longer. The drainage-area tapped would be 190 square miles. No information is yet available as to the probable minimum flow in the river. The drainage-area is mountainous, reaching an elevation of over 7,000 ft., but hardly any of the main range is drained by the river. There is a small lake (Tennyson). It does not tap any large area, and would not be likely to greatly affect the flow of water, though it would help, and its effects might be increased. I think it likely that at least water enough should be available to give 15,000 to 20,000 b.h.p. The information regarding this scheme I got from Mr. Rutherford, Chief Draughtsman of this Department, who obtained a number of heights in this locality.

The River Acheron joins the Clarence about seven miles down from the probable intake of the Jollie's Pass scheme. To reinforce this scheme from the Acheron would require a race probably twelve miles or more long, depending on the fall in the Acheron. The junction is about 160 ft. lower than the river at the intake. The valley below the junction is narrow, perhaps sufficiently so to justify the construction of a dam to raise the water high enough to send it through Jollie's Pass, and some storage might be got by adjusting the level of the tunnel. The drainage-area of the Acheron is about 360 square miles, and the bounding mountain-ranges attain a height of 5,000 to 6,700 ft. It is probable that a dam would be less costly than a race, and it would certainly be much more reliable. Data can be got for this scheme when the other is being investigated. The tunnel would likely be at a different level in each scheme, and if the first scheme were undertaken it would be advisable to put the tunnel at the proper level if the reinforcement scheme is feasible.

The power-station at Jollie's Pass would be about eighty miles from Christchurch, and the transmission-line would serve all North Canterbury. This scheme may prove better than one at Coleridge; and if a good scheme can be got at Opihi the two would command all the country from Waitaki to the Conway.

Opposite the Conway the Clarence is about 2,150 ft. above the sea. It might be possible to get a very good fall by diverting the Clarence into the Conway. So far as I can ascertain from the plans of the Waiau-Kaikoura Road, there is about 1,050 ft. of fall between the road-crossing of the Conway and a point in the Clarence opposite. The distance is about seven miles and a half. How much of this fall could be utilised by a tunnel and conduit along the slopes of the Conway Valley to a point near the road or lower down the Conway can only be determined by an examination. The scheme would appear to be one that might give a large amount of power—100,000 b.h.p. or over.

Within about thirty-six miles of its mouth the Clarence River doubles on itself, while the fall is great. Tunnels could be driven between points on the river in three alternative places as shown, giving, say, about 800 ft. fall in the first, 650 ft. in the second, and 430 ft. in the third; while a tunnel to the sea in the fourth instance should give a very considerable fall, perhaps 400 ft. or more. Taking for the present a uniform slope in the river-channel, each of these four schemes would give a large amount of power. How much, and which is best, can only be determined by survey. Of course, only one of the three could be carried out. As taking water from Upper Clarence through Jollie's Pass appears to give a higher fall than any of the other four schemes, that scheme could be carried out, and the remainder of the water used in whichever of the other schemes was thought best at any future time.

Nelson.

Some preliminary information has been got regarding the rivers and lakes in the Nelson District, but it is not yet very complete in any case.

The Maitai River, flowing through the Town of Nelson itself, is a small stream. It has a high fall per mile, 60 ft. to 80 ft. The low-water flow is small—said to be 15 to 20 cubic feet per second in the upper reaches, where water would have to be taken from. With a long race only a small amount of power would be obtained. This might be increased if a reservoir of some size could be got. Any scheme without storage in the Maitai is likely to be considerably under 1,000 b.h.p.

The tributaries of the Waimea— the Wairoa, Lee, and Roding—have been examined. The Wairoa has a probable low-water flow of 30 to 40 cubic feet of water per second. By a race six miles and a half long a fall of about 160 ft. might be got, but the sides of the valley are not very favourable for the construction of a race, and the valley does not present very favourable conditions for storing water at an intake. Without storage only 500 or 600 b.h.p. could be got from the Wairoa.

The Lee has a minimum flow of about 20 cubic feet per second. Reservoir-sites are obtainable by a race four miles long, starting from its junction with the Wairoa. About 170 ft. of fall can be got. Only a small scheme is obtainable from the Lee—a few hundred horse-power.

The Roding, at a point behind Richmond, distant about three miles from the sea, is about 490 ft. above sea-level. A storage-reservoir could be got here. The drainage-area of the stream above this point is probably not more than about eighteen square miles. The minimum flow of the stream is put at from 20 to 25 cubic feet per second. A drive about one mile long would take the water through the hills, whence pipes of any length considered best could be led in as direct a line as possible to a power-station on the flats. Supposing the reliable flow could be raised by a dam by 50 per cent., about 1,400 b.h.p. could be got by taking the water to the sea-level—this for continuous working, and about double this for a plant working full power twelve hours per day. The cost of a dam, and its storage-capacity, would have to be ascertained before an estimate of the value of the scheme could be given. It does not appear to offer any marked advantages, but would perhaps prove a justifiable one.

A small power-scheme might be got for merely local requirements for Motueka from the Whangapeka.

There is a small lake, Boulder Lake, at the head of the Boulder River, a tributary of the Aorere. It is said to have a discharge of about 40 cubic feet of water per second, and this could probably be increased by conservation of the water. The lake is at a level of 2,850 ft. above the level of the sea. The rainfall at the lake is very heavy, I believe over 160 in. per annum. About six miles distant, the level of the Aorere is about 250 ft. above the level of the sea. If all this head could be utilised, either by a series of stations or one, about 9,000 b.h.p. would probably be got, or considerably more by conserving the water to the full capacity of the lake-basin.

Rotoiti Lake.

The drainage-area of this lake is about forty-six square miles. There is a fall from the lake to the Gowan junction according to the Survey Department heights of 1,200 ft. The area of the lake is small, about two miles and three quarters. Unless a high dam could be built the lake would probably be too small to store all the water from the drainage-area. The distance from the lake to Gowan junction is about sixteen miles. The drainage-area of the Buller River down to the Hope junction is 171 square miles. It should be possible to get a large amount of power from the Buller in this reach, say 20,000 b.h.p. by several stations in series, as has been done in one instance, at least, in the French Alps.

If any power-scheme for Nelson is investigated further, I think one of the first tried should be a scheme to utilise Rotoiti.

Rotoroa.

The area of this lake-basin is 150 square miles, and the area of the lake is four and three-quarter square miles. The upper end of the lake-basin is encircled by mountains reaching an altitude of over 7,000 ft. for a length of about sixteen miles. No gauging of the Gowan River has been made, but the flow in the river is evidently considerable. The lake-area is too small for complete regulation of the flow. A dam at the lower end of the lake would probably be of some length, and to improve the storage materially it would have to be of some height. There is a fall of 400 ft. in the Gowan River from the lake to its junction with the Buller; the length is about five miles and a half. Allowing for fall in conduit, flood-rise in the Buller, &c., about 340 ft. effective head should be available. I think power to the extent of 30,000 b.h.p. should be easily got at a power-station on the banks of the Buller just below the junction, for continuous working, or 60,000 b.h.p. or more for a twelve-hours day. If sufficient storage can be provided by a dam at reasonable cost, there is no reason apparent at present why this lake-basin should not yield relatively as large a flow as Lake Brunner. This would give much more power, by one third or more.

The Buller River below the Gowan junction would provide several schemes. The fall is not very rapid. It is shown approximately by the attached diagram compiled from the railway survey, but the connections to the river-level are only got by assuming that the Buller is about the level of the large tributaries crossed. The reach between the Gowan and Owen is steep, and should give some power. There are bends and rapids in the river near Newton which seem to offer favourable conditions for power-development. The bend of the river at Lyell could be utilised by a tunnel to take the low-water flow, and a scheme giving, perhaps, 25,000 b.h.p. got. The high flood-rise would give trouble in all cases, but this could be avoided as much as possible, and at least partly met.

Inangahua River.

By taking the water from the Inangahua River at a point a short distance above the Landing, in a tunnel to the junction of the Blackwater with the Buller, a scheme of some size could be got, perhaps 7,000 to 8,000 b.h.p. The fall to be got is about 125 ft. This could be supplemented by a low dam in the river, which would also store some water. The flood-rise in the Buller is about 50 ft., but the power-house could at the Blackwater be put above this, and the turbines work at a lower level in a shaft with a draw-off tunnel to Buller low-water level. The scheme would be relatively costly.

Waiau-ua.

This river could be utilised for the development of power by a dam built in any suitable site in the gorge below Hanmer Plains. Water could be taken out of the river just above the road-bridge, and the water-level raised by a dam 100 ft. high across the river, and a supplementary dam across the old river-channel. The drainage-area above this point is about 750 square miles. The river drains a length of about forty-seven miles of the main range, which varies in height from over 5,000 ft. to 7,100 ft. The conditions are favourable for a relatively high volume of flow. In the absence of data as to the flow of the river, the flow may be taken as equal to that of the Waimakariri per second per square mile, say a minimum flow of 1,600 cubic feet per second. The fall in the river from the road-bridge to the lower end of the gorge is 160 ft., the distance a little over seven miles. There is a fall of over 30 ft. in a short distance below the bridge. A dam 100 ft. high should in this short distance, or a little more, give about 20,000 b.h.p. at a cost of about £160,000 for the purely hydraulic works.

By taking the water in a conduit to the lower end of the gorge, about seven miles in length, 30,000 b.h.p. would be got. Probably this would cost about twice as much per brake horse-power for the purely hydraulic part of the scheme.

A gauging taken recently gave about 3,300 cubic feet per second for what was supposed to be a low-water level of the river, but the result seems high. It is possible the figures given for available power are low. It is not, perhaps, improbable that the Waiau-ua may have a high flow per second per square mile, in view of the great length of the main range drained by the river.

Westland.

The Chief Surveyor, Hokitika, has furnished a very complete report on the rivers of this provincial district.

Some of the tributaries of the Grey River might be found suitable for power schemes, but detail information as to fall and flow are not yet available.

The Arnold River, flowing from Lake Brunner, has a fall of about 234 ft. from the lake to its junction with the Grey River. The drainage-area feeding the lake is 178 square miles. The area of the lake is fifteen square miles. Measurements of ordinary flow of the river made by the Engineer of the Greymouth Harbour Board some years ago gave 1,750 cubic feet per second. This is nearly 10 cubic feet per second per square mile. The distance to Arnold bridge from the lake-outlet is 11½ miles on the straight, and seventeen miles by the river. Allowing for fall in conduit, the limit of power to be got from the lake would be 22,000 b.h.p. if a nearly straight conduit were possible, but much less than this for a conduit following the river. A complete scheme would be a relatively costly one. It might be possible to get one or two smaller schemes along the river by dams and short races, but no information on this point is available.

The Teremakau is a large river, but it flows in a wide shingle bed. It would therefore be difficult to take water out of it. Below Jackson's the fall is 20 ft. per mile, and this is too small to give any chance of a cheaply developable power scheme. Above Jackson's the fall is greater, but the river-bed is wide. A race to take a large volume of water would be expensive, and of considerable length to get a fair amount of power. Above the Otira, where the fall will be steeper, a conduit would require much tunnelling. The river is not a good one for power purposes.

Power could probably be got easier from the Taipo River, a tributary of the Teremakau, than from that river itself. About four miles up from the main road there is a narrow chasm where a dam could be built and the water taken to a power-station on the main road. The minimum flow is given as 350 cubic feet per second, but the fall is not available.

The Arahura River, if free from mining grants, would be a likely river to get some power schemes, and should be worthy of attention if a power scheme is investigated for the Hokitika–Greymouth district.

Arthur's Pass (Otira and Rolleston).

The possibilities of water-power in the Otira Gorge have a double interest, as the minor schemes may be developed for tunnel-construction, and the larger ones for an electric-traction scheme to work the railway traffic over the tunnel incline, and thus avoid all smoke nuisance in the long tunnel.

For working air-drills, ventilation, haulage, &c., at the Otira end of the tunnel, the falls in Holt's Creek, Barrack Creek, and Westley's Creek are available. Each is probably good for 200- or 300-horse power, Holt's Creek being quite near the lower end of A 4 tunnel. At the Bealey end the Punch-bowl fall is available. A head of about 700 ft. is to be got by a little over half a mile of pipes. Ordinarily several hundred horse-power would be got, perhaps five or six hundred, but in frost the amount would be reduced.

For electric working of the railway traffic there are several schemes possible.

To draw the full train-loads up the grade that could be brought up to Otira Station by the 84-ton locomotives contemplated to be used by the Railway Department in the future—without the steam locomotives—would require turbines of at least 1,600 b.h.p. For the existing B engines turbines of about 1,200 b.h.p. would be required.

There is a rocky gorge in the Otira at the road-hut, at an elevation of about 2,080 ft. From this point, by a drive about 7,000 ft. long, water could be taken to a point on the Rolleston spur, where a small service reservoir could be cut in the solid rock to hold water enough for one or more train-journeys, as deemed best. About 1,000 ft. of pipes would take the water to a power-house a short distance below the lower end of A 4 tunnel. Fully 500 ft. effective head should be available here. A minimum flow in the Otira of about 40 cubic feet per second would suffice without a reservoir to just work the traffic' or with a reservoir, about 20 cubic feet per second. A recent gauging of the Otira gave over 60 cubic feet per second. This was after five days' frost. In addition, there was water apparently flowing in quantity under the boulders. A gauging of the Rolleston under the same conditions gave 39 cubic feet per second, and also water was flowing under the boulders in the bed of the creek that could not be measured. The streams were not at their lowest at the time of the gauging, but even allowing for this, there should not be any lack of water.

There is a rock gorge on the Rolleston at practically the same level as that in the Otira. Both are about 40 ft. wide, and could easily have weirs built across them. A length of about 8,000 ft. of drive would be required to take the water from the Rolleston gorge to the pipe-head. The Otira scheme could be augmented in this way if at any time it was decided to extend the length of electrically worked line.

The reservoir, in combination with another settling-tank at a suitable location on the race, would be utilised for clearing the water from grit.

The water can also be taken from the Otira just below the junction of Pegleg Creek, and from there carried in a drive to a suitable point on the hillsides above the Rolleston Spur. There is a difference of level between the Pegleg junction and a power-station on the Rolleston below A 4 tunnel of nearly 1,200 ft. The measured flow of the Otira would give about 6,000 b.h.p at this station. The direct distance between Pegleg and the power-station is 2 miles 55 chains. The conduit-length would be longer, say 2 miles 70 chains, or perhaps more. I do not think there is any chance of getting a storage-reservoir, however small, on this alternative, except by cutting chambers in the rock, which would be too expensive. This scheme can be reinforced by taking the Bealey water into the Otira by a drive under Arthur's Pass. By doing this about 10,000 b.h.p. should be obtainable at the Rolleston power-station. This would be sufficient (and more) to electrify the line from Rolleston to Greymouth.

Water can be taken from the Bealey River in a pipe under the sleepers in the tunnel, to the lower end of the tunnel. This would be more expensive, and give less power than the last scheme, the total fall obtainable being only about 860 ft., and the volume of water perhaps less.

Kanieri Lake.

This lake lies at a level of 422 ft. above sea-level. Its drainage-area is sixteen square miles, and the lake area 5·6 square miles. The rainfall at Hokitika averages about 120 in. a year, and is probably greater on the hills from which the streams feeding the lake flow. In a distance of six miles a fall of 314 ft. is obtained, probably giving about 270 ft. effective head. With the probable flow from the lake about 2,800 b.h.p. would be obtainable for twenty-four hours a day continuous working, or, say, 5,500 for twelve hours a day full power. The lake-level could easily be raised 25 ft. This would provide a large storage-volume.

The Whitcombe River has a fall of just over 200 ft. per mile for four miles, starting about four miles from the divide. It flows in a rock-bound gorge, and carries 250 cubic feet of water per second. This would give about 16,000 b.h.p. if a conduit was carried along this length of gorge. In this country probably a drive would be the only safe conduit. A series of schemes should be possible, giving a very large amount of power.

The Kakapotahi passes through an old lake-bed easily dammed, and at this point has an elevation of 580 ft. above the sea. Below this lake-bed the stream flows down a deep chasm for several miles, over several large falls. The low-water flow is given as 100 cubic feet per second. From Mr. Roberts's description there appears every possibility of getting a fairly cheap and reliable scheme of some thousands of horse-power within about twenty miles of the mining centre of Ross.

The Wanganui and Wataroa Rivers, from Mr. Roberts's description, would be sufficient to give very large amounts of power. If it is possible to take the water from the Millpond to Hende's, 30,000 to 40,000 b.h.p. would be got (usually very much more) from the Wanganui, and in the Wataroa; taking the water from the lowest gorge to the road, with a fall of 700 ft., 70,000 to 80,000 b.h.p. should be available. The country here is not the friable slate of the main range.

A considerable amount of power could be got from the Haast River by utilising the fall between the Wills and the Burke's junction. This could be transmitted over Burke's Pass to Central Otago.

Perusal of Mr. Roberts's report (which would only be spoiled by any attempt at condensing) shows that a very large amount of power is available from the Westland rivers, but, having to be got by carrying the water in conduits parallel to the river-valleys generally for considerable distances, the cost for development would, as a rule, be relatively great, and more especially so when the rivers are in slate-rock country, with the hillsides covered with *débris* from the mountain-tops.

The following table gives information regarding power obtainable from falls in Westland. All the information is from Mr. Roberts's reports, but I have added the brake horse-power in each case :—

Water-power available for Electrical Purposes in Westland.

["Heads of water = lowest quantity running during year.]

No.	Locality.	Heads of Water.	Height in Feet.	Nearest Town.	Direct Distance from nearest Town.	Horse-power.
					M.	
1	Coal Creek	6	35	Greymouth ...	5	19
2	Upper Ahaura Valley	6	370	Ahaura ...	18	202
3	Lake Brunner (Mitchell's)	4	80	Kumara ...	15	29
4	Lake Brunner	8	100	" ...	11	73
5	Poerua	6	72	" ...	18	39
6	Upper Teremakau Valley	5	100	" ...	27	45
7	Jackson's...	7	67	" ...	21	42
8	Inchbonnie	9	160	" ...	13	131
9	Taipo	6	70	" ...	12	38
10	Otira (Barrack Creek)	10	210	Otira ...	0½	191
11	Otira (Wesley's Creek)	9	140	" ...	2	114
12	Lake Kanieri (Dorothy Falls) ...	7	70	Hokitika ...	14	45
13	Hokitika River (Doctor's Creek) ...	12	40	Ross ...	8	44
14	Hokitika River	12	25	" ...	9	27
15	Upper Hokitika	6	60	" ...	11	33
16	Upper Mikonui	6	150	" ...	7	82
17	Tuke River, Mikonui Valley... ...	27	90	" ...	9	220
18	" "	27	70	" ...	11	172
19	Kakapotahi	35	60	" ...	9	191
20	"	35	60	" ...	10	191
21	Duffer's Creek, Waitaha	8	40	" ...	14	29
22	Totara River	20	30	Okarito ...	12	54
23	Upper Callary Valley	7	110	" ...	15	70
24	Kaiser Fritz Falls, Franz Josef Glacier	14	1,209	" ...	17	1,539
					Direct Distance from Coast.	
25	Balfour Valley	70	40	...	15	254
26	Karangarua	7	85	...	8	54
27	"	6	90	...	12	49
28	Makawiho	14	370	...	10	471
29	Karangarua	7	80	...	14	51
30	Upper Paringa Valley	33	40	...	14	120
31	Upper Clark Valley	20	70	...	20	127
32	Upper Macfarlane	16	50	...	15	73
33	Haast Valley	25	450	...	14	1,023
34	"	10	115	...	13	104
35	Staircase Valley	30	90	...	10	245
36	"	35	1,115	...	8	3,548
37	Turnbull Valley	20	400	...	7	727
38	Lower Awatere Valley	7	350	...	7	222
39	Waipara Valley	45	70	...	17	286
40	"	25	80	...	21	182
41	"	20	60	...	22	109
42	Upper Arawata Valley	15	800	...	23	1,091

WAIMAKARIRI.

It has been proposed by Mr. A. D. Dobson, M. Inst. C.E., to use part of the Waimakariri water by a race starting from the lower gorge near Sheffield. The idea was to take part of the water without building any weir, as the configuration of the gorge appears likely to insure a constant flow of water against and past the cliff where the intake would be located. The conduit would be nearly five miles and a half long to get 86 ft. of fall. Somewhat less than 4,000 b.h.p. would be got by taking about a quarter of the low-water flow of the river. The cost for hydraulic works for this scheme would be very low, by Mr. Dobson's estimate. A low-water flow of the river was got by Mr. Dobson in August, 1899, and found to be 1,955 cubic feet per second. The gaugings were taken after watching the river for some time, and are therefore of value. The drainage-area above the gorge is 927 square miles. The length of the Alps drained is twenty-seven miles. The flow measured gives about 2·1 cubic feet per second per square mile, but part of the drainage-area is not likely to be any better than the Coleridge basin, and the strip of the river-basin lying along the eastern side of the Alps will be relatively the best. Rainfall-records are available for some years at the Bealey. If the rainfall over the Waimakariri basin follows in a general way that at the Bealey, the year 1895 would be likely to have furnished a lower flow than 1899. The rainfall in those two years at the Bealey was 23·81 in. in 1895, and 50·46 in. in 1899, and there were some months of very low rainfall in the winter of 1895. It is therefore probable that 1895 might have given a smaller low-water flow. The minimum flow measured is greater than would be expected from the August, 1899, rainfall at the Bealey, but the rainfall on the hills would be greater than in the Waimakariri Valley at the level of the Bealey. Only continuous records of river-flow can give any results of value, and these records would require to extend over many years to be reliable for rivers where no storage is possible.

It is popularly supposed that rivers such as the Waimakariri may be made to yield large amounts of power. While this is so, the cost will be relatively great, owing to the height of dam or length of conduit required to get the necessary fall.

The following schemes for the Waimakariri are possible, in addition to the partial one proposed by Mr. Dobson:—

1. Build a weir at the gorge bridge to enable all the water to be taken out of the river, and take all the low-water flow of the river to the point proposed by Mr. Dobson. This would give, say, 15,000 b.h.p.
2. Build a dam 80 ft. high at gorge, and use water near dam-site. This would give a little over 14,000 b.h.p.
3. Take water by weir from the river at about Patterson's Creek, and run tunnel and canal to take water to top of terrace, and then down to river-level by pipes; or continue conduit down edge of terrace by armoured concrete pipes, followed by steel pipes to gain extra head, and then take water down to power-station at river.
4. Build a dam or weir at Broken River junction, and take water to point near Patterson's Creek by tunnel conduit. The fall in river is 100 ft., and with a dam, say, 100 ft. high, an effective head of 160 ft. to 170 ft. should be got. The cost of dam, tunnel, and other hydraulic works, but exclusive of the pipe-line from end of tunnel to power-station would not be less than £525,000. The power obtainable would not be likely to exceed 28,000 b.h.p. If about the same fall were to be got by building a dam at Broken River junction about 200 ft. high, the cost would be about £700,000—much more expensive than the low dam and tunnel.

From Broken River junction to the proposed crossing of the Midland Railway over the Waimakariri, the river rises about 620 ft. in a distance of about twenty-two miles by the river. If most of this fall could be used by, say, two or more power-stations, perhaps as much as 50,000 b.h.p. could be got. In all, about 115,000 b.h.p. should be got from the five schemes. The cost would probably be, say, £4,500,000. Smaller schemes would be possible on some of the tributary streams. A fairly good power scheme could be got by running the waters of the Bealey and the Mingha to a common point at their junction.

Lake Coleridge.

This lake has a drainage-area of eighty-six square miles, and the area of the lake is 13·8 square miles. Its altitude is 1,667 ft. above sea-level, yet it never freezes. The lake lies parallel to the Rakaia River valley, in a trough cut in the rock on the slopes of the valley. Its length is eleven miles. The lake enables the fall in the Rakaia River bed in this distance to be utilised for power purposes. The lake-basin is bounded on the north by some high mountains, the highest peak being 7,200 ft.; nevertheless the flow from the lake was relatively very small when measured at the end of November last year. The Southern Alps probably screen the Coleridge basin from the westerly rains, and other mountains, Torlesse and Ben More, may do the same for the easterly rains. The flow is surprisingly small when compared with the results obtained from the other lakes whose discharges have been measured, and in view of the fact that the lake-basin comprises very high mountainous country.

It is possible by the construction of suitable works to divert the water from the Acheron, Harper, and Wilberforce Rivers into Lake Coleridge. The Acheron rises from Lake Lyndon, and has a drainage-area of twenty-one square miles above the race-intake. The Harper has a drainage-area of 124 square miles. It drains high country, and one of its branches is glacier-fed. The Wilberforce has a drainage-area of 202 square miles. It drains the eastern slopes of the Southern Alps for a length of fifteen miles, and its branches are fed by a number of glaciers.

Gaugings were made of these three streams, and also of the Coleridge overflow in November last year. The results are given in the table below, and Mr. Dobson's result for the Waimakariri is added for comparison:—

—	Flow in Cubic Feet per Second.	Drainage-area in Square Miles.	Flow in Cubic Feet per Square Mile.	Assumed Low-water Flow.
Wilberforce	1,144	202	5·72	600
Harper	419	124	3·38	200
Coleridge	82	86	0·95	50
Acheron	30	21	1·43	20
Waimakariri	1,955	927	2·12	...

Considering the physical conditions, the low-water flow of the Wilberforce in cubic feet per second per square mile may be higher or lower than that of the Waimakariri, but most likely higher. The Harper would, I think, certainly be lower, and the Acheron would be much lower. In view of the Waimakariri and other results, also of the season of the year in which the gaugings were taken, it is not safe to take the several results as the minimum flow for the streams in question. At present I would not be prepared to assume more than the figures in the last column. The Coleridge and Acheron results are surprising. Only a small part of the Acheron flow is regulated by Lake Lyndon, while all the Coleridge outflow is regulated by the lake. Mr. A. D. Dobson, M. Inst., C.E., thinks it probable there may be a leakage from Lake Coleridge, besides the overflow. An examination of the slopes between the lake and the Rakaia, and at the upper end of the lake failed to discover any stream flowing that would account for the lowness of the outflow. Further investigation as to the reason for the low flow from Coleridge is necessary.

Many combinations of the four rivers may be made to form a scheme. Of these the following five are the most important to investigate, a draw-off tunnel at a sufficient depth below the present lake-level being assumed in each case:—

(*a*.) All the water of Acheron and Harper to be diverted into the lake. No dam on Coleridge.
(*b*.) Same, with a dam, say, 30 ft. high across Coleridge-outlet.
(*c*.) All the water from Acheron, Harper, and low-water from Wilberforce diverted into Coleridge. No dam on Coleridge.
(*d*.) Same as (*c*), with dam 30 ft. high across Coleridge-outlet.
(*e*.) Dam built across Wilberforce to divert Wilberforce and Harper into Coleridge. This may be of various heights.

I think (*a*) might fail seriously in years of remarkably low rainfall, such as 1895 and 1896 were at the Bealey. It would give about 17,000 b.h.p. ordinarily.

To test the value of (*b*) in the absence of measurements of flow of the several rivers extending over a considerable period, computations have been made of the probable fluctations in the level of Lake Coleridge due to a rainfall equal to the Bealey rainfall for the thirteen years from 1890 to 1902, both inclusive. A coefficient of run-off equal to 85 per cent. of the total rainfall is assumed as a fair value for steep slate country. With a draw-off equal to 720 cubic feet per second, the lake-level would attain a level slightly higher than it started with, the range of level being about 58½ ft. The attached diagram shows the variations in lake-level as computed. The investigation may be taken to show that with a range in lake-level of, say, 60 ft., it would probably have been possible to equalise the flow of wet and dry years for the period dealt with, for a rainfall equal to that at the Bealey. The Bealey is only about three miles outside of the drainage-area at the nearest point, and not more than twenty-four miles from the furthest point. Even if the actual average rainfall on the basins of the Harper, Coleridge, and Acheron were different from that at the Bealey, the curve of fluctuation would probably have considerable resemblance to that given, as the average yearly rainfall would probably vary in a similar manner each year over the combined areas as at the Bealey. The assumed mean flow-off would give 29,000 b.h.p. continuously, or 58,000 b.h.p. for a plant working twelve hours a day full power.

The scheme (*c*) would probably give, say, 41,000 b.h.p. if the Wilberforce were good at all seasons for a flow of 600 cubic feet per second.

The scheme (*d*) would probably give, say, 53,000 b.h.p. on the same supposition as for (*c*).

The scheme (*e*), with a dam across the Wilberforce diverting both that river and the Harper, would probably give much greater power than the last scheme. There would probably be loss of flood water frequently, even with a dam 40 ft. above the present lake-level. The maximum power to be obtained may for the present be taken at 70,000 b.h.p.

The works required for (*a*) would be a weir across the Harper 30 chains long, and a new channel 85 chains long; also a race 2 miles 30 chains long to divert the Acheron. The diversion of the Harper would be somewhat costly, and perhaps difficult to maintain. Cost for these works, say, £45,000.

The works required for (*b*) would be the same as for (*a*), the new channel for the Harper being a little shorter, with the addition of an earth dam across Coleridge-outlet. The length of dam would be 5,350 ft., and its cost £125,000 at least. A concrete dam would be much more costly. The cost of these works would be, say, £170,000.

The works required for (*c*) would be the same as for (*a*), with weir across the Wilberforce and a conduit about four miles long. As the Wilberforce is a wide shingle river, about a mile wide at the intake, the diversion of its water would be a serious problem to undertake. The cost of these works would be, say, £345,000.

The works required for (*d*) would be the diversion-works outlined above for the Acheron, Harper, and Wilberforce, with a dam across Coleridge-outlet. The cost of these works would be, say, £475,000.

The works required for (*e*) would be the diversion-race for the Acheron and a concrete dam across the Wilberforce. This would be over half a mile long (44 chains), and, assuming good foundations to be got about 20 ft. below the river-bed, the cost would be over £1,000,000 to dam the water to a level of 40 ft. above the present level of Lake Coleridge. The cost of these works would be £1,050,000.

The above works are in each case for diversion of water into the lake, or for that purpose and storage. The cost of works for sluices, draw-off tunnel, pipes, &c., are not included in the above estimates.

To utilise the lake for storage of water, the draw-off tunnel must be placed at a considerable depth below the surface of the lake. The exact depth would be fixed when complete information is available. This will necessitate some under-water excavation for approach-channel. It also involves the execution of a considerable amount of work by means of a coffer-dam or otherwise in connection with the tunnel end, sluice-gates and their gear, &c. The cost of these works will be considerable.

The cost of the scheme (*b*), to give 29,000 b.h.p. continuously, delivering in Christchurch, say, 17,400 b.h.p., would be, in round figures, £760,000, and to give 58,000 b.h.p. for twelve hours each day, £1,200,000. These figures are given as approximations on the information available, to give some idea of the magnitude of the works involved. The gross revenue obtainable if all the energy could be sold, in either case would be about £200,000 a year. The scheme (*b*) is the only one worth considering at present, the height of dam and depth of tunnel being adjusted to make cost a minimum.

Diverting all the low-water flow from any wide shingle river by a weir and draw-off chambers on the banks would, in any case up to 500 ft. or 600 ft., be fairly troublesome; when the width reaches a mile the problem is too serious to consider, for there would be many risks. A dam across the Wilberforce is feasible, but too costly.

Rakaia.

A proposal has been made to utilise the water from the Rakaia by building dams near the road—one over the main river and another over the overflow-channel at the gorge above Methven. The drainage-area of the river above this point is about 1,020 square miles. The various branches of the river drain a length of forty miles of the Southern Alps, as against about twenty-seven miles drained by the Waimakariri, the distances being measured on the straight in both cases. Allowing for the extra length of the Alps drained by the Rakaia, until the low-water flow is determined by reliable measurements and observation, I do not put the low-water flow of the Rakaia at more than 2,600 cubic feet per second.

The lowest point of the road approaching the bridges is 45 ft. above low-water level. After making adequate provision for the flood-water passing over the dams or otherwise, it would not be possible to raise the low-water level of the river by more than about 30 ft. If a power-station were placed near the bridge, after deducting back-water due to flood, there would not be more than 5,000 or 6,000 b.h.p. at the most obtainable from a scheme such as this. The cost of two dams would be about £50,000, or more if the depth to the rock in the river-bed is great, and there would be other accessory works.

If the Rakaia were to be utilised by damming, the rock gorge just above the bridges would be suitable. A greater height would be obtainable, but the cost would be very large.

Lake Heron.

This lake lies in the Rakaia Valley, at an elevation of 2,267 ft. above sea-level. Its drainage-area is sixty-six square miles, and it is partly fed by a glacier-stream. The flow from the lake was found to be about 300 cubic feet per second. By taking a race to the Rakaia River about 200 ft. fall would be obtainable. The length of race would be about twelve miles. The lake-stream would be utilised for about four miles, leaving eight miles of race to construct. Somewhat over 8,000 b.h.p. continuous working would be obtained by utilising Lake Heron. The area of the lake is about five square miles. Its level could cheaply be raised by 10 ft. The high elevation is objectionable, as likely to engender trouble from frost. There are no streams that could be diverted into Lake Heron to increase the power.

Ashburton.

Both the south and north branches of the Ashburton River were examined. The south branch has a drainage-area of 205 square miles, and its flow at the time of inspection was over 300 cubic feet per second. The north branch is rather smaller than the south branch. Dams to store water could not be constructed, and without these any scheme to utilise either stream would only be a small one, and, in the absence of storage, uncertain. Further survey to give fuller information might, however, show that a scheme of fair size could be got.

Rangitata.

There is a site for a dam or weir on the Rangitata, in the gorge twenty-three miles above Geraldine. The sides of the gorge are of rock for a height of 200 ft. or more, and probably rock foundations would be got in the river-bed at a reasonable depth, but this has not yet been tested. The drainage-area of the Rangitata above this point is about 608 square miles, and the watershed drains a length of about thirteen miles of the Alps. Its low-water flow for the present may be taken at 1,100 cubic feet per second, until reliable data are obtained from observations extending over a sufficiently long period.

Two schemes are possible for utilising the water from the river at this place. One is to build dams and use the water at a power-station near the dam. A dam 150 ft. high would probably cost £250,000, and give about 14,000 b.h.p. A dam 200 ft. high would cost £500,000, and give 19,000 b.h.p., the power in both cases being computed on the assumed flow of 1,100 cubic feet per second. As the gorge is narrow above the proposed dam no storage could be got to modify these results, except that perhaps storage for twelve-hours-a-day schemes might be got.

With a dam, say 100 ft. high, costing perhaps £140,000, and a race to carry the water to a point seven miles down the river, an effective fall of, say, 250 ft. might be got. The amount of power obtainable would be about 25,000 b.h.p.

These Rangitata schemes would be relatively expensive.

Opihi.

The Opihi gorge begins about three miles below Fairlie, and is about three miles long. There is a fall of about 300 ft. in the gorge, and a further fall of about 100 ft. to the junction of the Opihi and Opuha. It is probable that some of this 100 ft. could be utilised by armoured concrete or steel pipes extending beyond the end of the gorge. The drainage-area of the Opihi above the gorge is 150 square miles. A flow of about 200 cubic feet per second was observed last winter. No minimum summer flow has been observed. It is an easy matter to reinforce the Opihi by running into it the low-water flow of the two Opuhas, with a drainage-area of 140 square miles; also, the Tengawai Stream, with a drainage-area of sixty square miles, could be diverted into the Opihi. All four streams drain mountainous country, with peaks 2,100 ft. to 7,600 ft. high. About two hundred square miles out of the 350 may be classed as mountain-area, and should give a good flow of water. It is probable that some storage could be got by building a dam at the upper end of the gorge, but no data have been got as yet on this point, and the reservoir would likely silt up in a short time. The sides of the Opihi gorge are very steep, and there will likely be a large proportion of drive and flume in the conduit. Though the rainfall at Fairlie is relatively low, I think the mountain-areas should yield water enough to give at least 6,000 to 7,000 b.h.p. for continuous working, or, say, 13,000 b.h.p. for twelve hours a day.

A power-scheme at Opihi would command a large tract of country from Oamaru up to, say, Ashburton, or to Christchurch, to join up with a transmission-line from the Clarence scheme at Jollie's Pass.

A full survey of the whole scheme is, I think, warranted, with extended observations on the flow of water in the various streams, so that the probable amount of power and the cost of the necessary works may be estimated.

Lake Tekapo.

The Tekapo River is the largest volume of water at a very high level (2,323 ft. above the sea at the lake-outlet) available for power purposes in the colony. Lake Pukaki, thirteen miles distant, lies 735 ft. below Tekapo on the south, while on the north the valley of the Opihi at Silverstream is 1,060 ft. lower than the lake, and the distance from the lake is eleven miles and a half in a straight line.

The drainage-area of the lake is about 610 square miles, and the area of the lake thirty-four square miles. The length of the Alps drained is relatively short, only ten miles. The flow from the lake, when gauged, was 5,100 cubic feet per second. Water from the Forks River and the Edwards could be diverted into the lake to slightly reinforce the flow.

The question of how best to utilise the water flowing from the lake, in whole or in part, for the generation of power, is one of interest, even though the complete carrying-out of so vast a scheme is quite beyond present-day requirements.

Trial lines for races have been run from Tekapo to Pukaki Lake, and a branch from this down Mary's Range to Simon's Pass, and from Tekapo through Burke's Pass down the Opihi; also from this line branching down the Tengawai.

The line to Pukaki Lake has a final fall of 600 ft. between the end of the race and the lake, and the pipe-line would be 145 chains long. The race would be 16 miles 7 chains long. There would be six tunnels, one 94 chains long, starting at the lake; the total length of tunnels being 3 miles 21 chains. The first four tunnels are necessary if water is taken out of the lake at about its present level. About 93 chains of flume would be required, and about 11 miles 53 chains of race. The difficulties in this line lie in getting out of the Tekapo Lake and clear of the terraces along the Tekapo River. The lake-level is now much too low to enable the best ground for a conduit being got. Raising the water-level by a dam would help, but only partially. The lake-level could be raised about 50 ft. by a dam. After that height the cost would increase by the dam lengthening. There would be difficulty in providing for flood-flow in exceptional seasons. The dam would be built on moraine drift, and protecting the toe of a dam would be expensive.

A line was run branching from the Pukaki line at about fourteen miles towards Simon's to ascertain what fall was obtainable from a suitable point on Mary's Range. Simon's Pass was too low and wide to allow of a race being carried over it. A race terminating at Simon's Pass would only have 360 ft. fall, and be twenty-five miles long.

A grade was run from Tekapo towards Burke's Pass, and then down the Opihi to a point about five miles and three-quarters below the pass, where a fall of 560 ft. is available. The length of race would be about seventeen miles and a quarter. There would be 3 miles 44 chains of tunnels on this grade—one at the outlet of Tekapo two miles long, and one through Burke's Pass 74 chains long. About 135 chains of fluming would be required, and about twelve miles of ditch. The pipes from the end of the race to a power- station would be about 28 chains long. It would be less expensive to carry a given volume of water by this route than to Pukaki. The shorter length of pipe between the end of race and power-station would cause a great saving if a large quantity of water were used. The power-station would be nearer settled districts, and over thirty miles of transmission-line would be saved. A race to carry 600 cubic feet of water per second would give 30,000 b.h.p. at the power-station about ten miles from Fairlie.

Branching from this line at Burke's Pass, an exploration was made towards the Tengawai, and split into three branches. The first ran through the hills towards Fairlie, and gives a line about 20¼ miles long, with a final fall to the flat at the back of Fairlie of 600 ft. There would be four and three-eighths miles of tunnelling on the line, and some fluming.

The second terminal branch of this line ends over the Tengawai gorge, giving a line 27¼ miles long, with a final fall of 1,030 ft. into the Tengawai. The length can be reduced by about two miles by a tunnel. Rough hillsides would be traversed, and in the last seven or eight miles a number of expensive flumes would be required. The cost of the works would be great as compared with the other line to Opihi. The power obtainable would be about 56,000 b.h.p. for a race carrying 600 cubic feet of water.

A third branch of this line goes down a spur to the junction of McKenzie Creek with the Tengawai. Its length is 21 miles 50 chains, and the final fall obtainable is 550 ft. A great length of fluming would be required over the last three miles and a half of the race. This would be a longer line than to the point selected on the Opihi, and would be much more expensive, while slightly less power would be got.

To attempt to utilise all the water from Tekapo by taking it either to Pukaki Lake or to Opihi by the respective routes above described would be very costly, and tunnelling through the moraines would be attended with some risks during construction, and after, if leakage of water through the tunnel-lining occurred. It is possible that fluming along the river-bank would be cheaper and safer. I have no doubt this would be seriously considered if any scheme were ever undertaken. If all the water were taken the wear of the river on the banks would cease, except in exceptional floods, and then would not last long.

Any water brought from Tekapo to a power-station in the upper Opihi could be used again at a power-station in the Opihi gorge, and a very large additional amount of power be thus got.

The best scheme for utilising all the flow from Tekapo, if ever it is desired to do so, would be to drive one or more tunnels from the lake towards Silverstream, and from the end of the tunnel take the water in pipes to the level of the Opihi. About nine miles and a half of tunnel would be required. About two miles and a quarter of this length could be excavated from adits as well as from the end. The length of continuous tunnel would be seven miles and a quarter. The other two miles and a quarter should be all tunnel in preference to part open conduit.

The pipe-line would apparently be from a mile and three-quarters to two miles long. The tunnel might be straight or bent to get an adit, if possible, to shorten the length of lead. All leakage losses from conduit would be avoided by this scheme. The fall obtainable would be from 850 ft. to 900 ft., and the power would be 400,000 b.h.p. for continuous working, and, say, 800,000 for twelve hours per day.

The lake would be dammed to store water to the maximum possible height—perhaps 50 ft. The cost for dam, sluices, pipes, &c., all work up to the turbines, would be great, say, £6,000,000—a sum relatively small compared with the £880,000 for the "Jonage" canal, giving only about 4 per cent. of the power. In the wide valley of the Opihi, with the large extent of relatively flat land and easy transit facilities, many industries should be possible in which the power would be used direct, and all the conversion and transmission losses saved. The scheme should create industries enough to support a large city. In addition to the 400,000 b.h.p. available from the first scheme, another giving, say, 150,000 b.h.p. from using the water a second time in the Opihi gorge would be possible.

Utilised near the power-stations without conversion, the power in the two schemes is equal to that obtainable from the best steam plant using 4,300,000 tons of the best coal a year, and, if transmitted to various places, equal to power obtainable from 2,500,000 tons of coal per year.

The cost of the combined schemes would be, say, from £16,000,000 to over £31,000,000, according as twenty-four hours per day, or, say, twelve hours per day full power were worked. At the rates assumed above, the revenue would be at least £3,500,000 a year. The scheme is an immense once; so will the results be whenever New Zealand's industrial progress warrants the development. I think the scheme would be a financial success with lower tariffs than assumed in computing the above revenue. The difficulty will be in using the power.

Other schemes would probably be possible, starting from the Tekapo River and taking the water through Mackenzie's Pass, or in any other direction where a good fall is obtainable; as to Mary's Range below Simon's Pass, these would not offer the same advantages as the Silverstream scheme, and there would be loss of water from the canals.

There would be objections to the Silverstream scheme from the large increased volume of water in the Opihi. This would have its real force only at times of extremely high flood. In view of the advantages to be gained, the objection will not hold One difficulty may lie in the risk of the water cutting a deep channel in the present bed of the Opihi from Silverstream to the gorge. This depends much on the nature of the materials immediately underlying the bed of the stream. The fall per mile in the Opihi channel to the gorge is only a little greater than the fall per mile in the bed of the Tekapo River from the lake to its junction with the Waitaki. This point and many other questions would require to be carefully investigated.

Lake Pukaki could be made use of to develop power. The flow from the lake is very large. The water could be raised by a dam, and then carried down the terraces as far as possible. No surveys have been made to determine the fall likely to be available, but it would not be more than 120 ft., if so much. The greatest height of dam would be about 70 ft. The dam would be about 650 ft. long on top, and about 300 ft. at water-level, raising the lake-level by, say, 60 ft. If Pukaki were dammed to any height, a corresponding diminution of the height available for a power-station for Tekapo would result. About 70,000 b.h.p. would be available for a complete scheme for Pukaki. The works would be costly. Providing for the flood overflow over the dam would necessitate heavy works, as the dam would be in moraine. No information was got as to any partial scheme, as the conditions did not seem very favourable. The drainage-area of the lake is 523 square miles; the area of the lake is thirty-one square miles; and the length of the Southern Alps drained is thirty miles. The volume of flow measured in October last was 6,800 cubic feet per second, with a corresponding probable low-water flow of 5,000 cubic feet per second, as deduced from the levels given for low-water level of the river, but this appears low when compared with the similar results obtained for Ohau.

Ohau Lake.

A dam about 70 ft. high, or more, could be built at the outlet of the lake, and there would be a smaller dam likely to be required to the west of the outlet, to close an old channel. The height of this old channel above the lake was not determined. Perhaps it is too high to require any bank. A fall of about 225 ft. in the river is available at a point about four miles and three-quarters below the lake, measured in a straight line. The whole water or a part of it could be taken to this point in a suitable conduit in the form of a canal, flume, or in tunnels, as required by the configuration of the country, which consists of old river flats and terraces. Just beyond the point selected for the termination of the conduit, there is some slipping country, along which it would be injudicious to carry a conduit for water, while further down there is the sloping plain leading up to Benmore Station, which would be likely to cause a considerable *détour*. The Ohau Lake is 1,720 ft. above sea-level. The river falls about 300 ft. to the road-bridge, which is seven miles from the lake in a direct line, or about nine miles and a half by the river. There is, probably, a further fall of about 300 ft. at the junction of the Ohau with the Waitaki. The distance from the bridge to the junction is about seven miles.

The volume of flow in the Ohau River, when measured in October last, was 5,870 cubic feet per second. The flow at low-water level would be just under 5,000 cubic feet. The area draining into the lake is 420 square miles. The area of the lake is twenty-four square miles. The length of the Southern Alps drained is twenty-one miles.

It should be possible by building a dam to conserve the water and to raise the lake-level a height of, say, 60 ft.—30 ft. to be used for storage and the remainder to give additional head and perhaps thereby facilitate the construction of the conduit. Somewhat over 100,000 b.h.p. can be got at the power-station at the point on the river above described. The works would be very costly, and no survey having been made, it is not possible to give any approximate estimate.

A dam could be built across the Ohau at the rock gorge where the road-bridge is built. Its extreme height, having regard for the safety of the terraces on each side, would be, say, 75 ft., but to give due provision for flood-water passing, the low-water level should not be raised more than 60 ft. to 65 ft. A power-station could be built a short distance below the bridge, where about 30,000 b.h.p., at most, would be available. The dam would cost £175,000. The conduit could be taken to any further distance down the river which might be deemed desirable. There would be some apparently open ground to be crossed, where there might be danger of loss of water through the shingle. A survey would be required before any further statement could be made as to the value of this proposal. A considerable addition to the power available at the bridge would be got, but at a very considerable addition to the cost.

Below the junction of the three streams from the lakes, the Waitaki continues to flow over a wide shingle bed for about eight miles; then the hills close in, and at about ten miles down a dam might be built to utilise the water. Further down stream at the Goose Neck, about one mile in a straight line above the junction of the Ahuriri River, a dam could be built, or at the best place in the bend. There can be no very great fall in the river here, and only the height due to the dam would be available, whatever it might be. The fall in the river is too slight to justify any attempt to carry the water any distance beyond the dam by tunnels. The low-water flow of the river might be taken as 15,000 cubic feet per second at this point. The flood-rise would begin to be felt here in damming back water against the turbines. A dam about 90 ft. above low-water level should easily give 100,000 b.h.p.

The Waitaki might also be dammed a few miles above Kurow, but I did not ascertain to what height, as this would be one of the last projects likely to be attempted.

Ahuriri River.

There should be a considerable fall obtainable by taking a race from the Ahuriri River at the commencement of the gorge just below the junction of the Otamatapaio or Gala River with the Ahuriri. The race would go in a tunnel, if necessary, through the neck, about a mile above the junction of the Ahuriri, and then through a short tunnel through a neck between the Ahuriri and the Waitaki to a power-station on the banks of the Waitaki. The total length of race would be about five miles. The fall obtainable might amount to about 200 ft. The drainage-area of the Ahuriri above the race intake is 620 square miles. The river is said to run low in the summer, but as the head-waters rise in very high country, I am inclined to think there must always be a very considerable flow of water in it, sufficient to give, at the very least, 5,000 or 6,000 b.h.p. When I saw the river in November last there was water enough in it to give four or five times this amount of power. A little storage might be got, enough to conserve the low-water flow for the hours not worked in a week. The power-station would be in an easily accessible position, being about two miles and a half from the main road, with ground easy to travel over between. The distance from Kurow is twenty-one miles.

This would be an excellent location for a power-station for a light electric line from Kurow to Pukaki Lake and Hermitage.

Deep Stream.

An examination has been made of this stream to a point twenty-two miles above its junction with the Taieri. The height of the Taieri at this point above railway datum is 294 ft., and at the twenty-two miles, the Deep Stream attains an elevation of 1,210 ft. The best point to take the water from the stream may be just above the traffic bridge. The river for five miles above this point has only a rise of 40 ft. The minimum flow at the twenty-two-mile point was taken to be 90 cubic feet per second. The drainage-area above this is seventy-seven square miles. Above the traffic bridge the drainage-area is 101 square miles. The minimum flow should therefore be somewhat greater—about 110 cubic feet. Supposing a dam were built at this point, say 40 ft. high, water would be stored in a length of about five miles of the river-channel. The width, however, would not be great. It is advisable to locate a race as high as possible, to keep clear of the precipitous gorge near the Taieri. Raising the level by a dam would help this, and also making the race on a flat grade. The power obtainable at the power-station would be 7,000 b.p.h. continuous working, or 14,000 for twelve hours, so far as the information at present goes. The power-station would be quite near the Deep Stream Railway-station.

Taieri River.

This river was gauged in November last year at a point about a mile below the Sutton junction. The flow was found to be 1,094 cubic feet per second. The drainage-area of the river above this point is about 1,260 square miles. The corresponding minimum flow of the river is put at about 700 cubic feet per second. By taking a race from the Sutton to the Deep Stream—a distance of 14½ miles—a fall of about 220 ft. effective head would be got. This would give about 14,000 b.h.p. at the power-station. The length of the race would make the cost of the hydraulic part of the scheme somewhat costly, whether the water is taken in whole or in part only. It is possible to store water in some of the upper tributaries of the Taieri. Two dams proposed to be built in the Taieri Floods Commissioners' report in 1877 were estimated to store 4,200,000,000 cubic feet, at a cost of £66,000. One of the possibilities, the Taieri Lake, could only be partly utilised now, owing to the level at which the railway has been constructed, but possibly further supplementary storage could be found. It is possible that the reservoir on the Kyeburn basin would not always be filled in years of low rainfall, and without reliable data as to yearly flow for the streams on which a reservoir is situated, there may be some doubt as to its efficiency for power purposes. The low minimum flow of the Manuherikia throws some doubt on the above assumed minimum flow of the Taieri. Considerable portions of the two river-basins are fairly comparable as to climatic conditions. Should it be found that the minimum flow of the Taieri falls as low relatively as that of the Manuherikia, the value of the river for power purposes would be seriously diminished.

It should be possible to get some power from the Taieri in the gorge between the Taieri Lake and Hyde. No levels have been got for this part of the river. There is a fall of about 500 ft. between the lake and the Sutton. Part of this may be concentrated in the gorge. At one or two places in this reach of the river probably a dam would give fairly favourable results. Smaller power schemes might be possible in the upper sections of the river.

Clutha River.

Suggestions were made as to utilising the flow of the Clutha River above Beaumont. For five miles above Beaumont the fall in the river is about 8 ft. per mile, and from Talla Burn to Teviot the average fall is under 5 ft. per mile. The flood-rise is 20 ft., more or less, according to the width of the river. It would take a number of miles of useless conduit to get water for power purposes clear of the flood-level, and the suggestion is not worth any detailed consideration.

Beaumont Stream.

This stream joins the Clutha at Beaumont. The ordinary level of the Clutha River at this point is 131 ft. above sea-level. The flood-rise is 20 ft. The stream rises to a height of about 930 ft. above the sea, five miles from its junction with the Clutha. The drainage-area above this point is small—only seven square miles. The flow at the time of examination was 12 cubic feet per second. A dam to store a considerable quantity of water could be got at the 930 ft. level. Possibly about 800 b.h.p. continuously could be got by a race five miles long, or more, to carry the water from the 930 ft. level to a power-station on the Clutha River. A dam would enable more power to be got, the amount depending on the storage obtainable.

Talla Burn.

This stream joins the Clutha about five miles above the Beaumont. The Clutha River here is 170 ft. above sea-level, and the flood-rise is about 20 ft. About two miles and three-quarters up from the junction the Talla Burn attains a height of 1,085 ft. above sea-level. At this place a reservoir can easily be constructed to store a large quantity of water. The drainage-area above this point is nineteen square miles. The minimum quantity of water flowing in the stream at the proposed reservoir-site is given as 30 cubic feet per second. With a race of three miles or more to carry the water to a power-site on the Clutha clear of flood, about 2,600 b.h.p. should easily be obtainable for continuous working; or, say, 5,000 b.h.p. for twelve hours' full-power working each day. The actual amount of power will depend on the storage obtainable by the expenditure of a reasonable sum on a dam. A considerable increase in power over the figures given would be got by storage.

Teviot River.

This river joins the Clutha just opposite Roxburgh. The level of the Clutha here is 257 ft. above sea-level, and the flood-level of 1878 is 291 ft. above sea-level, as ascertained by levelling down from a trig. station. At a distance of about three miles and a quarter from the Clutha the Teviot attains a level of 1,203 ft. Above this point the drainage-area is 115 square miles, and the minimum flow is put at about 140 cubic feet per second. The flow actually measured in March last was 230 cubic feet per second. A dam at this proposed point of intake would store a large quantity of water. In addition to this there is a large reservoir already constructed, known as Lake Onslow, 2·28 square miles in area; also some others. Onslow Lake controls sixty-six square miles of watershed, and this should be by far the best part of the river-basin for catchment purposes. The storage-capacity of the lake can be increased considerably. The power obtainable should be over 15,000 b.h.p. or more, depending on the amount of storage available, effects of frost, &c. These figures are for continuous working; for half-time full-power working about 30,000 b.h.p. should be available. A number of water-rights are held to take water from this stream to a total amount of 153 heads. Only about half of this quantity is used. Thirteen separate rights have been issued. Seven of these, for a total of sixty-five heads, expire at various times from 1940 to 1945; the remaining six, for a total of eighty-eight heads, expire at various times from the present year up to 1918, and of these, two for forty-seven heads in that year. The hillsides are not very suitable for the construction of water-races; the miners generally use flumes; and a large race for a power-station would therefore have to be in great part either flume or tunnel to avoid as much as possible all risk of failure. A complete survey of this river is required to determine the extent of storage available, the quantity of water flowing at various periods of the year, the best point of intake, length of race and pipes, frost-effects, &c. So far as the information available goes it seems to be a most promising scheme and is worthy of very complete investigation.

The Earnscleugh River is now utilised for an electric plant to work some dredges. A high fall is available in a short distance, and it appears likely that a considerable amount of power might be got here if storage could be cheaply provided. The drainage-area available may be taken as sixty-five square miles, but it is situated in a comparatively low-rainfall region.

Manuherikia River.

Water can be taken from this river just below Ophir, and carried by race to Chatto Creek, a distance of seven miles. Here a fall of 350 ft. is obtainable. The drainage-area of the river above Ophir is about 800 square miles, but the minimum volume of flow is very disappointing, only amounting to 200 cubic feet per second. The river-basin is bounded by high mountain-ranges, altitudes of 5,000 ft. to 6,000 ft. being reached by the peaks, yet the flow is very small. Power to the amount of 5,000 to 6,000 b.h.p. would be obtainable at a power-station at the junction of Chatto Creek with the Manuherikia, just alongside the second crossing of the Otago Central Railway over the Manuherikia. The race would traverse difficult ground for about two and a half miles, where it might be necessary to have recourse to drives. There would be flume or siphon about 1,300 ft. long, the depression to be crossed being 150 ft. deep, and there would be a second depression about half a mile long and about 30 ft. deep. This could be crossed by armoured concrete pipes. The works would be likely to be somewhat expensive for the amount of power obtainable. The river at present carries much silt, due to mining operations.

Hawea.

This lake lies at an elevation of 161 ft. above Lake Wanaka, as ascertained by accurate levelling from trig. stations to the water-level of each lake; Hawea being at a height of 1,083 ft. above sea-level, and Wanaka at a height of 922 ft. The distance between the lakes is 135 chains; but there is a lagoon of some size formed by detritus brought down by a creek flowing into Hawea, which reduces the distance to 100 chains. The lagoon is at a level of 8 ft. above the lake, and a channel could easily be cut to give free flow from the lake to the lagoon; though if the lake-level were permanently raised by a dam as proposed below, not much, if any, dredging would be required.

The drainage-area of the lake is 567 square miles, and the area of the lake is forty-five square miles. The length of the Alps drained is about fourteen miles. The flow measured in November last was 5,700 cubic feet per second. The corresponding low-water flow, as deduced from probable low-water levels, would be about 3,600 cubic feet per second, and the flow at high level about 9,600 cubic feet per second.

I think the lake can be safely dammed to a height of 60 ft., or perhaps a little more. The present outlet of the lake would be closed by a dam of sufficient height to prevent any chance of overflow. An overflow-channel would be provided, if thought necessary, in a second and smaller dam that would be required over an old channel on the right bank of the river lying parallel to the present channel, and distant a few chains from it. The old channel has rock sides, is separated from the present channel by a ridge of rock, and is in every way suited for an overflow-channel; and could, perhaps, be used to divert the river for forming the main dam during the construction of the latter. The lower end of the lake is bounded by a low moraine ridge with three old river-channels through it at the level of the plain, which slopes from the outer edge of the ridge evenly towards the Clutha River. The average level of the upper end of the plain is about 80 ft. above the lake.

Taking 30 ft. for storage and 30 ft. for permanent rise in the lake-level, the difference in level available would be 191 ft. The water-level in Wanaka rises in extreme floods such as in 1878—about 12 ft. When this happens there would be a corresponding rise in the Hawea Lake, or more, on account of the dam, as it is hardly possible for a flood of that height to obtain in Wanaka without a similar one in Hawea. It may therefore be taken that in extreme floods there would be no loss in power from a diminution in difference of levels, but there might be a small flood in Wanaka and no corresponding rise in Hawea. The best type of water-motors to meet the flood conditions would be turbines with vertical axes, fitted with draught pipes sufficiently long—15 ft., more or less—so that they would work safely in all levels of Wanaka Lake; the generators being fixed on the vertical shafts of the turbines at a safe height above flood-level. There would be wave-action to provide for in high floods. The waves might be of some height, and flood a power-station with broken water and spray.

The total length of conduit required from the lagoon to Wanaka by the shortest route is 6,600 ft. Of this length about 500 ft. would be pipes, 1,500 ft. canal at the Hawea end, and 4,600 ft. tunnel. This would begin about the upper end of the swamp above the lagoon, and apparently be in solid schist rock for its whole length. For continuous work a tunnel 24 ft. to 25 ft. in diameter would be required, depending on grade, the smoothness of finish, &c., of the lining, and the probability of the smoothness remaining unimpaired. The pure water of the lake should have but little cutting-action on the tunnel-lining, pipes, or working-parts of turbines, though the creek whose detritus formed the lagoon would at times cause some grit to go through the tunnel.

The power obtainable should be about 90,000 b.h.p. for continuous working. The cost for hydraulic works, dams, sluices, tunnel, pipes, &c., would be about £460,000, and the cost, complete with transmission-line to Dunedin, would be about £2,200,000. For a scheme to give more power for a shorter period each day, say, 180,000 b.h.p. for twelve hours, the cost would be about £4,300,000. Assuming that 50,000 b.h.p. were delivered in factories, or for lighting, &c., to Dunedin and intermediate places, the gross revenue, at the tariff assumed for this report, would be £600,000 a year, if so much energy could be sold.

There is a very good site for a power-station on the shore of Lake Wanaka, opposite the lagoon, in a slight indentation with some shallow water in front, though it would even there no doubt be exposed to effects of wave-action in heavy gales; but this is inevitable. This site is further up the lake than the point where the shortest line from the lagoon would cut the lake-shore. It will be a question whether the tunnel should not be made longer to enable the power-station to be located at this place.

The power-station would be distant about 170 miles from Dunedin by a transmission-line following the road *via* Cromwell, Alexandra, Clutha Valley, Tuapeka, and Milton. Another route might be practicable over the Dunstan Mountains *via* Thompson's Pass, and the route of the Otago Central Railway.

This would be about 140 miles long. By another route *via* Shag Valley the distance to Palmerston South would be about 110 miles, and from this point the distance to Dunedin would be about thirty eight miles, and to Oamaru, thirty-seven miles, making the total distance to Dunedin and Oamaru, say, 148 miles each. Power would be taken from a line at many intermediate points, and no doubt some branch-lines would be required. These have not been taken account of in the estimates given. Also there would be main lines following different routes with so much power to transmit.

Hawea is an excellent source of power. The only defect is the length of transmission-line required to reach the, at present, most populous districts. It has been found to be better in every respect than I anticipated in my first forecast to you of its value. The fall between the lakes is found to be greater by 27 ft. than is shown on the survey maps, and the quantity of water available is much greater than I thought it would be.

The Clutha was gauged just below the junction of the Hawea River at the punt-crossing. The observed flow was 23,540 cubic feet per second, but the river was in partial flood. The ordinary summer flow would be, as deduced from the summer level given, about 18,700 cubic feet per second, and the low-water flow about 9,000 cubic feet per second. These actual results seem to be higher and lower than the corresponding results for Wakatipu. They are, however, only approximate. Higher results might be expected from the Wanaka because of the relatively great glacier-area in the watershed.

Lake Wakatipu.

Many suggestions have been made as to utilising the Kawarau rapids at the outlet of this lake. Accurate levels of the relative height of the rapids and the flood-level of the Shotover River show conclusively that any such scheme is impracticable, as the flood-water from the Shotover backs up to nearly the level of the rapids. At the time the levels were taken there was only 2½ ft. of fall from the rapids to the Shotover junction.

No scheme for utilising Wakatipu by a dam at the lake-outlet would now be admissible. All settlements round the lake would be destroyed, except, perhaps, the higher parts of Queenstown.

The flow in the Kawarau was gauged and found to be 12,400 cubic feet per second. The lake ordinarily has a variation in level of about 5½ ft. A daily record of the lake-level for a continuous period of 800 days was obtained from the Postmaster at Queenstown, from which the probable mean flow of the Kawarau for this period was computed, and found to be just over 11,000 cubic feet per second; the actual discharge probably fluctuating between about 9,300 cubic feet per second and 16,800 cubic feet per second, the average discharge being 9·63 cubic feet per second per square mile of the lake drainage-area, 1,150 square miles. The area of the lake is 110 square miles. The flow represents a rainfall of about 131 in., all running off, during the period over which the above average flow obtained. The average annual rainfall at Queenstown is low; and during the period for which the above mean flow was computed, was at the rate of 31·08 in. a year. To account for the observed flow, the rain- and snow-fall on the mountain-tops and higher slopes must be very great—greater perhaps than at Puysegur Point. This result, so far as it goes, is very valuable, as showing the flow that may be expected from any of the large lakes in the Alpine districts of South Canterbury and Otago.

There is a fall of 544 ft. in the Kawarau from Lake Wakatipu to Cromwell, a distance of, say, thirty-three miles. It may be that the fall in some reaches of the river is more rapid than at others, and at such places, by means of a dam and a tunnel of some length to take the water to a wider reach where the flood-rise would not be seriously great, a power scheme of some magnitude should be obtainable. The reaches of the river at the bends above and below the Nevis junction appear promising places to get a fair fall by tunnels up to about four miles long. If the river has its average fall in these reaches, schemes up to 100,000 b.h.p. could be got.

The Kawarau schemes, like those on the Waimakariri, would, I think, be relatively costly.

Shotover.

From Lake Wakatipu to the Water-level of the Shotover at Arthur's Point Bridge there is a rise of over 130 ft. The rise from Arthur's Point to Skipper's Bridge is about 490 ft. Above Arthur's Point there appear to be some very narrow gorges, where the river could be easily dammed. With a dam and a conduit about four miles long, a considerable proportion of it being in tunnel, an effective fall of about 250 ft. should be obtainable at the lake for the water from the Shotover. The power obtainable might reach 15,000 b.h.p. The dam would tend to clear the water from mining-silt—if made high enough to dam the water back for say two miles or more—possibly quite clear enough for working water-motors without very serious wear. The lake-areas in the Shotover basin are not large enough, nor do they trap enough of the drainage-area to regulate the flow to an appreciable extent. The drainage-area of the river above Arthur's Point is nearly 400 square miles, and the rain- and snow-fall on some of the high mountainous country must be considerable.

Sutherland Falls, Etc.

These falls, if in a more accessible locality, would furnish a good power scheme. The area feeding them is not large; but, considering the rainfall along the coast, it is very probable that each square mile of drainage-area would yield water enough to give over 2,000 b.h.p. at a station located at the foot of the falls. Altogether a considerable amount of power could be got from the falls.

There are rapids on the Arthur River near the Sutherland Falls; also the Bowen and Stirling Falls in Milford Sound. These would all be small schemes, and of no present value. If Lake Marchant, between the head of Caswell Sound and George Sound, is at any considerable elevation above the sea-level, it should give a fair power scheme, as it apparently should possess a good drainage-area. Lake Alice, at the head of George Sound, is another lake which might furnish a considerable amount of power, depending on its elevation above the sea. It is only about three-quarters of a mile from the sea. There are falls on the stream flowing from it.

Lake Hall.

This lake lies at an elevation of 2,625 ft. above the sea-level on the north shore of Gear Arm, Bradshaw Sound. It discharges into another small lake at a level lower by 25 ft. A dam at the outlet of this second lake should easily divert all water back into Lake Hall (unless the conditions are very unfavourable); and thus the water from a drainage-area of about seventeen square miles would be rendered available for a power scheme on the shore of Gear Arm. The combined area of the lakes in the drainage-basin is about 2·7 square miles, as shown on the maps, but no accurate survey of the locality has yet been made. With the rainfall probable in this locality about 40,000 to 50,000 b.h.p. should be available, if there were no loss of water by overflowing. It depends, however, on the height to which the lakes can be dammed whether this condition would obtain or not. The lake is about a mile from the sea. Supposing there is safe ground to carry a pipe-line, and good ground to drive a short tunnel through, this should be perhaps the easiest scheme to develop in the colony. It may be that at the high elevation of the lake frost would in winter seriously interfere with the supply of water. On this point no information is available. The conditions appear favourable for the establishment of electro-chemical or electro-metallurgical industries, either on the shore of the Sound at the power-station, or at the islands at a short distance opposite. Deep-water access to a power scheme of this magnitude for sea-borne traffic may yet be found of value.

There should only be a short length of mountainous country to cross with a transmission-line *via* Lake Cecil. If there is no pass, or the ground is unfavourable on this route, a line could be tried *via* Lake Hall, down Gorge Burn. This line need not rise higher than the level of Lake Hall, as the line could be taken through a tunnel if the mountains are too high. There would be a distance of about ten or eleven miles to traverse to reach the shore of Lake Te Anau; twenty miles along the south shore of the lake would bring the line to the outlet of Te Anau—in all a distance of thirty-one miles. The stability of the ground between the power-station and Te Anau outlet would be a governing factor as to the value or otherwise of the scheme for transmission purposes. From the outlet of Te Anau to Lumsden is forty-three miles, all on good country, and from this to Invercargill fifty miles, and to Gore thirty-seven miles. In the future such a source of power could be used for an electric-traction line to Te Anau and Manapouri, and from Lumsden onwards for all classes of industrial uses.

Lake Cecil.

I think investigation would show that Lake Cecil and the three lakes in chain with it would give a considerable amount of power. The lowest lake is given as 900 ft. above Lake Te Anau, and the distance from the lowest lake to the end of the South Fiord of Lake Te Anau appears to be barely two miles. The drainage-area is about fifteen square miles. A drive and pipe-line should be possible. The only question unknown at present is the stability of the hillsides. About 15,000 b.h.p. should be obtainable, or more, by damming the lakelets. The combined area of these is two and a quarter square miles approximately.

Lake Hilda.

This lake lies at a height of 1,190 ft. above Lake Te Anau. Lake Te Au and Lake Duncan drain into it. There appears to be a drainage-area of about forty-five square miles, and the area of the lakes is three square miles. The distance from Te Anau is about five miles. A drive of about this length and pipes should take the water to the same power-station site at the end of the South Fiord as the conduit from Lake Cecil. About 55,000 b.h.p. should be available.

The flow from the drainage-area of this system of lakelets should be considerably above the Te Anau average, and the same remark should hold good for the Lake Hall and Lake Cecil schemes. It is unfortunate that these schemes are not nearer to good country

Te Anau–Manapouri Lakes.

The first suggestion I made regarding these lakes was to utilise the difference of level between them, augmented as much as possible by raising the level of Te Anau by a dam. The second was to utilise the difference of level between Manapouri and the sea-level, at the mouth of the Lyvia River at the head of Smith's Sound. This latter scheme divides into two if the first is abandoned—one between Manapouri and Smith's Sound, and one between Te Anau and the head of George Sound, as the length of tunnelling on this latter route is likely to be less than on the Manapouri–Smith Sound route, and 80 ft. more fall is got for the Te Anau water. In connection with these latter schemes, I collected all the information I could get from the survey Department relative to the chains of lakes between the South Fiord, Te Anau Lake, and Gear Arm, Bradshaw Sound. The lakes are too high to be of any use to aid in connecting Te Anau with the sea, but a direct connection by tunnels is possible by this route.

The shortest distance between Lakes Te Anau and Manapouri is about four miles and a half. Te Anau could be dammed to a height of 50 ft. If 20 ft. of this height were devoted to giving extra head, and 30 ft. to storage, a very large power scheme would be possible. Two tunnels would be required to take the water. If lined, they would be about 26 ft. diameter. If it were found that the gneiss rock would stand without lining, the diameter would have to be about 32 ft. depending on the finish of the excavation. At the Te Anau end, the tunnels would begin a very short distance from the lake. At the Manapouri end there would probably be a short length of canal. At about 20 chains from the lake the terrace is about 100 ft. high above the lake-level. This would be at some height above the water-level at the end of the canal. The ground slopes to a low swamp. The power-station would be at the foot of the slope, and draw-off canals would be cut through the swamp for a length of about 12 chains to the lake. The power obtainable here may be put at 90,000 b.h.p. The cost of the dam, canals, sluices, pipes, and all accessory hydraulic works may be put at £2,100,000. Compared with the cost of the "Jonage" canal hereinbefore given, the cost for the hydraulic part of the scheme is less than half per brake horse-power. For a scheme to give 180,000 b.h.p. for twelve hours each day, the corresponding cost for hydraulic works only would be say £3,800,000.

Until Southland industries are able to overtax the Hauroko scheme, there will be no need to develop the more expensive Te Anau-Manapouri scheme. There would be objections to the scheme on scenic grounds, for damming Te Anau would injure the appearance of the lake on the wooded shores.

When the cost of electric and distributing plant is added, this scheme would cost a large sum of money. It would be a relatively costly one. The fall between the lakes is only about 80 ft., instead of 97 ft. as shown on some maps. This diminishes the value of the scheme materially. The higher fall was the one taken when the scheme was first suggested.

To develop the powers of Te Anau and Manapouri to their full extent, the water from both lakes would have to be diverted into the sounds. For the Te Anau flow, it appears at present best to consider diversion to George Sound *via* Lake Hankinson. This lake lies at a level of a little over 20 ft. above Te Anau. The distance between the lakes is very short, and by cutting a channel of less than half a mile, the water from Te Anau would be taken about three miles nearer the sea. Lake Thompson lies between Lake Hankinson and the sea. If it could also be used, the cost of taking the water to the sea might be reduced. No information is available as to the height of Lake Thompson. The distance from the upper end of Lake Hankinson to George Sound is about six miles, but the correct distance has not yet been determined by accurate survey. The cost of all hydraulic works, exclusive of steel pipes at the George Sound end, may be taken at £3,500,000, and the power obtainable at 750,000 b.h.p. for continuous working; the cost being under £5 per brake horse-power—a very low figure. Unless the conditions are very unfavourable, the total cost, including pipes for the hydraulic section of the works, should not be high per brake horse-power. It is probable that for scenic reasons the lake would not be dammed to the full height possible, if ever a scheme like this was developed.

An alternative to taking the Te Anau water to George Sound would be to take it to Gear Arm, Bradshaw Sound, if the conditions at the other sound were found to be very unfavourable. It is likely a better transmission-line route could be got from this locality than from George Sound. At least there would not be the difficulty of getting across the Te Anau Lake fiords.

The drainage-area of Te Anau Lake is about 1,354 square miles, and the lake-area 138 square miles, The fluctuation in level is about 15 ft. The winter level is about 3 ft. below the summer level. The flow from the lake in November last was 12,660 cubic feet per second, but by conserving all the water I think a considerably greater flow per second should be obtainable for power purposes.

Manapouri.

To take the water from Manapouri to the sea, a dam would be built across the Waiau River just below the junction of the Mararoa River. A very small fall has been given from the lake to the Mararoa junction, and this seems to be correct in view of the very sluggish flow of the Waiau River for the greater part of the distance down to the junction. The Mararoa River carries a large volume of water. It has a drainage-area of about five hundred square miles. A dam to reverse the flow of the river to Lake Manapouri would not probably be more than say 15 ft. higher than at the Manapouri outlet, nor would it be longer. The cost of diverting the Mararoa would therefore be small. The banks of the Waiau at the junction are also high enough—about 60 ft.—to give ample storage-volume. The lake could be raised at least 55 ft. by a dam between the terraces a short distance below the outlet. Some of this height might be lost by a dam at the Mararoa junction. A complete survey only would supply data to determine the point.

It is not likely, for scenic reasons, that a high dam would be built at Manapouri. The present beauty of the lake is worth preserving to the fullest extent. A large storage-volume can be got by damming the water a few feet above the high-flood level, and lowering the level of the draw-off tunnel. In this way 30 ft. or more in height can be got for storage.

The lake summer level is 600 ft. above sea-level, as got from accurate levelling from a trig. to lake-level. The winter-level is 5 ft. below, and high-flood level 12 ft above this level. The area of the lake is fifty square miles. The combined Manapouri and Mararoa drainage-areas are 1,010 square miles. The distance between the lake and the sea is six miles and three-quarter to seven miles.

The power obtainable may be taken at 420,000 b.h.p. continuous working. The cost of dam, tunnels, sluices, &c., would be about £2,800,000. When the cost of pipes is added, unless this proves to be excessive, the cost of the hydraulic part of the scheme would be relatively low.

It is likely a better route for a transmission-line would be got for this scheme than for the corresponding one for Te Anau. At least there would, I think, be less trouble in getting along the shores of the lake. No doubt in both schemes there would be serious difficulties to overcome in the mountains and along parts of the lakes, and troubles from climatic conditions.

These two schemes will likely remain as reserves until all the smaller schemes are exhausted. It may happen that a great part of the power would be used at the power-station in the Sounds, in electro-chemical and electro-metallurgical work. The possession of such enormous possible hydraulic-power schemes at the seashore, with deep-water access, is, so far as I know, unique. This may lead to their utilisation, at no very distant date, for industries now non-existent. The data for both schemes should be made complete enough to enable complete preliminary estimates to be made.

MARAROA.

The Mararoa River has a fall of 1,480 ft. from Lake Mavora to its junction with the Waiau. The distance is about twenty-two miles, exclusive of windings of the river. There is a large volume of water flowing in the river, and there may be some possible power schemes. No examination of the river has been made.

Monowai Lake.

This lake lies at a level of 676 ft. above sea-level. The area of the lake is eleven square miles. The drainage-area is not yet very accurately known. It is probably about sixty-seven square miles. The junction of the Monowai River with the Waiau is 390 ft. above sea-level. There is therefore a fall of about 286 ft. from the lake to the river. The length of conduit would be over five miles, and about three-quarters of a mile of this would be pipes. The lake-level could be raised by an earth dam to conserve all flood-water for power purposes. This should give an average flow of say 700 cubic feet per second. Deducting loss of head in race, and allowing for the flood-rise in the Waiau River, about 225 ft. of head would be available. This should give about 14,000 b.h.p. continuously at a power-station on the Waiau River, or 28,000 b.h.p. for full-power working for twelve hours per day. The approximate cost of a scheme to develop 14,000 b.h.p. would be £430,000 to deliver energy in Invercargill, and to develop 28,000 b.h.p. for variable working during two shifts per day of eight hours each, would be £735,000, with a probable gross revenue of £100,000 per annum. There is a very good route available for transmission-line to Invercargill, and several small townships could be supplied with lighting and power by the way. The distance to Invercargill will be rather less than sixty miles.

More power could be got out of Monowai Lake by diverting the water into Hauroko Lake, to augment the Hauroko-Poteriteri scheme, in which an effective fall of at least 410 ft. is to be obtained. In this way about 70 per cent. more power could be got from the Monowai water. The length to drive between the lakes would be about three miles by the later maps, but is shown to be more on the older ones. Whether this method of utilising Monowai would be the most advantageous or not would require some investigation to decide. The tunnel would be in schist rock, and for the purpose required might be effective if unlined.

Hauroko-Poteriteri.

Hauroko Lake lies at an elevation of 514 ft. above sea-level, and Poteriteri at an elevation of 96 ft. The difference in level between the lakes is 418 ft., and the distance between them is about two miles and three-quarters. The conduit would be part canal for 20 or 25 chains at the Hauroko end; 2 miles 10 chains of tunnel and about 10 or 12 chains of pipes, and about 13 chains of draw-off canal at the Poteriteri end, through a flat on which a power-station could be built. The level of Hauroko Lake can be raised by a dam any height found to be best, up to, say, 60 ft. Part of the height, say 20 ft., could be used to gain additional head (in which case the canal at the Hauroko end of the conduit would be of smaller dimensions), and part to give whatever storage-volume was deemed necessary. The river Wairaurahiri, flowing from Hauroko Lake, was gauged, and the flow found to be 1,800 cubic feet per second. The probable low-water flow may for the present be taken at 1,000 cubic feet per second, and the flood-flow 4,800 cubic feet per second. The area draining into the lake is about 210 square miles; the area of the lake is twenty-seven square miles. To get the utmost power for a complete scheme, all the flood-water should be retained by the dam. In this way I think water enough should be got to give 80,000 b.h.p. at a power-station on the shore of Lake Poteriteri, for continuous working, or, say, 160,000 b.h.p. for twelve hours each day full power. The approximate cost of these two alternatives would be respectively £1,700,000 and £3,000,000, and the probable revenue likely to be derived from such a scheme, if the energy were fully utilised, should amount to £576,000 a year. The distance from the power-station to Invercargill is about seventy miles by the probable transmission-line route. The scheme is one of the best in the colony, and involves great industrial possibilities for Invercargill and the surrounding districts. This is a scheme in which a lower tariff than has been assumed for the purposes of this report could be charged and yet a sufficient margin be left to cover interest on capital, staff, maintenance, sinking fund, and management charges.

The question of bringing the water from the lake to the sea has been partially considered. The shortest distance between the lake and the sea is about eight miles. If the conduit followed this route it would be nearly all tunnel. By another route the least length of tunnel (believed to be the shortest possible) would be about four miles and three-quarters, and there would be four or five miles of race. About nineteen miles of transmission-line would be saved, and the same length of road-making. Much transportation-cost would also be saved. Over 10,000 b.h.p. extra would be got from a station on the sea-shore. Without knowing the exact length of tunnel and pipe-line leading from it to the power-station, it is not possible to estimate the increase of cost, but it would probably be from 25 per cent. to 30 per cent. on each scheme given above. The extra power obtainable would justify this additional expenditure.

The height of Lake Hauroko above the sea is now given as 97 ft. less than is shown on the latest maps. The correction is a recent one. The height has now been determined by triangulation, and may be taken as reliable. The greater height was the only one available when I first outlined this scheme.

Minor Schemes, South Island.

Only very incomplete information is available regarding the numerous smaller rivers and streams in the South Island, except for Westland. The following list of rivers and streams will be largely increased when complete data are obtained, but some will no doubt be found to be of little value: Pelorus River; Wakamarina; Upper Wairau; Branch, Leatham, and Goulter Rivers, tributaries of the Wairau; Motueka River, Nelson; Conway River; Mokihinui River; Hurunui River; Broken River, Esk River, tributaries of Waimakariri; Nevis River, tributary of Kawarau; Catlin's River; Mataura, and its tributaries Mokoreta, Waikaka, Nokomai, Robertburn, Otamita, Eyre Stream; Makarewa, and its tributaries Dunsdale, Lora, Otapiri; Oreti, and its tributaries Irthing, Cromwell, Acton, Windley, Wydon; Aparima River, and its tributaries Etat and Hamilton Burn; tributaries of Waiau River—Orauwia, Wairaki, Taylors', Ligur, Redcliff, Whare, Excelsior streams or creeks, Borland, and Lillburn.

Of the tributaries of the Waiau, the Wairaki would probably give some power. It appears to carry a large volume of water, and runs swiftly. The water would be taken by race to some convenient point where fall would be got. Similar methods would apply for developing the other streams on the east side of the Waiau, but they are all much smaller streams. In some cases very good fall should be got. No examination of these streams has been made to ascertain fall available or minimum flow. The Borland and Lillburn should carry considerable volumes of water.

If the ground at the bend of the Mataura at Athol would carry a canal from the Mataura to the junction of the Nokomai, a scheme of some size could be got. About four miles of canal should give probably over 130 ft. of fall, judging from the average fall in the Mataura. If the conditions are favourable, 3,000 or 4,000 b.h.p. should be obtainable.

It will take a very considerable time to get full information regarding all the above minor schemes, and many others. Many will not be worth the trouble, but it is impossible to say beforehand which will be of little or no value.

In addition to the schemes given above, a complete examination and survey of the colony would no doubt disclose many more possible schemes of greater or lesser magnitude and economic value, and more especially would numerous schemes be likely to be found in the mountain regions of the South Island. The three large lake schemes, Tekapo, Te Anau, and Manapouri, outlined herein, will remain, I think, the maximum schemes possible for New Zealand, and though too large for present-day requirements, they will stand as the final reserves to meet the industrial developments of the future.

Having seen that an immense amount of hydraulic power is available in the colony, it remains to be ascertained what power is now used, and its present rate of increase.

The colony now possesses locomotives capable of developing about 200,000-horse power. Locomotives work somewhat irregularly as to time, and also as to effort, as in going up and down grades, &c., so it is somewhat difficult to define, without a very lengthy investigation, the maximum actual expenditure of power that would be required to run all the locomotives now in use. Possibly about 50,000-horse power would be a fair approximation to take.

From a report furnished by the Chief Inspector of Machinery, and from his annual reports, the following tables have been prepared, showing the distribution of and the amount of power now used in the colony, and the increase of steam plant:—

TABLE I.

POWER IN NORTH AND SOUTH ISLANDS.

—	Steam.	Gas or Oil.	Water.	Electricity.	Total.
	H.p.	H.p.	H.p.	H.p.	H.p.
North Island ...	88,817	3,771	6,555	370	99,143
South Island ...	74,897	3,192	3,356	89	81,445
	163,714	6,963	9,911	459	180,588

The electric motors derive their energy from the steam plant, and are not included in the totals.

TABLE II.

AMOUNT OF POWER IN USE IN THE VARIOUS MACHINERY INSPECTION DISTRICTS, AND HOURS PER WEEK WORKED.

—	Hours per Week.	Steam.	Gas.	Water.	Totals.	Grand Totals.
		H.p.	H.p.	H.p.	H.p.	H.p.
Auckland ...	144	13,108	15	1,507	14,630	
	48	32,282	1,512	3,179	36,973	51,603
Hawke's Bay ...	144	1,825	...	...	1,825	
	48	7,648	385	30	8,063	9,888
Taranaki ...	144	17	16	220	253	
	48	7,500	370	961	8,831	9,084
Wellington ...	144	10,450	...	...	10,450	
	48	15,987	1,473	658	18,118	28,568
Nelson South ...	144	5,762	...	...	5,762	
	48	2,160	23	779	2,962	8,724
Nelson North ...	144	48	12	...	60	
	48	3,425	72	142	3,639	3,699

TABLE II.—*continued.*

AMOUNT OF POWER IN USE IN THE VARIOUS MACHINERY INSPECTION DISTRICTS, AND HOURS PER WEEK WORKED—*continued.*

—	Hours per week.	Steam.	Gas.	Water.	Totals.	Grand Totals.
		H.p.	H.p.	H.p.	H.p.	H.p.
Marlborough ...	144	75	...	...	75	
	48	2,100	125	315	2,540	
						2,615
Westland ...	144	2,838	77	32	2,947	
	48	3,832	119	258	4,209	
						7,156
Canterbury ...	144	2,545	212	...	2,757	
	48	9,435	1,073	311	10,819	
						13,576
Timaru ...	144	1,145	6	...	1,151	
	48	2,340	194	89	2,623	
						3,774
Otago ...	144	8,077	30	...	8,107	
	48	17,310	1,023	1,301	19,634	
						27,741
Southland ...	144	5,575	...	...	5,575	
	48	8,230	226	129	8,585	
						14,160
						180,588

The above two tables give the amounts of power being used in October, 1903. As similar tables are not available for each year, to show the exact increase in each year, the table below, compiled from the annual reports of the Chief Inspector of Machinery, gives some indication of the growth of steam plants in the colony during the past six years:—

TABLE III.

NUMBER OF STEAM-BOILERS IN USE IN NEW ZEALAND.

Size.	1899.	1900.	1901.	1902.	1903.	1904.
	No.	No.	No.	No.	No.	No.
Under 5-horse power ...	...	907	890	981	995	1,144
5 to 10-horse power ...	...	496	490	595	634	855
Over 10-horse power ...	...	909	1,004	1,194	1,237	1,448
Totals	2,285	2,312	2,384	2,770	2,866	3,447

There has been a large increase last year in the number of steam plants. The increase in power is equal to about 18,700 effective horse-power in steam plants alone, and there has, probably, been an increase also under the heads of oil, gas, and water motors.

Table II. shows 51,465-horse power working 144 hours per week, and 112,247-horse power working forty-eight hours per week. Dividing the last year's increase proportionately between the full-time working and eight hours a day, and taking the locomotives at 50,000-horse power for eight hours a day for the total amount of power now in use (250,000-horse power approximately), the mean number of hours per day now worked would appear to be about 11¾. This is the average for the colony. The mean time for the various districts would each differ from this. From this result the cases given above of installations of plant sufficient to utilise the whole of the water in any scheme when working full power for twelve hours each day, would appear to about meet present New Zealand conditions. The mean time per day got above for the working of the existing plant of the colony is, however, only approximate, as some of the plants returned as working 144 hours, actually work 168, while others may not work full power all the 144 hours. It is impossible to get an exact time without an immense amount of labour.

The estimated amount of hydraulic power, on the information now available, stands at 500,000 b.h.p. for the North Island, and 3,200,000 b.h.p. for the South Island—a total for the colony of 3,700,000 b.h.p. continuous working—about thirty times the amount of power now used for tractive and industrial purposes.

Supposing all the schemes to be developed to work continuously, the cost may tentatively be put at £115,000,000 for the 3,700,000 b.h.p., and if developed to work full power for twelve hours a day, the cost may similarly be put at £220,000,000. These figures are intended to cover some extra plant, cost of transmission to towns, but not cost of net works of distribution in towns or motors, or other necessary machinery in factories.

The amount of effective power for motive power, lighting, &c., available after transmission, may be put at 2,220,000 b.h.p. continuous working, or 4,440,000 b.h.p. for half-time full power. At the assumed rate of £12 for the horse-power-year, the gross revenue would be £26,640,000 a year in each case, if all the energy could be utilised.

To supply electric power to take the place of all steam, gas, and other plants, also locomotives now in use in the colony, would require an installation of, say, 420,000 b.h.p. to give 250,000 b.h.p. effective. The cost would be about £12,000,000 or perhaps less by selecting the easiest-developed schemes. In addition there would be the cost of conversion of railways and existing steam plants, the cost of which would be great, also for distributing networks in towns, &c.—together, perhaps, £5,000,000; but this is only tentative as the questions all require a very lengthy study. It is, however, impossible to displace all steam and other prime movers by electrically transmitted power. The percentage of inconvertible plant cannot now be estimated.

The cost of steam plant to give power equivalent to the 2,220,000 b.h.p. or 4,440,000, b.h.p. taken above, to be available from the hydraulic schemes after transmission, would be approximately about half, or rather more than the cost of the hydraulic and electric plant, but the cost of working per brake horse-power would be much greater; about double on the average, and much more for small plants.

The coal required to give power equivalent to the amount possible to deliver as given above, would be 17,500,000 tons of the best quality of coal, used in first-class large plants, and likely to be very much more if many small plants were employed, and still more if the inferior kinds of New Zealand coal were used. This amount of coal, in addition to what would be required for other purposes each year, would, in a comparatively short time, make an appreciable inroad on New Zealand's relatively slender stock of coal, a fixed quantity only which cannot be renewed. On the other hand the potentialities of water-power will remain as a national asset as long as the climatic conditions and the mountains endure.

Some information from the "Annales des Ponts et Chaussées," *re* the Chevres hydraulic-power installation at Geneva, is given below.

USINE DE CHEVRES.

This power-installation utilises the flow from Lake Leman, all the power being sold in the City of Geneva and its surrounding districts. A dam was built across the Rhone to give a fall in lowest state of river of only 14 ft. to 15 ft.; 12,000 to 15,000-horse power obtained; cost of scheme, 8,500,000 francs—say £340,000. 5,000-horse power sold for electro-chemical industries, 4,500-horse power sold for motive power and electric lighting, and 1,850-horse power for special purposes.

The works were begun in 1893 and the first year working appears to have been 1897. In 1900 the network of distributing-lines had a length of a hundred miles, some of these lines are underground somewhat less than half the length.

The dividends in 1900 amounted to 435,700 francs. The following table shows the progress made by the company in the first four years:—

Year.	Receipts, Gross.	Expenses.	Net Receipts.	Kilowatts Produced.
	Fr.	Fr.	Fr.	No.
1897	178,412 (£7,136)	110,113 (£4,404)	68,269 (£2,731)	3,669,876
1898	269,137 (£10,765)	129,390 (£5,176)	139,947 (£5,598)	9,517,262
1899	512,544 (£20,502)	223,167 (£8,927)	289,377 (£11,575)	28,066,480
1900	630,635 (£25,225)	295,000 (£11,800)	335,635 (£11,425)	31,111,454

The tariff varies from 8 to 23 centimes per kilowatt-hour, 0·57d. to 1·64d. per horse-power-hour, or from 150 francs to 750 francs per horse-power-year; or £6 to £30 per horse-power per year. (The figures given appear contradictory.) For electric lighting the charge is 8 centimes per hectowatt-hour, equal to 7·62d. per Board of Trade unit.

It is not necessary to assume that all the energy available from water-power should be converted into electrical energy, then reconverted into kinetic energy of motion with the resulting heavy losses involved in conversion, transmission, and reconversion. Industries, as in the French Alps, will in time move towards the sources of power, and use as far as possible the hydraulic power direct. When this comes to pass, the industrial value of the hydraulic power will be enhanced. No doubt for many purposes large amounts of power would continue to be transmitted long distances, but I think it is too much to assume that all will be so utilised.

Water-power is not to be obtained in New Zealand except at considerable cost. Apart from the lake schemes most of the possible schemes must of necessity be located in the central main range, or its offshoots, which runs from Otago to Marlborough, and thence through Wellington to Auckland Province. The best schemes appear, at present, to be obtainable by diversion of water from one lake to another or to the sea, or by diversion of water from one river-valley to another at a lower level. All other schemes must be got by dams, or by dams and conduits following the valley of the river utilised. Some of the methods adopted in the mountainous countries of Europe seem suitable as patterns for the development of some of the New Zealand water-power schemes, but many of these are at present unique in character and will demand special treatment, independent of precedent.

A power-scheme must of necessity be reliable in its working: this condition will make conduits expensive. Generally in steep country a tunnel in the solid rock will be found the most economical in the end. Races or canals and flumes will be more liable to damage by slips and exceptional rainstorms. A break in a conduit means loss of revenue; stoppage of industrial work with its attendant losses to employers and workers alike, and frequent or repeated failure would give impetus to the employment of competing types of prime movers, working independently of weather conditions. For lake schemes, a tunnel carrying pure water should last an indefinite time. For river schemes, where silt-laden water would at times have to be taken, tunnel-linings would not last so long, but how long it is not possible to ascertain, except by trial. A properly constructed tunnel is the ideal conduit, giving a maximum of safety with a minimum of loss of water and of power. In the lake-to-lake schemes, and in all others where possible, the works could be designed to avoid loss of pressure due to varying lake-level.

Any scheme undertaken should be developed to its full extent, or if only partially developed at first, the works executed should be integral parts of the works required to develop the scheme to its full extent, so that there may be no abandonment or reconstruction of works when the scheme comes to be completed. The temptation to follow other courses will be great, but if given way to will lead to much useless expenditure.

Before designs for the complete utilisation of all the power available in any proposed scheme can be prepared, a series of observations extending over a sufficiently long period would be required to determine the quantity of water likely to be available under all or the worst conditions.

For lakes, the total annual flow is required for as many years as possible, to ascertain if the lake is of capacity sufficient: (1) To equalise the variations of flow from month to month in each year; or (2) to equalise the variations in flow from year to year as may be possible in the case of some of the larger lakes, or lakes whose area is large relatively to their drainage-areas, or whose storage-capacity can be effectively increased by the construction of dams. To obtain the requisite data for lakes, it would be necessary to keep a daily record of the level of the outflowing river at various selected points, and to gauge the outflow at intervals when the river was at various levels. It would then be possible to compute the annual outflow to such a sufficient degree of approximation as would enable works to be designed with some degree of confidence.

In the case of rivers where no storage is available, the minimum flow will be the governing factor, unless it were possible to find uses, as it may be, for power during the annual periods of high flow. It will be, perhaps, more difficult to get complete data for rivers than for lakes. In both cases there will be cost and trouble in uninhabited localities. In schemes to use the low-water flow of rivers the chances of error, and inadequate design arising therefrom, would be greater than for rivers regulated by lakes. In river schemes where partial storage would be possible, the total annual flow and the variations in flow would be essential factors, in addition to the minimum flow.

Rainfall-records can only be of partial assistance in dealing with water-power questions. It is not only the total quantity of water which falls on a catchment basin that requires to be known, but the percentage of that quantity that flows off at the various seasons of the year which has to be determined. The percentage of flow-off varies with the storage-capacity of the rock-fissures and sub-surface strata of the river-basin, vegetation-covering, wind, cloudiness, and other conditions, so that rainfall-observations cannot be substituted for the more laborious and costly methods of continuous records of river-levels, combined with frequent gaugings of flow. In some cases where there is no great difference in altitude in the various parts of a river-basin for which rainfall-records are available, these records might be used to extend back the results of gaugings to previous years after a connection had been obtained by observation between the rainfall and flow-off in any such case.

It is evident from the data already obtained that generally the rainfall on New Zealand mountains is very much greater than on the lower ground contiguous to them, where most of the rain-gauge stations are now located. It is not possible to account for the flow from any of the lakes and in many of the rivers except by assuming that the mountain rainfall is much greater than on the lower tracts of country. The fluctuations of rainfall from year to year on the mountains may coincide with those observed for rainfall on the low adjacent country, and they may not. It would be of service to have some records to establish a connection, if there is any.

Each proposed scheme for water-power development would require independent observations to determine, completely, the local conditions governing the flow from the catchment-area proposed to be utilised.

From the information available, and on present-day conditions, there seems to be every reason to suppose that the gradual development of water-power would accelerate the general industrial progress of the colony by providing a supply of cheap power, much cheaper than steam or other motive power, and in a form to easily meet many varying conditions of service. The conditions for the successful installation of hydraulic-power schemes will, perhaps, alter materially as time goes on, as regards the industrial uses of electricity and the capabilities of electric machinery and devices for generation of and transmission of energy to long distances; also as regards the efficiency of steam and other engines for generating motive power; so that many conclusions that now seem valid may in the future be shaken, or be put on a firmer basis. Rates of interest to be paid for capital may fall, and cost of plant may decrease, rendering possible the development of relatively more costly schemes than herein considered.

Judging from the figures given herein, showing the growth of revenue for the "Jonage" and "Chevres" power installations, it takes a considerable period to get sale for all the power capable of being produced by a power-installation—three or four years in their case, and, possibly, it would be quite as long before any scheme installed in New Zealand would find sale for all its energy.

The utilisation of all the hydraulic power available in the colony seems to be quite probable in the not very distant future. A considerable amount of power is now used, and there has been a fair rate of increase in the past few years. Also the quantity of power used per head of population may increase, thus accelerating the annual rate of increase. The development of hydraulic power will shift present and create new industrial centres in the colony.

The collection of all possible information regarding yearly flow from all important catchment-areas likely to be utilised for water-power, should be begun and carried on continuously. Observations for a long period are required for the proper design of hydraulic works, unless great sacrifices of power are made, or risks taken needlessly as to the size of works; also heights along all important rivers and streams should be ascertained. If full information were available as to heights along streams, many possibilities would readily suggest themselves.

In addition to data for water-power development, a complementary investigation is required regarding all the existing industries to whose expansion providing electric motive power at low rates would materially contribute; or regarding industries now non-existent in New Zealand which could be established with profit if aided by the supply of power at low rates.

In French Alpine hydraulic electro-chemical factories, the products are carbide of calcium, alkaline carbides and chlorates, sodium and its derivatives, carborundum, and aluminium. In 1901 there were seventeen factories engaged in the manufacture of these products. The power used varied from 600-horse power to 10,000-horse power, the total for the seventeen factories being 74,000-horse power. Other factories manufacture paper, wood-pulp, &c. One of these is of sufficient magnitude to use 5,000-horse power.

It has been suggested by Sir W. Crookes and others, that nitrates can be manufactured by a hydro-electric process more cheaply than they can be procured from Chilian deserts. Should a satisfactory process ever be evolved, and it seems feasible, then some of the large New Zealand schemes, such as Hauroko, Manapouri, Te Anau, Hawea, Tekapo, Clarence, and others, would prove of value sooner than they otherwise would, for by using some or all of them to manufacture nitrogenous fertilisers, the yield from New Zealand wheat lands could not only be materially increased, but also a relatively permanent yield secured. Other contingent advantages would no doubt also accrue.

For the manufacture of nitrates by electrical processes, a supply of power at a cheap rate is required—much cheaper than can be got from coal. It is thought such power could be got from Niagara, but it could be got equally well from some possible New Zealand power schemes.

As some of the largest and most valuable developments possible in the colony involve raising lake-levels by dams, forming large reservoirs by dams across rivers, and the diversion of large volumes of water from one river-valley to another, &c., action might be taken to secure all necessary reserves of land, and all rights that may be required to secure the complete development of all possible power schemes in the future, unhampered by any unnecessary adverse conditions.

If it is desired to take immediate action as regards the development of water-power, the schemes to be first completely investigated as the most promising are: Rotoiti–Kaituna, and Huka as alternatives; Mangawhero to Wanganui; Tauherenikau; Hutt; Waihopai; Roding and Rotoiti (Buller); Clarence-Waiau-ua, and Coleridge as alternatives; Opihi; Teviot and Hawea as alternatives; Monowai and Hauroko schemes as alternatives. For these schemes observations to ascertain the flow of water more definitely should be started as soon as possible; then surveys to determine the proper location, and the magnitude of the requisite works would be required. When this information has been got and surveys made, it would then be possible to prepare detailed estimates of the cost of each scheme complete, and to investigate the economic value of each more exhaustively than is at present possible.

Many points of some importance relating to individual schemes have not been referred to in this report. These would be dealt with in special and independent reports on each scheme.

A note is attached showing amount of steam-power used in Great Britain, United States, and the Continent of Europe, for fixed steam plant on land and in locomotives. I have not been able to get information later than the years given. Complete and more detailed information of the same character up to the present time would help in judging the probable growth of the use of power in New Zealand, and might help in suggesting possible extensions. The figures give an idea of the power used by the great industrial nations in past years, and the rate at which the use of power has grown. A study of the figures, I think, shows that it will be possible to develop gradually and prudently the hydraulic-power resources of New Zealand in such a way as to render immense help to the development of future industries by supplying large amounts of power at cheap rates to meet ever-increasing demands.

The Surveyor-General has supplied much information for this report; Mr. R. W. Holmes for the central region of the North Island; and the various Public Works district officers for their several districts. Mr. H. Vickerman, B.Sc., has rendered most efficient assistance in computations and preparation of plans and data.

P. S. HAY, M.A., M. Inst. CE.,
Superintending Engineer.

NOTE ON POWER USED IN VARIOUS COUNTRIES.

(From Mulhall's Dictionary of Statistics.)

FIXED STEAM-POWER.

Year.	United Kingdom.		Continent of Europe.	United States.	Colonies.
	Population.	Power.			
		H.p.	H.p.	H.p.	H.p.
1840	26,700,000	350,000	100,000	360,000	20,000
1850	27,500,000	500,000	220,000	600,000	40,000
1860	29,070,000	700,000	650,000	800,000	70,000
1870	31,629,000	900,000	1,860,000	1,220,000	120,000
1880	35,026,000	2,000,000	3,270,000	2,200,000	200,000
1888	37,188,000	2,200,000	4,150,000	3,300,000	400,000

LOCOMOTIVES.

Year.	United Kingdom.	Continent of Europe.	United States.	Colonies.
	H.p.	H.p.	H.p.	H.p.
1840	200,000	90,000	200,000	...
1850	700,000	630,000	600,000	10,000
1860	1,400,000	2,210,000	1,800,000	300,000
1870	2,140,000	5,200,000	3,300,000	1,100,000
1880	3,200,000	9,640,000	5,700,000	2,700,000
1888	3,500,000	12,780,000	9,300,000	6,400,000

FRANCE.—1888: Steam-power, including shipping, 4,520,000-horse power. 1901: Locomotives, 4,000,000-horse power; fixed, 2,500,000-horse power.—"Annales des Ponts et Chaussées."

UNITED KINGDOM.—1904: 23,800 locomotives, probably 14,000,000-horse power.

NEW ZEALAND PUBLIC WORKS.

UTILISATION OF WATER-POWER.

SUMMARY OF BRAKE HORSE-POWER AVAILABLE FOR CONTINUOUS WORKING.

North Island.

Scheme.	Brake Horse-power.	Scheme.	Brake Horse-power.
Wairua	1,600	Waitara	2,000
Okere	15,800	Rangitikei	50,500
Huka	38,000	Waihi	400
Aratiatia	92,000	Makuri	3,000
Aniwhaniwha, or gorge below ..	48,000	Waiohine	7,000
Rotoaira, augmented	25,000	Otaki	4,000
Waikaremoana, Waikareiti	140,000	Tauherenikau	5,000
		Hutt	5,000
Te Reinga	12,000	Akatarawa	1,000
Mangawhero	24,000	Minor schemes, say	15,700
Manganui-a-te-ao	8,000		
Wangaehu	1,500		500,000
Turakina	500		

South Island.

Scheme.	Brake Horse-power.	Scheme.	Brake Horse-power.
Wairau	10,000	Tekapo	550,000
Waihopai	3,000	Pukaki	70,000
Awatere	5,000	Ohau, two schemes	130,000
Clarence	100,000	Waitaki, Goose Neck	100,000
Maitai	1,000	Ahuriri	6,000
Roding and Lee, &c.	2,000	Deep Stream	7,000
Boulder Lake	9,000	Taieri	14,000
Rotoiti and Buller	20,000	Beaumont	1,000
Rotoroa	30,000	Talla Burn	2,600
Buller, say three schemes below Gowan	50,000	Teviot	15,000
Inangahua	7,000	Manuherikia	5,000
Waiau-ua	25,000	Hawea	90,000
Brunner	22,000	Kawarau	100,000
Otira and Rolleston, &c.	6,000	Shotover	15,000
Kanieri	2,800	Lake Hall	40,000
Whitcombe, two or more schemes ..	30,000	Lake Hilda	55,000
Kakapotahi	3,000	Lake Cecil	15,000
Wanganui	30,000	Te Anau	750,000
Wataroa, say	60,000	Manapouri	420,000
Falls, Westland	11,500	Mararoa, say	10,000
Waimakariri	115,000	Monowai	14,000
Coleridge (with Wilberforce) ..	70,000	Hauroko	80,000
Rakaia, with 150 ft. dam	35,000	Minor schemes, say	24,100
Heron	8,000		
Rangitata	25,000		3,200,000
Opihi	6,000		

Grand Totals.

	Brake Horse-power.
North Island	500,000
South Island	3,200,000
	3,700,000

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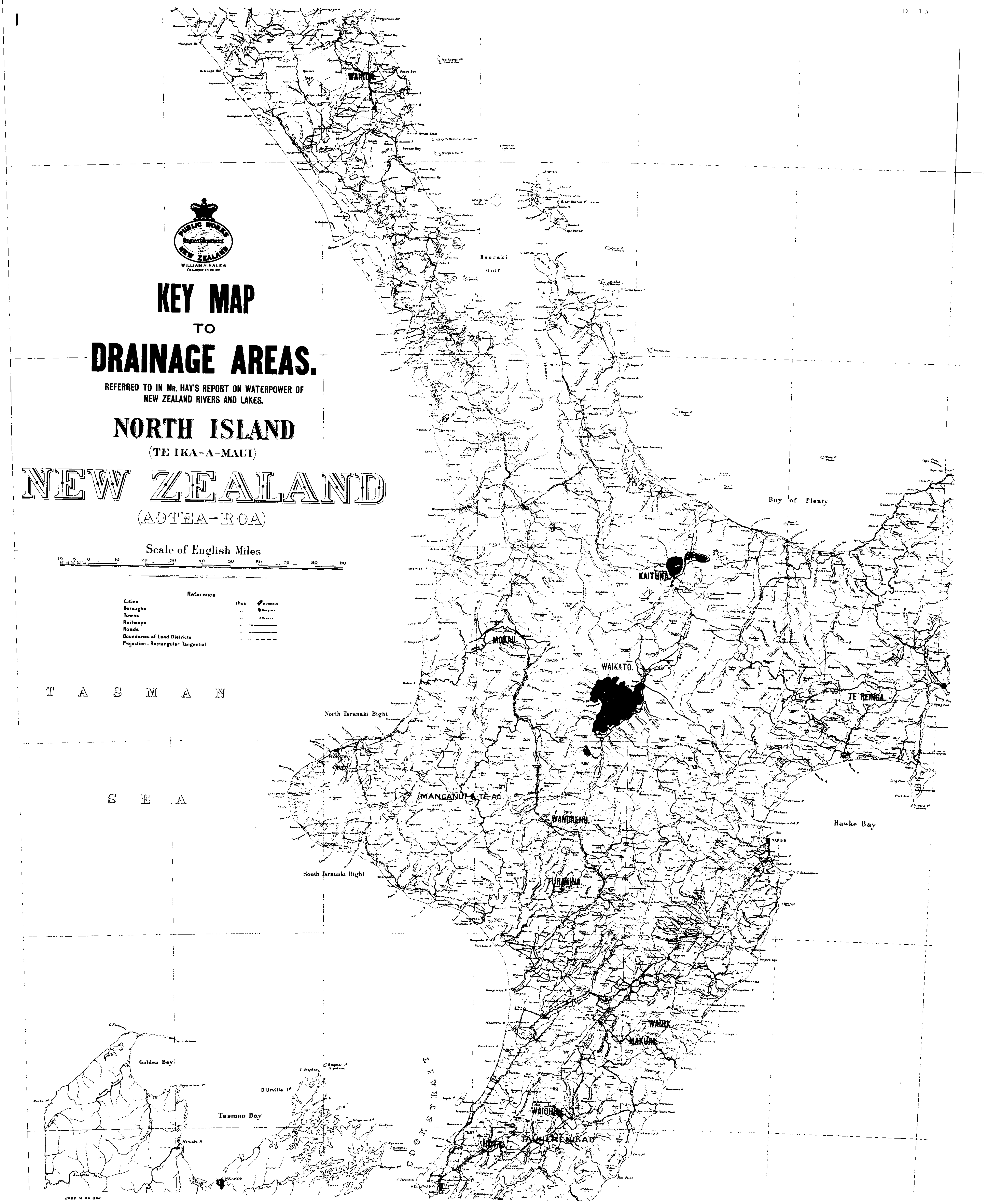
INDEX TO MAPS.


PUBLIC WORKS
Engineer's Department
NEW ZEALAND
WILLIAM H HALES
ENGINEER-IN-CHIEF
KEY MAP
TO
DRAINAGE AREAS.
REFERRED TO IN MR. HAY'S REPORT ON WATERPOWER OF NEW ZEALAND RIVERS AND LAKES.
NORTH ISLAND
(TE IKA-A-MAUI)
NEW ZEALAND
(AOTEA-ROA)
Scale of English Miles
Reference
Cities
Boroughs
Towns
Railways
Roads
Boundaries of Land Districts
Projection—Rectangular Tangential
TASMAN SEA
Hauraki Gulf
Bay of Plenty
Hawke Bay
North Taranaki Bight
South Taranaki Bight
Golden Bay
Tasman Bay
D'Urville Id
COOK STRAIT
WAIRUA
KAITUNA
MOKAU
WAIKATO
TE REINGA
MANGANUI-A-TE-AO
WANGAEHU
TURAKINA
MAKURI
WAIOHINE
HUTT
TAUHERENIKAU
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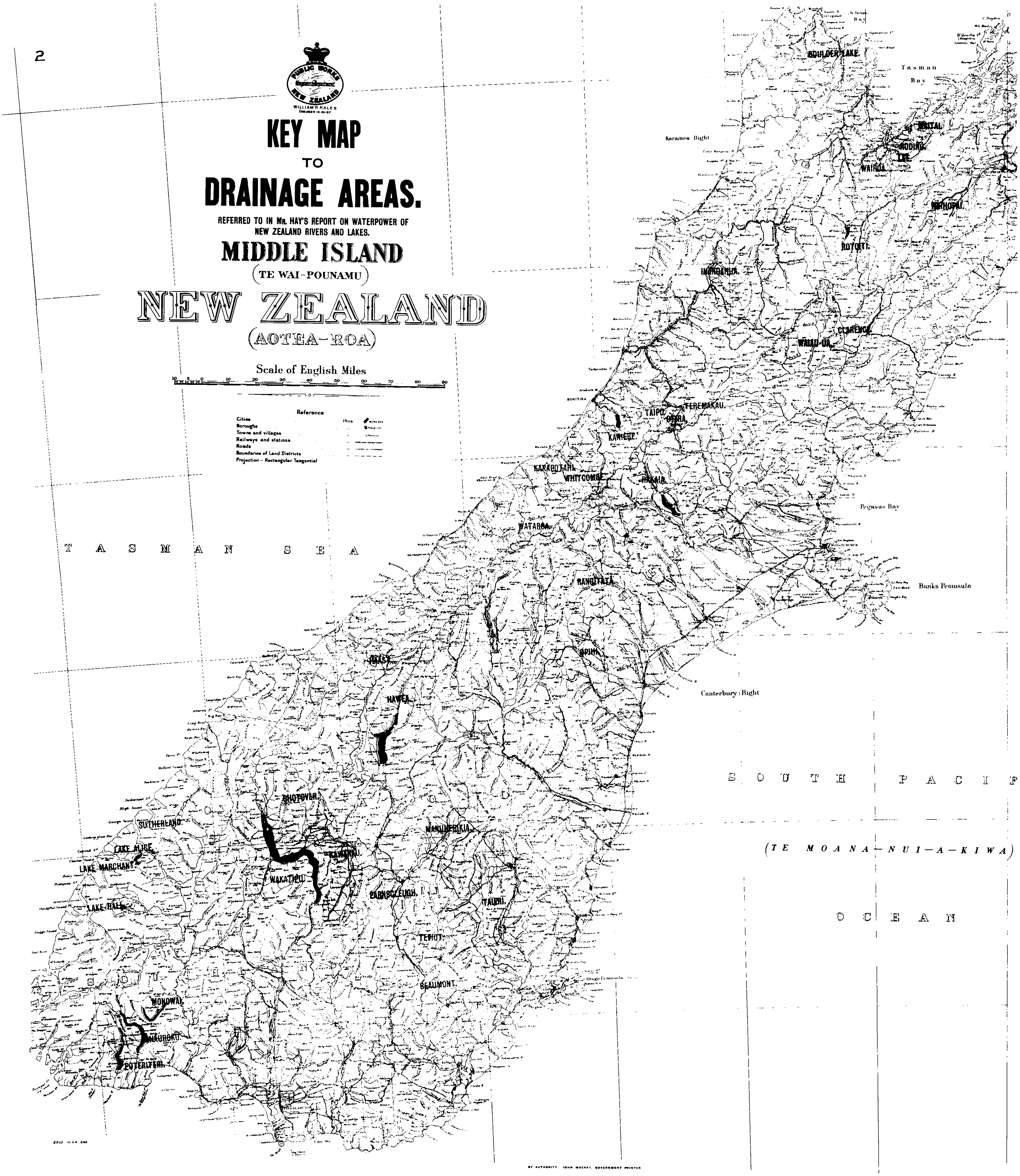

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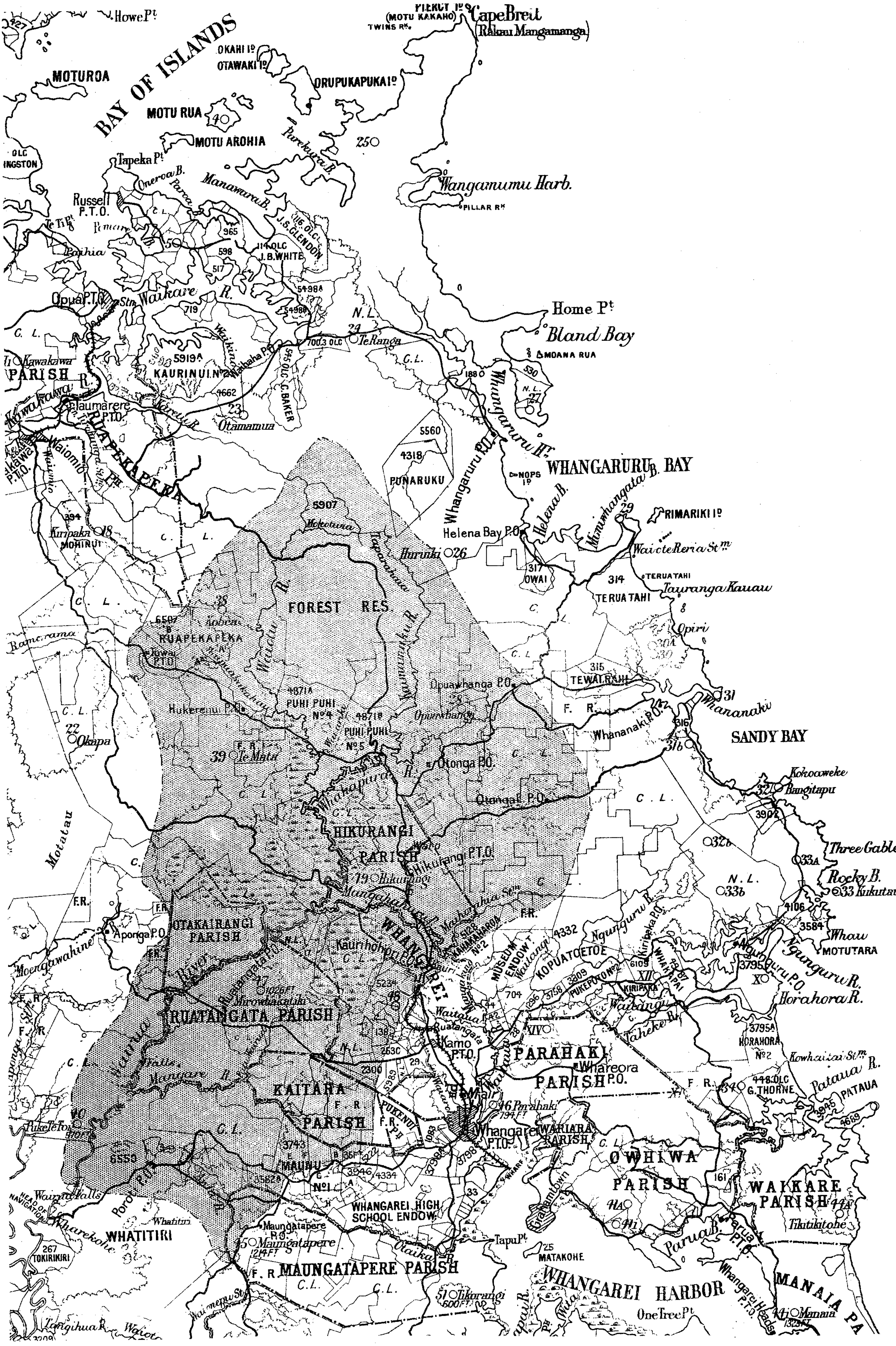
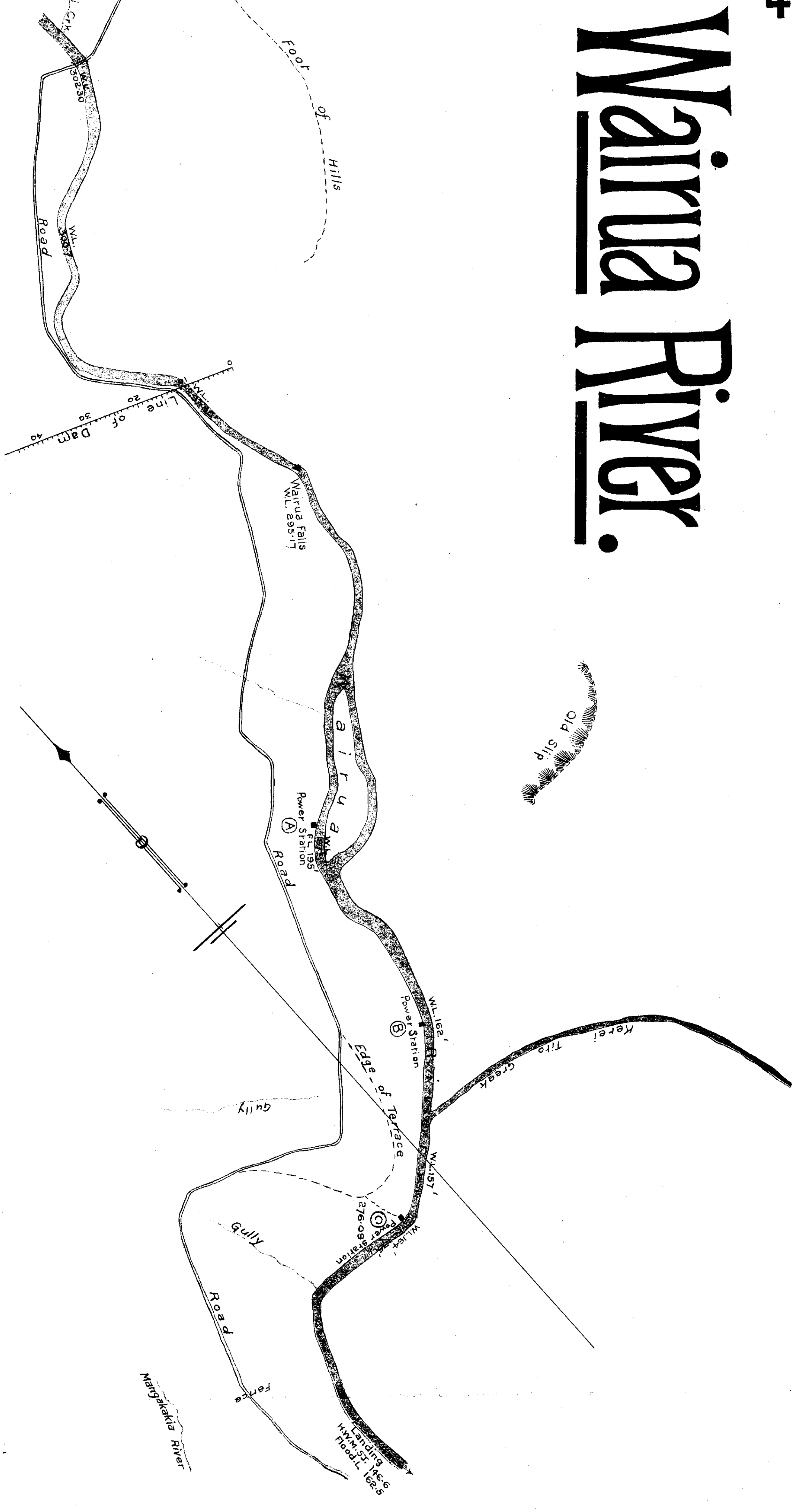
WAIRUA RIVER.

Portion of drainage area, coloured blue, 266 square miles.

SCALE: 4 MILES TO 1 INCH.



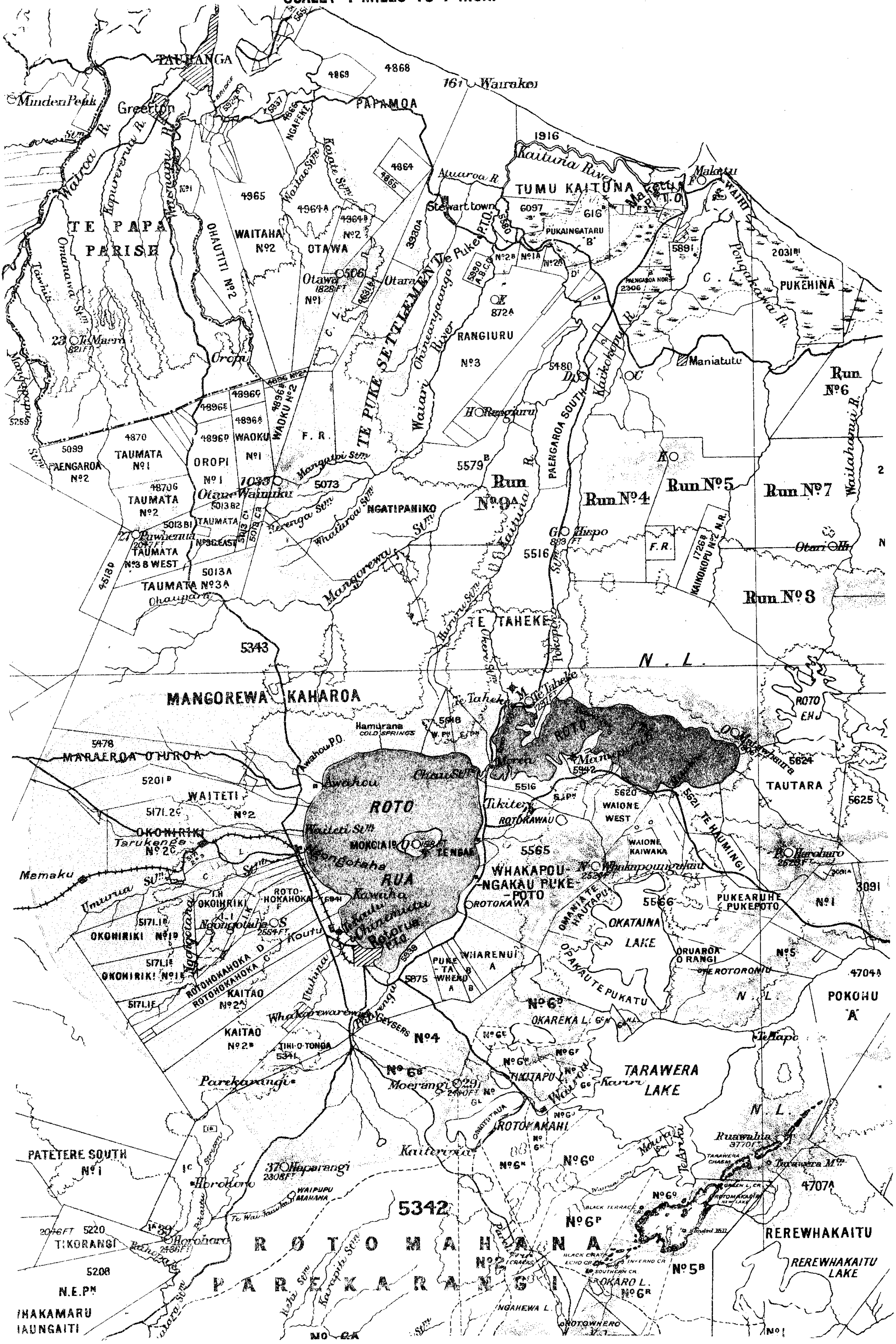

Wairua River.
Scale: 24 Chs. to 1 Inch.
Tiroki Crk.
W.L. 302.30
Foot of Hills
Road
W.L. 300.7
Line of Dam
0
20
30
40
Wairua Falls W.L. 295.17
Wairua
Power Station A
F.L. 195'
Road
Old Slip
W.L. 162'
Power Station B
Kerei Tito Creek
Edge of Terrace
Gully
W.L. 157'
Power Station C
276.09
W.L. 164'
Gully
Road
Fence
Mangakakia River
Landing
H.W.M. S.T. 146.6
Flood L. 162.5

KAITUNA.

(ROTOITI AND ROTORUA.)

Drainage area, 248 square miles.

SCALE: 4 MILES TO 1 INCH.



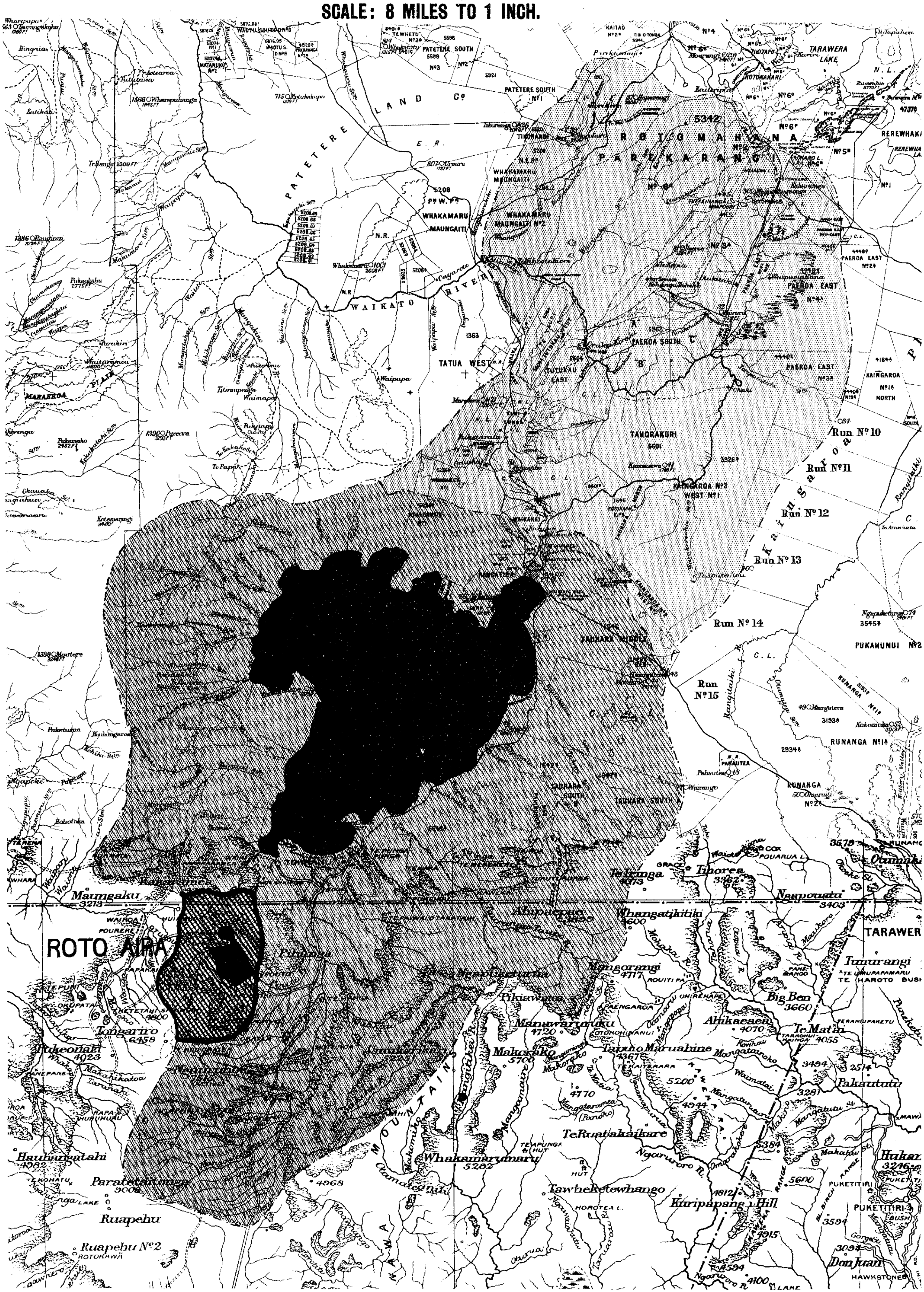
WAIKATO.

Drainage area above Huka Falls, 1,244 square miles.

ROTO AIRA.

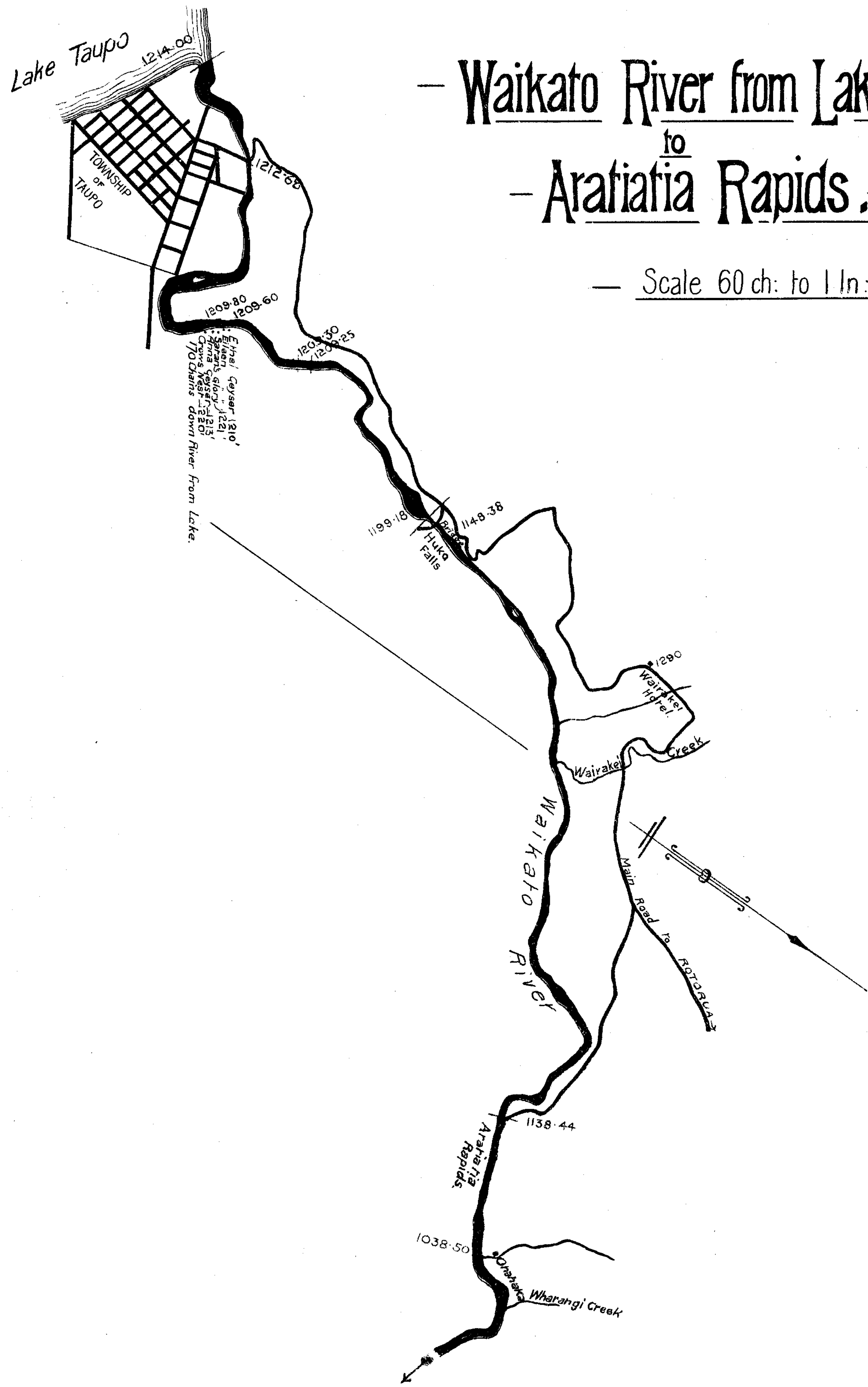
Drainage area, 48 square miles.

SCALE: 8 MILES TO 1 INCH.



Waikato River from Lake to Aratiatia Rapids.

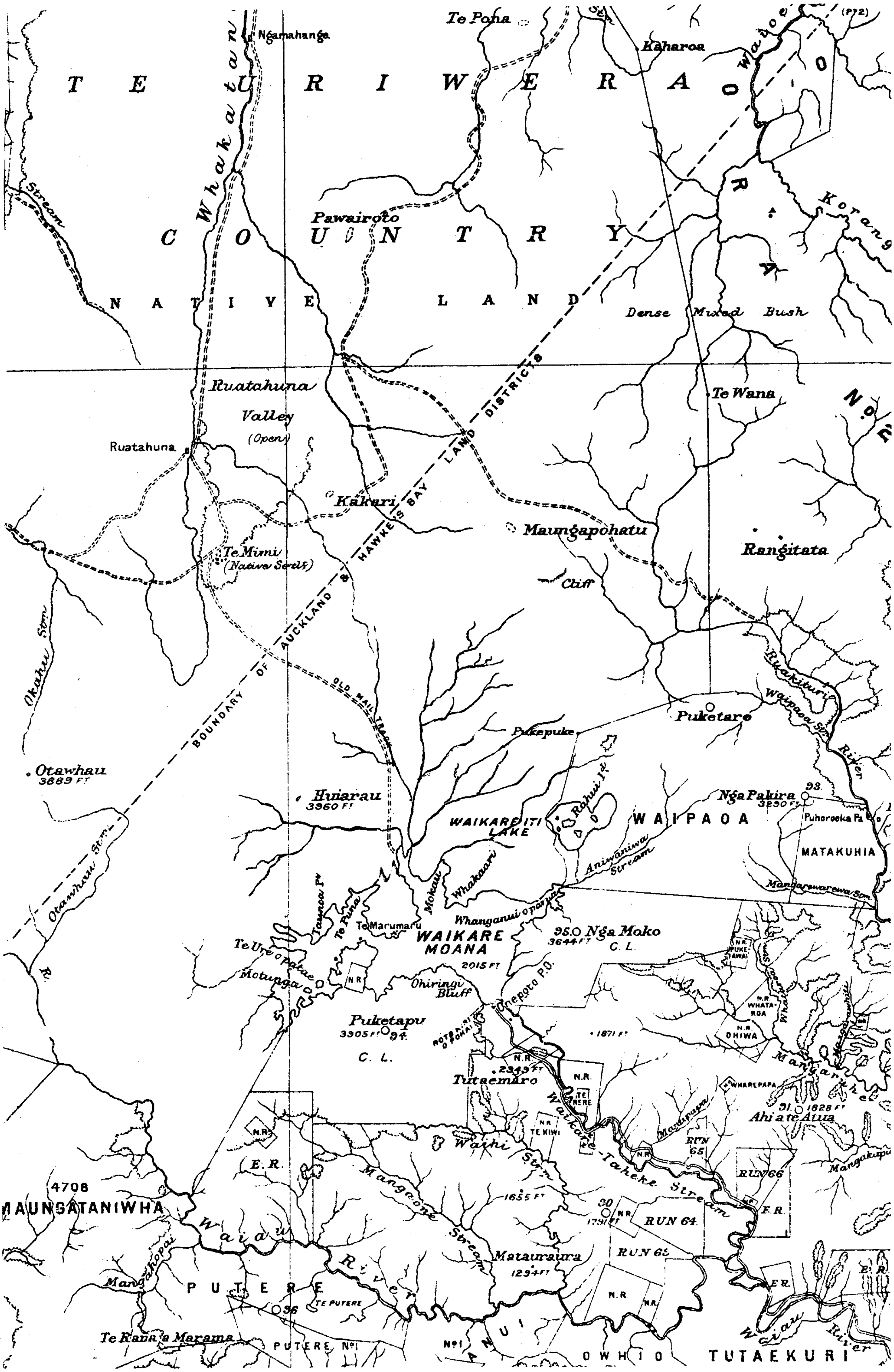
Scale 60 ch: to 1 In:



WAIKAREMOANA.

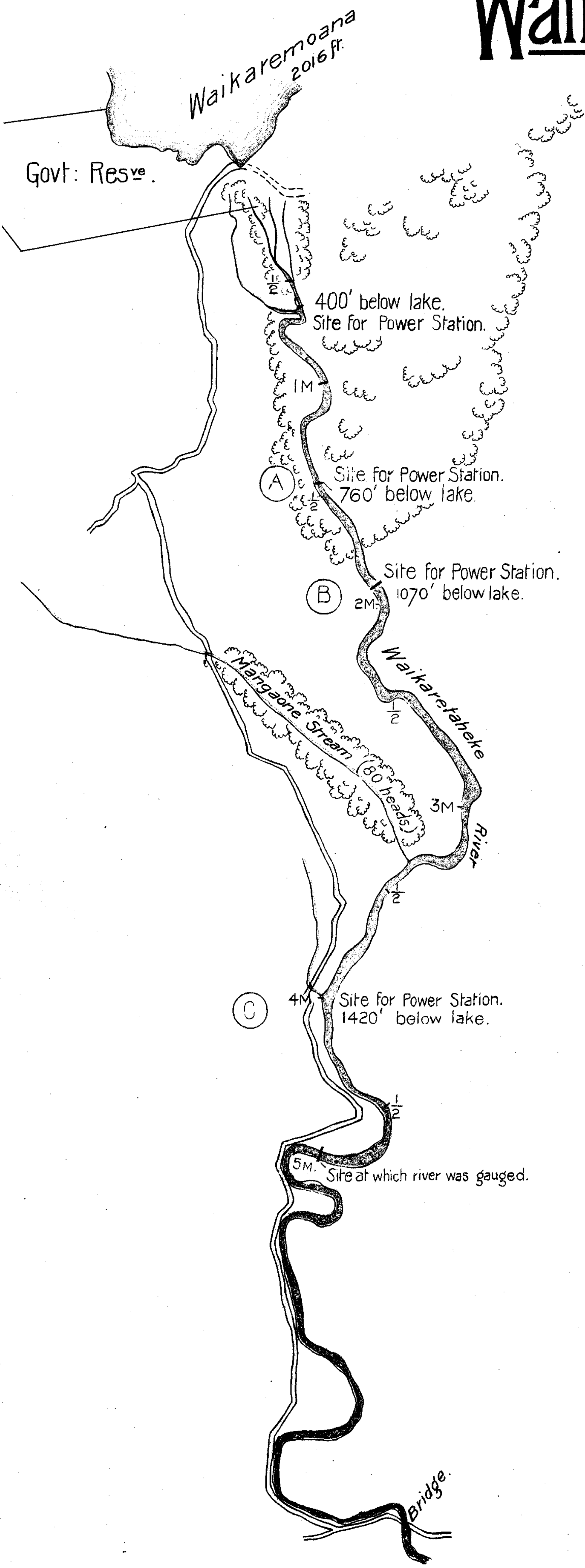
Drainage area, 143 square miles.

SCALE: 4 MILES TO 1 INCH.



Waikaremoana.

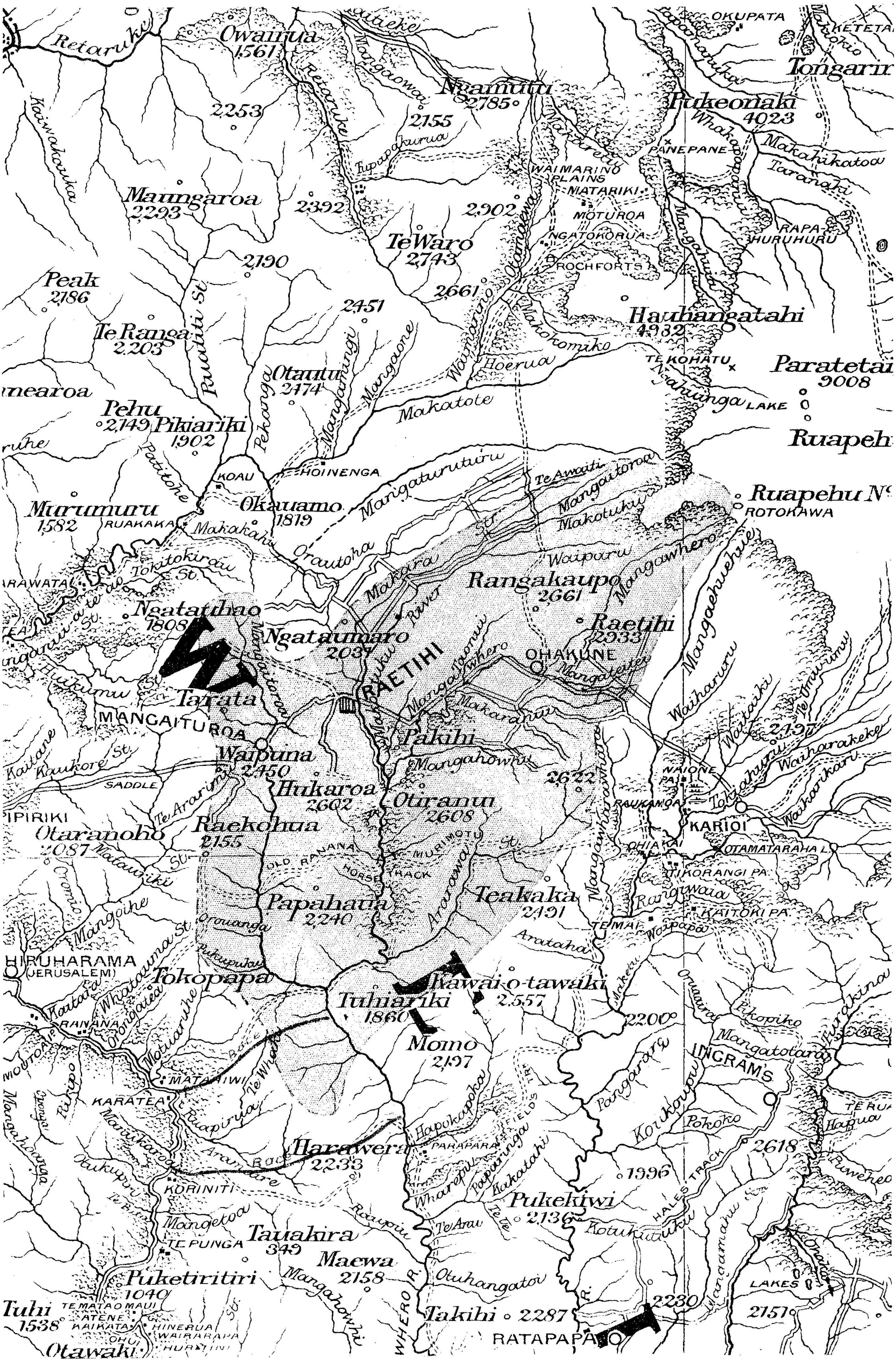
–Scale 40 Chs. to 1 Inch.–



MANGAWHERO.

Drainage area, 212 square miles.

SCALE: 4 MILES TO 1 INCH.



RANGITIKEI.

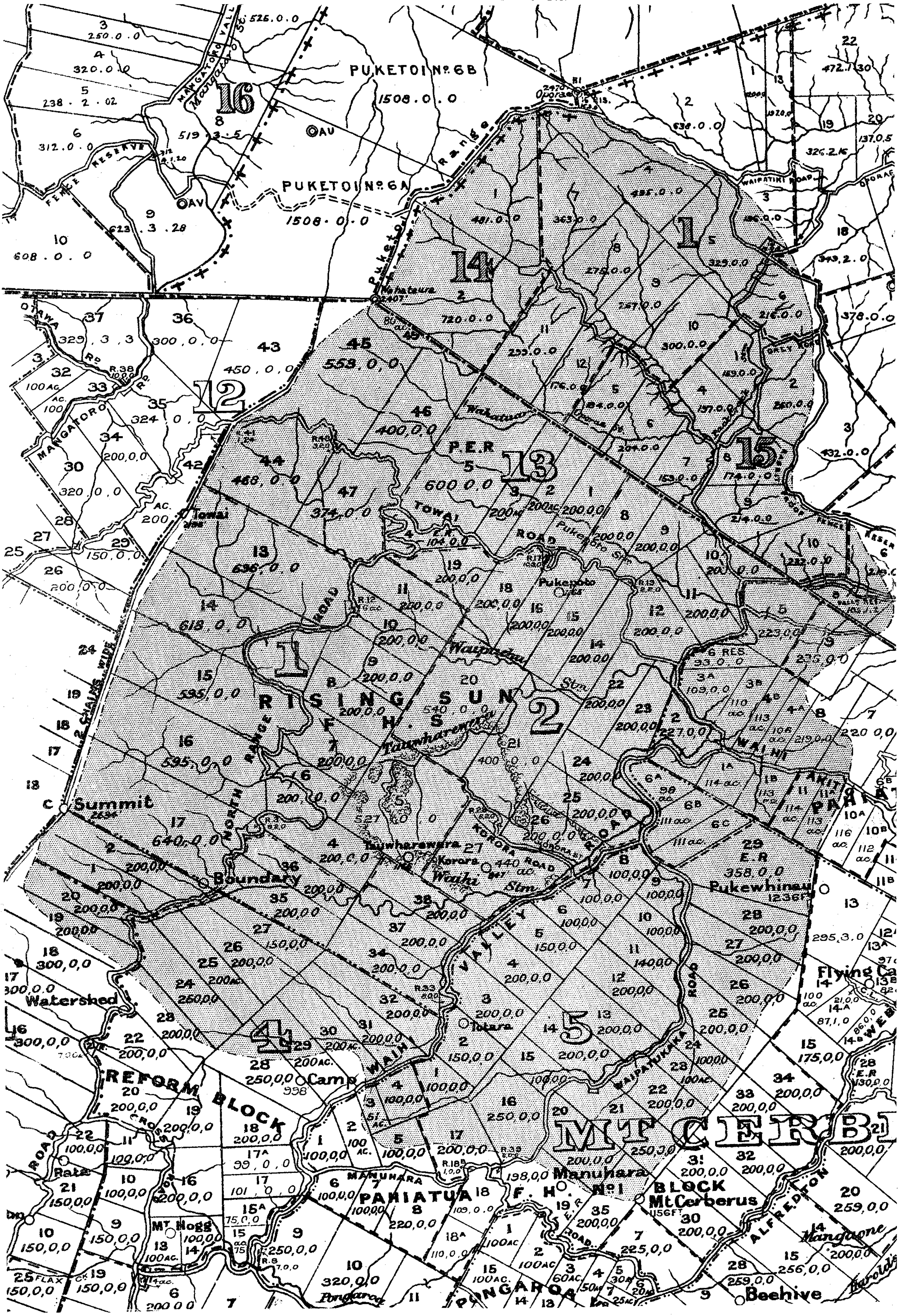
Drainage area, 1,025 square miles.

SCALE OF MILES

WAIHI.

Drainage area, 46 square miles.

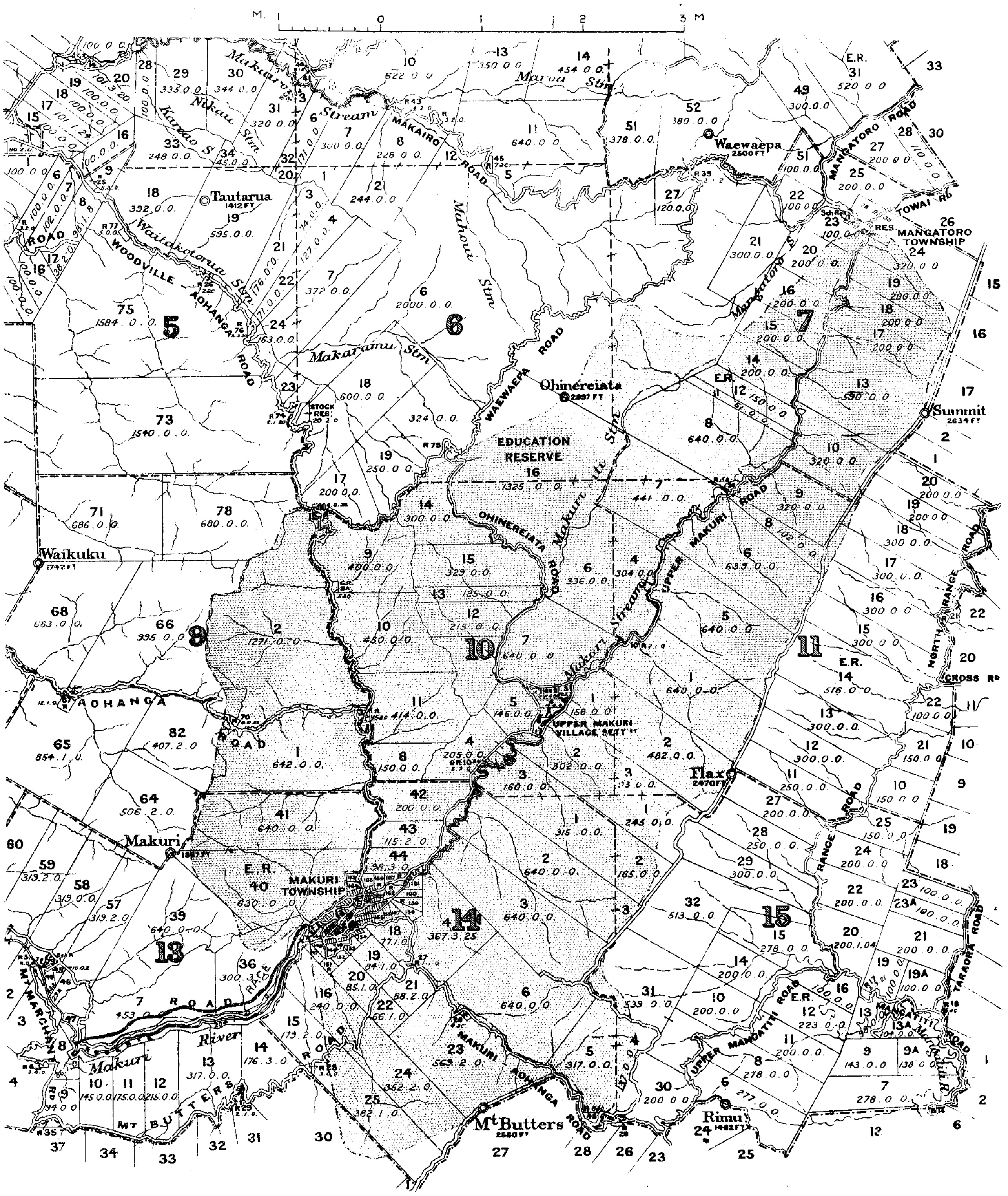
SCALE: 1 MILE TO 1 INCH.



MAKURI.

Drainage area, 38 square miles.

SCALE OF MILES



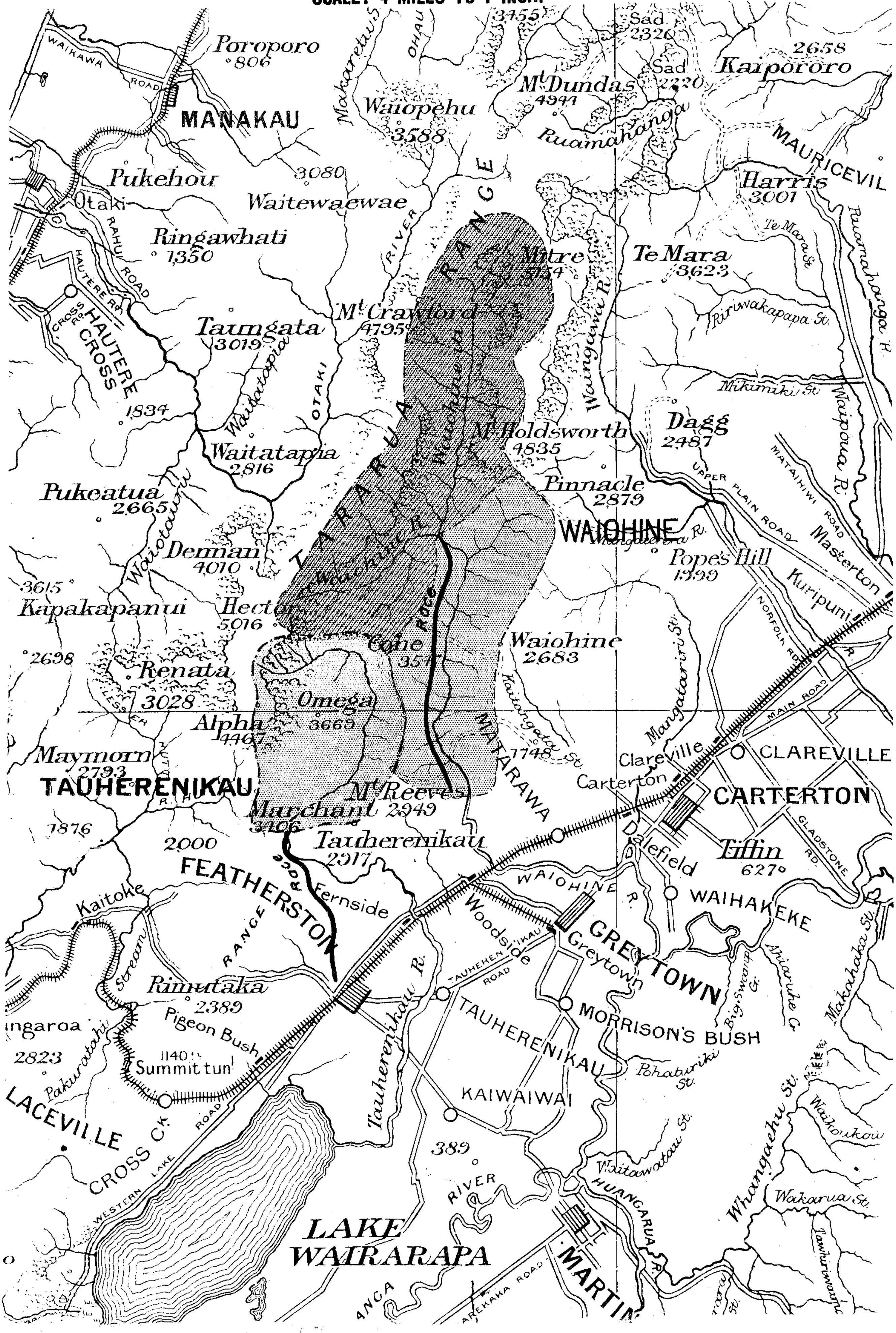
WAIOHINE.

Drainage area, 46 square miles.

TAUHERENIKAU.

Drainage area, 27 square miles.

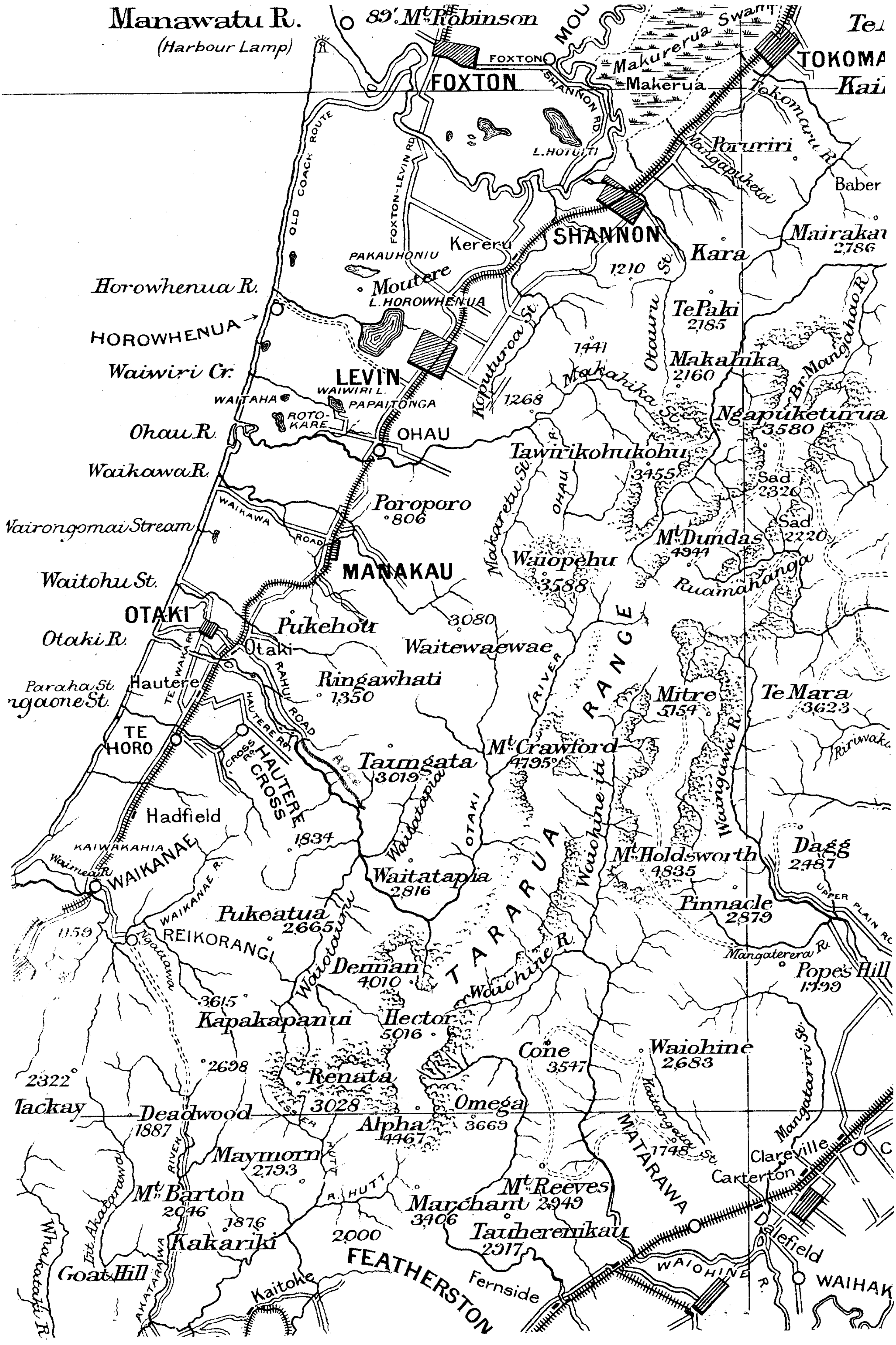
SCALE: 4 MILES TO 1 INCH.



OTAKI.

Drainage area, 112 square miles.

SCALE: 4 MILES TO 1 INCH.



HUTT.

Drainage area, 57 square miles.

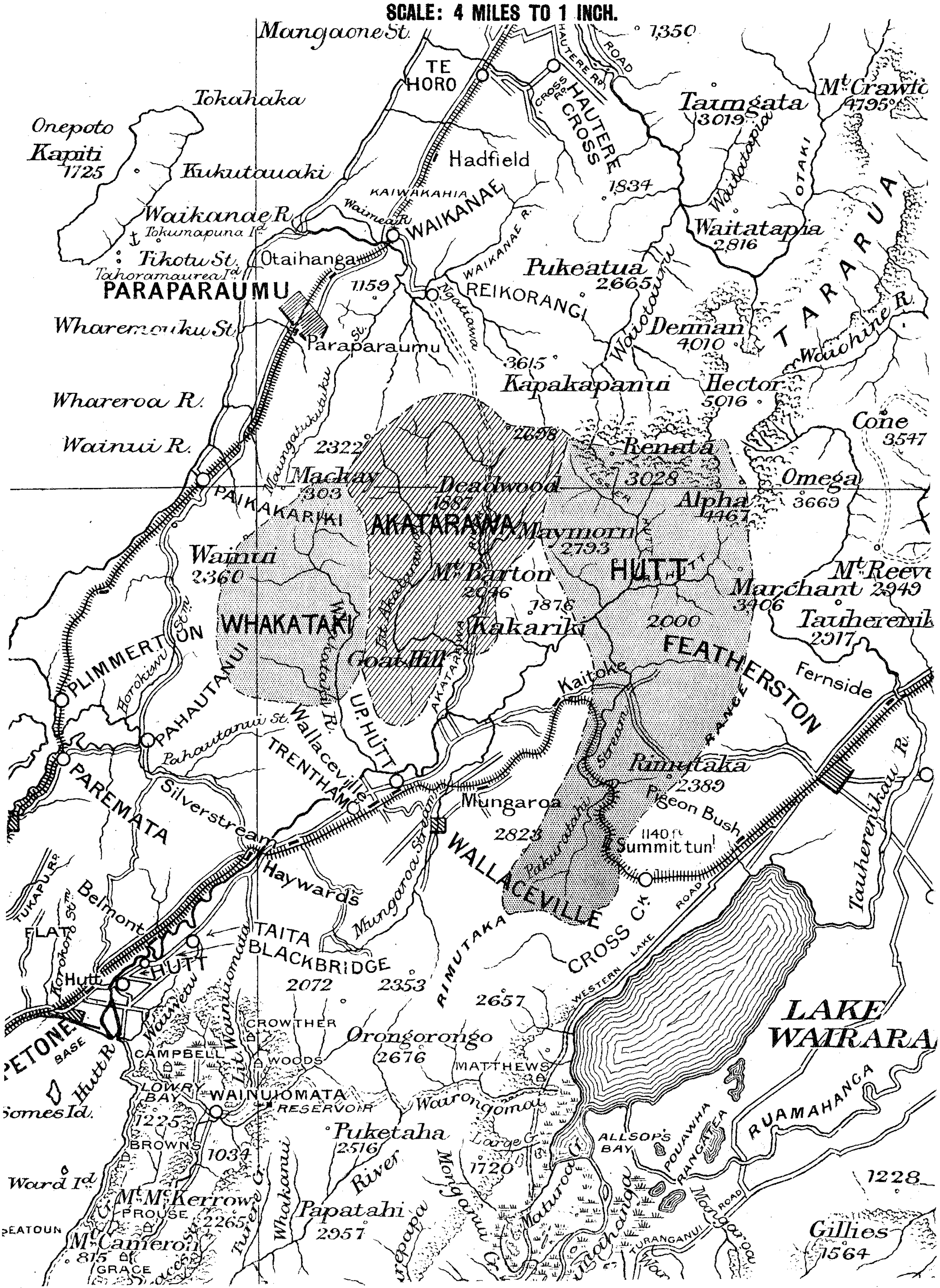
AKATARAWA.

Drainage area, 51 square miles.

WHAKATAKI.

Drainage area, 23 square miles.

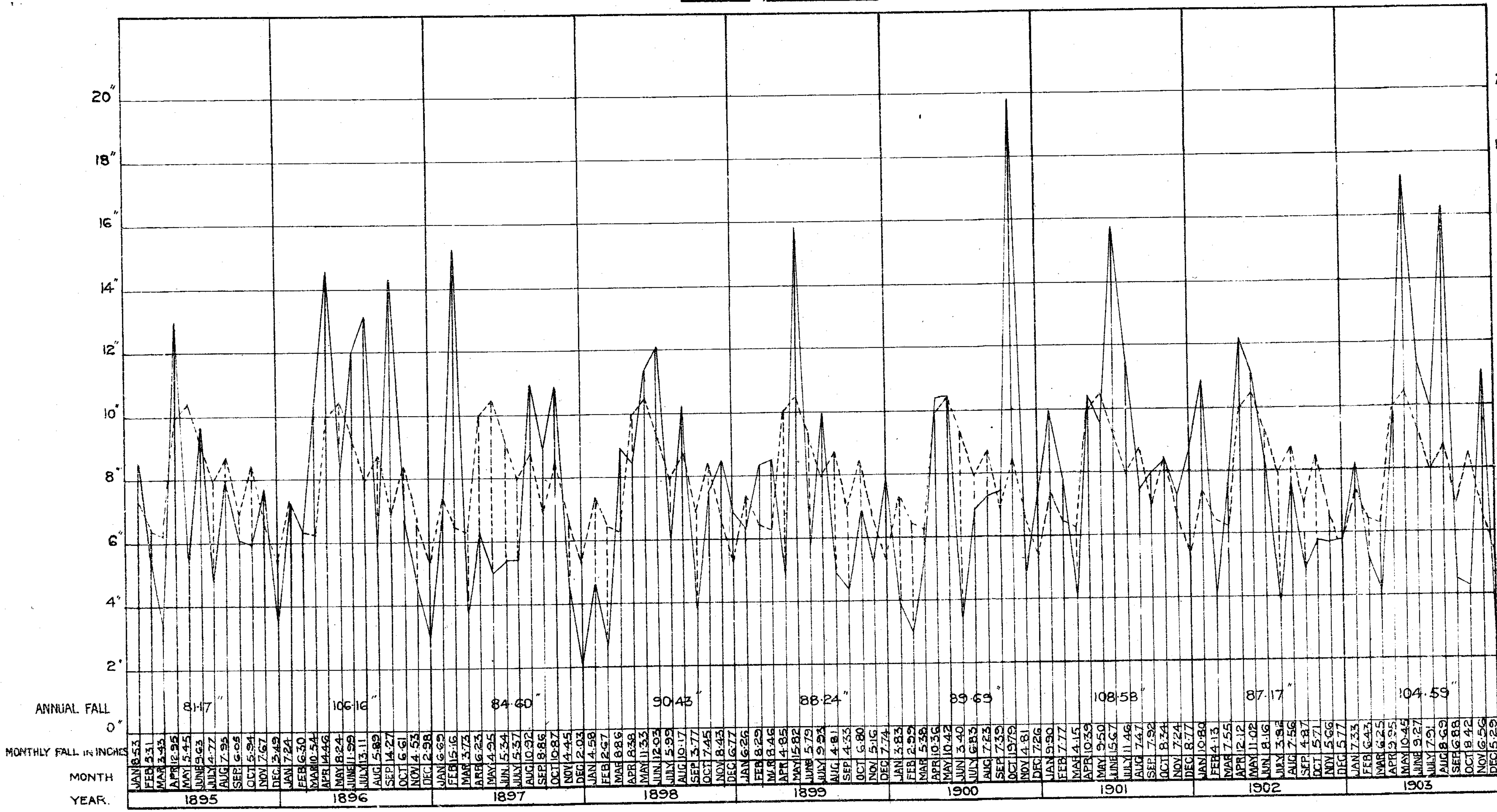
SCALE: 4 MILES TO 1 INCH.



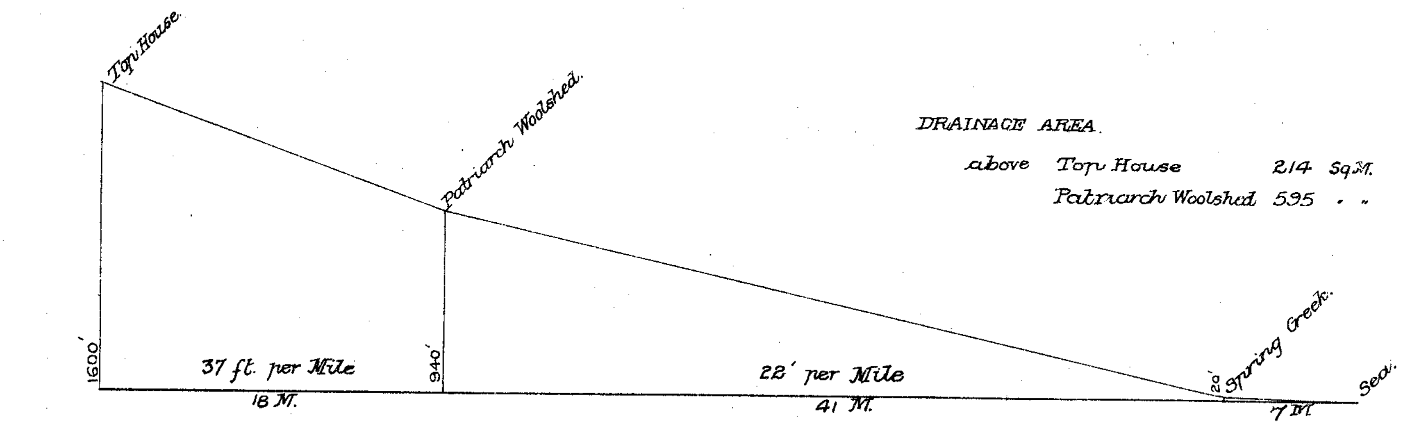
— Diagram shewing Rainfall at Summit. —

— Black Line actual monthly Rainfall for period. Black dotted line Mean monthly Rainfall through period. —

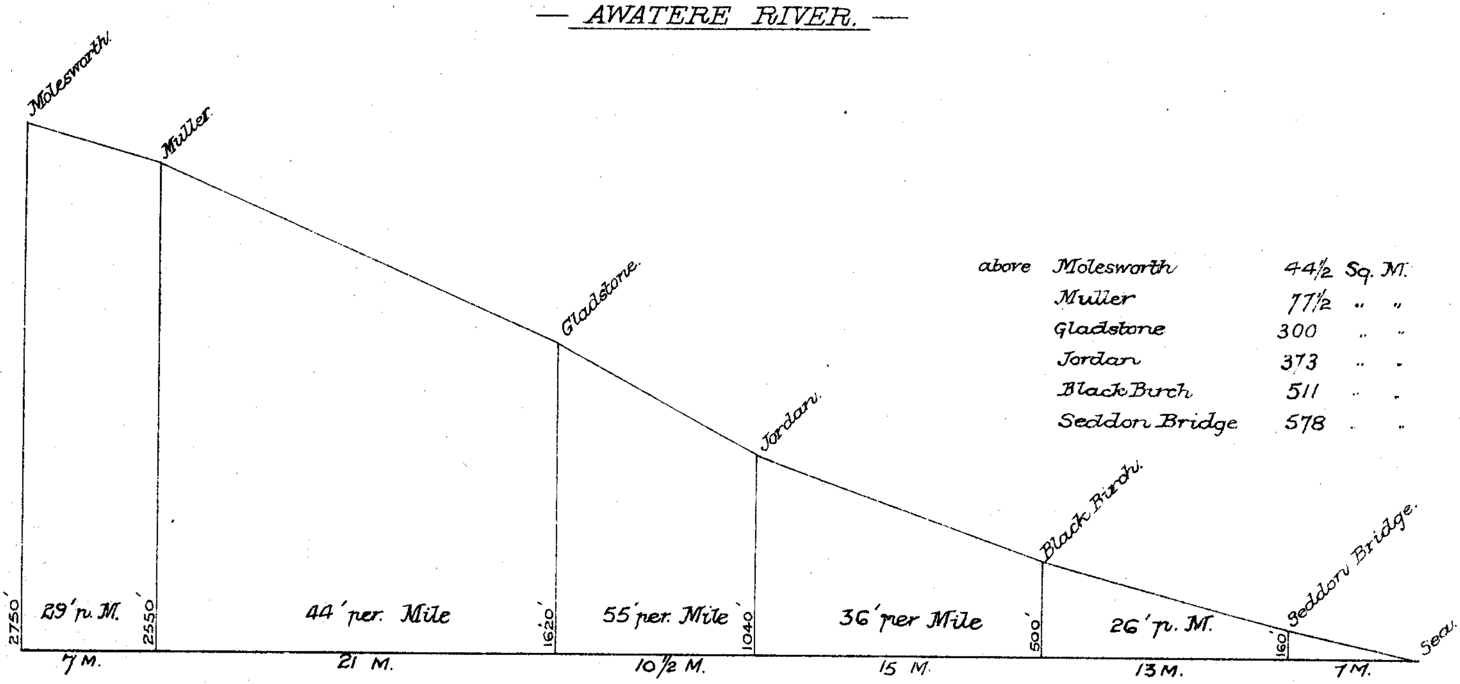
— Scales Vertical 1/4 inch = 1 inch. —
Horizontal 1/10 " = 1 month.



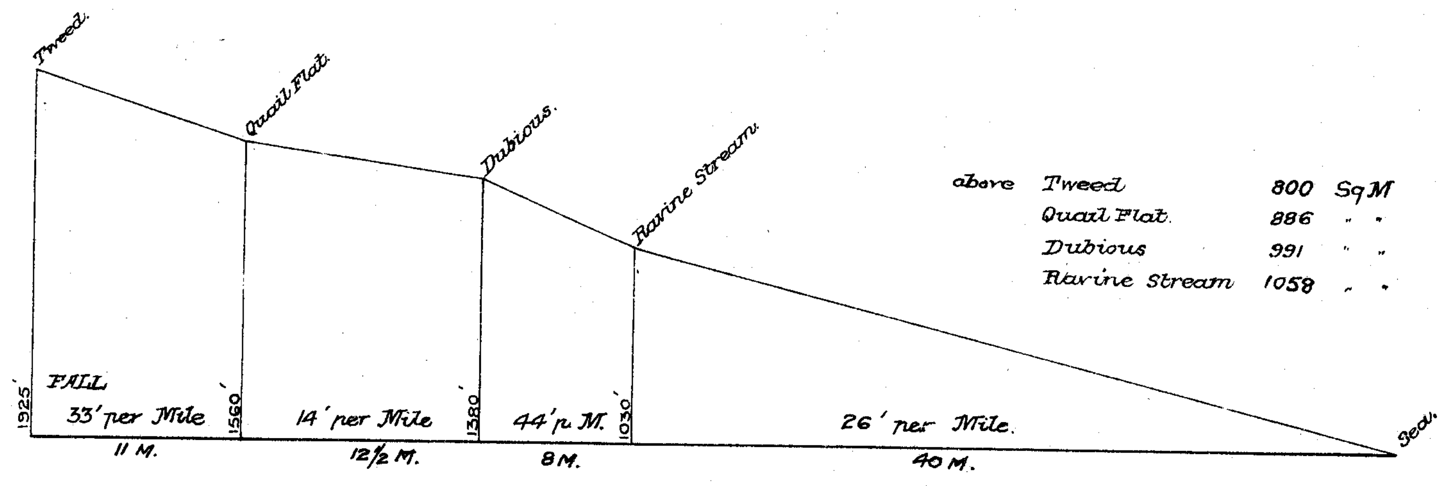
— WAIRAU RIVER. —



— AWATERE RIVER. —



— CLARENCE RIVER. —



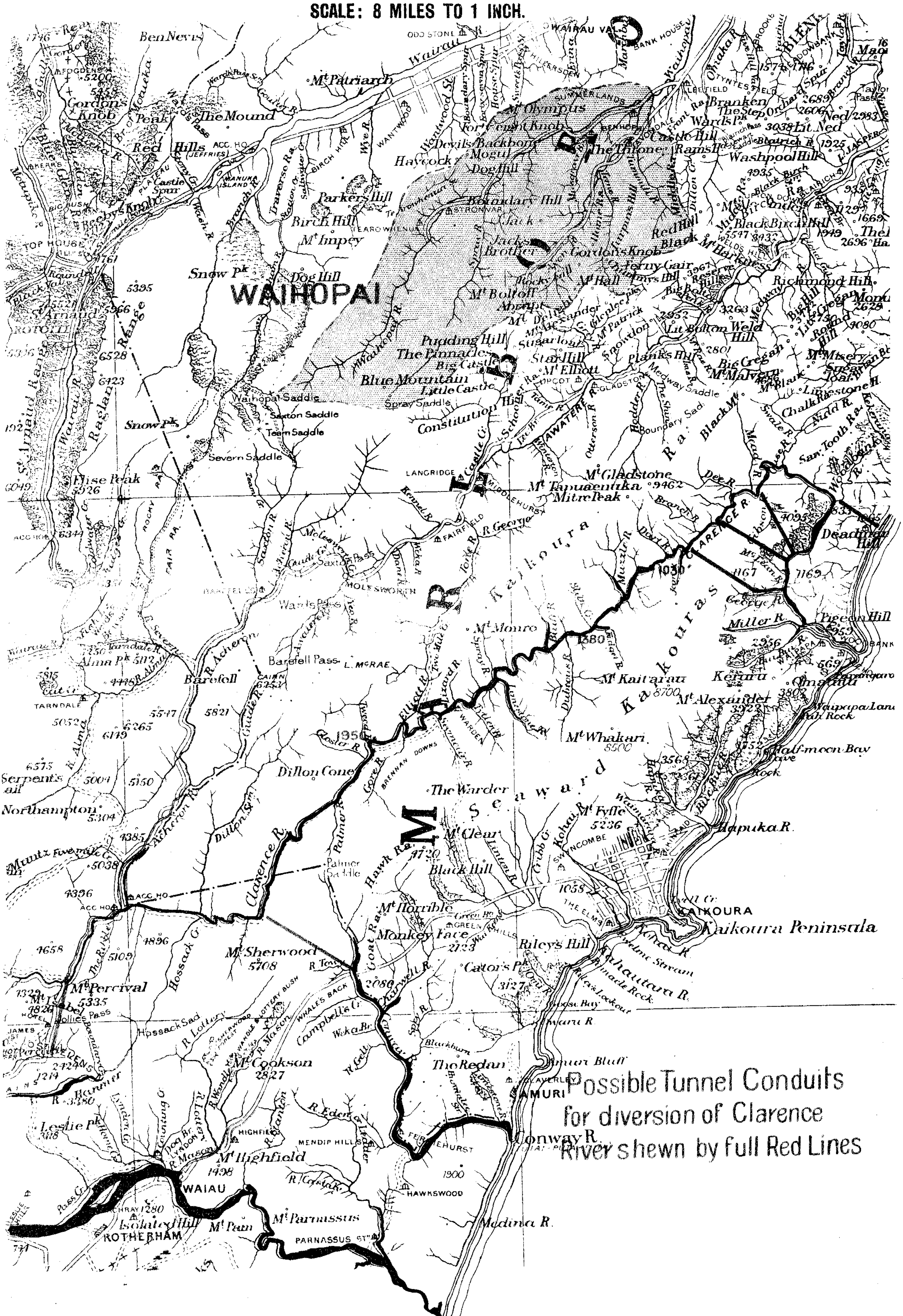
— Scales : Horizontal, 10 M. to 1 Inch. —
Vertical, 1000 Ft . 1 Inch.

WAIHOPAI.

Drainage area, 295 square miles.

CLARENCE.

SCALE: 8 MILES TO 1 INCH.



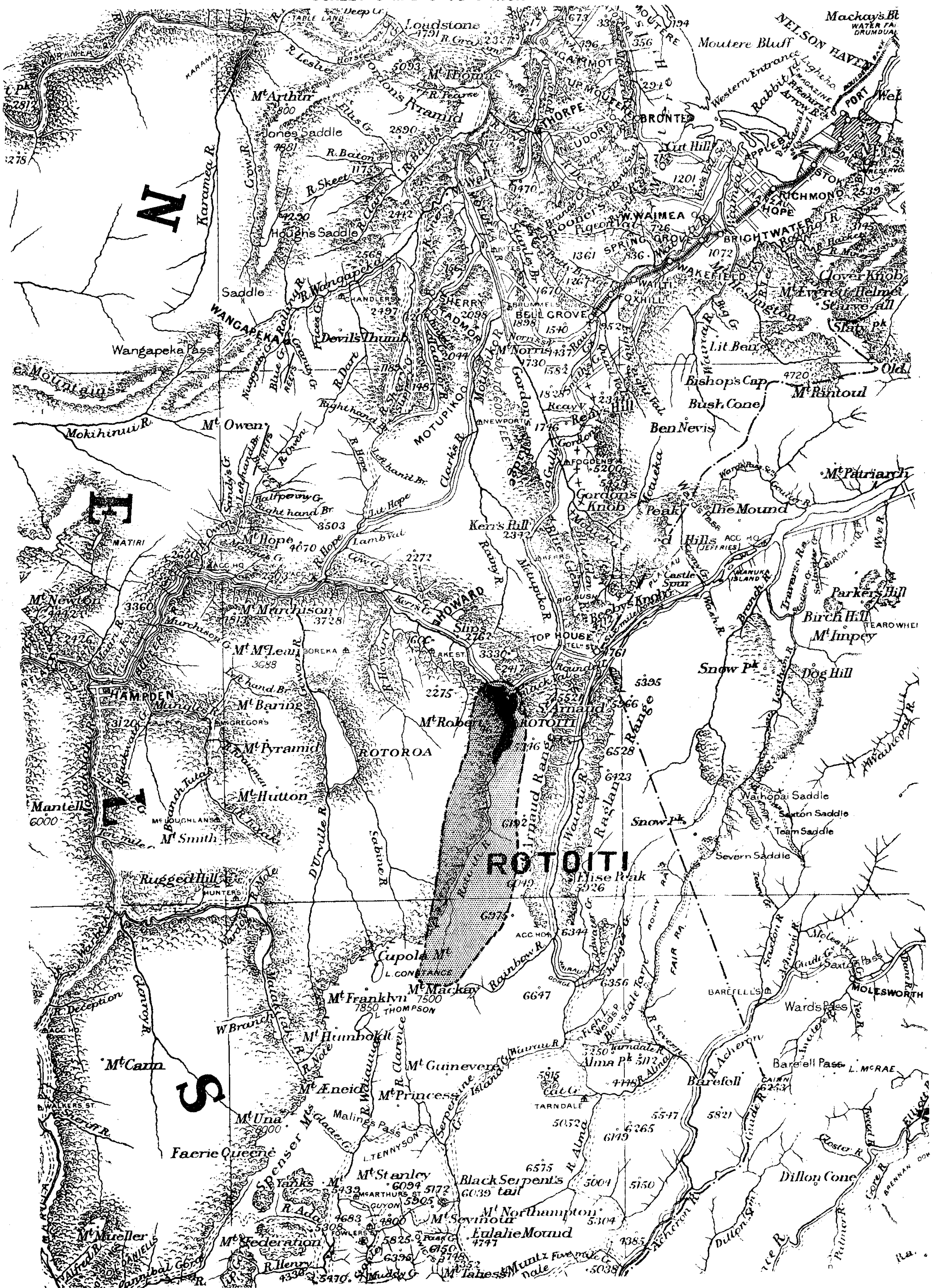
ROTOITI.

Drainage area, 46 square miles.

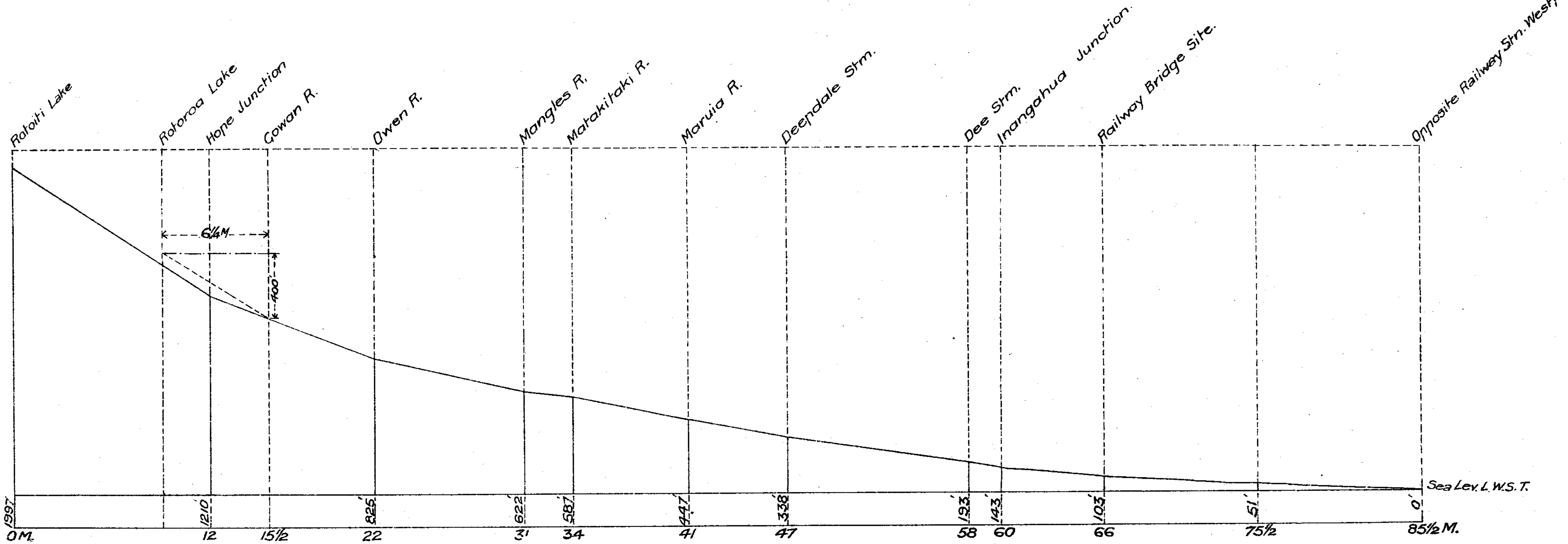
ROTOROA.

Drainage area, 150 square miles.

SCALE: 8 MILES TO 1 INCH.



—Section of Buller River-Lakes to Sea.—



— Scale: 8M. to 1 in hori. —
— do. 800ft. do. vert. —

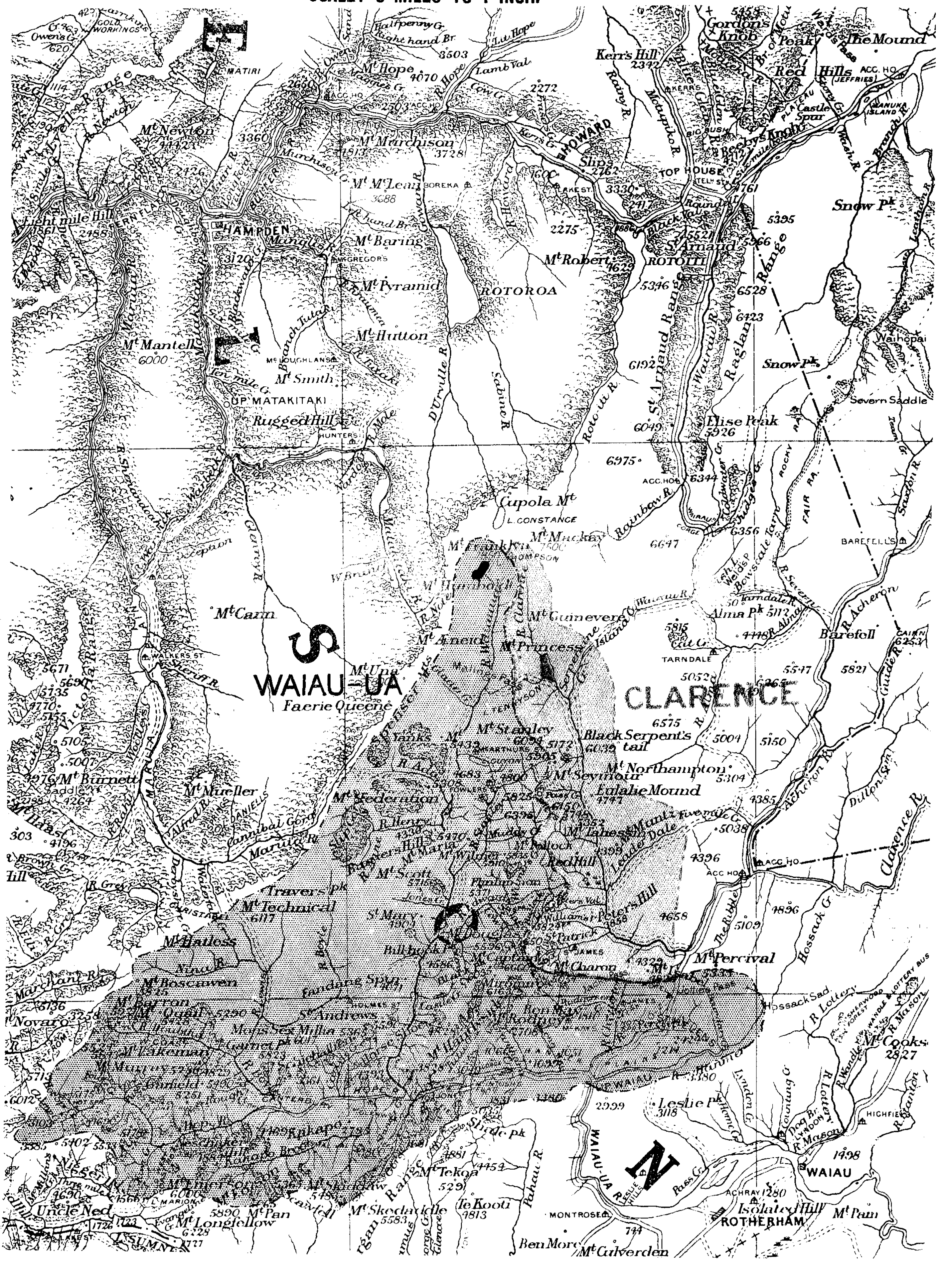
CLARENCE.

Drainage area, 190 square miles.

WAIAU-UA.

Drainage area, 750 square miles.

SCALE: 8 MILES TO 1 INCH.



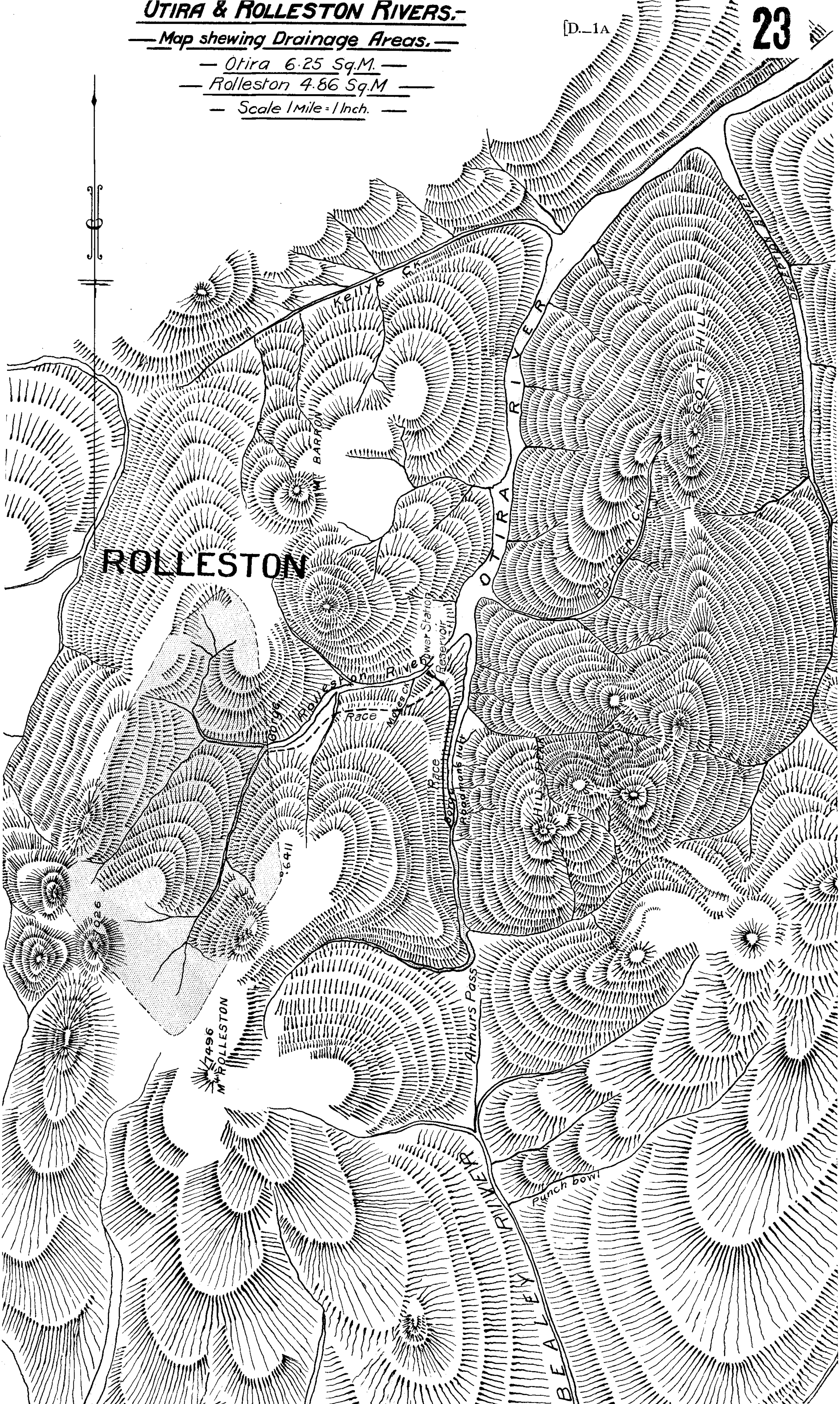
Utira & Rolleston Rivers.-

—Map shewing Drainage Areas.—

— Otira 6·25 Sq.M. —

— Rolleston 4·86 Sq.M —

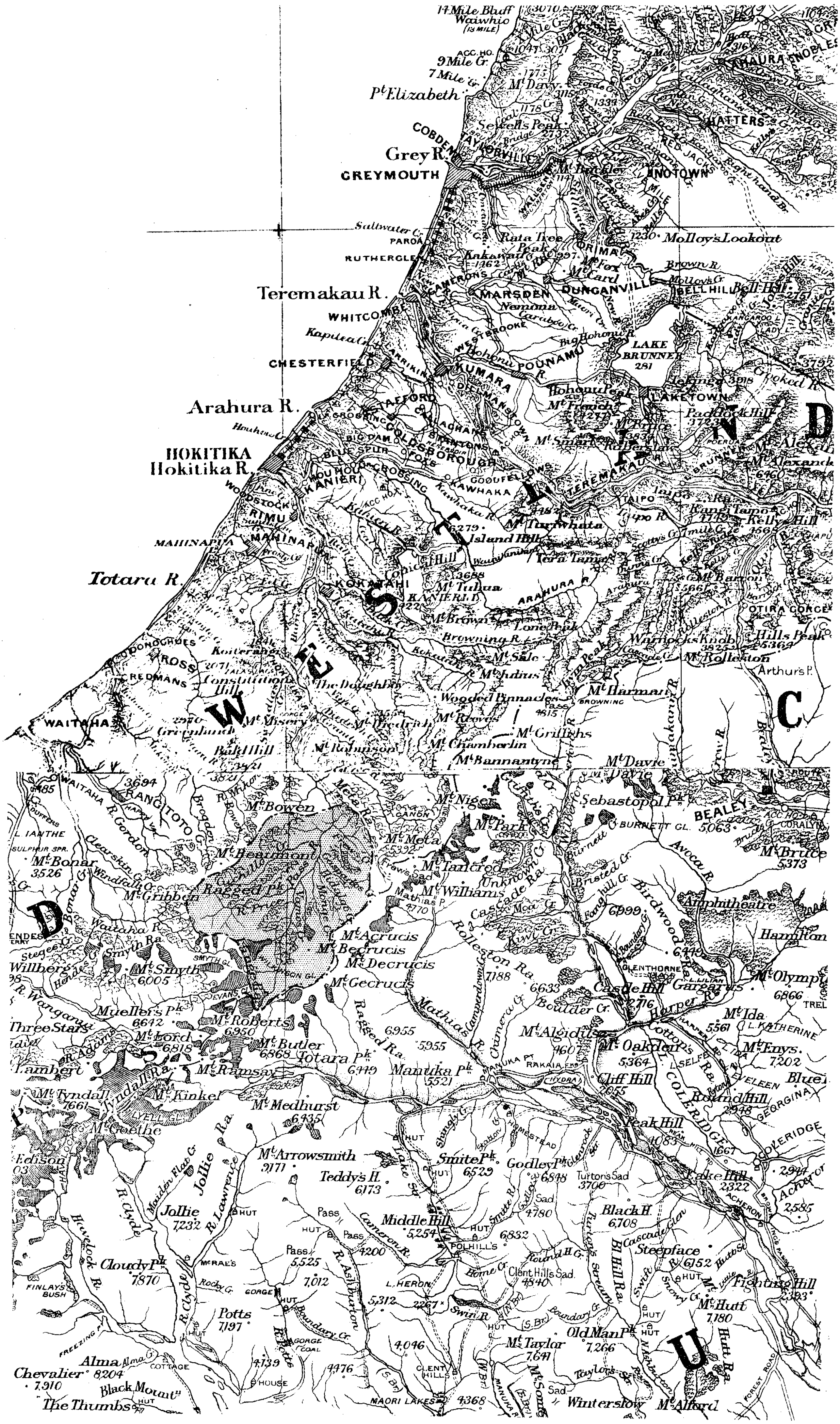
— Scale 1 Mile = 1 Inch. —



WHITCOMBE.

Drainage area, 88 square miles.

SCALE: 8 MILES TO 1 INCH.



KAKAPOTAHI.

Drainage area, 16 square miles.

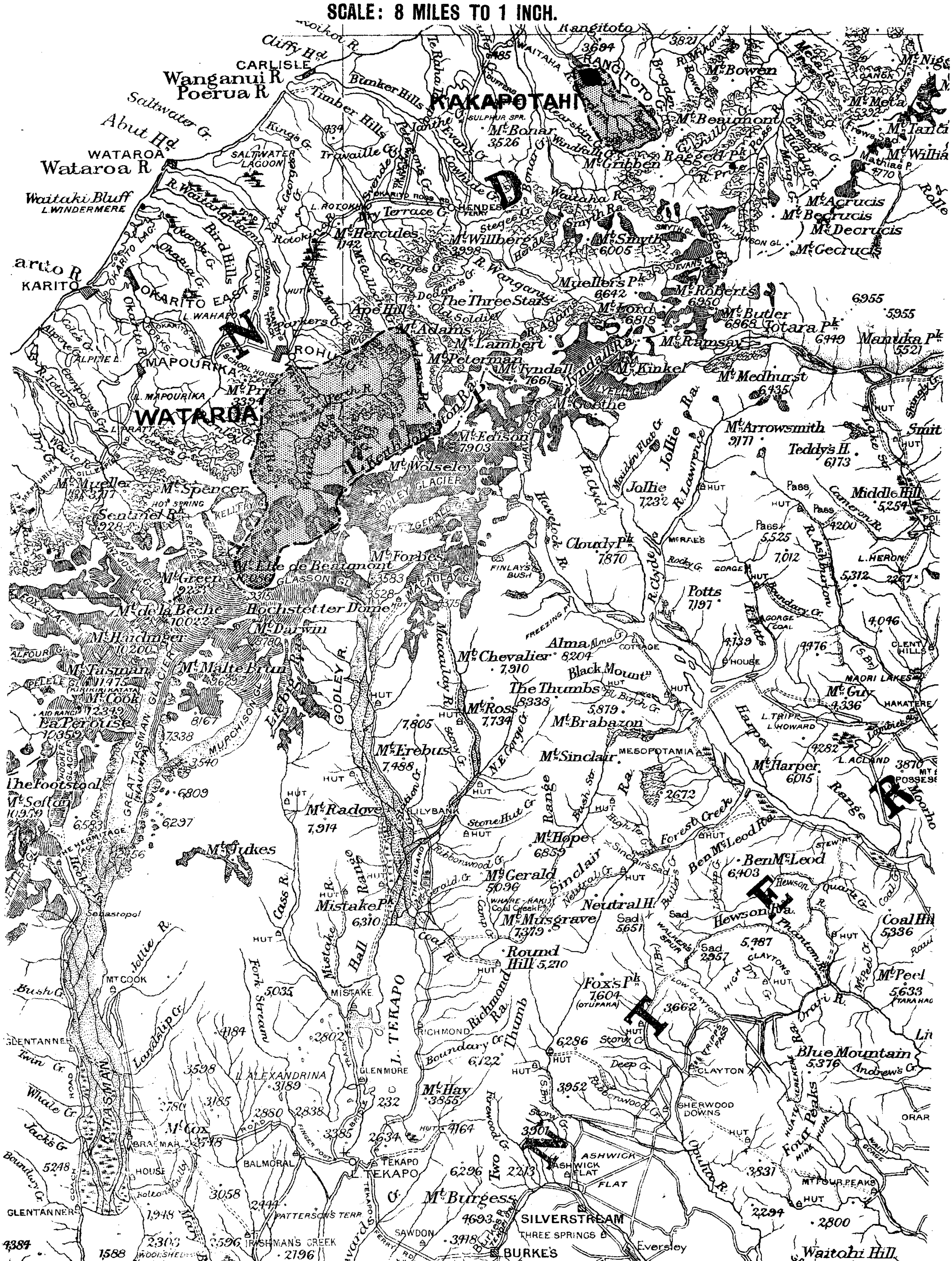
WANGANUI.

Drainage area, 88 square miles.

WATAROA.

Drainage area, 100 square miles.

SCALE: 8 MILES TO 1 INCH.



OTIRA.

Drainage area, $6\frac{1}{4}$ square miles.

WAIMAKARIRI.

Drainage area, 927 square miles.

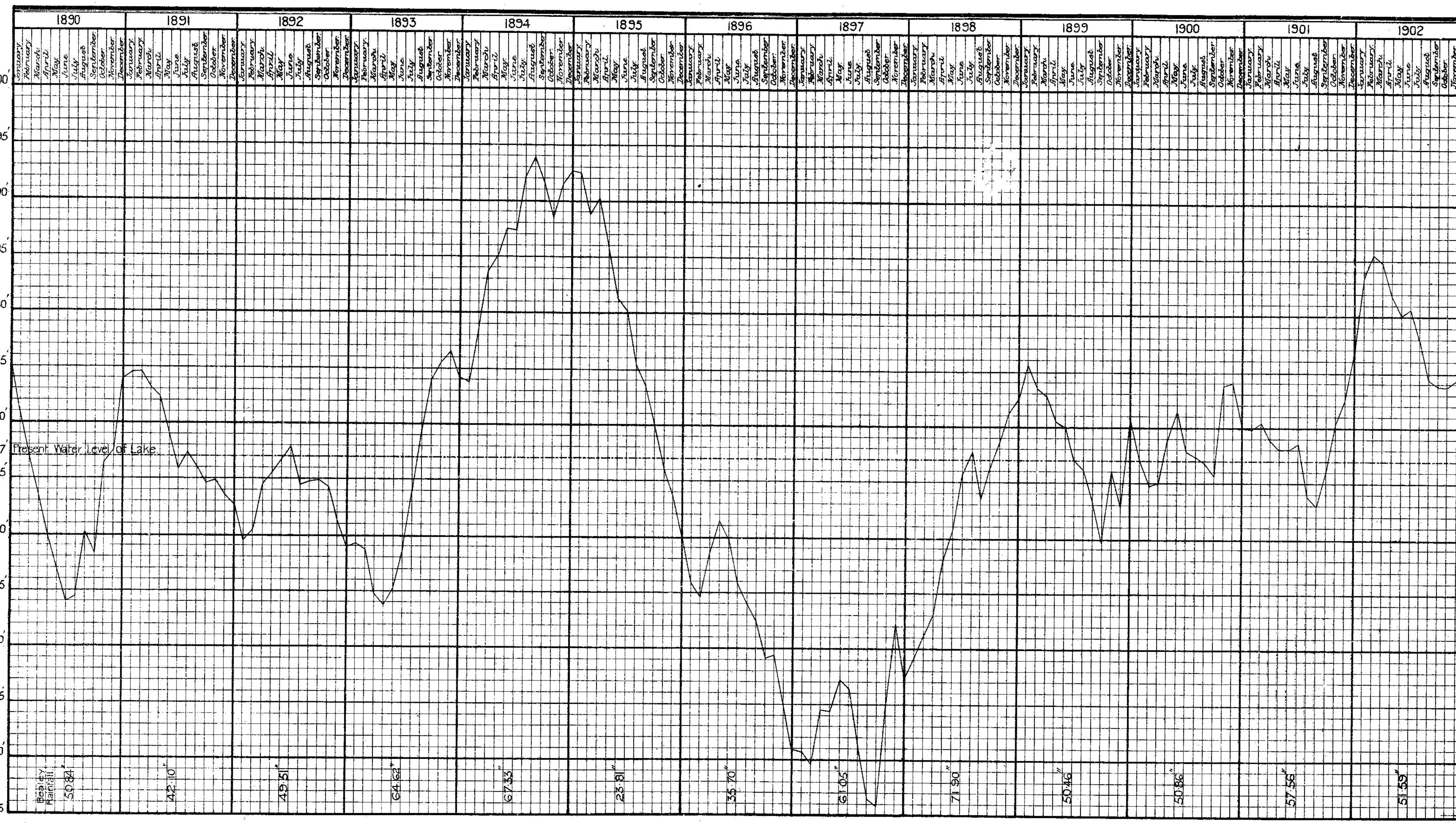
SCALE: 8 MILES TO 1 INCH.

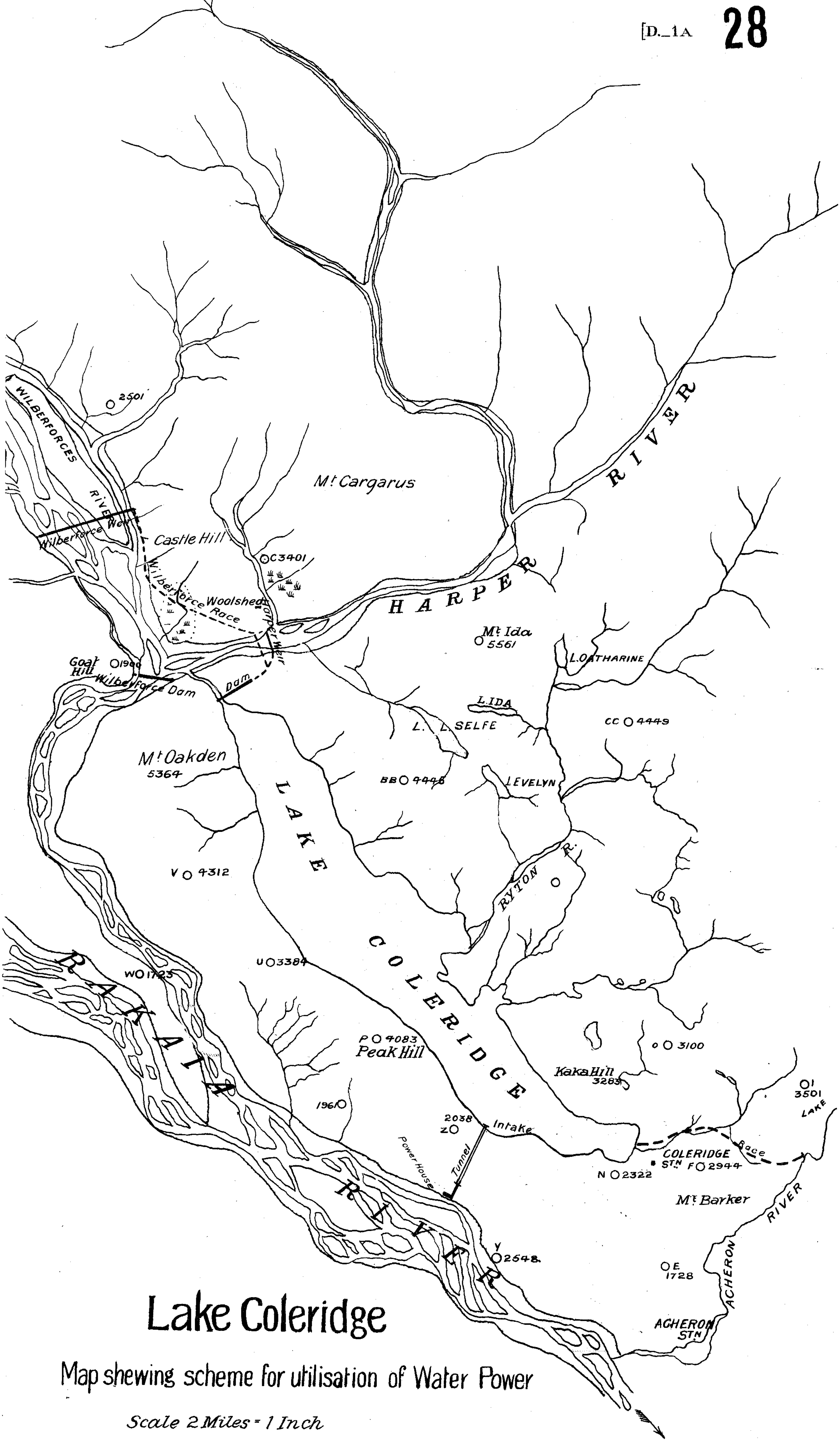
—LAKE COLERIDGE—

—Diagram shewing variation in Lake level with outflow of 1440 cub. ft. per sec. for 12 hours per day.—

—Inflow from Harper 123.46 Sq. M.; Coleridge 85.6 Sq. M.; Acheron 21.12 Sq. M.; Lake area 13.84 Sq. M.—

—Run off at 85% of Bealey Rainfall.—





Lake Coleridge

Map shewing scheme for utilisation of Water Power

Scale 2 Miles = 1 Inch

KANIARE.

Drainage area, 16 square miles.

RAKAIA.

Drainage area, 1,020 square miles.

SCALE: 8 MILES TO 1 INCH.

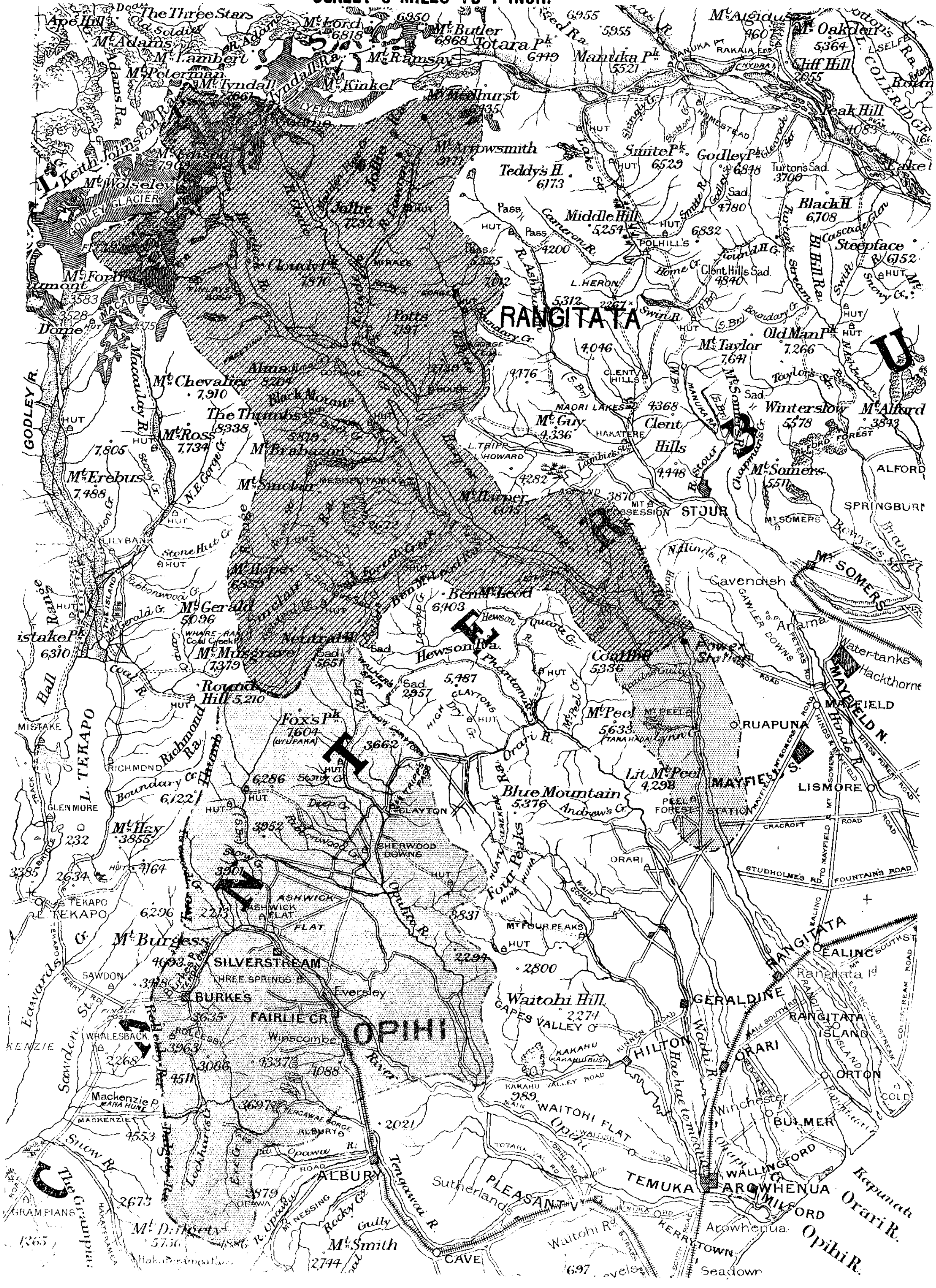
RANGITATA.

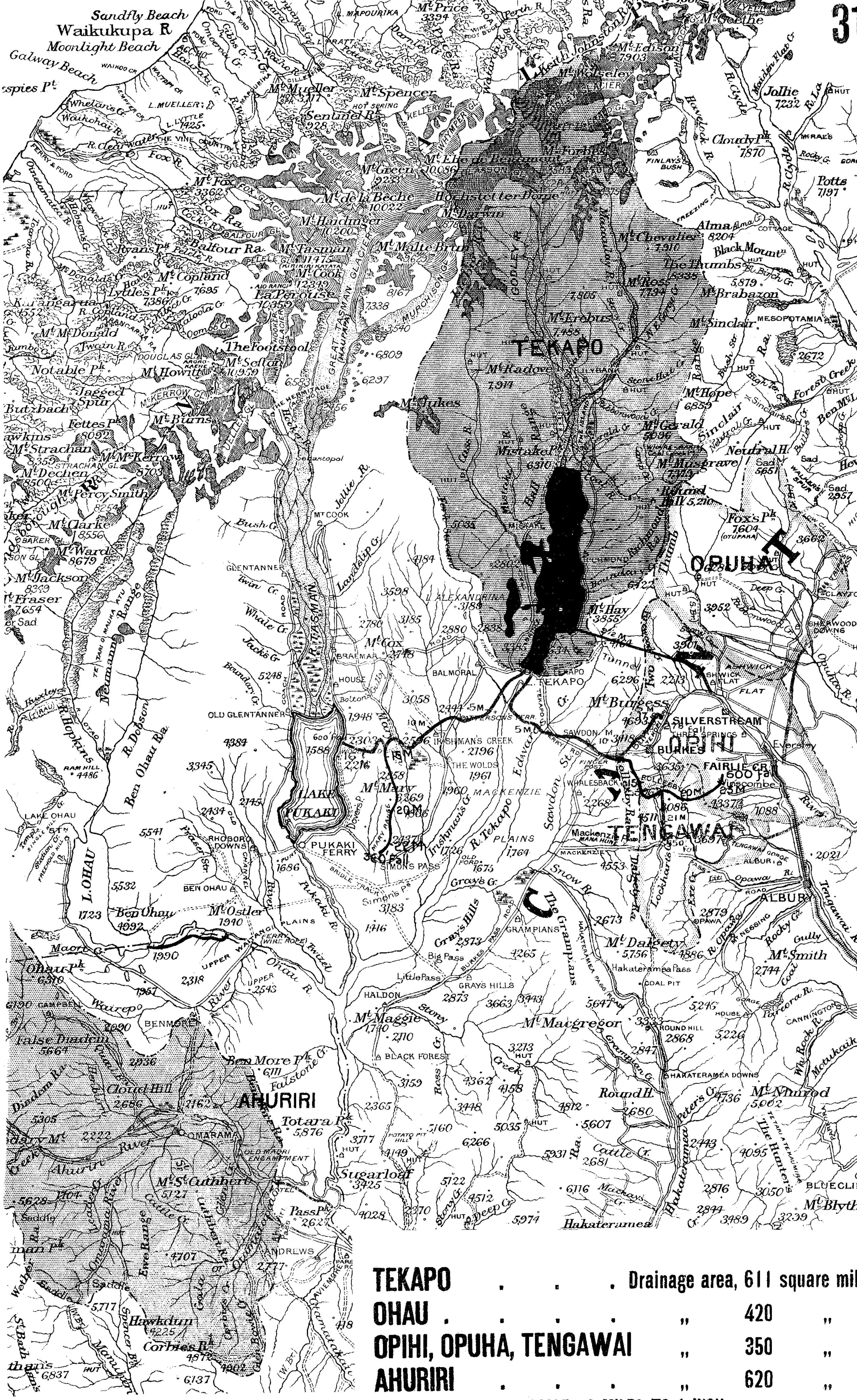
Drainage area, 586 square miles.

OPIHI (ALSO OPUHA AND TENGAWAI).

Drainage area, 350 square miles.

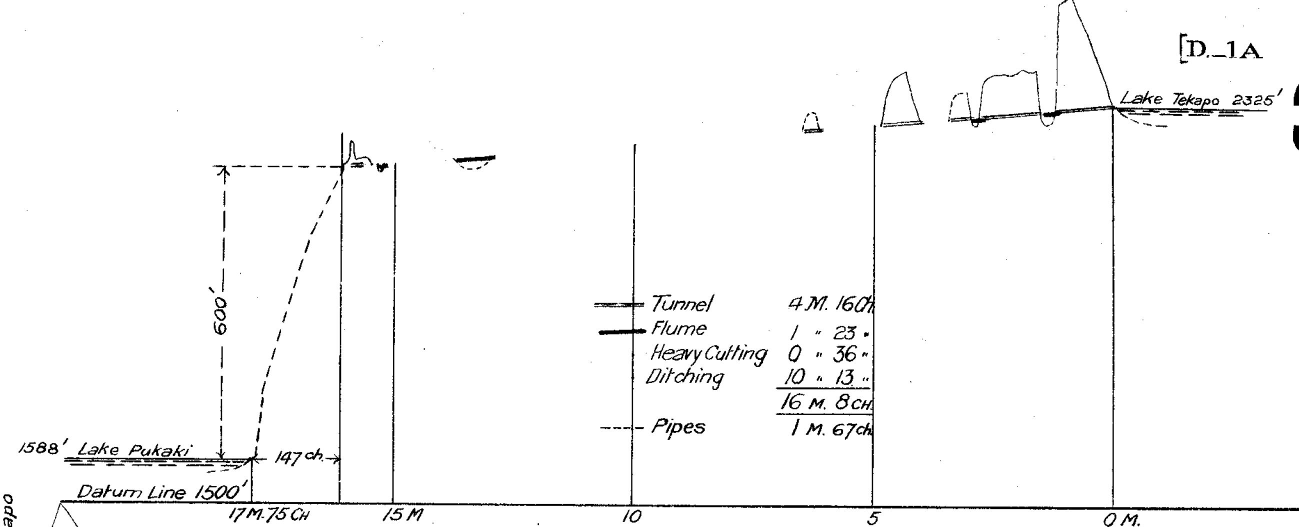
SCALE: 8 MILES TO 1 INCH.



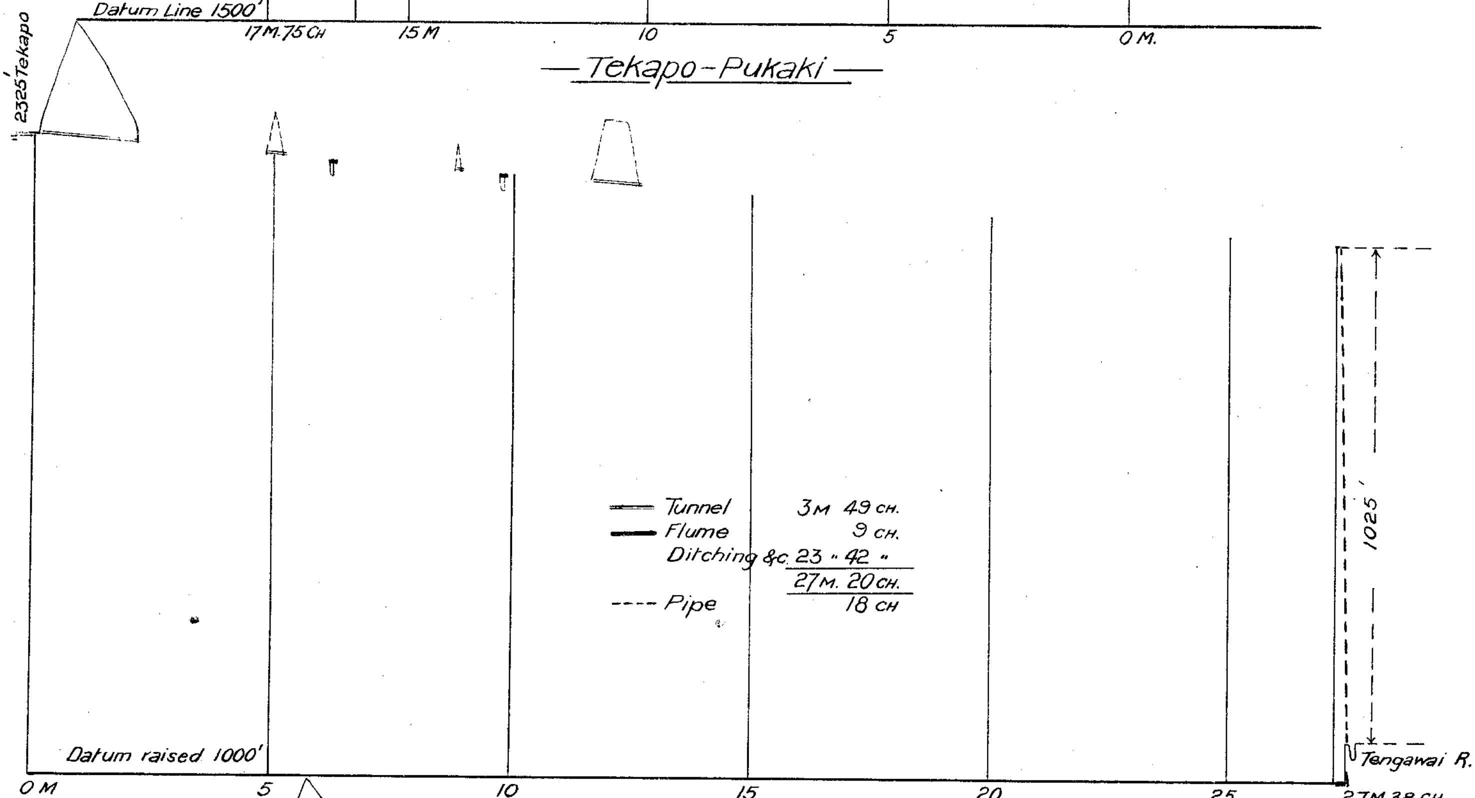


TEKAPO	. . . Drainage area,	611	square miles.
OHAU	. . . . . „	420	„
OPIHI, OPUHA, TENGAWAI	„	350	„
AHURIRI	. . . . „	620	„

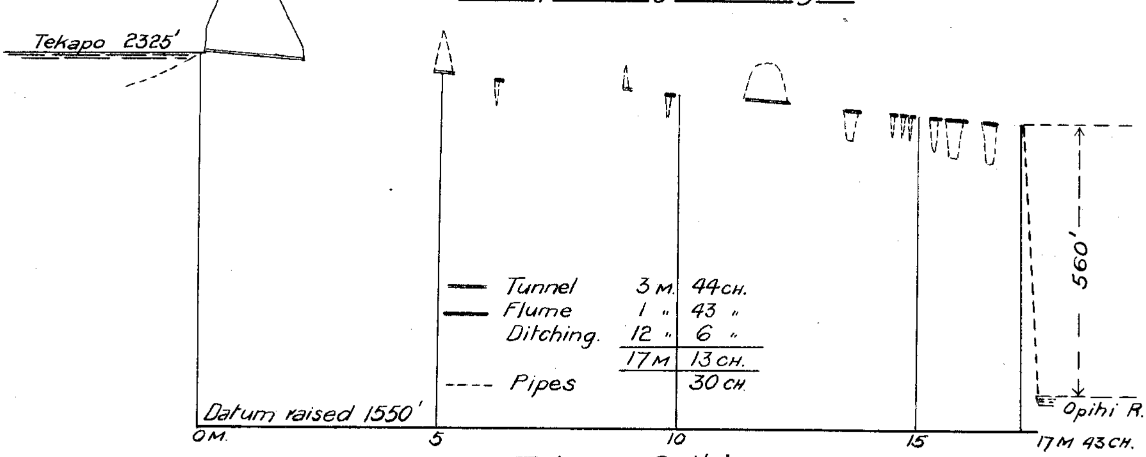
SCALE: 8 MILES TO 1 INCH.



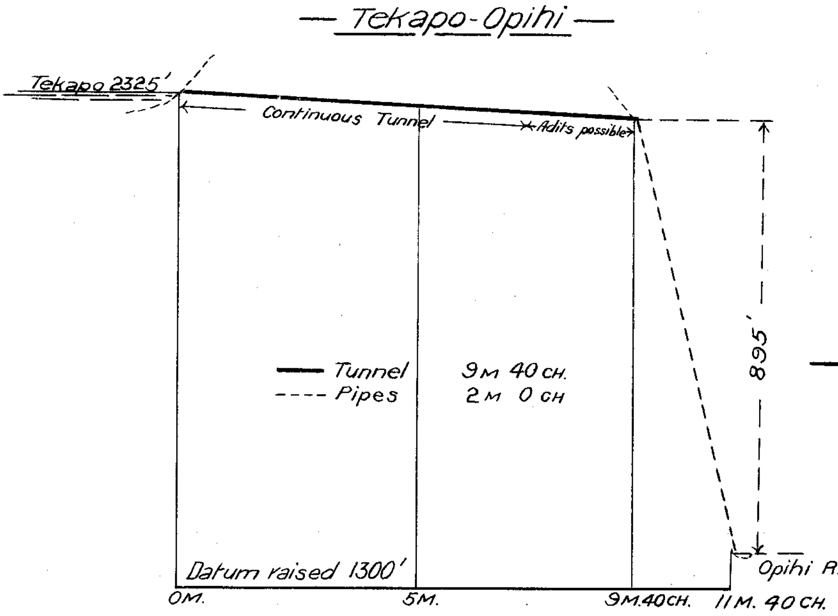
—Tekapo-Pukaki—



—Tekapo-Tengawai Gorge—



—Tekapo-Opihi—



—Tekapo-Opihi—

—Lake Tekapo—
—Power Schemes

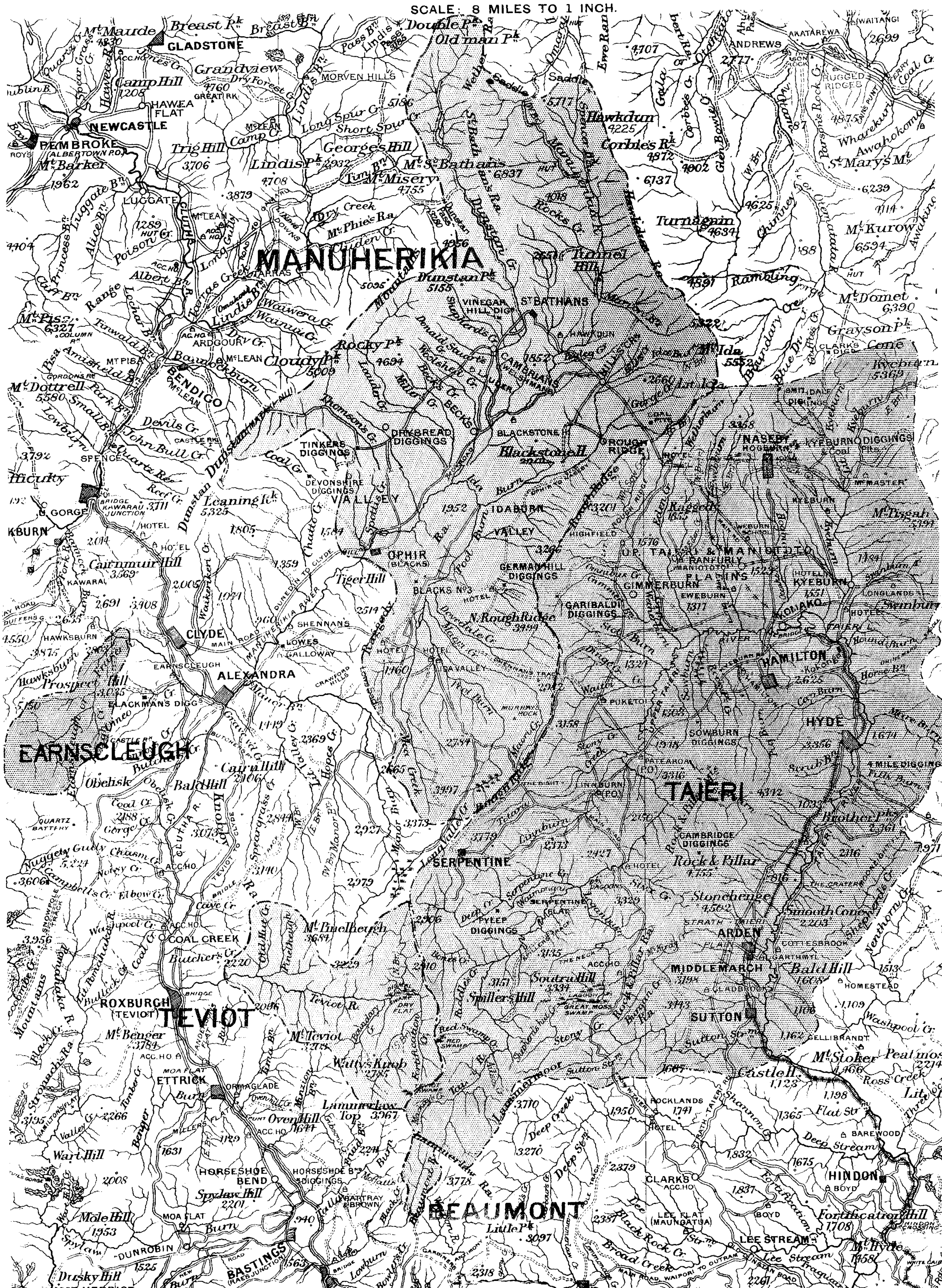
Scale ¼ in. to 1 m. Horiz.
" ¼ in to 100 ft. Vert.

WAITAKI. Drainage area, 2,645 square miles.

AHURIRI. Drainage area, 620 square miles.

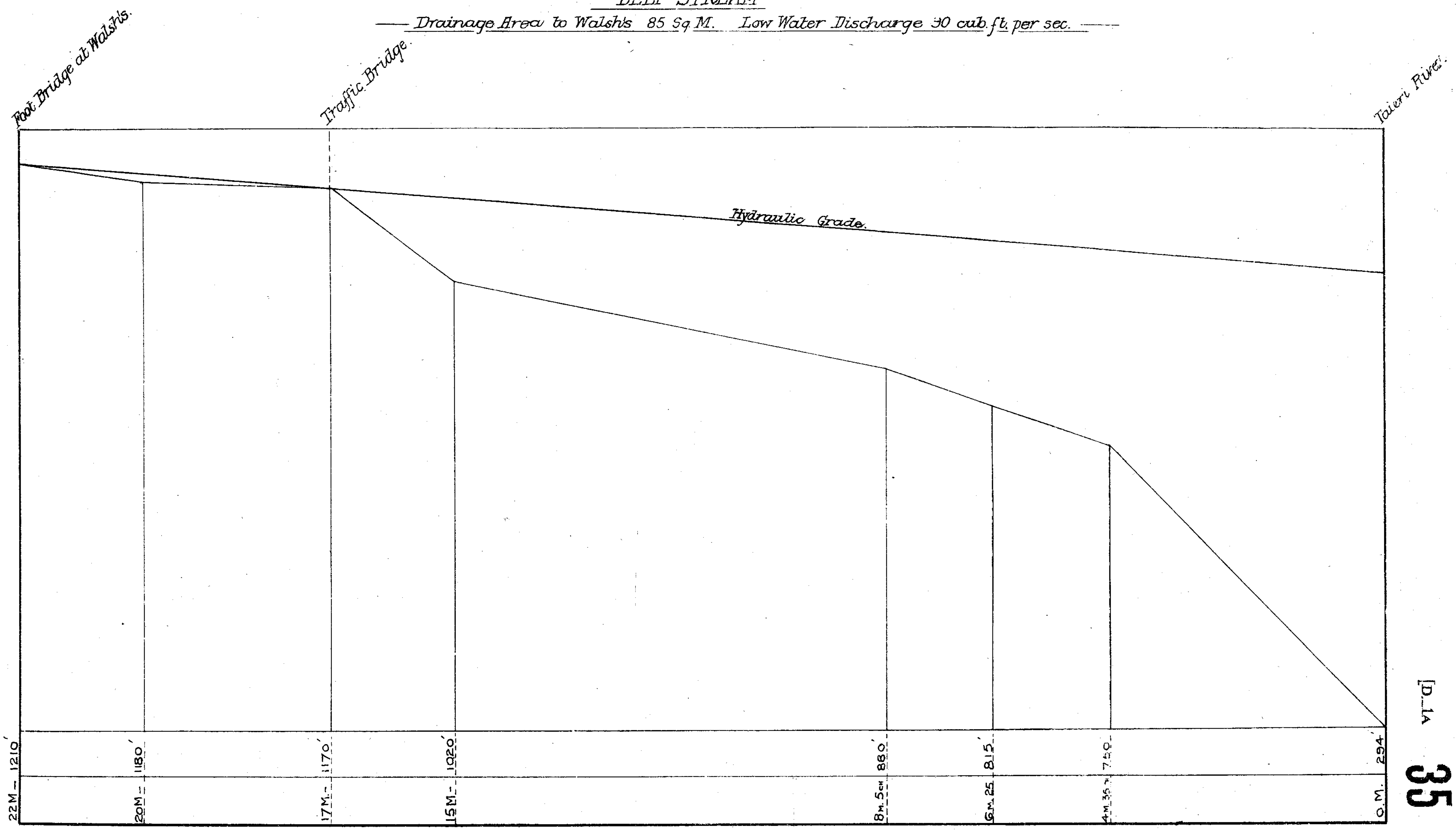
MANUHERIKIA . .	Drainage area,	797	square miles.
EARNSCLEUGH . . .	„	65	„
TAIERI	„	1,262	„
TEVIOT	„	115	„
BEAUMONT . . .	„	7	„
DEEP STREAM . . .	„	77	„
TALLA	„	19	„

SCALE: 8 MILES TO 1 INCH.



DEEP STREAM

Drainage Area to Walsh's 85 Sq. M. Low Water Discharge 30 cub. ft. per sec.



Scales Horizontal 2 Miles = 1 Inch.
Vertical 200 Feet = 1 Inch.

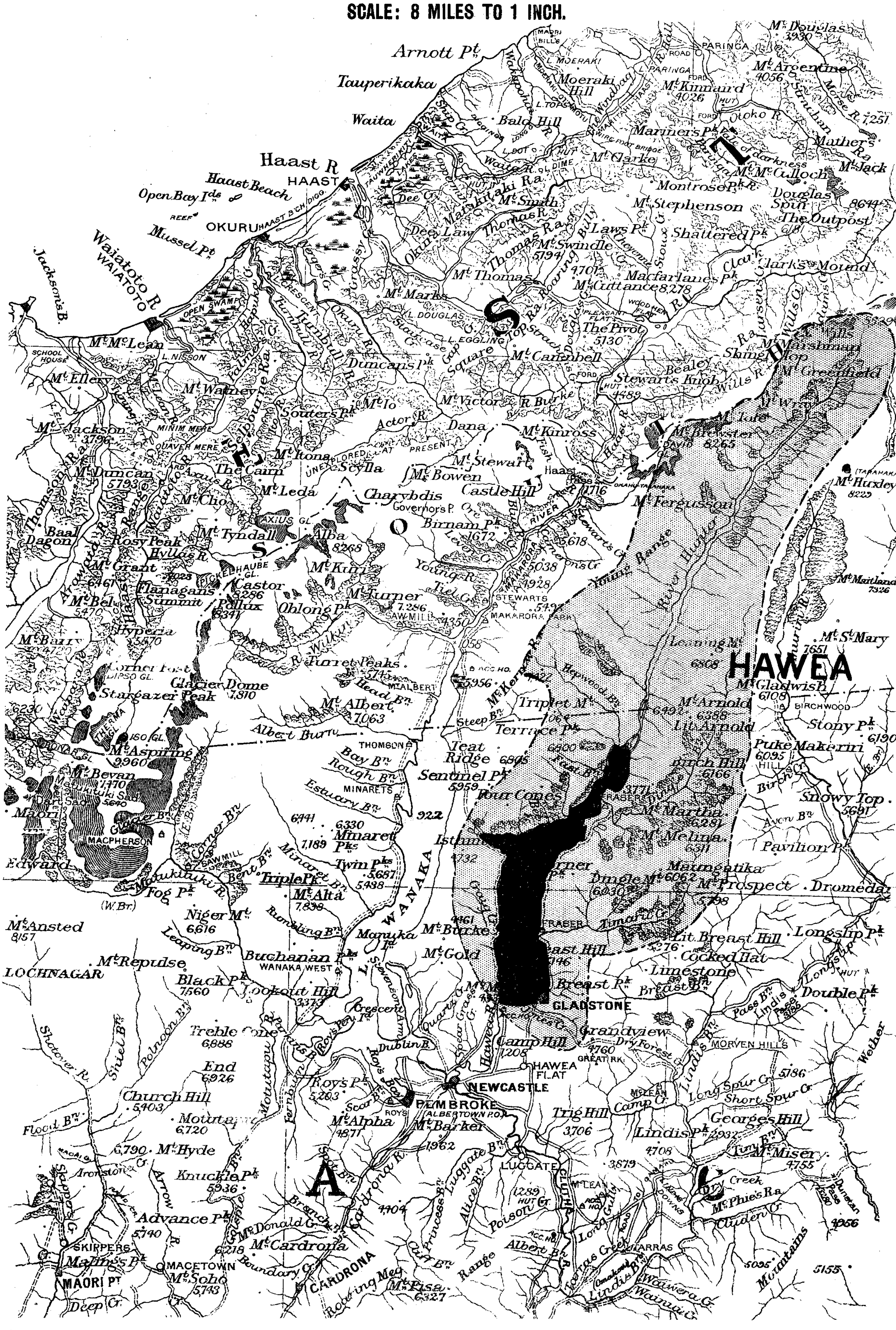
HAWEA.

Drainage area, 567 square miles.

WANAKA.

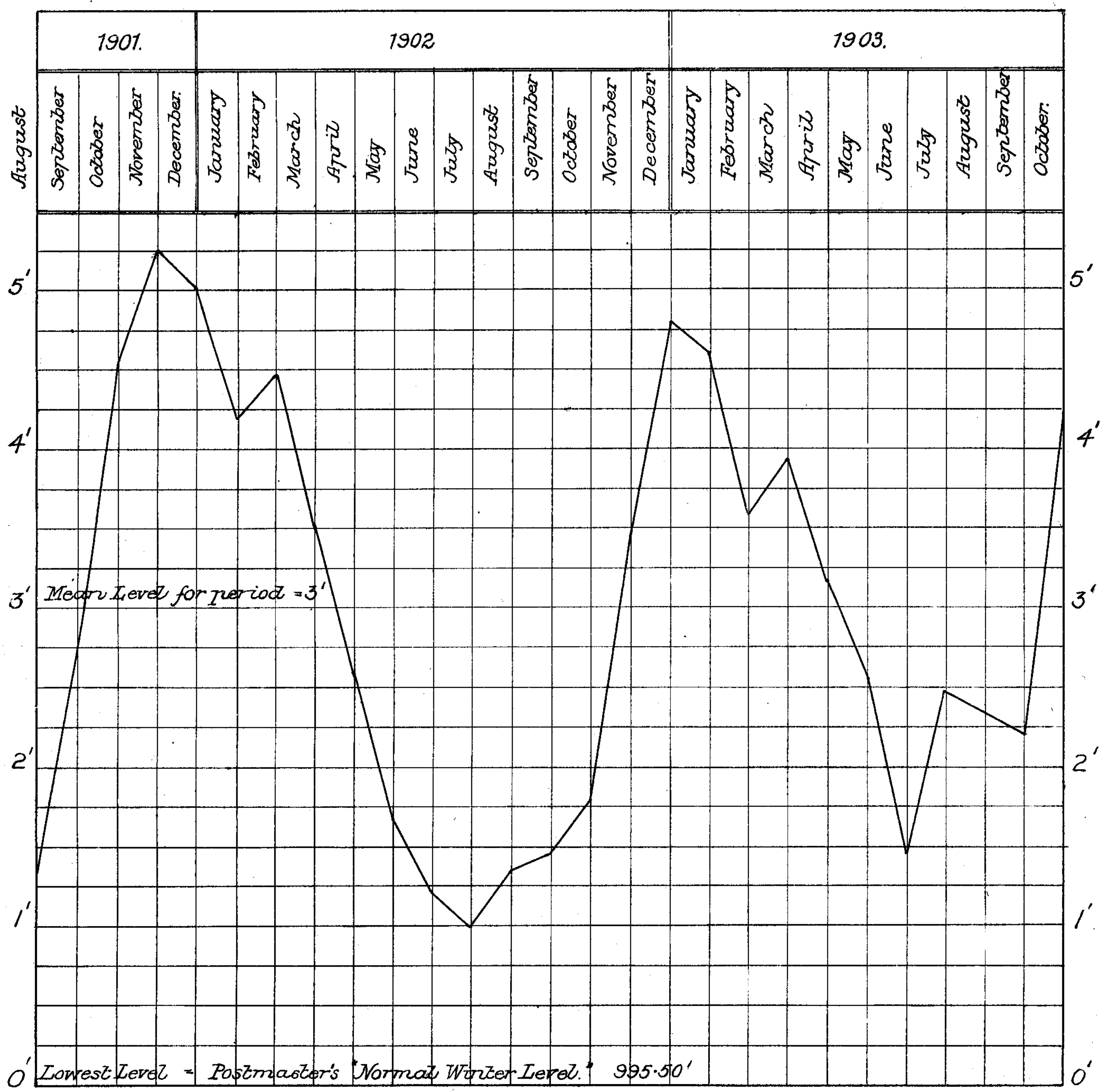
Drainage area, 982 square miles.

SCALE: 8 MILES TO 1 INCH.



—LAKE WAKATIPU.—

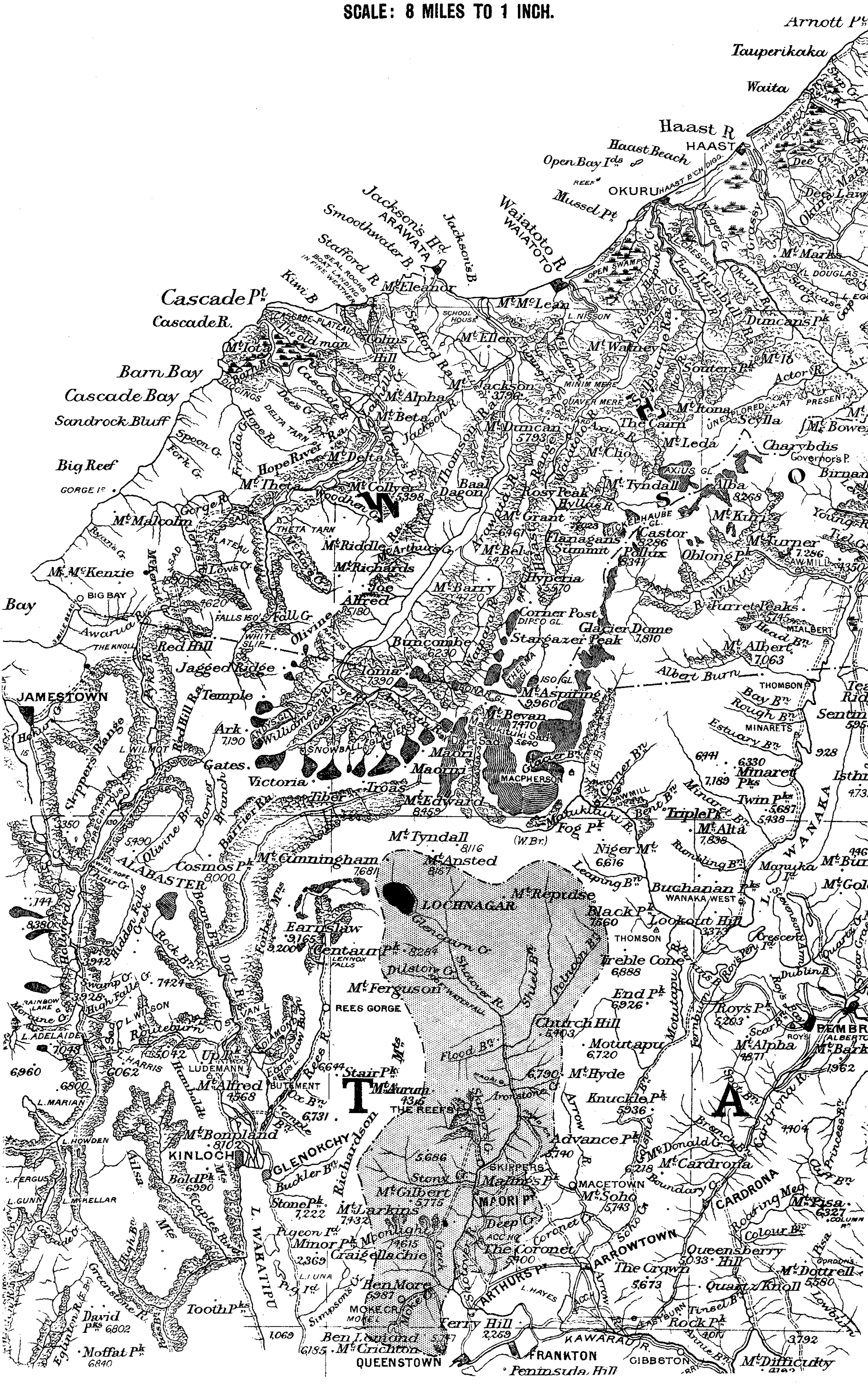
—Diagram shewing observed variation of Lake Level from Aug. 1901 to Oct. 1903.—



SHOTOVER.

Drainage area, 395 square miles.

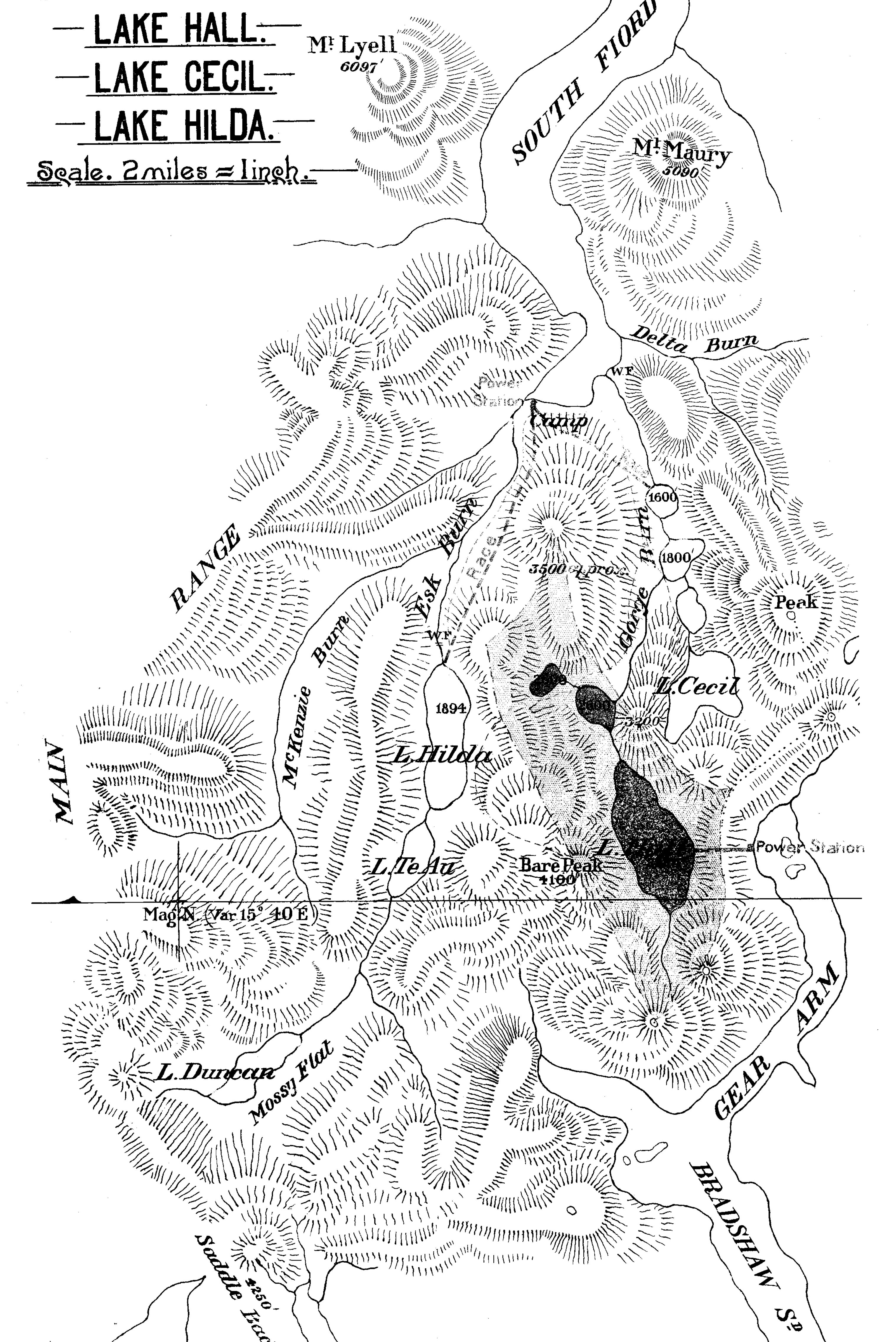
SCALE: 8 MILES TO 1 INCH.



HYDRAULIC POWER SCHEMES.

LAKE HALL.
LAKE CECIL.
LAKE HILDA.

Scale. 2 miles = 1 inch.



WAIAU	Drainage area,	2,377 square miles.
LAKE HALL	”	17 ”
MONOWAI	”	67 ”
HAUROKO	”	210 ”
POTERITERI	”	170 ”

SCALE OF MILES