McLAREN FALLS HYDRO-ELECTRIC POWER SCHEME

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Source: Proceedings of the New Zealand Society of Civil Engineers, 1928/29, Vol. 16, Wellington, 1930 pp. 152-175, National Library of New Zealand .

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Preliminary.

The power supply of Tauranga Borough was first obtained from a hydro-station at Omanawa Falls, 12 miles south of the town.

This development of 110 feet head was extended to its full hydraulic capacity of about 650 kW in 1921. Increasing demands on this plant showed that it would shortly become inadequate and surveys of various possible new developments in the surrounding district were therefore undertaken. Records of discharge in the Omanawa and Wairoa rivers were obtained by taking periodical readings of stage at selected control points, the discharge at certain stages being secured by Gurley current meter measurements. A practical difficulty met with in this work was the variation in calibration of the stage readings owing to the fouling of the river bed at the control points by logs or other debris carried down by freshes. Where the water is too deep to allow of the presence or absence of such obstructions to be seen errors may very easily occur.

Some consideration was given to a development of 250ft head on the Omanawa stream capable, with storage, of giving 3,500 kW, but the site eventually recommended to the Borough Council was that in the Kaimai district at the confluence of the Mangapapa and Maungakarenga streams.

Description of Site.

Here there is a fall of about 42 feet in height which for convenience of reference was termed McLaren's, and below this the Wairoa river drops 250 feet in a succession of rapids till it meets tidal water three miles below the falls. Above the Falls the Maungakarenga stream falls at a similar gradient but the Mangapapa, for miles above, falls only 40 feet. As will be seen from the contours of drawing this portion of its course forms an open valley with a very restricted outlet and the amount of storage obtainable by erection of a dam at the latter point is very suitable for daily pondage requirements. The arm of the reservoir, extending north-easterly from the dam, consists of the valley of a small stream conveniently situated to act as a head race. Instances of a tributary joining a river in a direction almost in direct opposition to that of the main stream are not frequent, and in this case the phenomenon has been of value by bringing the intake within 100 yards of the power house site and thus greatly contributing to the development. The Maungakarenga stream has been diverted into the reservoir at a point about $^3/_4$ mile above the Falls through a tunnel capable of carrying the summer flow. The river beds throughout are rocky and boulder strewn, the country being of rhyolite with contraction cracks running principally in parallel vertical planes in N.W. and S.E. directions.

River Discharges.

The drainage area of the Maungakarenga is 46 square miles, and of the Mangapapa 65 square miles. The watersheds are largely forest covered and the pumice soil of the locality is very porous. The combined summer flow will rarely fall below 220 cusecs of which about 170 are supplied by the last named stream and 50 cusecs by the former. These figures correspond to 2.6 and 1.1 cusecs per square mile. From an adjoining watershed the Omanawa stream maintains a minimum flow of about 2.9 cusecs per square mile. The high rates of discharge maintained by these streams is seen by comparing them with figures for the minimum summer flow quoted for rivers in the Hudson Bay and Mississippi basins which work out at from .01 to 0.4 cusec per square mile. They are accounted for by the storage afforded by the porous soil and its bush covering, also by the heavy and well distributed rainfall. The average elevation of the drainage areas is probably about 1,200 feet above sea level.

Flood Discharge.

Owing to the precipitous nature of the drainage areas, and to the high rate of precipitation sometimes experienced, violent floods occur. Falls of respectively 10 and 12 inches per 24 hours have been recorded at Omanawa Falls power station. In 1920 the author recorded a rise of 24 feet in the river at the present power house site when it is probable the discharge was about 40,000 cusecs. Reports of floods in the lower reaches showed that higher floods had been experienced in 1897 and 1907. One feature which became noticeable when the camp had been established at McLaren Falls was the fact that the Maungakarenga stream, although having the smaller drainage area, yet carried the greater floods of the two streams. This fact shows that formulas for flood discharges which include a function of the drainage area only cannot be very satisfactory. It is fairly obvious that a fan shaped area with the outfall at the apex will have a higher flood discharge than a stream draining a long narrow strip of country. Besides the shape of the drainage area a flood formula should also include the average gradient.

These high flood discharges naturally influenced the design of the plant. The power house has been built in a recess which protects it from their direct violence and it has been made water-tight up to 35 feet above normal water-level.

Vertical arrangement of the generating sets was adopted in order to have the generators as high as practicable, and a considerable amount of excavation was done in the river below the falls in order to assist the discharge of floods. The spillway has only to carry the flood waters of the Mangapapa, and is arranged to discharge approximately 29,300 cusecs should flood level in the Lake rise three feet above the balustrade of the arch dam. Since completion the highest flood passed over the spillway was 16,000 cusecs—in January 1926.

Access

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The site is 14 miles from Tauranga. Supplies were transported from that port by punt up the tidal waters of the Wairoa river, the upper reaches of which were snagged to give 3ft 6 inches depth at low tide. At the river landing a shed suitable for the storage of 100 tons of cement and a derrick designed for 6-ton lifts at 25ft radius were erected. The intervening length of public road presented difficulties as this $3^1/_2$ mile stretch was entirely unmetalled and included a hill with a 600 feet rise, also a 40 year old bridge of three 63 feet spans. This bridge was side guyed and understrutted off the rocky river bed 30 feet below with struts so arranged as to swing without damage to the trusses if struck by logs during floods; whilst the worst portions of the road were metalled. One mile of private roading was constructed about 30 chains of which was rock siding on a 1 in 8 gradient. An 81-feet span heavy traffic bridge is also included in the private access road.

Construction Equipment.

Power for construction purposes was available from the Omanawa plant from which it was secured at 11,000 V over a line erected for subsequent use as a tie line. From a 50 kVA transformer, current was distributed to the construction plant the principal items of which were:—

40 h.p. motor driving 15" x 9" rock crusher, sand making roller, mill and sand washer.

15 h.p. motor for air compressor.

15 h.p..motor concrete mixer and winch at dam sites.

$7^1/_2$ h.p. motor quarry hoist.

$7^1/_2$ h.p. motor concrete mixer and hoist at power house. Several smaller motors were employed for portable concrete mixers, pumps and winches. A cookhouse and camp were established for the accommodation of 80 men, the balance of the labour not so housed being farmers from localities near enough to enable them to ride to work. Two permanent staff cottages in concrete were also erected

Concrete Materials.

No satisfactory material for coarse aggregate was obtainable within 20 miles of the site nor could satisfactory deposits of sand be located in the vicinity. The best samples of the local rhyolite tested only 4,000 lbs per square inch in 3-in. and 5-in. cubes and, besides this low compressive strength, the stone is also porous. The author has met with no reference to engineering structures built with aggregate of such low quality, but after tests on test cubes and reinforced beams it was decided to make use of the rhyolite for both fine and coarse aggregate. This necessitated the use of a somewhat larger quantity of cement on the job since lower working stresses had to be employed, also mixtures stronger than ordinarily adopted were employed. However, the extra cost of cement was much more than offset by the higher cost of imported stone, and, in any case, transport of the latter was not practicable.

Quarry.

The site chosen for the quarry was immediately below the power house on the river bank where there was a rock face of about 25 feet with an overburden of 10 feet. The removal of 10,265 yards of spalls from this quarry effected a considerable widening in a previously restricted portion of the river. The stone was lifted by means of a derrick in $1\frac{1}{4}$-yard skips from the truck on the quarry floor and tipped direct into motor trucks. The average overall labour cost up to this point was 7s 10d per yard of spalls, the cost being high owing to interference and loss from floods and the high percentage of inferior stone which had to be rejected.

Main Dam and. Diversion Works.

The site selected is 15 chains above the Falls where an old channel running parallel with the river, but about 30 feet above it, has provided a spillway channel independent of the main gorge and separated from it by a rocky mound.

Various ideas were considered for the unwatering of the site. The first obvious solution was to divert the river by means of cofferdams into a tunnel 270 feet in length between the sites of the main and spillway dams. Another was the erection of cofferdams upstream and downstream of the site with the river carried by flume across the intervening space. If these cofferdams could be made and kept sufficiently watertight the intervening space would then be unwatered by suspended pumps. It was anticipated, however, that the frequency and violence of the floods would considerably hamper work carried on by these methods and the more tedious method was therefore adopted of unwatering the deep hole at the dam site by means of a diversion tunnel carried up from below the falls on a low enough level to drain the site by gravitation. The layout of the tunnel is shown on drawing. It is about 1,016 feet in length, 7' x 7' in section, and untimbered and unlined. It discharged three feet above water level below the falls, and has a fall of 12 feet in its length. It was driven from the lower end only, the spoil being dumped into the river. The work was done by contract, all plant being supplied by the employer, including air drills, pipes, rails, trucks and a supply of compressed and ventilating air. The contractor purchased explosives at cost price.

The rock drilled easily, but it required an excessive amount of explosive, blasting gelatine being favoured. The tender prices varied between 43s and 66s per foot, most prices being about 55s. The work was satisfactorily completed at the lower figure. The contractors worked 1,050 man shifts and averaged 43 feet per week including time lost by floods and other causes. They made use of about 15 holes per round using about five small plugs in each of three cutting holes, an equal number of holes and plugs for the lift and the side holes were charged with about $3^1/_2$ plugs each.

It will be seen that an angle was introduced into the alignment of the tunnel so as to reduce the length of cross cut which was driven to drain the depression in the river bed immediately below the dam site. This it did effectively, and it avoided the necessity of pumping out a large volume of water after each fresh. Actually only the last five feet of the foundation required pumping, and for this a 2-inch centrifugal sufficed. After the flap type gate for finally closing the diversion tunnel was installed the heads of both the main tunnel and crosscut, each of which were 20 to 25 feet below river level, were simultaneously blown in. The gate above mentioned was made up in position with 10" x 10" Jarrah timber and is supported on four hinges of 4" x 4" angle iron which are set in the top of the sill. The gate sill is of concrete reinforced with a clear gate opening 8' x 6'. The hydraulic thrust on this area is 98 tons at maximum water level. Until the dam was ready for use the gate was held open by tie rods secured to beam at top of the gate shaft.

The dam has a constant radius of 63′0" on the upstream side and is designed for a compressive stress at maximum flood of I40lbs per square inch or 20,000 lbs per square foot. Its total height is 77 feet. It is not reinforced except for horizontal reinforcement in the upper 15 feet. There was a depth of water at the site of about 20 feet and downstream from this the river bed rose about 15 feet. Soundings showed that the bed was very rough but it could not be readily determined whether the roughness was the result of potholes in the rock, or of large boulders covering the river floor. After the site was unwatered it was found that the bed was covered with boulders up to 7 feet in diameter but below these the solid rock contained potholes, one near the western bank being 18 inches wide by 6 feet deep, or a total depth below original water level of 29 feet.

Excavation for the abutments was carried in to the cliff faces from 6 to 30 feet. Owing to the extensive open heads this excavation could only be made to conform very poorly to the dimensions required for the curved faces of the dam. In view of the possible presence of further open heads behind the abutments it was decided to seal any such by pressure grouting. Holes up to 14 feet in depth were drilled at approximately three feet centres right up each face and neat cement grout was applied by means of a locally made appliance working under 100 lbs air pressure. On the west abutment where trouble was most expected all the holes proved tight, but on the east abutment several holes absorbed a considerable quantity and altogether two tons of cement were injected. The penetrating action of this process was demonstrated by the fact that in some instances the grout was seen weeping from heads in the cliff face some 35 feet away from the point of application. Some of these heads were so tight as to have been otherwise im-perceptible. It is probable that the filling of voids in this way, in addition to preventing leakage, has also obviated the introduction of indeterminate stresses into the dam through movement of the abutment. After the dam was filled no leakage occurred from the west abutment. The other one has leaked somewhat, but the weep has gradually decreased.

Maungakarenga Diversion.

At a point where a bar of rock across its bed provides a natural weir this stream has been tapped by a tunnel which passes under a low ridge delivering the water into a small gulley at an elevation of about 23 feet above normal lake level, whence the water traverses down the gulley into the lake. The grade of this gulley will eventually cause scour but so far it has not been necessary to take preventive measures. These would be inexpensive. The tunnel is approximately 310 feet in length and, except for 80 feet at the upper end which is in rhyolite, it traverses sedimentary pumice. This portion has been lined by inserting 33-inch concrete pipes. Admission of water is controlled by a flap type gate operated by a winch.

Spillway.

Originally the site of the spillway was covered with light bush growing on a thickness of 7 to 12 feet of soil. About 2,000 yards of this overburden were removed to expose the foundation and then a three feet deep excavation was made into the rock along the toe and heel of the dam. It is of interest to mention that the rock surface when thus uncovered of its 12 feet of overburden was found to contain large potholes in which were still lying some of the polished pebbles which had assisted to form the holes.

The cross section of the dam is such that its surface is wholly above the lower nappe of a free discharge over a vertical sharp crested weir under10ft head. The length of the crest is 156 feet, not including about 55 feet of water way which has been added at the sides by removal of the overburden, the rock so exposed being three to six feet above crest level. The discharge capacity is calculated at 14,500 cusecs under 8 feet head and 29,500 under 12ft head. This last figure includes an allowance for the quantity overtopping the main dam, the parapet of which is 8' 10" above the crest of the spillway.

Flashboards.

These have been provided and are used during seasons when the full plant capacity is required. It was considered that the increased expenditure necessary for the installation of any form of automatic or bear trap gates was not justifiable for this particular installation—at any rate not for many years. The flashboards are three feet high and are supported by $1^3/_4$ " mild steel pins standing in sockets let into the crest of the dam at three feet centres. So far their maintenance cost has not been high. The design of pins for supporting flashboards is not at present an exact science. For instance the bending moment on the pin due to the water thrust on the upstream side of the boards is variable depending on the shape of the dam crest and whether or not air is present below the nappe. Also the ordinary theory of bending stresses does not hold for material stressed up to the yield point. The performance of these boards is being observed and so far the heaviest flood carried by them rose $6^1/_2$ feet above the crest. At this time the pins in the centre bent over to about 35 deg. off the horizontal while those at the ends remained almost erect. Evidently therefore the head mentioned is about the critical figure for this particular installation.

Intake.

7,000 yards of spoil were removed in preparation of the site. No satisfactory, foundation was available for a considerable depth and this structure was therefore built on a reinforced concrete raft and designed throughout to carry on its exterior and bottom surfaces the loading due to hydrostatic pressure at maximum flood height. The main structure is a circular tower 28 feet diameter by 30 feet high. It is divided into two screen chambers each with racks 10' *x* 18' in area giving a mean velocity at full load of two feet per second between the rack bars. In order to secure against blockage of the intake by slips a double conduit of concrete was carried out for 60 feet in front of the gate chamber. The two gates, each giving a 7' *x* 6' opening, are of Jarrah and work on gunmetal faces. There is a decided tendency for the formation of a vortex over the entrance to the conduits which it is thought would most effectively be reduced by opening a slit along the top of each conduit for say 20 feet back from the entrance.

Penstock Tunnel.

This connects the intake with the breeches pipe giving supply to the two turbines in the lower floor of the power house. It is 8 feet, finished diameter, corresponding to a water velocity at full load of 10 feet per second, and is 300 feet long with a grade of 1 in 5. Approximately 70 feet at the upper end is through a fine pumice sand with much water in it. This was timbered on sets of curved 40lb rails. Infiltration of the fine pumice and scouring of the invert owing to the steep grade caused a certain amount of difficulty. 60 feet of the lower end of the tunnel is reinforced to withstand the internal bursting pressures with 1 inch rods at 41 inch centres. It is also reinforced longitudinally for the same length in order to provide anchorage of the penstocks against hydraulic thrust which, if full load were thrown off simultaneously by two machines during maximum flood, might rise to 200 tons. This is secured by bolting the breeches pipe to a short section of pipe which is let into the end of the concrete tunnel lining, a flange on which is secured by nuts on the end of the longitudinal rods.

Regulation of Speed and Water Pressure.

Owing to it being possible to bring the intake so near to the turbines some consideration was necessary in order to determine the need or otherwise of pressure regulating equipment. If sufficient strength against bursting be provided in the penstock and turbine casing this question is determined by the allowable limits of speed regulation. Given governors of average sensitivity, and with operating time adjusted to a definite figure, speed variations for given load change depend mainly on the flywheel effect of the generator rotor, and to a small extent on the pressure variations in the penstock. Mechanical pressure regulators will prevent undue rise of pressure when load is thrown off, but are ineffective in keeping up the water pressure when load is thrown on and the governor is opening the gates. At such times the speed must be maintained as nearly as possible by drawing on the stored energy of the revolving rotor. The alternative to the mechanical pressure regulator is the surge tower which may be of open or else of the closed type wherein the water surface is loaded by air pressure. On this development it was decided to call for a flywheel effect (WR^2) in the generators of 100,000ft-lbs which, however, necessitated the provision of a flywheel on top of the rotor. Calculation indicated that with a governor closing time of two seconds this amount of flywheel effect would secure a maximum speed rise, with full load thrown off, of 21 per cent, which is about the recognised limit. As, however, there was considered to be a possibility of resonant surges occurring in the pipe line with so short a closing time, it was decided to provide a branch on the penstock for the connection of a surge tower. This branch was built into the reinforced concrete section just at the rear of the power house. In practice it has been found satisfactory to allow a much longer closing time and a correspondingly higher speed change, and to omit the surge tower or other hydraulic pressure regulating device.

Draught Tubes.

Much attention has in recent years been devoted to this portion of the turbine equipment and this is, of course, essential on low head plants where the energy represented by the velocity of the water as it leaves the turbine runner forms a large percentage of the total available energy.

In the present installation the mean axial velocity of the water leaving the turbine is 20 feet per second at full gate and head and it gradually reduces to 4 feet per second where it emerges from the draught tube.

The draught tubes were each constructed by tunneling in from the floor of the tail race and then rising vertically under the centre line of each machine. This introduces a right angle bend which was carefully set out and the whole lined with concrete. The outlet dimensions are 10 feet high by 8 feet wide and the total lengths are 39 and 35 feet respectively. Much diversity of opinion exists as to the maximum allowable height of the draught tube, or rather of the allowable height of the turbine runner above tail water level. If the height is too great vibration and inefficiency of the turbine will result and also cavitation troubles will be intensified on the runner .

Gibson for the diameter of tube in question allows 21 feet less the velocity head, or in this case, 17 feet nett.

White in the A.I.E.E. Journal, Vol. XL., quotes 27 feet less the velocity head.

F. H. Rodgers gives curves based on the specific speed of the runner. For a wheel with a specific speed of 40 he allows a height of 22 feet, whilst for machines of the propeller types having specific speeds of 120 only 13 feet is allowable. The specific speed of the runners installed is 66 in English units and the makers authorise a maximum draught tube height of 17' 6".

Tail Race.

The tail race was excavated in rock its depth being 13 feet below river level so as to allow for lowering tail water level at a later date if desired. Its excavation, as well as the excavation and concreting of the draught tubes, was, of course, done by pumping out behind a cofferdam. The maintenance of the cofferdam gave trouble owing to its exposure to the turbulent flood waters immediately below the falls which were sometimes seen to travel up to 30 feet per second. A cofferdam consisting of filled bags between timber with the exposed face protected with logs was used. Probably reinforced concrete would have been more satisfactory. The reef of rock on which the cofferdam was built was finally mined and blown out.

Turbines.

The turbines are of the usual Francis reaction type the runner having pressed steel plate vanes cast in. They have one guide bearing only, and are controlled by butterfly valves which are operated manually from pedestals on the floor above. Hydraulic operation would, however, have been justifiable. The governors are belt driven, oil pressure type, with pump unloading valves, and provision for shutting the gates in the event of failure from any cause of the drive or oil supply. The pendulum is of the sensitive evolvent type.

Power House.

This building is of reinforced concrete 46' x 58' with an overall height, from floor of draught tubes to top of outgoing line supports, of 82 feet. There are two main floors. The upper floor has, of course, to carry the generators together with the hydraulic loading on the turbine runner. To design it so as to secure adequate stiffness, but without the support of piers which would be an obstruction on the turbine floor, was a matter of some interest. It consists of a reinforced slab 30 inches in depth supported in the centre by one pier. Cable ducts and other pipes were set in the slab.

Cranes.

The bay comprising the generating room is covered by a 10-ton travelling crane, hand operated with ball bearings throughout. The clearance of this crane is calculated to allow of the removal of the turbine shaft and runner after the upper generator frame casting has been removed. This height is insufficient to provide for lifting carcases out of the transformer tanks and, in order to obviate increase in the height of the building to allow for this, a 6 feet deep pit is provided in the floor of the generator room into which the transformers are dropped before being dismantled.

Ventilation.

The transformers are water cooled but the whole of the generator losses amounting to 168 kW at full load have to be carried away by the ventilating air. The cooling air enters the turbine room by a duct built up outside the power house wall to above maximum flood level. Passing through the generators it escapes through cowls in the roof slab. These cowls also serve the purpose of providing exit for the 33 and 50 kilovolt outgoing lines thus dispensing with the use of roof bushings which, for 12 outgoing leads, represent a considerable expense. The generators proved to be incapable of inducing sufficient draught and a motor driven fan has therefore been installed to force the necessary amount.

Generators.

The generators are each rated for 1,750 kVA at 0.8 pf. giving 3,000-3,300 Volts, and running at 375 r.p.m. The rotor is according to standard practice carried from the top thrust bearing which sustains a total bearing load of 21 tons. The makers originally put forward a roller bearing but eventually installed a Michel bearing with water cooled oil bath. The results have been entirely satisfactory. Some consideration was given as to the best arrangement of the exciters. Highest efficiency is obtainable by direct coupling special slow speed exciters above the thrust bearing of the main unit. An objection against this arrangement is that access to the thrust bearing is to a certain extent interfered with and the time required for opening up the main unit somewhat increased. It was decided to install two separately driven exciters each capable of exciting both generators. One is motor driven off the busbars and the other is direct coupled to a vertical turbine controlled by hand only.

Switchgear.

The main switchboard is on the generator floor and is of the truck cubicle type. Provision is made for sectionalising the busbars and for an incoming 3,000V tie line from the Omanawa Plant. The generators are protected by Mertz Price relays which open the generator circuit and kill the field should fault conditions introduce unbalance into the currents of generator windings. These have tested out very consistently. Reverse power but not overload relays are provided on the generator panels. Feeder switches are projected by induction type inverse current overload relays.

No switchgear, other than arresters and isolating switches, has been provided on the H.T. side.

Transformers.

Two 1,250 kVA 50,000 volt transformers capable of simultaneously giving 33,000 volts are in use, also one 1,350 kVA. transformer capable of being connected for either 11,000 or 33,000 volts. They are water cooled and are located on the generator room floor.

Outgoing Lines.

The following lines leave the station:—
1 — 3 kV circuit to Omanawa.
1— 11 kV circuit to Tauranga.
1 —11 kV circuit to Te Puke.
1 —50 kV circuit to Waikino.
The 11 kV circuits will be changed over to 33 kV.

Summary of Concrete Construction.

Part of Work	Date commenced	Date finished	Yards of concrete	Bags of cement per yard of concrete	Tons of cement used
Intake	20/2/24	25/9/24	483	3½	62
Spillway	21/8/24	—	1207 (60 yds spalls)	2 2/3	169½
Power house	25/7/24	6/5/25	1064	3½ - 4	178¼
Penstock tunnel lining.	15/10/24	4/4/25	419	3½ - 4	91¼
Main dam	17/12/24	8/5/25 crest 24/6/25 floodway	1609	4½	418½

Cost.

The works described in this paper, including staff cottages and expenditure on the public road; also preliminary expenses and administration, but not first year's interest, cost £82,882 or £19.3 per max. h.p. It may be of interest to add that the work was undertaken by a Borough with a population of 2,400 which had already expended £66,000 on its power scheme.

Trials.

Much of the interest in a development such as is here described attaches to the testing of the plant, but it frequently occurs that the proper completion of these preliminaries is interfered with by exigencies of the power supply service, or by other considerations. In this case, instead of being enabled to test out the dams by gradually filling the reservoir, a flood occurred on 22nd May, 1925, which, although the diversion tunnel and 42" scour valve were open, filled the reservoir (21,000,000 cubic feet) in 4 hours. On June 26th the trials of No. 1 unit were being carried out when it became necessary to hurriedly put the machine into service and it remained in continuous operation for some months. Again the second unit was first run up for drying out on 14th January, 1926. On the 22nd a heavy flood, previously referred to, occurred, accompanied with north-east gale. This caused interruptions elsewhere and the station was in consequence called upon for its maximum output which, however, it satisfactorily maintained.

Mr J. S. L. Deem desired to move a hearty vote of thanks to Mr Mandeno for his very instructive paper. He thought that it was a very creditable work from start to finish, and it had been entirely carried out by Mr Mandeno himself. The work was of particular interest to him (Mr Deem), as he was on the original work put in 1914, and, as Mr Mandeno had mentioned, the population of Tauranga was only about 2,000 so that it reflected credit on Mr Mandeno to have been able to get his ratepayers to vote another £82,000 to carry out the scheme. In regard to the concrete costs, Mr Mandeno had given the actual number of bags to the yard of concrete, but he was not sure what was the cost of the aggregate. He had been very much interested in the question of pressure grouting. If any other members would let him have their experience with pressure grouting he would be glad as he had a problem to tackle, and any experience of pressure grouting would be of interest to him.

Mr M. C. Henderson said this paper was of great interest to those members who had had to do similar work. There were many points of interest in the paper upon which he would have liked to have touched, but he would content himself with congratulating Mr Mandeno on the fact that he was able to persuade a town with **a** population of 2,400 people to start out upon a job costing about £100,000. The slides showed very well the layout of the job and the difficulties that had to be contended with, and much of the information given reminded him of the difficulties that they had had down in Dunedin.

A vote of thanks was accorded to Mr Mandeno for his paper.

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Mr E. L. Gosset, in discussing, by correspondence, the paper read by Mr Mandeno says the following notes deal with some matters of interest which have been noticed during operation.

Flashboards.—Lake levels are measured in feet and hundredths by means of a crude hook gauge from an imaginary datum 4 ft below crest of spillway. Tops of flashboards, when erect, are 7.04'. On 25th December, 1928, the lowest part of crest of flash-boards was 6.35'. On 30th December the lake rose to 11.46' and the lowest point of the flashboards was bent down to 6.21'. This seems to show that the pins are too stiff. Some damage was done by water flowing over the rock, between the dam and the spillway, and auxiliary flashboards have been erected to height 11.35' to guard against this in future. On 2nd April, 1929, flashboards were straightened up, and alternate pins omitted. On 14th April the lake rose to 7.64' and the pins were slightly bent. On 28th April the lake rose to 7.99' and the flashboards in the centre bent down to below 6.50'. The pins in the centre were bent down to an angle of two horizontal to one vertical, and near the ends to one horizontal to three vertical. This seems to show that 6 ft spacing is too great for these pins. When the lake level fell the flashboards in the centre rose well clear of the pins, leaving a large gap between the bottom of the flashboards and the concrete. The flashboards have since been straightened up again, alternate pins being omitted. On 12th June the pins were slightly bent.— L.L. 7.67.

Power Available.—In the dry spell at the beginning of 1928 there was always enough water at McLaren's to generate 1,100 kW continuously, *i.e.* 26,400 units per day. The figure "watts per square mile per foot head" is thus $\frac{1,100 \ x \ 1,000}{(65+46)x80}$ = 123. The greatest number of units generated in a day is 58,463, to which must be added 15,361 received from Omanawa, giving a total of 73,824. A change of level of one inch corresponds to 240 units at L.L 4.0, and to 300 units at L.L. 7.00. This will decrease as mud brought down by high floods settles out on the flats, and is held in place by rushes.

Water Level Indicator.—The first water level indicator consisted of a $3/8$" pipe fixed concentrically within a $3^1/_2$" pipe, the inner pipe being connected through ammeter and switch to the 230 volt A.C. supply, and the outer pipe to the earthed neutral. The ammeter was graduated to 20 amps, but was rewound for 6 amps. The original graduations were always used in taking readings. It was thought that if allowance were made for variation in the applied voltage the reading of the ammeter would at all times be proportional to the length of pipe submerged. However, it was found on the occasion of the first flood that the readings were low to the extent of about $2^1/_2$ ft. Subsequent experience showed that readings were always low during a flood, and for some days after. On 1st July, 1927, the lake level at 1 p.m. was 8.67 and the W.L.I. reading 15.75. At 9 p.m. the lake level was the same and the W.L.I. reading was 10.65.

The cause of this error is not known, but it appears worth investigating. Conceivably if other streams show the same effect, it might be used to operate a flood alarm. Reference to it was made on p. 158, Volume XIV. of the Society's *Proceedings*, the ammeter readings being converted to actual amperes.

As the main function of this water level indicator is to show the lake level in times of shortage of water its behaviour during a flood is not of much importance. It was found, however, that it read higher at sunset than at sunrise for the same lake level, due doubtless to the change of specific resistance of water with change of temperature, so it has been replaced.

In the second water level indicator eighteen wires, each rather over 10 ft long, of high resistance alloy 31 mils, diameter are stretched in a wooden frame at the intake. A wooden slide similar in shape to a T-square carries nine metal crossbars, and the wires are connected so that a movement of one inch of the slide alters the length of wire in circuit by 18 inches. In the power house is a wire 63 ft long of high resistance alloy 15 mils, diameter stretched zigzag fashion on a board, and a flexible lead terminating in a movable contact. A battery of three dry cells, a sensitive galvanometer, and a pair of ratio coils are provided, and the whole is connected up to form a Wheatstone bridge. Copper wires run from the power house to the frame at the intake. A movement of three inches of the slide corresponds to a movement of about $13^1/_2$ inches of the moving contact in the power house. The movement of the slide is controlled by a steel rigging cable passing over pullies connected at one end to a float and, at the other end, to a 16 lb counterweight. The float consists of two 40 gall. drums floating on their sides. The apparatus has not been in operation for very long.

Occasionally an obviously incorrect reading is obtained, probably due to dirt on the wires at intake, and occasionally no balance can be obtained, but, in nearly every case in which the readings have been checked, the error lies within the limits zero and $1^1/_2$ " high, which is near enough for our purposes.

At first the cross-bars were made of tinned brass wire. When the high resistance wires wore away the tinning one wire might be on the brass at one end of a cross-bar and another wire on the solder at the other end of the same crossbar, setting up unbalanced “contact effects” which made it impossible to obtain a steady reading of the galvanometer. This was cured by using copper nails for cross-bars — any “contact effect” at one end of a cross-bar cancels out with the equal but opposite effect at the other end.

It is intended to extend the range of the indicator during high flood, either by shifting one of the pullies, or by shortening the cable between the float and the slide so as to work to a false zero.

Alternator Cooling Water.—The cooling water from the alternator bearings flows into open inspection cups $3^1/_2$ ft above the floor, then flows by 2-inch pipes to the basement where it is joined by the water from No. 1. Turbine ejector and leaves by a pipe in front of the power house. Sometimes during high flood water flows out of the inspection cups “in gulps,” sometimes from one alternator, sometimes from the other, sometimes from both. During the flood of January, 1926, water came from both machines for some hours, but ceased at the time of highest flood, and started again as the river fell. In the flood of December, 1928, a dollop of water came from each cup of No. 1 every few seconds, for several hours, although the cups were at least $9^1/_2$ ft above highest flood level. No water came from No. 2. It is hoped to cure this trouble by diverting the cooling water during high floods to the sump in the basement, whence it will be removed by the sump-ejecter.

Alternator Oil Gauges.—The oil gauge of the lower bearing of each alternator is connected by pipe to a union which enters the bottom of bearing case vertically near the shaft. In consequence of centrifugal action of the oil the reading of the gauge is about an inch lower, when the machine is running at normal speed, than when it is at rest. When the plant was first started this error was not noticed and a considerable quantity of oil was poured into the bearing under the impression that it was leaking. This oil overflowed and was carried by the draught into the windings.

In the case of the upper thrust bearing the connection of the gauge enters radially, and the effect of centrifugal force is to cause the gauge to read higher, when at normal speed, than when stopped. Evidently the placing of connections for oil gauges is a matter that deserves more attention than it receives.

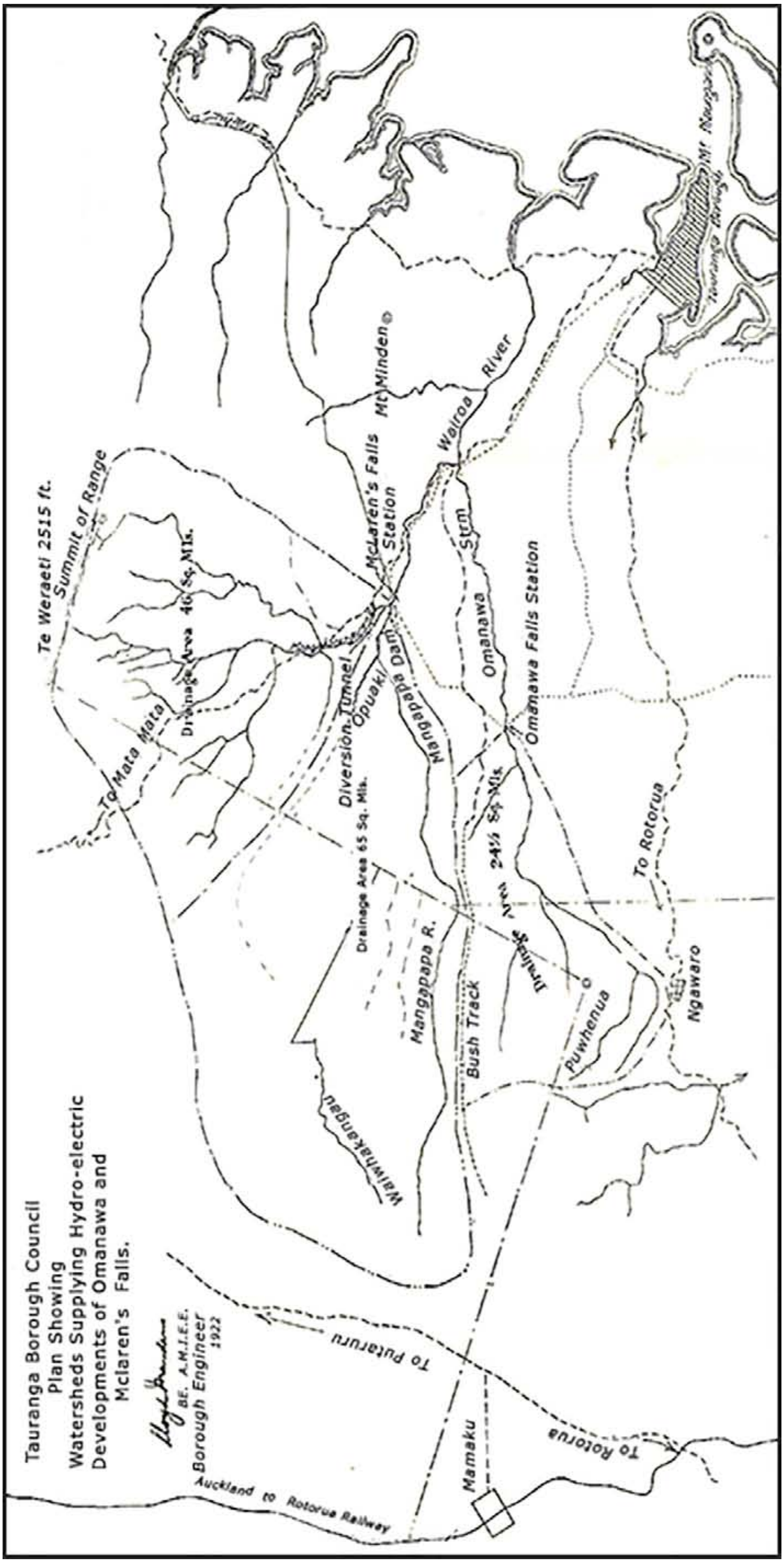
Instability of Alternators.—The alternators at McLaren’s run well in parallel with Horahora. It was soon found, however, that if the power factor of an alternator were allowed to fall to about 98 lead, when on full load, it would at times fall to zero in about a second, without any warning. When this occurred the oil switch was opened by the reverse power relay (see Vol. XII., p. 173 of *Proceedings*). The remedy consists in taking care that the Power factor never goes to lead when a machine is on heavy load in parallel with Horahora.

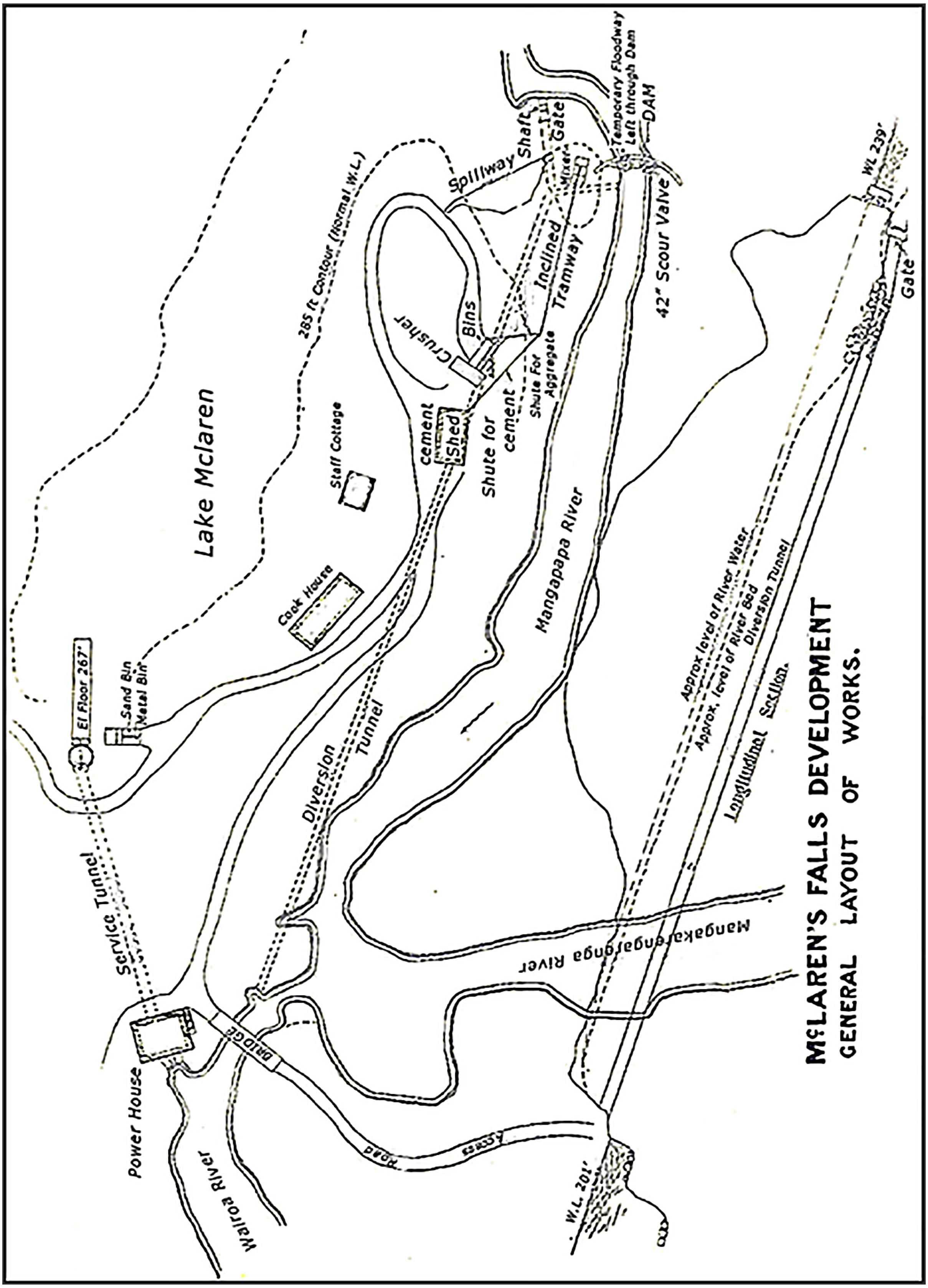
Omanawa.—The plant at present installed at Omanawa Falls consists of an 800 kVA 3,000 Volt alternator driven by a Francis turbine, and a motor exciter. On one occasion some branches lodged between the guide vanes, and the vanes were bent in an attempt to control the speed by hand. In consequence it is necessary to descend to the basement and partly close the main butterfly-valve by hand before the speed can be brought to normal for synchronizing. On several occasions hunting occurred as soon as the switch was closed. When the load was increased to 200 kW no further trouble was experienced, but at times the hunting became so violent that it was necessary to switch out before it was possible to open the butterfly-valve and take up load. This trouble only occurred between certain hours of the day, and has only been noticed rarely in the last year. The cause is not known, but may depend on which machines were on load at Horahora, or on the transformers in circuit at Waikino. It was found that if the alternator field strength were reduced to half as soon as the switch was closed the hunting was minimised.

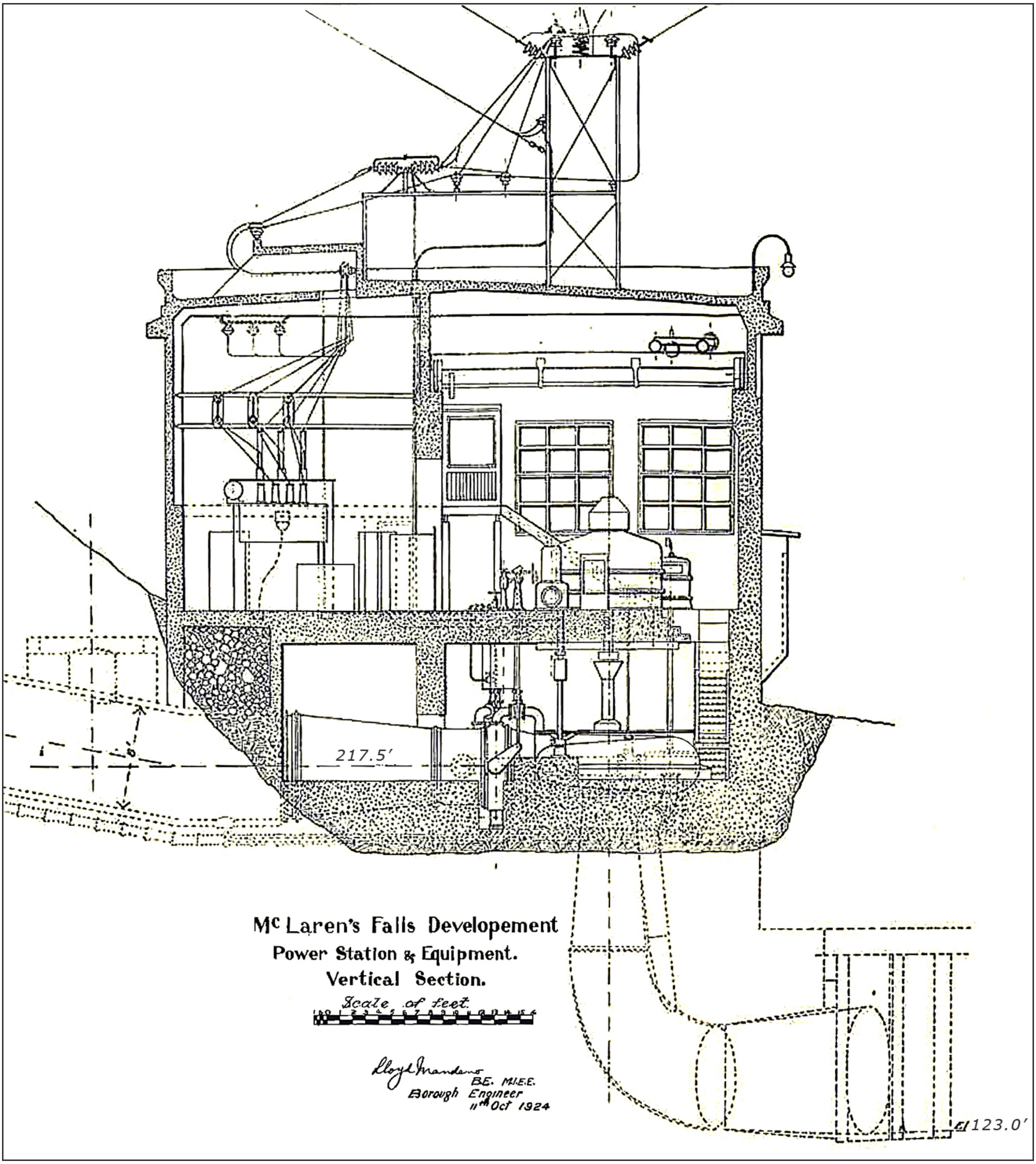
The output of the machine is controlled by a cubicle-type switchboard, then passes through a three-core paper insulated lead covered armoured cable, more than 100 yds long, to an H pole, then by overhead wires to the Omanawa substation, then by overhead wires insulated for 11,000 V to McLaren’s, where it terminates on the roof structure, and passes by cable to the switchboard of McLaren’s. Lightning arresters were provided at McLaren’s. From the H-Pole to the substation the working wires are covered by a set of spare wires, connected to a length of cable, and from the substation to McLaren’s by wires working at first at 11,000 Volts, and later at 33,000 Volts. On two occasions during thunder storms current transformers have been burnt out by lightning, in each case causing a fire. As it is commonly believed that a few feet of underground cable form an absolute protection against lightning this is worth putting on record. The spare wires between the H-Pole and the substation have since been earthed, and lightning arresters fitted on the working wires.

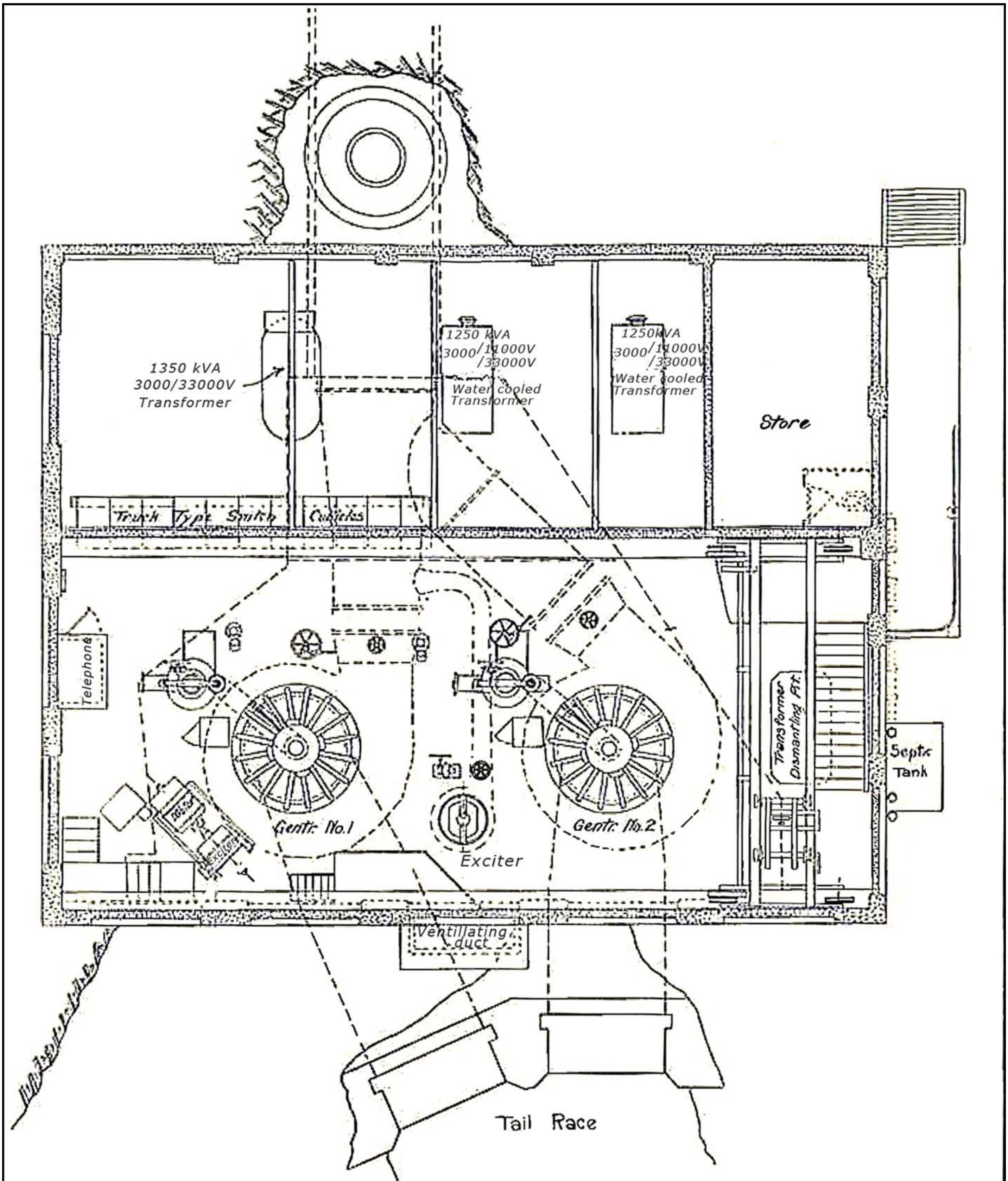
During the dry spell, at the beginning of 1928, the power available at Omanawa was 720 kW generated continuously, or 606 kW. received at McLaren’s. The figure “watts per square mile per foot head” is thus:

$$\frac{720 \ x \ 1{,}000}{24.5 \ x \ 110} = 268$$


Tauranga Borough Council
Plan Showing
Watersheds Supplying Hydro-electric
Developments of Omanawa and
Mclaren's Falls.
BE. A.M.I.E.E.
Borough Engineer
1922
Te Weraeti 2515 ft.
Summit of Range
Drainage Area 40 Sq. Mls.
To Mata Mata
Diversion Tunnel
Opuaki Dam
McLaren's Falls Station
Mt Minden
Wairoa River
Mangapapa R.
Omanawa Strm
Omanawa Falls Station
Drainage Area 65 Sq. Mls.
Drainage Area 24½ Sq. Mls.
To Rotorua
Ngawaro
Puwhenua
Bush Track
Waiwhakaangau
To Putaruru
Mamaku
To Rotorua
Auckland to Rotorua Railway


McLAREN'S FALLS DEVELOPMENT
GENERAL LAYOUT OF WORKS.
Lake Mclaren
285 ft Contour (Normal W.L.)
Spillway Shaft
Gate
Mixer
Temporary Floodway Left through Dam
DAM
42" Scour Valve
Inclined Tramway
Bins
Crusher
Shute For Aggregate
cement Shed
Shute for cement
Staff Cottage
Cook House
Sand Bin
Metal Bin
El Floor 267'
Service Tunnel
Diversion Tunnel
Mangapapa River
Mangakarengarenga River
Power House
Bridge
Access Road
Wairoa River
W.L. 201'
W.L. 239'
Gate
Approx level of River Water
Approx. level of River Bed
Diversion Tunnel
Longitudinal Section


217.5′
Mc Laren's Falls Developement
Power Station & Equipment.
Vertical Section.
Scale of feet
Lloyd Mandeno
BE. M.I.E.E.
Borough Engineer
11th Oct 1924
El 123.0′



McLaren's Falls Development

Plan Showing General Arrangement of Power House.

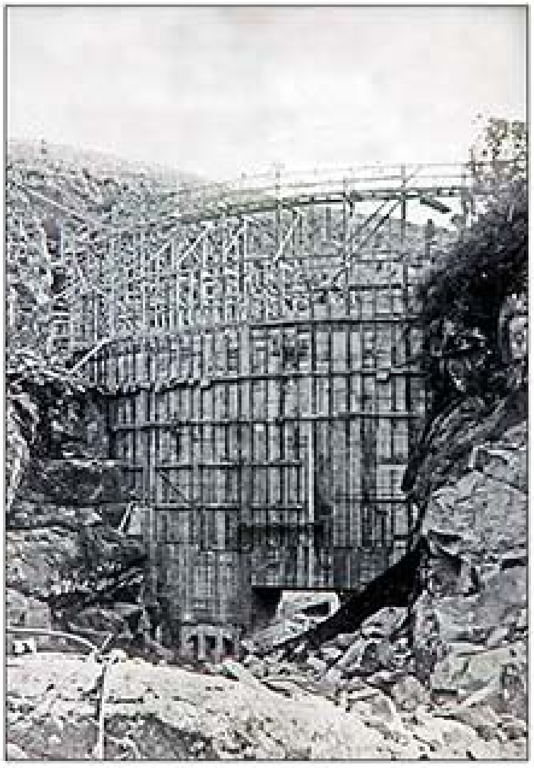
Scale of Feet.

Lloyd Mandeno BE
Borough Engineer

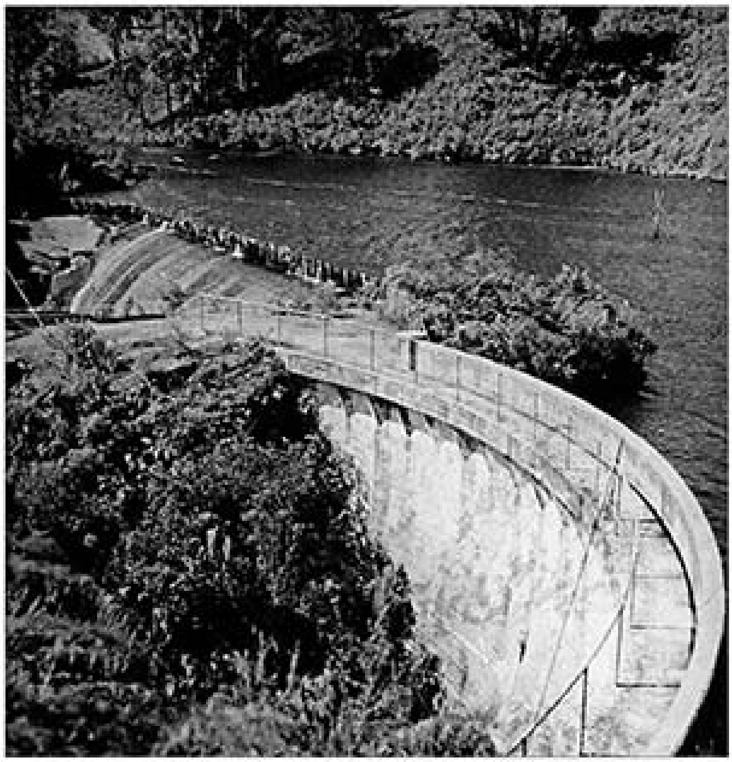
Mclaren Falls dam site overview - circa 1923

Mangapapa River at the Mclaren Falls Dam Site - circa 1921

L W M Mandeno Collection - PA12-12150 - Alexander Turnbull Library, Wellington, N.Z.



Mclaren Falls Dam Construction - circa 1924



Mclaren Falls Dam & Spillway - circa 1925

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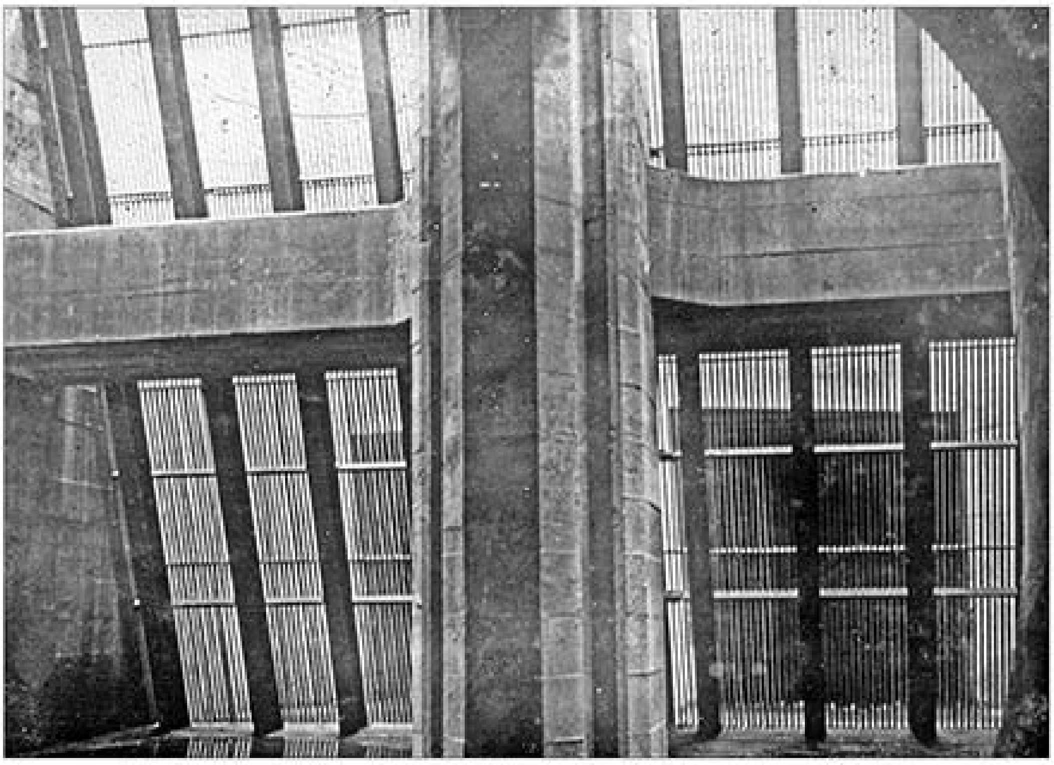

Intake screens for Mclaren Falls Power Station - circa 1924

Mclaren Falls Spillway Overflow - circa 1925

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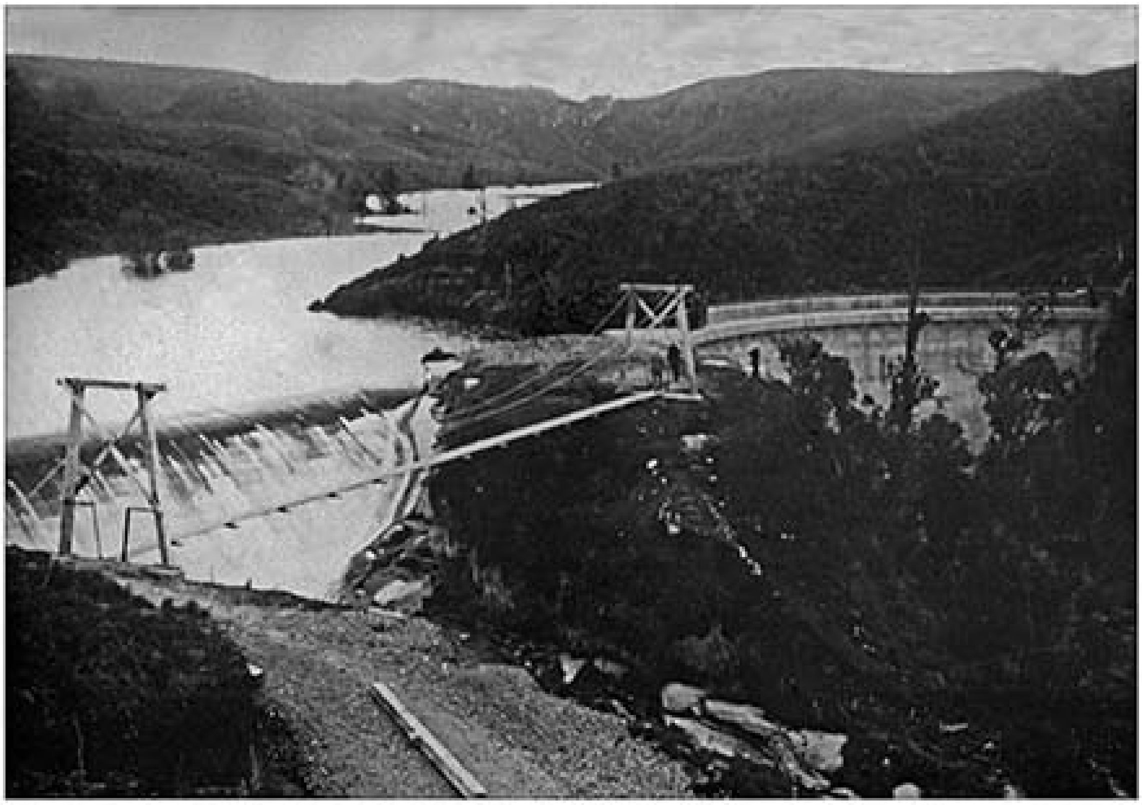

Mclaren Falls Spillway & Dam - circa 1924

Storm Damage - Mclaren Falls Spillway Site - circa 1924

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