Bend Pumping Plant (including power transmission line from Grand Coulee power plant)	$5,077,510
Feature no. *High-line canal system*	
1. Canal	2,293,020
2. Repumping plant	839,590
3. Canal	592,030
4. Kohler siphon	211,150
5. Canal	176,430
6. Wasteway	266,780
H-1. Lateral H-1	225,020
7. Sublaterals	1,394,820
Total high-line canal	5,998,840
Low-line canal system	
1. Canal	1,090,220
L-1. Lateral L-1	74,840
L-2. Lateral L-2	235,740
L-3. Lateral L-3	195,560
2. Sublaterals	1,556,100
Total low-line canal	3,152,460
Project items	
Preliminary surveys, etc	100,000
Drainage	702,600
Permanent buildings	140,000
Wells	45,000
Telephone system	30,000
Total project items	1,017,600
Recapitulation	
Bend pumping plant	5,077,510
High-line canal system	5,998,840
Low-line canal system	3,152,460
Project items	1,017,600
Project total	15,246,410

1281. *f. Stage development.*—In determining the final per-acre cost, where interest is considered on all money invested, it is necessary to build the system by stages in order to reduce the items of interest to the lowest possible point.

1282. For the same reason it is important to coordinate the construction of the system to meet the rate of colonization. The stage development proposed for the plan under consideration divides the project into four stages or units. It has been assumed that the land can be colonized at the rate of approximately 35,000 acres per year, that interest on all balances due will be at the rate of 4 percent per annum, that the land will be placed under cultivation when irrigation water is made available, and that repayments will begin after the third crop has been produced and that the rate of repayment will be at least 4 percent on the final per-acre cost.

1283. *a'. Power from Grand Coulee power development.*—Using power developed at Grand Coulee the following program of stage development is outlined:

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area begin repayment
			Acres	*Acres*	*Acres*
1	1	218,000			
2	2	2,200,000			
3		4,298,470	26,480		
4	3	3,263,990	39,940	26,480	
5	4	2,527,280	37,050	39,940	
6	5	2,738,670	37,050	37,050	26,480
7				37,050	39,940
8					37,050
9					37,050

1284. Under the above plan of development the first land would be placed under cultivation in the fourth year and repayments begin at the end of the sixth, the last area would be brought under cultivation in the seventh year and repayments begin at the end of the ninth. Carrying all capital expenditures through to the end of the eighth year with interest at the rate of 4 percent and deducting an annual repayment of $4.91 per acre, which also carries interest at the rate of 4 percent from time repayment is made to the end of the eighth year, gives the following:

	Per acre
Capital cost plus interest, $17,257,470	$122.81
Capital cost, $15,246,810	108.50
Interest, $2,010,660	14.31
Annual interest charge after completion, at 4 percent	4.91
Annual cost of operation and maintenance	1.05
Annual depreciation charge	1.20
Total annual charge less power	2.25
Annual cost of power	1.83
Total annual charge (operation, maintenance, and depreciation)	4.08

1285. The preceding estimate is based upon the assumption that power is to be purchased at and transmitted from the proposed Grand Coulee power development. If conditions are such that this power required for the operation of this system can be secured from the proposed Priest Rapids power development, then the Bend pumping plant can be reduced in cost. This reduction in cost is effected through the reduction of pumping head and the large reduction in the cost of the necessary transmission cost of the necessary transmission lines. If the Priest Rapids high dam is constructed and power secured from that source, the cost of the Priest Rapids irrigation project will be as follows:

Recapitulation

Bend pumping plant	$3,223,280
High-line canal (no change)	5,998,840
Low-line canal (no change)	3,152,460
Project items (no change)	1,017,600
Project total	13,392,180

1286. This change in the capital cost changes the set-up of the stage development to conform to that shown in paragraph 1287.

1287. *b'. Power from Priest Rapids power development.*—Using power developed at Priest Rapids the following program of stage development is outlined:

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area begin repayment
			Acres	*Acres*	*Acres*
1	1	$218,000			
2	2	1,700,000			
3	2	3,317,270	26,480		
4	3	3,152,440	39,940	26,480	
5	4	2,357,080	37,050	39,940	
6	5	2,647,390	37,050	37,050	26,480
7				37,050	39,940
8					37,050
9					37,050

1288. The change in the stage development due to securing power from Priest Rapids affects only the capital expenditures. No change is made in the rate of colonization or other items except that the minimum rate of repayment is $4.30 per acre instead of $4.91 as shown in the first case. Carrying these revised calculations through to the end of the eighth year gives the following results:

	Per acre
Capital cost plus interest, $15,092,800	$107.40
Capital cost, $13,392,180	95.30
Interest, $1,700,620	12.10
Annual interest charge after completion, at 4 percent	4.30
Annual cost of operation and maintenance	1.05
Annual depreciation charge	1.20
Total annual charge less power	2.25
Annual cost of power	1.59
Total annual charge (operation, maintenance, and depreciation)	3.84

7. PASCO PROJECT

1289. Consideration was given the reclamation of an area located north and east of Pasco, by pumping diversions from Snake River. (See plate no. 3.) Tentative estimates indicate the possibility of reclaiming about 100,000 acres in that manner at a per-acre cost practically identical with that of plan no. 4-A, of which this area forms a part.

1290. Provision was made in plan no. 4-A for the use of 710 second-feet of rediverted water. While unable in this present study to fix the point of application for this rediverted water, the topographic conditions indicate that the greater portion would be available only on the lands of lower elevation of which the Pasco tract considered forms the larger portion. For that reason the Pasco tract is considered a desirable portion of the area to be covered by plan no. 4-A.

1291. More detailed studies, however, may demonstrate the advisability of reclaiming a small area, possibly 10,000 or 15,000 acres by an independent system with a pumping diversion from Snake River.

8. PALOUSE PROJECT

1292. The Palouse project covers a gross area of 100,000 acres and is located in country north of Pasco. The area is bounded on the south and west by Columbia and Snake Rivers and on the north by high ground extending southwest from Eltopia to the Columbia River, and on the east by high ground extending from Eltopia, southeast to the Snake River. (See plate no. 3, page 591.)

The land has an elevation of from 500 to 700 feet, and is so located as to make it impossible to reach the area by a pumping diversion from either Columbia or Snake Rivers.

1293. This project has been the subject of considerable study by the United States Bureau of Reclamation. Investigations were made in 1903, 1904, and 1905. A more or less detailed examination was made in 1914 by a board of consulting engineers acting jointly for the then United States Reclamation Service and the State of Washington.

1294. The plan proposed by this Board consisted of a gravity diversion from the Palouse River near the town of Hooper. The Main Canal, extending to the upper end of the area to be reclaimed, would be about 60 miles in length, inclusive of the Washtucna Reservoir, which forms a part of the system. The board considered the Palouse River as the only source of water supply; the Palouse is a tributary of the Snake River and drains parts of Whitman and Adams Counties in Washington and Latah County in Idaho. The natural available flow of water in Palouse River near Hooper, the point of diversion, is entirely inadequate to provide a water supply for the project considered, and the plan included extensive storage developments.

1295. With a project exceeding 50,000 acres in area, the entire flow of the Palouse River, 1 year in every 4 of the 17 years of record available in 1914, would be inadequate to meet the irrigation requirements, and the reservoir system required must be designed to carry storage from one year to the next. Even with reasonable carry-over provisions, two years in the period would be extremely short on water supply. The system, as outlined by the Board, made it perfectly plain that the project would experience an occasional year when the water supply would be half or less of the estimated requirement. A casual study of the records of flow in that stream since 1914 shows several years when this condition would exist.

1296. Of the reservoirs considered by the Board, three were given most consideration. The Potlatch, Rock Lake, and Washtucna were given the most detailed study as they promised the best opportunity of developing the required storage. No geological studies were made of these reservoir basins at that time. It was proposed to impound 90,000 acre-feet in Potlatch Reservoir, 75,000 acre-feet in Rock Lake, and 125,000 acre-feet in Washtucna Reservoir.

1297. Studies regarding the proposed Columbia Basin irrigation project, made in 1924 by Gault for the United States Reclamation Service, and the studies made in connection with the present report include a geological report on Rock Lake which indicates the suitability of that site for storage purposes.[70] No geological report is available on the Potlatch site. No geological report is available regarding the proposed Washtucna Reservoir, but it is located within 4 miles of the site of the Kahlotus Reservoir, proposed by the State of Washington as a part of the Columbia Basin irrigation project development. Regarding this reservoir, the geologist reported in part, as follows: "From the facts, as given under Geology herein, it appears that away from the dams, however, these reservoirs leak to the extent that their comparison to sieves, for example, would not be unreasonable."[71] The Washtucna site as proposed by the Board is apparently in the same geological formation as that outlined by the

[70] Kirk Bryan, App. B. Gault Report (unpublished). Henry Landes, App. No. 1.
[71] J. T. Pardee, Report (1927) to State of Washington (unpublished).

Pardee report and the proximity of the two sites indicates the unsuitability of the Washtucna site. The Washtucna site also involves a conflict with the Oregon-Washington Railroad & Navigation Co. A branch line of that railroad extending from Kahlotus to Connel would be submerged by the proposed reservoir, and reconstruction of about 12 miles of the line would be required.

1298. In view of the fact that the available water supply, as determined by the records available at the time the Board reported on the project in 1914, indicated that a water shortage would occur on the project at not infrequent intervals; that subsequent records indicate that this shortage would be more frequent than estimated by the Board, and that the Washtucna Reservoir would be found unsuitable, thus eliminating 40 percent of the storage capacity considered available, this plan of developing the Palouse area by the gravity method outlined was given no further consideration in the present report.

9. LIND PROJECT

1299. The Lind project is located in Grant, Adams, and Franklin Counties and forms the eastern portion of the Columbia Basin irrigation project, discussed later in this report. The Lind project, together with the Quincy, Priest Rapids, Pasco, and Palouse projects, except for certain small areas marginal to each, constitute the maximum development proposed for the Columbia Basin irrigation project, with a gravity diversion from Clark Fork and Spokane River.

1300. The Lind project covers an area of 774,260 acres of irrigable land, including those tracts covered by supplemental pumping under a pumping head of not to exceed 100 feet.

1301. The classification of the land included within the project and the duty of water were determined in the manner outlined under the discussion of the Columbia Basin irrigation project, which follows in this report.

1302. The water supply for the area will be supplied from the Clark Fork and Spokane River, the only available sources of supply for this project.

1303. The proposed system includes regulating works at Pend Oreille Lake and Coeur d'Alene Lake and a main canal system 130 miles in length extending from the point of diversion from Clark Fork at Albany Falls to the bifurcation works, near Hillcrest, at the head of the irrigable area, together with the distributing system below the bifurcation works necessary to deliver the water to the land.

1304. The system required for the Lind project is identical with that proposed for plan no. 2–A of the Columbia Basin irrigation project, modified to conform to the reduced areas to be reclaimed.

1305. The same engineering treatment has been given this project in all respects as has been given the various plans considered for the Columbia Basin irrigation project, the same character and type of construction has been used, the same seasonal distribution of water, and the same consideration has been given canal and reservoir losses, rediverted water, power development on the project, etc.

1306. For a stage development the following estimates of cost are prepared based upon the assumptions that a 4 percent interest charge will be paid on balances due, that the land can be colonized at the rate of 50,000 acres per year, that the land will be placed under cultivation when the irrigation water is available, and that

annual repayments equal at least to 4 percent of the final per-acre cost will begin at the end of the third year of crop:[72]

		Per acre
Capital cost plus interest, $257, 491, 560, or		$328. 32
Capital cost, $178, 618, 910, or		227. 75
Interest, $78, 872, 650, or		100. 57
Annual interest charge after completion		13. 14
Annual operation and maintenance charge	$1. 27	
Annual depreciation charge	. 87	
		2. 14
Total annual charge		15. 28

10. HANFORD PROJECT

1307. The Hanford project is located in the northern portion of Benton County, Wash., and consists of the area on the south side of the Columbia River between Richmond Ferry and a point about 3 miles below Hanford that lies below the 650-foot contour.

1308. Included within this area is a small irrigation project which was developed some years ago by a company that undertook the irrigation of this land in connection with the development of power at Priest Rapids. A small power plant was constructed at Priest Rapids and a canal system with a pumping diversion from the Columbia River at Coyote Rapids was completed sometime prior to 1909. Very little reliable data are available regarding this project. The project is said to cover about 16,000 acres, of which possibly 3,000 or 3,500 acres are under cultivation at the present time. The project has not proven economically successful during past years because of the high value placed on the raw land which is in private ownership, the high cost of operation of the system, and because of the trouble and litigation between the promoters and the landowners which has involved court action for several years past. So unsatisfactory was the irrigation service that many of the landowners have abandoned their right to the irrigation system as constructed, and have installed individual pumping plants to divert water from the Columbia River or from wells to their lands. The power for the operation of these pumps is purchased at the commercial rate for power for that purpose, and the expense of operation is high.

1309. The land on the project is well adapted to the production of crops indigenous to the eastern portion of Washington, as is indicated by the areas now under cultivation, where excellent crops of fruits, berries, cereals, hay, and root crops yield a bountiful return.

1310. The topographic features of the tract are favorable for irrigation, and the elevation of the area with its protected position affords a long growing season and one that is possibly 2 weeks earlier than in other sections of that district.

1311. The area is served by a branch line of the Chicago, Milwaukee, St. Paul & Pacific Railroad.

1312. The Hanford project as proposed in this report includes about 40,000 acres of irrigable land, most of which is first class, not considering the area now under cultivation.

1313. Water for irrigation for this area can be most economically diverted from the Columbia River by pumping. A gravity diversion would involve many miles of main canal along a steep and

[72] Detail estimates and stage development, appendix no. 5.

sometimes precipitous area where a large amount of solid rock would be encountered and the cost would be extremely high.

1314. From the best information available, it seems that the entire area is underlain with a heavy underground flow of water at depths that permit of pumping. Some of the farmers secure their water supply in that manner at the present time, and the local opinion is that the underground supply is adequate to meet the demands of the entire tract. The investigation of this phase of the matter is beyond the scope of the present study; but it seems improbable that the underground supply would be adequate for so large an area, and it is assumed that, when developed, this area will secure its water supply from the Columbia River.

1315. The comprehensive plan for developing the Columbia River includes the development of a vast amount of power, a large portion of which will be secondary in character, that can be furnished for pumping purposes at a relatively low cost.

1316. The pumping plant for the proposed plan of developing this area will be located about 6 miles downstream from Priest Rapids, the site of one of the proposed power developments.

1317. Because of the character of the soil and the length of the growing season, and the character of the crops that will be produced, it is thought that the duty of water at the point of diversion should be 4.5 acre-feet, or a total requirement of 180,000 acre-feet for the project per season. The same seasonal distribution as used for the Columbia Basin irrigation project is considered adequate for this project.

1318. The proposed plan of development based upon a general reconnaissance of the area and upon preliminary surveys made for the main canal line consists of a pumping plant on the Columbia River at Richmond Ferry, pumping head 260 feet, a comparatively long discharge pipe line leading to the head of the main canal, a main canal about 30 miles in length, together with the necessary distributing system.

1319. Other than the length of the discharge pipe leading from the pump to the main canal, the plans offer ideal conditions from a construction standpoint. The pumping plant offers no unusual difficulties, and conditions along the entire length of the canal system are favorable. With the availability of secondary power for pumping purposes, this project offers the most economical irrigation development considered in this report.

1320. The estimated cost of this development, based upon 4 percent interest on unpaid balances, a colonization of 10,000 acres per year, land to be reclaimed upon the delivery of water, and repayments to begin at the end of the third year of crop, and to equal at least 4 percent on the final per-acre cost, is as follows: [73]

		Per acre
Capital cost plus interest $5,176,201 or		$129. 40
Capital cost $4,783,925 or		119. 60
Interest $392,281 or		9. 80
Annual interest charge after completion		5. 18
Annual operation and maintenance charge	$1. 00	
Annual depreciation charge	. 70	
Annual power charge	1. 20	
		2. 90
Total annual charge [74]		8. 08

[73] Detail estimate and stage development, see appendix no. 5.
[74] No item of amortization included.

11. MARGINAL AREAS

1321. Located along the Columbia River from the international line to the mouth of the Snake River are numerous small areas that are susceptible of irrigation by pumping water from the Columbia River. The Columbia River through this section of the State is located in a channel below the narrow valley which generally intervenes between the river and the mesa or table lands of the surrounding territory. Located in this narrow valley and on the lower mesa or table lands are numerous tracts, small in extent, that will eventually require water from the Columbia River for irrigation purposes.

1322. During the course of the present study, a reconnaissance was made to determine the extent of the irrigable areas along the river that might be reclaimed by pumping from that stream. The results of this reconnaissance show that there is a total of 100,300 acres of irrigable land along the Columbia River from the international boundary to Priest Rapids, that can be irrigated by a pumping lift of not to exceed 500 feet. Of this area about 24,000 acres are under irrigation at the present time.

1323. These irrigated areas are generally the lower lands along the river, and irrigation water is diverted from the adjacent creeks tributary to the river or by pumping from the Columbia River. The irrigation development along this section of the river has generally been the results of the efforts of companies organized for developing orchard properties, and the tracts vary from 50 to 700 acres in extent. Many small areas have been reclaimed through individual effort especially on that section of the stream in the vicinity of Wenatchee.

1324. The area of irrigable land as given above has reference to the Columbia River in its present condition. With the dams at Grand Coulee, Chelan, Rocky Reach, and Priest Rapids, as proposed in the study of the comprehensive uses of the water of Columbia River, these areas will be reduced.

1325. With the proposed high dam at Grand Coulee, the dams as proposed for Chelan and Rocky Reach and the high dam at Priest Rapids, the irrigable area will be reduced to 72,450 acres, of which 20,570 acres are now under irrigation, the balance representing the area submerged by the backwater from the proposed dams to be constructed in the Columbia River.

1326. Any further areas to be irrigated along this section of the Columbia River must secure a water supply by pumping from that stream. The areas are small and isolated and the topography is such that a gravity canal system is entirely infeasible except for relatively small areas located immediately below the dams as proposed in the power development of that stream.

1327. Those areas in this section that are under irrigation at the present time are devoted almost exclusively to fruit growing, and any further irrigation development will doubtless be devoted to crops of that nature. No attempt was made in the present study to make land or soil classifications as it was considered beyond the scope of the present report, to enter into these details for these areas, small in extent, though in the aggregate constituting a considerable area. The reconnaissance mentioned was made for the purpose of determining the extent of the remaining irrigable area in the territory that could be covered by a pumping lift limited as above stated. The

criteria in determining the irrigable areas during the reconnaissance were the existing farms which are at present producing excellent crops of fruit and where topography, soil, etc., were generally the same as that of the areas selected.

1328. The areas located in the section between Bridgeport and Kettle Falls are not well located with respect to markets. Railroad facilities are available at Brewster located 7 miles below Bridgeport and at Kettle Falls. The territory along the river between these two points is remotely located with respect to railroad transportation and is served only by an inadequate highway and road system. However, when the power dams at Foster Creek and Grand Coulee have been constructed, navigation will be feasible in the pools above the dams. This will give connections with the railway at Marcus and at Grand Coulee for supplies to be transported to and from the irrigated farms. Below Bridgeport, railroads are within a few miles of the areas in question and they are generally served by improved highways of the better class.

1329. The present report includes no study of the economics in connection with the development of these areas. Present developments have demonstrated the adaptability of these areas to the production of fruit crop, and demand will eventually be made upon the Columbia River for an irrigation water supply. This development will depend upon the availability and cost of electrical energy to operate the pumping equipment, on the development of adequate transportation facilities, either by improvement of navigation on the Columbia River or by the extension of the State highway system, and by the general market for the staple varieties of orchard products.

1330. The development of power at the sites proposed in the power section of this report will provide an abundance of cheap secondary power for irrigation purposes. When the power is available and the other conditions as to transportation and markets are favorable, the development of these areas will doubtless be undertaken, and at that time a demand will be made upon the Columbia River for a water supply for irrigation purposes. The areas are not situated favorably for a large general development either by private, State, or Federal agencies and future development will be through individual effort or the cooperation of a few landowners.

1331. General observations made during the reconnaissance of these areas, leads to the conclusion that with the type of construction, unlined canals, etc., that will probably be found in these individual developments, the relatively small areas of the unit developments and the character of the crops produced, an average gross diversion duty of 4 acre-feet per acre will be required from the river.

1332. Table no. 202 gives the pertinent data relative to the areas to be reclaimed in the sections along the Columbia River between the locations of the power developments proposed on that stream and discussed in the power section of this report.

TABLE NO. 202.—*Irrigable areas contiguous to the Columbia River*

Section	Tracts				Mean pumping lift	Gross water requirement
	Number	Minimum area	Maximum area	Total		
		Acres	*Acres*	*Acres*	*Feet*	*Acre-feet*
Between International Boundary and Grand Coulee High Dam	69	15	1,200	13,760	170	55,040
Between Grand Coulee High Dam and Foster Creek Dam	56	15	890	12,760	320	51,040
Between Foster Creek Dam and Chelan Dam [1]	63	15	1,230	16,880	430	67,520
Between Chelan Dam and Rocky Reach Dam	39	10	1,070	3,670	320	14,680
Between Rocky Reach Dam and Rock Island Dam	34	5	1,300	2,900	460	11,600
Between Rock Island Dam and Priest Rapids Dam	20	30	440	1,910	350	7,640
Total	281			51,880		207,520

[1] Includes about 4,800 acres on Brewster Flats.

1333. Between Priest Rapids and the mouth of Snake River the diversions from Columbia River for irrigation purposes are fully covered by two projects—the Priest Rapids and Hanford—which have been given individual treatment earlier in this report.

(C) IRRIGATION OF COMBINED AREAS

1334. Various projects have been discussed above, the possibility of combining two or more into a larger and perhaps more feasible one is worthy of consideration. Of the projects considered individually, Brewster Flats, Methow-Okanogan, Hanford, and Rathdrum Prairie do not permit of combination because of their isolated locations, and, if reclaimed, they must be treated individually.

1335. The Quincy, Priest Rapids, Pasco, and Palouse projects secure their water supply from different sources and no combination without the inclusion of the Lind project is possible for reasons noted below. The Quincy project draws its water from the Wenatchee River, and the project as outlined earlier in this report makes use of the entire available water supply from that source. The Priest Rapids project, with a pumping diversion from Columbia River near Bend, covers the maximum area that can feasibly be reclaimed, because of the topographic location of the land. The Pasco project, covered by pumping from Columbia River, might be enlarged to a very limited extent, but the topography does not permit of the addition of any considerable area of land. The Palouse project, covered by a gravity diversion from the Palouse River, covers practically a maximum development because of the limited water supply. The Lind project, covered by a gravity diversion from Clark Fork and Spokane Rivers, with their storage possibilities, is so located that an extension of the project might be made to include the Quincy, Priest Rapids, Pasco, and Palouse projects, and an abundant water supply be made available through a gravity system. For a gravity plan of development, various combinations of these projects with the Lind project will be discussed. By making a pumping diversion from the Columbia river at Grand Coulee, the Quincy, Priest Rapids, Pasco, Palouse, and a portion of the Lind projects may be united into one

large project. The maximum pumping project, together with various combinations of the above-mentioned areas, will be discussed later.

1336. During the past 10 years a number of plans have been developed for reclaiming a large area of land in Franklin, Grant, and Adams Counties, Wash. This area is a combination of the Quincy, Priest Rapids, Pasco, Palouse, and Lind projects mentioned above, together with certain marginal areas that could not feasibly be attached to the individual projects considered separately. This combined area constitutes what is commonly called the Columbia Basin project, but which will be referred to in this report as the Columbia Basin irrigation project. See plate no. 3, page 591. The Columbia Basin irrigation project, due to its magnitude and its general interest to the public—as is manifested by the numerous studies previously made—constitutes by far the major item of consideration in the irrigation section of this project.

1337. A number of possible combinations of areas for both a gravity diversion from Clark Fork and Spokane Rivers, and for pumping diversions from Columbia River, are considered, to determine the most feasible plan of development and to fix the points of diversion and the ultimate demand on the Columbia River for water for irrigation.

1. THE COLUMBIA BASIN IRRIGATION PROJECT

1338. *a. General data.*—Of the several preliminary investigations and reports that have been made on this project, there are three, namely, nos. 13, 23, and 25 of paragraph 1163, that outline a general plan or plans for reclaiming this area.

Columbia Basin project (1921), Columbia Basin Survey Commission.
Columbia Basin project (1924), Gault for United States Bureau of Reclamation.
Columbia Basin project (1925), Board of Engineers for United States Bureau of Reclamation.

These plans enter into more or less detail regarding general conditions, irrigable area, character of soil, source of water supply, duty of water, and estimates of cost, with other essential elements entering into the proposed plan of development. A fourth, no. 19, of paragraph 1163—Columbia River pumping and power project (1922), by Willis T. Batcheller—deals more particularly with the power development phase for the pumping plan, and offers no new data relative to the land on the project or the plan of development on the land. A brief outline of these reports may very properly be made, as many of the data noted therein were used in the present study.

1339. The first of these reports, made in 1920, was sponsored by the State of Washington, and the work done under the direction of an agency designated the Columbia Basin Survey Commission. This commission developed two general plans for reclaiming the lands on this tract, one consisting of a gravity diversion from the Clark Fork River at Albany Falls, Idaho, requiring an extremely long canal, incorporating several long tunnels and a series of artificial lakes, to reach the lands to be reclaimed; the second consisting of a pumping diversion from the Columbia River at Grand Coulee and requiring the construction of a main canal, much shorter than required for the gravity diversion, but also including several tunnels and an artificial lake about 24 miles in length covering an area of about 23,000 acres. While these two plans of development cover the same general

1346. The reports by the Columbia Basin Survey Commission, by Gault, and by the Board of Engineers are the only ones that deal with all phases of the project in its entirety, and will be referred to frequently in the present discussion of the project. Other reports mentioned earlier deal only with certain areas within the project, or with certain phases of the entire project, and will be mentioned when occasion demands.

1347. In developing the present plans for reclaiming the lands within this area, it may be well to reiterate that the reports of the Columbia Basin Survey Commission, Gault, and of the Board of Engineers dealing with the project in its entirety, together with maps, plans, appendixes, etc., appurtenant to each, were available and used to the fullest possible extent. These data were supplemented by such additional field surveys and investigations as were necessary and consistent with the scope of this report. These additional field data will be discussed later under the respective features.

1348. *a'. General location.*—The Columbia Basin Irrigation Project lies east of the Columbia River, in south-central Washington and occupies the southern portion of the area bounded in part by the river in its swing westward from its junction with the Spokane River to the mouth of the Okanogan, thence southwest to the Chelan and Wenatchee Rivers, and thence south and southeasterly to its confluence with the Snake River, and is located in Adams, Franklin, and Grant Counties.

1349. The area included within the project is very favorably located with respect to markets. Three transcontinental railroads—Great Northern, Northern Pacific, and the Chicago, Milwaukee, St. Paul & Pacific—together with several branch lines, traverse the project. Two trunk Federal-State highways cross the tract, and the several towns within the area are connected by well-built gravel roads. Any point on the project is within a very few hours' travel of the principal cities of the Northwest by either railroad or motor, and an excellent outlet is afforded to Spokane, the metropolis of the Inland Empire, and points east, and to Portland, Tacoma, and Seattle, the commercial centers of the Pacific Northwest, with their deep-water harbors inviting commerce with Alaska, South America, countries of the Far East, and European points via the Panama Canal.

1350. The lands within the project are strictly arid in character, the rainfall varying from 6.6 inches in the west to 12 inches in the north and east portions of the tract. Attempts have been made at dry farming over practically the entire tillable area; but most of these farms have been abandoned, and no measure of success is being realized on the lands remaining under cultivation. Irrigation is required over the entire area to insure the proper returns from the soil. The soil and climate, except for insufficient rainfall, discussed elsewhere in this report, are suitable for the bountiful production of grains, alfalfa, clover, grasses, corn, sugar beets, and fruits of the finest quality, and the district when developed should compare favorably with the developments in the Yakima and Wenatchee Valleys.

1351. *b'. Land classification.*—The first phase of the study necessary for the preparation of this section of the report was the determination of the extent of the irrigable area. The three previous reports (Columbia Basin Survey Commission, Gault, and Board of Engineers) each covered this item in some detail, but with a wide divergence in the estimate of the irrigable area within the project. In each the irriga-

ble area was given by townships. The report of the Columbia Basin Survey Commission was supplemented by township plats showing the location of the irrigable land within the township. The Gault report was accompanied by an appendix covering the land classification as made by A. T. Strahorn, of the Bureau of Soils, United States Department of Agriculture, supplemented by a small-scale map upon which the locations of the various classes of land are shown. This land classification was apparently made over the entire tract without respect to location of canals and included a large area eliminated because of elevation. It is very difficult to identify with certainty the irrigable area as used in the Gault report with that determined by Strahorn over the area included in his investigation. It is assumed, however, that the difference between the area as given by Strahorn and that used in the Gault report represents the area eliminated because of elevation.

1352. The Board of Engineers simply lists the irrigable areas as determined by that agency by townships, but gives no information as to the details of location within the township.

1353. In the present study it was found that the three reports were in close accord as to the irrigable area in many of the townships, in which case one or the other, or a slight modification of one of the areas was adopted for use in the present study. In many cases, where apparent discrepancies were found, it was possible to reconcile the results by making corrections for high land, poor soil, etc., while in the townships where wide discrepancies were found, field examinations and independent classifications were made.

1354. In those townships where the results were reconciled by an office study, equal weighting was given to the classification as given by each of the three agencies, where matters of topography, drainage, or irrigability were in question. Where the question was one of soil, the classification as made by Strahorn was adopted in all cases.

1355. In those townships where field inspections and independent classifications were made, the basis of these classifications was the same as that used by Strahorn [75] except that no attempt was made to differentiate between different classes of irrigable land. One of the principal objectives of the irrigation section of this report is the determination of water requirements for irrigation, and this will be fixed by the irrigable area irrespective of whether the land be first or second class.

1356. Of the 154 townships within the maximum project, the irrigable area of 67 was determined through an office study; on the remaining 87 townships, the classification was based upon an independent field examination.

1357. The irrigable areas, as determined by the methods outlined above, fixed the gross irrigable area within the project. When the canal system was projected upon the work maps, deductions were made for rights of way for canals, highways, and railroads, and for certain small isolated tracts where the cost of local distribution was not commensurate with the area reclaimed. The results, after these deductions were made, gave the net irrigable area used in the further consideration of the project.

1358. The net irrigable area thus secured for the maximum project considered in this report does not agree with that fixed by the

[75] Columbia Basin project, Gault report, (1924), appendix A.

Columbia Basin Survey Commission, by Gault, or by the Board of Engineers; but it is believed to be a fair estimate of the area which will demand water for irrigation in the eventual development of the country, and the area which should be used in allocating the available water supply to irrigation development.

1359. For the purpose of comparison table no. 203 gives the irrigable area as determined by the various agencies for the maximum project considered in this report; that is, a gravity diversion from Clark Fork with supplemental pumping to irrigable lands under a 100-foot lift. (See pl. no. 127.)

TABLE NO. 203.—*Irrigable areas*

Agency by which determined	Gravity	Gravity plus supplemental pumping
	Acres	*Acres*
Columbia Basin Survey Commission	1,753,000	[1] 1,834,000
Gault	1,086,819	[2] 1,424,555
Board of Engineers	1,550,000	[2] 1,770,000
United States Engineer Department	1,256,940	[2] 1,519,890

[1] Supplemental pumping not to exceed 150 feet.
[2] Supplemental pumping not to exceed 100 feet.

1360. The duty of water to be used over the lands in the projects under consideration was determined in a manner similar to that in which the land classification was made. Where the Columbia Basin Survey Commission, Gault, and the Board of Engineers were in accord as to the duty of water for a tract, that duty was used in this report. When there were any material discrepancies in the duties assigned to the land by those agencies, then a duty of water was fixed after a field examination of the area in question. This duty of water refers to the net amount delivered measured at the farm unit. The duty of water assigned to the areas in the Columbia Basin irrigation project for use in the present studies varies from 2.5 to 4 acre-feet. Land with a requirement of more than 4 acre-feet was eliminated. The mean duty of water for each plan considered is noted in the discussion of that plan.

1361. *c'. Duty of water and seasonal distribution thereof.*—In determining the seasonal distribution of water, there are many elements to be considered. Some of these are physical facts, determinable with considerable accuracy from existing records; others are more or less indeterminate, and depend largely upon judgment based on experience. Among the elements to be considered are precipitation, temperature, evaporation, soil conditions, and nature of crops grown.

1362. In fixing a feature of this sort, experiences on projects that are most nearly comparable as to temperature, precipitation, evaporation, soil, probable crops, etc., are most valuable, and, perhaps, form the best criteria for fixing the seasonal distribution of water on a new project.

1363. The Columbia Basin Survey Commission, Gault, and the Board of Engineers have all used the Sunnyside unit of the Yakima project as the criterion to fix the seasonal distribution of water over the Columbia Basin irrigation project. The reasons for using the Sunnyside unit are its location with respect to the Columbia Basin irrigation project, the similarity of the two projects as to soil and climate, and their general similarity as to probable crop production.

1364. In view of the general acceptance of the seasonal water distribution as used on the Sunnyside unit, as being adapted for use on the Columbia Basin irrigation project, those figures, with slight modification, are used for this study.

1365. In applying to the Columbia Basin irrigation project the seasonal distribution of water, as determined by experience on the Sunnyside division, corrections were made for differences in rainfall and evaporation between the two areas. With those corrections the following seasonal distribution of water was determined for use in the present study.

	Percent
April	10. 25
May	17. 80
June	17. 02
July	19. 20
August	18. 25
September	12. 07
October	5. 41
Total	100. 00

1366. In the determination of canal capacities, the above seasonal distribution of water was used as a basis. The Columbia Basin irrigation project is so large, and the diversity factor so wide, that it is believed that the peak demand may consistently be extended over a period of 1 month.

1367. *d'. Water supply.*—The Columbia Basin irrigation project may secure its water supply by either of two ways: By a gravity diversion requiring a long, expensive main canal, or by pumping from the Columbia River.

1368. Several modifications of the gravity plan of diversion will be discussed. The entire supply may be secured from Clark Fork; a portion of the supply may be secured from Clark Fork and the remainder secured from the Spokane River; the supply for the Quincy area may be secured from the Wenatchee River, and the remainder of the project supplied from Clark Fork and Spokane River.

1369. With the pumping plan of development the water would be taken from the Columbia River at the head of Grand Coulee. An alternative plan is also considered, wherein the Priest Rapids area is reclaimed by pumping from Columbia River near Bend, the supply for the remainder of the project coming from the Columbia River at Grand Coulee.

1370. The gravity diversions all require regulation and storage on the upper reaches of the streams from which diversions are made, to provide an adequate water supply.

1371. The pumping diversions from the Columbia River do not need storage to meet the requirements of a maximum irrigation development.

1372. The general plan of development for the utilization of the waters of the Columbia River, considering navigation, flood control, power, and irrigation, anticipates storage and regulation at points favorable to such development. In this general plan of development, storage and regulating works are proposed for Flathead, Hungry Horse, and Priest Reservoirs and Pend Oreille Lake, all of which are located on the Clark Fork or its tributaries, well above the point of

diversion for the gravity plan of irrigation development, and Coeur d'Alene Lake at the head of the Spokane River.

1373. The extent to which this storage and regulation can be developed, and other phases of the water-supply study, are discussed elsewhere in this report, under Stream Flow and Storage in paragraphs 161–274, but is mentioned at this point to show the limits to which this regulation can be carried, in the interest of navigation, flood control, and power without adversely affecting the gravity diversion for irrigation from Clark Fork.

1374. For engineering reasons it is desirable to divert from Clark Fork at Albany Falls, at the highest permissible elevation, to provide as much grade as possible between that point and Spokane River.

1375. In all plans provision has been made for a flow of not less than 7,000 second-feet passing Albany Falls, to care for existing rights below that point.

1376. With storage and regulation as outlined elsewhere in this report, a water-surface elevation of 2,051.7 (United States Coast and Geodetic Survey datum) would have been required in Clark Fork at Albany Falls in August 1926 (the most critical period in 27 years of record) to provide the main canal with the required head of water for a development of plan no. 2, discussed later, and permit the 7,000 second-feet to pass Albany Falls. This elevation of 2,051.7 for August requirements has been the determining factor in fixing the elevation of the point of diversion for plan no. 2.

1377. *e'. Canal and reservoir losses.*—The Columbia Basin irrigation project involves such a large area of land, and the canal system is of such magnitude, that the question of canal losses is an important one. The estimates, as prepared by the Columbia Basin Survey Commission, and also by Gault, contemplated the concrete lining of all canals having a capacity of 100 second-feet or more. The plans of the Board of Engineers contemplated the lining of all canals leading to the individual farm unit. Preliminary comparative estimates and studies made in connection with this report demonstrated the economy of using a canal system lined throughout, as suggested by the Board of Engineers, the cost of the additional canal lining being more than justified by the saving effected in the reduction of the canal section due to higher permissible velocities, and to the reduction in seepage loss from the system. The economy effected by lining the canal system throughout is so marked that that feature has been adopted in all plans of development outlined in this report for the reclamation of the lands of the Columbia Basin irrigation project.

1378. Available data on seepage losses in concrete-lined canals are somewhat limited, but the best information available indicates that the losses in a well-lined canal system would be so small that they could be ignored, even in a system as large as that contemplated for the Columbia Basin irrigation project. However, the probable loss was calculated, and a factor of about 3 used to secure the following losses, which have been used in the design of canals for the system, whether the diversion be by gravity or pumping; this represents the loss by seepage and evaporation from the entire lined canal system.

	Per cent
Loss in main canal	2
Loss in distributing system	6

1379. In all of the plans considered, one or more reservoirs are included as a part of the main canal system, to avoid heavy hillside location for the canal with its attendant high cost, to conserve grade, and to be used, in a measure, in regulating the flow through a long canal system. These reservoirs are, of course, unlined, and the losses therefrom are considered independently of the loss in the lined canals.

1380. The gravity plan of development included six reservoirs, with a combined area of about 8,110 acres, as a part of the main canal. The loss in these reservoirs is a function of the wetted area, and not of the capacity of the canal of which it forms a part, and it will be the same for all modifications of the gravity plan of development using these reservoirs as a part of the canal system. The seepage loss in these reservoirs is based upon an assumed loss of 10 feet in depth over the wetted area in the season of 214 days, an assumption believed to be conservative, as indicated by losses in the Deer Flat and Salmon River Reservoirs in Idaho, where conditions are similar to those under consideration.

1381. With seepage loss, as determined on the basis outlined above, and evaporation loss as indicated by the hygrometric data for that section, a maximum rate of loss from these reservoirs was found to be 290 second-feet during July, the month of maximum evaporation. This loss of 290 second-feet is independent of and in addition to the loss in the lined canal.

1382. In the plan of development with a pumping diversion from Columbia River at Grand Coulee, it is proposed to form a large reservoir at the head of Grand Coulee from which water will be drawn by a gravity system to serve the lands on the project. The question of probable loss to be encountered in this reservoir has been the subject of considerable study in the preparation of the present report, and is discussed fully under feature no. 4, plan no. 4.

1383. *f'. Rediverted water.*—In a study of the Columbia Basin irrigation project allowance has been made for the rediversion or reuse of water on the project. This project lends itself to the reuse of water. It is manifest that if a certain amount of water on the project can be recovered and rediverted to other lands, the main canal requirement will be reduced by the amount so rediverted. Waters diverted for irrigation purposes are accounted for in the following manner.

(*a*) Canal and reservoir losses (seepage and evaporation).
(*b*) Field losses (evaporation, surface run-off and deep percolation).
(*c*) Plant transpiration.

1384. The canal losses are reduced to a minimum by the concrete lining of all canals; the water lost through evaporation and that consumed in plant life are, of course, not recoverable. The loss through surface run-off, seepage, and deep percolation is, however, subject, to some extent, to recovery and reuse. The surface run-off may be diverted from the natural drainage channels throughout the project, and the loss by seepage intercepted and collected, in part, by the drainage system proposed as a part of the canal system. A portion of these waters will be subject to reuse on lands at a lower elevation on a strictly gravity system, or on the higher lands if supplemental pumping is considered.

1385. The extent of these losses, and the possibility of recovery, varies greatly on different projects. The results are dependent on so

many different features—soil, subsoil, topography, duty of water, crops, and methods and care in the use of water—that no project can be used as anything more than a rough criterion for the study of any other project. The data on this subject are rather meager, but the office study in the preparation of this report makes use of the best data available on the subject in determining or estimating the amount of rediverted water used in the calculations for the various plans.

1386. This rediverted water is taken into consideration only in the design of the main canal for each plan considered. It is not given consideration in the design of the lateral system because of our inability at this time to determine the points on the project where this water may be recovered. The distributing system will, therefore, in some sections have a slight excess capacity, depending upon the point of recovery of this rediverted water.

1387. *g'. Engineering treatment.*—The magnitude of the Columbia Basin irrigation project is so great that any development even approximating a maximum one would require works of such proportions as to be practically without precedent as far as present irrigation is concerned.

1388. Any gravity plan of development calls for an extensive main canal leading to the areas to be reclaimed. These canals involve all types and classes of construction—canals, dams and reservoirs, siphons and tunnels. The pumping diversion from the Columbia River at Grand Coulee requires a main canal much shorter than that required by any gravity plan of diversion, but encounters the same structural features, and includes also a pumping plant that is without precedent as to size and capacity.

1389. Studies made of the various plans proposed by the agencies previously reporting on the project demonstrated fully the advisability of using a concrete lining in the entire canal system. Several factors have entered into the determination of this point, the most important of which are the permissible increase in velocity; thereby decreasing the sectional area and cost of the excavation, the reduction of canal losses, and the increase in the factor of safety in operation, a not inconsiderable item in projects of the magnitude of those considered.

1390. Accordingly, the various plans considered in this report contemplate the use of concrete-lined ditches from the point of diversion to the point of delivery at the individual farm unit, except in a few cases when a river improvement is incorporated in the canal system. These river improvements when used will, of course, be unlined sections and will be so specifically mentioned in the estimate following. Except in solid rock, the concrete lining in all canals is reinforced against temperature stresses. The maximum thickness of lining used is 9 inches; while the minimum for the small laterals is 3 inches, as is indicated on the canal sections shown on various drawings. In the design of all canal sections and tunnels having a concrete lining, 0.014 is used as the value of n in Kutter's formula. Canal sections have been designed with the most advantageous hydraulic properties consistent with the territory traversed and the material encountered. Along the main canals, advantage has been taken of various reservoir sites, which have been incorporated in the canal system, in the interest of economy and conservation of grade. In the main canal for plan no. 2, for example, reservoirs are formed by the

construction of the Camden, Dry Creek, Deep Creek, Deadman Creek, Latah Creek, and Rock Lake dams. These reservoirs form a part of the main canal, and each takes the place of several miles of canal that would be required were these reservoirs eliminated. Some of these reservoirs are small and might be eliminated if necessary, but some, notably the Rock Lake Reservoir, are practically indispensable. This reservoir is about 16 miles in length and replaces probably 20 miles of canal, the greater portion of which would be along almost precipitous canyon walls, where the cost would be extremely high if not absolutely prohibitive.

1391. In the estimates for the various plans the location of the larger and more important canals was projected upon line topography which had been taken during the preparation of the earlier estimates prepared by other agencies, or which had been secured in the present investigation. From these line projections, profiles were constructed and a station-to-station estimate prepared of the canal system.

1392. Some of the smaller canals were projected over the United States Geological Survey quadrangle sheets, and a mile-to-mile estimate prepared. Canals below 100 second-feet in capacity are covered by a blanket estimate based upon the acreage covered.

1393. Classification of material to be encountered in canal construction is based upon surface indications, washes, road excavations, and wells when available, and from information in previous estimates. No testing has been done along the location of these canals.

1394. Tunnels are of the horseshoe type with a freeboard amounting to one sixth, or 16 percent, of the depth of water carried. No exploratory work was done to determine the condition or character of material to be encountered in the tunnels, and the classification as used in the estimates following is based upon the information given in the report of the geological examination made by Kirk Bryan in connection with the Gault report.

1395. Where tunnels are utilized a double-bore construction has been used in the present plans on the main canal and the larger laterals of the system. A careful analysis and comparison of single versus double-bore tunnels on the main canal of plan no. 2, discussed later, revealed the fact that a considerable decrease in the capital cost of this item would be made by using a single-bore construction. A further analysis based upon 4 percent interest on the capital invested showed that at the time of completion of the second bore of the double-bore plan, the total cost of each plan was practically the same. This being the case, the double-bore plan was adopted for this estimate as it lends itself more readily to a stage construction and does not require as large an expenditure during the earlier life of the project.

1396. Several inverted siphons will be required for any one of the various plans considered, and on the main canals these structures are large; the largest ones consist of one or more steel pipes with the necessary stiffness, with concrete saddles, anchors, and end structures. On some of the smaller ones reinforced-concrete structures were used throughout when the operating head was permissible. On even the larger siphons a final analysis might show that some saving could be made by using a combination of these two methods.

1397. Plans for dams, siphons, diversion works, etc., required as a part of the present plan of development have been prepared in only such detail as was necessary to make an estimate of the cost. Inci-

dental to the development of the Columbia Basin irrigation project, all the plans considered carry certain potential power possibilities that will be considered under the discussion of that particular plan. All plans considered afford possibilities for the development of power at various drops in the canal system on the project. This power, a byproduct strictly seasonal in character, can be used to good advantage to pump water to the desirable areas above the gravity systems.

1398. In preparing the various estimates the unit prices adopted, as indicated in table no. 204, are based upon prices which have prevailed during the past 2 or 3 years, due consideration being given to the local conditions to be found under the various areas considered, and are thought to be ample to cover the contract cost of the work under conditions that will be encountered in the project.

TABLE NO. 204.—*Unit prices*

Item	Character	Unit	Unit price
Canals:			
Excavation	Little Spokane River.	Cubic yard	$0.30
	Canal:		
	Earth	do	0.14- .20
	Loose rock	do	.50- 1.00
	Solid rock	do	1.25- 2.00
	Structure:		
	Earth	do	.40- 1.00
	Loose rock	do	1.00
	Solid rock	do	1.50- 2.50
Backfill		do	.20- .40
Concrete (not including steel)	Footings, etc	do	12.00-15.00
	Transitions	do	20.00
	Siphons	do	25.30
	Canal lining	do	14.00
	Tunnel lining	do	15.00
	Special	do	20.00-30.00
	Gunite	do	30.00
	Rubble masonry	do	7.00-10.00
Steel	Reinforcing	Pound	.07
	Pipe lines	do	.07
	Structural	do	.07- .10
	Gates	do	.12
	Hoists	do	.20
Lumber	Tunnel timbers	1,000 feet b.m	60.00
Dams and embankments: Embankment	Earth	Cubic yard	.50- .75
	Gravel	do	.50- 1.00
	Riprap	do	1.00- 2.00
	Paving	do	1.50- 2.00

1399. The Columbia Basin irrigation project presents conditions favorable to a low unit cost of the various classes of work. Climatic conditions are good. The nature, extent, and magnitude of the work is such as to justify the most modern and up-to-date equipment. Transportation facilities are excellent, and the area is well located with respect to markets for both labor and supplies.

1400. The canals are of such design that they are adapted particularly to machine work. Electric power is available at various points over the area to be reclaimed. Modern motorized equipment will dispense with large strings of livestock with their attendant problems of feed and water.

1401. Sand, gravel, and rock for concrete or masonry construction is available within a reasonable distance from all points of the work. Water when not available will be made so by the sinking of wells, for which an item is included in all estimates.

1402. The various plans proposed, as stated previously, are based upon field data decidedly preliminary in character; further field work and investigation doubtless would point the way to changes that would be an improvement upon those proposed at present.

1403. h'. *Plans considered.*—In connection with the development of the Columbia Basin irrigation project the following plans have been considered and will be treated in the order listed below:

Plan no. 2-A
Plan no. 2
Plan no. 1
Plan no. 6-A
Plan no. 4
Plan no. 4-A
Plan no. 3

1404. Following is a brief description of each of these proposed plans. These outlines will be followed with a detail discussion and estimate of cost for each.

1405. Plan no. 2-A covers the maximum project with a gravity diversion (including supplemental pumping within 100 feet), the major portion of the water supply being secured from Clark Fork at Albany Falls. This supply would be supplemented in Spokane Valley by a diversion from Spokane River, the amount of which would be fixed by the limit to which regulation may be carried in Coeur d'Alene Lake. (See pl. no. 127.) The main canal for this plan consists of a series of canal sections, tunnels, artificial lakes and inverted siphons extending from Albany Falls to a point near Hillcrest at the upper end of the irrigable area, including a canal in the Spokane Valley connecting Spokane River to the main canal. For the location of the main canal and its constituent features see plate no. 128.[2] At the bifurcation works near Hillcrest the main canal is divided and the general distribution system begins. (See pl. no. 129.[2])

1406. Plan no. 2 is identical with plan no. 2-A in all respects except that the entire water supply is obtained from Clark Fork at Albany Falls and no physical connection is made between the main canal and Spokane River. The distributing systems are identical for both plans.

1407. Plan no. 1 is identical with plan no. 2-A, except that no consideration is given to supplemental pumping.

1408. Plan no. 6-A is a combination of a modification of plan no. 2-A and the greater Wenatchee project which has been discussed earlier in this report. The eastern and southern portion of the project is reclaimed as outlined in plan no. 2-A, and the Quincy area as outlined in the discussion of the greater Wenatchee project. (See pl. no. 130.[2]) The total area reclaimed under this plan is somewhat less than that of plan no. 2-A, because of certain areas marginal to each unit where the cost of local distribution was prohibitive.

1409. Plan no. 4 contemplates a pumping diversion from the Columbia River at Grand Coulee. The water supply is pumped from the Columbia River to the Grand Coulee Reservoir, from which it is delivered to the project through a gravity system similar in character to that of plan no. 2-A. Plan no. 4 includes also supplemental pumping to a maximum height of 100 feet, and represents the maximum area that can be included in a project with a pumping diversion, as shown

[2] Not printed.

on plate no. 131. The location of the canal system as required for this plan of development is shown on plate no. 132.[2]

1410. Plan no. 4-A is identical with plan no. 4 as to area reclaimed. In plan no. 4-A it is proposed to reclaim the Priest Rapids area with a pumping diversion from Columbia River near Bend, the balance of the project being covered by the pumping diversion from Columbia River at Grand Coulee. The canal system is modified to meet these changed conditions.

1411. Plan no. 3 is identical in all respects with plan no. 4, except that no consideration is given to supplemental pumping.

1412. In discussing all plans of development involving a gravity diversion, in whole or in part, from Clark Fork, it must be remembered that the elevation of the point of diversion, and the end of the main canal are fixed within certain very narrow limits.

1413. The regulation of Pend Oreille Lake fixes the elevation at the point of diversion, and the lower end is fixed by the elevation of a broad saddle through which the canal passes.

1414. Any combination of gradients that may be used throughout the main canal system must recognize the fact that the increase of the grade through any one feature requires a corresponding decrease elsewhere in the system.

1415. *i'. Plan no. 2-A—Main canal system.*—Gravity diversion (maximum project with supplemental pumping). Diversion from Clark Fork and Spokane River.

Area reclaimed by gravity	acres	1, 256, 940
Area reclaimed by supplemental pumping	do	262, 950
Total area reclaimed	do	1, 519, 890
Mean irrigation requirement at land	acre-feet per acre	2. 88
Total seasonal requirements at land	acre-feet	4, 378, 357
Capacity of main canal, Clark Fork to Spokane Canal Junction	second-feet	11. 750
Capacity of Spokane Canal	do	2, 490
Capacity of main canal, Spokane Canal Junction to bifurcation works	do	14, 240
Loss in main canal	do	290
Loss in reservoirs	do	295
Quantity delivered at bifurcation works	do	13, 655
Rediverted water on project	do	890
Total requirements for project	do	14, 545

Table no. 205 gives the monthly requirements at the land and the monthly diversion requirements after correcting for losses in canals and reservoirs and taking credit for water rediverted on the project.

TABLE NO. 205.—*Water requirements for Plan no. 2-A (acre-feet)*

Place	April	May	June	July	August	September	October	Total
At land	448, 782	779, 348	745, 196	840, 644	799, 050	528, 468	236, 869	4, 378, 357
At bifurcation works	477, 427	829, 093	792, 762	894, 303	850, 053	562, 200	251, 989	4, 657, 827
At diversion, canal loss only	487, 171	846, 013	808, 941	912, 554	867, 401	573, 673	257, 131	4, 752, 884
Reservoir loss	13, 500	14, 900	15, 680	17, 720	16, 760	14, 060	13, 030	105, 650
Total requirements	500, 671	860, 913	824, 621	930, 274	884, 161	587, 733	270, 161	4, 858, 534
Less rediverted water	6, 822	27, 379	39, 112	54, 758	46, 935	35, 201	23, 464	233, 671
Diversion requirements	493, 849	833, 534	785, 509	875, 516	837, 226	552, 532	246, 697	4, 624, 863

[2] Not printed.

1416. In designing the main canal, no modification in capacity was made at any point for losses accruing above that point, the main canal from the Spokane Canal junction to the bifurcation works having a designed capacity of 14,240 second-feet.

1417. In considering the main canal, reference is made to 16 detail line topographic sheets, scale 400 feet to 1 inch, with a contour interval of 5 feet, and to detail profiles in three sections, giving the data upon which the estimates were based. These topographic maps and profiles are unpublished.

1418. This plan provides for a gravity diversion from Clark Fork, supplemented by a gravity diversion from the Spokane River.

1419. *a''. Main canal.*—(See plate no. 128.[2]) The main canal extending from the point of diversion from Clark Fork at Albany Falls to the bifurcation works at the head of the irrigable tract is about 130 miles in length, and consists of a diversion dam in Clark Fork at Albany Falls, which also serves as regulatory works for Pend Oreille Lake, together with a series of canal sections, tunnels, reservoirs, inverted siphons, and a viaduct crossing Spokane River.

1420. The six reservoirs included in the main canal system, Camden, Dry Creek, Deep Creek, Deadman Creek, Latah Creek, and Rock Lake, are generally utilized as a measure of economy and as a means of conserving grade. The Camden, Latah Creek, and Rock Lake Reservoirs eliminate long sections of canal where the construction would be extremely difficult and expensive, while the Dry Creek, Deep Creek, and Deadman Creek Reservoirs could be constructed at a cost considerably less than that of the canal replaced. In addition to the question of cost, these reservoirs effect the saving in grade that would be required in the canal should the reservoirs be eliminated.

1421. With the exception of the Rock Lake Reservoir, no provision is made for storing water. At the Rock Lake Reservoir, provision is made for storing water between elevations 1,798.9 and 1,802.4, which provides a capacity of 12,200 acre-feet.

1422. The canal sections throughout the main canal are indicated on plate no. 133.[2] Three inverted siphons are required. Each of these structures consists of four lines of steel pipe with the necessary concrete cradles, anchor blocks, and end structures. Plate no. 134 [2] shows the plan of the Cow Creek siphon and is also typical of the structures at Dragoon Creek and at Wassun Creek, the two remaining siphons on the main canal. The Spokane River crossing consists of a 3-span concrete structure carrying three structural steel flumes as indicated on plate no. 135.[2]

1423. In the Spokane Valley the main canal is joined by the Spokane Valley Canal which diverts from the Spokane River at a point about 2 miles below Post Falls. This diversion from Spokane River is made by a low-gate structure across that stream and the canal, which involves no unusual features, affords the physical connection between Spokane River and the main canal.

1424. *b''. Distributing system.*—(See pl. no. 129.[2]) The distributing system begins at the bifurcation works near Hillcrest. At that point the main canal is divided into the main north and the main south. The main north extends along the northern boundary of the project to the Quincy area and thence south to the Frenchman Hills. The area covered by the main north and its lateral system is that

[2] Not printed.

portion of the project located north of Lind Coulee to its confluence with Crab Creek and then north of that creek to its junction with the Columbia River, and consists of an area of 689,700 acres, including areas to be covered by supplemental pumping.

1425. The main south extends in a southwesterly direction from the bifurcation works. About 15.5 miles below that structure, the main central is diverted; the main south continuing in a southerly and westerly direction to a point near Pasco, and the main central extending westerly to the Priest Rapids area. The main south with its distributing system serves 251,760 acres including areas covered by supplemental pumping, while the main central with its lateral system covers an area of 578,450 acres also including areas covered by supplemental pumping.

1426. The main north, main south, and main central, with their lateral systems, consist of a series of canal sections, tunnels, siphons, both steel and concrete, and the necessary turnouts and other necessary structures. These canal sections, tunnels, and other structures involve no unusual features other than those incidental to the unprecedented capacity of the system.

1427. In considering the proposed system for plan no. 2-A, reference is made to certain office records (unpublished) that provide essential data. These records indicate the location of all canals having a capacity of 100 second-feet or more, area of land served under each lateral with the water requirements for that area, and capacities of all canals and laterals at strategic points.

1428. The location of the larger lateral, when so stated in detail description in appendix 5, has been located on line topographic sheets and transferred from these sheets to the work map while the balance of the system has been projected upon the United States Geological Survey quadrangles which, when available, have formed the background of the work map.

1429. For those lines that have been projected on the line topographic sheets, profiles were prepared and form the basis of the estimates for the canals. Estimate of laterals having a capacity of less than 100 second-feet are covered by a blanket estimate based upon the area served.

1430. *c''. General project items.* —Above has been given a general description of the main canal and its distributing system consisting of the main north, main south, and main central with their respective lateral systems. The entire system is described feature by feature in appendix 5. The following items pertain to the general project rather than to any one of the subdivisions mentioned above.

1431. *a'''. Drainage.*—A blanket estimate is included to cover this item. The question of drainage is one that will require a great deal of detail study, and is one that will probably not be determined until some time after water has been applied to the land. The requirements for drainage will vary with different sections of the tract. Some sections will require extensive work, while others will require little or none. For the present purposes, an estimate of $5 per acre was included to cover this item throughout the entire project. In the plan of stage development, it was assumed that this expenditure would be required 5 years after the land in question was first placed under irrigation.

1432. *b'''. Wasteways.*—At the Spokane River crossing a wasteway, the only one on the main canal, is provided, that will waste the entire flow of the main canal for an unlimited time. About 35 miles below this wasteway Rock Lake Reservoir is located, where the storage facilities will provide for the entire flow of the main canal for only a very limited period. Below the Rock Lake Reservoir no wasteway is provided for the main canal. The possibility of providing one at Cow Creek siphon merits consideration in any further study of this plan. A favorable site for such a wasteway exists at that crossing, but the improvements required in Cow Creek from that point to its junction with the Palouse River, a distance of 20 miles or more, may be excessive.

1433. Wasteways on the project for the present study are the same as those used by Gault with the addition of an item covering the improvement of Lind Coulee. As shown earlier, the Gault report used the Lind Coulee as the upper end of the system, carrying water to the Priest Rapids area. Under the present plan Lind Coulee will be used only as a wasteway.

1434. *c'''. Supplemental pumping.*—The main south and the main central are located over territory, the topography of which is such that drops or chutes are required in certain portions of the system to absorb the excess grade. At these points in the system, where conditions are favorable, it is proposed to develop the power for pumping water to desirable lands located above the gravity system. This power would, of course, be strictly seasonal in character, and would be available only during the irrigation season. While the commercial value of this product, because of its seasonal character, would be low, it is particularly adapted to meet the requirements for pumping to lands located above the gravity system.

1435. There is, according to the present land classification, an area of 262,950 acres lying above the gravity system that can be covered by pumping against a static head of not to exceed 100 feet. The greater portion of this land is very desirable and it is proposed to utilize the power possibilities along the gravity system to provide the power necessary to pump water to these supplemental areas.

1436. Table no. 206 shows the power possibilities that have been given consideration in this report.

TABLE NO. 206.—*Power possibilities, plan no. 2-A*

Power plant no.	Location [1]	Quantity (second-feet)	Net head	Penstock [2]	Capacity	
					Horsepower	Kilowatt
1	Main south	1,815	95		15,000	11,200
2	do	417	100		3,790	2,820
3	Lateral S–5	320	85		3,000	2,240
4	Main central	2,988	132		38,000	28,350
5	do	139	138		1,850	1,380
6	Lateral C–4	677	49		3,200	2,390
7	do	392	80		3,040	2,270
8	Lateral C–6	926	100		8,400	6,270
9	Lateral C–12	85	255		2,100	1,570
Total					78,380	58,490

[1] For locations, see pl. no. 127.

[2] Penstocks included as a part of canal.

1437. In designing penstocks for the above-listed power plants some sacrifice in output of power was made in order that the cost of penstock pipes might be reduced. These penstocks are of considerable length, and are included as a part of the canal system. As the power possibilities on the project are in excess of the demands for supplemental pumping to a maximum elevation of 100 feet, this loss at the pipe line is not objectionable.

1438. The total area to be provided with water by supplemental pumping, in the plan under consideration, amounts to 262,950 acres in tracts of various areas. The seasonal water requirements of these areas are 739,040 acre-feet. The average gross head is 70 feet. Acre-feet feet per season, 51,733,430.

1439. These areas vary in extent, from 15,000 acres to those as small as 20 acres, and are scattered throughout the project as will be seen from plate no. 127, page 909.

1440. Estimates for pumping installations to cover these tracts are taken from graphs, and include all electrical equipment from the low side of the step-down transformers, also pumping equipment, valves, pipe lines, etc., and is dependent upon the acre-feet feet of water to be pumped. It is evident that the per-unit price of these installations depends upon the size of the development.

1441. To meet the requirements of supplemental pumping, it has been shown that the total installation required amounts to 51,733,430 acre-feet feet per season. The following installations would be required:

50 percent, or 25,866,715 acre-feet feet, 1,000 kilowatt installation.
30 percent, or 15,520,000 acre-feet feet, 500 kilowatt installation.
10 percent, or 5,173,340 acre-feet feet, 250 kilowatt installation.
5 percent, or 2,586,670 acre-feet feet, 100 kilowatt installation.
5 percent, or 2,586,670 acre-feet feet, 10–50 kilowatt installation.

1442. The cost of these developments was determined by applying the unit prices as determined from the graph, to the unit quantities as given above.

1443. The power installation required to furnish electrical energy to operate the above pumping units is 22,000 kilowatts. The above is based upon the seasonal requirement of water as outlined elsewhere for the various plans considered and on a 65-percent overall efficiency of the power and pumping system.

1444. Plans were not developed for the individual power plants on the project. The estimates for each plant were prepared upon the following unit cost basis:

	Per kw.
Hydraulic equipment	$13
Electrical equipment	27
Power house and miscellaneous [76]	20
Total	60

1445. The following estimate is for the development of the power required to meet the demands of supplemental pumping up to the 100-foot limit only. This requires 22,000 kilowatts, leaving 39,490 kilowatts to be developed for further use. The disposition of this excess power will be discussed later in the present report.

1446. Included in the estimate for supplemental pumping is the cost of transmission lines necessary for delivering the power from the

[76] Penstocks included as a part of the cost of canal system.

power plants to the points of use at various locations on the project. This item includes 348 miles of primary transmission line and 100 miles of secondary line. This amount of transmission line would deliver power to 95 percent of the area to be covered by supplemental pumping. The remaining 5 percent represents small isolated areas that would be reclaimed at a later date when commercial lines will be available for transmitting the small amount of power required for that purpose. The estimate of the cost of transmission lines includes the step-down transformers necessary to deliver the current to the pumping units at the proper voltage.

1447. *d'''. Telephone system.*—Included in the estimate is an item covering the telephone plant necessary in the operation of the system. No detail plans have been made of this feature, but an estimate was made of the cost of a system believed to be adequate to cover the completed project. This includes about 400 miles of pole line, 1,500 miles of metallic circuit, instruments, equipment, etc.

1448. *e'''. Wells.*—In fixing unit prices for concrete throughout the project, no attention was given to the availability of water for construction purposes. Rather than use a variable unit price for concrete construction because of water conditions, an item was included for making water available within a reasonable distance of any feature of the work. In view of the availability of water at certain points on the project at the present time, and because the stage development proposed will improve water conditions for the later stages, it is believed that the present estimate will be adequate. The estimate includes the cost of a system of wells with their equipment, minus salvage value after completion of the construction work.

1449. *f'''. Permanent buildings.*—This item covers the buildings, offices, shops, warehouses, quarters, etc., required in the operation of the completed system. No details were prepared covering this feature and the estimate used in the Gault report has been accepted.

1450. *g'''. Other features.*—The estimate includes an item for fencing all canals in the system, also bridges over all ditches that cross existing highways. Where bridges are required, standard types of the Washington State Highway Department with an H-15 loading are used in all cases. The fences, bridges, etc., are included in the estimate of the feature of which they form a part.

1451. *d''. Estimates of cost.*—Following are the estimates of the various features that consitute the irrigation system as designed for plan no. 2-A. They include overflow damages in Pend Oreille and Coeur d'Alene Lakes.

Feature no.	*Main canal*	
1.	Albany Falls Dam (The above includes an item of $2,471,370 covering overflow damages at Pend Oreille Lake.)	$6, 468, 670
2.	Diversion headworks	470, 920
3.	Newport Tunnel	18, 598, 620
4.	Canalization Little Spokane River	2, 743, 500
5.	Great Northern Railway line change	3, 000, 000
6.	Camden Dam	1, 552, 620
7.	Canal	2, 012, 830
8.	Dry Creek Dam	1, 177, 490
9.	Canal	445, 260
10.	Milan Tunnel	7, 285, 560
11.	Canal	733, 200
12.	Deep Creek Tunnel	4, 044, 230

Feature no.		
	Main canal—Continued	
13.	Canal	$201,540
14.	Deep Creek Dam	687,430
15.	Deadman Creek Tunnel	4,756,040
16.	Canal	157,640
17.	Deadman Creek Dam	4,402,460
18.	Canal	2,284,210
19.	Pleasant Prairie Tunnel	9,032,010
20.	Canal	499,690
21.	Spokane River Crossing	713,170
22-A.	Canal	1,373,350
S-V-1.	Overflow damages Coeur d'Alene Lake	2,561,350
S-V-2.	Diversion canals and headworks	138,450
S-V-3.	Canal	3,170,090
22-B.	Canal	1,133,490
23.	Manito Tunnel	10,431,810
24.	Latah Creek Dam	2,667,600
25.	Bonnie Lake Tunnel	47,151,630
26.	Canal	407,850
27.	Rock Lake Dam	3,609,390
28.	Canal	6,191,370
29.	Wassun Creek Siphon	977,200
30.	Canal	3,068,900
31.	Dragoon Siphon	511,040
32.	Canal	3,330,810
33.	Patterson Tunnel	2,279,200
34.	Canal	8,404,880
35.	Cow Creek Siphon	3,333,630
36.	Canal	1,361,980
37.	Bifurcation works	104,010
	Total, main canal	173,475,120
	Main north	
1.	Canal	1,633,330
2.	McElroy tunnel	2,618,570
3.	Canal	991,000
4.	Paha tunnel	699,740
5.	Canal	118,270
6.	Paha siphon	851,400
7.	Canal	1,909,500
8.	Klemmer tunnel	6,357,760
9.	Canal	980,860
10.	Third Coulee siphon	601,030
11.	Canal	4,386,280
12.	Second Coulee siphon	1,722,810
13.	Canal	1,582,180
14.	Flaig siphon	931,330
15.	Canal	1,387,030
16.	First Coulee siphon	1,492,580
17.	Canal	2,256,580
18.	Sand Coulee siphon	1,629,390
19.	Canal	1,031,680
20.	Black Rock siphon	1,263,100
21.	Canal	1,809,570
22.	Broken Rock siphon	2,827,180
23.	Canal	2,872,960
24.	Round Lake siphon	1,191,410
25.	Canal	366,880
26.	Adrian siphon	3,223,540
27.	Canal	843,790
28.	Soap Lake siphon	3,927,150
29.	Canal	2,833,380
30.	Canal	380,460
31.	Great Northern siphon	200,040
32.	Canal	780,720
33.	Potholes siphon	2,156,850