type of dam, is outlined below under the Warrendale plan. The results of exploration drilling suggested the advisability of locating the heavier gate section over the somewhat firmer foundation material encountered near the Oregon shore. The axis of the dam at the gate section would then be normal to the general direction of flow.

858. *Canal.*—Two locations for canal and power house have been considered in this plan, one on the Washington side and one in Oregon.

859. In the Washington location the canal would begin just above the dam. It would be entirely open, have no intake, and closely parallel the river down to a point just below the approach to the Bridge of the Gods. At the end of the canal the power house would be located approximately parallel to the river.

860. The character of the ground in which the canal section would be excavated and the practicability of locating a hydroelectric plant in the great slide in the State of Washington between Cascades Rapids and Hamilton slough is discussed below under the "North Shore plan." The excavation for the canal would involve the removal of approximately 20,000,000 cubic yards of material.

861. The alternate plan of locating the plant on the Oregon side would involve an open canal beginning a short distance above the upper end of present navigation canal. The canal would run practically parallel to the present navigation system for a distance of about 4,000 feet and end at the power house which would be located between the lower end of the present navigation canal and the easterly approach to the Bridge of the Gods.

862. Most of the material in which the canal would be excavated is Eagle Creek formation in place. The normal water surface in the canal would be at elevation 72, the water level in the controlled pool above the dam. The bottom width of the canal would be 390 feet, the side slopes 1½ to 1. The depth below normal operating water level would be 38 feet. The slopes would be designed with a concrete lining, allowing a velocity of about 7 feet per second at 115,000 second-feet flow. The average depth of the canal would be about 125 feet and the total excavation would involve some 7,000,000 cubic yards.

863. *Power house and power output.*—Because of the drowning-out effect during periods of high water, with consequent loss of head, units designed for the head at low-water stages would produce little power or none at all during high water. A large number of additional lower head units would be required to insure firm power to the extent dictated by conditions at ordinary stages. To provide these extra units would make the cost of plant excessive. For this reason 10 units only, designed for maximum efficiency at lower stages of the river, have been estimated in the plan; and the plant has been assumed to form an auxiliary or supplementary plant in a power system outside the regimen of Columbia River, in which system it would, for a considerable portion of the year, be able to furnish power at periods when conditions at other units in that system might prevent their operation at full capacity. In this manner a plant at Cascade Locks would assist that system in maintaining a comparatively uniform output at reasonable cost.

864. The 10 units proposed would be rated at 32,000 kilowatts at 50 feet head and the turbines would be of the adjustable-blade propeller type. At a flow of 55,000 second-feet, with a net head of 55

feet, the output would be 225,000 kilowatts. At a flow of 110,000 second-feet the plant output would reach a maximum of 345,000 kilowatts. At a flow of 200,000 second-feet 270,000 kilowatts would be realized and at 400,000 second-feet 140,000 kilowatts. At a flow greater than 400,000 second-feet the power output is doubtful on account of the loss in head. A probable output of 50,000 kilowatts may be assumed at 600,000 second-feet flow. With a flow of 600,000 second-feet or more, occurring about 2 percent of the time, or on an average of one week each year, the plant would be completely out of commission.

865. *Navigation.*—With a hydroelectric plant at Cascade Locks such as outlined above, conditions affecting present navigation of the river would remain unchanged.

866. *b''. North Shore plan—Location.*—The dam in this plan has the same location, at the head of Cascades Rapids, as in the Cascades Rapids plan. Headwater can be limited optionally to elevations 54, 60, or 72. For comparison with the Bonneville and Warrendale plans, elevation 54, utilizing the full natural fall between head of Cascade Rapids and tidewater, has been adopted in this investigation.

867. From a point on the Washington shore just above the dam, excavation for power canal would follow the general location of the present railroad for about 3½ miles down to the head of Hamilton Slough, where the power house and (possible) new navigation locks would be located. (See pl. 83.) The tailrace, about three quarters of a mile long, would enter the present channel at a point opposite Bonneville.

868. *Dam.*—The length of the dam would be practically the same as in the Cascades Rapids plan. It would, however, include only three gates located in the deep channel next to the Washington shore. They would be of the roller type, 130 feet long by 15 feet in vertical height. Adjacent to the gate section would be an open spillway 1,200 feet long with crest at elevation 72. Between the easterly end of this spillway section and the Oregon connection would be another spillway 1,000 feet in length and with crest elevation at 54. The combined spillway capacity would be such that floods above 660,000 second-feet would pass over the dam without exceeding the natural flood heights. A flood peak of 660,000 second-feet or more has occurred in the past somewhat less frequently than once every other year. The flood crest at 660,000 second-feet at Cascades Rapids is at elevation 72. Between Cascades Rapids and The Dalles this elevation is the approximate dividing point in estimating the value of land for which damages must be paid.

869. *Canal.*—At the dam the canal bottom would be at elevation −2. It would be 480 feet wide, with side slopes of 1 vertical on 1½ horizontal below high-water line and 1 to 1 above high-water line and with frequent 20-feet berms. The greatest cut would be about 350 feet deep, and the average about 200 feet. The excavation would involve the removal of about 75,000,000 cubic yards of material.

870. Hesitation in undertaking an excavation project of such magnitude would be further reinforced by the uncertainty as to the behavior of the potential slide material discussed under the Cascades Rapids plan. Annual maintenance charges in highly speculative amounts add to the financial as well as to the engineering hazards.

871. A system of drainage tunnels is said to have stopped movements of slide material in the railroad cuts on the Oregon side. A lump sum has accordingly been included in the cost estimates for similar work to protect the canal slopes against slides. Effectiveness, however, in view of the size of the cuts, compared with those of the railroad, seems problematical. The canal has been designed for a velocity of less than 4 feet per second at all flows and would remain unlined.

872. The Spokane, Portland & Seattle Railroad and the Evergreen Highway would be located on berms provided on the upper side-slope of the canal

873. *Power.*—A hydroelectric power plant as proposed in this plan would utilize the natural fall at Cascades Rapids and through the gorge almost to its full extent in generating power. The variation in the total head with a dam at the head of the rapids and tailrace entering the river at Bonneville is shown in the following tabulation:

Flow in second-feet:	*Head in feet*
43,000	53
60,000	50
100,000	45. 5
200,000	42
500,000	40
800,000	38
1,200,000	34

874. *Navigation.*—As the proposed dam would be above Cascades Rapids and no changes in the river below are contemplated, the present lock system at the rapids would be retained. Due to the diversion of part of the flow through the power canal, the reduced flow with corresponding lower velocity through the gorge at moderate stages, would then constitute the only benefit to navigation.

875. This plan, however, opens the possibility for practically slack water navigation from the mouth of the river to The Dalles. By abandoning the present navigation canal at Cascade Locks and constructing new locks adjoining the proposed power house at the head of Hamilton Slough, traffic would enter the tailrace at a point opposite Bonneville, be locked into the power canal and reenter the river at the head of the rapids, thus avoiding entirely the Columbia gorge with its swift currents.

876. *c''. Bonneville plan to elevation 54—Location.*—The site studied for a proposed Bonneville development below Cascades Rapids includes the stretch of Columbia River between Boat Rock, about one fourth mile upstream from head of Bradford Island, and the mouth of Tanner Creek on Oregon side, a distance of about 1½ miles. The main channel, having an average width of about 600 feet, lies, at this point, to the north of Bradford Island. The channel on the south has an average width of about 300 feet, and at low stages carries no water.

877. *Geology and test borings.*—The Washington shore between the upper and lower limits of site as just defined snows only sand, gravel, clay, and boulders with no certain bedrock in evidence at any point. About one half of the length of Bradford Island from the lower end is a brush-covered flat, except where cleared, lying at small elevation above river level. At about the midpoint in its length the ground rises in an upstream direction to a summit elevation of 195 feet and

then drops steeply to practically river level, though a boulder strewn bar or reef extends upstream a distance of about 1,250 feet, to a connection with Boat Rock.

878. The downstream portion of Bradford Island is made up of sand, gravel, and boulders. The high upstream portion shows Eagle Creek formation at the summit and on both its north and south nearly vertical faces near upper end. Boat Rock is a solid basaltic island showing columnar structure along several hundred feet of its vertical northern side and a laminated type of the lava at the less abrupt southerly side. The Oregon shore from opposite Boat Rock for about one third the length of Bradford Island shows Eagle Creek in place and some masses of the Columbia basalt; then for a short distance the shore line is of solid jointed basalt which is part of or underlies and is thus older than the Eagle Creek formation. Below this ancient lava and extending down to mouth of Tanner Creek is a flat composed of sand, gravel, and boulders on which the Bonneville railroad station and the State fish hatchery are located.

879. Four test holes were drilled at Bonneville site, three on land and one in the river. The result of the exploration drilling is shown on plate 85. Hole no. 1,[1] located about 75 feet from water edge on Washington shore opposite midpoint of Bradford Island, was started at elevation 49 and penetrated 167 feet of clay, sand, gravel, and boulders, before reaching what is considered Eagle Creek formation in place, consisting of alternating coarse to fine-grained soft sandstone and ashy to shaly and sandy compact volcanic tuff. Hole no. 2,[2] at elevation 39 near water edge on Washington shore opposite midpoint of Boat Rock, was drilled to a total depth of 195 feet, from the upper 127 feet of which core could not be obtained. The materials down to 127 feet were alternating sands or soft sandstone and compact or cemented bouldery gravels, probably part of the Eagle Creek beds. Below 127 feet, the core shows firm shaly to sandy tuff and sandstone with a 16-foot layer of hard granular basalt between 151 and 167 feet of depth. Hole no. 3, at elevation 17, at about midpoint of the bar connecting Bradford Island and Boat Rock, went through 24 feet of gravel and boulder overburden and an additional 100 feet in the shaly tuffs and ashy sandstones of the Eagle Creek formation. Hole no. 4 was drilled in the main channel 225 feet to north of midpoint of Boat Rock, the water surface at time standing at mean elevation 14. The drill log shows: Depth 0 to 49.5 feet, water; 49.5 to 133.9 feet, sand and gravel overburden; 133.9 to 163.0 feet, light to dark gray hard basalt; 163.0 to 168.9, coarse basaltic agglomerate; and 168.9 to bottom at 182.8 feet, shaly to coarsely sandy tuff. Below 133.9 feet is undoubtedly substantial Eagle Creek formation in place.

880. *Plans for development.*—The first plan considered was that proposed by the State engineer of Oregon (par. 848). Failure to find anything but sand and gravel overburden at the Washington end of the proposed dam for a depth of nearly 200 feet below normal water level, and the finding of somewhat better conditions at a site farther upstream led to the adoption of a different plan. In this plan it is proposed to place the dam across the main channel at Boat Rock and the power house across the minor, or high-water, channel along the Oregon shore near the foot of Bradford Island, utilizing the minor

[1] The correct location of this hole is about 2,180 feet downstream from the location described, and shown in plate 85.
[2] The elevations shown for this hole on plate 85 should be corrected by the addition of +3.26 feet.

channel as a power and navigation canal, and excavating the flat on the Oregon shore at this point to form forebay and tailrace. The general location of this development is shown on plate 83.

881. *Dam.*—The dam as designed is in two parts; a crest-gate section across the main channel from Boat Rock to the Washington shore; and an overfall section extending from Boat Rock to the head of Bradford Island. The dam across the main channel would be of the concrete-gravity type having a length of about 800 feet. This section would have four regulating gates 150 by 12 feet of the roller type set between piers 16 feet thick. The portion of dam between Boat Rock and head of Bradford Island would have a length of 1,250 feet and be designed as an open high-water spillway without gates. The lower end of the present high-water channel between Bradford Island and the Oregon shore would be closed by the power house. To complete the forebay the low portions of Bradford Island would be raised by means of an earth embankment, averaging 30 feet in height.

882. The foundation material for the dam is basalt and Eagle Creek formation. At the power house location sand, gravel, and boulder material is encountered necessitating spread-out aprons to allow for percolation under the structures. Except for the dam in the main channel no unusual difficulties are expected to arise to affect design and construction.

883. The great depth of sediment overlying the rock in the main channel at the gate section of the dam introduces a very difficult and expensive foundation problem. Unusual and unprecedented methods would have to be employed in constructing the dam in the main river channel between the Washington shore and Boat Rock. The distance across the stream along the axis of the dam is about 600 feet at low water. The water depth is 40 feet maximum and averages 30 feet. Bedrock is found at approximately 140 feet below the low-water surface in the middle of the river. Overlying the rock are layers of sand, gravel, and boulders. On the Washington shore some shale and sandstone cover the basalt, which is in turn overlaid by sand and gravel. At Boat Rock the basalt is exposed.

884. On account of the deep deposits of water-bearing gravels in the main channel, ordinary cofferdams have been ruled out. The method investigated for constructing the dam in this section is the "Sand Island method." The procedure as outlined is as follows:

Reinforced concrete caissons would be sunk within steel shells. The location of the caissons would be along the upstream and downstream faces of the dam, but outside of dam proper. The caissons would not be incorporated into the dam but would be employed only for purposes of unwatering of the foundation.

With the two rows of caissons resting on bedrock and their dredging wells filled with tremie concrete, the space between the two rows would be dredged out. As the dredging progresses, structural steel struts would be lowered between the rows of caissons to serve as bracing.

With the caissons properly braced a structural steel superstructure would be placed on top of the caissons extending well above ordinary low water. This structure would consist of steel posts serving as guides for stoplogs, and heavy steel bracing. Wooden stoplogs would be lowered between the guides.

The dam would then be constructed in the dry. The work would progress in sections allowing the water to pass outside of the enclosed section and leaving temporary openings through the finished sections. Part of the flow of the river would also be diverted through the low portion of Bradford Island downstream from Boat Rock.

885. It is believed that the plan as here outlined for building the dam across the main channel of the river has its merits. It is not held

impossible, however, that interlocking steel sheet piling could be employed and a procedure followed similar to the one used in raising of the *Maine*. The degree of permeability of the sand and gravel material would, however, determine the advisability of that method. Possibly some of the new processes now on the market and used more in Europe than in this country for solidifying sand and gravel deposits could be used in securing a more firm and more watertight foundation for the cofferdams.

886. The effective head for a plant at the Bonneville site, the power output, and other principal facts are practically the same as for the Warrendale plan, next described. For this reason they are not given here.

887. *d''. Warrendale development to elevation 54—Location.*—The Warrendale site is 140 miles from the mouth of the Columbia and at the head of tidal reach for low-water stages. It is 36 miles from Portland, Oreg., by line of Union Pacific and 38 miles by Columbia River Highway. It is 45 miles from Portland by Spokane, Portland & Seattle Railway, and 35 miles from Vancouver, Wash., by North Bank Highway.

888. The river at the site is directed into main and secondary channels by Ives and Pierce Islands. The main channel next the Oregon shore has a low-water width of 800 to 1,400 feet and the secondary channel next the Washington shore, an average width of about 500 feet. The latter carries very little water at low stages. The greatest depth at low water in the main channel is 40 feet. Average depth at the site is about 25 feet. A plan of the Warrendale development is shown on plate 87.

889. *Geology and test borings.*—There is no surface indication that rock of any character is to be found at the Warrendale site. Ives and Pierce Islands are merely low sand bars which become partially submerged during high stages. The only rock visible in this vicinity is Beacon Rock, formerly called Castle Rock. This prominent landmark stands practically at water's edge on the Washington shore and rises some 800 feet above the surrounding country. According to Mr. J. T. Pardee, geologist, United States Geological Survey, Beacon Rock is an andesitic upthrust which may be connected to a far-spreading base of similar formation or may continue with vertical sides to a great depth. Only drilling would determine the facts. There is another outcropping of the same rock at a considerably higher elevation in the mountainside to the northeast of Beacon Rock.

890. As to the character of the material in the river channel, where the structures must be located, the following excerpt from "Notes On Geological Reconnaissance, Dam sites Below Junction Of Snake River" (unpublished), by James Gilluly, geologist, United States Geological Survey, may serve as introduction:

Because of the drowned character of the lower Columbia and the evidence furnished by soundings above and below, it is considered probable that bedrock will not be found at elevations higher than 40 feet below sea level at this site. It is possible that a buried channel, or more than one, will be found at depths as great as 70 feet below sea level, or even more, but this is not probable. Fifty feet below sea level is the most probable depth to the buried channel. The bedrock will probably be found to be chiefly volcanic breccia and conglomerate and sandstones, with possibly some basalt. Basalt is unlikely to form more than a small part of the bedrock in a section across the river here.

891. The bedrock that would be reached here is the Eagle Creek formation. The top of this formation where the Columbia basalt rests upon it is to be seen in McCord Creek Gorge just above Warrendale on the Oregon side where it is roughly 200 feet above river level.

892. One test hole was drilled at the Warrendale site (see pl. 86). This hole was put down on the north side of the main channel at edge of the sandbar marking the upper limit of Pierce Island. It was drilled to a depth of 150 feet, or to elevation −144. The material penetrated from the surface to a depth of 48 feet is a mixture of sand and gravel; from 48 to 110 feet gray sand; and from 110 feet to the bottom, at a depth of 150 feet, sand and gravel. These are all unconsolidated river-carried sediments filled into the buried former bedrock channel of Columbia River.

893. *Plan for development.*—The dam as tentatively located, with its axis normal to the course of the stream, would extend from Oregon shore directly across the main channel, with an open spillway section 2,200 feet long to the foot of Pierce Island. From this point, making a slight angle downstream from axis of the dam, the power house would extend northerly to a connection with the Washington shore at Beacon Rock (see pl. 87).

894. At Warrendale, mean low water elevation is approximately 4 feet; extreme low water, 1 foot. The crest of the spillway section of the dam has been assumed at elevation 54, the controlled low-water level of the pool. The head is about 50 feet at low water, and with a rising river drops off to about 40 feet at ordinary high water and to about 23 feet at extreme high stages.

895. As described above, the dam and power house, as proposed for this site would be founded on the existing river bed material. Cut-off walls, even to very great depth, would not reach impervious strata to form a curtain against percolation below the main body of the structures. To insure safety and permanence, the dam and power house in this project could be constructed only at relatively high cost.

896. *Dam.*—On a foundation material such as prevails at Warrendale, no dam can form a perfectly waterproof barrier. Regardless of depth to which cut-off walls may be carried, there will always be some percolation below the superimposed structures. Whereas a direct flow would disturb the foundation material and threaten the safety of the structure, a slow percolation would do no harm so long as the velocity is kept low enough to prevent movement of sand particles. On account of the difference in water levels above and below the dam some seepage water will always find its way through the foundation material. With provisions for an extended path of percolation there would be no direct flow but only a slow-moving moistening effect in the foundation.

897. For a dam constructed on pervious material the ratio of the length of the path of percolation to the head against the dam is designated the percolation coefficient. Extended studies in this country and abroad, particularly in India, have established the fact that the percolation factor is a function of the character of the material on which the dam is built.

898. The late W. G. Bligh, noted authority on dams on pervious foundations, recommended the following values of percolation coefficient:

Class I. River beds of light silt and sand of which 60 percent passes a 100-mesh sieve ---- C=18.
Class II. Fine macaceous sand of which 80 percent of the particles passes a 75-mesh sieve ---- C=15.
Class III. Coarse-grained sands ---- C=12.
Class IV. Boulders, gravel, and sand mixed ---- C varies from 9 to 5.

899. Samples of sand and gravel from the drill hole at Warrendale were submitted to a mechanical sieve analysis, the results of which are tabulated as follows. (Figures indicate percent passing sieve.)

Sample no.	1	2	3	4	5
Sample taken between elevation	+6 to −9.1	−13 to −19.4	−21 to −39.2	−42 to −104.1	−104.1 to −144
Size of sieve					
1½ inch	100.0	100.0	100.0	100.0	100.0
¾ inch	100.0	100.0	79.2	100.0	92.3
⅜ inch	100.0	98.4	72.3	100.0	86.5
No. 4 mesh	99.8	95.0	71.8	99.4	79.2
No. 8 mesh	90.3	80.8	60.3	97.2	68.3
No. 14 mesh	51.2	52.6	42.5	89.6	54.9
No. 28 mesh	26.5	30.6	28.5	78.4	46.8
No. 48 mesh	11.3	14.1	16.2	37.2	25.6
No. 100 mesh	4.0	6.8	9.4	6.2	4.8
No. 200 mesh	1.5	4.2	5.8	2.2	1.6

900. A study of the above sieve analysis indicates that a percolation coefficient of 12 could have been chosen for the design. However, as the samples taken are indicative of conditions in only one drill hole, and in consideration of the importance of the project, the conservative coefficient of 20 has been used in determining the required length of seepage travel under the structure. With maximum head of 50 feet, this gives a total length of percolation of 1,000 feet. The estimated saving with a percolation coefficient of 15 would approximate $2,000,000. The path of percolation is figured as the total horizontal distance between point of entry of seepage at upper end of upstream apron to the drained outlet at end of downstream apron, plus twice the depth of cut-off walls.

901. A section of the dam is shown on plate 87. It will be noted that a considerable portion of the apron (435 feet) would be placed upstream of the rollway. This involves a considerable saving in material, as the hydrostatic uplift here is counter balanced by the weight of the water on the apron above the rollway.

902. As mentioned in paragraph 893, the spillway section, 2,200 feet in length, would be located across the main channel of the river and the power house across the present high-water channel between Pierce Island and the Washington shore. An abutment section with aprons similar to those of the spillway would connect the spillway section at the south end with the higher ground on the Oregon shore. Another abutment section would connect the north end of the power house with the Washington shore, where it would tie into Beacon Rock. The navigation locks would be located in this latter abutment section. The total length of spillway, power house, and abutment sections would

be about 6,000 feet. The length of the spillway would remain the same regardless of which one of the five series of development of the river below the mouth of Snake be adopted. The length of the power house, however, would vary, depending upon which series is chosen for power development of the stream. Thus, for development of the Warrendale site in series D, the comprehensive plan, the power house would be about 400 feet longer than if series A were adopted. To complete the dam at Warrendale in series A, a bulkhead section about 400 feet long would be constructed between the spillway and the power house.

903. *Power house and equipment.*—The foundation material at the proposed power-house location is of the same general character as encountered for the dam. This necessitates applying the same principle of design as to the percolation factor as described above for the dam. Thus an upstream and downstream apron have been included in the design and a deep cut-off wall provided at the upstream end of the intake. The power house would be located north of the dam and across the high-water channel between Pierce Island and the Washington shore. (See pl. 87.) In series D it would be about 1,800 feet in length. There would be installed 19 units, rated at 44,000 kilowatts at a head of 50 feet. This installation would carry a peak load of 480,000 kilowatts at 50 percent load factor. The turbines would be of the adjustable blade propeller type. In series A the installation would be 15 units of same rating, which would carry a peak load of 400,000 kilowatts at 50 percent load factor. A section of the power house is shown on plate 88.

904. The substation equipment would be installed on the roof of the power house.

905. *Navigation.*—This project would completely revise the river channel from present tidewater at Warrendale to a point above Cascade Locks. The present locks at Cascades Rapids would be submerged and rendered obsolete. Two new locks, in tandem, would be located adjacent to the power house and next to the Washington shore and the cost of the locks is included in the estimate for the Warrendale project. At low and at moderately high water, navigation through the gorge would be much improved over present conditions. It is only when a stage of 700,000 to 800,000 second-feet flow is reached that the current would still render navigation difficult or impossible. During the 52 years of record, this has occurred for periods averaging 2 weeks, and only once every 4 years.

906. *Fishways.*—There would be two fishways installed for this project. One would be located along the navigation locks near the Washington shore, and the other at the end of the dam near the Oregon shore. The general dimensions of fishways would conform to rules as laid out in paragraph 610.

907. *General property damage.*—Raising low-water levels about 50 feet by the introduction of a power dam at Warrendale would completely submerge the grounds of the Oregon State Fish Hatchery at Bonneville. The cost of moving the hatchery buildings to another site has been included in the estimate. Other damages to property in this project would be small, the greatest being the purchase of the privately owned cannery at Warrendale.

908. *Revision of railroads and highways.*—Construction of a dam at the Warrendale site with pool level at elevation 54 would necessitate

the revision of 17 miles of railroad, assuming that profile grade be maintained at an elevation 10 feet above a flood level of 82 feet in the pool. A portion of this revision may be accomplished by raising the tracks in place, but a portion will involve relocation.

909. Revision of the tracks of the Union Pacific System would begin at a point about 1 mile west of the dam site and terminate at a point about 2 miles west of Cascade Locks, Oreg., a distance of 7 miles. The maximum change in elevation of grade would occur at the dam site and would amount to 31 feet.

910. Revision of the tracks of the Spokane, Portland & Seattle Railway Co. would begin at a point about 4 miles west of the dam site and terminate at Rand, Wash., a distance of 10 miles. The maximum change in elevation of grade would occur at the dam site and would amount to 40 feet.

911. Revision of 2 miles of the Columbia River Highway would be necessary, assuming that profile grade be maintained at an elevation not less than 10 feet above flood level in the pool. This revision would involve relocation of portions that are below the proposed grade or within the proposed right-of-way of the Union Pacific tracks. The revision would begin about 1 mile west of the dam site and terminate about 2 miles west of Cascade Locks. There are no modern highways on the north bank of Columbia River that would be affected by construction of a dam at the Warrendale site with flood level in the pool at elevation 82.

912. The tabulation below shows the mileage of required revision of railroads and highways.

Railroads and highways	Miles		
	Relocate	Raise	Revise
Union Pacific system, main line	6.5	0.5	7.0
Spokane, Portland & Seattle Ry. Co., main line	9.3	1.0	10.3
Columbia River Highway	2.1		2.1
Total	17.9	1.5	19.4

913. *General data.*—The principal facts relative to Warrendale development in series D follow:

Drainage area ... square miles	240,000
Area of pool ... acres	22,000
Length of pool ... miles	50
Natural mean low water elevation ... feet	4
Length of dam (including power-house section) ... do	6,000
Height of dam (maximum section, foundation to crest of spillway) ... feet	70
Average static head ... do	44
Proposed hydraulic capacity ... second-feet	254,500
Power capacity ... horsepower	264,000
Plant capacity factor ... percent	66
Firm power (99.3 percent of time) ... kilowatts	240,000
Firm output ... kilowatt-hours	2,102,400,000
Secondary power:	
90 percent of time ... kilowatts	10,000
80 percent of time ... do	35,000
70 percent of time ... do	60,000

Head, tailwater and power curves, hydrographs and powergraphs, output in kilowatt-hours for firm, secondary and potential power are shown graphically on plates [2] 89, 90, and 91.

Cost in mills per kilowatt-hour for load factors from 50 to 100 percent, for 4- and 6-percent money, and for 50- and 100-percent power market factors are shown graphically on plate 98.[2]

914. *General data.*—The principal facts relative to Warrendale development in series A follow:

Drainage area	square miles	240, 000
Area of pool	acres	22, 000
Length of pool	miles	50
Natural mean low water elevation	feet	4
Length of dam (including power house section)	do	6, 000
Height of dam (maximum section, foundation to crest of spillway)	feet	70
Average static head	do	45. 4
Proposed hydraulic capacity	second-feet	205, 500
Power capacity	horsepower	272, 000
Plant capacity factor	percent	75
Firm power (99.3 percent of time)	kilowatts	200, 000
Firm output	kilowatt-hours	1, 752, 000, 000
Secondary power:		
90 percent of time	kilowatts	70, 000
80 percent of time	do	95, 000
70 percent of time	do	135, 000

Head, tailwater and power curves, hydrographs and powergraphs, output in kilowatt-hours for firm, secondary and potential power are shown graphically on plates [2] 92, 93, and 94.

Cost in mills per kilowatt-hour for load factors from 50 to 100 percent, for 4- and 6-percent money, and for 50- and 100-percent power market factors are shown graphically on plate 95.[2]

915. *Estimates.*—Two estimates of costs are presented below for the Warrendale site. Both assume a controlled low water level in pool at elevation 54. Table 26 gives the estimate for a project at Warrendale as included in series D, the comprehensive plan of development. The installation of units is here based on a flow as regulated by 4,625,000 acre-feet storage at The Dalles. Table 27 gives the estimate for a project at Warrendale as included in series A, the low head step development between the mouth of Snake and tidewater. The natural flow in the river has been used in this case as a basis to determine the installation, and no effect from possible storage above Warrendale has been considered.

TABLE 26.—*Warrendale development, series D*

ESTIMATE OF COST

I.	Preliminary expense	$850, 000
II.	Railroads, roads, and bridges (for construction purposes only)	150, 000
III.	Reservoir and damages	3, 600, 000
IV.	Dam and diversion	12, 540, 000
V.	Conduits (including forebay)	
VI.	Intake and equipment (including gates, racks, cranes, etc.)	5, 610, 000
VII.	Power-house substructure	5, 450, 000
VIII.	Power-house superstructure	2, 090, 000
IX.	Hydraulic equipment (including governors and auxiliary equipment)	6, 935, 000

[2] Not printed.

X.	Electrical equipment (including generators and all electrical equipment between generators and low-tension side of transformers)	$8, 550, 000
XI.	Power-house cranes and miscellaneous auxiliary equipment	300, 000
XII.	Tailrace	1, 260, 000
XIII.	Fishways	405, 000
XIV.	Switching station (structural only)	760, 000
XV.	Operators' village and permanent improvements	280, 000
XVI.	Contingencies, 10 percent	4, 878, 000
XVII.	Overhead (engineering, supervision, clerical, legal, insurance, etc.), 12½ percent	6, 707, 000
XVIII.	Interest during construction (3 years to build), 4-percent money	3, 625, 000
XIX.	Carrying charges, 50-percent power market factor and 4-percent money	3, 010, 000
	Total estimated cost, chargeable to power	67, 000, 000
	Cost of navigation locks	3, 100, 000

ANNUAL CHARGES

Item	4-percent money	6-percent money
Interest on investment	$2, 680, 000	$4, 222, 000
Depreciation	744, 000	538, 400
Taxes		1, 055, 000
Amortization	703, 500	
Operating charges	380, 000	380, 000
Total annual charge	4, 507, 500	6, 195, 400

TABLE 27.—*Warrendale development, series A*

ESTIMATE OF COST

1.	Preliminary expense	$850, 000
II.	Railroads, roads, and bridges (for construction purposes only)	150, 000
III.	Reservoir and damages	3, 600, 000
IV.	Dam and diversion	13, 390, 000
V.	Conduits (including forebay)	
VI.	Intake and equipment (including gates, racks, cranes, etc.)	4, 380, 000
VII.	Power-house substructure	4, 040, 000
VIII.	Power-house superstructure	1, 950, 000
IX.	Hydraulic equipment (including governors and auxiliary equipment)	5, 475, 000
X.	Electrical equipment (including generators and all electrical equipment between generators and low-tension side of transformers)	6, 750, 000
XI.	Power-house cranes and miscellaneous auxiliary equipment	300, 000
XII.	Tailrace	1, 000, 000
XIII.	Fishways	400, 000
XIV.	Switching station (structural only)	600, 000
XV.	Operators' village and permanent improvements	225, 000
XVI.	Contingencies, 10 percent	4, 311, 000
XVII.	Overhead (engineering, supervision, clerical, legal, insurance, etc.), 12½ percent	5, 929, 000
XVIII.	Interest during construction (3 years to build), 4-percent money	3, 200, 000
XIX.	Carrying charges, 50-percent power marker factor and 4-percent money	2, 320, 000
	Total estimated cost, chargeable to power	58, 870, 000
	Cost of navigation locks	3, 100, 000

ANNUAL CHARGES

Item	4-percent money	6-percent money
Interest on investment	$2,355,000	$3,703,800
Depreciation	592,800	427,100
Taxes		924,300
Amortization	618,200	
Operating charges	300,000	300,000
Total annual charge	3,866,000	5,355,200

916. The tabulation below shows the cost in mills per kilowatt-hour, dollars per kilowatt-year, for power at site and at Portland, Oreg., for both public and private development, financed with 4- and 6-percent money, respectively, and based on a load factor of 55 percent, for Warrendale development in series D. Costs were selected from the graphs shown on plate 98.[2]

Point	Mills per kilowatt-hour 55 percent load factor		Dollars per kilowatt-year 55 percent load factor	
	4 percent money	6 percent money	4 percent money	6 percent money
At site	2.01	2.79	17.60	24.50
At Portland	2.31	3.17	20.20	27.80

917. The tabulation below shows the cost in mills per kilowatt-hour, dollars per kilowatt-year for power at site and at Portland, Oreg., for both public and private development, financed with 4- and 6-percent money, respectively, and based on a load factor of 55 percent, for Warrendale development in series A. Costs were selected from the graphs shown on plate 95.[2]

Point	Mills per kilowatt-hour 55 percent load factor		Dollars per kilowatt-year 55 percent load factor	
	4-percent money	6-percent money	4-percent money	6-percent money
At site	2.13	2.94	18.70	25.80
At Portland	2.43	3.32	21.30	29.10

918. *Sites below Warrendale.*—At Warrendale the basalt on Oregon shore tops the Eagle Creek formation at about 200 feet in elevation above river level. Dipping downstream the contact between basalt and Eagle Creek formation intersects water level at a point about 4 miles below Warrendale. Assuming that the contact continues to dip at approximately the same angle, it would be reasonable to expect that basalt, several hundred feet thick, would lie below water level along a line extending from Bridal Veil, Oreg., to Cape Horn on Washington shore, about 10 miles downstream from Warrendale.

[2] Not printed.

919. To determine whether basalt rock might be found at reasonable depths at this Bridal Veil-Cape Horn site, two holes were drilled. (See pl. 86, p. 1597.) Hole no. 1, located near Oregon shore about 1 mile upstream from Bridal Veil, was started in water 5 feet deep and drilled to a depth of 126.4 feet, measured from river bottom, or to elevation −125.7. The material was found to be river alluvium to elevation −100 and sand, gravel, and a few boulders below that level. Hole no. 2, located about 200 feet downstream and to the south of Lone Rock near Cape Horn on Washington shore, was started in water 11.5 feet deep and drilled to a depth of 97 feet below river bottom, or to elevation −103.2. The material penetrated is fine and coarse sand with small amount of gravel at bottom.

920. The building of a dam and power plant at a point below Warrendale would, as judged by the explorations, involve the same problems as those to be encountered at the Warrendale site. Any dam at a site below Warrendale would necessarily be longer than one at Warrendale and would thus involve a greater expenditure. On account of the sand and gravel foundation material no gain in head could be obtained at such prospective site. Furthermore, the cost of revisions to railroads and highways would rapidly increase the further downstream from Warrendale a site is selected. For the above reasons it has not been thought advisable to investigate any site below Warrendale; and Warrendale has been fixed as the site farthest downstream which is suitable for power development.

(3) Developed

I. POWER PLANTS

921. There are no developed water-power plants on the main stream of the Columbia between the mouth of Snake River and the sea. There are, however, a number of companies and municipalities engaged in generating electric power to meet the requirements of the region covered by this report. Of these, the principal ones are as follows:

Utility companies:
- Portland General Electric Co.
- Northwestern Electric Co.
- Pacific Power & Light Co.
- Inland Power & Light Co.
- Eastern Oregon Light & Power Co.
- Mountain States Power Co.
- Idaho Power Co.

Municipalities: Eugene.

United States Bureau of Reclamation:
- Minidoka project, Idaho.
- Boise project, Idaho.

Below are brief descriptions of each of these utilities.

PORTLAND GENERAL ELECTRIC CO.

922. The present Portland General Electric Co., controlled in recent years by Central Public Service Corporation, has operated under a number of different names. It was incorporated in 1906 under the laws of Oregon as the Portland Railway, Light & Power Co. In 1924 the name was changed to Portland Electric Power Co. and later to Pacific Northwest Public Service Co.

923. The company does much of the electric light and power business in Portland, Oreg., and vicinity, and all of this business in Salem, St. Helens, Hillsboro, Oregon City, and other smaller communities. Power is supplied to the electric railways of Portland and vicinity. At Oregon City the company supplies direct water power to pulp and paper mills.

924. Willamette Falls Electric Co., a predecessor of the present utility, started business in 1889 with a station of approximately 1,000 kilowatts capacity at Willamette Falls on the Oregon City side of the river. In 1894 the present 1,350 kilowatt hydroelectric plant located at West Linn across the river from Oregon City was put into operation. The Portland General Electric Co. now operates 6 water-power plants and 3 steam plants with a combined capacity of 181,480 kilowatts, as follows:

	Installed capacity in kilowatts	
	Plant	Total
Hydroelectric:		
Station B, West Linn	5,930	
Station G, Faraday	15,250	
Station J, Silverton	250	
Station M, River Mill	14,050	
Station O, Bull Run	21,000	
Station P, Oak Grove	38,000	94,480
Fuel:		
Station E, Portland	7,000	
Station H, Salem	2,500	
Station L, Portland	77,500	87,000
Combined total—hydroelectric and fuel		181,480

925. The main transmission system of this company is operated at 57,000 volts. In addition the company operates an 11,000-volt network between the various generating stations and substations in Portland. Plate 102 [2] shows the gradual development of the load of Portland General Electric Co. and its predecessors from 1905 to 1930, inclusive, and also a forecast by the company's engineers.

NORTHWESTERN ELECTRIC CO.

926. Northwestern Electric Co. serves part of the city of Portland and some suburban areas in Oregon. It also serves Vancouver and numerous smaller communities in Washington, where its system extends from Kelso on the Cowlitz River to its interconnection with the Pacific Power & Light Co. at Condit on the White Salmon River. It was incorporated under the laws of Washington in 1911. Service was begun by the company in 1913 with a 12,000-kilowatt installation in its Condit power plant under a 25-year Portland franchise requiring competition with the established Portland Railway, Light & Power Co. Besides its electrical business the company does a large steam-heating business in the down-town section of Portland. The company has in

[2] Not printed.

operation 1 hydroelectric plant and 2 steam plants, with a combined capacity of 59,000 kilowatts, as follows:

	Installed capacity in kilowatts	
	Plant	Total
Hydroelectric, Condit	14,000	14,000
Fuel:		
Lincoln	40,000	
Pittock	5,000	45,000
Combined total—hydroelectric and fuel		59,000

927. A dam and water-power plant belonging to a different corporation (Inland Power & Light Co.) but under the same management is being constructed at Ariel, Wash., on Lewis River, which will provide for the ultimate installation of four 45,000-kilowatt units, of which one is expected to be ready for operation about November 1, 1931.

928. The main transmission system of the company is now operated at 66,000 volts with the expectation that when the Ariel plant is put in service the line between Ariel and Condit will be changed to 110,000 volts. Distribution by the company is mainly at 11,000 and 2,400 volts.

929. Plate 103 [2] shows the growth of the load of the company from its beginning in April 1913 down to the present time, together with a forecast by the engineers of the company.

930. Northwestern Electric Co. is controlled by American Power & Light Co. and is operated under the supervision of Electric Bond & Share Co.

PACIFIC POWER & LIGHT CO.

931. Pacific Power & Light Co., controlled by American Power & Light Co., and operated under the supervision of Electric Bond & Share Co., was incorporated in June 1915 under the laws of Maine. The company does the retail electric light and power business in 125 communities in Washington, Oregon, and Idaho, and supplies electrical energy at wholesale in eight Oregon communities. Among the communities served are Astoria, The Dalles, Hood River, and Pendleton, Oreg.; Yakima, Prosser, Walla Walla, and Kennewick, Wash.

932. The power plants which are located within the territory of the Portland district are as follows:

	Installed capacity in kilowatts	
	Plant	Total
Hydroelectric:		
Tygh Valley	2,200	
Powerdale	6,000	
Husum	75	
Cove	1,100	
Bend	1,110	
Cline Falls	200	10,685
Fuel: Youngs Bay	8,000	8,000
Total hydroelectric and fuel		18,685

[2] Not printed.

As yet these plants are not fully interconnected. The existing transmission lines operate at 66,000 volts and less.

933. A record of the growth made by the business of the Oregon properties of Pacific Power & Light Co. from 1912 to the present time is shown on plate 104.[2]

INLAND POWER & LIGHT CO.

934. Generating capacity is being installed and planned on Lewis River, a tributary of the lower Columbia, by the Inland Power & Light Co. The stock of this company is all owned by Pacific Power & Light Co. The first site to be developed and the lowest on the river is located at Ariel, about 36 miles from Portland, where a storage and power dam has just been completed. One 45,000-kilowatt unit is included in the initial installation, which is to be completed in the autumn of 1931. Provision is made for three additional units of the same capacity.

935. Preliminary plans of the company contemplate the progressive development of a number of additional power sites and storage sites on the Lewis River above Ariel until a final installed capacity of approximately 1,200,000 kilowatts is reached.

936. A transmission line to operate at 110,000 volts connects the Ariel power plant with distributing system of the Northwestern Electric Co. at Vancouver, Wash., and at their Albina substation in Portland. It continues on and connects again at the Condit power plant on the White Salmon River.

937. From Condit the 110,000-volt line has been constructed to Union Gap near Yakima, Wash., where it feeds power into the main interconnected system of the Pacific Power & Light Co. Further construction will continue this line to Taunton for connection with the Washington Water Power Co.

EASTERN OREGON LIGHT & POWER CO.

938. Eastern Oregon Light & Power Co. occupies a portion of eastern Oregon. It owns five small power plants as follows:

	Installed capacity in kilowatts	
	Plant	Total
Hydroelectric:		
Rock Creek	800	
Fremont	1,100	
Morgan Lake	380	
Cove	300	2,580
Fuel: South Baker	1,000	1,000
Total of system		3,580

Plate 105 [2] shows the business of the company during recent years.

939. Its transmission lines operate at 66,000 and 22,000 volts. The company's system is interconnected with that of the Idaho Power Co. from which it received 4,600,000 kilowatt-hours during 1930. Its own generation in that year was 9,700,000 kilowatt-hours.

[2] Not printed

MOUNTAIN STATES POWER CO.

940. The Mountain States Power Co., a subsidiary of the Standard Gas & Electric Co., operates in the agricultural and timbered part of Oregon south of the territory occupied by the Portland General Electric Co. Through management and physical connections, it is closely associated with the California-Oregon Power Co., which operates several power plants near the boundary of California and Oregon.

941. Although some of the local distributing systems of the Mountain States Power Co. are not tied in with the main transmission system, these transmission lines occupy the gap between the large California systems and those in the vicinity of Portland. They are of small capacity but are occasionally used for interconnecting between the large systems. The most important operate at 66,000 volts.

942. The power plants owned by the company are as follows:

	Installed capacity in kilowatts	
	Plant	Total
Hydroelectric:		
Albany	800	
Scio	50	
Stayton	200	
Lebanon	125	1,175
Fuel:		
Springfield	3,000	
Albany	300	
Dallas	750	
Lebanon	100	
North Bend	15,000	
Tillamook	4,000	
Delake (oil engine)	64	23,214
Total of system		24,389

943. During 1930 the Mountain States Power Co. received 45,600,000 kilowatt-hours from the California-Oregon Power Co. over connections at Springfield and Marshfield, Oreg. Over 8,200,000 kilowatt-hours were obtained from Coos Bay Lumber Co. at Marshfield. There were received from the Portland General Electric Co., through the interconnection at West Salem, Oreg., 9,500,000 kilowatt-hours, and there were delivered to that company 1,360,000 kilowatt-hours. Through exchanges with the municipal plant at Eugene, Oreg., 3,000,000 kilowatt-hours were received during 1930 and 490,000 kilowatt-hours were delivered. (See plate 106.)[2]

IDAHO POWER CO.

944. The Idaho Power Co. was incorporated in Maine in 1915. It is owned by Power Securities Corporation, a subsidiary of Electric Power & Light Corporation, through ownership of the common stock. It is operated under the supervision of Electric Bond & Share Co. At the time of its organization there were consolidated in it a number of previously independent electric power properties. The company now owns and operates an interconnected system of hydroelectric power houses, transmission and distribution lines covering a large

[2] Not printed.

part of southern Idaho and extending into eastern Oregon. Idaho communities served are Boise, Weiser, Caldwell, Nampa, Twin Falls, American Falls, Pocatello, Blackfoot, and others. In Oregon the towns of Ontario, Nyssa, and Huntington are served.

945. Power plants of the company are as follows:

Hydroelectric	Installed capacity	Hydroelectric	Installed capacity
	Kilowatts		*Kilowatts*
American Falls	27,000	Malad River	4,400
Shoshone Falls	10,080	Horseshoe Bend	1,200
Swan Falls	9,060	Oxbow	640
Thousand Springs	8,000		
Lower Salmon	6,080	Total	66,460

946. In addition the Idaho Power Co. purchases part of the power produced at several plants operated by the United States Bureau of Reclamation in connection with the Boise and Minidoka irrigation projects.

947. The company generates a large block of energy (257,000,000 kilowatt-hours in 1930) for delivery to the Utah Power & Light Co., principally at American Falls, Idaho. It also sells power to the Eastern Oregon Light & Power Co. Both the Utah and Eastern Oregon companies are, like the Idaho Power Co., controlled by the Electric Bond & Share Co.

948. Energy generated by the United States Bureau of Reclamation is transmitted over the company's lines for delivery to the Gem irrigation district and for other Government use. The transmission system consists of 140 miles of line designed for 132,000-volt operation and other lines operating at 66,000 and 44,000 volts.

949. Plate 107 [2] shows the changing load of the company from 1917 down to the present time.

CITY OF EUGENE, OREG.

950. Eugene, Oreg., with a population of 19,000 operates a municipal power system with two power plants, as follows:

	Installed capacity in kilowatts
Hydroelectric:	
Walterville	2,950
Leaburg	6,000
Total	8,950

951. Transmission to Eugene is over a 44,000-volt line. The municipal system is connected with that of the Mountain States Power Co. During 1929 delivery of energy to the company amounted to 784,000 kilowatt-hours, while 4,332,000 kilowatt-hours were received. The Leaburg power plant was put in operation December 28, 1929. The increase in the available power modified the 1930 record. During 1930 the city delivered to the Mountain States Power Co. 3,020,000 kilowatt-hours and received 492,000 kilowatt-hours. The city has recently constructed a 3,500-kilowatt steam plant which began operation May 1930.

[2] Not printed.

952. During recent years the production of electricity by the city of Eugene has been as follows:

Year:	*Kilowatt-hours*
1927	21, 057, 000
1928	22, 601, 000
1929	24, 464, 000
1930	32, 007, 000

UNITED STATES BUREAU OF RECLAMATION

953. As part of its irrigation projects in Idaho, the United States Bureau of Reclamation owns and operates two hydroelectric power stations, known respectively as the "Minidoka power house" on the Minidoka project and the "Black Canyon power house" on the Boise project. A third station at the Boise diversion plant is owned by the United States but leased to the Idaho Power Co. Two old stations located at American Falls, Idaho, were purchased from the Idaho Power Co. in connection with the acquisition of rights for the construction of the American Falls Reservoir. They were operated by the United States Bureau of Reclamation for a few years at times of peak load but have been retired and are not now considered to be available for regular service.

954. The Minidoka power house on Snake River supplies power for pumping to high lands on the Minidoka project and since 1909 has served the towns and rural communities of the project with electric power for all purposes. Energy is transmitted over 33,000-volt circuits and delivered in wholesale quantities to irrigation districts, municipalities, and mutual companies. The usual delivery voltage is 2,300. The Minidoka system is connected on the east and on the west with the system of the Idaho Power Co. and considerable quantities of energy are interchanged from time to time. The Government holds rights for the construction of a 30,000-kilowatt power house at American Falls.

955. The Black Canyon power house on Payette River at this time is operated primarily to supply power for the operation of the pumping plants of the Gem irrigation district to which power is transmitted over the circuits of the Idaho Power Co. Surplus power is supplied to the Idaho Power Co. When Owyhee Reservoir and irrigation system, which is now under construction, has been completed, Black Canyon power will be available for other uses.

956. The capacities of the United States Bureau of Reclamation power houses are as follows:

Hydroelectric:	*Installed capacity in kilowatts*	
Minidoka project:		
Minidoka	10, 000	
American Falls (west side)	400	
		10, 400
Boise project:		
Diversion (leased to I.P. Co.)	1, 500	
Black Canyon	8, 000	
		9, 500
Total		19, 900

957. Plates [2] 108 and 109 show the development of the power business on the two Idaho projects of the United States Bureau of Reclamation.

II. TRANSMISSION LINES

958. The more densely populated portions of this district are supplied with electric power over numerous transmission lines which connect the developed water-power sites with the markets and which serve many cities and towns. Some small outlying communities are not yet reached by transmission lines but are served exclusively by small local generating stations. The present situation is shown by plate 101[2] on which present transmission lines are shown in black.

959. There is already some interconnection between the several systems occupying the territory. When necessary or advantageous, power can be interchanged in important quantities. This is facilitated by the fact that the systems with only minor exceptions all operate at a frequency of 60 cycles per second. There is a wide difference in voltage of transmission lines. It is highly desirable that standardization of voltages be encouraged although present differences are not an insurmountable obstacle to further cooperation and interconnection.

960. Development of Columbia River power will obviously be in large blocks. Transmission distances will necessitate high voltages. The power will be mainly delivered to large consuming or distribution centers. For this purpose present transmission lines will be unsuited. A new system operating at higher voltage than any of the present local lines will be superimposed to deliver power to large substations where the voltage can be lowered for distribution over a network made up of the present lines and additions to them.

(4) Market Present and Prospective

I. PAST AND PRESENT USES

(A) Character

961. The power market in the Columbia Basin below the mouth of Snake River may be divided into four principal classifications:

(1) The well diversified load of the metropoiltan area, including Portland and the surrounding communities, in which is concentrated the bulk of the population;
(2) The large lumber and paper mills which at the present time are basic industries of this region;
(3) The loads of the scattered smaller towns and rural communities;
(4) The seasonal irrigation pumping load of the desert areas.

962. Domestic load, both urban and rural, has expanded rapidly during recent years. The same can be said of commercial uses of electricity. The metropolitan areas contain many factories which serve the basic timber and paper industries and the population of the region. While individually they are relatively small, in the aggregate they are an important factor in balancing the electrical industry and contributing to its diversification and stability. The lumber and

[2] Not printed.

paper mills at present generate a large part of the power they use and in some cases have a surplus which is sold to the utilities. Their fuel is the refuse of the industry.

(B) Growth of Territory

1. BEARING OF POPULATION GROWTH ON POWER USES

963. Obviously, population is one basis for a potential market for electrical energy. However, the rapid application of electricity to a great diversity of uses in all fields has obscured the effect of increasing population on the market for electric power, as shown by the statistics which are available. Thus in table 28, it will be observed that although during the past decade California has been increasing in population far more rapidly than the United States as a whole or than either Oregon or Washington, yet the relative increase in the number of kilowatt-hours produced in California is not very different from that in its neighbors. It follows that the production per capita in the United States and in both Oregon and Washington has increased more rapidly than in California.

Table 28.—*Average increase for 10-year period ending in 1930 in percent*

The following percentages compounded annually give the increase in the 10-year period

Subdivision	Population	Production	Production per capita
		kw-hrs.	*kw-hrs.*
United States	1.5	8.2	6.5
Pacific States	3.9	8.7	4.9
Washington	1.4	7.7	6.4
Oregon	1.8	9.6	7.7
California	5.1	9.1	3.7
Montana	-.2	1.5	1.7
Idaho	.7	4.2	4.1

964. Such deviations are not surprising in a new and rapidly growing business. They show that changes in population are not as yet the controlling factor. Nevertheless, population and its character cannot be disregarded. Its influence is more direct upon the statistics for small consumers than upon those for the large industries in which the consumption of electricity has little relationship with the number of men employed or with the population of the locality in which they are found.

965. Reports of two of the principal Oregon utilities give figures for the use of energy by residential consumers over a period of years. They give an indication of the rapidity with which sales to small consumers are growing. The analysis will be found in table 29.

TABLE 29.—*Use of electricity by residential consumers*

Utility	Year	Number of residential consumers		Sales to residential consumers			
				Total		Average per consumer	
		Total	Increase over preceding year	1,000 kilowatt-hours	Increase over preceding year	Kilowatt-hours	Increase over preceding year
			Percent		*Percent*		*Percent*
Portland General Electric Co.	1925	72,252		39,491		546	
	1926	79,915	11	47,730	21	596	9
	1927	84,085	5	58,559	23	697	17
	1928	88,181	5	68,041	16	771	11
	1929	89,762	2	78,097	15	870	13
Northwestern Electric Co.	1925	16,079		10,733		669	
	1926	18,857	17	15,367	43	814	22
	1927	20,423	8	19,148	25	936	15
	1928	21,880	7	22,288	16	1,019	9
	1929	23,786	9	25,161	13	1,058	4

2. INDUSTRIAL DEVELOPMENT

966. The settlement of the Pacific Northwest followed the explorations of hunters and trappers. Agricultural communities were gradually established, and towns grew up to serve the increasing population. Because of the distance from centers of industry, small manufacturing plants and repair shops were established.

967. As transportation has improved, a number of basic industries, such as lumber, paper, fishing, wheat raising, fruit growing, and others, have developed. These convert the native wealth of the region into exportable commodities. In the same manner that small industries were established in the early days, many auxiliary industries are now undertaking to furnish various specialized materials and supplies to meet the needs of the larger establishments and of the population. The tendency has been and continues to be toward an integrated community along the Pacific seaboard.

968. The relative importance of manufacturing industries in the State of Oregon is shown in table 30, compiled from reports of the Bureau of the Census. The figures represent the "value added in manufacture." This is obtained by subtracting the cost of the raw materials from the selling value of the products. It avoids the misleading duplications which enter when the "selling value of the product" is used for comparison. These duplications are due to the fact that the product of one process is used as raw material for another.

TABLE 30.—*Value added in manufacture by Oregon industries by census years, expressed in $1,000 units; industries arranged in order of size in 1927*

Industry	1909	1914	1919	1921	1923	1925	1927
Lumber and timber products	17,787	16,040	55,739	36,510	86,627	73,613	68,478
Printing and publishing	3,938	4,291	6,903	7,486	8,514	9,921	10,668
Paper and wood pulp					4,389	4,670	9,606
Bread and bakery products	1,208	1,446	3,322	4,191	4,635	4,641	4,823
Canning and preserving fruits and vegetables	118	493	4,050	2,709	5,044	4,504	4,692
Foundry and machine shop	1,663	1,090	12,413	4,003	6,358	5,645	4,566
Gas, manufactured		1,124	2,100	1,914	3,296	4,081	4,212

TABLE 30.—*Value added in manufacture by Oregon industries by census years, expressed in $1,000 units; industries arranged in order of size in 1927*—Contd.

Industry	1909	1914	1919	1921	1923	1925	1927
Railway shop, construction and repairs	654	1,564	4,018	4,659	4,521	4,091	4,148
Furniture	610	791	1,961	2,246	3,233	4,110	3,938
Butter, cheese, condensed milk	968	1,064	2,526	2,151	2,355	2,416	3,345
Slaughtering and meat packing	865	1,284	2,119	2,936	2,360	2,417	2,433
Flour and grain mill products	1,224	1,365	4,748	2,772	3,461	3,535	2,401
Woolen goods	402	758	1,410	1,747	2,221	2,576	2,268
Canning and preserving fish	902	1,054	1,867	1,769	2,220	1,777	1,778
Confectionery	666	936	925	1,106	686	1,096	1,270
Clothing, men's	367		705	1,850		1,543	1,012
Other industries not shown	11,081	13,204	55,761	21,944	27,874	28,703	25,443
Total—all industries	42,453	46,504	160,576	99,993	167,794	159,339	155,081

969. Although the annual percentage increase in the sales of electricity to small consumers is greater than for large industries, the total consumption by the latter represents more than half the sales of utility companies. The number of kilowatt-hours sold during 1929 to each class of consumers by the Portland General Electric Co. and the Northwestern Electric Co. are given in table 31. These figures do not, of course, represent the relative importance of the different classes from a revenue standpoint since the average rate per kilowatt-hour to large consumers is materially less than the rate to residential and retail light and power consumers. Revenue figures are not available for the several classifications. Many of the principal sawmills and paper mills have large generating plants of their own. The production of such plants does not appear in statistics published by various reporting agencies except for that part which is sold to utility companies.

TABLE 31.—*Distribution of energy sold during 1929 among different classes of consumers*

Classifications of consumers	Portland General Electric Co.		Northwestern Electric Co.	
	Sales in kilowatt-hours	Percent of total sales	Sales in kilowatt-hours	Percent of total sales
Large power and light consumers	218,577,000	56.6	192,069,000	78.6
Residential	78,097,000	20.2	25,161,000	10.3
Retail light and power, commercial	55,910,000	14.5	23,655,000	9.7
Electric railways	12,398,000	3.2		
Municipal purposes	21,145,000	5.5	3,387,000	1.4
Total	386,127,000	100.0	244,272,000	100.0

3. WATER-BORNE COMMERCE

970. Portland and cities on the lower Columbia River conduct an important ocean and river commerce. A channel with a low-water depth of 30 feet is maintained from the mouth of the river to Portland. This was increased to 35 feet under the act of July 3, 1930, and

is now being constructed. During 1930 the tonnage handled, exclusive of logs and piling, which were floated or rafted, amounted to over 8,710,000 tons, valued at $347,500,000. When logs and piling are included, the tonnage increases to 12,790,000 and the value to $367,200,000. These later figures were exceeded in 1929 when the total tonnage was 15,850,000, with a value of $413,200,000. Practically 75 percent of this business passed through the port of Portland.

971. Next in importance to the Columbia River is Coos Bay, with a 1930 tonnage of 605,674, valued at $12,360,000 and Yaquina Bay, with 157,817 tons, valued at $2,094,569. The 1929 tonnage of Yaquina Bay was 303,000 tons, valued at $4,300,000. The difference between the 1929 and 1930 figures is due to the fact that 90 percent of the coastwise receipts and 100 percent of the shipments consist of lumber. This industry was much more active in 1929 than in 1930.

972. During the decade up to 1929 the water-borne commerce of the Columbia River has shown a slow but consistent growth both in tonnage and value. However, due to the recent decline in world commerce, which affected the lumber industry, these figures have been slightly reduced for 1930. This will be seen from the Comparative Statement of Traffic (table 32), and the corresponding graphs (pl. 111).[2]

TABLE 32.—*Comparative statement of traffic, Columbia and lower Willamette Rivers below Vancouver, Wash., and Portland, Oreg.*[a]

	Handled by ocean going vessels (tons, millions)	Handled by inland river vessels (tons, millions)	Total, exclusive of rafted timber (tons, millions)	Rafted timber (tons, millions)	Total (tons, millions)
1920	2.91	1.57	4.48	2.77	7.25
1921	3.63	1.50	5.13	2.20	7.33
1922	4.16	1.72	5.88	2.60	8.48
1923	4.83	2.15	6.98	2.66	9.64
1924	5.18	1.96	7.14	2.64	9.78
1925	5.24	2.42	7.66	2.79	10.45
1926	6.30	2.35	8.64	2.32	10.96
1927	6.71	2.33	9.04	5.44	14.48
1928	6.97	2.01	8.98	5.74	14.72
1929	7.10	2.22	9.32	6.53	15.85
1930	6.76	1.95	8.71	4.08	12.79
	Value (millions)	Value (millions)	Value (millions)	Value (millions)	Value (millions)
1920	$170.6	$52.4	$223.0	$30.5	$253.5
1921	163.2	30.7	193.9	16.4	210.3
1922	221.0	36.9	257.9	19.4	277.3
1923	267.2	43.9	311.1	25.1	336.2
1924	288.7	43.3	332.0	21.8	353.8
1925	268.1	42.1	310.2	21.6	331.8
1926	315.1	41.8	356.9	18.6	375.5
1927	318.6	40.9	359.5	22.1	381.6
1928	338.3	45.2	383.5	23.1	406.6
1929	349.5	37.5	387.0	26.2	413.2
1930	316.9	30.6	347.5	14.7	362.2

[a] Adapted from table in Report of Chief of Engineers, U.S. Army, 1931, Commercial Statistics.

[2] Not printed.

TABLE 33.—*Summary of commerce on Columbia and lower Willamette Rivers below Vancouver, Wash., and Portland, Oreg., for year 1930* [1]

[Arranged in order of relative importance of total tonnage of classes of commodities handled]

Classes of commodities	Foreign		Coastwise		Internal	Total
	Imports	Exports	Receipts	Shipments		
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Wood and paper	3, 265	853, 796	99, 711	1, 534, 565	5, 161, 147	7, 657, 484
Nonmetallic minerals	9, 284		2, 488, 911	2, 163	804, 374	3, 304, 732
Vegetable food products	70, 541	811, 330	141, 550	294, 844	50, 184	1, 348, 449
Ores, metals, and manufactures of	14, 425	6, 242	136, 949	25, 019	4, 963	187, 596
Chemicals	20, 625		53, 068	1, 946	2, 992	78, 631
Animals and animal products	2, 255	4, 172	19, 385	21, 281	4, 053	51, 146
Textiles	10, 709	63	14, 518	18, 497	538	44, 325
Machinery and vehicles		244	32, 833	2, 030	5, 181	41, 228
Other vegetable products	248	479	9, 894	6, 229	39	16, 689
Unclassified (merchandise)	2, 979	845	31, 110	15, 100	15, 701	65, 795
Total tons	134, 331	1, 683, 171	3, 027, 929	1, 922, 734	6, 029, 172	12, 796, 337
Value, dollars	14, 143, 839	43, 748, 884	172, 025, 100	87, 017, 868	45, 341, 633	362, 275, 324

[1] Rearrangement of table found in Report of Chief of Engineers, U.S. Army, 1931. Pt. 2, Commercia Statistics.

973. Of the exports and outgoing shipments carried in 1930 by ocean-going vessels in foreign and coastwise commerce, 66 percent of the tonnage is classified as wood and paper. Of the total, 53.3 percent is made up of lumber, lath, shingles, and millwork, followed in this classification by logs and piling, 7 percent, and paper 5.6 percent. (See table 34.)

974. Vegetable food products account for 30 percent of the total tonnage of exports and outgoing shipments. Wheat makes up 18.5 percent of the total, flour 6.8 percent, fruits and vegetables 2.5 percent, and canned goods 1.7 percent. (See table 36.)

975. Of the imports and incoming shipments carried in 1930 by ocean-going vessels in foreign and coastwise commerce, 79 percent are classified as nonmetallic minerals. Petroleum products brought in by coastwise vessels account for 75.5 percent of the total. Among petroleum products fuel oil alone amounts to 44.6 percent, while gasoline and distillate amount to 29 percent of the total of the imports and incoming shipments. (See table 35.)

976. In the class of vegetable food products, sugar to the amount of 59,275 tons was the largest item. Among imports from foreign countries, copra, amounting to 41,800 tons, was not only the largest item in the vegetable food class but also the largest item in the entire list of imports for 1930. (See table 36.)

977. A summary of commerce on the Columbia and lower Willamette Rivers below Vancouver, Wash., and Portland, Oreg., and also analyses of the four major classes are given in the accompanying five tables, 33 to 37, inclusive.

TABLE 34.—*Wood and paper, 1930*

[Schedule of commodities arranged in order of total tonnage handled on Columbia and lower Willamette Rivers below Vancouver, Wash., and Portland, Oreg., during year 1930 [1]]

Commodities	Foreign		Coastwise		Internal upbound and downbound	Total
	Imports	Exports	Receipts	Shipments		
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Logs and piling		145,502	66,417	108,439	4,076,937	4,397,295
Lumber, lath, shingles, and millwork	250	698,082	21,273	1,223,105	129,630	2,072,340
Wood for fuel					750,698	750,698
Paper	2,599	15,212	11,740	188,442	193,060	411,053
Wood pulp			281	14,579	7,869	22,729
Pulpwood					2,953	2,953
All other	416					416
Total	3,265	858,796	99,711	1,534,565	5,161,147	7,657,484

[1] Compiled from table of Freight traffic, 1930. Report of Chief of Engineers, U.S. Army, 1931. Pt. 2, Commercial Statistics.

TABLE 35.—*Nonmetallic minerals, 1930*

[Schedule of commodities arranged in order of total tonnage handled on Columbia and lower Willamette Rivers below Vancouver, Wash., and Portland, Oreg., during year 1930 [1]]

Commodities	Foreign imports	Coastwise		Internal upbound and downbound	Total
		Receipts	Shipments		
Petroleum products:	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Fuel oil		1,416,234	450	149,244	1,565,928
Gasoline and distillate		910,679		5,779	916,458
Lubricating oil and grease		28,482	200	618	29,300
Other	495	31,812		473	32,780
Total petroleums	495	2,376,207	650	156,114	2,544,466
Sand and gravel	1,315			400,667	401,982
Stone	423			227,945	228,368
Cement	577	40,763		1,453	42,793
Sulphur		23,217		9,270	32,487
Salt		22,253		2,887	25,140
Glass and glassware	305	8,794	269		9,368
Coal and coke	5,110	2,298		286	7,694
All other	1,059	4,379	1,244	5,752	12,434
Total	9,284	2,488,911	2,163	804,374	3,304,732

[1] Compiled from table of Freight traffic, 1930. Report of Chief of Engineers, U.S. Army, 1931. Pt. 2, Commercial Statistics.

TABLE 36.—*Vegetable food products, 1930*

[Schedule of commodities arranged in order of total tonnage handled on Columbia and lower Willamette Rivers below Vancouver, Wash., and Portland, Oreg., during year 1930 [1]]

Commodities	Foreign		Coastwise		Internal upbound and downbound	Total
	Imports	Exports	Receipts	Shipments		
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Wheat		618,495		50,346	1,717	670,558
Flour		116,775		128,504	568	245,847
Fruits and vegetables		60,876	11,272	30,195	16,911	119,254
Canned goods		9,677	26,247	52,398		88,322
Sugar	8,895		59,275		2,851	71,021
Copra	41,800	4,397				46,197
Mill feed and meal	9,698	46	2,707	23,076	6,045	41,572
Coffee, tea, and beverages	2,784		8,547			11,331
Sirup and molasses			8,247		84	8,331
Linseed and linseed cake	3,937					3,937
All other	3,427	1,064	25,255	10,325	2,008	42,079
Total	70,541	811,330	141,550	294,844	30,184	1,348,449

[1] Compiled from table of Freight traffic, 1930. Report of Chief of Engineers, U.S. Army, 1931. Pt. 2, Commercial Statistics.

TABLE 37.—*Ores, metals, and manufactures of, 1930*

[Schedule of commodities arranged in order of total tonnage handled on Columbia and lower Willamette Rivers below Vancouver, Wash., and Portland, Oreg., during year 1930 [1]]

Commodities	Foreign		Coastwise		Internal upbound and downbound	Total
	Imports	Exports	Receipts	Shipments		
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Iron and steel, manufactured	13,336	40	82,340	1,923	2,201	99,840
Plumbing supplies			25,562	377	2,662	28,601
Tin plate		207	19,735			19,942
Lead, manufactured				14,351		14,351
Hardware			8,763	1,025		9,788
Iron and steel scrap		5,995				5,995
Copper and brass, manufactured and scraps				4,824		4,824
Tin and tin scrap				2,519		2,519
Iron and steel, unmanufactured	489				100	589
All other	600		549			1,149
Total	14,425	6,242	136,949	25,019	4,963	187,598

[1] Compiled from table of "Freight traffic, 1930." Report of Chief of Engineers, U.S. Army, 1931. Pt. 2, Commercial Statistics.

978. These figures emphasize the concentration of the industry and commerce of this district in a few commodities. Logs, piling, lumber, lath, shingles, millwork and paper, together with wheat and flour, constitute 88 percent of all the tonnage carried by ocean-going vessels outbound from the mouth of Columbia River. Petroleum products, mostly fuel oil, gasoline, and distillate, make up 75.2 percent of the tonnage of incoming freight.

979. Another striking feature is that the tonnage of imports from foreign countries is less than 8 percent of the tonnage of exports. If oil be subtracted, coastwise receipts are only 33.5 percent of outgoing coastwise shipments.

980. This empty cargo space on incoming vessels offers an opportunity to bring in raw materials at low freight rates for manufacture and refining. This condition and the ability to secure electrical energy at tide water in large quantity and at a moderate price make a combination that will in time appeal to industries in which transportation and power are important factors. Further diversification of industries is greatly to be desired from many angles. In the power business as in other fields the increase in sales expands far beyond the consumption by a new industry. The aggregate of the domestic requirements of employees and the demands of secondary or service industries and their employees often exceed the load of the primary industry.

C. SOURCES OF POWER SUPPLY AS AFFECTING MARKETS AND MARKETING

1. CHARACTERISTICS OF SUPPLY OF POWER

981. *a. Steam fuel, etc.*—Steam power plants are an important source of energy in the vicinity of Portland. All of the public-utility steam plants at Portland, as well as those of the lumber, pulp, and paper companies, wherever located, use sawdust and wood waste which has been reduced to the form of "hogged fuel",[22] to the extent that it is

[22] Slabs and other large pieces included in the waste wood are run through a "hog" which chips and shreds them into flakes of a size suitable for conveyors and automatic feed to boiler furnaces. The resulting material mixed with sawdust and planer shavings is known as "hogged fuel." It is measured in "units" of 200 cubic feet each.