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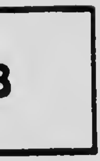
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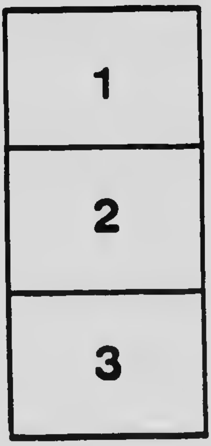
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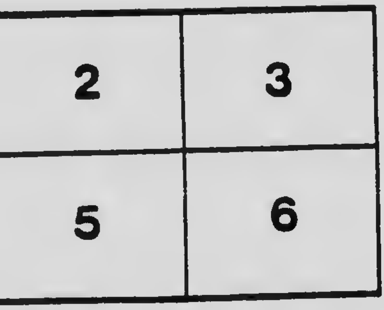
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DEPARTMENT OF THE INTERIOR
DOMINION WATER POWER BRANCH
OTTAWA, CANADA

WATER RESOURCES PAPER No. 13

COQUITLAM-BUNTZEN HYDRO-ELECTRIC DEVELOPMENT, BRITISH COLUMBIA

BY

G. R. G. CONWAY

Chief Engineer, British Columbia Railway Company, Limited

Prepared at the request of the Superintendent of Water Power

Part XII, Annual Report, Superintendent of Water Power, 1913-14

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

DOMINION WATER POWER BRANCH
DEPARTMENT OF THE INTERIOR
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REPORT

ON THE

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Appendix 9B, Part VIII, Annual Report 1913-14

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

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LIST OF PLATES

WATER POWER BRANCH,
OTTAWA, April 23, 1915.

W. W. CORY, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

SIR,—I beg to submit for your consideration the attached report on the Coquitlam-Buntzen hydro-electric development of the Vancouver Power Company, British Columbia, by G. R. G. Conway, chief engineer of that company.

This report was prepared for the department by Mr. Conway at the request of the undersigned, in order that the department might have a complete authentic statement of the Vancouver Power Company's power project at the Coquitlam-Buntzen lakes, B.C., and with special reference to the Coquitlam dam. This structure being of the hydraulic earth-filled type, the first of its kind in Canada, has been of great interest to the engineering profession, and is probably one of the most unique dam structures in this country. Its construction was authorized by this department by an agreement with the Vancouver Power Company dated March 24, 1910.

Owing to very strenuous opposition to the proposed type of structure by the authorities of the municipal council of Coquitlam and the city of New Westminster, this department obtained the best possible expert advice before the company's plans were approved, and construction operations on the work were carried on under the continuous inspection of Mr. R. S. Stronach, Government engineer, acting under the direction of Mr. J. R. Freeman, consulting engineer to the Dominion Government in this matter.

Throughout the construction period the officers of the Vancouver Power Company cheerfully accepted the views of the department regarding the design of the structure and all work in connection therewith. Particular mention should be made of the very strict requirements of the department's consulting engineer in respect of timber removal from the overflowed margins of the lake, which the Vancouver Power Company complied with at great expense, in order that there might be absolutely no doubt about the purity of the Coquitlam lake waters for the municipal water supply of the city of New Westminster.

The successful completion of the dam in strict accordance with the desires of the department, in compliance with departmental conditions and the onerous requirements exacted by the municipal authorities of the city of New Westminster in connection with its municipal water supply, intake works, etc., is due entirely to the engineering and executive ability of Mr. Conway as consulting engineer to the Vancouver Power Company of Vancouver, B.C.

The department is fortunate in having available such a satisfactory report on the Coquitlam dam structure and its general connection with the Vancouver Power Company's complete power project.

Owing to the unique character of this dam and to the great interest it has caused in the engineering world, I think that Mr. Conway's report should be published and made available to the interested public. I would therefore recommend that it be published as Water Resources Paper No. 13.

I have the honour to be, sir,
Your obedient servant,

J. B. CHALLIES,
Superintendent, Dominion Water Power Branch.

REPORT ON THE COQUITLAM-BUNTZEN HYDRO-ELECTRIC DEVELOPMENT, BRITISH COLUMBIA.

The Coquitlam-Buntzen hydro-electric power scheme for the supply of electrical energy to the city of Vancouver and the municipalities of the lower mainland of British Columbia, is owned and operated by the Vancouver Power Company, a company incorporated under the provisions of the "Water Clauses Consolidation Act, 1897," of the statutes of British Columbia, a subsidiary company of the British Columbia Electric Railway Company, Limited, which controls the electric railway, light and power systems in the cities of Vancouver, New Westminster, Victoria and the surrounding districts. The growth of the district supply during the decade 1900-10, as shown by the census returns, is indicated by an increase in the population from 26,133 to 100,000, or 282 per cent, and including the surrounding municipalities the increase was 306 per cent, e.g., from 41,000 to 175,000. The estimated population within the area of supply is now approximately 200,000 persons.

Prior to the year 1903 the requirements of the district were served by a small steam plant, but, by the active signs of growth that were in evidence at that time, it was necessary to make provision for an entirely new plant to meet the requirements of the developing territory, and the utilization of lakes Coquitlam and Buntzen for power purposes was decided upon in that year.

ORIGINAL DEVELOPMENT.

The essential feature of the original development was the raising of Coquitlam lake by means of a small crib dam with a crest level of 443 feet above sea-level, and delivering the water so stored through a tunnel due west of the lake to connect with lake Buntzen (formerly called lake Beautiful or Trout lake), a distance of about 2¼ miles, and from there delivering the water through pipe lines under a head of about 395 feet to a power-house at sea-level on the north arm of Burrard inlet.

Coquitlam Lake.

This lake, which is the main storage reservoir of the scheme, is situated in townships 4, 5 and 6, range 6, west of the 7th meridian, in the province of British Columbia. The lake is about seven miles in length, and its average width about one-half mile. Its average summer level prior to the building of the small crib dam at its outlet was about 432 feet above sea-level, and its original area about 2,190 acres. The watershed which is formed by granite and other granitic rocks is approximately 105 square miles, and the mountains rise precipitously on either side to a height varying from 3,000 feet to 6,000 feet. The greater part of the watershed is well covered with heavy timber, chiefly cedar and hemlock, with some fir and spruce. The Coquitlam river has its source in a small lake called lake Disappointment, at an elevation of 3,000 feet, and falls in a distance of about 13 miles through a series of narrow canyons and waterfalls to the lake level.

The precipitation over the watershed has averaged for the last eleven years 153 inches. The maximum year during that period was in 1906, when the precipitation was 189·97 inches. The minimum year was in 1913, with a record of 130·72 inches. The maximum monthly precipitation is during the month of November, which averages 28 inches; the maximum recorded rainfall during that month is 37¼ inches; the minimum recorded is 10·62 inches. The minimum month is July, the average for eleven years being 2·61 inches.

The following is a record of the precipitation for the years 1903 to October, 1914:—

Coquitlam Lake.—View looking North.

COQUITLAM LAKE Watershed, T. 5, R. 6, W. 7. Precipitation, 1903-14.

	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.
	"	"	"	"	"	"	"	"	"	"	"	"
January	18.48	28.81	13.25	26.50	12.38	16.80	15.50	32.41	21.59	21.71	15.90	26.51
February	5.21	21.16	16.94	18.66	16.93	15.45	23.03	15.78	10.12	15.48	10.40	9.54
March	8.67	22.70	23.36	6.60	10.35	21.98	16.46	7.16	9.06	2.13	11.91	10.00
April	9.34	7.25	1.50	4.41	15.71	13.50	3.07	8.61	5.63	9.97	7.56	6.92
May	7.78	6.14	4.61	13.21	5.20	9.20	12.62	6.95	6.62	3.75	9.59	4.71
June	7.30	3.53	3.16	12.08	3.92	3.49	3.90	5.14	1.34	5.59	8.21	5.26
July	3.55	5.10		1.48	2.45	3.62	4.65	0.25	1.45	2.66	3.78	0.57
August	2.68	1.05		3.04	5.15	4.31	8.66	4.43	2.21	9.55	3.04	1.30
September	17.47	5.82	50.00	28.53	8.98	7.24	7.51	5.01	9.51	6.72	8.14	13.85
October	16.88	10.41		31.09	4.28	20.31	21.21	21.49	5.45	13.61	14.43	20.27
November	33.10	25.02	10.62	22.78	37.09	33.75	37.29	28.77	29.48	29.28	26.09	...
December	14.75	20.00	18.07	20.89	24.78	21.19	12.02	23.62	22.96	26.69	11.64	...
Total	146.21	156.57	144.48	189.87	147.25	170.80	159.90	159.62	132.05	147.14	130.72	...

The winter snows over the watershed are heavy and remain in the higher parts of the mountains until late in summer. The maximum rate of precipitation recorded occurred on November 27, 1909, when 8·25 inches of rain fell in twenty-four hours, the maximum fall in ten minutes being 0·1 inches, and in one hour 0·56 inches.

The average run-off as determined by observations over a period of eight or nine years is about 1,000 cubic feet per second, the coefficient of run-off being about 78 per cent. There are short periods during the winter and summer months when the run-offs drop considerably below the average, but there are no extended dry periods such as obtain further inland. The maximum recorded rate of run-off occurred in November, 1908, and amounted to 12,200 cubic feet per second. The maximum recorded run-off per square mile of drainage area is, therefore, 116 cubic feet per second.

Coquitlam lake was proposed in 1885 as a source of water supply for the whole peninsula between the Fraser river and Burrard inlet. At that time the site of the present city of Vancouver was still covered with primeval forest.

About that period the question of the water supply of the city of New Westminster was under consideration by some ex-members of the Canadian Government engineering staff in British Columbia, and a comprehensive scheme prepared for the whole peninsula. In 1886 the promoters of the scheme procured an Act of the Legislature of British Columbia incorporating them as the "Coquitlam Water Works Company, Limited," and one of the incorporators, Mr. A. E. Hill, M. Inst. C.E., went to England in September, 1886, as managing director of the company in an endeavour to secure the capital necessary to construct the proposed works. He was unsuccessful, however, in satisfying capitalists of the wisdom of providing at a large cost water supply works for the city at so early a stage in its history. In 1888, Mr. Hill prepared for his company an estimate of the cost of works to supply the city of New Westminster alone. The system was designed to include a 14-inch steel supply pipe 73,100 feet in length, a service reservoir, and 50,000 feet of cast-iron distribution pipes. There was to be no pressure maintained on the upper level of the city. The cost was estimated at $198,000, and the population at that time within the area of supply was estimated at 5,000. A small surplus of revenue was expected to accrue from the operation of the system at the out-set. As this estimate showed that a reasonably efficient water works could be constructed at a cost falling within the limits of the financial resources of the city at that time, and also that such works would pay directly from the start, the city council decided to undertake the construction of the system as a civic enterprise, and in March, 1889, the council acquired by purchase from the Coquitlam Water Works Company all necessary and sufficient powers to construct, under the authority of the company's charter, works for the supply of the city from Coquitlam lake. Under an agreement the Coquitlam Water Works Company agreed to grant and sell over to the corporation of the city of New Westminster so much of their rights and interests as would allow the city to supply water within the city limits as then defined, or as they might be extended in the future, the company reserving the right to supply water to any districts outside the city limits.

Prior to this date and up to the time that the new works were placed in operation, the city's water supply had been drawn from wells, and from small spring-fed plank-lined tanks, excavated in the upper streets, from which the water was led in small wrought-iron pipes to consumers on the lower streets where the population was chiefly resident. Water for fire protection was drawn from the Fraser river, or in emergencies from some of the tanks above mentioned, or from others sunk in the streets in the neighbourhood of the principal business blocks, these being kept filled with water pumped from the Fraser river by the steam fire engines of the city fire department.

In July, 1889, a staff of engineers was employed by the city council to prepare plans and specifications for a system of works. These were prepared during the remainder of 1889, and tenders were invited upon the specifications prepared in February, 1890. In the meantime a board of water commissioners had been constituted by special enactment, and these commissioners took office on February 1, 1890. On

March 1, 1890, they appointed Mr. A. E. Hill, engineer to the board of commissioners, and directed him to prepare new designs and specifications along the lines of his original scheme. These works[1] were carried out and were placed in full operation on August 16, 1892, and finally passed over to the control of the city council on January 1, 1893, the board of commissioners ceasing at that date to exist as a board.

In 1903 the rights and charter of the Coquitlam Water Works Company were acquired by the Vancouver Power Company, who obtained further rights from the Dominion and provincial authorities to extract water from Coquitlam and Buntzen lakes for the production of electrical energy by water-power, the water of Coquitlam lake after storage to be diverted by means of the tunnel previously mentioned, to lake Buntzen.

Original Dam, Coquitlam Lake.

The original dam was built across the Coquitlam river a little below the outlet of the lake (see reproduction on page 11) in 1903. It is a rock-filled crib over-flow dam 170 feet in length, built so that the over-flow would take place at an elevation of 443 feet, about 11 feet above the original lake level. The length of the crest of the dam was 113 feet with 9 feet of free board. The storage thus gained amounted to 25,100 acre feet, or 1,096,000,000 cubic feet.

This dam gave entirely satisfactory service until 1908, when owing to the increased demand for electric light and power in Vancouver and neighbourhood, it was decided to increase the available storage capacity of Coquitlam lake, and conserve all the water that had hitherto been running to waste.

New Coquitlam Dam.

In considering the question of increasing the storage of the lake, fairly complete records were available since 1903, which made it obvious that the top water of the lake might be raised another 60 feet, i.e., from 443 feet O.D. to 503 feet O.D. This would increase the top water area of the lake from 2,328 acres to 3,075 acres, and the available storage for power purposes from 13,800 acre feet to 180,500 acre feet, or a total available storage of 7,873,000,000 cubic feet above the level of the New Westminster water supply intake.

Various types of dams were considered, and in 1908, upon the recommendation of Mr. J. D. Schuyler, M. Am. Soc. C.E., at that time consulting engineer for the Vancouver Power Company, a dam of the hydraulic-fill type was adopted.

The site of the hydraulic-fill dam is a little below the old crib dam, which is now buried in the upper toe of the new one. The hydraulic-fill type of dam was recommended owing to the impracticability of obtaining a satisfactory foundation for a masonry dam, as bed-rock was only revealed on the eastern portion of the site. The new dam is built upon a great natural barrier which had been formed at the outlet of the lake by a receding glacier, and the formation is made up of fine blue and grey glacial boulder clays together with inter-stratified layers of cemented gravel and boulders.

As the city of New Westminster had drawn its water supply since 1892 from Coquitlam lake, the new works had therefore to include a modification of the old intake near the original crib dam, and it was necessary to safeguard the interests of the city, which were accordingly protected by an agreement dated the 24th day of March, 1910, between the Dominion Government and the Vancouver Power Company. To ensure that the terms of this agreement would be carried out, the Water Power Branch of the Department of the Interior, under the direction of Mr. J. B. Challies, M. Can. Soc. C.E., appointed Mr. J. R. Freeman, M. Am. Soc. C.E., of Providence, R.I., to represent them as advisory engineer.

[1] For a description of these works see Proceedings, Institution of Civil Engineers, Vol. 122.

Original Coquitlam Dam, New Westminster.—Intake and Screen House in foreground.

Original Coquitlam Dam.

To determine exactly the design of the new dam, a large amount of exploration work was carried out in 1909 and 1910, but the final details of the dam were not settled until January, 1911. The following are the chief particulars relating to the main features of the new dam as now completed (see Plates Nos. 25, 26 and 27A):—

Height of dam on centre line.............................. 99 feet.
Extreme width of dam at base.............................. 655 "
Length of dam along crest (exclusive of spillway).............. 950 "
Width of spillway .... 250 "
Slope of up-stream face—1 in 5.
Slope of down-stream face—1 in 2 to 1 in 4.
Elevation of spillway—503 feet above sea level.
Elevation of crest of dam—518 feet above sea level.
Capacity of spillway, 5 ft. flood— 9,000 cu. ft. per second.
" " 10 " 21,000 " "
" " 15 " 37,500 " "
Original area of lake (old dam)........................acres 2,328
Area of lake at elevation 503 feet...................... " 3,075
Capacity of reservoir formed by dam..................cu. ft. 7,873,000,000
(See Plates Nos. 25 and 26.)

New Coquitlam Dam completed.

Elevation Feet.	Storage. Cubic feet	Equivalent Kilowatt Hours, calculated at 78 efficiency, and average head 395 feet.
450	1,333,000,000	9,650,000
460	2,439,000,000	17,650,000
470	3,615,000,000	26,150,000
480	4,853,000,000	35,100,000
490	6,140,000,000	44,460,000
503	7,873,000,000	57,010,000

The general design of the dam is shown on Plates Nos. 25, 26 and 27A.

The upstream and downstream toes of the dam are formed of heavy [illegible] rubble, while the remainder is of hydraulically sluiced material. Both slopes are covered with heavy rip-rap, and on the east side a low concrete core wall was built on a granite foundation along the longitudinal axis of the dam.

Spillway.

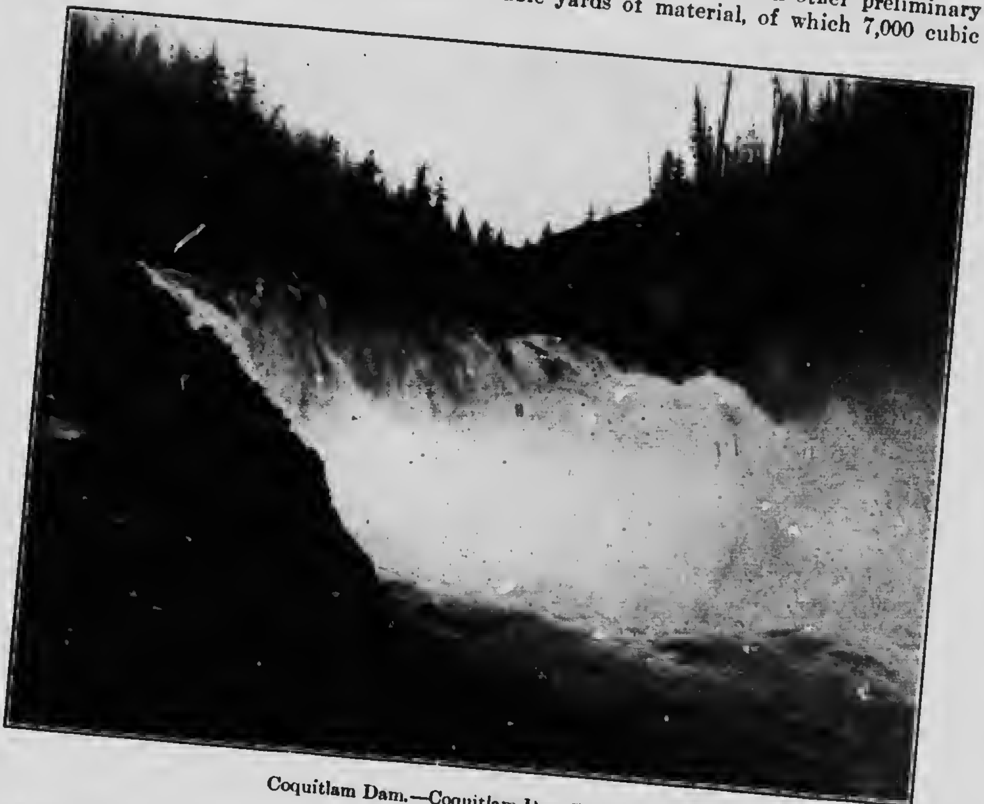
The spillway is located at the east end of the dam, and was cut through a ledge of solid granite. The width of the cut at the entrance is 250 feet and tapers to 185 feet at the lower end in a length of 150 feet. The main floor of the spillway was cut down to El. 502, and across the entrance of the spillway a concrete sill was placed at

Coquitlam Dam. View looking west showing Coquitlam and Spillway.

El. 503 feet or 15 feet below the crest of the dam. The capacity of the spillway was designed so that it would have a discharge when running 7 feet deep over the sill equal to the maximum recorded flood, or about 12,000 cubic feet per second. The spillway cut involved an excavation of over 75,000 cubic yards, of which about 53,000 yards was solid rock.

Sluice Tunnel and Approach during the Construction of the Dam.

The outflow from the lake was carried around the dam site in a tunnel driven through the ledge under the spillway. This tunnel is 490 feet in length, and has a sectional area of 412 square feet. The clear width is 26 feet, and the height is 18½ feet to the centre of the roof, which is semi-circular in form. The tunnel was completely lined with concrete for a distance of 190 feet, the remainder being lined on the sides and floor with concrete. The floor of the tunnel is at elevation 449 at the entrance, with a fall of 5 feet to the outlet portal. The tunnel was designed to carry 12,000 cubic feet per second, which was assumed to be the extreme flood that might have to be dealt with during the construction of the dam. This was calculated to be discharged through the tunnel when the lake surface was at elevation 475 feet, although actually the greatest flood experienced during the construction period did not exceed 6,500 cubic feet per second. The approach to the tunnel is 860 feet long, tapping the lake at elevation 443 immediately north of the old dam. This approach is 40 feet wide at the bottom, with sides sloping 1½ to 1, and involved with other preliminary work the excavation of about 220,000 cubic yards of material, of which 7,000 cubic

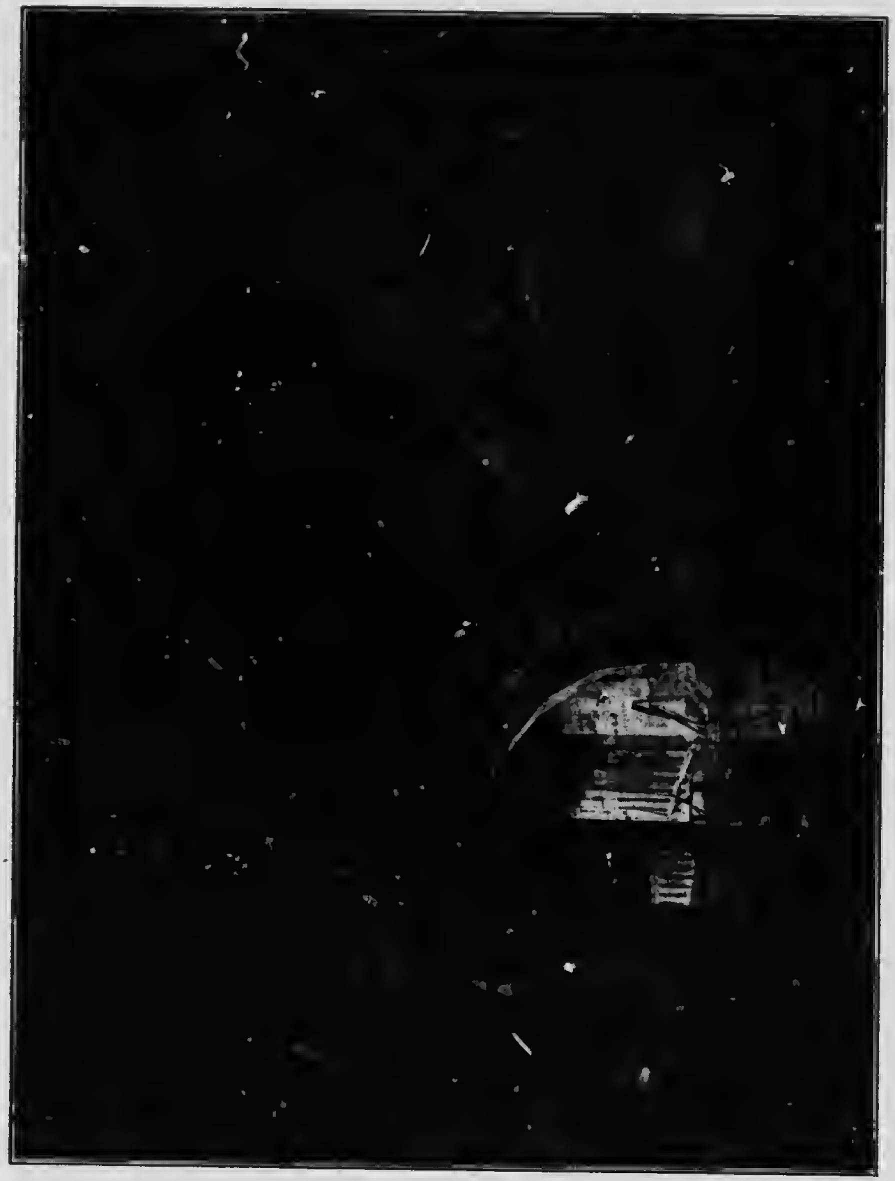


Coquitlam Dam.—Coquitlam Dam Spillway.

yards was rock, but the remainder mostly clay, gravel and boulders. From the outlet of the tunnel a channel was cut to connect its lower end with the old river bed. This involved an excavation of about 97,000 cubic yards of material.

Sluice Gates and Tower (see Plate No. 27).

The gates for controlling the flow of water through the sluice tunnel are placed in a concrete tower at the upper end of the tunnel, and are fully illustrated in figs. The floor of the tower is at elevation 455 and spans the tunnel entrance. Under the floor of the tower three 10 feet by 15½ feet openings were left for dealing with the floods during the construction of the dam. Into each of these openings were placed two temporary steel roller gates which were operated from stagings by means of an 18 horse-power Fairbanks-Morse gasolene engine. These gates after the completion of the dam were closed tight and packed solid with concrete to form a permanent plug.



Coquitlam Dam—View looking towards Head Gates in Sluice Tunnel.

The tower is rectangular in form and is built up of three separate compartments, feet by 11 feet, each one independent of the others. It is built back in the rock c at the tunnel entrance, so that the back wall and side walls are against solid rock f three-fourths of their height. The tower is surmounted by a concrete gate house wi floor at elevation 513, and a short concrete bridge connects the balcony with the sho of the lake. The main sluice gates in the tower are five feet in diameter, and a placed in the back wall of the tower at the intermediate floor level, discharging direct into the tunnel. The openings in the front wall can be closed by auxiliary gates mad up of I-beams and timber operated by means of worm gearing by an 18 horse-powe gasolene engine inside the tower, which is also arranged for operating the three mai gates.

New Westminster Water Supply Tunnel.

The original water supply intake is shown in reproduction on page 11. A the completion of the new dam and the raising of the lake level rendered these works useless, it was necessary to construct an entirely new intake system. The new intake structure, which is a great improvement upon the old, is a heavy concrete tower built on a spur of bed-rock on the east side of the lake about 1,000 feet north of the dam (see Plate No. 27). The floor of the tower is at elevation 428, and the floor of the concrete gate house is at elevation 518. The tower is circular in plan, with an inside diameter of 18 feet top and bottom. The walls are 4 feet 6 inches thick at the bottom, and taper to a thickness of 18 inches at the top. A concrete arch bridge connects the intake tower with the roadway on the shore. In the walls of the tower there are four 40-inch square intake openings placed at elevation 430, 451, 469, and 487 at angles of 60 degrees to each other. The exterior openings are belled on the outside and covered with racks 6 feet square to protect them from water-logged timber and trash. Gates are placed over the openings on the side of the tower, and since these gates are subjected to back pressure only, tending to force the disc away from its seat, it was necessary to build them of special design. The cast-steel gate disc slides in vertical guides, but the gate seat and the back of the gate are at a slight angle to the direction of travel. The disc is, therefore, wedged tight to the seat when in the lowest position, the guides taking the full thrust of the pressure of the water against the back of the disc. In all other positions of the disc the seats are not in contact, hook wedges are provided at the top and bottom of the gate to hold it against the seats; the seats and all wearing surfaces are lined with gun metal. The gates are enclosed in a sheet-steel box having an opening directly in front of the gate over which fine screens are placed. These screens are made up in teak wood frames, and are lowered in position by means of a winch placed on the screen handling floor at elevation 508. The screen frames slide in channel guides secured to the tower wall by brackets and anchor bolts.

A secondary intake is placed entirely within the tower so as to enable the water to be drawn off at any desired level. This intake consists of a steel stand-pipe 42 inches in diameter, built up in four separate sections, each section having a conical seat on the upper and lower ends, and each section rests on the one next below it, the bottom section resting on a heavy cast-iron elbow set in the tower floor. The intake pipe sections are guided between two 60-pound rails placed on the opposite sides of the pipe and attached to the tower wall at frequent intervals. Lifting rods 1½ inch in diameter are attached diametrically opposite near the top of each pipe section. This intake is operated by hand by means of a special lifting gear which may be attached to any set of lifting rods. The openings in the intake pipe are at elevations 433, 451, 473, and 481.

A channel 20 feet wide at the bottom with sides lopes 1½ to 1, heavily rip-rapped, leads the water from the lake to the base of the tower.

From the intake tower the water [illegible] a tunnel 1,938 feet in length around the east end of the dam, passing under the [illegible] tunnel and connecting to a distributing chamber near the lower toe of the dam. [illegible] is chamber is supp[illegible] with a pressure-

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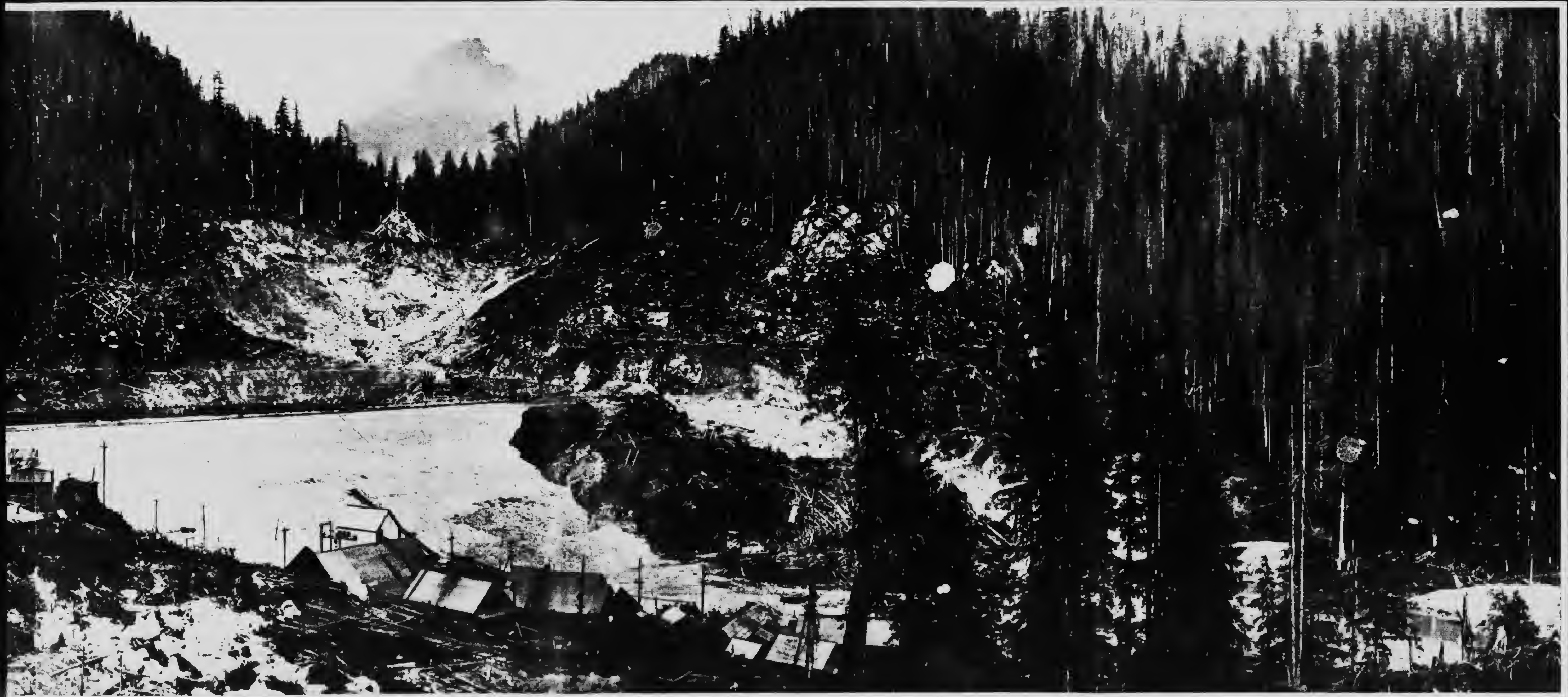
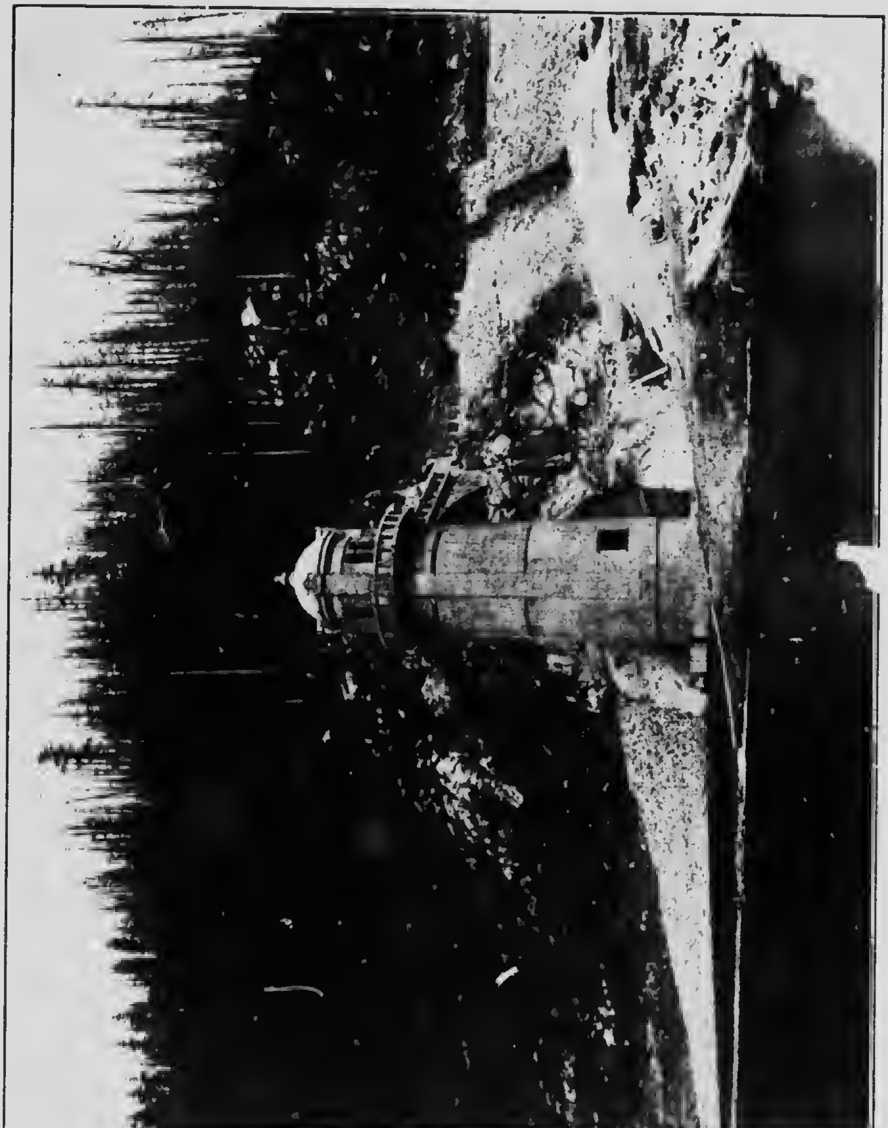
COQUITLAM DAM.





Coquitlam Dam.—New Westmin Water Works Intake Tower.

reducing valve and pipe connections for the 14-inch and 25-inch water supply mains. The tunnel is all lined in rock excepting for a distance of 508 feet, where it passes through gravel and boulders. In this portion it is lined with steel pipe 4 feet in diameter and cased in concrete. The tunnel in rock is 4 feet wide by 6 feet 6 inches high, the floor being lined with concrete. From the distributing chamber two main supply pipes of riveted steel, one 14 inches and the other 25 inches in internal diameter, carry the water to the city of New Westminster.

Tunnel Driving.

Both the sluice tunnel and water supply tunnel were constructed under contract. Two shafts were sunk along the line of the water supply tunnel, and it was worked from the several faces. One of the shafts was lined with concrete so as to form a permanent inspection shaft. The sluice tunnel was driven from the upper face, and also both ways from the break up directly over the point where it crosses over the water supply tunnel. The tunnel was driven with one heading and a bench, the heading included the whole tunnel section above the springing line of the arched roof, and the bench was 5 feet deep. Most of the rock removed from the water supply tunnel was wasted, but all of that taken from the sluice tunnel was used in the toes of the dam.

Construction Methods.

The preliminary work in connection with the construction of the dam was started in the winter of 1908. The whole of the dam site was covered with heavy virgin forest and it was necessary to clear about 60 acres before other construction work could be started. During the winter of 1909 a pumping plant was installed, and in the spring of 1910 the stripping of the dam foundations and the excavation of the diversion channel connecting the sluice tower with the lake was started. All of this excavation work was done by the hydraulic process, and the method proved very successful. When the work was in progress on the upper portion of the cut, as much as 11,000 cubic yards of material were removed in one week in about 120 hours actual working time. This work was done with one monitor delivering 10 cubic feet of water per second under a pressure of 110 pounds per square inch at the nozzle, the flume having a grade of 3 per cent. In the excavation of the lower levels, however, great difficulty was experienced on account of the very low flume grades obtainable, and the heavy materials encountered made it necessary when excavating the bottom of the diversion channel to use hydraulic elevators, to raise the sluiced material from the floor of the channel a height of from 5 to 12 feet, depending on the distance the flume end extended into the cut. This flume was run on a grade of only 2½ per cent, and it was necessary to use great care in the grading of the sluiced material in order to prevent the clogging of the flumes.

During the time this work was in progress and prior to the actual construction of the dam, a large amount of exploration work was done over the whole site (see reproduction on page 17) so as to determine accurately the exact nature of the foundations, and as already mentioned, it was not until January, 1911, that the main details of the work were completed, such for example as the location of the water supply tunnel, sluice tunnel, approach and outlet canals, and also the site of the towers of the water supply and sluice tunnels.

The rock used for the upstream and downstream toes of the dam was partly obtained, as already mentioned, from the sluice tunnel excavations, and also from the excavation of the spillway and approach channel. During the building of the upstream toe, it was necessary for the company to obtain additional water storage. This was obtained in the early stages of the work by raising the old dam by means of flash

Coquitlam Dam.—View looking West showing Trestles and Flumes. No. 1 Borrow Pit is seen on the extreme left of the picture.

boards, afterwards backing it with rock fill and sluicing clay upstream of the old dam. At a further stage in the progress of the work, additional storage was obtained by raising the upstream toe and filling in the space between the old dam and the new toe with sluiced material. By this means the company was able during the dry seasons of 1911 and 1912 to obtain an additional 15 feet of storage.

The material for constructing the dam proper was obtained from two borrow pits on either side of the river. These were situated so that convenient grades could be obtained for the flumes over the whole site of the work. The first of these pits to be opened up was situated downstream from the dam on the west side, the second was

Coquitlam Dam.—Trestle carrying Flume from No 2 Borrow Pit over Spillway.

immediately to the northeast of the site of the sluice tower. The material in the pit on the west bank consisted roughly of 50 per cent of fine stratified clay and about 50 per cent of sand, gravel and large boulders. In the pit on the northeast side there was a large proportion of clay amounting to approximately 75 per cent, together with about 25 per cent of sand, gravel and boulders. In both pits the boulders in many cases were too large to be handled through the flumes, and were accordingly broken up before being sluiced into them. Over the whole of the borrow pits the timber and stumps had previously been removed from the site with the aid of donkey engines.

The clay in these two pits was very similar to the clays in the foundation of the dam. The analyses of two among other samples shows it to be composed as follows:—

	No. 1.	No. 3.
Silica	59·80	61·70
Alumina	16·92	17·36
Iron as Ferric Oxide	7·84	7·00
Lime	5·0	5·00
Magnesia	3·35	2·62
Alkalies	3·69	1·42
Combined water	3·40	4·30

NOTE.—The above analyses were made on samples dried at 100°C.

From complete analyses that were made (see appendix No. 1 to this report) it will be seen that the material is an ideal one for forming a water-tight dam, and proved in the construction of the work an almost ideal one to obtain proper consolidation, water-tightness and satisfactory drainage during settlement.

The general layout of the flume is well illustrated in reproduction, page 20, and need not be described in detail. The main grade of the chief flume lines was about 4 per cent, and the flumes were all of uniform pattern, being built of two 1-inch by 12-inch planks on the bottom and two 1-inch by 6-inch planks on each side. They were lined on the bottom with 6-inch hemlock blocks placed on end and there was also a 1-inch by 6-inch plank nailed along each side of the flume above the blocks to protect the sides. The bents supporting the flumes were built of 6-inch by 6-inch posts, caps and stringers for the first deck; for the second deck, 4-inch by 4-inch posts and caps and 6-inch by 6-inch stringers were used. The bents were an average distance of 16 feet apart, the lumber used being hemlock sawn on the spot at a saw-mill erected for the purpose. These flume lines stood up very well throughout the whole of the work, the block lining adopted being very satisfactory; in fact, except in the case of the flume from the borrow pit on the northeast side, they required merely occasional patching; that on the northeast side had to be renewed once after having carried approximately 150,000 cubic yards of material. The material was deposited in the dam through 24-inch by 24-inch openings in the sides of the flumes along the slopes; these openings had each an adjustable timber gate, which was lifted and placed across the flume just below the opening, thus diverting the stream through them and depositing the material at any required point, as the slope was built up, lateral flumes were laid from these openings towards the centre of the dam.

The pumping plant consisted of two Dayton centrifugal three-stage pumps with 10-inch suction, 8-inch discharge, working at 150 pounds pressure, rated to deliver 4 cubic feet per second; two Byron-Jackson three-stage, centrifugal pumps, 10-inch suction and 10-inch discharge, rated to deliver 7½ cubic feet per second; and one Worthington three-stage centrifugal pump rated to discharge 4 cubic feet per second. These pumps were driven by five electric motors having a combined capacity of 1,125 horse-power.

Ball-bearing monitors or giants with 4-inch and 5½-inch nozzles, fitted and controlled by the Hendy deflector were used under a pressure of about 80 pounds per square inch at the nozzle. These delivered for sluicing operations 215,000,000 cubic feet of water during the actual dam construction. The total quantity of material in the dam amounted to 544,710 cubic yards. In addition to this quantity about 40,000 yards of material were sluiced in front of the old dam for the purpose of gaining additional storage during the construction of the work. Of the total quantity of material in the dam, 489,130 cubic yards were sluiced from the borrow pits, 343,800 cubic yards from the northeast pit, and 145,330 cubic yards from the west pit. In

Coquitlam Dam.—View looking East showing Trestle and Flumes for placing hydraulic fill. The Sluice Tower is seen on the left of the picture.

addition to this material there were 116,360 cubic yards of heavy rock placed in position by hand and by cableways. The average quantity of material sluiced into the dam was 47,400 cubic yards per month from October 7, 1912, to July 8, 1913, the greatest quantity being 77,700 cubic yards during January, 1913, an average of 2,500 cubic yards per day

The following are the monthly figures for sluicing:—

	Sluiced Material placed in Dam.
	Cubic yards.
1912—October	44,300
November	42,000
December	62,500
1913 January	77,700
February	52,900
March	31,600
April	43,500
May	37,000
June	28,500
July	7,000
Total	427,000

Average 47,400 cubic yards per month.

The total number of days in which sluicing was carried on with two shifts of ten hours each was 296, included in which time were periods necessary for removing and repairing flumes. The percentage of solids to water carried from the pits amounted to 6·14 per cent, this percentage representing 5·36 per cent of solid material as measured in place in the dam.

In the early stages of sluicing the hydraulic fil between the rock toes, the depth of the pond into which the clay was sluiced, varied between 14 feet and 11 feet. This depth was decreased to 7 feet in January, 1913, and 2½ feet in February. As the dam rose the [illegible]ond was kept very shallow—not more than 7 inches or 8 inches in depth. The water was drawn off from the settling pond by means of an over-flow channel on the downstream slope. This channel was built of 1-inch by 12-inch planks at the sides, and its width was 4 feet. The bottom of the over-flow channel was filled with boulders and heavy stones, while the sides were kept level with the downstream slope of the dam. On completion of the sluicing the over-flow channel was filled up with heavy rip-rap.

In January, 1913, when the hydraulic fill had reached elevation 468, the resident inspecting engineer put a bore through [illegible]nto the clay in order to ascertain the condition of the impervious portion of the fill. The following is a record of the specific gravity and percentage of moisture found in the samples secured, as tested under the direction of Dr. Shutt of Ottawa:—

Sample Collected from Elevation.	Percentage of Water.	Specific Gravity.
468·0	28·98	1·798
462·0	27·39	1·842
458·0	24·94	1·871
454·0	28·78	1·762
450·0	25·67	1·853
446·0	24·17	1·844
442·0	25·13	1·859
438·0	27·58	1·821
434·0	28·24	1·814
430·0	31·43	1·740
426·0	24·80	1·841

Elevation 468·0 was the top of the fill when the samples were taken, and elevati 426·0 was 0·8 feet above the original clay stratum. The low percentage of water, a the high and uniform specific gravity of the fill showed that the draining out and co solidation of the hydraulic fill was very satisfactory. Although cold weather w experienced during some periods when the hydraulic sluicing was going on, t temperature falling during January, 1913, to 11 degrees Fahr., no trouble was expe enced from the freezing of the pond or of any of the material.

Lake Clearing.

For the protection of the Westminster water supply, the company carried o extensive clearing operations on the shores surrounding the lake which were cover

Coquitlam Dam.—Lake Clearing Operations.

with a heavy growth of cedar and hemlock. For a distance of over three miles above the intake the whole of the land to be flooded was cleared and the stumps sawn close to the ground. The clearing over this section was completely done to elevation 508, and in the upper part of the lake the whole of the shores have been cleared to elevation 480. The total area of land completely cleared amounts to approximately 750 acres, inclusive of the area surrounding the dam site. This work proved enormously difficult and costly, owing to the steep sides of the lake and the necessity of constructing rafts plated with steel for burning much of the debris. The cost of clearing has amounted to $649,289. The lowest cost for clearing was about $350 an acre, while sections of the work in swamps where the timber was decayed and heavy, cost as much as $2,000 per acre.

In carrying out these operations which were begun in March, 1911, a camp was built on the west shore of the lake close to the intake of the Coquitlam-Buntzen tunnel.

This camp was capable of accommodating 300 men, and particular care was observed regarding the sanitation, a drainage system being installed throughout the camp, and a sewer connection made to the lake Buntzen tunnel at a point behind the control gates, so that no sewage could possibly find its way into Coquitlam lake. An incinerator was also built and all camp and cookhouse wastes carefully burned in it. For the use of the men working on the land to be cleared, canvas houses with zinc conveniences were supplied, the foreman of each crew being held responsible for the good conduct of his men. These houses were moved forward as the work advanced, buckets being changed twice each week and their contents burned in the incinerator. By careful supervision of the sanitary requirements no trouble whatever was experienced, although as many as six hundred men were employed on the work.

Where the timber was small all the clearing was done by hand, but with the heavy timber areas donkey engines were used. The underbrush and scrub timber was piled and burned. The mercantile timber was left on the ground, being flooded off at a later date when the lake level was raised. The work was abandoned owing to snow during the winter of 1911, and renewed again in the spring of 1912 when two additional camps were built, one at the north end of the lake capable of accommodating 200 men, and one on the east shore north of the Coquitlam-Buntzen tunnel capable of accommodating 150 men. At the camp to the north of the lake an incinerator was also built and all refuse burned in it, while the refuse from camp No. 3, on the east side of the lake, was placed in zinc buckets and burned at the camp at the Coquitlam-Buntzen tunnel portal.

For the purpose of clearing, a steam tug 50 feet in length was built at the lake, and was used for taking the men to and from their work, and also for towing scows and log booms up and down the lake.

For the purpose of taking out the merchantable logs, a logging railway was constructed from the south end of the lake to Port Moody, a distance of about 8 miles, and a large number of logs were taken out during the season of 1914.

Condition of Water Supply.

The following analysis taken immediately after the completion of the dam is typical of the water supply:—

WATER ANALYSIS—October 18, 1913.

(Parts per million.)

Physical Examination.—	
1. Turbidity	None.
2. Reaction	Neutral.
3. Smell	None.
4. Taste	Good.
5. Sediment	Slight.
6. Color	30
Chemical Examination.—	
1. Ammonia, free, expressed as Nitrogen	·056
2. Ammonia Albumenoid, expressed as Nitrogen	·07
3 Nitrates, expressed as Nitrogen	·06
4. Nitrites	None.
5. Chlorine	3·24
6. Hardness, total, expressed as CaO	2·20
7. Hardness, permanent	1·40
8. Hardness, temporary	·80
9. Oxygen consumed, 4 hours at 37°C	2·7
10. Oxygen consumed, 3 minutes at 37°C	·4
11. Solids, total	18
12. Solids volatile	8
13. Solids, fixed	10
14. Poisonous metals	None.
Microscopic Examination.—	
Vegetable fibres and crystalline matter.	
Biological Examination.—	
Number of Bacteria per c.c.	30
Presumptive test for Colon Bacilli	Negative.

Samples of water have been carefully analyzed fortnightly during the past fo years, and the number of bacteria per c.c. has varied from 15 to 100 at the water suppl intake, and has averaged throughout the whole period of the work about 40 or 50 pe c.c. In spite of the fact that over 800 men were employed upon the works, of whon nearly 600 were employed on lake clearing alone during some months, no pathogeni organisms were discovered at any time, a result due to the very careful sanitary pr cautions which were taken in connection with the construction of the works.

Attached to this report will be found a recent special report on the condition o the water of Coquitlam lake taken in November, 1914. This report is very satisfac tory, and shows that the effect of storage at Coquitlam has, if anything, improved th water supply from Coquitlam lake.

Electric Power for Works.

A transmission line was built from the company's transmission system at Westminster junction to the site of the works; power was transmitted at 34,600 volts and transformed down to 2,200, 220 and 110 volts at the works as required. All pumps used in connection with the sluicing were electrically driven, and the two cableways used for depositing rock in the toes of the dam were operated bp electric motors.

COQUITLAM-BUNTZEN HYDRAULIC TUNNEL.

Original Tunnel.

The total length of the Coquitlam-Buntzen tunnel is 12,650 feet (see reproduction on page 12). This work was begun in 1902 and completed in 1903. Owing to the great elevation of the mountains—4,000 feet above the tunnel—the sinking of shafts was impracticable, so that the tunnel had to be driven from two faces only, through hard granite. A square section about 9 feet by 9 feet with rounded corners was adopted. It was designed originally to carry 500 cubic feet per second, but actual gauging after the work was completed showed a flow of only slightly over 300 cubic feet per second. The tunnel was left unlined throughout and had a mean sectional area of 81 square feet.

Enlargement of the Tunnel.

When the original tunnel was designed it was thought that ample provision had been made for any increased demand for water which might occur on account of extensions to plant No. 1, lake Buntzen, but the rapid development and growth of the district around Vancouver soon made it evident that the demand for power would in a very short time exceed the maximum capacity of the tunnel. After careful investigation it was decided that the existing development could be considerably enlarged so as to utilize almost the entire run-off of the Coquitlam watershed. The enlargement of the Coquitlam-Buntzen tunnel, and the construction of a dam to increase the storage capacity of Coquitlam lake was therefore decided upon as part of the complete programme. Work on the enlargement of the tunnel was commenced in 1908; the method of enlargement adopted was the "overhead" method, which consisted of taking out enough rock on each side of the tunnel near the roof to set heavy timbers close to the roof, wedging these timbers across the tunnel and also supporting the ends on wall plates and posts placed against the tunnel sides. These timbers were placed about 6 feet apart, and a floor of 6-inch by 8-inch timbers was laid loose upon them close up to the tunnel roof. By means of this system of timbering a heading was driven above the tunnel, and using the timbering as the floor of the heading, the work was carried on in both directions from as many "breakups" as was practicable. The several headings were mucked into cars on the track in the tunnel below by withdrawing the floor timbers directly in front of the muck pile. The timbering was kept well ahead of the faces and was left standing for some distance behind them. During the first part of this work, horizontal holes about 6 feet deep were drilled into the face of the heading in the usual way, but on account of the hardness of the rock and the heavy charges of powder necessary to make a clean break, it was found impracticable to make the timbering of sufficient strength to withstand the blow. The method of drilling was therefore changed, and vertical holes were drilled from the tunnel below before the timbering was put in, the drilling being kept well in advance of the face. This system of drilling and shooting proved satisfactory as the force of the shot did not act downward on the timbers, but threw the muck back from the face. This method of enlargement gave the tunnel a section much the same as an egg held with the point down, with an area of 176 square feet. Some very fair work was done under this system after the crew was well broken in, but as it as absolutely necessary to leave Coquitlam tunnel open for a large part of the time in order to maintain a supply of water in lake Buntzen, the actual working time in the tunnel was very uncertain and of short duration. During the summer months more than half the time was lost in this way on account of the very light run-off from lake Buntzen watershed; in addition, the timbering cut down the area of the tunnel to such an extent that its capacity was greatly reduced and very little time for actual work was available. The greater the number of headings worked, the greater was the obstruction in the tunnel, as timbering was necessary at every heading. The demand for water was increasing daily, and the limited storage necessitated the construction of an auxiliary steam plant in the city, and in July of 1910 for the purpose of obtaining greater speed the top heading method was abandoned in favour of one in which no timbering was required. At this time about 1,800 feet of enlargement had been completed and the tunnel was drilled to a point 3,000 feet from the portal. Before changing over, the drilled portion was completed by the first method.

The method by which the remainder of the tunnel was enlarged consisted of removing sufficient rock from one side and the roof to increase the area from the original 81 square feet to 192 square feet. The side headings were started at intervals of from 100 to 130 feet, and were worked in both directions. The drilling was all done from the main tunnel at right angles to the centre line. The holes were drilled 8 feet deep, and were placed in vertical rows spaced 3 feet apart, each row having five holes. Two rows of holes were drilled from one setting of the drill column, on which were mounted two drills on horizontal arms, one on each side of the column. The drilling was carried on independently of the shooting and mucking, and was kept well ahead of these two operations. When the "break-outs" were first started and the distance between the faces was small, only one row of holes was shot on each face, but two rows were shot on each face after the headings had widened out sufficiently to accommodate the muck pile without spilling it out over the tracks in the old tunnel. As many as fourteen "break-outs" were worked at one time, giving twenty-eight working faces. This operation removed the rock from the side of the tunnel, and the roof was trimmed up by a separate gang. The heavy shots in the side of the tunnel broke out well into the middle of the roof, and it was often necessary to do very little trimming. After the side holes had been shot and mucked, a small gang followed with stoping drills and drilled the roof where necessary.

The work was carried on in the tunnel as long as the water in lake Buntzen was above a certain minimum level. When this level was reached the tunnel was opened and allowed to remain open until the lake filled again. Two ten-hour shifts were worked in the tunnel; all of the drilling was done on the day shift, and the shooting was done when the drilling shift went off duty.

When the night crew came on the two tunnel locomotives took the men as far as the first face, where they started to clear the track of all muck. As soon as the track was cleared, cars were spotted at each of the faces, and the mucking was carried on as quickly as possible and the tunnel cleared ready for the day shift.

The muck was hauled in 1½ cubic yard side dump cars, which were handled in the tunnel in trains of 25 to 30 cars by electric locomotives of 10 horse-power, taking

current at 500 volts from a trolley wire hung from the roof of the enlarged tu
Side tracks 500 feet long, for the passing of trains and the storage of cars, were l
in the enlarged tunnel at intervals of about 1,200 feet. The track was constructe
20-pound rails laid to 3 feet 0 inch gauge. Two lighter locomotives were used
handling the cars outside of the tunnel on the dump, and making up trains for
tunnel locomotives.

The muck was all dumped into lake Buntzen, which is very deep at the tu
entrance. The dumping tracks extended down the shore from the tunnel for a dista
of about 1,000 feet. On account of the tendency of the rock dump to slide under
weight of the loaded cars, it was carried out on two levels and the tracks were k
some distance apart.

When the gates at the Coquitlam end of the tunnel were closed it was necess
to wait for sometime before the tunnel was sufficiently free of water to allow the wo
men to enter. In order to better this condition, an automatic shutter dam was pla
in the tunnel at station 72 + 00. This dam was pivoted on its horizontal axis
closed automatically when the water was 4 feet deep, thus storing the water to t
depth behind the dam, and allowing the lower end of the tunnel to clear quickly. Wh
the gates were again opened and the water raised, the dam swung parallel to the f
of water, offering practically no resistance to the flow.

The original tunnel was not driven on one continuous grade, but sloped fr
elevation 409 at the Buntzen portal to elevation 410 at station 72 + 00. From there
sloped to elevation 407 at station 119 + 00, and to elevation 428 at the Coquitlam e
at station 126 + 50. There was, therefore, a sump nearly 5,000 feet long near t
Coquitlam end of the tunnel, where the maximum depth of water was about 4 fe
It was at first intended to enlarge this portion by shooting down enough rock fr
the roof of the tunnel to fill the sump and bring the floor to an even grade, but th
plan was rejected in favour of placing a large motor-driven centrifugal pump at t
Coquitlam end of the sump and pumping back into Coquitlam lake; the pump w
set up in a water-tight compartment blasted out of the side of the tunnel. The pu
motor was started from above shortly after the gates were closed and the sump w
pumped dry in a very short time. The method of enlarging the tunnel from t
summit, through the sump, and to the gates at the Coquitlam end, was the same
that used up to the summit.

The tunnel being open at both ends, it was a comparatively simple matter
ventilate and clear out the gases after blasting; a large motor-driven exhaust fan
56,000 cubic feet per minute capacity was placed at the lake Buntzen portal. Afte
the shooting was done, the portal was closed and the blower started, and all gases we
cleared out within thirty minutes.

No. 7 Water Leyner drills were used almost exclusively in the work of enlarge
ment, and they proved highly satisfactory; the length of hole drilled by each machi
averaged a little over 40 feet per day of less than 9 hours actual drilling time. Th
greatest number of drills in use in the tunnel at one time was 54, not counting th
stopers, which numbered from three to seven. Each drilling foreman had charge c
four machine crews. Upon going off shift, the drill foreman loaded all of his machine
and steel on the train and took it to the repair shop, where the machines were gon
over by the repair crew during the night and any necessary adjustments were mad
In this way the machines were always kept in first-class order. On going into th
tunnel each morning each drill crew attended to the loading of their machines an
sharp steel. One repair man was kept in the tunnel on the drilling shift and an
slight repair or adjustment was made at once. The steel sharpening was done by thre
Leyner sharpeners working two shifts of ten hours; one man on each shift tempere
all the steel.

Air was furnished to the drills by two compressor plants, one being located a
each end of the tunnel. The Buntzen plant consisted of one Ingersoll-Rand and fou
Leyner motor-driven compressors having a total capacity of 2,250 cubic feet of fre

air per minute. The Coquitlam plant consisted of two Ingersoll-Rand motor driven compressors having a capacity of 500 cubic feet of free air per minute. Both of these plants fed into a 5-inch diameter air main running the whole length of the tunnel. Water under pressure was furnished to the drills through a water main laid parallel to the air main.

A 2,200 volt power line was run from the dam substation to the east portal of the Coquitlam-Buntzen tunnel for supplying power for driving the air compressors and other machines during the work of enlarging the tunnel. Current for the electric locomotives was obtained from a motor generator set.

The tunnel enlargement was completed in March, 1911, in less than 100 working days after the side method of enlargement was started. The average advance per day of two shifts during this time was very close to 100 feet of enlargement. The maximum advance for one day was 175 feet, when 730 cars of muck were hauled out of the tunnel. The maximum number of men at work at one time was 450. Very few serious accidents occurred to the workmen during the course of the work.

Tunnel Intake.

When the tunnel enlargement was started a 9-foot diameter coffin sluice gate was installed in the tunnel a short distance below the old gates. This gate was placed in the tunnel at the bottom of a shaft sunk from the operating tunnel, which was driven above the proposed high-water level of Coquitlam lake; it was designed to operate under a head of 85 feet.

When the tunnel enlargement was completed the coffin gate was taken out and re-erected about 40 feet upstream in place of one of the original sets of gates, and the old gates were removed. In the place of the coffin gate two stony sluice gates were installed. These gates are each 4 feet 6 inches wide and 10 feet high. Th coffin gate is set in a Venturi throat and the tunnel is lined with concrete between the coffin and the stony gates. The stony gates are used as the usual operating gates, and the coffin gate as an emergency gate, or whenever perfect water tightness is required.

T[illegible]inal intake consisted of a rock-filled timber crib built out into the lake and i[illegible]hree intake tunnels 7 feet square, made up of 12-inch by 12-inch timber[illegible]e. These short intake tunnels were joined together into one tunnel back in [illegible] rock in front of the gates. The capacity of this intake was not sufficient for the enlarged tunnel, and the intake was, therefore, reconstructed.

The new intake consists of a heavy masonry retaining wall founded on bed-rock and built against the steep hill above the tunnel entrance, the elevation of the top of the wall being well above the high-water level of Coquitlam lake. The main wall is flanked by two inclined wing walls.

A trash rack 41 feet wide and 35 feet high, made up of a framework of I-beams, with 40-pound T rails laid vertically, and mounted on eight wheels, is provided at the tunnel intake; the rack is supported by heavy steel cables, and counterbalanced so that it can readily be raised and cleaned.

A log boom is anchored across the approach channel, and a stiff leg derrick is provided over the tunnel portal for removing any heavy driftwood which may approach the intake should the log boom be carried away.

Both of the stony sluice gates and the coffin gate can be operated by g[illegible]lene engines or by hand. The operating gear is placed in chambers cut in the face of the mountain at the level of the top of the retaining wall.

From observations that have been carried out since the tunnel was enlarged, its maximum discharging capacity is estimated to be about 1,350 cubic feet per second, the value of "C" in the Chezy formula being 46·6, the value of "N" in the Kutter formula, 0·0388. The discharging capacity is, therefore, well in excess of the requirements.

Lake Buntzen Storage Reservoir.

Lake Buntzen lies immediately to the west of Coquitlam lake, from which it separated by a range of mountains which reach an elevation of 4,000 feet.

The average rainfall at lake Buntzen over the last eleven years was 112·53 inche the maximum year was 1906, when 136·71 inches were recorded, and the minimu year 1911, when the precipitation was 98·60 inches.

The following is a record of the precipitation for the years 1903-1914:—

LAKE BUNTZEN, B.C.—Precipitation—Drainage Area, 7 Square Miles.

	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914
January	18 89	20 66	14 10	21 44	16 40	12 52	13 17	8 20	10 10	15 94	17.38	19 2
February	5 20	13 61	11 23	11 45	13 86	9 68	10 09	12 03	6 44	10 13	8 89	7 8
March	6 90	11 46	15 72	2 57	7.25	17 12	5.69	11 38	9 41	3 02	9 28	8.0
April	7 37	5 18	5 34	2 39	10 10	8 07	5 51	12 01	2 26	6 74	5 28	5.0
May	6 32	3 80	6 02	10 32	2.46	5 85	6 69	4 54	9 18	3 23	7.31	3 3
June	5.58	3 05	4 30	8 94	3 02	2 70	4 52	4 02	2.99	4 62	6 37	4 6
July	3 33	3 30	2 12	0 79	1 61	3 50	3 64	0 25	1 03	2 58	3 48	0 8
August	2 30	1 08	1 85	1 79	3 38	0.30	6 26	5 92	1 39	8 25	2.44	1 1
September	15 26	5 25	20 69	24 05	6 75	5 65	4 85	3 27	10 10	4 71	6 25	13 8
October	16 26	7 29	9 46	24 57	1 34	13 81	14 30	15 62	3 65	11 10	10 44	15 2
November	24 19	20 93	9 21	14 95	25.98	24 64	22 63	19 51	20 45	19 08	21 26	18 9
December	9 85	13 73	16.16	14 35	11 44	8.33	7.59	17 75	21 60	19 04	8 53	
Totals	121 44	109 34	116 14	137 61	106 59	112 17	105 75	111 50	98 60	108 77	106 91	

The area of lake Buntzen is about 500 acres, and the drainage area about seven square miles. Although the storage capacity of this lake is small, it forms an excellent natural forebay for the power plants.

During 1902, while the preliminary work in connection with the driving of the tunnel connecting the two lakes was in progress, a concrete dam was built at the south end of lake Buntzen, and storage amounting to 6,000 acre feet was obtained. This dam is of gravity section and is founded on bed-rock. It is 51 feet in height, with a top width of 10 feet, and 361 feet long at the top, which is 400 feet above sea-level.

In the dam, ten 51-inch outlets with the necessary trash screens and hand operated head gates are provided for the main pipe lines, which convey water to power-house No. 1, and two openings 24 inches in diameter are provided for the exciter pipe lines.

Plant No. 1, Lake Buntzen.

The original power-house of the Coquitlam-Buntzen development is situated on the east shore of Burrard inlet at a distance of about 16 miles from Vancouver.

The power-house is built of hewn granite, the main floor being 5 feet above high water. The generating equipment at present installed consists of seven units made up as follows:—

Four 1,500 k.w. Westinghouse generators driven by Pelton water wheels.

One 5,000 k.w. C.G.E. generator driven by Pelton water wheels.

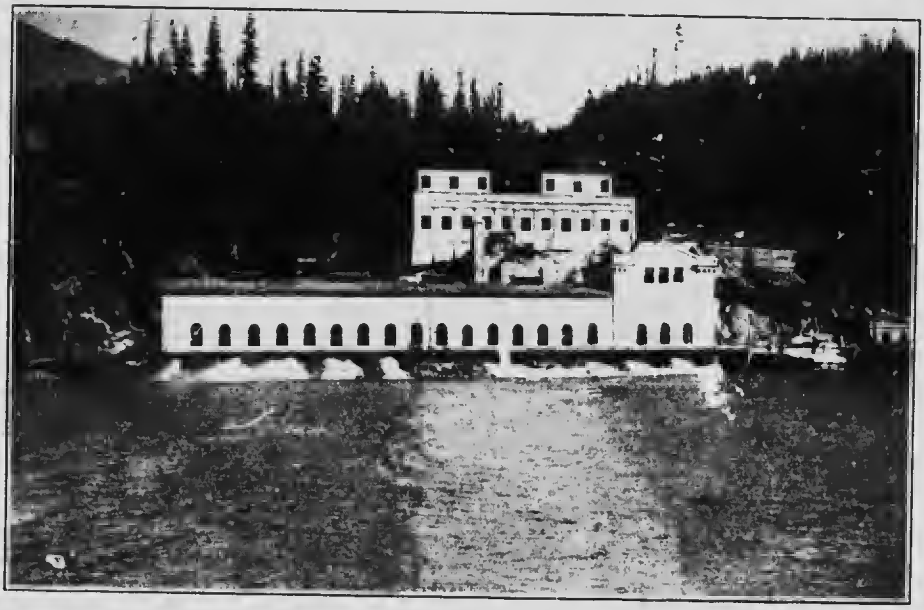
One 5,000 Dick-Kerr generator driven by Doble water wheels.

One 5,000 C.G.E. generator driven by Doble water wheels.

All of the above units are of the horizontal type, the water wheels and generator being in all cases mounted on the same shaft.

The first four units (installed 1903-4) are of similar construction; the water wheels driving the 1,500 k.w. generators are of the deflecting nozzle type. Each of these units is controlled by a Lombard governor which by means of a rack and pinion device deflects the nozzle through which water is delivered to the wheel. In the case of a sudden decrease in load, the governor causes the nozzle to deflect downwards, thus preventing a portion of the water jet from impinging on the buckets.

Units Nos. 6 and 7 (installed 1910-11) show a great advance in hydraulic design; they are much more economical as regards water consumption than any of the units previously installed. The speed regulation is controlled by a Lombard governor which opens and closes the main nozzles according to the load on the unit through links attached to a rocker shaft. When the load on the unit falls off suddenly, two auxiliary relief nozzles are opened by the action of the governor on the rocker shaft to which, the needle stems are connected through links. These relief nozzles close slowly by the operation of a spring and dashpot, thus reducing the water hammer effect on the pipe lines. All of the generators are of the 3-phase, 60-cycle type, generating at 2,200 volts.



Power House No. 1.—Lake Buntzen.

In addition to the above generating equipment, four exciter units are provided, current for excitation purposes being generated at 110 volts.

The voltage at the A.C. bus bars is controlled by Tirrell regulators.

The generating equipment is installed on the main floor of the power-house, which, as mentioned above, is 5 feet above high-water level. The operating bench board and switch board are placed on a gallery along the back wall of the generator room. Behind the switch board the generator switches are located and on the floor above the generator switches the low tension transformer switches are located. The transformers and high tension switching equipment are located in a separate building behind the power-house; the transformer equipment consists of three banks of three 3,000 k.w., single-phase, oil insulated water-cooled transformers, manufactured by the C.G.E., which step up the voltage from 2,200 to 34,600. The lightning arresters are placed on the roof of the transformer house. All of the high tension switches are of the C.G.E. K-15 type. At a later date, the transformer connections will be changed and the voltage stepped up to 60,000. All of the high tension equipment is suitable for this higher voltage.

Pipe Lines, Plant No. 1.

Each of the 1,500 k.w. units in the power-house is supplied with water from lake Buntzen by means of one pipe line 48 inches in diameter, and about 2,000 feet in length. Two pipe lines 60 inches in diameter are provided for No. 5 unit. One pipe line 84 inches in diameter at the upper end and tapering to 72 inches in diameter at the power-house, is provided for each of the last two 5,000 k.w. units installed.

In the original installation the first 800 feet of the pipe lines below lake Buntzen dam were of wood stave construction; the wood stave portions of these pipe lines have now been replaced with pipes of riveted steel construction. One pipe line 24 inches in diameter is provided for all four exciter units; all of the pipe lines are connected by riveted joints to pipe sections built into the dam.

Plant No. 2, Lake Buntzen.

In the autumn of 1911, the installation of additional machines at lake Buntzen was decided upon in anticipation of further increases in load such as had been experienced in the preceding five years. As it was impracticable to build further extensions at the south end of power-house No. 1, a number of drill holes and test pits were sunk at the north end, but the bed rock was found so far below the surface, and its dip in a northerly direction was so great, that the idea of making further additions to No. 1 power-house was abandoned.

The shores of Burrard inlet in the neighbourhood of lake Buntzen are precipitous, and only one practicable site for a new power-house was available; about one-third of a mile to the south of power-house No. 1 a bench was located, and although the preparation of the foundation necessitated the excavation of over 30,000 cubic yards, most of which was solid rock, an admirable site for the new power-house was obtained.

The work undertaken in connection with plant No. 2, lake Buntzen, comprises the construction of a reinforced concrete power-house, containing water wheels of a total capacity of 40,500 horse-power, generators and transformers, together with the necessary high and low tension switching equipment. Water for driving the hydro-electric units is obtained from lake Buntzen through a concrete lined pressure tunnel about 1,800 feet long (see reproduction on page 33), driven through solid rock, and controlled by three Doble needle intake valves; near the end of the pressure tunnel, and close to the top of the hill, a steel surge tank is provided, and from this point the water is conducted to the power-house through three steel pipe lines. Close to the surge tank, a Pelton-Doble Patent Venturi Butterfly valve is installed in each pipe line.

The greater part of the construction plant used on the enlargement of the Coquitlam-Buntzen tunnel, including the air compressor plant, was available for the new work, and the machine shop and camp buildings at the old tunnel camp at the west portal of that tunnel, were repaired and made habitable. This camp is situated on the east side of lake Buntzen, but as all the new construction work contemplated was on the west side of the lake, a pontoon bridge, made up of large cedar and fir logs on which were laid stringers and ties carrying 36-inch gauge track, was constructed across lake Buntzen, for providing communication between the two sides of the lake. All the drill steel, sand, etc., required for the driving and the lining of the tunnel was transplanted over this bridge in cars drawn by an electric locomotive. On the completion of the work, the logs were taken down to Burrard inlet and sold.

The wharf camp situated near power-house No. 1, which had been in use during 1911 in connection with the work of installing No. 7 unit at plant No. 1, was also used for the accommodation of the workmen, and a third camp was built near the new power-house site. A timber runway was built out from the cliff over the waters of Burrard inlet about 10 feet above sea-level between power-house No. 1 and the site of power-house No. 2, to provide access to the new power-house site.

Hydro-Electric Plants, Lake Buntzen.—Power House No. 1 on the left of the picture. Power House No. 2 on the right.

Intake Works.

The intake works consist of three Doble needle intake valves placed on a concrete foundation on the bottom of lake Buntzen. The design of these valves differs radically from the head gates generally used for intake works. The seats on which the needles

Plant No. 2, Lake Buntzen—Intake Valve H

rest when closed are in a horizontal plane; an outer cylinder is provided which may be lowered down to a seat, thus excluding water from the needle valves so that they may be inspected without the use of a diver. The needle gates are operated by oil pressure. The entrance losses at the intake are small. (See reproduction above.)

Main Tunnel.

From lake Buntzen, water is conducted for a distance of about 1,800 feet through a concrete lined tunnel, 14 feet 8 inches internal diameter, thence through pipe lines to the power-house. Two shafts, designated shaft No. 2 and shaft No. 1, were sunk at distances of 400 feet and 900 feet, respectively, from lake Buntzen; the work of driving the tunnel was prosecuted in both directions from each shaft, and also from the west end where the tunnel emerges from the cliff; five working faces were thus obtained.

The tunnel was driven as nearly as possible 16 feet 2 inches in diameter, and on measuring up the work the overbreak was found to be about 8 per cent.

The concrete lining was placed in three operations; the invert section, which covers about 8 feet of circumference in the bottom, was first placed by means of sweeping boards, along the entire length of the tunnel. When this concrete had set, a

Power Plant No. 2.—Intake at Lake Buntzen.

narrow gauge track was laid on it for carrying forms for concreting the middle section, and a second track, with passing places, was erected slightly above the horizontal diameter of the tunnel for transporting concrete to the forms. Concrete cars of one cubic yard capacity were used for this work.

The forms for the middle section were 64 feet in length; as soon as the concrete in this length was set, the middle form was pulled ahead, and the next section in advance was then concreted. The form for the upper or roof section was then pulled forward and supported on timbers resting on the concrete of the middle section.

The forms for both the middle and roof sections were so designed that it was possible to pull them ahead without dismantling the framework. The forms for the middle section travelled on wheels supported on the invert track, while the upper forms travelled on steel rollers, and excellent results were obtained with these forms.

The concrete used was in the proportion 1:2:4; rock was crushed on the ground, but all sand was purchased and transported to lake Buntzen by scow. The crushing and mixing plant was located on the surface of shaft No. 1, and all concrete for the tunnel lining was lowered in cages through this shaft.

Surge Tank.

In order that better speed regulation of the hydro-electric units might be obtai and that the effects of water hammer in the pipe lines due to sudden changes of l might be reduced, a surge tank was installed near the west portal of the tunnel.

The surge tank (see illustration below), which is 30 feet in diameter and ab 90 feet high, is constructed of steel plates riveted together, and placed in a sh excavated in the rock. From the roof of the tunnel an upraise about 6 feet by 10 f was first driven; the remainder of the excavation was then mucked through upraise and dumped outside the west portal.

Plant No. 2, Lake Buntzen.—Top of Surge Tank.

Pipe Lines.

The pipe lines (see reproduction on page 37), of which there are three, a connected to the surge tank by means of flanged reinforcing plates. The upper end of the pipes project into the surge tank, and are provided with bell mouths, thus min mizing entrance losses.

The pipes are 8 feet 6 inches in diameter, and one-half inch thick at their upp ends, and taper to 7 feet in diameter at the power-house, where the thickness is 1½-inc About 200 feet from the power-house the pipe line passes into tunnels driven throug the rock, which is badly fissured. The pipe line grades are very steep, the slope ranging from 28 to 53 degrees, thus rendering difficult the handling of the large pip sections, the heaviest of which weighed 16 tons.

Plant No. 2, Lake Buntzen. View of Surge Tank showing openings for pipe line connection

Butterfly Valves.

A short distance below the surge tank a Double Venturi Butterfly valve is provi in each pipe line; it will, therefore, be possible to carry out repair work on any p line, and on all parts of any unit, while the remainder of the plant is in service.

These valves possess several excellent qualities, the chief of which are absol water tightness, simplicity of design, and moderate cost.

Plant No. 2. Lake Buntzen.—View showing three pipe lines at entrance to line tunnels behind Power House No. 2.

Power-house No. 2.

Power-house No. 2 (see reproduction on pages 40 and 41), is founded throughout on solid rock and is of reinforced concrete construction. The design of the building was carefully studied from an architectural point of view, and its massive proportions harmonize with the precipitous mountains which form the background.

On the main floor of the building, which is 5 feet above high-water level, three hydro-electric units have been installed. Each unit consists of one Dick-Kerr 8,900

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Plant No. 2 Lake Buntzen.—Pipe Lines at west portal of Pressure Tunnel.

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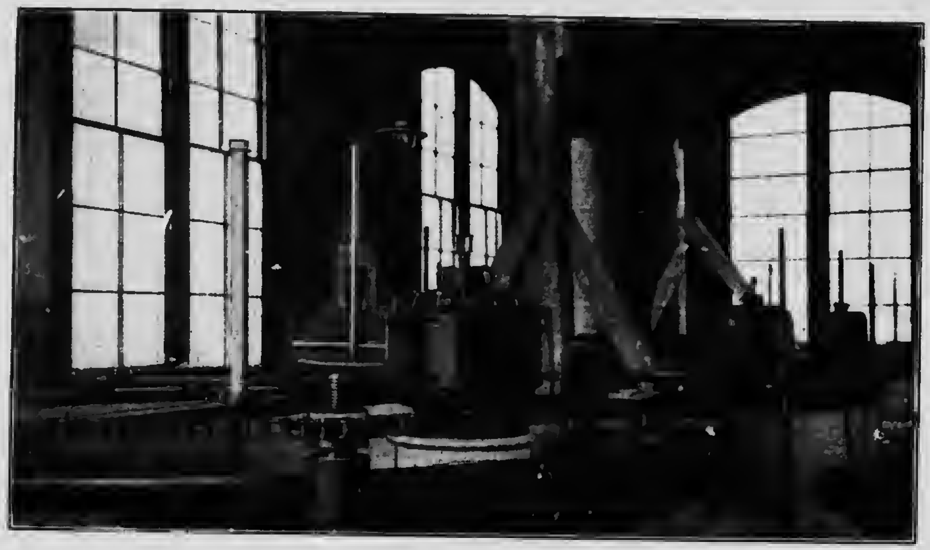
vel, three
Kerr 8,900

k.v.a., 3-phase, 60-cycle alternator of the revolving field type, generating current at 2,200 volts, direct driven at a speed of 200 revolutions per minute by four Pelton-Doble water wheels of the impulse type the combined capacity of which is 13,500 horse-power; the alternator and four water wheels are all pressed on to a hollow nickel steel shaft 51 feet 3 inches long, forged in one piece. A separate pipe line is provided between

Power House No. 2.—Lake Buntzen

the surge tank and the power-house for supplying water to each unit. Close to the back wall of the power-house this pipe divides into four branches, each branch supplying water to one wheel of the unit. On each branch a Doble hydraulically operated gate valve is provided which controls the admission of water to two needle nozzles, which direct the water on to the buckets of the wheel.



Power House No. 2, Intake House, Lake Buntzen.

Power House No. 2, Generator Room, Lake Buntzen.

The speed regulation of each unit is controlled by a Lombard governor, which opens and closes the main nozzles according to the load on the unit, through links attached to a rocker shaft. Should the load on the unit fall off suddenly, two auxiliary relief nozzles are opened by the action of the governor; these relief nozzles close slowly by the operation of a spring and dashpot, thus reducing the water hammer effect on the pipe lines.

For excitation purposes, three 300 k.w. exciter units are provided, one of which is located at the rear of each main unit. Each exciter is composed of a Dick-Kerr induction motor-generator set direct, driven by two Pelton-Doble water wheels mounted on the end of the shafts. The speed of the exciters is 600 revolutions per minute; current is generated at 250 volts, and fed either direct or through D.C. bus bars to the fields of the generators.

The voltage regulation on the A.C. bus bars, which are built in cell structures behind the exciters, is controlled by the action of a Tirrell regulator.

Owing to the great size and weight of some parts of the units, it was found necessary to provide two 50-ton electrically operated travelling cranes. These cranes control the entire length of the main generator room floor.

Immediately above the generator room is located the high tension switch room, which also contains the lightning arrester equipment. The high tension switches are of the Canadian General Electric K-15 type, and are suitable for 60,000 volts. The lightning arresters are of the four-tank electrolytic type, and are of the latest design evolved by the Canadian General Electric Company.

To the rear of the generator room and above the bus bar compartments, the low tension generator and transformer switches are installed; these switches are all of the Canadian General Electric H-6 type. The transformer room is situated immediately above the low tension switch room; the transformer equipment consists of four banks of three 3,000 k.w., single-phase, oil insulated, water-cooled transformers, by means of which the voltage is raised from 2,200 to 34,600. At a later date, the transformer connections will be changed and the voltage increased to 60,000. One 25-ton electrically operated travelling crane, which travels the entire length of the transformer room is provided, together with the necessary oil tanks, oil filters and pumps. Current is fed to the lines through the above-mentioned K-15 high tension switches.

The construction work in connection with plant No. 2 was practically completed in October, 1914.

Transmission Lines.

The electrical energy generated at lake Buntzen is transmitted at 34,600 volts (to be increased later to 60,000) to Vancouver substation, and to other substations in the territory served by the company (see Plate No. 28b), by two 2-circuit transmission lines. Two of these circuits which are connected in at plant No. 1 are carried on wood poles. The other two circuits are connected to the bus bars at plant No. 2, and are carried on steel towers spaced about 600 feet apart. These two transmission lines traverse very rough country between lake Buntzen and Burrard inlet, where all four lines cross the inlet at Barnet by means of a single span 2,850 feet long.

A tie line of wood pole construction connects power-houses Nos. 1 and 2.

Power House No. 2, Lake Buntzen.—High Tension Switch Room.

Cost.

The following is a statement of the capital expenditure upon the whole development since 1903:—

APPROXIMATE SUMMARY OF COST.

Power-house and Plant No. I	$ 902,409 00
Transformer houses	318,778 00
Original hydraulic tunnel, Coquitlam lake to Lake Buntzen, including subsequent enlargement	1,715,558 00
Power-house and Plant No. II	2,087,266 00

Power House, Lake Buntzen—Transformer Room.

Water Supply—	
Lake Buntzen concrete dam	170,786 00
Lake Coquitlam—	
Original crib dam	31,834 00
New Coquitlam Dam including New Westminster water supply works	1,646,411 00
Clearing shores of Coquitlam lake of timber	649,289 00
General expenses	208,286 00
Wharves, camps, lands, and miscellaneous	163,258 00
Total	$7,893,456 00

Engineers, etc.

The engineers for the original Coquitlam-Buntzen plant as designed in 1903 were Messrs. Herman & Burwell, M.M. Can. Soc. C.E., of Vancouver, and Mr. Wynn Meredith, M. Am. Soc. C.E., of San Francisco. Mr. Meredith also acted as consulting engineer for the tunnel enlargement. All the new works described in the report carried out since December, 1910, including Coquitlam dam, the New Westminster intake works, plant No. 2, and extensions to plant No. 1, have been under the direction of

New Transmission Towers, from Plant No. 2, Lake Buntzen.

Mr. G. R. G. Conway, M. Inst. C.E., M. Can. Soc. C.E., chief engineer, British Columbia Electric Railway Company, Limited; the late Mr. J. D. Schuyler, M. Am. Soc. C.E,. represented the company as consulting engineer during the early stages of the dam construction; Mr. J. R. Freeman, M. Am. Soc. C.E., acted as advisory engineer to the Dominion Government in connection with Coquitlam dam and water supply matters. The Department of the Interior was also represented by Mr. J. B. Challies, M. Can. Soc. C.E., superintendent of Water Power Branch, assisted by J. T. Johnston, Assoc. M. Can. Soc. C.E., chief hydraulic engineer, Department of the Interior, and by Mr. R. S. Stronach, Assoc. M. Can. Soc. C.E., as resident inspecting engineer.

Appendix No. 1.

FALKENBURG & LAUCKS,
SEATTLE, WASH., November 28, 1914.

VANCOUVER POWER COMPANY, LTD.,
Vancouver, B.C.

Report No. 14365.

GENTLEMEN,—Pursuant to your request, the quarterly series of water samples was taken from lake Coquitlam, November 24, 1914, by the writer.

All the samples were taken carefully and in accordance with the best practice for securing such samples for investigation as to the sanitary and industrial condition of the water at the time of sampling.

Weather.—The day on which the samples were taken was bright and sunny, although it had been preceded by many days of more or less steady rainfall.

Temperature of Atmosphere.—The temperature on the day of sampling was 59 degrees Fahr. at 1 p.m. The maximum temperature during the preceding twenty-four hours up to 8 a.m. of the 24th inst. was 45 degrees Fahr., and the minimum temperature was 43 degrees Fahr.

Temperature.—The temperature of the water one foot below the surface was taken at each station, and was as follows:—

TEMPERATURE OF WATER.

Station No. 1	47.6° Fahr.
" 2	47.7 "
" 3	47.5 "
" 4	47.7 "
" 5	47.7 "
" 6	47.7 "

Elevation of Lake.—The elevation of the surface of the lake was 504.07 feet = 60.1 feet above the old dam.

Snow.—Considerable snow was noticeable at the head of the lake, and there was some toward and on the tops of all of the hills surrounding the lake.

Floating Debris.—There was considerable timber collected in the log booms at the lower end of the lake.

The central portion of the lake and the water behind the island were very free from floating logs, timber, etc. There was considerable floating timber in the upper portion of the lake, due to the breaking of a boom below the Narrows. A boom was stretched across the Narrows, holding considerable floating timber above it and preventing ingress into the portion of the lake above the Narrows.

The timber floating in the lake was confined to large logs and trees, there being very little small pieces afloat.

Lake Buntzen Tunnel.—The gates of the lake Buntzen tunnel were open one foot on the date of sampling, but had been closed for two preceding days.

Drainage.—Water was flowing into the lake from all parts of the watershed, and as would be inferred from the elevation of the lake, a large volume of water was being expelled over the spillway.

Sampling.—The samples were taken in the usual manner and places. Those for chemical analysis were taken at from 3 to 4 feet depth below the surface of the lake, and those for bacteriological examination were taken 6 inches below the surface. The bacteriological samples were taken in vacuum tubes and placed in Thermos bottles with ice water, as usual, and were plated the following morning.

Results.—The results of our examination of the various samples are contained in the following tables:—

Physical Examination.	Samples.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Turbidity	None.	None.	None.	None.	None.	None.
Reaction	Neutral.	Neutral.	Neutral.	Neutral.	Neutral.	Neutral.
Smell	None.	None.	None.	None.	None.	None.
Taste	Good.	Good.	Good.	Good.	Good.	Good.
Sediment	Very slight.	Very slight.	Very slight.	Very slight.	Very slight.	Very slight.
Colour	30	30	30	30	30	30

Chemical Examination.	Parts per Million.					
	No. 1.	No. 2.	No 3.	No. 4.	No. 5.	No. 6.
Ammonia free as nitrogen	·15	·14	·12	·13	·11	·12
Ammonia Albuminoid as nitrogen	·12	·10	·12	·09	·07	·10
Nitrites as nitrogen	·05	04	·05	·04	·05	·06
Nitrites	None.	None.	None.	None.	None.	None.
Chlorine	4·0	4·3	4·3	4·0	4·7	3·8
Hardness total expressed as CaO	2·8	2·8	2·5	2·2	2·2	2·8
Oxygen consumed 4 hrs. at 37°C	1·8	2·0	1·9	2·2	2·1	2·3
Solids volatile	8	9	9	10	9	9
Solids fixed	7	7	8	7	9	8
Solids total	15	16	17	17	18	17

Biological Examination.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Bacteria per c c.	30	20	50	35	25	40
Colon bacilli presumptive tests	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.

There were no gas or acid forming bacteria present in any of the samples. All organisms present were common water forms similar to those isolated in the past.

Microscopic Examination.—The examination of sediment under the microscope revealed no diatomes or infusorians. The sediment consisted of a small amount of earthy matter and a few vegetable fibres.

Opinion.—From the above results it will be noted that the water was in normal condition on the date of sampling and excellent for both domestic and industrial uses.

Respectfully submitted.

(Signed) FALKENBURG & LAUCKS,

By M. J. FALKENBURG.

Appendix No. 2.

FALKENBURGH & LAUCKS,

SEATTLE, WASH., September 4, 1912.

Mr. G. R. G. CONWAY,
Chief Engineer,
B. C. Electric Railway Co., Ltd.,
Vancouver, B.C.

Report No. 10227.

SIR,—As requested by you, the writer took samples of the various clays in the borrow-pits at the site of the hydraulic-fill dam at lake Coquitlam, B.C., on August 28, 1912.

Samples were taken so as to truly represent the various clays in the pits, and a general sample was also taken of the clayey material after it had been dep sited in the dam.

A separate sample was taken representing each distinctive clayey material entering into the work. The samples are referred to hereinafter in this report by a number and the location and description of each of these samples were as follows:—

Five samples were taken in all.

Sample No. 1.—This sample was taken from the borrow pit near the saw-mill. This material comprised the major part of the clay entering into the fill.

Sample No. 2.—This sample contained clayey material similar to that of sample No. 1, but was interspersed with strata of fine sand. The sample was taken to represent the clay and sand, as they were associated together naturally. This sample was also taken from the borrow pit near the saw-mill.

Sample No. 3.—This sample was an average of the material from the various deposits after it was in place.

Sample No. 4.—This sample was blue clay from the centre line of the dam underneath the old river bed.

Sample No. 5.—This sample was brown clay similar in other respects than colour to sample No. 4. This deposit lies above the so-called blue clay, referred to in sample No. 4.

All of the samples taken contained varying proportions of clayey material, and were what would ordinarily be called glacial clay of the types commonly found in this region. Some contained more clayey material than others, as will be seen in the following.

On the above samples, we made the following described tests in an endeavour to ascertain the nature of the samples, both from a mineralogical standpoint and also as to their physical properties.

1. *Rational Analysis.*—The so-called rational analysis for "true clay substance" was made on all of the samples. This is the analysis commonly used in ceramic technology to determine the mineralogical character of any sample of clay. The complete rational analysis was made on sample No. 3, determining clay substance, feldspar and quartz.

The rational analyses were as follows:—

	No. 1	No. 2	No. 3	No. 4	No. 5
Clay substance	36.3%	39.5%	27.3%	21.6%	26.8%
Feldspar	...	...	22·2		
Quartz	...	...	50.5		

From the above, it will be seen that sample No. 1 contained the highest amount of true clay substance, and sample No. 4 the smallest amount, with the others lying in between.

2. *Elemental Analysis.*—Elemental analyses were also made on Nos. 1 and 3 to show the nature of the chief clayey material entering into the fill, and also the nature of the clayey material in the fill.

The analyses were as follows:—

	No. 1	No. 3
Silica	59.80	61.70
Alumina	16.92	17.96
Iron as Ferric Oxid	7.84	7.00
Lime	5.00	5.00
Magnesia	3.35	2.62
Alkalies	3.69	1.42
Combined water	3.40	4·30

The above analyses were made on samples dried at 100 degrees C.

The moisture on the samples as received was determind as follows:—

No. 1	No. 2	No. 3	No. 4	No. 5
21·2	20	22	18.5	18.3%

3. *Physical Tests.*—The following physical tests were made to show the nature of these samples as compared with other clayey materials.

Bricks were made of all the samples and dried, determining the drying shrinkage and the strength of the air-dried bricks.

These bricks were then burned at two different temperatures. The tests were as follows:—

Plasticity.—No. 1 had the highest plasticity, and the other samples possessed this property in a lesser degree, although all had good plasticity.

The water used in tempering to develop maximum plasticity was as follows:—

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
26%	24%	27%	26%	26%

This percentage of water used to develop plasticity is a rough measure of the plasticity of a clay. It will be noted that all were about the same as nearly as could be determined by this test.

Drying Shrinkage.—This refers to the percentage which a brick shrinks when it is thoroughly air dried. The higher the shrinkage in drying, in general the higher is the plasticity.

The drying shrinkage runs as follows:—

No. 1	No. 2.	No. 3.	No. 4.	No. 5.
5.5%	3%	3%	3%	3%

This property of a clay is also a rough measure of its plasticity. It will be noted that this test showed No. 1 to have the highest plasticity, and the others a lesser amount.

Strength of Air-dried Bricks per Square Inch:—

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
36%	47%	33%	41%	48%

The strength of air-dried brick is an essential property of clays. The strength roughly varies according to the amount of true clay substance, although other factors enter into this strength.

Burning Tests.—The samples were burned at Seger cones Nos. 03, equals 1090 degrees C., and 01 equals 1130 degrees C.

At cone 03, No. 1 was well vitrified and steel hard. No. 2 was nearly vitrified, while Nos. 3, 4, and 5, at a good hard burn, were not vitrified.

Colours were as follows:—

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Brown.	Brownish red.	Red.	Red	Red.

At cone 01, No. 1 had nearly reached its softening point, but the edges were still sharp with a very fine enamelled surface.

No. 2 was well vitrified. Nos. 3 and 4 were not vitrified, but were close to vitrification, and No. 5 was vitrified.

The shrinkage on burning was as follows:—

—	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	%	%	%	%	%
At Cone 03	3.5	9	5	5.5	9
At Cone 01	10.5	9	6	4.5	12

From the above physical tests and analyses, it is our opinion that each of these samples is a glacial clay.

The physical properties as given above are those of the clays which are being used in this territory for the manufacture of clay ware, such as common brick and the like.

The percentage of true clay substance present in these samples as given under the rational analysis is about the amount usually present in such clays, these clays being usually low in true clay substance.

The term, clay substance, as used in the rational analysis, represents merely what might be called kaolin, which is present in varying degrees in clays from only a small percentage in the more important clays up to nearly a hundred per cent in the highest grade china and porcelain clays, the balance of the clay being composed of decomposed rock material, such as feldspar, mica, quartz, etc.

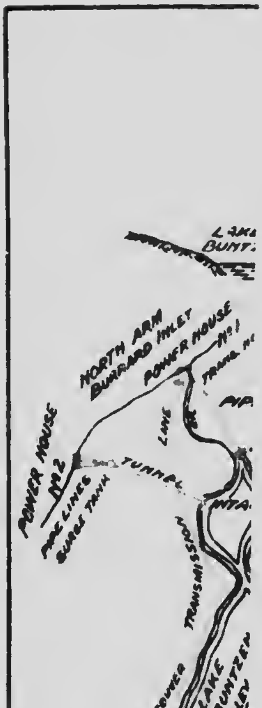
All the clays show a fair strength air dried and all burn to a good common brick.

The elemental analyses represent the usual run of glacial clays, these being rather high in silica.

It is our opinion from the above described properties, that all of these samples are rightly classed as clays.

Respectfully submitted.

(Sgd.) FALKENBURG & LAUCKS.
By M. J. FALKENBURG.


NORTH ARM
BURRARD INLET
POWER HOUSE No 1
POWER HOUSE No 2
PIPE LINES
SURGE TANK
TUNNEL
LINE
TRANSMISSION
TO VANCOUVER
LAKE
BURRARD INLET
POWER HOUSE No 1
SURGE TANK
POWER HOUSE No 2
BURRARD INLET
CROSS

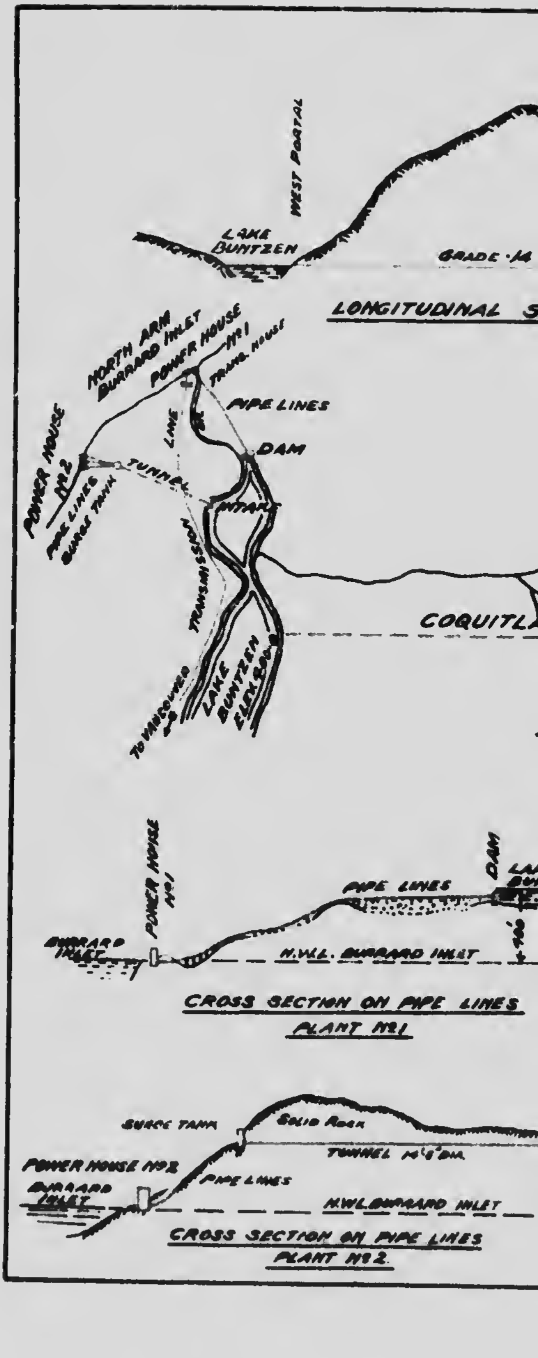
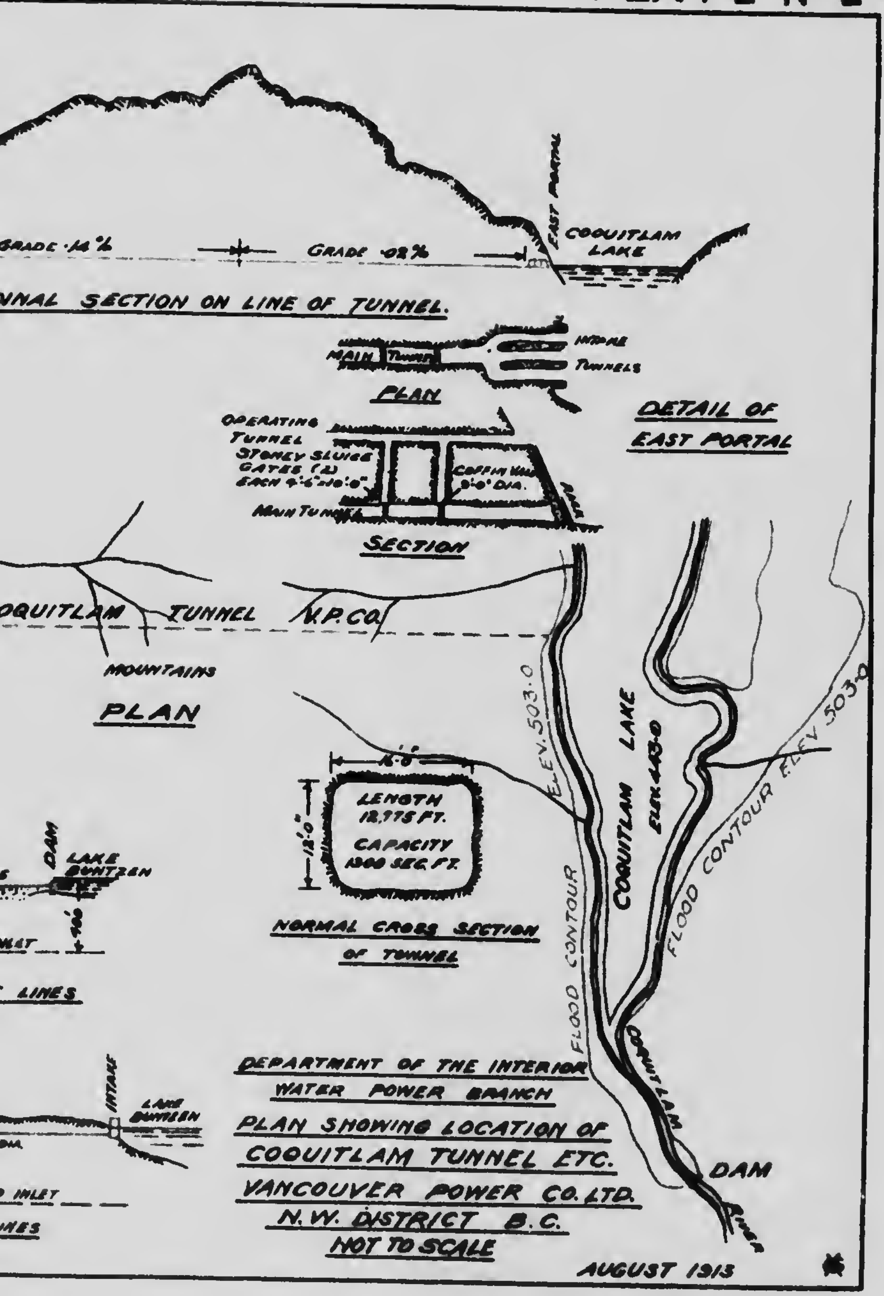
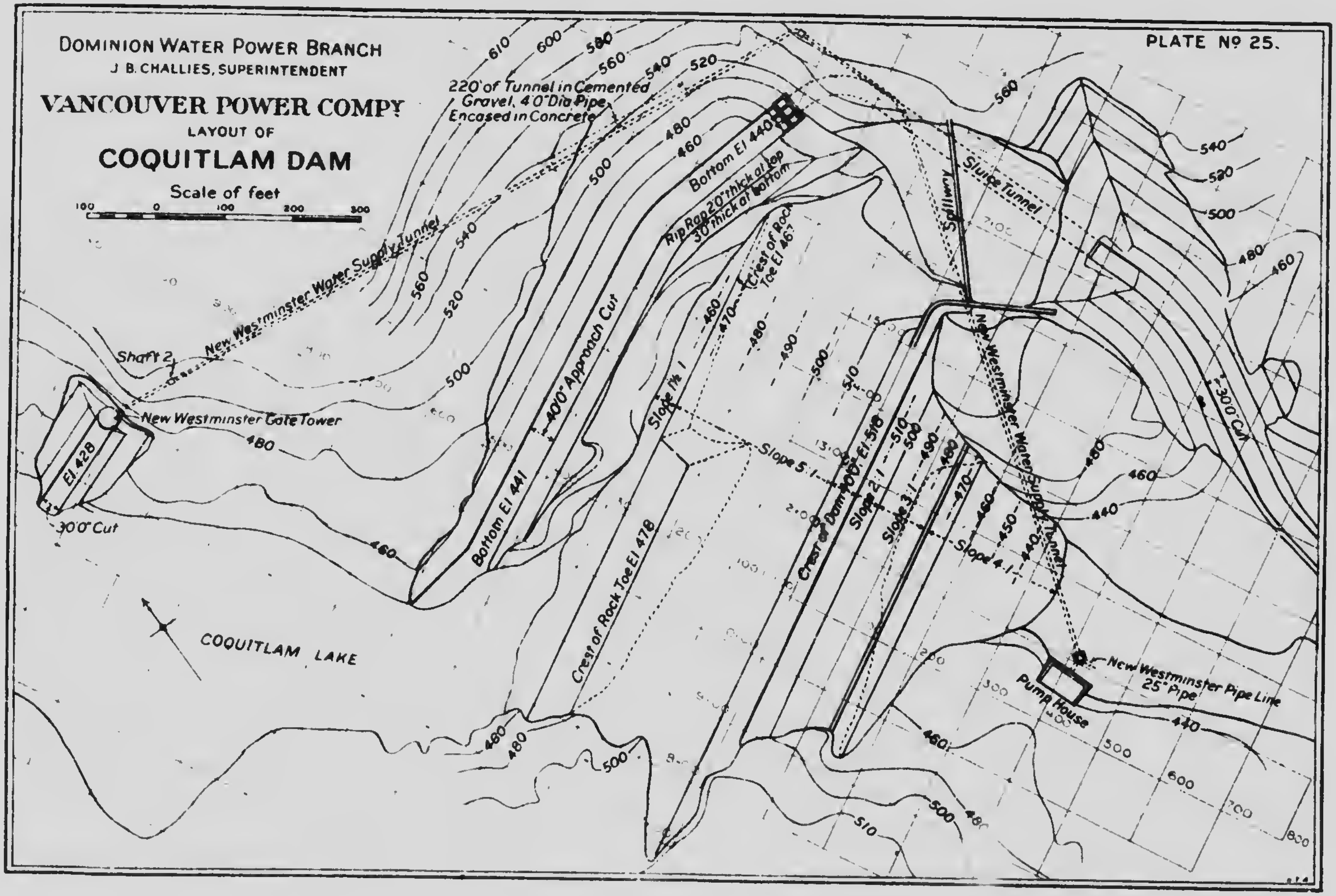

LAKE BUNTZEN
WEST PORTAL
LONGITUDINAL S
NORTH ARM BURRARD INLET
POWER HOUSE No1
PIPE LINES
DAM
POWER HOUSE No2
PIPE LINES
SURGE TANK
TUNNEL
LINE
INTAKE
TRANSMISSION
COQUITL
LAKE BUNTZEN
TO VANCOUVER
POWER HOUSE No1
PIPE LINES
DAM
BURRARD INLET
H.W.L. BURRARD INLET
CROSS SECTION ON PIPE LINES
PLANT No1
SURGE TANK
SOLID ROCK
POWER HOUSE No2
BURRARD INLET
PIPE LINES
H.W.L. BURRARD INLET
CROSS SECTION ON PIPE LINES
PLANT No2.

PLATE N°24



GRADE ·02%
EAST PORTAL
COQUITLAM LAKE
SECTION ON LINE OF TUNNEL.
MAIN TUNNEL
INTAKE TUNNELS
PLAN
DETAIL OF EAST PORTAL
OPERATING TUNNEL
STONEY SLUICE GATES (2) EACH 4'-6"×10'-0"
MAIN TUNNEL
SECTION
TUNNEL
V.P.CO.
MOUNTAINS
PLAN
LENGTH 12,775 FT.
CAPACITY 1300 SEC. FT.
12'-0"
NORMAL CROSS SECTION OF TUNNEL
ELEV. 503.0
FLOOD CONTOUR
COQUITLAM LAKE
FLOOD CONTOUR ELEV. 503.0
DAM
LAKE BUNTZEN
LINES
INTAKE
LAKE BUNTZEN
INLET
DEPARTMENT OF THE INTERIOR
WATER POWER BRANCH
PLAN SHOWING LOCATION OF
COQUITLAM TUNNEL ETC.
VANCOUVER POWER CO. LTD.
N.W. DISTRICT B.C.
NOT TO SCALE
DAM
AUGUST 1913


El. 428


DOMINION WATER POWER BRANCH
J. B. CHALLIES, SUPERINTENDENT
VANCOUVER POWER COMPY
LAYOUT OF
COQUITLAM DAM
Scale of feet
100 0 100 200 300
PLATE No 25.
220' of Tunnel in Cemented Gravel. 4'0" Dia Pipe Encased in Concrete
New Westminster Water Supply Tunnel
Shaft 2
New Westminster Gate Tower
El 428
30'0" Cut
COQUITLAM LAKE
Bottom El 441
40'0" Approach Cut
Bottom El 440
Rip Rap 20" thick at top 30" thick at bottom
Crest of Rock Toe El 467
Crest of Rock Toe El 478
Slope 1½:1
Slope 5:1
Crest of Dam El 516
Slope 2:1
Slope 3:1
Slope 4:1
Spillway
Sluice Tunnel
30'0" Cut
New Westminster Pipe Line 25" Pipe
Pump House


EL. 467.

PLATE No 26

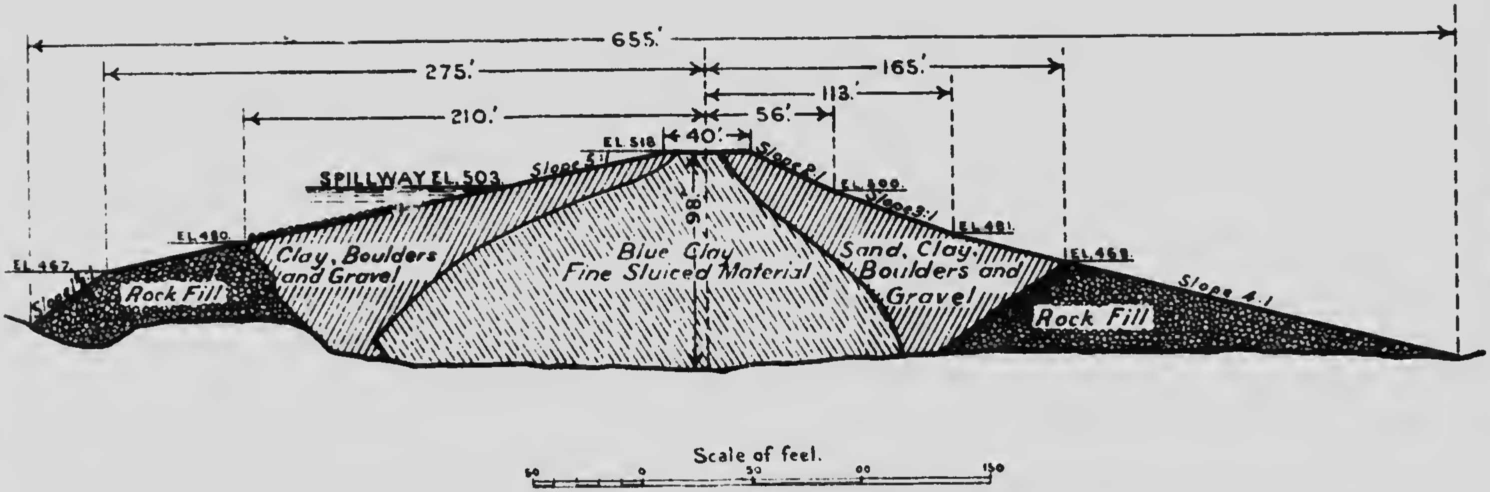
DOMINION WATER POWER BRANCH

J. B. CHALLIES, SUPERINTENDENT

VANCOUVER POWER COMPY

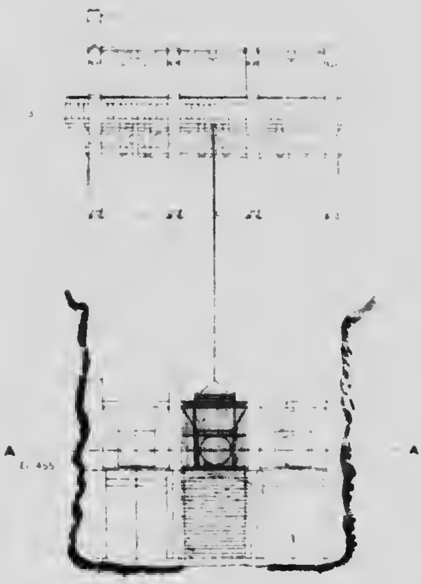
MAXIMUM CROSS SECTION

COQUITLAM DAM

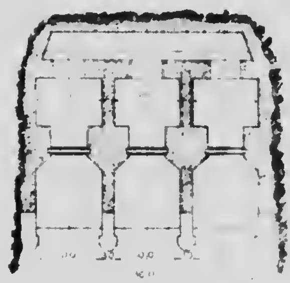


G. E. J.

END ELEVATION OF TOWER HOUSE



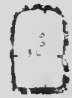
FRONT ELEVATION OF HEADWORKS TOWER



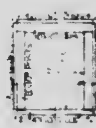
SECTION ON A.A.

Scale of feet

SECTION ON CENTRE LINE OF SLUICE TUNNEL



SECTION IN ROCK

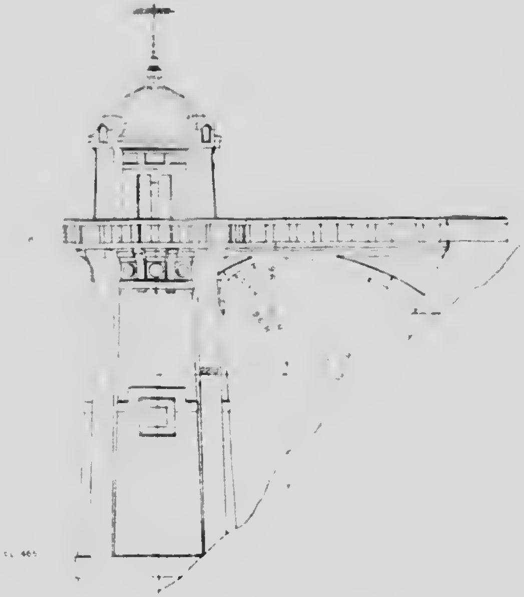


SECTION WHE
TIMBERING IS RE

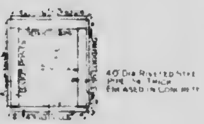
SECTION ON CENTRE LINE OF NEW WESTMINSTER WATER SUPPLY TUNNEL

PLATE Nº 27

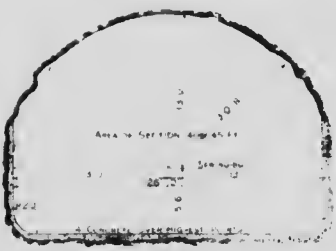
WER HOUSE



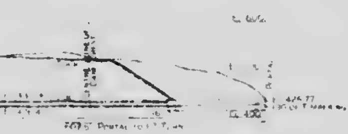
ELEVATION OF TOWER AND BRIDGE



ECTION WHERE
BERING IS REQUIRED



CROSS SECTION OF SLUIC



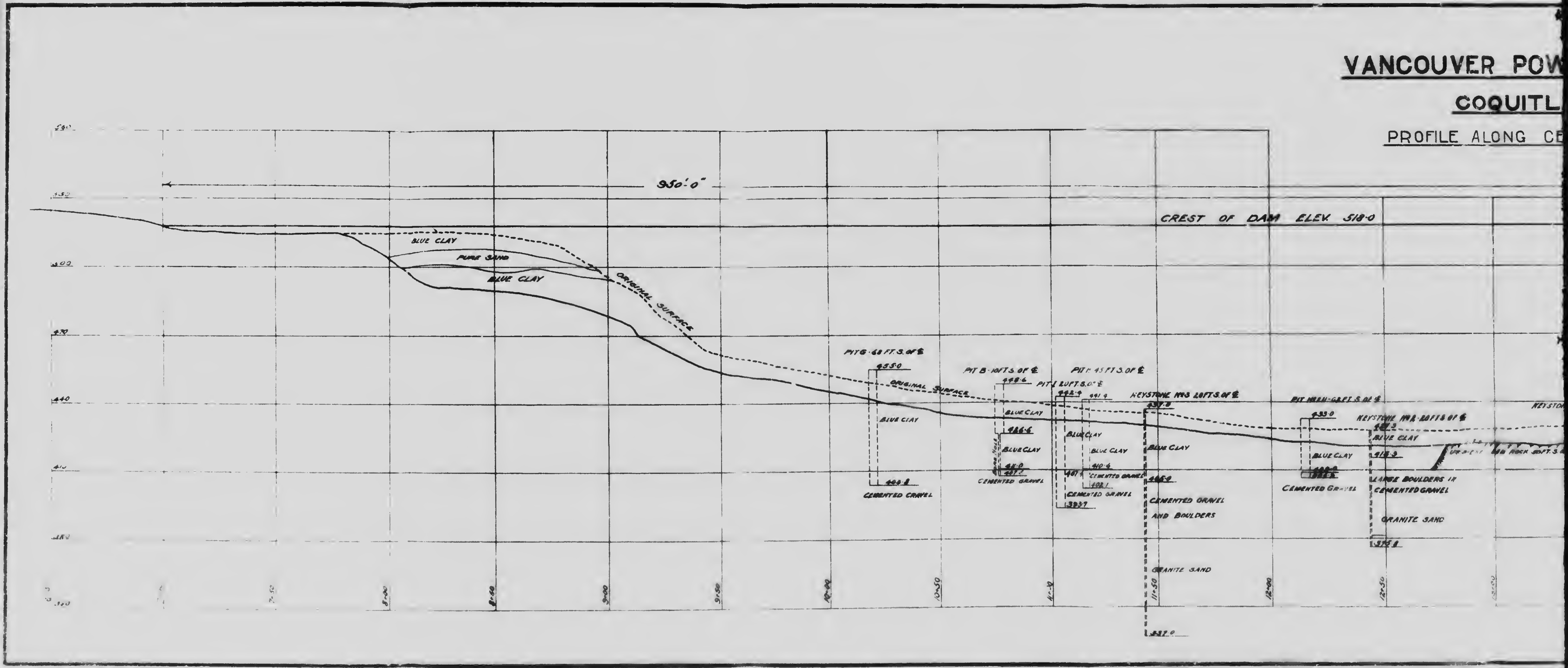
LY TUNNEL

Water Power Branch

VANCOUVER POWER COMPANY

COQUITLAM DAM

SECTIONS AND ELEVATIONS OF SLUICES AND WATER SUPPLY
TOWERS AND TUNNELS



VANCOUVER POW
COQUITL
PROFILE ALONG CE
950'0"
CREST OF DAM ELEV. 518·0
BLUE CLAY
PURE SAND
BLUE CLAY
ORIGINAL SURFACE
ORIGINAL SURFACE
455·0
BLUE CLAY
CEMENTED GRAVEL
BLUE CLAY
CEMENTED GRAVEL
BLUE CLAY
BLUE CLAY
CEMENTED GRAVEL
BLUE CLAY
CEMENTED GRAVEL AND BOULDERS
GRANITE SAND
433·0
BLUE CLAY
CEMENTED GRAVEL
BLUE CLAY
LARGE BOULDERS IN CEMENTED GRAVEL
GRANITE SAND

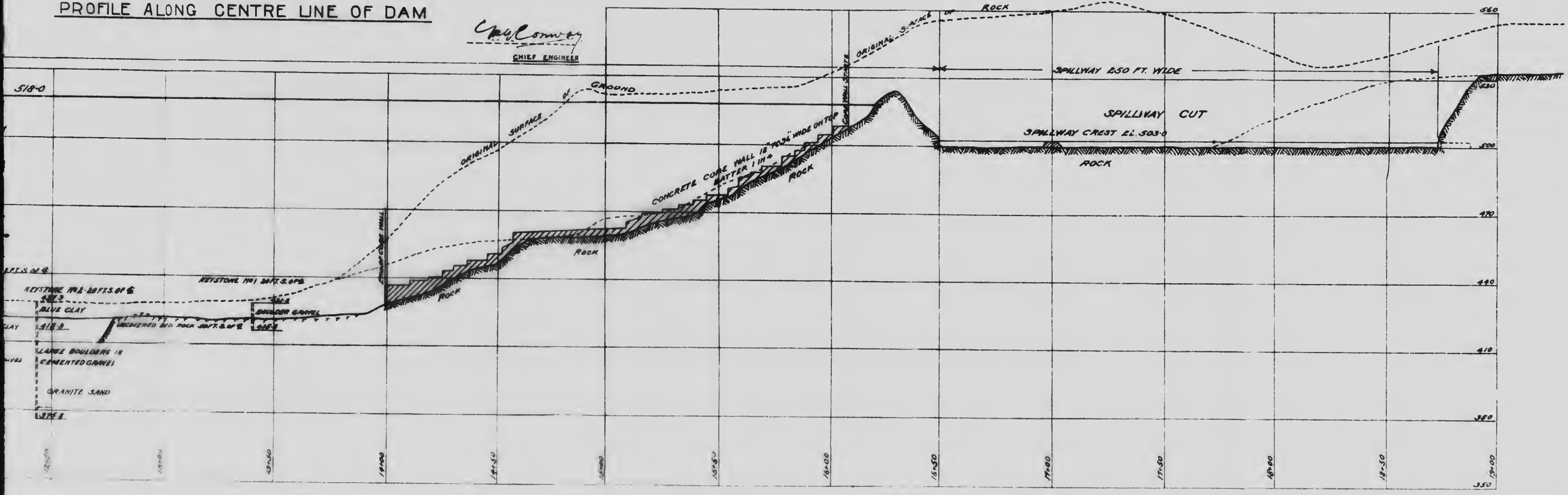
PLATE No. 27A

DIAGRAM Nº 6

VANCOUVER POWER COMPANY LTD

COQUITLAM DAM

PROFILE ALONG CENTRE LINE OF DAM



VANCOUVER POWE

GROUND FLOOR PLAN -

—19

— SCA

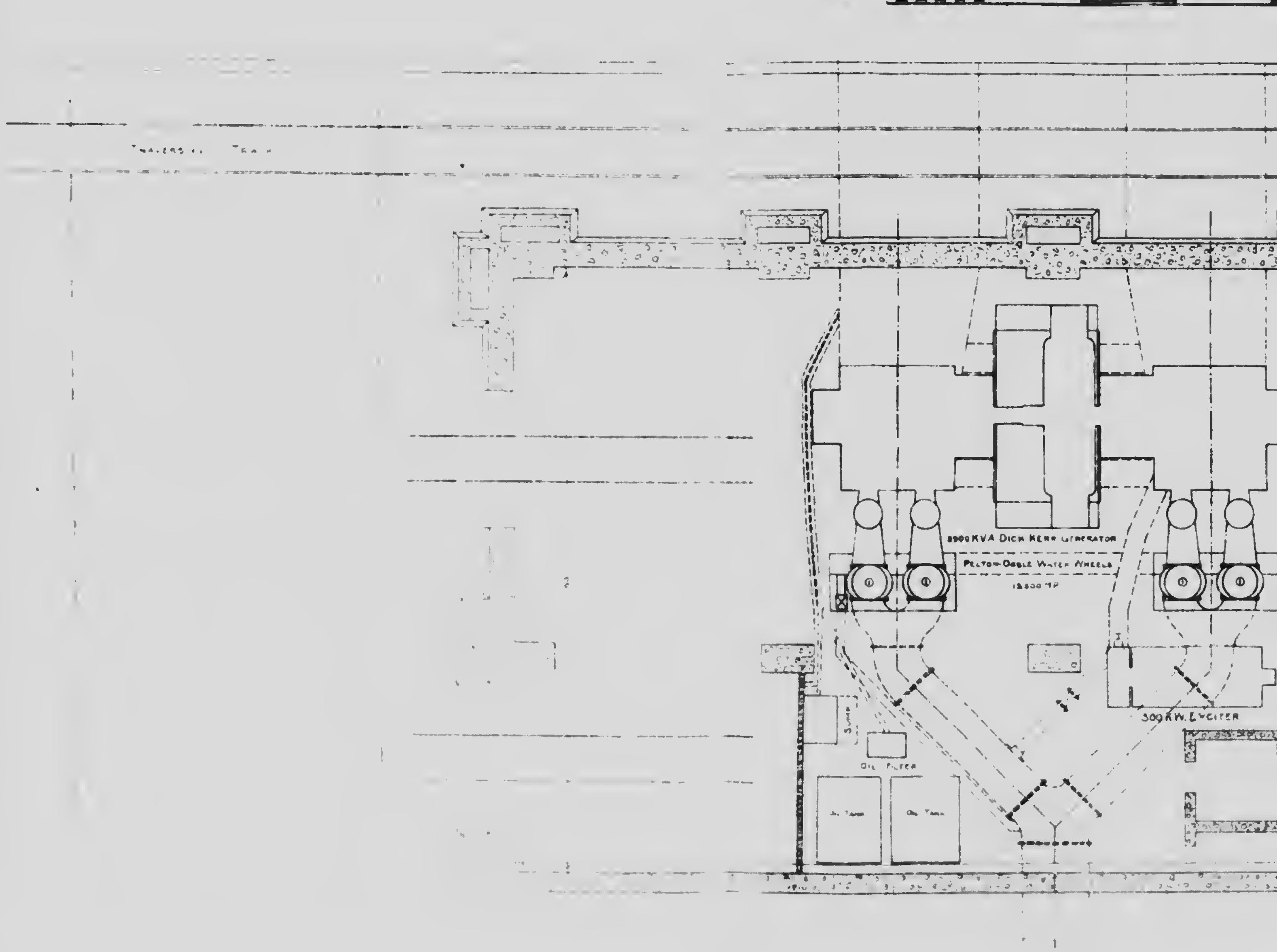


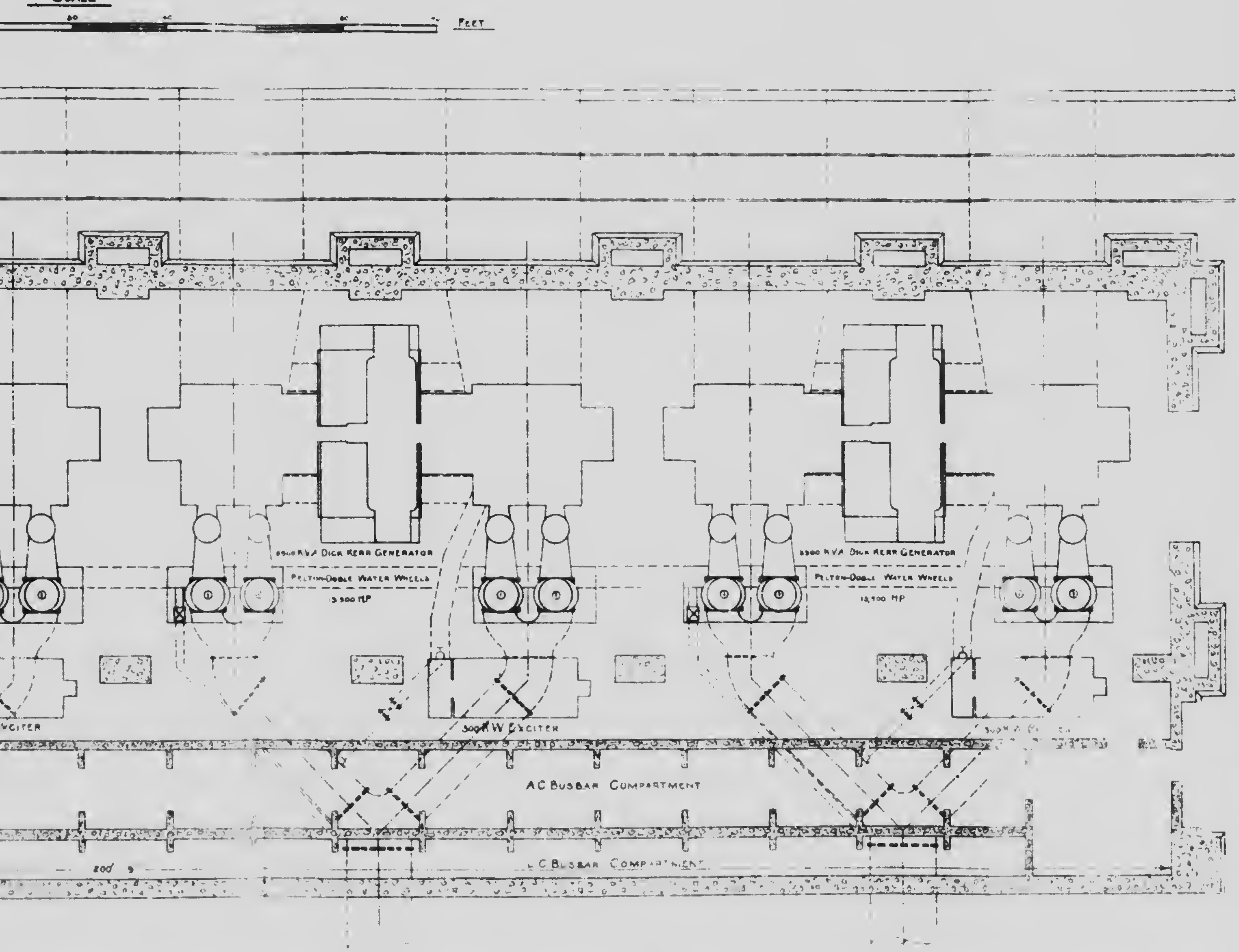
PLATE No 27B

POWER COMPANY LTD.

N – PLANT Nº 2 LAKE BUNTZEN

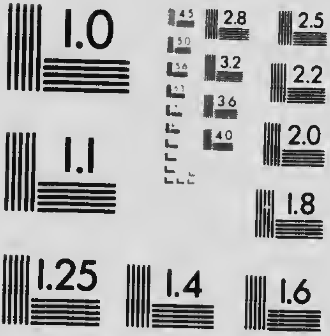
1912

SCALE



MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

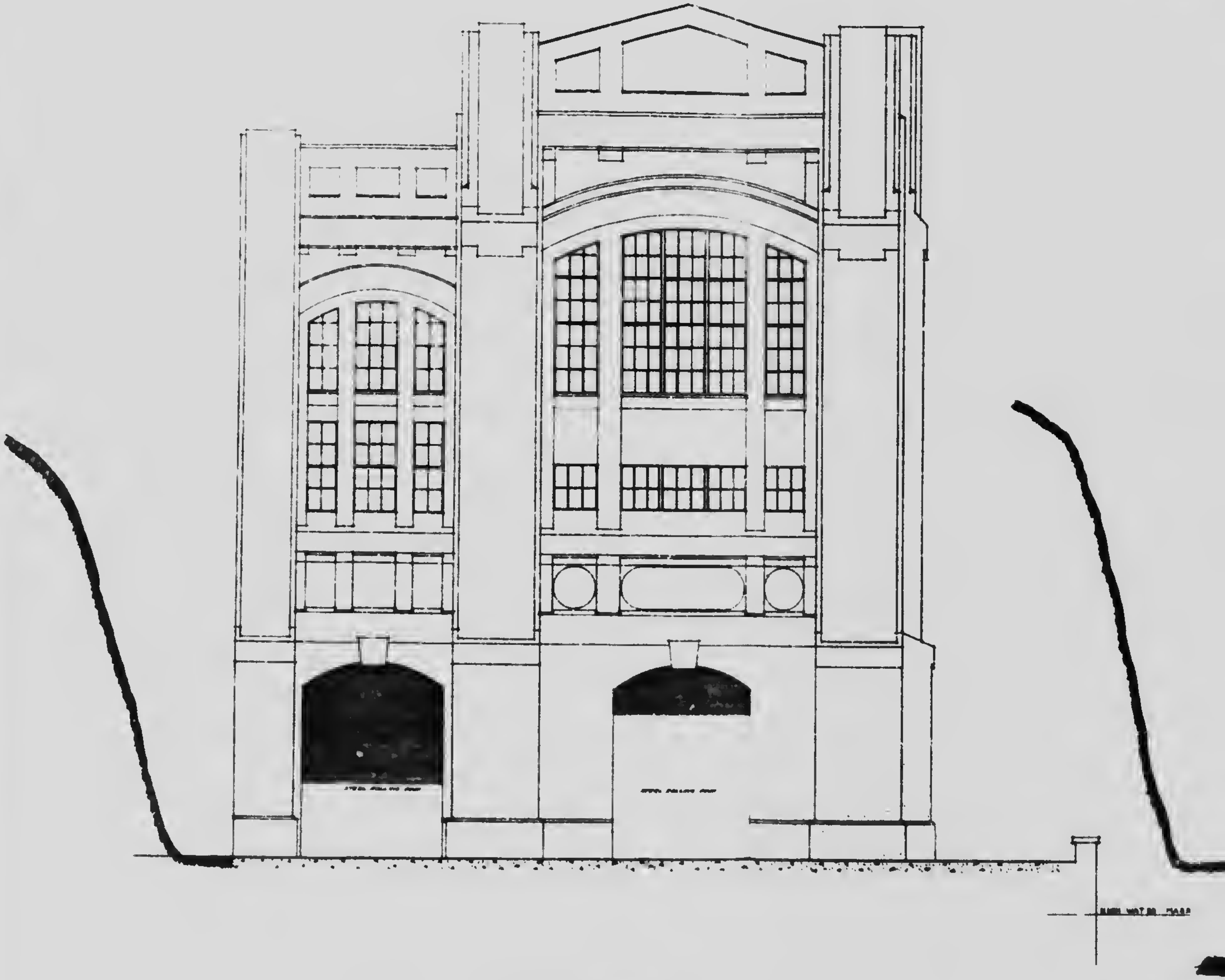


APPLIED IMAGE Inc

1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

VANCOUVER

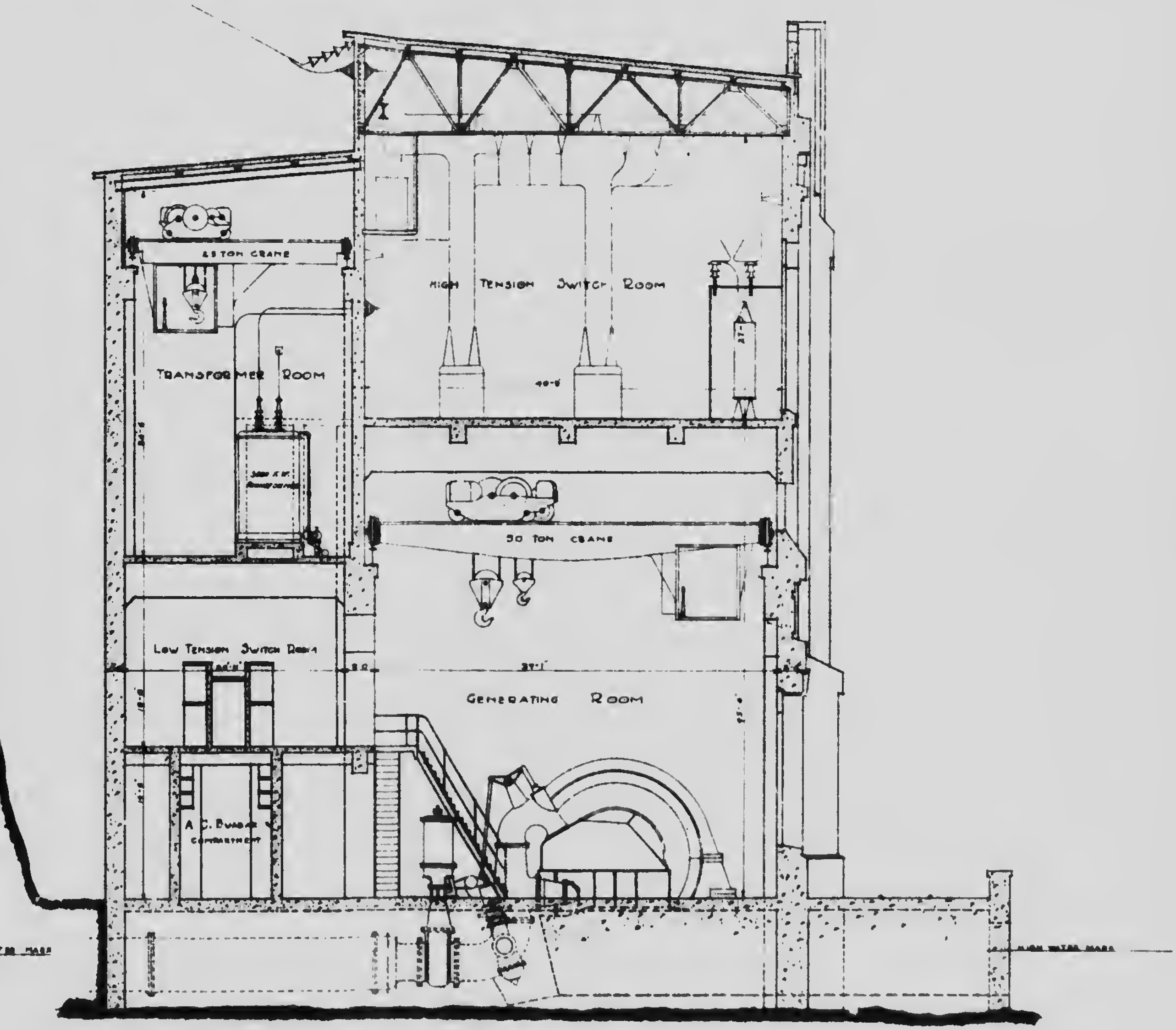
PLANT



— END ELEVATION —

…UVER POWER COMPANY LTD.

…PLANT No 2 LAKE BUNTZEN

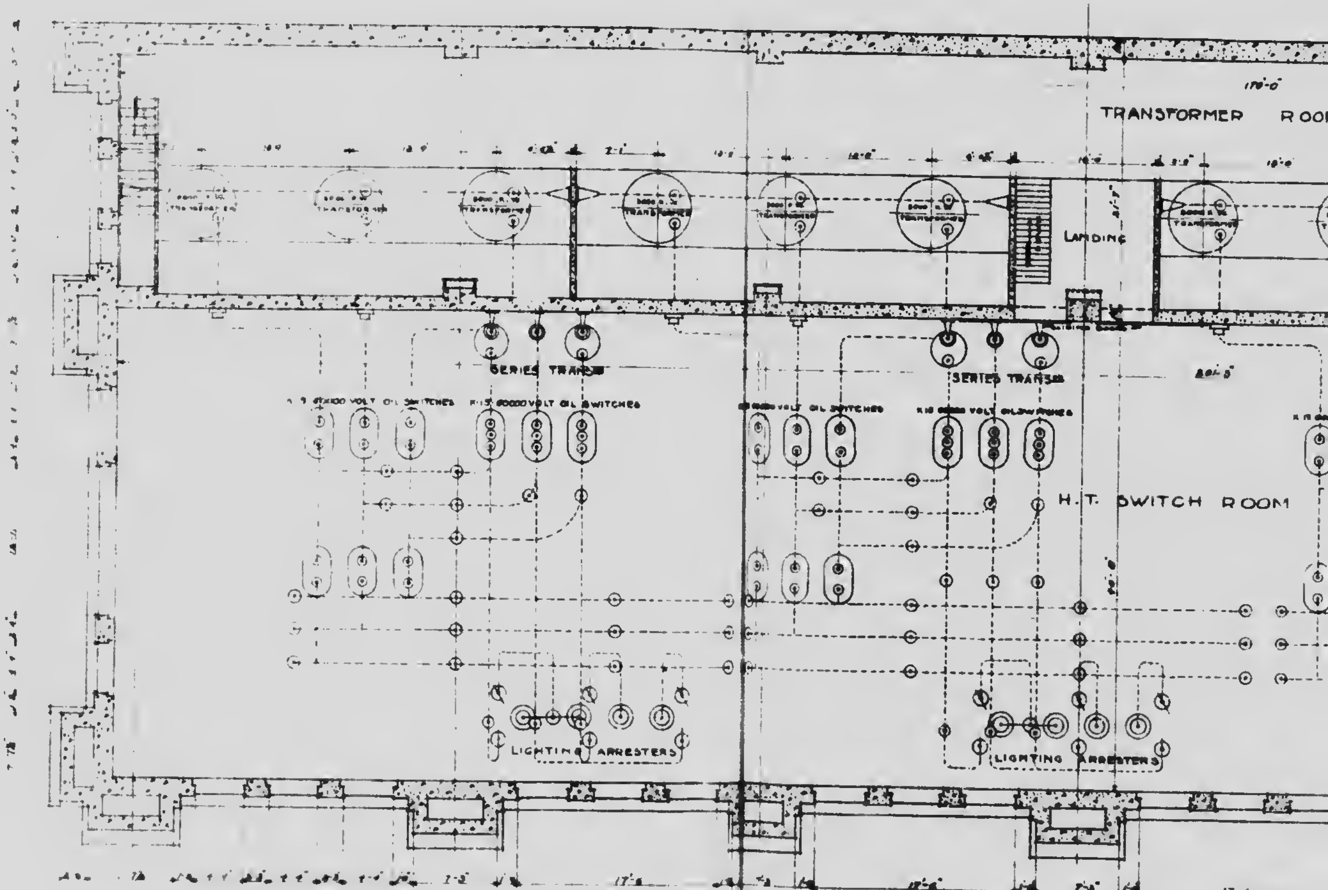


— CROSS — SECTION —

B.C. ELECTRIC RY. CO. LTD.	
POWER HOUSE No 2 LAKE BUNTZEN	
TITLE — SECTION & END ELEVATION	
SCALE [illegible] ONE FOOT	CHECKED
DRAWN .191.	DRG. NO. [illegible]
TRACED .191.	DATE DEC 27th [illegible]

VANCOUVER POW

PLANT Nº 2

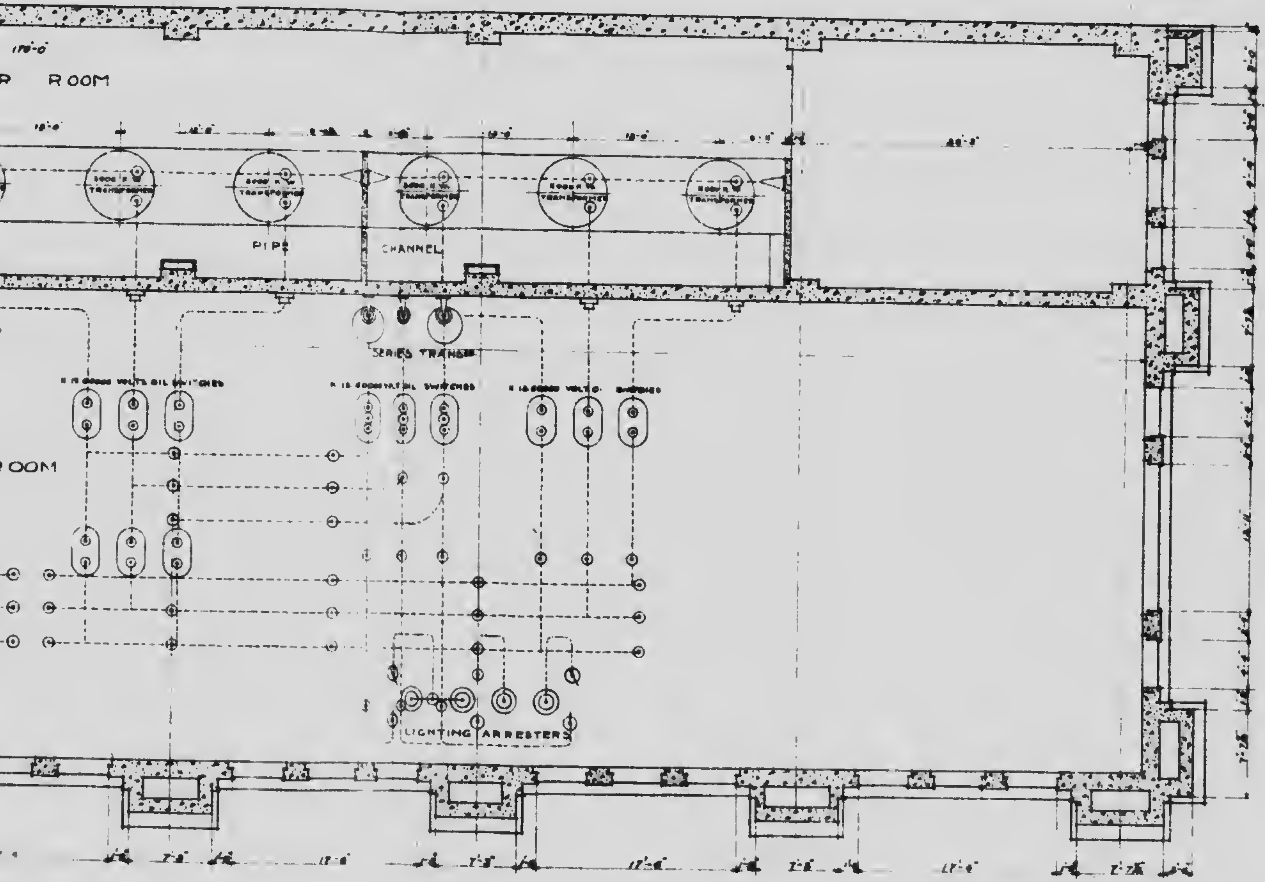


TRANSFORMER

PLATE No 27D

R POWER COMPANY LTD.

No 2 LAKE BUNTZEN

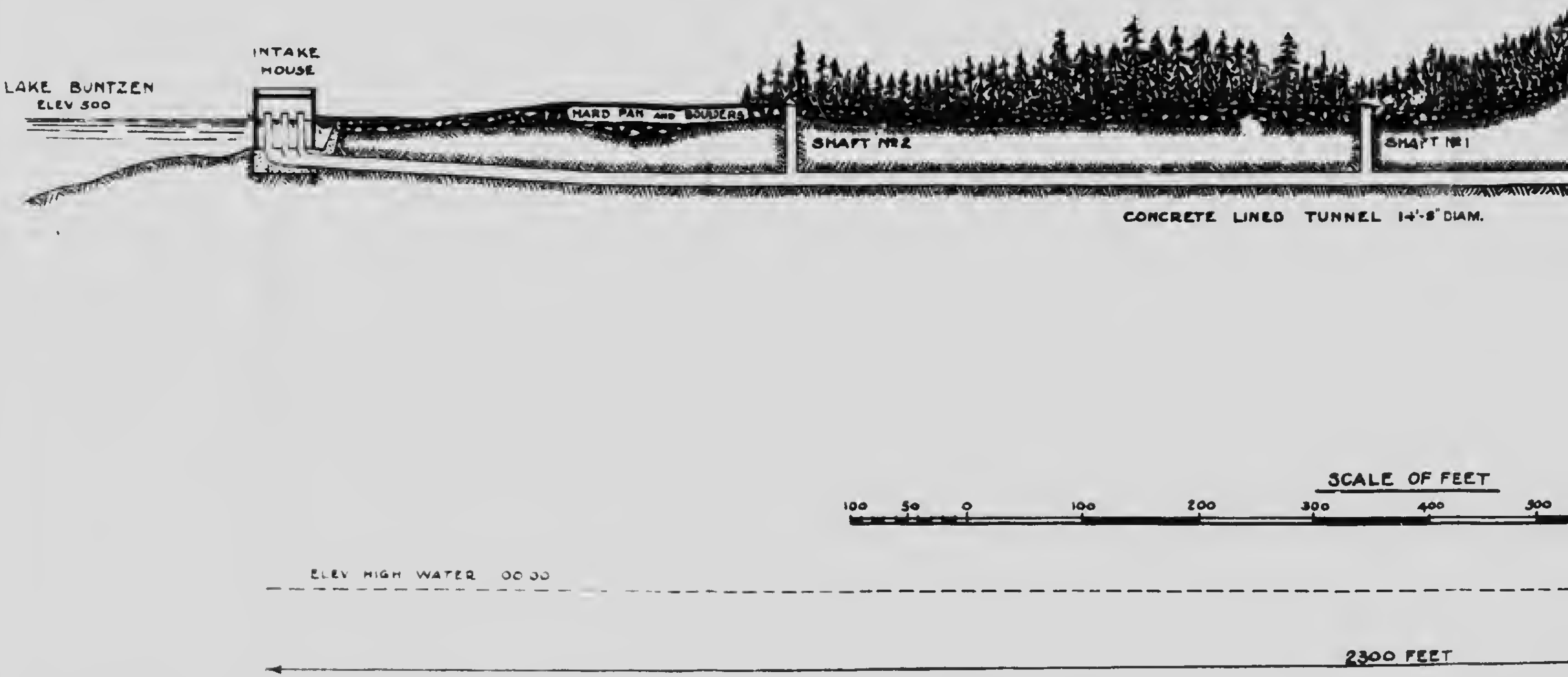


RMER & H.T. ROOM PLAN

B.C. ELECTRIC RY. CO. LTD.
POWER HOUSE No 2 LAKE BUNTZEN.
TITLE – TRANSFR. & H.T. ROOM PLAN.
• Scale ⅛" = ONE FOOT • CHECKED
• Drawn • Dwg. No 13213
• Traced • Date DEC. 27th

VANCOUVER POWE

PLANT №2 —



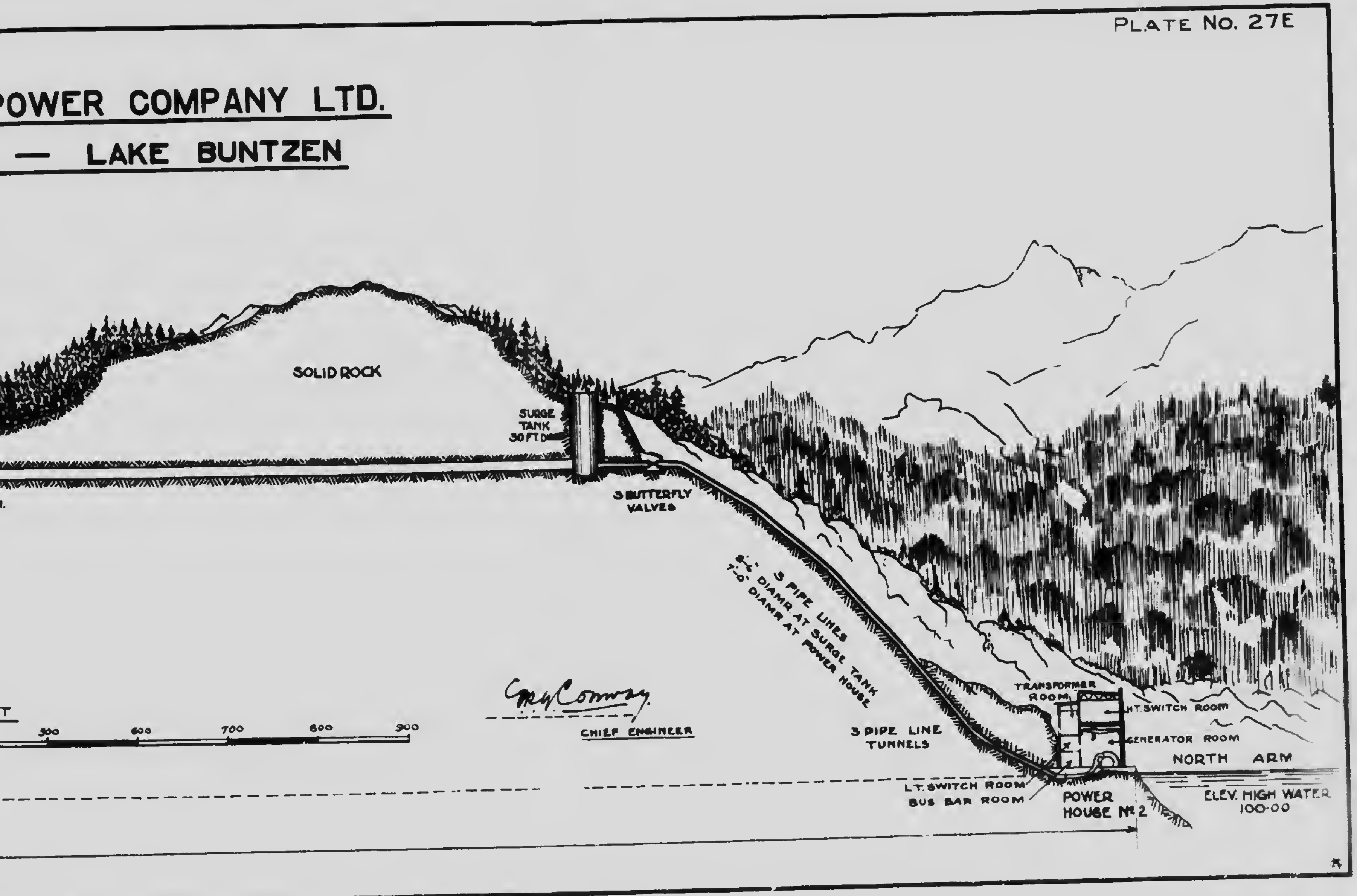
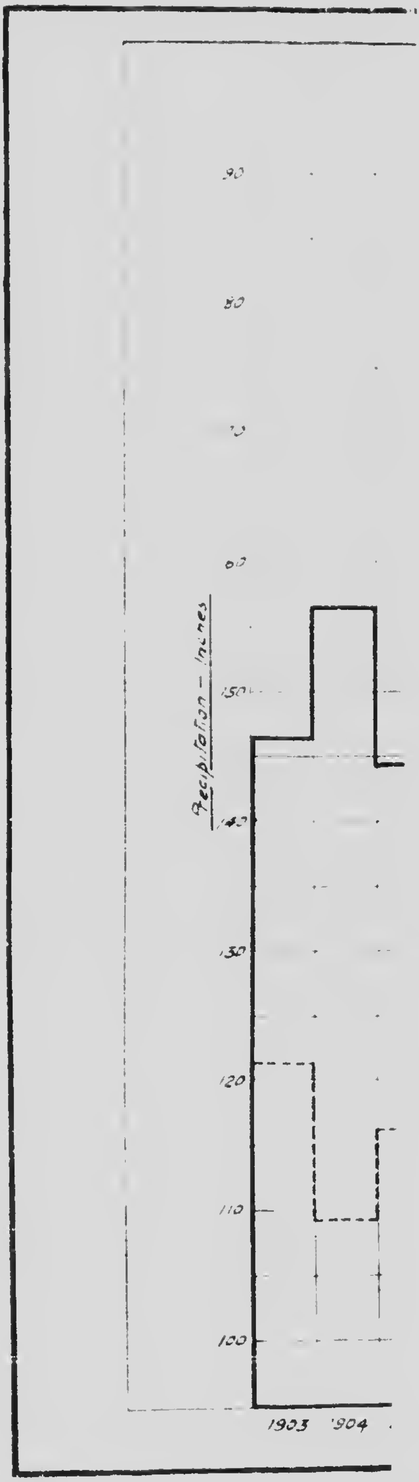


PLATE No. 27E
POWER COMPANY LTD.
— LAKE BUNTZEN
SOLID ROCK
SURGE TANK 30 FT. D.
3 BUTTERFLY VALVES
3 PIPE LINES
8'-6" DIAM. AT SURGE TANK
7'-0" DIAM. AT POWER HOUSE
3 PIPE LINE TUNNELS
TRANSFORMER ROOM
H.T. SWITCH ROOM
GENERATOR ROOM
NORTH ARM
L.T. SWITCH ROOM
BUS BAR ROOM
POWER HOUSE No 2
ELEV. HIGH WATER 100.00
CHIEF ENGINEER
500
600
700
800
900



Precipitation - Inches
90
80
60
150
140
130
120
110
100
1903
1904

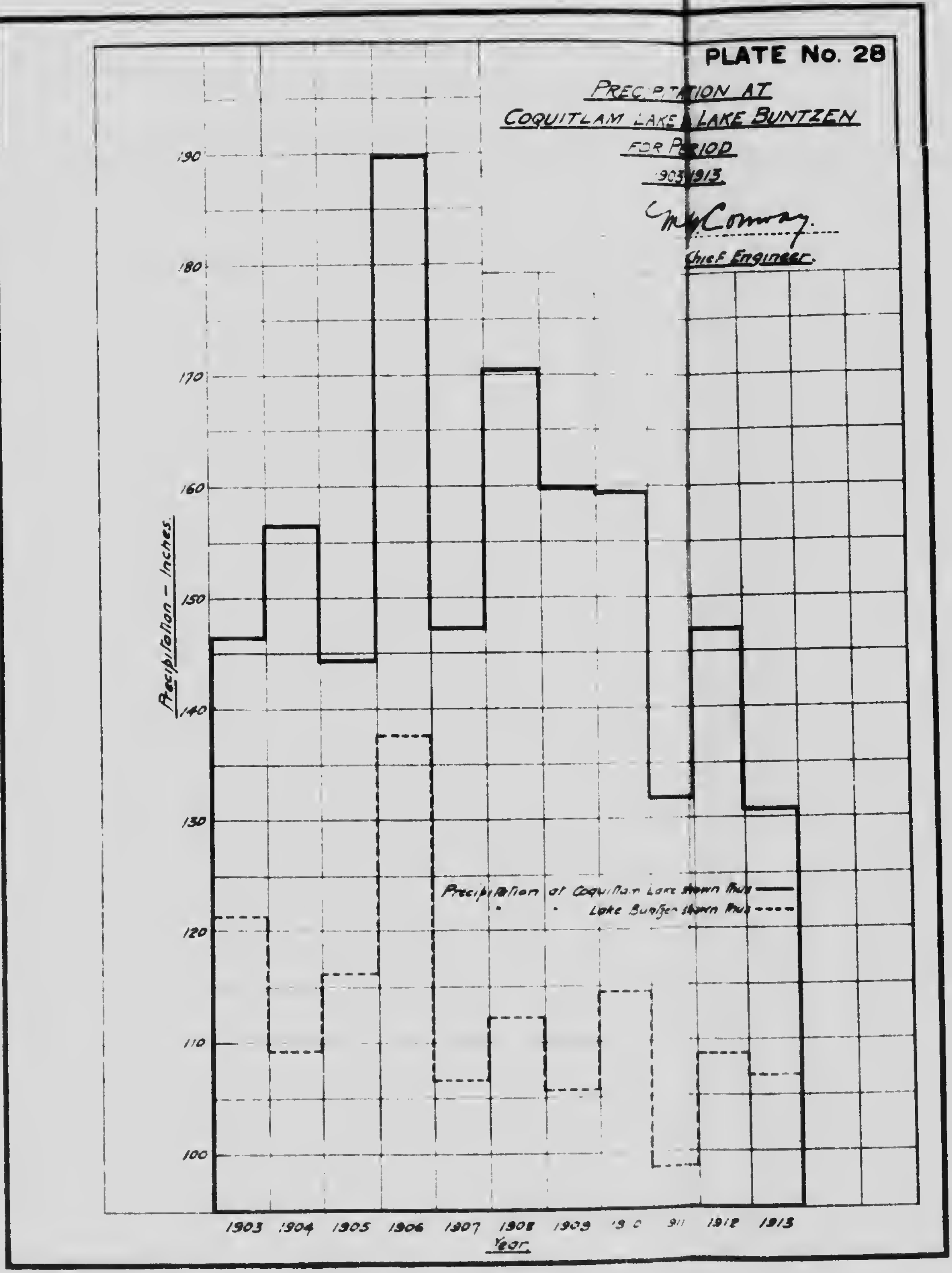
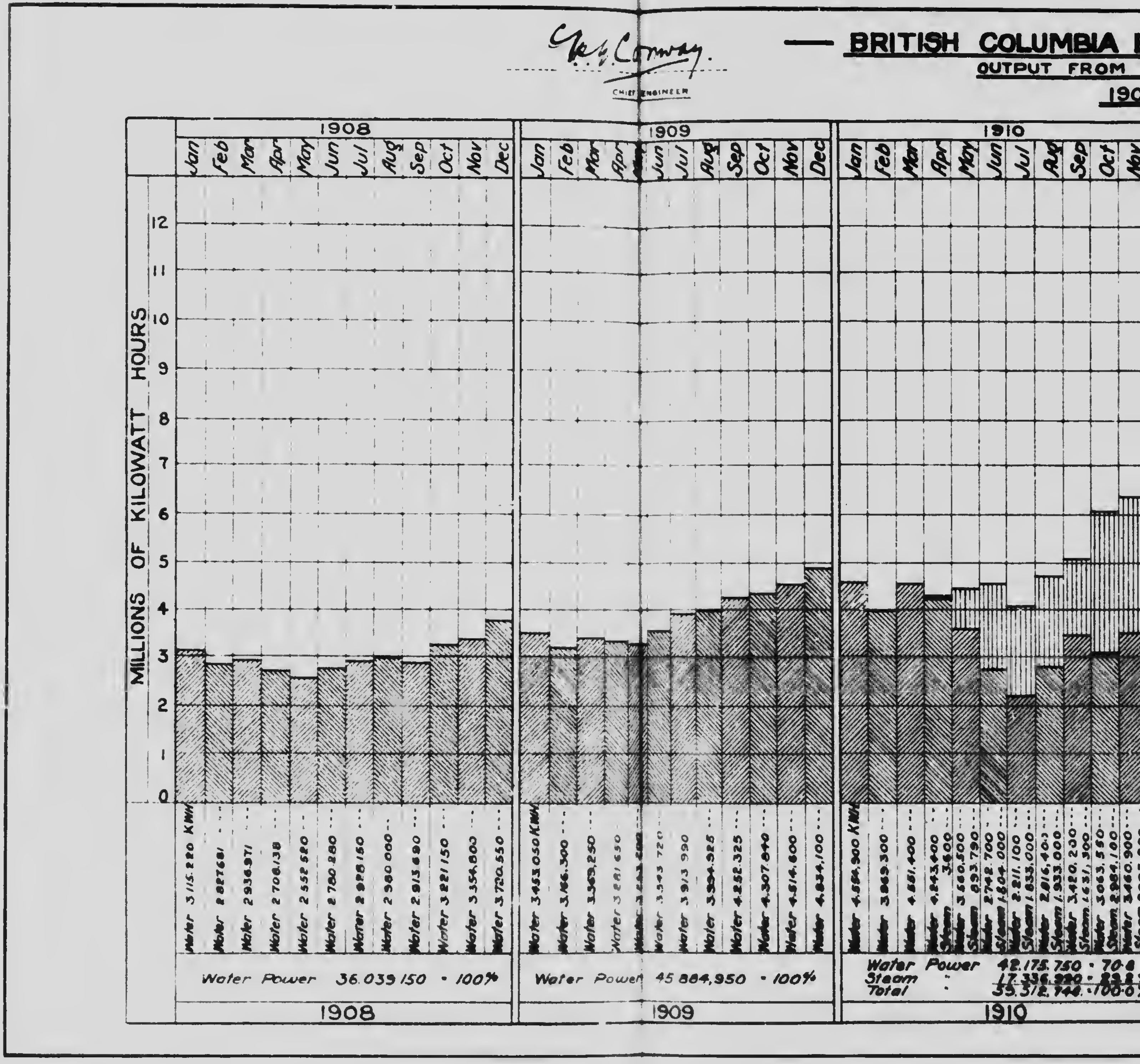
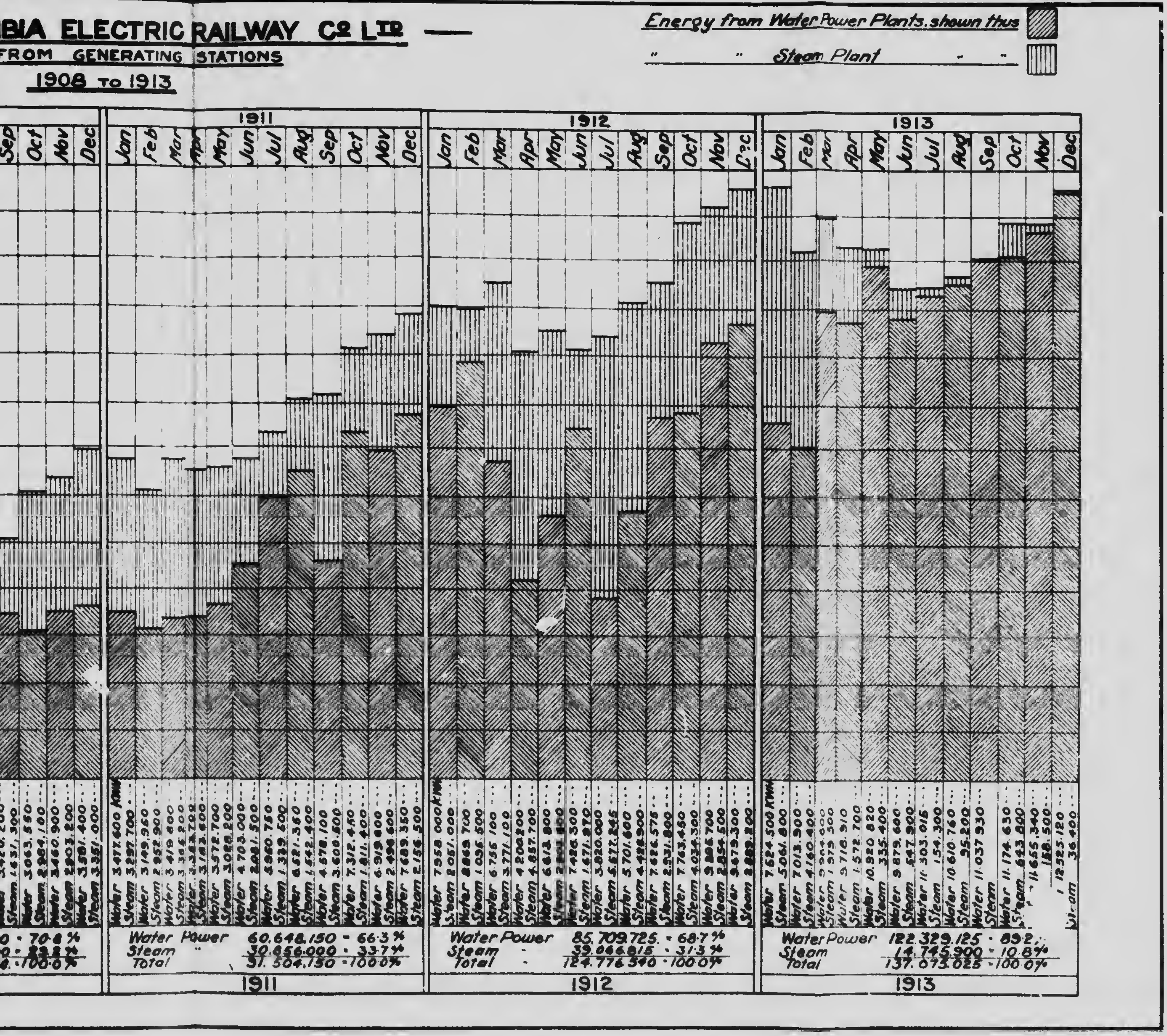


PLATE No. 28
PRECIPITATION AT
COQUITLAM LAKE & LAKE BUNTZEN
FOR PERIOD
1903-1913
Chief Engineer.
Precipitation - Inches.
190
180
170
160
150
140
130
120
110
100
Precipitation at Coquitlam Lake shown thus
" " Lake Buntzen shown thus
1903
1904
1905
1906
1907
1908
1909
1911
1912
1913
Year.



CHIEF ENGINEER
— BRITISH COLUMBIA
OUTPUT FROM
1908
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1909
1910
MILLIONS OF KILOWATT HOURS
0
1
2
3
4
5
6
7
8
9
10
11
12
Water 3 115.220 KWH
Water 2 936.971
Water 2 706.138
Water 2 552 520
Water 2 780.280
Water 2 980 000
Water 3 221 150
Water 3 354.800
Water 3 720.550
Water Power 36.039 150 · 100%
Water 3.453 050 KWH
Water 3.166.300
Water 3.369.250
Water 3.913 990
Water 3.994.925
Water 4.252.325
Water 4.307.040
Water 4.514.600
Water 4.654.100
Water Power 45 884,950 · 100%
Water 4.654.900 KWH
Water 3.869.300
Water 4.551.400
Water Power 42.175.750
Steam
Total

BIA ELECTRIC RAILWAY Co. LTD —
FROM GENERATING STATIONS
1908 TO 1913



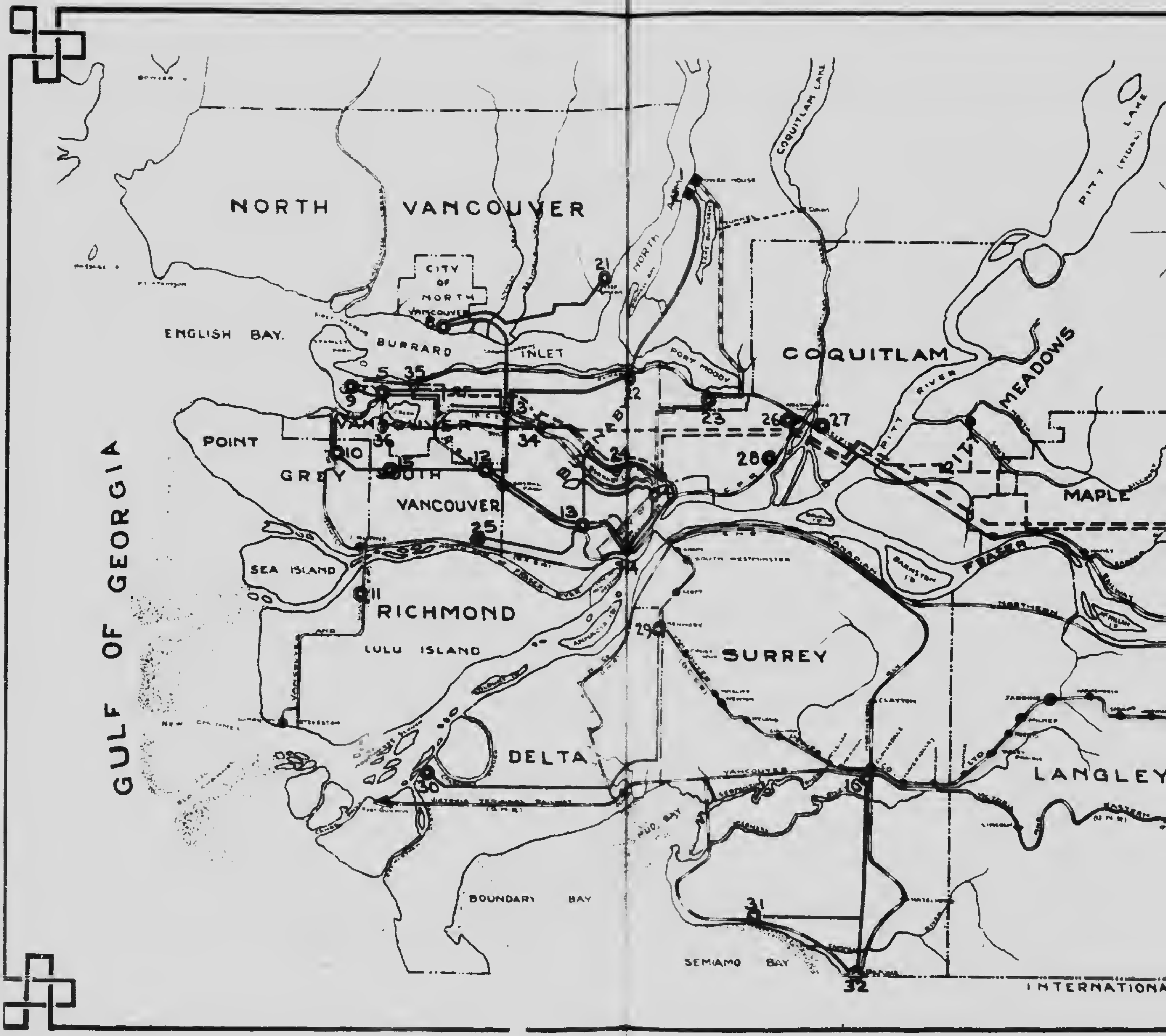
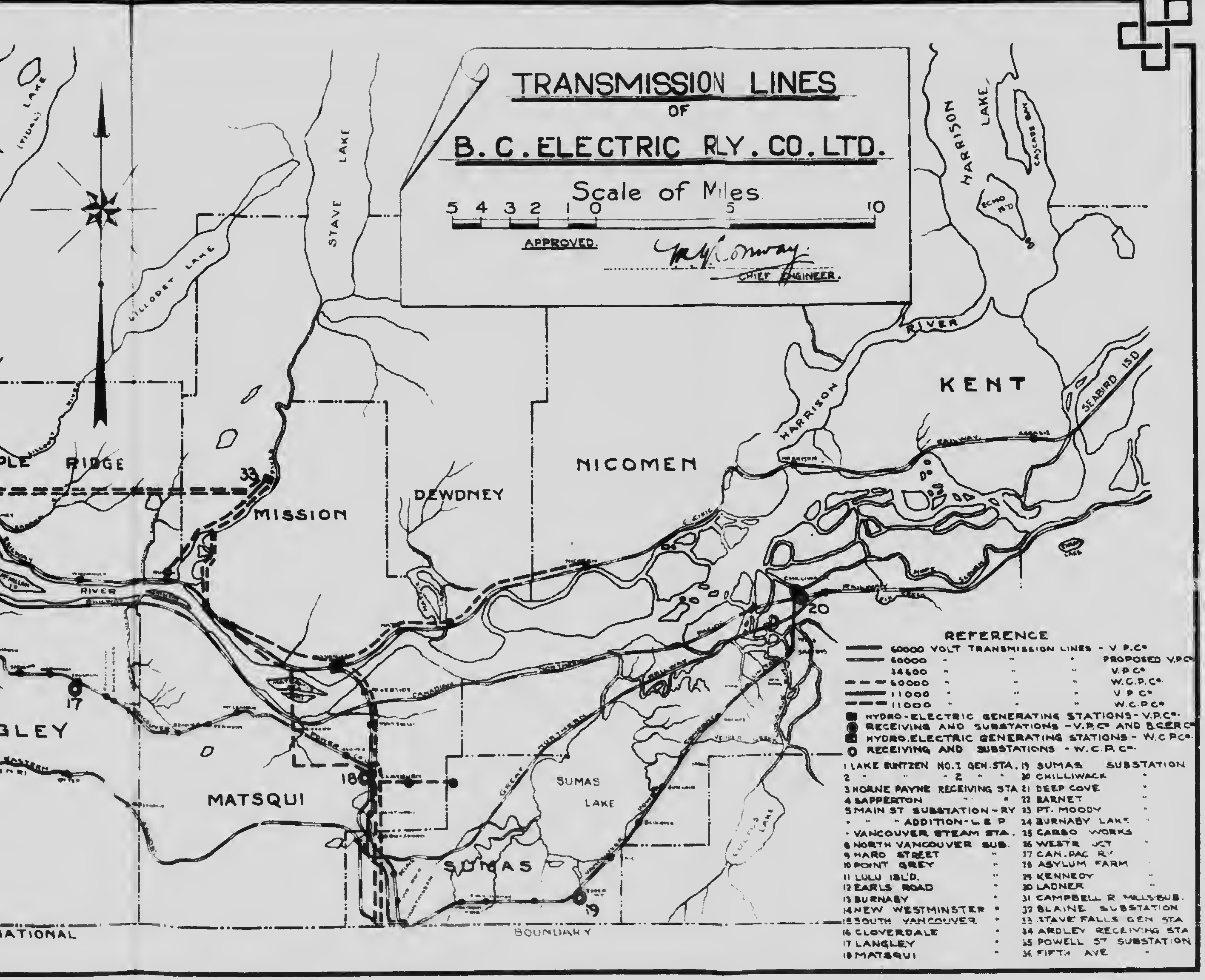

GULF OF GEORGIA
NORTH VANCOUVER
CITY OF NORTH VANCOUVER
ENGLISH BAY
BURRARD INLET
PORT MOODY
COQUITLAM LAKE
COQUITLAM
PITT LAKE (TIDAL)
PITT RIVER
PITT MEADOWS
MAPLE
POINT GREY
VANCOUVER
SOUTH VANCOUVER
SEA ISLAND
RICHMOND
LULU ISLAND
FRASER
SOUTH WESTMINSTER
SURREY
CLAYTON
DELTA
LANGLEY
BOUNDARY BAY
SEMIAMO BAY

PLATE No. 28B


TRANSMISSION LINES
OF
B. C. ELECTRIC RLY. CO. LTD.
Scale of Miles
5 4 3 2 1 0 5 10
APPROVED
CHIEF ENGINEER
HARRISON LAKE
CASCADE BAY
ECHO IS'D
STAVE LAKE
LILLOOET LAKE
KENT
SEABIRD ISD
HARRISON
RIVER
NICOMEN
DEWDNEY
MISSION
RIDGE
RIVER
MATSQUI
SUMAS LAKE
SUMAS
BOUNDARY
NATIONAL
GLEY
CULTUS LAKE
17
18
19
20
33
REFERENCE
60000 VOLT TRANSMISSION LINES - V. P. Co
60000 " " " PROPOSED V.P.Co
34600 " " " V.P.Co
60000 " " " W.C.P.Co.
11000 " " " V.P.Co
11000 " " " W.C.P.Co
HYDRO-ELECTRIC GENERATING STATIONS - V.P.Co.
RECEIVING AND SUBSTATIONS - V.P.Co AND B.C.E.R.Co
HYDRO.ELECTRIC GENERATING STATIONS - W.C.P.Co.
RECEIVING AND SUBSTATIONS - W.C.P.Co.
1 LAKE BUNTZEN NO.1 GEN.STA.
2 " " " 2 " "
3 HORNE PAYNE RECEIVING STA
4 SAPPERTON " "
5 MAIN ST SUBSTATION - RY
" " " ADDITION - L & P
- VANCOUVER STEAM STA.
8 NORTH VANCOUVER SUB.
9 HARO STREET "
10 POINT GREY "
11 LULU ISL'D. "
12 EARLS ROAD "
13 BURNABY "
14 NEW WESTMINSTER "
15 SOUTH VANCOUVER "
16 CLOVERDALE "
17 LANGLEY "
18 MATSQUI "
19 SUMAS SUBSTATION
20 CHILLIWACK "
21 DEEP COVE "
22 BARNET "
23 PT. MOODY "
24 BURNABY LAKE "
25 CARBO WORKS
26 WESTR JCT "
27 CAN. PAC RY
28 ASYLUM FARM
29 KENNEDY "
30 LADNER "
31 CAMPBELL R MILLS SUB.
32 BLAINE SUBSTATION
33 STAVE FALLS GEN STA
34 ARDLEY RECEIVING STA
35 POWELL ST SUBSTATION
36 FIFTH AVE "

CLASSIFIED LISTS OF REPORTS

The Reports published by the Dominion Water Power Branch with the exception of the Annual Reports, have been called Water Resources Papers, and have been numbered 1, 2, etc.

Annual Reports previous to 1913 are included with the Annual Report of the Department of the Interior, and can be secured from the Secretary of the Department.

Annual Report for 1912-13, published 1914.

Annual Report for 1913-14, published 1915.

Annual Report for 1914-15. In Press.

WATER RESOURCES PAPER No. 1.—Report of the Railway Belt Hydrographic Survey for 1911-12, by P. A. Carson, B.A., D.L.S., Chief Engineer. Published 1914.

WATER RESOURCES PAPER No. 2.—Report of Bow River Power and Storage Investigations (Bow river west of Calgary,) by M. C. Hendry, B.A.Sc., Chief Engineer in charge of surveys. Published 1914.

WATER RESOURCES PAPER No. 3.—Report on Power and Storage Investigations, Winnipeg river, by J. T. Johnston, B.A.Sc., Hydraulic Engineer of Water Power Branch. In Press.

WATER RESOURCES PAPER No. 4.—Report of the Manitoba Hydrographic Survey to the year ending 1914, by M. C. Hendry, B.A.Sc., Chief Engineer. In [illegible]

WATER RESOURCES PAPER No. 5.—Preliminary Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S., Chief Engineer in charge of Reclamation Survey. Published 1914.

WATER RESOURCES PAPER No. 6.—Report on cost of various sources of power for pumping in connection with the South Saskatchewan Water Supply Diversion Project, by H. E. M. Kensit, M.I.E.E. and Mem. Am. Inst. E. E. Mem. Can. Soc. C. E. Published 1914.

WATER RESOURCES PAPER No. 7.—Report on the Manitoba Water Powers, by D. L. McLean, S. S. Scovil, and J. T. Johnston, compiled for the Manitoba Public Utilities Commission. Published 1914.

WATER RESOURCES PAPER No. 8.—Report of the British Columbia Hydrographic Survey for 1913, by R. G. Swan, B.A.Sc., Chief Engineer. Published 1915.

WATER RESOURCES PAPER No. 9.—Report of Red River Navigation Surveys, by S. S. Scovil, B.Sc., Assistant Chief Engineer of Manitoba Hydrographic Survey. In course of preparation.

WATER RESOURCES PAPER No. 10.—General Guide for Compilation of Water Power Reports of Dominion Water Power Branch, prepared by J. T. Johnston, B.A.Sc., Hydraulic Engineer of Water Power Branch. Published 1915. Limited edition.

WATER RESOURCES PAPER No. 11.—Final Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S., Chief Engineer in charge of Reclamation Survey. Published 1915.

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