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JORDAN RIVER POWER DEVELOPMENT, VANCOUVER ISLAND, B.C.

BY CHARLES A. LEE, A.M.CAN.SOC.C.E.

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On Vancouver Island, about 36 miles west of Victoria, is located what is known as the Jordan River Power Development. This development is owned and operated by the Vancouver Island Power Company, a subsidiary of the British Columbia Electric Railway Company, which is the principal public service corporation of Victoria.

At different times during the past two years articles have been printed in engineering journals describing parts of this development, but there has been no complete description of the whole undertaking, and it is the object of this paper to give a fairly full description of the development, together with a brief history of the work. Although the Jordan River Development is small as compared with many modern plants, it includes a variety of engineering work not common to even those developments of much greater magnitude, and it is believed that a setting forth of the more important features will prove of interest to many engineers. This development possesses another point of interest in that it is—so far as the writer has been able to learn—the highest head development of any considerable size in Canada.

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HISTORY.

The growth and expansion of the districts in and around Victoria, which are wholly dependent on the British Columbia Electric Railway Company for street railway service, light and power, have been phenomenal, and the demand for electrical energy has been doubled and re-doubled several times within the past 7 years. In 1907 power was being furnished by a 2,000 k.w. hydroelectric plant at Goldstream and an 800 k.w. steam plant in Victoria, but it was realized at that time that a material increase would be required in order to meet the demands of the near future. It was therefore decided to look into the available water-power possibilities within a radius of commercially feasible power transmission to the city of Victoria. This investigation was continued for over a year, and practically all of the sources of water power around Victoria were examined. The exploration was carried on only under exceptional difficulties. Within a very short distance of Victoria the country was practically unmapped and unexplored. The mountains and valleys are densely covered with a growth of heavy timber, both standing and fallen, and the underbrush is of such a nature as to make it almost impenetrable. These conditions can be properly appreciated only by those who have experienced them.

The preliminary surveys of Jordan River were started the latter part of 1907, but on account of the winter setting in, it was impossible to finish this work until the following summer. A gauging station was, however, established near the mouth of the river and a series of records of rainfall and runoff were started. The surveys and records determined the fact that the watershed with the runoff observed, and the use of certain of the reservoir sites which had been discovered, would, with the available head, warrant the development of the system. It was also considered that the Jordan River project was better suited to the needs of the Company than any of the other projects investigated.

In October 1909, a party of engineers and a few workmen landed near the mouth of Jordan River and established a temporary camp. This camp was used as a base while other camps of a more permanent nature were being built, and in a very short time construction work was started all along the line as determined by the surveys.

The original installation was completed early in 1912, but in the meantime the demand for power had increased so rapidly that work was started immediately on the installation of the second unit in the power house. This unit was put into operation in the fall of 1912, but the steadily increasing demand for electrical energy made it quite evident that still further extensions were necessary in order to keep abreast of the demand. The installation of the second unit marked the ultimate capacity of the initial development, and it was therefore necessary, before making further additions to the power house, to increase the storage capacity of the system, enlarge the flume, and install about two miles of pressure pipe line between the forebay reservoir and the power house. The storage increase was obtained by the construction of the Jordan River Dam, which was started in the summer of 1912, and in the spring of 1913, the construction of the addition to the power house was started. The flume and pipe line construction followed soon after, and the work was completed in October, 1914.

JORDAN RIVER.

The Jordan River flows into the Strait of Juan de Fuca at a point 37 miles west of Victoria. The direction of flow is roughly from north to south, but the actual course of the stream is very tortuous. It is a typical mountain stream flowing in a deep and precipitous valley, and the fall is rapid from the source to the mouth. The source of the main river is in Jordan Meadows, which lie about midway between the east and west coasts of the Island, and at an elevation of about 1,700 feet above sea level. Several large creeks join the river within the upper ten miles of its course, the principal ones being Bear Creek, Wye Creek and Alligator Creek. The total drainage area is about 75 square miles, the greater part of which lies at an elevation of over 1,200 feet above sea level, and this entire area is covered by a growth of heavy timber.

Hydrography.—The precipitation is heavy, probably averaging about 90 inches per year over the whole watershed. During the winter months there is a heavy fall of snow varying from 4 to 11 feet in depth in the higher parts, and this snow, protected by the heavy timber and underbrush, often remains on the ground until well on in June or July, thus forming a splendid natural reservoir.

In spite of the heavy rainfall and the snow, the river has a wide variation of flow between the summer and winter months. One flood of over 12,000 cu. ft. per sec. has been recorded at the point of diversion, and the river falls each summer until the average minimum flow does not exceed 25 cu. ft. per sec., and the lowest recorded flow at the diversion point was only 9 cu. ft. per sec.

The usual length of the dry season is not over 40 days, but during exceptionally dry years there have been three months of very light runoff. The average yearly runoff measured at the point of diversion is about 275 cu. ft. per sec., and the area tributary to this point is close to 60 square miles, giving an average runoff of about 4.5 cu. ft. per sec. per square mile. The heaviest floods are usually caused by warm rains and winds coming at a time when the greater part of the catchment basin is covered with several feet of snow. During the peak of the heaviest recorded flood the rate of runoff was slightly over 200 cu. ft. per sec. per square mile.

On account of the nature of the country with its thick covering of timber and underbrush, the runoff coefficient is high, averaging about 70 per cent. of the total precipitation.

The fact that the rate of runoff varies between wide limits makes it necessary to provide reservoirs of comparatively large capacity in order to take advantage of any considerable portion of the runoff.

Reservoir Sites.—The total reservoir capacity of the system is 2,661,000,000 cu. ft., which is divided among five reservoir sites as follows:—

Height of Dam.	Location.	Capacity, cu. ft.
75 ft.	Bear Creek	607,000,000
125 ft.	Jordan River (Diversion Point)..	612,000,000
50 ft.	Jordan Meadows	980,000,000
50 ft.	Alligator Meadows	352,000,000
35 ft.	Wye Lake	110,000,000
	Total	2,661,000,000

At the present time only two of these reservoirs have been developed. A 57 ft. dam impounds the water in Bear Creek, creating ing a storage of 328,000,000 cu. ft., but this dam can be raised to the full height of 75 feet, when necessary, and the storage nearly doubled. The reservoir at the diversion point on Jordan River is developed to its full capacity. These two reservoirs provide a storage capacity of 940,000,000 cu. ft., which is sufficient for all present requirements.

GENERAL PLAN OF DEVELOPMENT.

The power house is located on the beach near the mouth of the river, the centres of the water wheel nozzles being only a few feet above extreme high tide. Water is conveyed to the wheels from the forebay reservoir through steel pressure pipe lines about 9,300 feet long. The forebay, which is a small equalizing reservoir formed by two earth fill dams, is 1,152 feet above sea level, giving a static head of 1,145 feet at the power house. Water is carried from the diversion point to the forebay reservoir in a wooden flume about 5.3 miles long, built along the east side of the Jordan River valley. A small dam in Alligator Creek diverts the water from that creek into a small flume which joins the main flume about a mile below the main diversion point on Jordan River. Wye Creek joins the river above the diversion dam. Bear Creek flows into the Jordan River about 3.5 miles above the main diversion dam, and the Bear Creek storage dam lies near the headwaters of that creek and about a mile above its junction with the Jordan River.

Plate No. 1 shows a general plan of the Jordan River Development.

TRANSPORTATION.

One of the most serious problems connected with a development of this kind is that of designing and organizing an efficient transportation system. The distances are comparatively great, many of the grades are heavy, and the country through which the roads must be run is rough and heavily timbered.

Victoria is the nearest shipping point to Jordan River, and as there is no railroad connection between the two places it has been necessary to transport all freight by water. This method of transportation presents many difficulties on account of the unprotected nature of the coast, the rough water often encountered, and the lack of any harbor at Jordan River. At the time the work was started there was a Government-built road to within 9 miles of the power house site, and although this road has since been extended to Jordan River, it does not offer a practical means of transportation of large quantities of heavy freight, and has only been used to a limited degree for passenger travel and for emergency transportation. The transmission line material was distributed by means of this road.

All freight has been transported from Victoria on 60-ton scows towed by a powerful and seaworthy tug owned by the company. The water at Jordan River is too shallow to allow the tug to bring the scow to the wharf, so the tow lines are run ashore and the scow is pulled alongside the wharf by hand, and there unloaded by a steam derrick.

Cable Tramway.—At the wharf the freight is loaded onto double truck, 3-ft. gauge cars, which are hauled by horses about a quarter of a mile to the foot of an inclined cable tramway. Here the cars are made fast to a ¾-inch plow steel cable and hauled up to the forebay reservoir, a distance of approximately 9,500 feet. The total rise in this distance is 1,125 feet, and the maximum grade is 48 per cent. The cable is operated by a steam winding engine with 12″ by 12″ cylinders, and the drum has a capacity of 10,500 feet of ¾-inch line. On account of several comparatively level portions along the road the empty car will not overhaul with the heavy cable dragging behind, so another winding engine is placed at the lower end of the line and hauls the car back by a ½-inch cable. This lower engine is driven by a variable speed induction motor of 50 h.p. The haulage lines are supported on sheaves or rollers placed between the rails, and there is very little wear on the rope. This tramway parallels the pressure pipe lines, so that it has not been necessary to build other tracks or roads for laying the pipes. Loads of 5 tons and under are hauled on a single line, but heavier loads are blocked over the steepest grade. It requires about 35 minutes to make the round trip, and as many as 18 trips have been made in a 10-hour day.

At the end of the tramway a small hand-operated stiff-leg derrick is located, and by means of this the loads are transferred to single or double truck cars to be hauled over the flume railroad.

Flume Railroad.—The flume railroad parallels the flume for its entire length of 5.3 miles, and is on a grade about 15 feet above that of the flume. This road is also of 3-ft. gauge and is built of 20-pound rails, as are all the other roads on the transportation system. The writer believes this to be about the most crooked piece of railroad in the world, there being practically no tangent, and many of the curves being as sharp as 90 degrees. There are many short bridges and trestles along the line where it crosses small creeks, and it is built for almost its entire length along the steep hillside. The cars are drawn by horses, or by a small saddle tank locomotive which uses oil as fuel in order to guard against fire caused by sparks.

During a part of each winter the flume railroad is put out of commission by the deep snow, and this has made the transportation to the upper camps very difficult. During this time it is practically impossible to haul any heavy freight, but camp provisions have been carried on horse-drawn sleighs along the railroad tracks.

From the end of the flume railroad at the main diversion dam a wagon road continues for about 4.5 miles to the Bear Creek damsite.

BEAR CREEK DAM.

Bear Creek Dam is built at a point about a mile above the junction of Bear Creek and Jordan River. The water is backed up the narrow valley for about two miles above the dam and forms a lake which at high water level with the water surface 5 feet below the dam crest, has an area of 285 acres, and provides storage for about 328,000,000 cu. ft. of water. The drainage area above the dam is 8 square miles in extent, and raises to an altitude of over 2,000 feet above sea level.

Geological Formation.—The sloping sides of Bear Creek valley are composed of a coarse slate bedrock covered by a comparatively thin layer of soil and decayed vegetable matter. At the damsite the bedrock dips sharply from either side toward the centre of the valley and the old bedrock river channel is covered to a depth of about 85 feet with coarse sand and semi-cemented glacial gravel mixed with clay and capped by a shallow covering of soil.

Hydraulic Fill Dam.—The dam is an earth embankment built by the hydraulic process. The greatest height above the bottom of the valley is 57 feet, and the length on the crest is 1,020 feet. The crest has a width of 15 feet; the downstream slope is 2½ to 1, and the upstream slope is 3 to 1. The spillway is excavated from the solid bedrock at the north end of the dam. The volume of the dam as measured in the embankment is 148,400 cu. yds.

Dam Foundation.—Before starting the construction of the dam, the site was thoroughly prospected to determine the nature of the underlying material. A trench was excavated parallel to the axis of the dam and directly under the downstream edge of the crest. The bottom of the trench followed bedrock as far as safety would permit, the depth varying from 16 to 31 feet, with side slopes of ¼ to 1. Test holes were put down in the bottom of this trench, using churn drills and casing the holes with 3-inch pipe. The drilled material was removed by water jet.

The formation was generally found to consist of a layer of top soil from 2 to 4 feet thick. Below this was a bed of large boulders and gravel. At a depth of 12 to 16 feet the boulders diminished in size and gave way to coarse semi-cemented gravel, and under this, at a depth of about 20 feet, there lay alternate layers of loose water carrying sand and gravel extending to bedrock.

Curtain Wall.—In order to assure water-tightness and provide a secure foundation, not only for the initial structure 57 feet high, but for an ultimate structure 87 feet high for developing the reservoir to its ultimate capacity, it was decided to drive steel sheet-piling to bedrock, thus forming a curtain wall across the valley.

Interlocking 12-inch, 40-lb. Carnegie steel sheet-piling was driven in the bottom of the trench to bedrock by two pile drivers with 2,000-lb. drop-hammers. The piling was furnished in lengths of 50 feet and less. The driving was hard on the north end of the dam, but all piles were driven until bedrock was reached, as indicated by the test holes. The piles were cut off at a height of 4 to 6 feet above the bottom of the trench, and the trench was thoroughly cleaned out before sluicing was started. The total yardage excavated from the trench was 8,700 cu. yds., and this material was piled about 15 feet from the downstream edge of the trench, and is included in the dam just below the puddle core. A total of 28,500 feet of sheet-piling was driven to form the curtain.

Borrow Pits.—Both slopes of the valley were prospected to locate a borrow pit from which to sluice the material into the embankment. The best site was found on the north side of the valley, about 400 to 800 feet distant from the end of the dam. The material consisted of sand, gravel, clay and hard-pan in favorable proportions to be sluiced into the dam. The pits afforded a working face from 8 to 20 feet deep above bedrock, and were at an elevation of 150 to 250 feet above the floor of the valley.

Clearing Land.—The damsite and borrow pits were very heavily timbered, and were cleared by means of powder and logging engines, the logs and brush being piled and burned. In preparing the foundation for the dam all soil, roots and decayed vegetable matter were removed over the entire area to be occupied by the base of the dam. The total area cleared was about 30 acres, of which 10 acres were grubbed and stumped, and 4 acres were stripped of all surface soil.

Water Supply.—A gravity supply of water for sluicing was obtained from Tripp Creek, a small stream on the north slope of the valley near the dam. A storage reservoir was built on the ridge near the headwaters of the creek, in which 1,500,000 cu. ft. of water were stored. This was sufficient to carry on the sluicing for 6 or 7 days. The water was taken from the creek about a mile and a half below the storage dam in a 10-inch wood stave pipe 1,300 feet long, and conveyed to a tank or head box near the borrow pits, from which 8-inch, 12-gauge, slip-joint, riveted steel hydraulic pipe carried the water to the borrow pits, delivering it to the monitors at a static head of 150 to 200 feet.

The filling of the dam was started in September, 1911, and owing to the necessity of completing the work in time to store water for the 1912 dry season, it was considered advisable to provide a steam pumping plant to preclude, as far as possible, interruptions in sluicing due to the failure of the gravity supply. A steam pumping plant was, therefore, installed, which consisted of two 6-in. belt-driven centrifugal pumps, having a capacity of 1,000 gallons per minute each, against a head of 250 feet. The boiler plant consisted of three 50-h.p. boilers using wood as fuel.

Sluicing.—The quantity of water used in sluicing varied from 3 to 6 cubic feet per second, and was discharged through 3-inch or 4-inch nozzles. It was not attempted to break up the ground, which was largely hardpan, with the jets, but powder was used throughout the job, the holes being gophered for 10 to 16 feet into the base of the bank along the surface of the bedrock. This use of powder broke the ground nicely, and made it easy for the monitors.

Sluicing Flumes.—The sluicing flumes for carrying the material to the dam extended from the borrow pits the full length of the dam. The main flume was built on a grade of 6 per cent., and was constructed of 2-inch planks, the size of the box being 16 inches wide and 18 inches deep. The bottom was lined with wood paving blocks 4 inches deep, the grain being perpendicular. Three decks or levels of main flume were used as the work progressed. The first and lowest flume was 1,050 feet long, the second deck was 1,150 feet long, and the last deck was 1,400 feet long, making a total of 3,600 feet of main flume. The flume trestle was mostly built of round poles cut on the site. The lateral or distributing flumes were built on 7 to 9 per cent. grades. They were made up in sections with a lap or telescoping joint to facilitate moving. The total length of lateral flume was 3,000 feet.

The material was sluiced into the dam between rock toes or dykes built of the rock excavated from the spillway cut. The slopes of the dam are not paved, but were carefully trimmed to an even surface and present a very pleasing appearance. Grass and clover seed have been sown on the crest and the lower slope, and this has proved very effective in preventing the washing away of the slopes by the heavy rains.

Sluicing Records.—Of the total volume of the dam 134,405 cu. yds. of material was placed by sluicing. This work was done in 3,718 hours of actual sluicing, or an average of 870 cu. yds. placed per 24 hours. The average quantity of water used was 4.5 cu. ft. per sec., and the average proportion of solids to the water used was 6.3 per cent.

Temporary Spillways.—A temporary spillway constructed as a heavy wooden flume 50 feet wide and 12 feet deep, was maintained through the dam during the winter season. The sluicing was carried on on both sides of this spillway, and the gap was filled in when the structure was removed at the end of the wet season. After this time and until the elevation of the permanent spillway was reached, an emergency overflow spillway was maintained over the dam with a plank apron extending down the lower slope and secured to timbers embedded in the fill. This emergency spillway was never used.

Permanent Spillway.—The permanent spillway is located at the north end of the dam and is excavated through a ledge of solid slate bedrock. The sill of the spillway is 50 feet long and is 15 feet below the dam crest elevation. The cut is about 350 feet long and has a maximum depth of 35 feet. Six concrete piers are erected in the throat of the spillway, and against the sloping face of these piers stop-logs can be set to hold the pond at any desired level up to 5 feet below dam crest. A bridge is built across the spillway on the tops of the piers, and from this bridge the stop-logs are handled by means of a traveler and chain blocks with hooks for attaching to the logs. In case of emergency the stop-logs can be wedged off the piers and the whole spillway opened in a very short time. The total quantity of material excavated from the spillway cut was 10,400 cu. yds. of rock, and 850 cu. yds. of earth, all of which material was placed in the toes of the dam.

Reservoir Outlets.—The outlet for the reservoir consists of two 30-inch riveted steel pipes, ¼-inch thick, and 300 feet long. These pipes are set in a trench excavated in the bedrock immediately south of the original stream bed, and are embedded in concrete 12 inches thick. Concrete collars are built around the pipes where they cross through the puddle or core of the dam. At the upper end of the pipes a reinforced concrete intake structure was built. This includes the intake racks and two rising stem 24-inch gate valves with the stem extended to the top of a structural steel tower 50 feet in height, where the operating gear is located. Taper pieces connect the gates to the 30-inch pipes.

Flooded Area Not Cleared.—The flooded area behind the dam was not cleared, but all the timber was left standing. As was to be expected, the water killed the trees, and they are gradually becoming loosened from the soil holding the roots, and are floating to the surface, or, as in case of the hemlocks, becoming water-logged and sinking to the bottom of the pond. All floating timber is held back from the dam and spillway by a heavy log boom drawn across the lake a short distance above the dam. A logging engine is set up near the spillway, and by this means the floating trees can be dragged out of the lake and burned.

Dam Leakage.—The construction of the dam was started in November, 1910, and the work was completed in April, 1912. Since that time the dam has been in service and its behaviour has been entirely satisfactory. Measuring weirs were built at several points below the dam to record the leakage, and this was found to be so slight as to be almost negligible. Shortly after the completion of the dam, and before the fill had drained out, the weirs showed 0.19 cu. ft. per second, but this has since decreased to less than 0.1 cu. ft. per second. There has been no appreciable settlement of the fill.

Unit Costs.—The total volume of the Bear Creek Dam is 148,400 cu. yds. Of this total, 134,405 cu. yds. was placed by sluicing at a cost of $.703 per cu. yd. This includes the work in the borrow pits, the costs of the flumes and trestles, and all other work connected with the hydraulic operations. The cost of the completed structure, including foundation work, core wall, and spillway, was $1.39 per cu. yd. This unit cost does not include transportation costs, or other costs not directly chargeable to the work.

The undertaking to raise the height of this dam to 75 feet should be comparatively simple, as a safe foundation is provided and most of the perplexing and expensive features of the construction are solved. An extra 20 feet in height will nearly double the capacity of the reservoir.

Plate No. 2 shows the general plans of the Bear Creek dam and spillway, and Figure No. 1 shows a view of the completed work.

JORDAN RIVER DAM.

Immediately below the junction of Wye Creek and Jordan River, the canyon narrows and is crossed by a ridge of bedrock which extends well up on both sides of the canyon and across a flat on the east side of the river. This site was recognized as the best site for a concrete or masonry dam of a permanent character, and it was originally intended to place the diversion dam at this point, but owing to the limited time, the lack of a ready supply of concrete material near the site, and also in view of the probability of using the site at some future time for the construction of a high dam which would, in addition to diverting the stream into the flume, form a large reservoir, another location was chosen for the temporary diversion dam about 2,000 feet further up stream. In order to utilize the runoff from Wye Creek, a small diversion dam was also built on this creek and a branch flume was built to carry the water from this dam to the main flume on the east bank of the river.

Temporary Diversion Dams.—The temporary Jordan River diversion dam was a substantially built rock-filled log crib, sheeted with two thicknesses of 2-inch planks. It was founded on bedrock and the bottom edge of the upstream sheeting was set in a concrete sill. The length of the crest was 128 feet, and the width 8 feet. Both faces were built on 1 to 1 slopes, and the maximum height was 18 feet above bedrock. The flume intake was located at the east end of the dam, and was also constructed as a rock-filled crib, lined with two layers of 2-inch planks. The regulation of the flow of water was controlled by three timber head gates, operated by rack and pinion. These gates discharged directly into an intake basin depressed two feet below the floor of the flume and provided with sand gates through which the silt and sand which might collect in the basin could be discharged.

The Wye Creek dam was of similar construction, but the crest length was only 90 feet.

These two temporary dams were completed during the summer of 1911, and gave satisfactory service up to the time when they were replaced by a permanent structure built on the site which had originally been chosen for the diverting dam.

Required Storage Increase.—The storage provided by the Bear Creek reservoir was sufficient to supply the demands of the original power plant, but on account of the rapidly increasing demand for power it became necessary to increase the power house capacity and also provide greater storage. The increase of storage capacity could have been provided by developing any one of several reservoir sites, or by raising the Bear Creek Dam, but the development of a reservoir at the diversion point offered advantages over any of the other propositions and the decision was made in favor of this site.

Type of Dam.—The choice of the type of dam for impounding the reservoir lay between a gravity type concrete or masonry dam and a hollow, reinforced concrete dam of the Ambursen type. Test pits were sunk along the proposed centre line of the dam and bedrock was struck at depths varying from nothing to 18 feet below the surface, the average depth being about 8 feet. This foundation was suitable to either type. The quantity of material required for building the structure was, however, much in favor of the hollow type dam. Time was also an important consideration, for it was very desirous of storing a good part of the 1913 spring runoff. Under these conditions the hollow dam was considered most suitable, and in August, 1912, the construction of this dam was started.

Reservoir.—The reservoir is formed in the narrow Jordan River valley, but the water is also backed up into the Bear Creek and Wye Creek valleys, forming a lake slightly over three miles in length, having an area of 398 acres at the spillway level. The capacity of the reservoir above the outlet gates is 612,000,000 cu. ft.

Geological Formation.—The rock formation under the greater part of the reservoir is a coarse slate, but this changes a short distance above the dam site to a hard serpentine rock or trap rock. The line of contact between these two formations is almost due east and west, and the stratification of the trap rock formation lies in an almost vertical plane and parallel to the centre line of the dam. This rock is extremely hard and the surface is comparatively free from cracks, so that it was not difficult to prepare a suitable foundation for the dam.

Dimensions of Dam.—At the dam site the sides of the valley slope up rapidly from the river, but at a height of about 70 feet the east bank flattens out and the slope is gradual back to the base of the hill. The crest of the dam is 891 feet in length, of which 130 feet is earth embankment with a concrete core-wall. The spillway is located well toward the east end of the dam. It is 305 feet in length and the crest is 8 feet below the top of the dam, providing for a flood discharge capacity of 23,000 cu. ft. per second. The curved crest and rollway apron discharge the water clear of the toe of the dam and into a natural channel across the flat. This channel joins the river about 200 feet below the dam. The extreme height of the dam is 126 feet from the deepest part of the buttress foundations in the river bed to the crest. This is believed to be the highest dam in Canada, and it is the next highest Ambursen-type dam built at this time.

Foundations.—In preparing for the foundations the whole area to be occupied by the base of the dam was not stripped to bedrock, but only those portions to be occupied by the buttresses and the cut-off trench. Trenches were excavated along these lines and all loose rock was removed and the bedrock was carefully cleaned before placing any concrete. Wherever necessary the surface of the bedrock was roughened by blasting, or a shallow trench was excavated in the rock to provide a good bond for the concrete and to guard against possible slipping. The cut-off trench was excavated along the upstream toe of the dam and varied in depth from 3 to 12 feet, depending upon the condition of the rock. In all cases it was carried to a sufficient depth to assure watertightness.

Buttresses.—The dam consists of a reinforced concrete face or deck, inclined at an angle of 45 degrees, and supported on concrete buttresses, which are spaced 18 feet centre to centre across the whole length of the dam. These buttresses are 12 inches thick at the top and increase, by steps or lifts 12 feet high, to 42 inches in thickness at the bottom of the highest buttress. The upstream edge is built on a slope of 1 to 1, and the downstream edge has a batter of 1 to 4 to a point 18 feet below the crest, from which point it is vertical to the crest. Just back of the upstream edge a heavy reinforced haunch or shoulder is built on either side of the buttress and the decks are supported on these haunches. The buttress projects beyond the haunches a distance equal to the thickness of the deck, and a bonding groove or key is cast in this projection. No vertical reinforcement is used in the buttresses excepting along the downstream edge and in the haunches, which are heavily reinforced to carry the decks. Horizontal reinforcement is used along the top and bottom of each of the 12-foot lifts or steps. Horizontal columns or tie beams, which are reinforced top and bottom, connect the buttresses at various elevations and give them lateral support. The reinforcement in these beams is continuous through each three consecutive buttresses, but is not carried continuously through the dam on account of possible strains set up by expansion and contraction.

Decks.—The decks are designed as a simple beam uniformly loaded, and are supported on the buttress haunches and keyed into the projecting portion of the buttresses. The thickness varies from 15 inches at the crest to 55 inches at the cut-off wall in the deepest part of the dam. The deck slab is keyed into the top of the cut-off wall. The horizontal reinforcement consists of ⅞-inch square corrugated bars on 4-inch centres up to a point 45 feet below the crest of the dam, and above that point on 4½-inch centres. Every third bar is bent up at the third point to form a truss and to take the diagonal shear. The vertical reinforcement consists of 6 ⅝-inch square corrugated bars in each bay or deck slab, and these rods are continuous from the toe to the crest of the dam. There is no connection between the deck reinforcement and that in the buttresses.

The crest of the dam is 6 feet wide and is provided with a walkway protected by suitable pipe hand-railing. A second concrete walkway passes entirely through the dam underneath the spillway, and is connected to the walk on the crest by concrete stairs at each end of the spillway.

Spillway.—The spillway crest is 4 feet wide to allow for setting up flashboards if desired. The apron is built on an ogee curve, and is designed for a depth of 7.5 feet of water over the crest of the spillway without the water tending to leave the surface of the concrete. This depth is well in excess of any probable flood. Both the crest and the apron are very strongly built and are reinforced in the same manner as the decks to enable them to withstand the battering of heavy logs passing over the spillway during floods.

Earth Fills.—About 130 feet of the extreme east end of the dam is built as an earth fill with a reinforced concrete core-wall founded on bedrock. This wall is 3 feet thick at the bottom and tapers to 18 inches at the top. It is reinforced both horizontally and vertically to resist cracking due to any settlement of the fill. The maximum height of the wall is 44 feet, but 28 feet of this height is below the original ground surface, and the trench was backfilled with selected material. The crest width of the fill is 10 feet and the slopes are 2 to 1.

Reservoir Outlets.—The outlet structure is built into the dam near the west end, and occupies the space between two of the buttresses. The bottom of the gate openings is 93 feet below the crest of the dam. There are two openings in the face of the dam, and two sets of two gates each control the flow of water. Each set consists of an emergency gate set at an angle of 45 degrees, or parallel to the deck of the dam, and behind this gate, but in the same chamber, a service gate set vertically. All gates are identical in design and size, and have a clear opening 5 ft. 6 in. high by 3 ft. 6 in. wide. The gate stems pass through the roof of the gate chamber in oil-filled pipes with a packing gland on each end. The operating stands are placed on a concrete floor about 3 feet above the roof of the chamber. These are geared, roller bearing stands, and are so designed that one man can operate the gates under the maximum head. The gates and operating gears were supplied by the Coldwell-Wilcox Company, and are of their standard design. By closing the emergency gates the operating gates can be examined or repaired, access to the gate chamber being provided through a manhole in the roof of the chamber. Stop-log guides provide for shutting off either set of gates if necessary.

The outlet gates discharge directly into a settling basin, and from here the water enters the flume. Sand gates are provided for discharging any silt and sand which may settle in the basin.

The outlet openings in the deck of the dam are protected by two trash racks made up of ¾-inch by 3-inch bars placed on edge on 5-inch centres. These rack bars are mounted on channel iron frames which are supported on flanged wheels and run on rails up and down the face of the dam. The rails are laid at two different levels on concrete projections or walls on the face of the dam, so that one rack passes under the other one. By this arrangement either rack can be lowered in front of the outlet openings while the other one is hoisted to the top of the dam to be cleaned. The racks are lifted by means of ¾-inch crane chains which pass over suitable hand gears on the dam crest and are attached to counterweights inside the dam. Each rack has approximately 450 sq. ft. area.

Concrete.—The concrete for the decks, cut-off wall and spillway apron was mixed in the proportion 1 part cement to 2 parts sand to 4 parts crushed rock. In the buttresses and foundations, the mix was one part cement to 3 parts sand to 6 parts crushed rock. The completed structure contains 21,185 cu. yds. of concrete.

Reinforcing Steel.—Only two sizes of reinforcing steel was used in the entire dam, these being ⅞-in. and ⅝-in. square corrugated bars. ⅞-in. bars were specified for all of the main reinforcement, and the ⅝-inch bars used only for hooks and vertical reinforcement. The total weight of steel used in the dam was 380 tons.

Forms.—Standard sectional forms, as developed by the Ambursen Hydraulic Construction Company, were used throughout in the construction of the dam. All buttress forms were built in sections or panels 12 ft. 6 in. high by 8 ft. wide. The mitre forms for forming the 45 degree slope at the back of the haunch, fitted against the edge of the panel forms, and the haunch forms were supported on the mitre forms. Each 12-foot lift of the buttresses was several inches thinner than the next lift below it, so the forms were supported on the finished portion of the buttresses. All of the sectional forms were substantially built of heavy timber frames with bolted joints, and faced with surfaced planks 2 inches thick. These buttress forms were accurately set by means of a transit and securely braced. ¾-inch bolts with cast washers held the forms from spreading under the pressure of the wet concrete, but these bolts were driven out before the mass got its final set. The form-work was usually stripped in four to eight days after the concrete was poured, the time depending on the temperature and the state of the weather.

Forms for the under side of the decks were made up of 2-inch planks, placed on the line of the decks, and supported on 3-inch by 10-inch purlins on 18-inch centres. The purlins were supported on 2-inch by 2-inch bearing strips set in a rebate or shoulder on the side of the haunches. In stripping these forms it was only necessary to knock out the bearing strip and the purlins could be removed. The top deck forms were made up of 1-inch planks in sections 3 feet wide and spanning the distance between the buttresses. These sections were secured in place by heavy timber strong-backs with 1¼-inch truss rods. The strong-backs were placed on 18-inch centres and were held down to the deck by 1¼-inch bolts which were placed in the edges of the buttresses when they were poured. These bolts were set in 2-inch pipes in the concrete, and were provided with a nut and washer on the embedded end so that they could be unscrewed and withdrawn when the decks were poured, and the pipes filled with grout. The forms for the spillway apron were handled in much the same way as the deck forms. These forms were built on the curve of the apron, but the backs were straight so that they could be secured by means of the strong-backs.

Very little special form work was necessary excepting for the concrete just above bedrock, and for the outlet structure.

Rock Crushing Plant.—Before starting the construction of the dam, samples of the bedrock at the damsite were crushed and tested as concrete material. The results were satisfactory, and it was decided to open a quarry, install a crushing plant, and manufacture the sand and crushed rock at the works. The quarry was located about 200 yards from the east end of the dam, and at an elevation of about 50 feet above the crest, and the crushing plant was located just below the quarry. The rock was carried to the crushers in 1 yard side dump rock cars which were pushed by hand the short distance from the quarry. The crushing plant consisted of two No. 2 Aurora jaw crushers and two 16-inch by 30-inch Superior sand rolls. The crushers discharged through a revolving sand screen into a 100 cu. yd. capacity rock bin, or the crushed rock could be taken through a chute to the sand rolls, which were placed in tandem below the crushers. From the rolls the sand was lifted in a belt bucket elevator to the sand bin, which was directly in front of the rock bin and of the same capacity. The crushing plant was driven by a 150-h.p. induction motor.

The rock proved difficult to crush on account of its extreme hardness. It was necessary to replace the manganese steel crusher jaws and roll shells several times during the job, and it was never possible to work the rolls or crushers up to their rated capacity. The plant was large enough, however, to take care of the work without any serious delays. The rock was crushed to 2 inches and under, and the sand passed a 3-mesh screen. On account of the peculiar nature of the rock, the rolls turned out a considerable quantity of pulverized rock. This was watched closely, but did not seem to affect the quality of the concrete in any way. The total output of the crushing plant was 21,000 cu. yds. of crushed rock and 11,000 cu. yds. of sand.

Mixing Plant.—The concrete mixing plant was placed directly below the storage bins, and both the sand and rock were fed to it by gravity. The space under the bins was utilized for cement storage and held about 5,000 sacks. The mixing plant consisted of a 1 cu. yd. batch mixer driven by a 30-h.p. induction motor. This mixer dumped directly into 1 cu. yd. centre dump buckets which were placed on a small flat car running on a track between the mixer and the cableway. There was sufficient space on the car for two buckets, and the empty one was placed on the car by the cableway before the filled one was picked up.

Placing Concrete.—Practically all the material in the dam was handled by a cableway spanning the valley on the centre-line of the dam. The length of the span was 920 feet. The standing line was 2¼ inches in diameter, on which a heavily-built carriage was operated by a two-spool cable engine. In placing the concrete the cableway brought the bucket over hopper-bottom cars which were pushed by hand along tracks laid on top of the buttress forms. These tracks were made up in sections about 12 feet long with platforms 3 feet wide on each side of the rails. The space between the rails was not floored over so that the car could be emptied into the buttress form as it was pushed along the track. The car body was mounted on the trucks as a turntable, and the spout could be turned in any direction. The track sections were secured to the buttress forms by means of chains with turnbuckles. The concrete was dumped from the bucket into the car and was then distributed in the buttress form, or through chutes into the deck forms. Men worked in the forms and the concrete was carefully puddled as it was dumped. Shovels were used for puddling and no tamping was done.

Forms, scaffolds and reinforcing steel were also placed by means of the cableway.

Excavation for Foundations.—In excavating for the foundations the earth and rock was handled by stiff-leg derricks in 1-yard skips, or in wheelbarrows where the derricks could not reach. This excavated material was dumped on the upstream side of the cutoff trench. The total foundation excavation amounted to 7,770 cu. yds. of earth, and 5,980 cu. yds. of rock.

Temporary Flume Work.—The original flume was on the east bank of the river, but on account of the spillway being located on that side of the river it was necessary to locate the flume intake on the opposite side. Consequently, about 600 feet of flume immediately below the dam was re-located, and at that point it was carried across the river to join the old flume on a concrete arch bridge having a span of 80 feet. In making this change the service was not interrupted. The dam was built around the old flume and the opening was provided with stop-log grooves. When the main closure was made in the dam, this opening was also closed with stop-logs and a concrete bulkhead was placed behind them. The water was turned through the flume intake in the west end of the dam and carried across the river in a temporary flume at the lower toe of the dam until such time as the re-located flume and the concrete bridge were completed.

Progress of Construction.—When the construction work on the dam was started, it was planned to take advantage of the low stage of the river to rush the work on the buttresses standing in the river channel and get this work completed to a point above high-water level before the wet season set in. Coffer-dams were built across the river and the water was carried over the foundation excavations in a wooden flume. On account of unavoidable delays, concreting was not started until the first part of October. By the end of that month two of the buttresses were completed to a height of about 15 feet, and by cutting the coffer-dams the water was caused to flow between these buttresses, thus leaving the river bed dry to allow the excavation to proceed for the foundations of the other buttresses in the river. On November 10th, while this work was going forward, a sudden flood swept down the river, tipped over one of the two buttresses between which the water was flowing, destroyed the coffer-dams, and filled the partially completed excavations with gravel and boulders. This flood marked the beginning of the wet season, and for over three months there was little use of attempting to work in the river bed as the water remained high and floods were frequent. It was not until the first part of February that the work in the river was resumed, and although a good deal of coffer-damming and pumping were necessary, the river buttresses were finished to a height of 36 feet early in April.

The construction work was carried on right through the winter, all work being confined to those parts of the dam on both sides of the river above high-water level. This was only done under great disadvantage, as the winter was particularly severe, there being a depth of over 6 feet of snow on the level at one time, and the ground was well covered until well on in May. The cost of clearing away the snow was a considerable item, and much time was lost. During the winter all sand and water used in the concrete was heated by steam, but no further precautions were taken, and no trouble was experienced due to the freezing of the concrete in the forms.

The deep snow made transportation over the railroad impossible excepting in horse-drawn sleighs. This condition was, of course, foreseen, and 75,000 sacks of cement were stored in the sheds at the damsite before winter set in. This was a sufficient supply to last until the railroad was opened in the spring. Only the necessary camp supplies were transported over the snow.

While the decks were being constructed across the river portion of the dam the water was passed through the usual Ambursen closure opening between two of the buttresses. This opening was provided with grooves for 18-inch by 18-inch stop-logs, with space behind to cast in a concrete plug to entirely fill the opening and make the closure permanent.

On account of the necessity of storing a part of the spring runoff, the closure was made on May 22nd, before the dam was completed to its full height. The height of the water behind the dam was controlled by the outlet gates, and the reservoir was not allowed to fill rapidly, but the water was held down so that only that portion of the dam which was sufficiently aged to insure it having the required strength, was subjected to any pressure. An emergency spillway was provided, however, in case of a flood which might exceed the capacity of the outlet gates. The reservoir was allowed to fill gradually as the work progressed, and sufficient water was stored to carry the plant over the dry months.

Dam Leakage.—The first water passed over the spillway in October, 1913, and since then the reservoir has been kept filled most of the time. On January 4th, 1914, water flowed over the spillway to a depth of 5.2 feet, or at the rate of about 12,000 cu. ft. per second. The dam is surprisingly watertight, and such leaks as showed when the reservoir was first filled have steadily decreased, and many of them have entirely disappeared. The fact that the water carried in suspension a considerable amount of vegetable matter and silt may account for the leaks taking up so rapidly, but from present indications the dam will be practically "bottle-tight" after it has stood for a year or more.

Electric Power.—With the exception of the cableway engine and the derrick engines, all plant used in the construction of the dam was operated by electric motors. A transmission line 7½ miles long, built on the pipe line right-of-way and the flume right-of-way from the power house to the damsite, furnished current at 6,600 volts. This voltage was stepped down in a substation at the damsite to 2,200 volts, the large motors operating at this voltage, and it was further reduced to 220 and 110 volts for the small motors and the lighting circuits.

Cement.—All cement used in the dam was manufactured in British Columbia. A laboratory was fitted up at the dam and the usual physical tests were made on all cement as it was received. Tests were also made by an outside laboratory not connected with the work in any way. Each lot of 1,000 sacks was separately sampled for the two sets of tests, and no cement was used unless both tests showed favorable results. Boiling or accelerated tests were made each day in the field laboratory on the cement to be used the following day. Compression tests were made on 6-inch cubes which were cast from the concrete as it was being placed in the buttresses, representing the material actually in the dam. The results of these tests were satisfactory. 132,000 sacks of cement were used in building the dam.

Lumber.—All lumber used in the construction of the dam for form work, scaffolds, camp buildings, etc., was sawn in the company's mill located at the lower end of the flume. This lumber was transported to the damsite over the flume railroad. The total quantity of lumber used was 1,200,000 feet B.M.

Unit Costs.—The completed dam contains 21,185 cu. yds. of concrete. The unit costs for the principal items which make up the total are as follows:—

Quarrying and crushing the rock and sand used in the concrete, $1.86 per cu. yd. Mixing, placing and puddling the concrete, $2.52 per cu. yd. The cement and reinforcing steel cost $5.23 per cu. yd. Form work, including first cost of moveable forms and the moving and stripping of all form work, $3.45 per cu. yd. of concrete. The total cost of the concrete in the completed structure was $14.01 per cu. yd.

The plans of the dam were prepared and the work was carried out under contract by the Ambursen Hydraulic Construction Company of Boston, Mass., represented by the Puget Sound Bridge and Dredging Company of Seattle, Washington.

Plates Nos. 3 and 4 show the general plans, sections and elevations of the Jordan River Dam, and Figs. Nos. 2 to 7 inclusive, give views of the dam under construction and of the completed structure.

FLUME.

The main flume follows the east side of the Jordan River valley from the Jordan River Dam to the forebay reservoir, a distance of 5.3 miles. The side of the valley is steep for the entire distance and is broken by frequent precipices and deep indentations. As a rule, the formation is suitable for the flume foundations, rock or hardpan lying only a foot or so under the surface, but in a few places it was rather difficult to get a secure footing.

Clearing Right-of-way.—The right-of-way traverses a belt of heavy timber, and extensive clearing was necessary in order to protect the flume from falling trees. Only a narrow strip was cleared on the lower side of the flume, but above the flume all trees which might reach it in falling were taken down. The fallen timber was hand-logged to the lower side of the clearing, and all branches and trimmings, as far as the season would permit without danger, were piled and burned. Over 6,000,000 feet B.M. was cut in making this clearing.

Design of Flume.—The flume is built entirely of timber, and was designed for an ultimate carrying capacity of 175 cu. ft. per second. The box is 6 feet by 6 feet in section, allowing for a depth of 5 ft. 6 ins. of water, and has a grade of 1 foot in 1,000 feet. As originally built, the box was only boarded up to a depth sufficient to carry 75 cu. ft. per second, and was supported on bents placed 15 feet centre to centre. During the summer of 1913 the box was completed to its maximum capacity and in order to support the additional weight of water, it was necessary to erect intermediate trestle bents, making the bents 7 ft. 6-ins. centre to centre.

The box is built of fir planking 2-ins. thick and 12-ins. and 18-ins. wide. The planks are surfaced on one side, the smooth side being turned toward the water, and the cracks are covered by ½-inch by 3½-inch battens. The frames for the box are placed on 30-inch centres, and are built up of a 4-inch by 8-inch sill, 4-inch by 6-inch side posts, and a 4-inch by 6-inch cap, or yoke. The side posts are dapped into the sill and the yoke. The sills are supported on 6-inch by 14-inch stringers which lap for about a foot on the caps of the main trestle bents. These bents are built up of 8-inch by 8-inch posts dapped into an 8-inch by 8-inch cap and braced with 2-inch by 8-inch braces. The intermediate bents, when the height does not exceed 12 feet, are built in the form of the letter T with 10-inch by 10-inch posts and caps. Above 12 feet in height, the standard two-post bent is used. All posts are set on ample footings of cedar blocks or concrete, according to the nature of the ground, the maximum bearing pressure being not greater than one ton per square foot on the supporting ground. The timber used in the flume is fir, cedar and a small amount of spruce.

The line of the flume follows the contour line as closely as possible, and excepting where it is necessary to cross over some small creek or depression, the trestle is low, averaging not over 7 feet in height. There are, however, a few short stretches where it was necessary to build the trestle more than one deck high, the highest of these being at the Alligator Creek crossing where a four-deck trestle is used, the height of which is about 75 feet.

No cutting into the hill side was done to attempt to straighten the line of the flume, but it was built on the steep slope for the entire distance, and the line is a series of curves from end to end with very little tangent. The sharpest curves are laid out on a radius of 71 feet, making 90 degree curves. It might be expected that these sharp bends would seriously retard the flow of water, but this does not seem to be the case. A weir was built at the lower end of the flume where it enters the forebay, and by means of measurements taken the flow was found to check closely with the original calculations. The results of these measurements indicate a value of about 122 for the "c" coefficient in Chezy's formula,—$V = c\sqrt{rs}$.

Method of Construction.—In building the flume the footings for the bents were accurately located with transit and level, and the post heights were calculated by the instrument men. These notes were forwarded to the sawmill, and all flume members were cut to true length and daps and gains were cut by machine in the sawmill yard. The timbers were delivered along the flume at the proper locations and in this way confusion and crowding were avoided, and greater rate of progress was made possible.

In placing the intermediate bents when the flume was enlarged the same plan was adopted and all timbers were cut to length in the saw-mill yard. This work was done without interruptions to the flume service. The new bents were made to take their share of the load by wedging between the posts and caps with fir wedges driven in with mauls. The posts were cut about half an inch short of the exact height, and the top was trimmed off at a slight angle, corresponding to the taper on the wedge. The wedge was driven until all sag was taken out of the stringer.

Flume Railroad.—The railroad which parallels the flume for its entire length, greatly facilitated the work, as all lumber and other construction materials could be delivered at the points at which they were to be used.

Waste Gates.—Five combination sand and waste gates are provided along the length of the flume. These gates are set in short boxes formed by dropping the floor of the flume about three feet below grade, and serve to catch all sand and silt which may enter the flume. The gates may also be used to empty the flume quickly in case of emergency.

Alligator Creek Dam and Flume.—A small diversion dam, similar to the original dams built on Jordan River and Wye Creek, was built on Alligator Creek, and the water thus diverted is carried to the main flume in a small branch flume about 900 feet long. This flume is similar to the main flume, but is only 3 feet wide and 3.5 feet deep, and is built on a grade of 3 feet in 1,000 feet. It joins the main flume about 4,000 feet below its head and forms a splendid emergency supply in case of any trouble at the intake, or a washout above the junction point.

Saw Mill.—About 5,000,000 feet B.M. of lumber were used in the construction of the flume. This was all cut in the company's mill located at the lower end of the flume and adjacent to the forebay reservoir. Logs were procured from splendid timber limits near the mill, and were hauled to the mill over skid roads by steam logging engines. The mill was rated at 20,000 feet per day, but by replacing the steam power by electric motors the capacity was greatly increased, as high as 45,000 feet being turned out in a ten-hour day. Although the mill was primarily built to supply the flume lumber, all the lumber used on the job has been sawn in this mill, and the total output to date is nearly 8,500,000 feet B.M., all of which was used for construction work.

Unit Costs.—The unit costs of the completed main flume having a capacity of 175 cu. ft. per second, and a length of approximately 5.3 miles, are as follows:—

The cost per M.B.M. of lumber in the structure was $17.41. The total cost per 100 ft. length of flume, including all excavation and foundation work, was $419.27. This does not include transportation costs, or the costs for clearing the right-of-way.

Service.—The flume has been in continuous service since its completion. There have been several short interruptions due to slides and falling timber, but none of a serious nature. With a flume of this character it is only natural to expect some trouble, but it is patrolled daily, and maintained in first-class condition, so that troubles are neither frequent nor serious.

Plate No. 5 shows the standard flume construction, and Fig. No. 8 gives a view of the Jordan River flume, high trestle construction.

FOREBAY RESERVOIR.

The flume discharges into the forebay reservoir, which is a small artificial lake formed in the comparatively flat saddle between two hills by two earth-fill dams built across the valleys immediately to the north and south of the ridge. These dams or embankments were built of the material excavated from the higher ground lying between them, thus adding to this extent to the capacity of the reservoir. The capacity is 4,350,000 cu. ft.

Earth-Fill Dams.—The reservoir site, which was originally covered with a heavy growth of timber, was carefully cleared, and all trimmings and branches were piled and burned. The good timber was logged to the mill. The dam foundations were prepared by stripping off the surface soil to the underlying hardpan, and cutoff trenches were excavated into the impervious material along the centre lines. Concrete cutoff walls were built in these trenches and cedar sills were embedded in the top of the concrete. On these sills posts were erected, and were sheeted with two thicknesses of 2-inch cedar planks, thus forming a timber core-wall or diaphragm.

The material of which the fills were made was a semi-cemented gravel or hardpan which required blasting to loosen. No particular attempt was made to puddle the fill or to compact the material during construction, but a limit of 3 feet was placed on the thickness of the layers deposited, and a small amount of puddling was done immediately in front of the core-walls.

The timber diaphragms in these dams insured water-tightness for a period of at least 10 years, and it was thought that by that time, when the timber had rotted out, the fill would have settled and compacted itself to form an absolutely tight dam. The south dam was built with wheelbarrows and with scrapers and sleds hauled by donkey engines. The north dam was built by horses and carts.

The north dam has a length of 560 feet on the crest, and contains 24,290 cu. yds. of material. The south dam is 700 feet long, and has a volume of 26,560 cu. yds.. The slopes of both embankments is 2½ to 1 on the water side, and 2 to 1 on the lower side. The maximum height of both dams is 35 feet.

Reservoir Outlets.—Two 44-inch diameter riveted steel pipes pass through the base of the south dam at the head of the pipe lines. From the core-wall to the upper toe of the dam these pipes are embedded in concrete, but from the core-wall to the lower toe they are in open culvert with a common centre wall and reinforced roof, insuring perfect drainage and allowing inspection. A concrete intake structure is built at the upper end of the pipes, and the control of water is obtained by means of two 54-inch diameter roller-bearing sluice gates, behind suitable trash racks. The gates are controlled from the top of a structural steel gate tower, which is connected with the crest of the dam by a light foot bridge.

Spillway.—An emergency spillway is built in the solid ground at the east end of the north dam, and any surplus water is here returned to the river, which flows in the valley about 400 feet below the forebay level. The crest of the spillway is 5 feet below the dam crests.

Costs.—The two earth fill dams which impound the water in the forebay reservoir contain a total of 50,850 cu. yds. of material. The cost of this work, including clearing and foundation work, was at the rate of $1.55 per cu. yd. in the fills.

The function of the forebay is to increase the peak load capacity of the power house by providing storage immediately at the head of the pipe line, and also to furnish a reserve supply of water sufficient to operate the generating machinery for a few hours in case of accident to the flume. Although the capacity was sufficient to provide for the original installation at the power house, subsequent installations have increased the demand until the reserve supply of water in the forebay only serves to operate the plant for a few hours if the flume is cut out. The storage is sufficient, however, to carry the plant over peaks, and this is by far the most important consideration.

The capacity of the forebay reservoir can be increased materially by raising the height of the dams, but this would necessitate the replacing of several thousand feet of the lower end of the flume with steel or concrete pipe, as it would necessarily have to discharge under the surface of the water in the forebay.

PIPE LINES.

The pressure pipe lines from the forebay to the power house are 9,290 feet long. They follow the general slope of the hill, and are laid in shallow trenches with the earth back-filled to form a cover over the pipe. There are numerous vertical bends of a few degrees each, as the slope of the hill side is not uniform, but there are no sumps or crests in any of the pipes. The lines are practically straight from the forebay to the power house, with only a slight horizontal bend near each end. In excavating the trenches for the pipes, all surface soil was removed, and the pipes are well supported on hardpan or gravel for their entire length. The space between the bottom of the pipe and the trench is tightly packed with small rocks and gravel, and this serves to give uniform support over the entire length of the pipe, and also forms a drain for seepage water. Concrete deflecting walls built at intervals along the pipe turn this water out of the trench and into natural drains along the hill.

The pipe line right-of-way traverses a belt of very heavy timber, and in order to protect the pipe from falling trees, the clearing was made much wider than the width of the right-of-way. Since the installation of the first pipe, most of the hill side has been logged off by a lumber company operating at Jordan River, so that there is now no danger of interruptions to the service due to falling timber.

No. 1 and No. 2 Pipe Lines.—The west pipe through the forebay dam supplies water for No. 1 and No. 2 generating units, which have a capacity of 4,000 k.w. each. A 44-inch inside diameter riveted steel pipe, made up of parallel inside and outside courses and varying in thickness from ¼-inch at the top to ⅜-inch at the bottom, extends 3,067 feet down the hill from the dam. At this point it is flanged and bolted to a cast steel wye piece having 36-inch diameter outlets, to which are bolted 36-inch single disc steel body gate valves with rising stems. Immediately below the gates are 36-inch expansion joints. From here the pipe decreases in diameter from 36 inches to 30 inches at the power house.

No. 1 pipe is a lap-welded steel pipe varying in thickness from 5/16-inch at the wye to 9/16-inch at the power house. The joints between the sections are spherical "bump joints," with double or single rows of rivets depending on the thickness of the steel. For 2,200 feet above the power house the pipe is banded with 1-inch steel bands having malleable cast-iron shoes. This banding was considered necessary on account of possible severe rams in the pipe caused by quick governing.

No. 2 pipe is a heavy riveted pipe made up of parallel outside and inside courses, the thickness varying from ½-inch at the wye to 1-inch at the power house. The longitudinal joints are provided with double cover plates, making a joint of about 78% efficiency. Although this pipe is ¼-inch greater in diameter than No. 1 pipe, the results obtained are not so good. The very rough interior surface of the pipe which results from the parallel courses and the numerous rivet heads, increases the friction, so that there is a very considerable loss of head when the unit is loaded. The friction loss, or loss of head, is nearly 15% greater for No. 2 pipe than for No. 1.

No. 3 Pipe Line.—The east outlet gate in the forebay dam supplies water for No. 3 generating unit, which has a capacity of 8,000 k.w. No. 3 pipe is connected to the outlet pipe just below the dam by a taper section of pipe, increasing in diameter from 44 inches to 54 inches at the bottom. The upper 1,960 feet of No. 3 pipe is 54 inches in diameter, and below this point it is 48 inches in diameter to the power house. For 2,500 feet below the forebay, the pipe is riveted steel, made up in parallel courses and varying in thickness from ¼-inch to 7-16-inch. Below this, and extending to the power house, the pipe is lap-welded, varying in thickness from ½-inch to 1⅛-inches. Riveted spherical bump joints are provided, those in the heavier pipe being double riveted and in the lighter pipe single riveted. The standard length of the sections of this pipe is 30 feet, and they are made up of two large sheets of steel with one longitudinal joint, the two lengths being welded together to form the section. The specials or bends are made up in the same manner with the angle at the centre or circumferential weld. The abrupt angle in the pipe may offer some resistance to the flow of water, but the smooth interior surface of the pipe more than compensates for this slight loss.

Piers.—Immediately behind the power house the pipe lines ascend a steep hill about 175 feet high. The nature of the ground in this slope is none too stable, there being several strata of sand or loose gravel, and on this hill the pipe is supported on substantial concrete piers carried down to sound foundations. With the exception of these piers, and a few small concrete supports under No. 3 pipe where it passes over some doubtful ground, there are no piers or other supports under the pipes. The cast steel wye pipes and gate valves on No. 1 and No. 2 pipes are, of course, set in concrete. At the back of the power house each pipe is securely anchored to a heavy concrete block. This anchor block for No. 3 pipe is 18 feet deep and weighs approximately 150 tons.

Air Valves.—Pipes No. 1 and No. 2 are each equipped with 6 air valves, about equally spaced along the lines. Each pipe has also three manhole openings, one located at the lower end, one at the wye pipe, and one half-way between these two. There is also a manhole in the 44-inch pipe just below the forebay. Pipe Line No. 3 is provided with 7 air valves, about equally spaced along the line, and the manhole openings are located 1,000 feet apart along the entire length of the pipe. This generous use of manholes was of great assistance in the erection of the pipe, the extra cost being more than compensated for by the time gained and the wages saved.

Erection of Pipe Line.—The sections of No. 1 and No. 2 pipes were comparatively light, and were easily handled in the trench, but the lower sections of No. 3 pipe weighed from 7.5 to 9 tons each. These heavy sections were assembled in the trench by means of a moveable A frame, placed parallel to the trench and guyed forward and backward. The pipes were picked up with the tackle and the frame was then allowed to lean over the trench by loosening the back guy, and the pipes were lowered into place. The rig was operated by means of a double drum hand winch. As many as 10 sections of the heavy pipe were placed and bolted up in an 8-hour day.

All rivets were driven by pneumatic hammers and held up by air dollies. Air at 100 or 125 pounds pressure was furnished by a small steam-driven air compressor, which was moved along the line as the work progressed.

Pipe Coating.—The welded pipe in lines No. 1 and No. 3 is coated with some special pipe paint. This paint was applied with a brush while the pipes were hot, and forms a coating of exceptional durability. It is smooth and hard and adheres tightly to the metal, but even under the severe conditions of handling the pipe many times in the transportation, it has shown no tendency to flake or crack off. The riveted pipes are coated with Pioneer pipe compound, applied by dipping the sections into a tank of the hot compound.

The erection of pipe line No. 1 was completed the latter part of 1911, and No. 2 pipe, from the power house to the wye, was installed the following year. These two pipes have been in constant use and have given no trouble of any kind.

Tests on No. 3 Pipe.—Connected with the installation of No. 3 pipe there are some experiences which might prove of interest. The erection of this pipe was started late in the summer of 1913, and the field work was finished the first part of January, 1914. On filling the pipe for the first time, several leaks developed in the circumferential welded joints of the heavier pipes near the power house when the pressure was only a small fraction of the static head to which the pipes would be subjected when filled to the top. These leaks were repaired by riveting heavy butt-straps around the pipe at the faulty welds, but on account of the possibility of other leaks developing and damaging the power house or the other pipe lines, it was decided not to fill No. 3 pipe until it had been tested and made safe against further failures.

All of the pipe sections had previously been tested at the pipe factory by subjecting them to a test pressure at least 50 per cent. in excess of the static head under which they would operate. It was thought, however, that the pipes might have been injured in transportation.

It was planned to test the pipe in comparatively short sections, so that in case of failure the amount of water in the section under test would not be sufficient to do any damage. To make these tests, a bulkhead was designed to fit in the pipe at the upper end of the section under test and to confine the water between that point and closed gates at the lower end of the pipe.

The bulkhead was made up of a dished steel casting about 2½ inches less in diameter than the internal diameter of the pipe. The circumference of this casting formed the base of a packing gland built up of steel rings which confined the packing. The packing consisted of two rings of 1 inch square hard steam packing, one on either side of a ring of rubber packing 1 inch thick and 2 inches wide. The back steel ring of the gland was provided with 16 forged steel dogs which held the ring from moving up the pipe, the ends of the dogs resting against the end of the next section of pipe at a riveted joint. The pressure of the water against the bulkhead compressed the packing by forcing the bulkhead or disc into the back ring of the gland, which was in turn held securely in place by the dogs, thus making a water-tight joint. The whole contrivance was mounted on rollers to enable it to be moved along the pipe.

The pipe line was cut at the upper end of the welded portion of the pipe, and the bulkhead was lowered from here by means of a light wire rope to the upper end of the section to be tested first. Some trouble was experienced at first in setting up the bulkhead in the pipe, but after several unsuccessful attempts the pipe crew learned to overcome their difficulties and were able to make a tight joint.

The pipe was filled up to the bulkhead through a by-pass from one of the old lines, and the pressure was raised to the required test pressure by means of a large hand operated boiler test pump. The bulkhead was provided with an air valve to exhaust all air from the pipe and make sure that the space was entirely filled with water. A pressure gauge was attached to the pipe and in each test the pressure was raised by means of the pump to 35% in excess of the presure due to the static head, this pressure being recorded at the lower end of the section under test. Before making the excess pressure test, each section was tested under static head by hammering along the welds with 3-pound hammers.

So far as the writer has been able to learn, this is the first time a large, high-pressure pipe line has been tested in the field after erection. The results obtained at Jordan River would indicate the practicability of such a test, and it must be admitted that such a test is of great value in proving the pipe, not under shop conditions, but under actual working conditions.

These tests suggest the use of a bulkhead, similar to the one used at Jordan River, in connection with the erection of almost any long pressure pipe line. By the use of such a bulkhead the pipe could be tested from the bottom as the work proceeds. It could be kept filled with water and the trench could be backfilled at once, thus avoiding the usual temperature stresses set up in such a pipe line.

The Pelton Water Wheel Company, who were the contractors for No. 3 pipe line, designed the bulkhead and made the tests on the pipe under the direction of the Vancouver Island Power Company's engineers.

Plate No. 6 shows the design of the bulkhead and the method of setting it in the pipe for testing. Figs. Nos. 9, 10 and 11 are views of the bulkhead and of the pipe lines.

POWER HOUSE.

The power house is located near the beach and about 2,500 feet east of the mouth of the river. The pressure pipe lines enter the rear of the building, and the water from the wheels is discharged at the front, where it enters a short tailrace channel, which empties into a tidal slough joining the river near its mouth.

The original power house building, completed in 1911, is a concrete structure, having a ground area 91 feet 6 inches long by 47 feet wide. In this building space was provided for two generating units of 4,000 K.W. capacity each, two 100 K.W. exciter units, two banks of transformers, and other auxiliary electrical apparatus to complete the equipment. No. 1 generating unit was put in operation the latter part of 1911, and the following year No. 2 unit was installed.

Sub-Surface Investigation.—Before starting on the construction of this building test pits were sunk to determine the nature of the underlying material. Test piles were also driven and were loaded, and found to successfully support over 5 tons per square foot. The pits uncovered a stratum of hard, sandy clay about 18 to 20 feet below the ground surface. Bedrock was known to lie about 50 to 75 feet below the surface, but it was not considered necessary to go this deep to be assured of a satisfactory foundation. The building and machinery foundations were designed to be placed on the hard clay stratum, about 18 feet below the surface, with a maximum load of not over 4 tons per square foot.

When the construction was nearly finished it was noted that the building and machinery foundations appeared to be sinking, and this fact was verified by taking levels. By means of a small well-drilling outfit several test holes were sunk to bedrock, and it was then found that the hard sand and clay stratum extended only some 16 feet below the base of the foundations, where it merged into coarse gravel and sand, extending about 10 feet further, below which, at a depth of about 25 feet beneath the foundations, a 20-foot layer of soft mud and peat existed, which yielded to the pressure of the stratum above with its super-imposed load. This bed of peat and clay lay directly over the soft sandstone bedrock. These test holes proved very conclusively that the flat on which the power house was built was formed by a series of slides off the steep hill behind. It is of interest to note that in sinking the test drill holes and the foundation piles the drill passed through fir logs about 6 feet through and 40 feet underground, which appeared from the chips and borings brought up in the sand pump, to be in a perfect state of preservation. Later on some pieces of Indian basket were pumped up from a depth of about 25 feet. The great age of the fir logs and the basket may be estimated from the fact that trees growing on the surface of the ground could not be less than 400 or 500 years old.

Machinery Foundations.—When the sub-surface formation was determined, steps were at once taken to reinforce the machinery foundations. A trench was excavated around these foundations, and they were cut entirely free from the building. By means of a well-drilling outfit 22 12-inch standard pipe casings were sunk around the foundations to bedrock, and these casings were filed with concrete. Holes were cut through the foundations near the bottom and large I-beams were inserted, resting on the tops of the concrete piles. These beams were concreted into the foundations and the tops of the piles were encased in concrete, making a solid mass above the tops of the piles and assuring a rigid support.

No. 1 pipe line was cut about three-fourths of the way around in two places immediately behind the power house. These cuts were banded with heavy cast-iron muffs, which were caulked with lead wool, and in this way flexible joints were provided so that no strain could be thrown on to the pipe by any movement of the building or the machinery foundations.

A pile foundation similar to that for No. 1 unit was driven for supporting No. 2 unit, but in this case the concrete foundation was built directly over the piles and not supported on I-beams. No piles were put down to support the building, as this was not considered necessary, since it was cut entirely free from the foundations of the machines. Such slight settlement of the building as has occurred has not been serious. The walls are cracked in a few places, but aside from this no damage has been done.

Addition to Power House Building.—The construction of the addition to the power house was started in the spring of 1913, but on account of unavoidable delays, which necessitated shutting down all construction work for about 8 months, the work was not finished until September, 1914. The new building is not altogether an extension to the old one, but was constructed as an entirely separate building, not being tied to the old one in any way. It covers about double the area of the old building. The main part of the new building is a continuation of the old one, and is 120 feet long and 47 feet wide, forming the generator room. Behind this, and also extending behind the old building for over half its length, is a large room, 130 feet long by 27 feet wide, which forms the high-tension switching room.

The floor of the old building is at elevation 107.5, or 7½ feet above high tide. This was considered too low, as there might be a possible combination of high tide and strong wind, which would back the water up into the wheel pits and put the plant temporarily out of commission. The floor of the new building was, therefore, built 5 feet higher than this, with a corresponding difference in the elevation of the wheel pits.

Foundations.—The whole weight of the building and machinery is supported on concrete piles resting on bedrock. These piles are similar to those supporting No. 1 and No. 2 units in the old power house. They were cast in 12-inch diameter standard pipe casings, which were driven by a well drill, and vary in length from 45 to 75 feet, the average length being 56½ feet. The total number of piles under the building and machinery foundations is 102, and these are so placed as to equalize the load as nearly as possible, the average load per pile being about 28 tons.

The piles were cut off below the basement floor level, which is at elevation 102.5. Those under the walls of the building are capped by a heavy reinforced concrete beam, which supports the walls of the building and also the edges of the basement floor. The floor of the basement is a reinforced concrete slab, 8 inches thick, which is continuous over the entire area of the basement, securely tying together the tops of all the foundation piles, and thus assuring a very solid and rigid structure. Between the piles all soft surface soil was excavated down to gravel stratum, and the excavation was backfilled to the bottom of the floor slab with gravel and sand, tamped in, to form an unyielding support for the floor above. Over the groups of piles which support the machinery the floor thickness was increased to 2 feet and reinforced with 1-inch square rods on 12-inch centres both ways. This heavy slab extends for nearly the whole length of the generator room and supports the concrete foundations for the generators and exciters. Reinforcement rods are embedded for 6 feet into the tops of all the piles and are bent over to tie into the concrete resting on the piles.

Building Details.—In order to limit the loading on the foundation piles the building was constructed as light as is consistent with good design. The walls are 12 inches thick up to the level of the main floor, and above that they are 8 inches thick, but stiffened by pilasters placed 13 ft. 6 ins., centre to centre. The pilasters are heavily reinforced with ⅞-inch rods and the walls are reinforced with ⅜-inch rods on 18-inch centres both ways. The roof is a reinforced concrete slab, 3½ inches thick, and supported on steel roof trusses and I-beam purlins. The front crane girder is supported on the front wall pilasters, which extend 12 inches inside the wall, but the back girder rests on 15-inch I-beam columns, which are supported on concrete columns below the main floor. These I-beam columns are continued above the crane girder step, and support one end of the roof trusses along the peak of the roof.

The new part of the power house building is not joined to the old part in any way, and in case of any further settlement of the old building, the new part will not be affected. Wherever the walls, floors or roof of the new building come in contact with the old work a slip joint is provided. This joint was made by painting the old concrete along the surfaces of contact with several thick coats of asphaltum compound, which is commonly used for filling expansion joints in concrete work. This compound does not become soft and run out of the joints at any ordinary temperature.

Space is provided in the new building for two generating units, with exciters and other auxiliary electrical apparatus, but only one unit is installed at the present time. The new high-tension switch room is designed to accommodate all of the high-tension switches for both the old and the new installations, and space is also provided in this room for two sets of inside type lightning arresters.

4,000 K.W. Generating Units.—No. 1 and No. 2 units, in the old building, are identical in size and design. Each of these has a 4,000 k.w., 2,200 volt., 3-phase, 60 cycle Allis-Chalmers-Bullock generator, driven at 400 r.p.m. by a single Doble tangential water wheel of 6,000 h.p., which is mounted on one end of the shaft and overhangs the bearing at that end of the unit. The shaft is a hollow, nickel steel forging, having a diameter of 14 inches in the bearings, which are 48 inches long. These bearings are peculiar in that they have no top shell. The weight of the revolving parts is sufficient to overcome any tendency of the shaft to lift or roll out of the bottom shell, and the whole upper half of the shaft being exposed, a great quantity of oil is spread over it by the oil rings, and efficient lubrication is assured.

Water is conveyed from the terminal end of the pressure pipe through a cast-steel flanged taper pipe, which is bolted to the flanged end of the pipe. This taper piece decreases in diameter from 30 inches to 24 inches at the outlet end, where it is bolted to a hand-operated, 24-inch, single disc, steel body, rising stem gate valve, which is provided with a by-pass. The steel nozzle casting is bolted to this valve. The jet of water is projected on to the wheel through a Doble needle regulating nozzle, and the governing is done by a type "Q" Lombard governor, operating the needle gear by means of an oil pressure cylinder. Surges or rams in the pipe line, caused by the quick closing of the main nozzle, are prevented by the Doble relief nozzle. This nozzle is similar to the main nozzle, but is located below it, and the stream does not hit the buckets on the wheel, but discharges freely down the tailrace. This relief nozzle is operated by the governor through links connected to a dash-pot or differential cataract on the relief needle stem. The gradual closing of the main nozzle does not operate the relief, but in case of quick closing the cataract comes into operation and the relief opens as rapidly as the main nozzle closes. Heavy coil springs bring about the gradual closing of the relief nozzle, and the time of closing can be regulated by adjusting the cataract by-pass valves. Oil pressure for the operation of the governor is supplied by a motor-driven oil pump which automatically maintains the pressure in the supply tank.

8,000 K.W. Generating Unit.—No. 3 unit was put into operation in October, 1914. This unit is an 8,000 k.w., 2,200 volt, 60 cycle, 3-phase, Canadian General Electric generator, driven at 400 r.p.m. by two Doble tangential water wheels, one mounted on each end of the shaft and overhanging the bearings. The water wheels are rated at 13,000 h.p. The shaft is a hollow, nickel steel forging, and is 16 inches in diameter in the bearings, which are 60 inches long. These bearings are of the single shell type, similar to those on No. 1 and No. 2 units.

The two wheels on this unit are supplied with water through a flanged cast-steel wye, which is bolted to the terminal end of the pressure pipe immediately behind the unit foundation. The entrance connection of the wye is 48 inches in diameter and the branches are 34 inches. To these branches are bolted cast-steel taper pipes, reducing to 24 inches, and to these are bolted the 24-inch single disc, steel body gate valves. These gate valves are operated by small, reversible water wheels, which are mounted on brackets on the yokes of the valves. The water motors operate the bronze nut on the rising stem of the valve through a system of spur and bevel gearing, and provide a dependable means for opening or closing the valves. Water is supplied to the wheels through short pipes connected to the hood of the valve, and an automatic device is provided which prevents over-running. The cast-steel nozzle bodies, with main and relief nozzles, are bolted directly to the gate valves.

Governors.—Each wheel is provided with an entirely separate direct motion, oil-operated, relay type governor, the piston of the governor motor cylinder being mounted directly on the extended needle stem of the main nozzle, and from this stem the auxiliary or relief nozzle is operated by double levers connected to the cataract on the stem of the auxiliary needle. This direct application of the motive power of the governor to the controlling means of the water wheel, without any intermediate connections, is a great improvement over the old system of applying the power through a system of links, with their inherent lost motion and backlash. These governors have given exceptionally good regulation without causing any appreciable surges in the long pipe line. In testing the governors the unit was run with water on both wheels and both governors in gear, with no load on the generator.

Connected with the governors is a special hand control consisting of a separate cylinder, the piston rod of which is connected to the main needle levers, and a hand oil-pump for operating this cylinder. When the governer is in gear the hand control is thrown out by opening a by-pass and allowing the oil in the cylinder to flow freely past the piston.

Oil pressure for the operation of the two governors is provided by a water motor driven gear type pump with a welded steel oil pressure accumulator tank. The pump motor is controlled by a float in a chamber connected with the accumulator tank.

Exciter Units.—A separate exciter unit is provided for each main generator unit. No. 1 and No. 2 exciters are 100 k.w., 125 volt, direct current generators on the same shaft with a 100-h.p. water wheel and a 150-h.p., 2,200 volt induction motor. No. 3 exciter is a 200 k.w. generator direct connected to a 200-h.p. water wheel and a 300-h.p., 2,200 volt induction motor. No governors are provided for the exciters, the speed being held constant by the induction motors. Water is supplied to the exciter wheels from a header connected to all three main pressure pipes. An arrangement of valves permits any exciter unit to be run off any main pressure pipe.

Cranes.—The old portion of the building, in which No. 1 and No. 2 units are located, is served by two hand power cranes of 30-ton capacity each. On account of the difference in elevation of the two buildings, these cranes could not be used in the new part. The new building is served by one 50-ton 4-motor electric crane.

Transformers.—The transformer equipment consists of two banks of 1,450 k.w. transformers, with one spare, and one bank of 3,000 k.w. transformers; all of the oil-insulated, water-cooled type. They step the voltage up from 2,200 to 60,000 volts, at which pressure the current is transmitted to Victoria. The transformers are set in compartments along the back wall of the generator room.

Switching Equipment.—The cables from the generators are carried in tile ducts embedded in the concrete floor of the building, to the generator switches, and thence to the bus room located in the basement at the west end of the new building. Directly above the bus structure, on the main floor, are located the 2,200 volt, oil break, automatic switches. After passing through these switches the current at 2,200 volts is carried along the back wall of the building behind the transformers, and from here is tapped to the primary side of the transformers. All of the 2,200-volt conductors are made up of ¼-inch by 4-inch copper bars, the number of bars used varying in proportion to the current to be carried.

Current at 60,000 volts is conducted from the transformers through the back wall of the generator room in porcelain wall bushings, and into the high-tension switch room. The high-tension buses are supported on insulators on the back wall of the room, and the oil-break switches are in a line down the centre of the room, directly under the disconnecting switches, which are mounted on a structural steel frame. All high-tension conductors are 1-inch copper tubing. Two 60,000-volt lines leave the building through large wall bushings, and lead to a steel distributing tower a short distance in the rear of the power house.

All lighting and control wiring in the power house is concealed in conduit pipe embedded in the concrete floors and walls.

Unit Costs.—The unit cost of the Jordan River Power Plant, including the power house building and all hydraulic and electrical equipment, is $20.60 per horse-power capacity. The present capacity is 25,000 horse-power, but provision has been made for the addition of one 13,000 horse-power unit, and when this machinery is installed the unit cost will be reduced to about $17.00 per horse-power.

Plate No. 7 shows a typical cross section of the power house, and Figs. Nos. 12 to 18 inclusive, are views of the exterior and interior of the building.

TRANSMISSION LINE.

The transmission line from Jordan River to the Victoria Sub-station is 37 miles long. For about 15 miles from the power house it follows the shore line through some very rough and heavily timbered country, but at that point it strikes inland for the remaining distance. The right-of-way is cleared on both sides of the line to a sufficient width to guard against the breaking of the line by falling trees.

The poles are of cedar cut from the forest adjacent to the line. They have a minimum diameter of 9 inches at the top, and are from 50 to 60 feet high. The cross-arms are of galvanized steel 9 feet long, and are made up of two 1¾-inch by 1¾-inch angles, with 1¼-inch angle diagonal braces to the pole. This provides for two 3-phase circuits, one carried on either side of the pole. The spacing of the poles varies from 300 to 400 feet, but there are several spans across gulleys which are much longer.

The conductor is aluminum cable made up of 7 strands of No. 8 wire. It is supported on two-piece brown glazed porcelain suspension type insulators. At all angles where the line is drawn towards the pole it is dead-ended, using two insulators with the conductor taken across in a suspended loop.

At present only one circuit is carried on the poles, but it is intended to string the second circuit in the near future.

Unit Cost.—The unit cost of the transmission line, including the cost of the right-of-way and all clearing, was $5,034 per mile.

ORGANIZATION.

The work, from the first pioneering to the final completion of the installation of the first 4,000 k.w. unit in the spring of 1912, was done under contract by Sanderson and Porter, of New York and San Francisco, under the direction of Wynn Meredith, who is one of that firm. The preliminary surveys were under the immediate charge of A. B. Carey, and E. E. Carpenter was in immediate charge of all construction.

Since the completion of the initial development, all work has been done under the direction of G. R. G. Conway, M.Can.Soc.C.E., Chief Engineer of the Company, with G. M. Tripp as engineering superintendent in Victoria. The writer has had charge of construction since September, 1912.

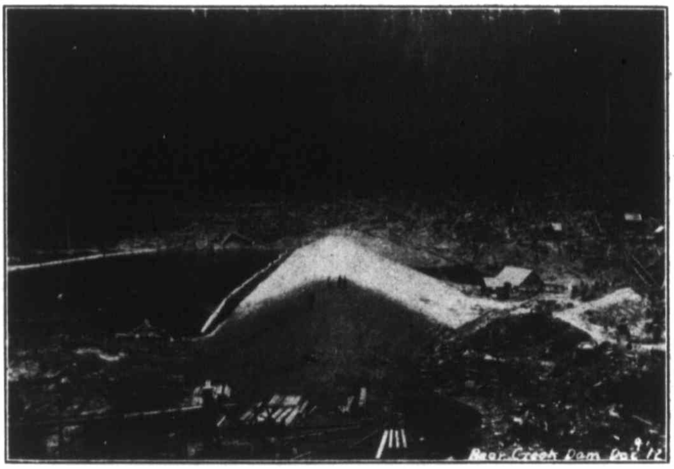


Fig. 1.—Bear Creek Storage Dam.

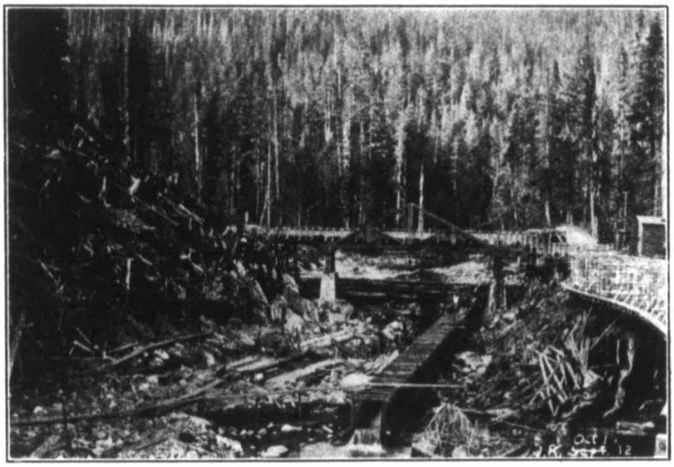


Fig. 2.—Starting construction of Jordan River Dam.

Fig. 3.—Deck construction, Jordan River Dam.

Fig. 4.—Looking down-stream, Jordan River Dam, during construction.

Fig. 5.—General view of the Jordan River Dam during construction.

Fig. 6.—Crib work for protecting flume below Jordan River Dam.

Fig. 7.—Jordan River Dam.—Completed structure.

Fig. 8.—Jordan River Flume.—High trestle construction.

Fig. 9.—No. 3 Pipe Line.—View from power house.

Fig. 10.—Pipe line right-of-way, showing No. 3 Pipe under construction.

Fig. 11.—Bulkhead used for making tests on No. 3 Pipe Line.

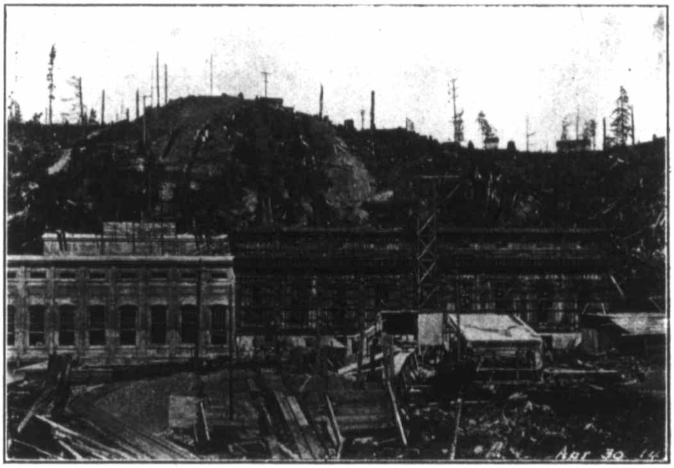


Fig. 12.—Front view of power house under construction.

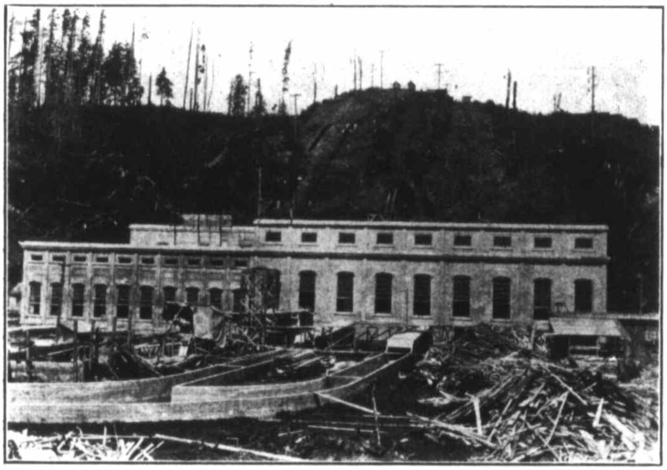


Fig. 13.—Front view of completed power house building, showing tailrace flumes.

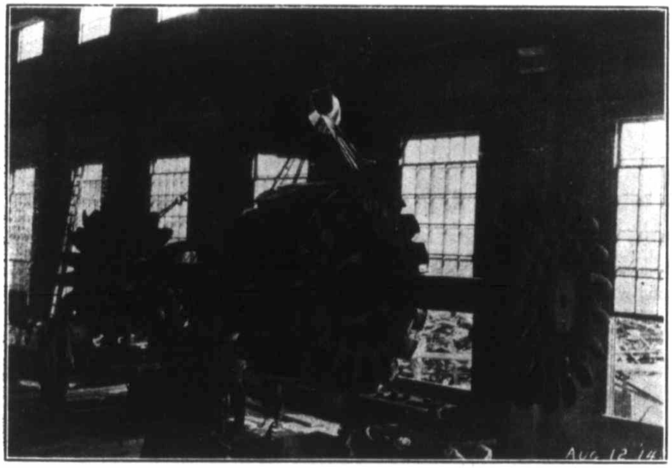


Fig. 14.—Rotating parts of 13,000 H.P. unit.

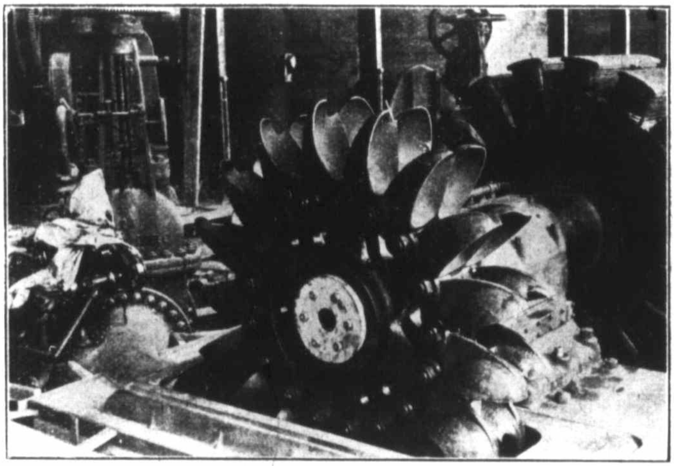


Fig. 15.—Near view of water wheel, 13,000 H.P. unit.

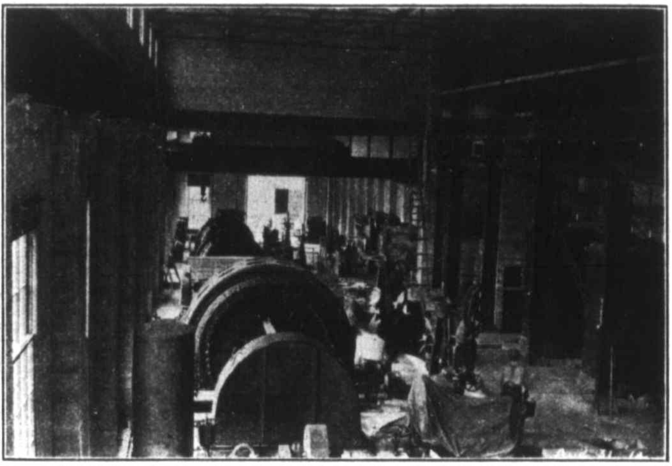


Fig. 16.—Interior view of power house.

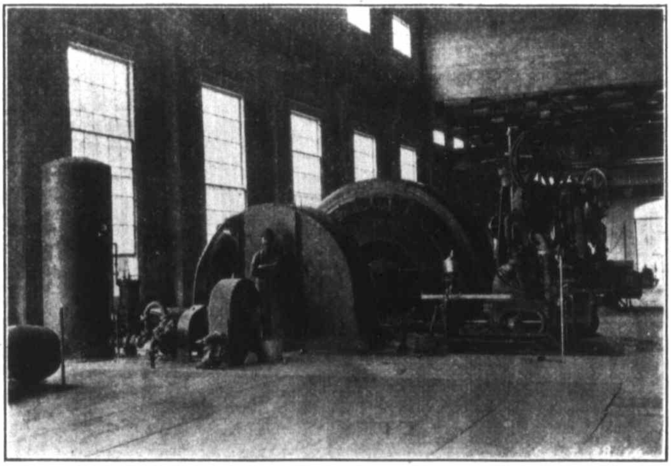


Fig. 17.—13,000 H.P. Generating Unit.

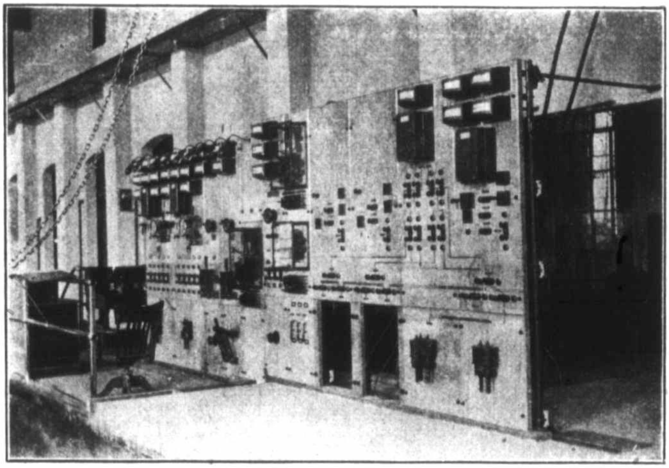


Fig. 18.—Switch-board, Jordan River power house.

PLATE 1.

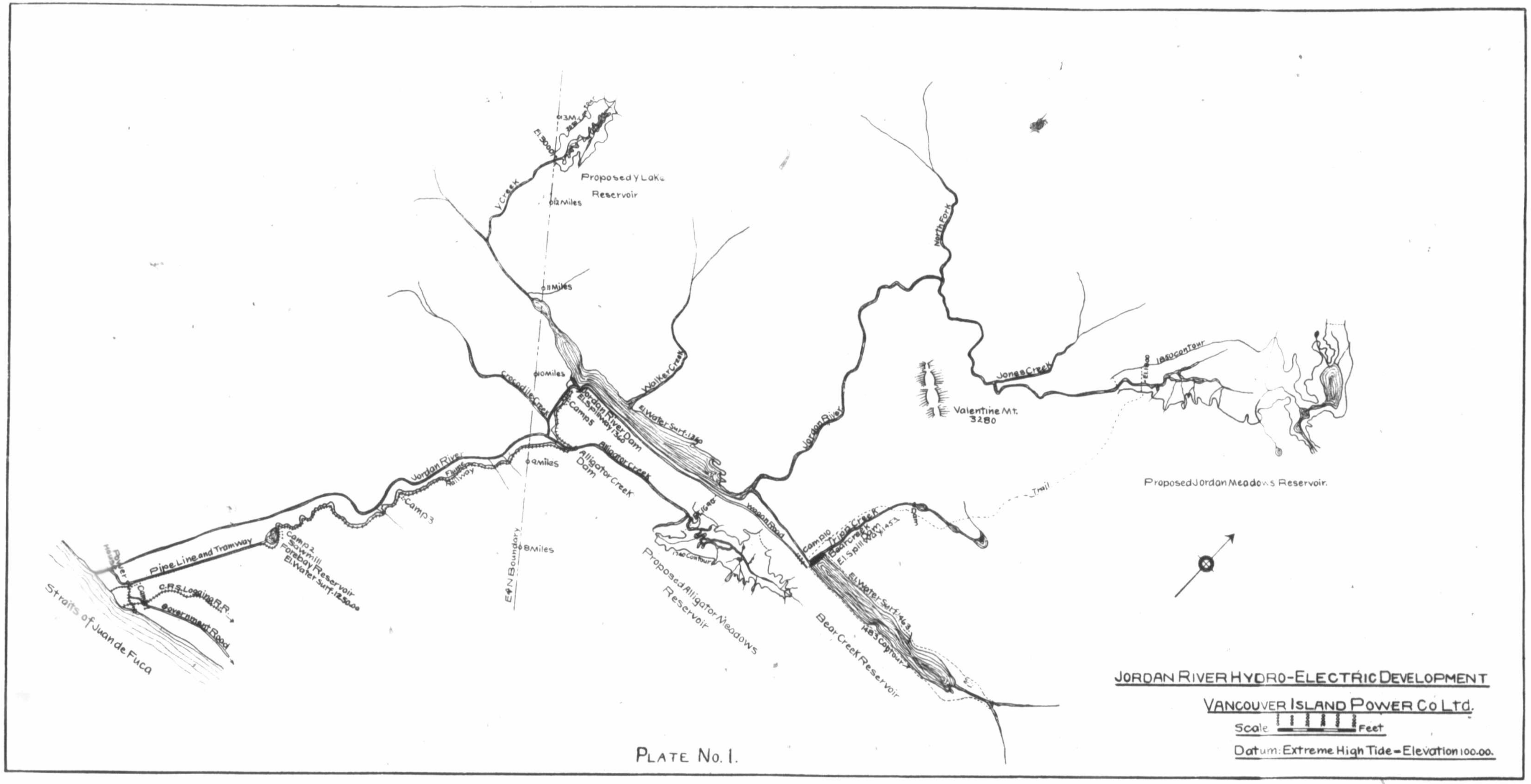
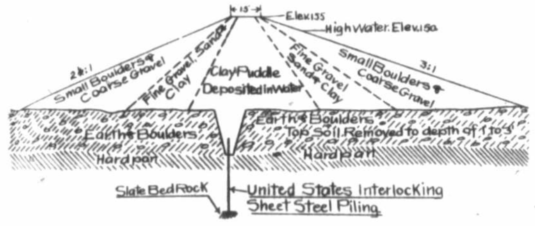


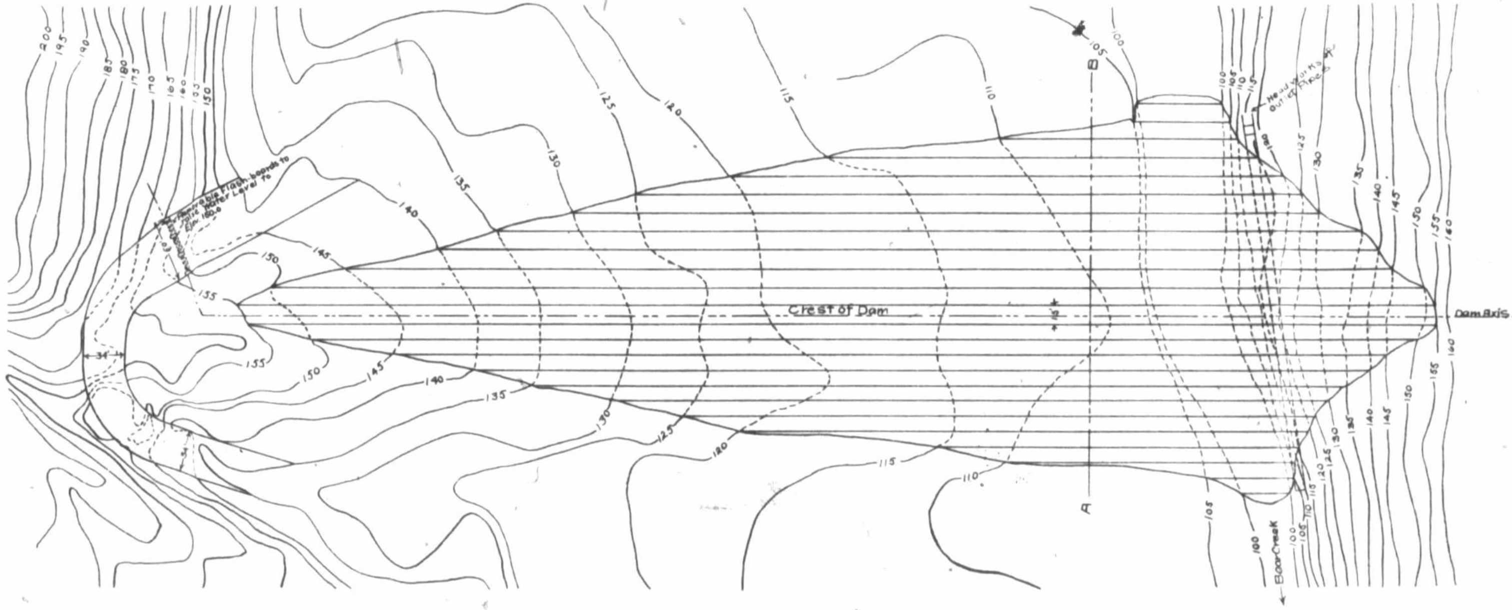
PLATE No. 1.

PLATE 2.



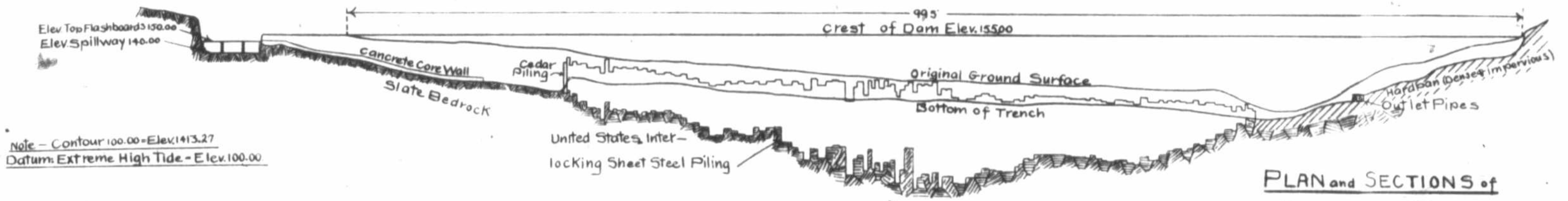
SECTION A-B

Scale 0 10 20 30 40 Feet



TOPOGRAPHY and PLAN of DAM SITE

Scale 0 10 20 30 40 50 Feet



Note – Contour 100.00 = Elev. 1413.27
Datum: Extreme High Tide – Elev. 100.00

PLATE No. 2.

LONGITUDINAL SECTION OF DAM

PLAN and SECTIONS of
BEAR CREEK DAM
VANCOUVER ISLAND POWER Co.

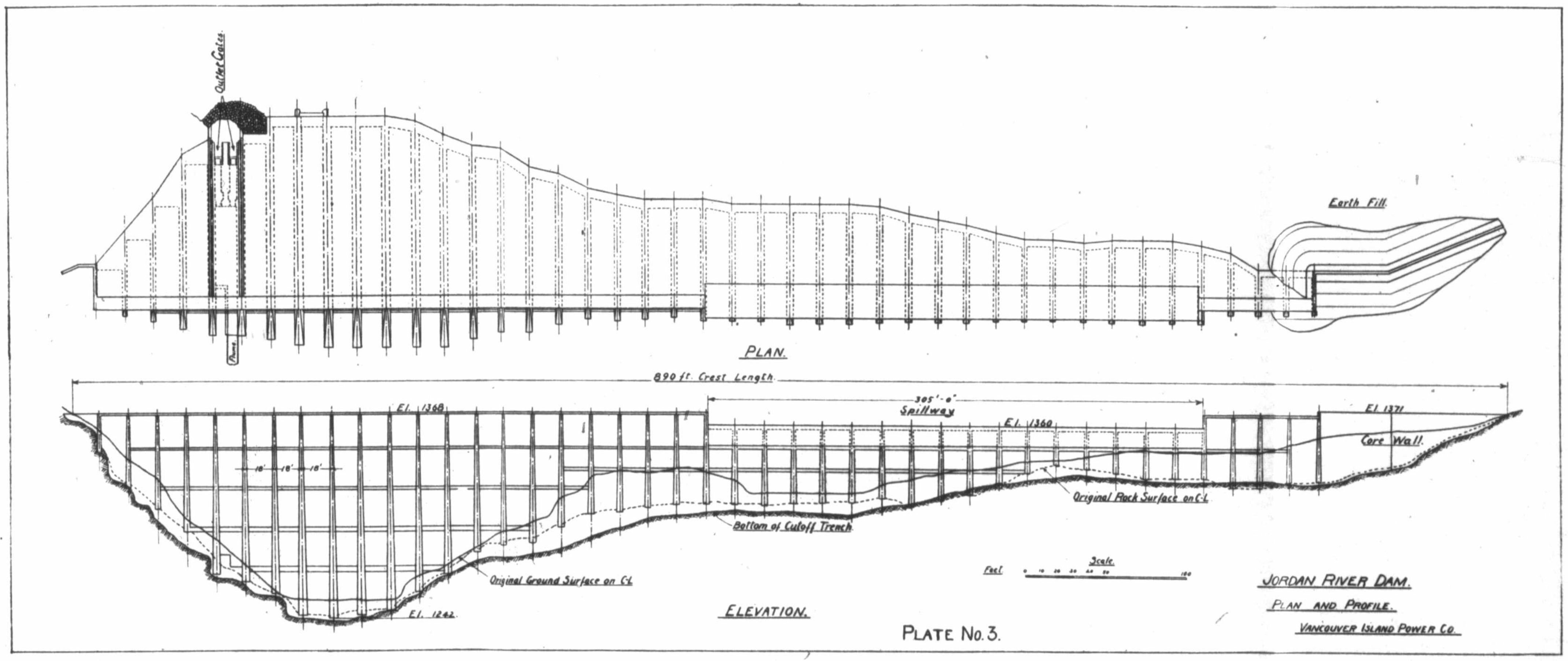
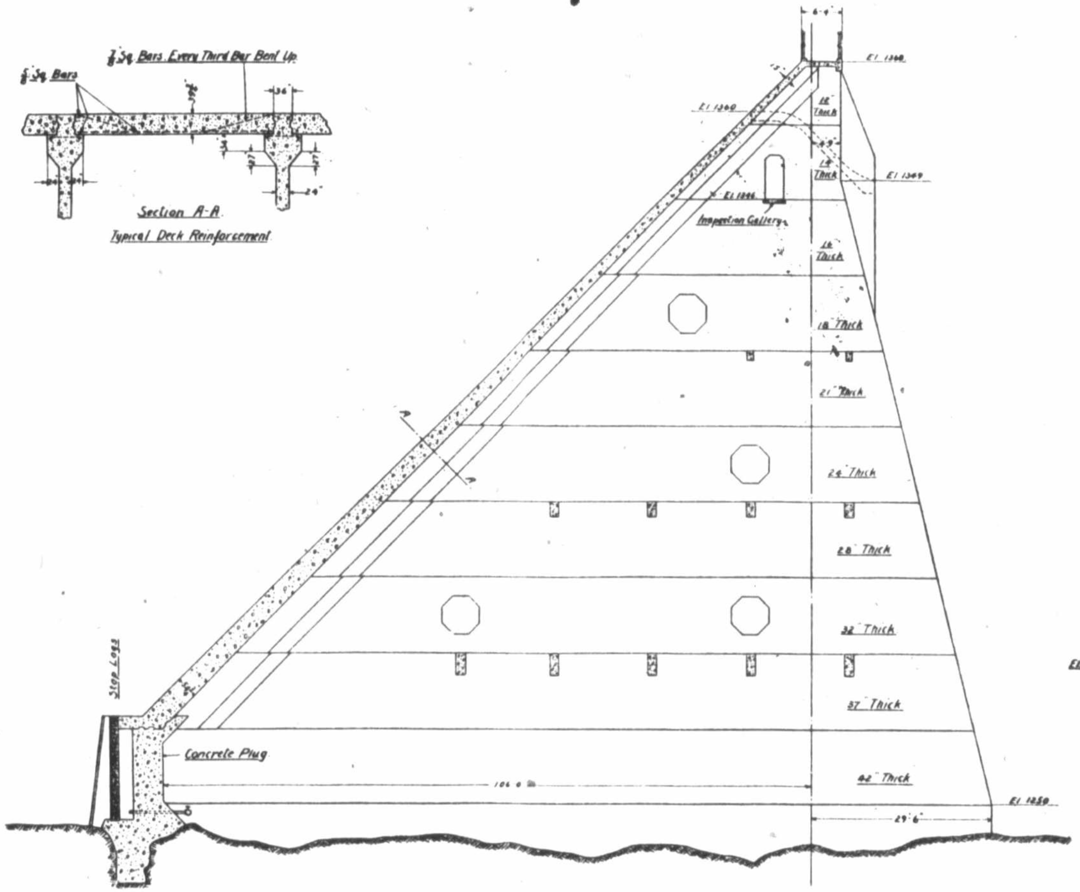

Outlet Gates
Flume
Earth Fill
PLAN.
890 ft. Crest Length
305'-0"
Spillway
El. 1368
El. 1360
El. 1371
Core Wall
18'
18'
18'
Original Rock Surface on C-L
Bottom of Cutoff Trench
Original Ground Surface on C-L
El. 1242
ELEVATION.
Scale.
Feet
0
10
20
30
40
50
100
JORDAN RIVER DAM.
PLAN AND PROFILE.
VANCOUVER ISLAND POWER CO.
PLATE No. 3.

PLATE 4.

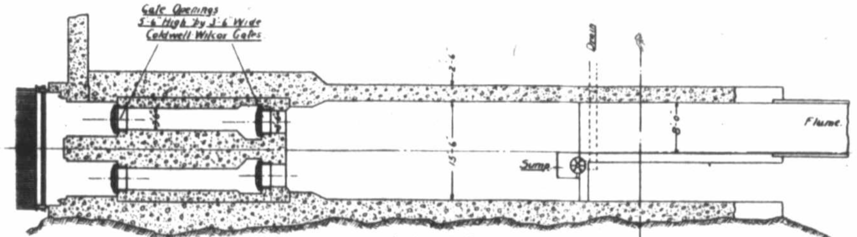


Section A-A.

Typical Deck Reinforcement

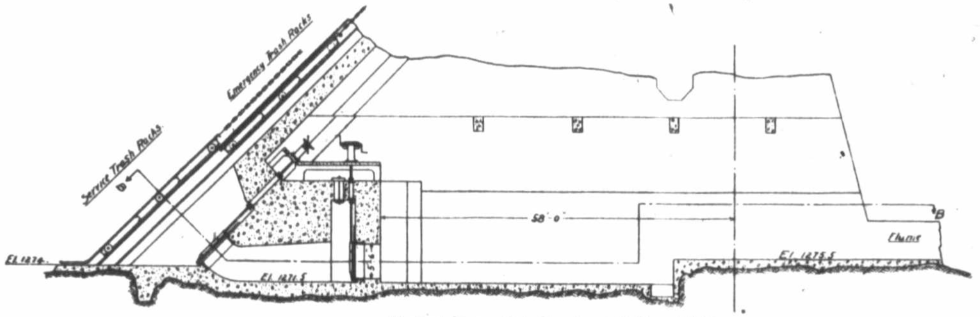
Elevation Maximum Buttress.

Showing Ambursen Closure



Section B-B.

Horizontal Section. Gate Chamber and Flume Intake.



Vertical Section. Gate Chamber and Flume Intake.

Scale

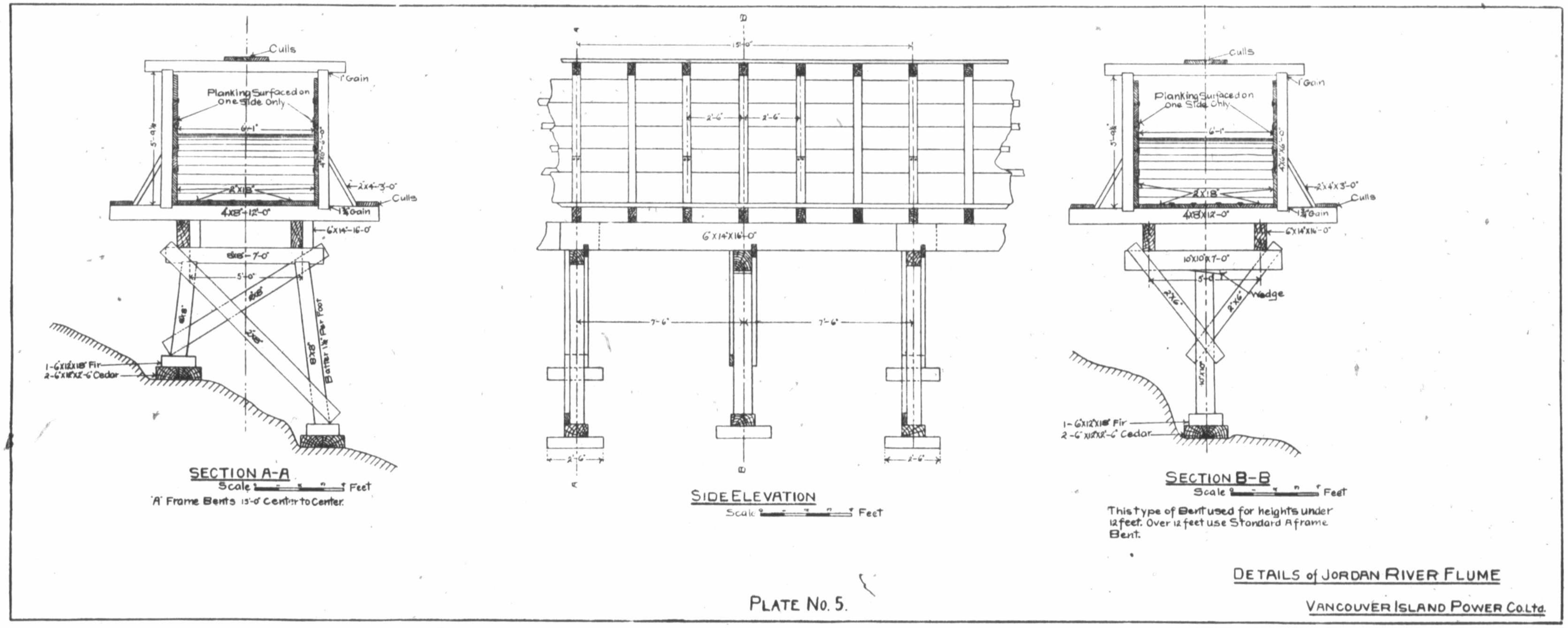
Feet

JORDAN RIVER DAM.

SECTIONS.

VANCOUVER ISLAND POWER CO.

PLATE NO. 4.



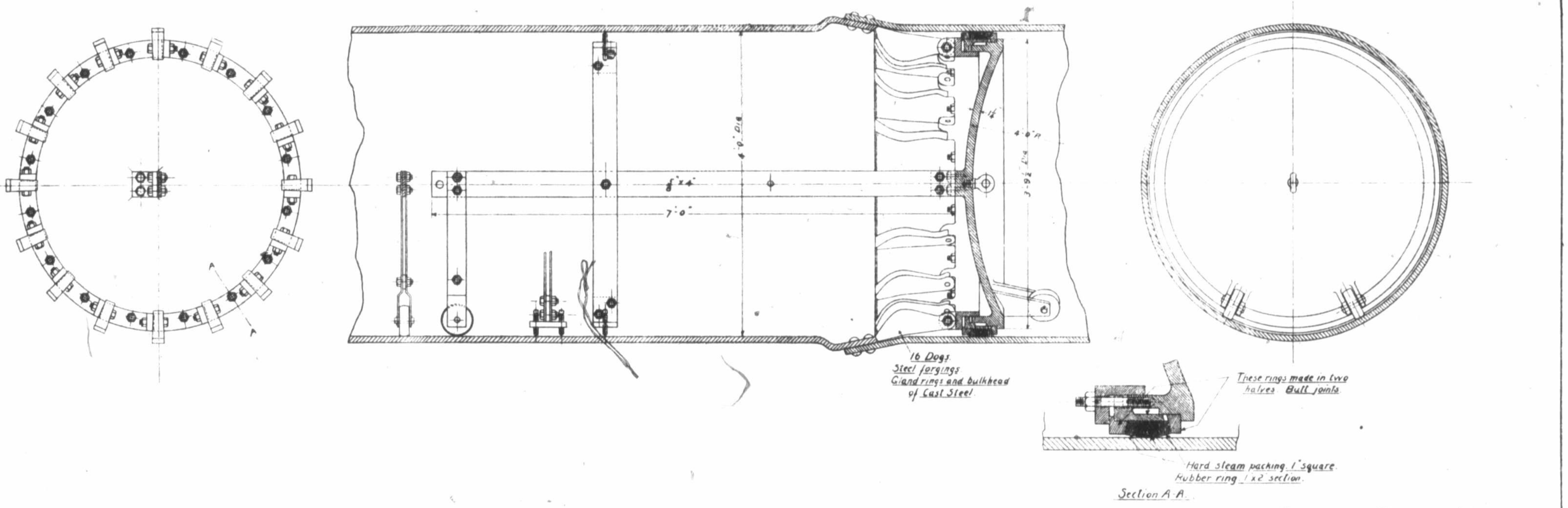
SECTION A-A
Scale Feet
'A' Frame Bents 15'-0" Center to Center.

SIDE ELEVATION
Scale Feet

SECTION B-B
Scale Feet
This type of Bent used for heights under 12 feet. Over 12 feet use Standard A frame Bent.

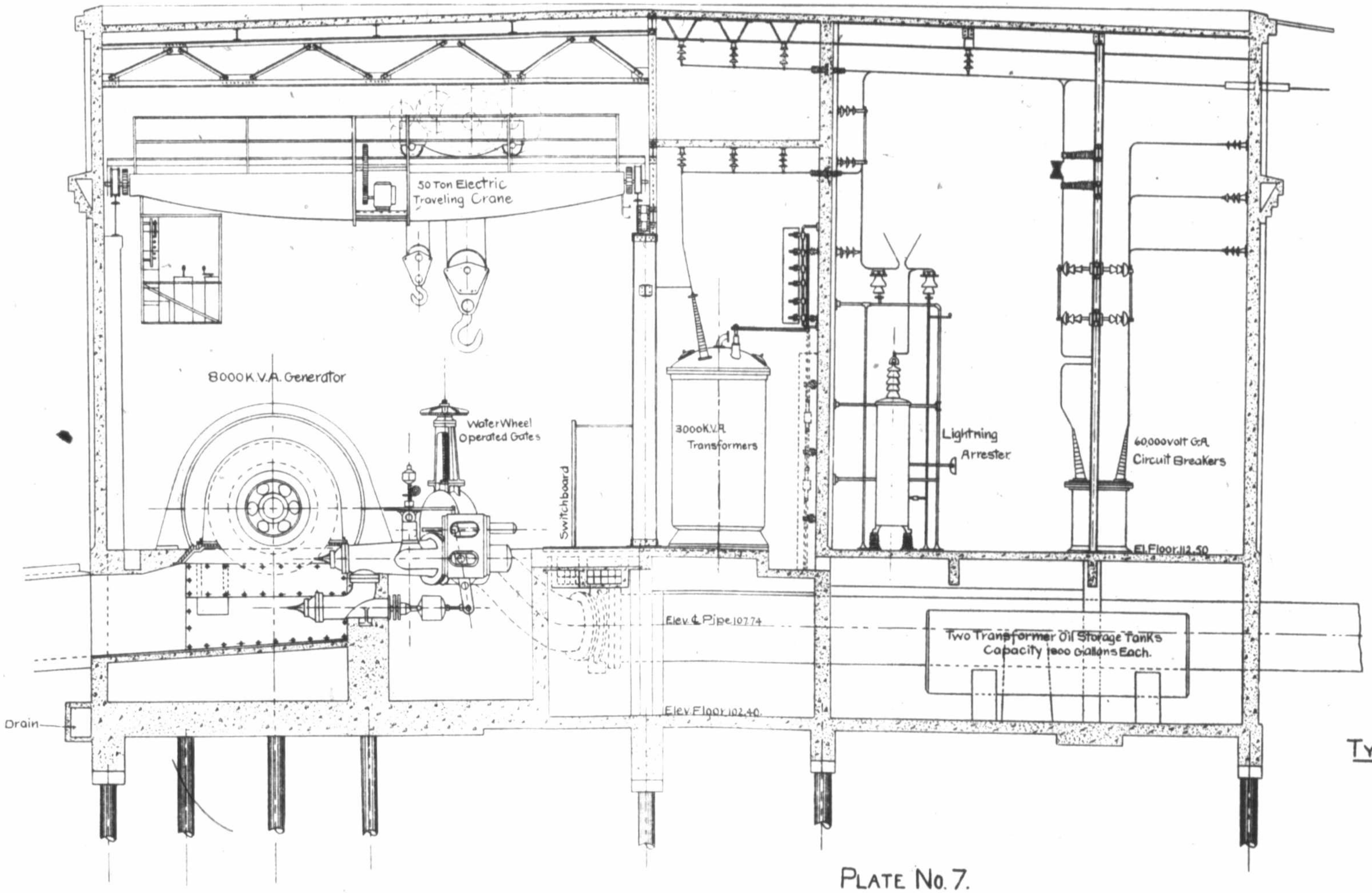
DETAILS of JORDAN RIVER FLUME
VANCOUVER ISLAND POWER Co. Ltd.

PLATE No. 5.



BULKHEAD FOR TESTING 48" LAP-
WELDED STEEL PIPE
JORDAN RIVER
VANCOUVER ISLAND POWER CO.

PLATE No 6.



TYPICAL CROSS SECTION JORDAN RIVER

POWER HOUSE

VANCOUVER ISLAND POWER Co. Ltd

Scale Feet

PLATE No. 7.