

Feature no	<i>Main north—Continued</i>	
34. Canal.....		\$771, 230
35. Frenchman siphon.....		880, 750
36. Canal.....		1, 211, 620
37. Low Gap tunnel.....		855, 040
38. Canal.....		1, 418, 820
N-1. Lateral N-1.....		602, 060
N-2. Lateral N-2.....		1, 585, 850
N-2-1. Lateral N-2-1.....		51, 700
N-2-2. Lateral N-2-2.....		141, 150
N-3. Lateral N-3.....		122, 320
N-4. Lateral N-4.....		815, 580
N-4-1. Lateral N-4-1.....		38, 390
N-4-2. Lateral N-4-2.....		54, 700
N-5. Lateral N-5.....		310, 340
N-6. Lateral N-6.....		81, 810
N-7. Lateral N-7.....		152, 770
N-8. Lateral N-8.....		907, 990
N-8-1. Lateral N-8-1.....		141, 250
N-9. Lateral N-9.....		1, 138, 600
N-9-1. Lateral N-9-1.....		190, 130
N-9-2. Lateral N-9-2.....		216, 590
N-9-3. Lateral N-9-3.....		83, 440
N-10. Lateral N-10.....		737, 150
N-10-1. Lateral N-10-1.....		253, 090
N-11. Lateral N-11.....		93, 000
N-12. Lateral N-12.....		90, 130
N-13. Lateral N-13.....		567, 400
N-14. Lateral N-14.....		31, 510
39. Sublaterals.....		14, 483, 700
Total, main north.....		85, 886, 460
<i>Main south</i>		
1. Milwaukee siphon.....		530, 290
2. Canal.....		2, 039, 180
3. Main south tunnel.....		1, 187, 260
4. Canal.....		1, 303, 570
5. Main central bifurcation works.....		73, 630
6. Main South Penstock No. 1.....		491, 070
7. Canal.....		1, 490, 720
8. Canal.....		598, 100
9. Kahlotus siphon.....		1, 599, 500
10. Canal.....		481, 650
11. Canal.....		286, 930
12. Canal.....		312, 660
13. Canal.....		786, 100
14. Main South Penstock No. 2.....		41, 380
15. Canal.....		474, 540
S-0. Lateral no. S-0.....		410, 590
S-1. Lateral no. S-1.....		78, 790
S-2. Lateral no. S-2.....		52, 820
S-3. Lateral no. S-3.....		270, 360
S-4. Lateral no. S-4.....		491, 780
S-5. Lateral no. S-5.....		1, 040, 390
S-6. Lateral no. S-6.....		36, 440
16. Sublaterals.....		5, 286, 540
Total, main south.....		19, 364, 290
<i>Main central</i>		
1. Canal.....		1, 047, 300
2. Main central tunnel no. 1.....		736, 660
3. Canal.....		382, 840
4. Hatton Coulee siphon.....		262, 050
5. Canal.....		231, 440
6. Main central tunnel no. 2.....		805, 500

Feature
no.*Main central—Continued*

7. Canal.....	\$565, 400
8. Main central tunnel no. 3.....	375, 050
9. Canal.....	508, 170
10. Providence Coulee siphon.....	574, 390
11. Canal.....	1, 108, 190
12. Main Central Penstock No. 1.....	564, 970
13. Canal.....	1, 387, 570
14. Canal.....	257, 030
15. Shano siphon.....	1, 050, 880
16. Canal.....	211, 710
17. Scootency siphon.....	1, 825, 740
18. Canal.....	2, 301, 260
19. Canal.....	1, 858, 100
C-1. Lateral no. C-1.....	549, 700
C-1-1. Lateral no. C-1-1.....	223, 750
C-2. Lateral no. C-2.....	218, 600
C-3. Lateral no. C-3.....	546, 590
C-4. Lateral no. C-4.....	1, 338, 090
C-4-1. Lateral no. C-4-1.....	340, 110
C-4-2. Lateral no. C-4-2.....	157, 600
C-5. Lateral no. C-5.....	261, 600
C-6. Lateral no. C-6.....	3, 938, 480
C-6-1. Lateral no. C-6-1.....	29, 080
C-6-2. Lateral no. C-6-2.....	219, 980
C-6-3. Lateral no. C-6-3.....	116, 700
C-7. Lateral no. C-7.....	97, 610
C-8. Lateral no. C-8.....	566, 380
C-8-1. Lateral no. C-8-1.....	70, 870
C-9. Lateral no. C-9.....	15, 220
C-10. Lateral no. C-10.....	33, 280
C-11. Lateral no. C-11.....	90, 690
C-12. Lateral no. C-12.....	317, 960
20. Sublaterals.....	12, 147, 450
Total, main central.....	<u>37, 333, 990</u>
<i>Project items</i>	
Preliminary surveys.....	1, 000, 000
Supplemental pumping.....	7, 570, 170
Drainage.....	7, 599, 450
Wateways.....	8, 690, 990
Permanent buildings.....	1, 502, 000
Wells.....	200, 000
Telephone system.....	300, 000
Total, project items.....	<u>26, 862, 610</u>
<i>Recapitulation</i>	
Main canal.....	173, 475, 120
Main north.....	85, 886, 460
Main south.....	19, 364, 290
Main central.....	37, 333, 990
Project items.....	26, 862, 610
Project total.....	<u>342, 922, 470</u>

1452. *e''*. *Stage development*.—In determining the final per acre cost, where interest is considered on all money invested, it is important that the system be constructed by stages in order to keep the item of interest as low as possible. It is also important for the same reason to coordinate the construction of the various stages with the rate of settlement in order that no capital expenditure be made until the colonization of the land demands that addition to the system.

1453. The stage development proposed gives proper consideration to this feature, and the construction of each stage is delayed as long as possible, consistent with the colonization of the area to be served.

1454. Some features of the construction work do not readily lend themselves to a stage development. For example, the main canal is long and expensive, being approximately 50 percent of the cost of the entire project. Certain features in the main canal system can be developed by stages; the tunnels are planned for a double-bore type of construction, which adapts itself in a measure to a stage development; siphons may be constructed in four stages, but many features, such as the canal sections, dams, rights-of-way and other items are not possible of a stage development and in those cases the initial investment represents the final one.

1455. In order to outline a stage development, assumptions must be made as to the rate of colonization, as the construction of the system must keep step with the demand for water on the land.

1456. It has been assumed that interest on unpaid balances would be at the rate of 4 percent per annum, that the land would be colonized at an approximate rate of 50,000 acres per year, that land would be placed under cultivation when irrigation water was made available, that repayments would begin after the third crop had been produced.

1457. In constructing the canal system to meet the requirements of the above-assumed rate of colonization, the system has been divided into 16 stages. This stage development of the canal system on the project must be modified to meet local topographic and other conditions, and most of the individual stages include an area requiring 2 or even 3 years to colonize. Table no. 207 gives the proposed stage development. The first stage brings no land under cultivation, but is for preliminary work; the second stage, covering a period of 5 years, includes the construction of all of the main canal that does not lend itself to a stage development and to the first units of those features that may be constructed in stages, together with that portion of the system required to cover the area within the unit considered.

TABLE NO. 207.—*Stage development, plan no. 2-A*

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area beginning repayment
			<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
1	1	\$500,000			
2		600,000			
3		7,400,000			
4	2	9,450,000			
5		25,386,190			
6		39,392,600			
7	3	49,912,500	104,600		
8		4,155,000		52,300	
9		6,498,140	85,580	52,300	
10	4	1,830,000		42,790	52,300
11		2,159,380	98,980	42,790	52,300
12	5	4,903,000		49,490	42,790
13		5,745,380	123,180	49,490	42,790
14		427,900		41,060	49,490
15	6			41,060	49,490
16		11,515,870	49,240	41,060	41,060
17		16,695,750	65,940	49,240	41,060
18	8	15,059,370	90,640	65,940	41,060
19		25,345,000		45,320	49,240
20	9	31,355,120	100,450	45,320	65,940
21		3,566,200		50,220	45,320
22	10	6,395,220	113,590	50,220	45,320
23		1,853,200		37,860	50,220
24	11	7,553,480		37,870	50,220
25		19,335,710	127,050	37,860	37,860

TABLE No. 207.—*Stage development, plan no. 2-A*—Continued

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area beginning repayment
			<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
26	12	\$715,000		42,350	37,870
27		4,777,950		42,350	37,860
28		9,859,680	115,670	42,350	42,350
29	13	200,000		38,560	42,350
30		2,785,250		38,560	42,350
31		2,753,120	93,820	38,550	38,560
32	14	3,633,080		46,910	38,560
33		9,300,360	137,440	46,910	38,550
34		1,410,500		45,810	46,910
35	15 and 16	1,410,500		45,810	46,910
36		1,879,600	150,000	45,820	45,810
37		1,410,500		50,000	45,810
38		2,097,700		50,000	45,820
39		1,410,500	50,000	50,000	50,000
40		2,243,720	13,710	50,000	50,000
41				13,710	50,000
42					63,710
Total		342,922,470	1,519,890		

1458. Under this plan of development, the first land would be brought under cultivation in the eighth year and repayments begin in the tenth; the last area would be brought under cultivation in the forty-first year and repayments begin in the forty-third. Carrying all capital expenditures to the end of the forty-second year with interest at the rate of 4 percent, and deducting an annual repayment of \$15.74 per acre per year, which also carries interest at 4 percent from the time repayment is made to the end of the forty-second year, gives the following:

Capital cost plus net interest	\$598,285,020 or	<i>Per acre</i> \$393.63
Capital cost	342,922,470 or	225.62
Interest	255,362,550 or	168.01
Annual interest charge after completion		15.74
Annual cost of operation and maintenance		1.22
Annual depreciation charge		.83
Total annual charge operation, maintenance and depreciation		2.05

1459. *j'*. *Plan no. 2*.—Plan no. 2 covers the maximum project with a gravity diversion (including area to be covered by supplemental pumping with a head not exceeding 100 feet). This plan (no. 2) is identical with plan no. 2-A, except as to the source of water supply. Plan no. 2 secures its entire water supply from Clark Fork, while plan no. 2-A secures its water supply from both Clark Fork and Spokane River.

1460. In plan no. 2-A the Main Canal leading from Clark Fork has a capacity of 11,750 second-feet to Spokane Valley Junction, where it is joined by the Spokane Valley Canal carrying 2,490 second-feet diverted from the Spokane River. Below Spokane Valley Junction, the Main Canal has a capacity of 14,240 second-feet to the Bifurcation Works at the head of the irrigable area on the project.

1461. The plan now under consideration (plan no. 2) requires a modification of the Main Canal from Spokane Valley Junction to the point of diversion from Clark Fork at Albany Falls. The capacity of this section of the canal must be increased to 14,240 second-feet. The Spokane Valley canal with its diversion works and the regulation of Coeur d'Alene Lake, as proposed for plan no. 2-A, are omitted from plan no. 2.

1462. The above is the only difference between plan no. 2 and plan no. 2-A. Below the Spokane Valley junction, they are identical in every respect. The point of diversion of the Main Canal from Clark Fork for plan no. 2 is at the same elevation as that proposed for plan no. 2-A. As plan no. 2 demands a greater quantity of water from Clark Fork than is required under plan no. 2-A, the amount of water passing Albany Falls will be somewhat reduced. Under plan no. 2-A, with regulation of Pend Oreille Lake as proposed, a minimum discharge of 8,680 second-feet could pass Albany Falls without interfering with the irrigation requirements, while in the case of plan no. 2 the amount would be reduced to 7,000 second-feet. Should the irrigation project be constructed as outlined in plan no. 2, power development on the Clark Fork below Albany Falls would be adversely affected to that extent.

1463. *a''*. *Estimates of cost.*—The features listed in the following estimate constitute the entire irrigation system for plan no. 2. These features are identical with those described in plan no. 2-A, except those marked (*), which have been modified to meet the demands of a larger capacity between the point of diversion at Albany Falls and the Spokane Valley junction.

Feature no.	<i>Main Canal</i>	
1. Albany Falls Dam.....	-----	\$6, 468, 670
(The above includes an item of \$2,471,370 covering overflow damages at Pend Oreille Lake.)		
2. Diversion headworks.....	-----	*554, 030
3. Newport tunnel.....	-----	*20, 865, 880
4. Little Spokane River improvement.....	-----	*3, 288, 750
5. Great Northern Line change.....	-----	3, 000, 000
6. Camden Dam.....	-----	1, 552, 620
7. Canal.....	-----	*2, 341, 270
8. Dry Creek Dam.....	-----	1, 177, 490
9. Canal.....	-----	*474, 000
10. Milan tunnel.....	-----	*8, 207, 240
11. Canal.....	-----	*780, 400
12. Deep Creek tunnel.....	-----	*4, 365, 330
13. Canal.....	-----	*216, 280
14. Deep Creek Dam.....	-----	687, 430
15. Deadman Creek tunnel.....	-----	*5, 322, 120
16. Canal.....	-----	*165, 300
17. Deadman Creek Dam.....	-----	4, 402, 460
18. Canal.....	-----	*2, 493, 670
19. Pleasant Prairie tunnel.....	-----	*10, 033, 470
20. Canal.....	-----	*526, 560
21. Spokane River crossing.....	-----	*805, 040
22. Canal.....	-----	*2, 562, 400
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 Creek 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.....	-----	174, 121, 710

Main north

It is identical with main north, plan no. 2-A----- \$85, 886, 460

Main south

It is identical with main south, plan no. 2-A----- 19, 364, 290

Main central

It is identical with main central, plan no. 2-A----- 37, 333, 990

Project items

They are identical with project items, plan no. 2-A----- 26, 862, 610

Recapitulation

Main canal-----	174, 121, 710
Main north-----	85, 886, 460
Main south-----	19, 364, 290
Main central-----	37, 333, 990
Project items-----	26, 862, 610
Project total-----	343, 569, 060

1464. *b''*. *Stage development*.—The stage development for plan no. 2 is identical with plan no. 2-A in all respects except for the capital expenditures which would be modified somewhat during the earlier stage of the construction period, because of the increase in capacity of the main canal above Spokane Valley Junction, and because of the elimination of the Spokane Valley Canal. The stage development on the project, the date of starting, and rate of colonization are identical with those of plan no. 2-A. Details are given in table no. 208.

TABLE No. 208.—*Stage development, plan no. 2*

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area beginning repayment
			<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
1	1	\$500, 000			
2		600, 000			
3		7, 630, 000			
4	2	9, 880, 000			
5		26, 521, 440			
6		37, 627, 900			
7	3	47, 984, 400	104, 600		
8		4, 155, 000		52, 300	
9		6, 498, 140	86, 580	52, 300	
10	4	1, 530, 000		42, 790	52, 300
11		2, 159, 380	98, 980	42, 790	52, 300
12		4, 903, 000		49, 490	42, 790
13	5	5, 745, 380	123, 180	49, 490	42, 790
14		427, 900		41, 060	49, 490
15				41, 060	49, 490
16	6			41, 060	41, 060
17		11, 735, 960	49, 240	41, 060	41, 060
18		17, 115, 750	65, 940	49, 240	41, 060
19	7	15, 529, 370	90, 640	66, 940	41, 060
20		26, 015, 000		45, 320	49, 240
21		32, 139, 200	100, 450	45, 320	65, 940
22	8	3, 505, 200		50, 220	45, 320
23		6, 395, 220	113, 590	50, 220	45, 320
24		1, 853, 200		37, 860	50, 220
25	9	7, 553, 480		37, 870	50, 230
26		19, 335, 710	127, 050	37, 860	37, 860
27		715, 000		42, 350	37, 870
28	10	4, 777, 950		42, 350	37, 860
29		9, 858, 680	115, 070	42, 350	42, 350
30		200, 000		38, 560	42, 350
31	11	2, 785, 250		38, 560	42, 350
		2, 763, 120	93, 820	38, 560	38, 560

TABLE No. 208.—*Stage development, plan no. 2*—Continued

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area beginning repayment
			Acres	Acres	Acres
32.....	14	\$3,633,080		46,910	38,560
33.....		9,300,360	137,440	46,010	38,550
34.....		1,410,500		45,810	46,910
35.....		1,410,500		45,810	46,910
36.....		1,879,600	150,000	45,820	45,810
37.....	15, 16	1,410,500		50,000	45,810
38.....		2,097,700		50,000	45,820
39.....		1,410,500	50,000	50,000	50,000
40.....		2,243,630	13,710	50,000	50,000
41.....				13,710	50,000
42.....					63,710
Total.....		343,569,060	1,519,890		

1465. Under this plan of development, the first land would be brought under cultivation in the eighth year, and repayments begin at the end of the tenth; the last area would be brought under cultivation in the forty-first year and repayments begin in the forty-third. Carrying all capital expenditures to the end of the forty-second year with interest at the rate of 4 percent, and deducting an annual repayment of \$15.74 per acre per year, which also carries interest at 4 percent from the time repayment is made to the end of the forty-second year, gives the following:

Capital cost plus interest, \$597,879,490 or.....	<i>Per acre</i> \$393. 37
Capital cost, \$343,569,060 or.....	226. 05
Interest, \$254,310,430 or.....	167. 32
Annual interest charge after completion.....	15. 73
Annual cost of operation and maintenance.....	1. 22
Annual depreciation charge.....	. 83
Total annual charge—operation, maintenance, and depreciation.....	2. 05

1466. *k'. Plan no. 1.*—Plan no. 1 is identical with plan no. 2 or plan no. 2-A, except that no provision is made for supplemental pumping. An area of 1,256,940 acres is reclaimed by this plan, all served through a gravity system. The distributing system on the project affords opportunity for the development of a large amount of power during the irrigation season that can be utilized to irrigate desirable areas above the gravity system. Plan no. 1 makes no provision for developing power on the project for the purpose of supplemental pumping and has been eliminated because of the fact that it does not utilize the possibilities to the fullest extent.

1467. *l'. Plan no. 6-A.*—This plan for developing the Columbia Basin irrigation project contemplates the reclamation in two divisions. Division A covers the eastern and southern portion of the project consisting of the Lind, Palouse, Pasco, and Priest Rapids area, which secures its water supply from the Clark Fork and Spokane River in the manner described for plan no. 2-A. Division B consists of the Quincy area, which is reclaimed in the manner heretofore described under the greater Wenatchee project. See plate no. 130.²

1468. The combination of divisions A and B constitutes the entire Columbia Basin irrigation project, as outlined for a gravity diversion under plan no. 2-A, except for the elimination of some marginal areas that cannot be economically included in either division considered separately.

² Not printed.

area from division A. Considered separately the estimates for the greater Wenatchee and division A are unbalanced to the extent that division A carries the cost of power for supplemental pumping on the Quincy area. In like manner the cost of transmission lines and step-down transformers sufficient to meet the requirements of the Quincy area are included with the estimate for those items for division A.

1484. *d''''*. *Telephone system*.—Included in this estimate is an item covering the cost of telephone system necessary in the operation of the system.

1485. *e''''*. *Wells*.—This item is included for the reason outlined in the discussion in plan no. 2-A.

1486. *f''''*. *Permanent buildings*.—This estimate is a modification of the estimate as given in plan no. 2-A.

1487. *g''''*. *Preliminary work*.—This item is also a modification of the one used in plan no. 2-A.

1488. *h''''*. *Other features*.—Included in the estimate are items for fencing all canals in the system, for providing highway crossings over all canals and ditches that will cross existing highways. Where bridges are required, standard types of the Washington State Highway Department with a H-15 loading have been used in all cases. The fences, bridges, etc., are included in the estimate of the particular feature of which they form a part.

d'''. *Estimates of cost*

1489. Following are the estimates of the various features that constitute the irrigation system as designed for plan no. 6-A, division A:

Feature no.	<i>Division A.—Main canal</i>	
1. Albany Falls Dam.....	-----	\$6, 468, 670
(This feature includes an item of \$2,471,370, covering overflow damages at Pend Oreille Lake.)		
2. Diversion headworks.....	-----	294, 350
3. Newport Tunnel.....	-----	10, 209, 520
4. Canalization Little Spokane River.....	-----	2, 178, 390
5. Great Northern line change.....	-----	3, 000, 000
6. Camden Dam.....	-----	1, 530, 070
7. Canal.....	-----	1, 795, 740
8. Dry Creek Dam.....	-----	1, 150, 360
9. Canal.....	-----	369, 060
10. Milan Tunnel.....	-----	4, 383, 850
11. Canal.....	-----	611, 940
12. Deep Creek Tunnel.....	-----	2, 266, 750
13. Canal.....	-----	168, 600
14. Deep Creek Dam.....	-----	783, 530
15. Deadman Creek Tunnel.....	-----	2, 669, 400
16. Canal.....	-----	131, 310
17. Deadman Creek Dam.....	-----	4, 372, 610
18. Canal.....	-----	1, 879, 220
19. Pleasant Prairie Tunnel.....	-----	5, 334, 190
20. Canal.....	-----	408, 200
21. Spokane River crossing.....	-----	533, 420
22-A. Canal.....	-----	1, 126, 740
S-V-1. Couer d' Alene storage.....	-----	2, 561, 350
S-V-2. Diversion dam and headworks.....	-----	138, 450
S-V-3. Canal.....	-----	3, 170, 090
22-B. Canal.....	-----	1, 063, 920
23. Manito Tunnel:		
First bore.....	-----	4, 576, 070
Second bore.....	-----	4, 491, 590

Feature no.	<i>Division A.—Main canal—Continued.</i>	
24. Latah Creek Dam.....		\$2, 667, 600
25. Bonnie Lake Tunnel:		
First bore.....		19, 378, 900
Second bore.....		19, 310, 280
26. Canal.....		358, 180
27. Rock Lake Dam.....		3, 600, 310
28. Canal.....		5, 599, 040
29. Wassun Creek siphon.....		732, 900
30. Canal.....		2, 793, 320
31. Dragon Creek siphon.....		383, 310
32. Canal.....		2, 912, 560
33. Patterson Tunnel:		
First bore.....		1, 086, 960
Second bore.....		890, 290
34. Canal.....		7, 488, 670
35. Cow Creek siphon.....		2, 521, 010
36. Canal.....		1, 236, 130
37. Bifurcation works.....		96, 240
	Total, main canal.....	<u>138, 723, 090</u>

Main north

1. Canal.....	1, 091, 770	
2. NeElroy Tunnel.....	1, 650, 270	
3. Canal.....	607, 880	
4. Paha Tunnel.....	447, 380	
5. Canal.....	69, 580	
6. Paha Siphon.....	391, 730	
7. Canal.....	1, 169, 520	
8. Klemmer Tunnel.....	3, 923, 180	
9. Canal.....	581, 640	
10. Third Coulee siphon.....	222, 590	
11. Canal.....	2, 567, 860	
12. Second Coulee siphon.....	583, 450	
13. Canal.....	793, 520	
14. Flaig siphon.....	294, 700	
15. Canal.....	570, 620	
16. First Coulee siphon.....	333, 600	
17. Canal.....	620, 890	
18. Sand Coulee siphon.....	187, 240	
19. Canal.....	1, 870	
N-1. Lateral N-1.....	602, 060	
N-2. Lateral N-2.....	1, 585, 850	
N-2-1. Lateral N-2-1.....	51, 700	
N-2-2. Lateral N-2-2.....	141, 150	
N-3. Lateral N-3.....	122, 320	
N-4. Lateral N-4.....	815, 580	
N-4-1. Lateral N-4-1.....	38, 390	
N-4-2. Lateral N-4-2.....	54, 700	
N-5. Lateral N-5.....	310, 340	
N-6. Lateral N-6.....	81, 810	
20. Sublaterals.....	6, 282, 990	
	Total, main north.....	<u>26, 196, 180</u>

Main south

The main south is the same as for plan no. 2-A..... 19, 364, 290

Main central

The main central is the same as for plan no. 2-A..... 37, 333, 990

Project items

Supplemental pumping	\$6, 867, 240
Drainage	5, 646, 900
Wasteways	8, 396, 870
Permanent buildings	1, 302, 200
Wells	165, 000
Telephone system	275, 000
Preliminary work	900, 000
	23, 553, 210

Recapitulation

Main canal	138, 723, 090
Main north	26, 196, 180
Main south	19, 364, 290
Main central	37, 333, 990
Project items	23, 553, 210

Total project, division A 245, 170, 760

e''' . Stage development

1490. The following stage developments are predicated upon the same assumptions as in plan no. 2-A. An annual rate of colonization of 50,000 acres is assumed, interest on unpaid balances is computed at the rate of 4 percent, payments to begin at the end of the third year of crop and the payments to equal, at least, 4 percent on the final per acre cost. Table no. 210 gives the stage development proposed for the plan under consideration.

TABLE NO. 210.—*Stage development—plan no. 6-A, division A*

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area beginning repayment
			<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
1	1	\$400, 000			
2		612, 000			
3		6, 350, 000			
4		8, 200, 000			
5	2	21, 799, 180			
6		37, 782, 600			
7		50, 566, 620	104, 600		
8		4, 155, 000		52, 300	
9	3	6, 508, 140	85, 580	52, 300	
10		1, 830, 000		42, 790	52, 300
11		2, 169, 380	98, 980	42, 790	52, 300
12		5, 807, 680		49, 490	42, 790
13	5	9, 245, 380	123, 180	49, 490	42, 790
14		4, 927, 900		41, 060	49, 490
15		4, 600, 000		41, 060	49, 490
16		9, 153, 850	49, 240	41, 060	41, 060
17	7	14, 842, 910	65, 940	49, 240	41, 060
18		4, 949, 370	90, 640	65, 940	41, 060
19		8, 385, 000		45, 320	49, 240
20		13, 840, 180	100, 450	45, 320	65, 940
21	10	2, 316, 200		50, 220	45, 320
22		4, 510, 840	115, 680	50, 220	45, 320
23		2, 703, 200		37, 840	50, 220
24		3, 883, 080		37, 840	50, 220
25	11	5, 832, 420	137, 440	45, 810	37, 840
26		2, 300, 000		45, 810	37, 840
27		2, 878, 400		45, 820	45, 810
28		4, 633, 450	187, 650	50, 000	45, 810
29				50, 000	45, 820
30				57, 650	50, 000
31					50, 000
32					57, 650

1491. Under this plan of development the first area would be brought under cultivation in the eighth year and repayments would begin on that unit at the end of the tenth year. The last area would be placed under cultivation in the thirtieth year and repayments on that unit begin at the end of the thirty-second year. Carrying all capital expenditures to the end of the thirty-first year with interest at the rate of 4 percent on unpaid balance and deducting annual payments at the rate of \$12.24 per acre, also carrying interest at the rate of 4 percent to the end of the thirty-first year gives the following:

	<i>Per acre</i>
Capital cost plus interest, \$345,425,130 or.....	\$305. 85
Capital cost, \$245,170,760 or.....	217. 08
Interest, \$100,254,370 or.....	88. 77
Annual interest charge after completion.....	12. 24
<hr/>	
Annual cost of operation and maintenance.....	1. 32
Annual depreciation charge.....	. 79
<hr/>	
Total annual charge (operation, maintenance, and depreciation).....	2. 11

1492. As stated earlier, division B is identical in all respects with the greater Wenatchee project discussed earlier in this report. Table no. 211 gives the results of combining these two areas to secure the cost of reclaiming the Columbia Basin irrigation project by these two methods.

TABLE NO. 211.—*Plan no. 6-A*

Division	Area	Capital cost plus interest		Capital cost		Interest		Annual interest charge after completion
		Total	Per acre	Total	Per acre	Total	Per acre	
A.....	1, 129, 380	345, 425, 130	305. 85	245, 170, 760	217. 08	100, 254, 370	88. 77	12. 24
B.....	320, 310	94, 896, 200	296. 26	75, 662, 810	236. 22	19, 233, 390	60. 04	11. 85
Total.....	1, 449, 690	440, 321, 330	303. 73	320, 833, 570	221. 31	119, 487, 760	82. 42	12. 15

¹ B = Greater Wenatchee.

1493. *m'. Plan no. 4.—a''. Main Canal system.*—Pumping diversion (maximum pumping project with supplemental pumping). Diversion from the Columbia River at Grand Coulee:

Area reclaimed by direct pumping.....	acres..	980, 340
Area reclaimed by supplemental pumping.....	do.....	219, 090
<hr/>		
Total area reclaimed.....	do.....	1, 199, 430

Mean irrigation requirement at land.....	acre-feet per acre..	2. 92
Total seasonal requirement at land.....	acre-feet..	3, 502, 047
Capacity of Main Canal, pumping plant to Grand Coulee Reservoir.....	second-feet.....	16, 000
Capacity Grand Coulee Reservoir to bifurcation works.....	do.....	11, 160
Rediverted water on project.....	do.....	710
Requirement at head of irrigable area.....	do.....	11, 870

1494. Table no. 212 gives the monthly requirement at the land and the monthly requirements at the point of diversion after correcting for canal and reservoir losses and taking credit for rediverted water on the project:

TABLE No. 212.—*Water requirements for plan no. 4 (acre-feet)*

Place	April	May	June	July	August	September	October	Total
At land.....	358,960	623,365	596,048	672,306	639,124	422,897	189,460	3,502,047
At bifurcation works.....	381,841	663,100	634,043	715,254	679,864	449,642	201,538	3,725,282
At diversion.....	389,665	676,687	647,035	729,910	693,795	458,855	205,667	3,801,614
Loss in reservoir.....	59,504	61,488	59,504	61,488	61,488	59,504	61,488	424,464
Total at diversion.....	440,169	738,175	706,539	791,398	755,283	518,359	267,155	4,226,078
Less rediverted water.....	6,259	21,907	31,295	43,813	37,554	28,166	18,777	187,771
Net diversion requirements.....	442,910	716,268	675,244	747,585	717,729	490,193	248,378	4,038,307

1495. In addition to above the following will be required to cover loss in reservoir during nonirrigation season:

	<i>Acro-feet</i>
November.....	59,504
December.....	61,488
January.....	61,488
February.....	55,537
March.....	61,488
Total loss in reservoir during nonirrigation season.....	299,505
Net diversion requirements.....	4,038,307
Total yearly requirement.....	4,337,812

1496. In designing the Main Canal, the section extending from the pumping plant to the Grand Coulee Reservoir has a capacity of 16,000 second-feet for reasons that will be discussed later. The section of the Main Canal extending from the Grand Coulee Reservoir to the bifurcation works has a capacity of 11,160 second-feet throughout its entire length. Reference is made to line topographic maps prepared in the course of the present study upon which the Main Canal was projected.

1497. The following features, listed geographically, constitute the entire irrigation system for plan no. 4.

1498. *Feature no. 1. Columbia River dam and power development.*—This is considered to be a feature of power development and not of irrigation and accordingly is discussed under the heading of "Power", beginning at paragraph 525.

1499. *Feature no. 2. Pumping plant.*—The pumping plant is considered the first feature of this irrigation development. The operating cost of the irrigation system includes an item covering the purchase of power for pumping purposes and no part of the capital cost of the power development is charged against irrigation.

1500. The power installation as proposed for Grand Coulee will generate secondary power sufficient in most years to operate the pumps required to provide the water necessary to meet the irrigation requirements of the project. However, in certain unfavorable years, this secondary power is insufficient to meet the current irrigation demand during the month of April. To furnish water during that month without the use of prime power, this plan provides for storage of water in the Grand Coulee Reservoir. The water so stored is to be pumped into the reservoir before the beginning of the irrigation season and provides the necessary irrigation supply during the month of April without encroaching upon the output of primary power.

1501. The elevation of the normal water surface in the Columbia River back of the high dam is 1,287.6. The power development proposed and discussed elsewhere in this report contemplates a draw-down to elevation 1,207.6 during the winter months.

1502. The elevation of the water surface in the upper end of the irrigation canal leading from the pumping plant to the Grand Coulee Reservoir is 1,570.90 when operating at full capacity with water surface in Grand Coulee Reservoir at elevation 1,570. For the purpose of the present calculations this elevation has been assumed to be 1,575 and the elevation in the river back of the dam has been assumed to be normal (elevation 1,287.6) during the pumping season.

1503. The proposed pumping plant is located on the upstream side of the dam, with a floor elevation slightly above the normal backwater surface. The plant consists of 10 pumping units, each consisting of two pumps of 1,600 second-foot capacity, operating in series, each pump being driven by a 50,000-horsepower synchronous motor. See plates nos. 57 and 58, page 746.

1504. Each pump unit discharges into an individual pipe line 11.5 feet in diameter, extending for a distance of approximately 530 feet to the structure at the head of the irrigation canal.

1505. The ten 1,600-second-foot units proposed give a capacity well above the maximum irrigation requirement. This excess capacity provides spare units; it also permits of refilling the reservoir at any time when secondary power is available; it also permits of shutting down some of the pumps to care for a peak commercial power demand and making up the deficiency during the off-peak hours.

1506. *Feature no. 3. Open canal, pumping plant to Grand Coulee Reservoir. Length, 1.67 miles. (See plate no. 136,² type no. 43).*—This section of canal extends from the structure at the end of the discharge pipes to the north end of the Grand Coulee Reservoir. Normal water surface in the Grand Coulee Reservoir is elevation 1,560 while the elevation of extreme high water is 1,570. This section of canal is designed to discharge its full capacity, 16,000 second-feet, into the reservoir when the water surface is at elevation 1,570.

1507. The canal is designed to operate under normal condition of flow when the elevation of the water surface in the reservoir is 1,560, and the canal banks are raised to give the required capacity when the water surface in the reservoir is at elevation 1,570.

1508. *Feature no. 4. North Reservoir Dam—G. and Coulee Reservoir. (See plate no. 137.)²*—The Grand Coulee Reservoir forms an important link in the Main Canal system of the plan under consideration. The reservoir is formed by the construction of two dams; the North Reservoir Dam, located about 1½ miles from the Columbia River at Grand Coulee, and the South Reservoir Dam, located about 4½ miles north of Coulee City. The reservoir thus formed will be about 23 miles in length and will vary from ½ to 3 miles in width. With a flow line to elevation 1,570, the area submerged is 23,100 acres.

1509. This reservoir is important because of the 24.4 miles of canal which would be required if it were eliminated and because of the conservation of elevation which it effects. The canal required to eliminate this reservoir utilizes 50 feet in grade between the two dams, while the loss of head for that distance utilizing the reservoir amounts to only 2.3 feet. If the loss in the reservoir amounts to 1,000 second-

² Not printed.

feet, as assumed, no material change in power requirements will be apparent if the reservoir be omitted, as the increase in head for the one case is equalized by the reduction of the quantity of water required in the second.

1510. The use of this reservoir is desirable as a matter of capital cost. The capital cost of the two dams and the overflow damages in the reservoir basin are \$17,656,220 less than the cost of the section of canal that would be required to detour the basin.

1511. As the utilization of this reservoir is desirable from the standpoint of both first cost and possibly the cost of operation, a considerable amount of additional work has been done during the preparation of the present plans to determine the suitability of the basin for reservoir purposes and to the selection of the most desirable sites for the dam required at each end. A topographic survey was made of the reservoir basin. This survey was made by plane-table method by the United States Geological Survey for the War Department. The map was made on a scale of 1: 31,680, with a contour interval of 5 feet to elevation 1,560, above which the interval is 20 feet. Topographic surveys were made of the one favorable location for the North Reservoir Dam, and for three possible sites for the South Reservoir Dam. Tests for foundation conditions were made at the North Reservoir Dam site and at two of the sites proposed for the South Reservoir Dam. At the site for the North Reservoir Dam, six test holes were drilled with depths varying from 120 to 320 feet.

1512. At the Coulee City site for the South Reservoir Dam, 11 holes were drilled to depths that varied from 31 to 199 feet. (See pl. no. 138.)² At the Orchard site for this structure (the one adopted for the present report) no drilling was done, but shallow tests were made by hand auger to determine the suitability of the site for the type of structure proposed.

1513. Several geological studies have been made to determine the water-tightness of the reservoir basin and the characteristics of the various dam sites. Of the various geological reports⁷⁷ to which reference will be made, one was prepared in connection with the Gault report, and the remainder were prepared in connection with the present study. These geological reports form the basis of the assumption that the basin is suitable for reservoir purposes, and that the dam sites are adapted to the structures proposed for the respective sites.

1514. The geological report made in connection with the Gault plan of development includes a detailed discussion of the geological characteristics of the area. The conclusion by Kirk Bryan as to the water-tightness is covered by the following:

The conclusion has been reached that leakage from the proposed reservoir or lake in Grand Coulee is unlikely. The area of greatest danger lies a short distance above the Coulee City Dam where the Coulee monocline crosses the reservoir. This is a restricted zone and in the event of leakage, contrary to expectations, a remedy can be obtained by the expenditure of a large but measurable sum.

1515. This reservoir site, because of its perched position and because of its importance as an element of any plan based upon a pumping diversion from the Columbia River at Grand Coulee, has been the subject of considerable detailed study in the preparation of this report.

² Not printed.

⁷⁷ Kirk Bryan, Gault report, app. B (unpublished); Henry Landes, report of Oct. 26, 1929, app. no. 3; Henry Landes, report of Oct. 13, 1930, app. no. 3; Ira A. Williams, report of Oct. 22, 1930, app. no. 3; F. L. Ransome, report of Dec. 10, 1930, app. no. 3.

It was thought advisable to obtain further opinion as to the suitability of the basin for reservoir purposes, and to secure something tangible regarding the probable seepage loss, for which provision must be made in determining the cost of installation and operation of the pumping equipment required.

1516. A geological examination and report made in 1930 by Henry Landes⁷⁸ in connection with the present study includes the following conclusion regarding this reservoir basin:

The leakage from the Grand Coulee Reservoir would be of the slow but persistent type, in an amount difficult to calculate in advance. Once the water entered the basalt its opportunity to be contained in the lower and lower layers would be almost unlimited. The great basaltic basin that lies to the south, and which covers many hundreds of square miles, is capable of storing an enormous volume of water. The leakage would be at such a depth that probably no indication of it would appear anywhere at the surface, certainly not for a long space of time.

1517. A further geological examination and report was made by Ira A. Williams,⁷⁹ in conjunction with the present study, the conclusion of which is given in the following quotation:

Based upon consideration of present data, therefore, I recognize now in and about Grand Coulee, no conditions that in my judgment should be prohibitive of its development as a successful storage basin to the proposed elevation 1,552.50. Such outcome is contingent, of course, upon the effecting of suitable closures across the Coulee bottom by the two proposed dams, the southerly one of which shall be located conservatively to the northward of the position of the monoclinical fold that crosses the lower end of the Coulee.

I am expressing the above opinion, and have made the preceding comments, as the result of my brief field study and of careful deliberation over all available matter on the situation. It can not be gainsaid, I think, that the creation of a reservoir in Grand Coulee amounts to the partial reproduction of some of the water conditions that formerly existed there, of which those of the present are but a bare remnant.

Admittedly, any suspended body of ground water is in a geologically precarious position; as is that in the Coulee today. Increasing the bulk and extent of this body of water by artificial means would, therefore, be unavoidably rather more experimental than is sometimes the case, and an instance as it were of adding to the load, or the contents, of a now partially emptied elevated vessel (the Coulee) whose ultimate integrity must depend upon the physical continuity and tightness of every part of the bottom and sides and ends. A comparatively few important openings could be disastrous in much greater degree than if the disposition of surrounding ground water conditions were different from what they appear to be.

As expressed in my introductory paragraphs, it nevertheless goes without saying that favorable as the locality may appear superficially, further careful study of the region and more detailed investigations of both dam sites, and of intervening portions of the Coulee trough, should be made before its adoption is decided upon, and in advance of the definite laying out of plans of development.

1518. A third geological examination and report was made by F. L. Ransome,⁸⁰ in the interest of the present study. The conclusion reached in this latest geological report is as follows regarding the water-tightness of the reservoir basin:

The reservoir, although probably subject to a rather high evaporation loss, owing to its large area and shallow depth, will not develop any appreciable leakage.

1519. In addition to the above-mentioned geological reports regarding the suitability of the basin as a reservoir site, advice was secured from A. J. Wiley, a consulting engineer of wide experience in irrigation and power development, as to the suitability of the various dam sites, and the Grand Coulee Reservoir in general.

⁷⁸ Appendix no. 3.

⁷⁹ Appendix no. 3.

⁸⁰ Appendix no. 3.

1520. As the various geological reports indicate that the point of greatest loss in the reservoir would be at the Coulee Monocline, about 4 miles north of Coulee City, it was decided to locate the South Reservoir Dam north of that point, leaving the questionable area outside the reservoir. With the elimination of this area from the reservoir, the various geological reports seem to justify the conclusion that any loss in the reservoir would not be exorbitant.

1521. Regarding the possible amount of leakage to be expected, Mr. Ransome⁸¹ remarks that, "Leakage, if any, will probably not lower the water surface as much as 1 inch per day."

1522. In the present plan it has been assumed that the daily loss from seepage and evaporation, would amount to 1,000 second-feet. This estimated reservoir loss has been used throughout in the water-supply studies, and is used in determining pumping plant requirements both as to installations and power consumption.

1523. While the reservoir has been included in the present plan on the basis outlined above, further examinations and investigations should be made of this phase of the matter before any definite plan is fixed.

1524. Mr. Wiley has recommended that before any action be taken that definitely commits the project to the use of this reservoir, tests be made to determine its water-tightness.

1525. In considering the present plan of irrigation development with the construction of the high dam in the Columbia River at Grand Coulee, and utilizing storage in the Grand Coulee Reservoir between elevations 1,560 and 1,570, secondary power will be used almost entirely for pumping purposes. Should the reservoir be eliminated the amount of water required from the pumping plant would be reduced 1,000 second-feet, the estimated loss in the reservoir, the head as stated would be increased 21 percent. The resultant increase in the demand on the pumping plant due to the elimination of the reservoir would be small, about 2 percent, the advantages of storage in the Grand Coulee Reservoir would be lost.

1526. Practical test, however, might prove the losses in the reservoir to be prohibitive, in which case the only alternative would be the substitution, with its additional cost, and increase in pumping head and power consumption, of the section of canal required to replace the reservoir. The adoption of one or the other of these plans would, of course, be necessary before the design and construction of the pumping plant could be undertaken.

1527. It is assumed that 6 years will be required in the construction of the high dam in the Columbia River. During the earlier portion of this period, a practical test might be made to determine the water-tightness of the reservoir basin. This testing would involve the construction of a dike at each end of the basin to the height required to cover the floor of the basin, and the pumping of a large volume of water from the Columbia River for a period of several months. The expense involved in this test would be large, but small, as compared to errors that might follow a false assumption as to the seepage losses. This testing could be accomplished and the system completed according to one method or the other by the time of completion of the dam in the Columbia River.

⁸¹ Appendix no. 3.

1528. The estimate given for plan no. 4 is based upon the use of the reservoir with the seepage and other losses assigned above. Following that estimate is a statement as to the per-acre cost for plan no. 4, if the reservoir proves to be unserviceable. As stated previously, the Grand Coulee Reservoir is formed by the construction of two dams, the North Reservoir Dam and the South Reservoir Dam.

1529. For the North Reservoir Dam, the topographic conditions are such that the site for a structure of reasonable cost is limited to a restricted area. The site considered in the present report is the one used by all prior agencies reporting on a proposed pumping plan for developing the project. Additional testing was made at this site to determine foundation conditions, and geological opinion, to supplement that accompanying the Gault report, secured as to the suitability of the dam site.

1530. Regarding this dam site, the following conclusions have been rendered by the geologists:

Mr. BRYAN. The contact rises east and north of the dam where it quickly attains elevations above the proposed flow line. If then the movement of the water through the basalt is resisted at the dam, no leakage can take place. The massive basalt of the abutment will not transmit much water, but the base, where it rests on the granite, may prove to be much more open. Grout holes should, therefore, be carried to the contact. It is a matter of regret that test drilling was not carried on to determine the position and character of this contact.

1531. The above opinion was rendered in 1924. The remaining opinions are based upon the results of five of the six test holes drilled during the present investigation.

Mr. WILLIAMS.⁵² I would anticipate that such openness as may exist in and between the layers of basalt at the westerly side of this Grand Coulee site, can be corrected and the abutment rock rendered sufficiently resistant against movement of water around the end of the dam, by application of customary deep grouting methods during construction.

On the whole, therefore, and as stated, I recognize no condition at this time which appears prohibitive to the placing of a safe and effective dam at this location in Grand Coulee, at some position within the limits outlined by the present drill holes.

Mr. RANSOME.⁵³ It is suggested that, before final plans for a dam are made, at least one drill hole should be put down through the basalt of the north abutment to make sure that this is resting on compact silt and not on any loose or bouldery material through which water might readily escape eastward to the Columbia. * * * In my opinion, unless unexpected unfavorable conditions are brought to light by the additional drill hole suggested, it will be practicable to build a safe and effective dam, approximately 60 feet high, at the Grand Coulee site. To the geologist, the site appears better suited for an earth or rock-earth embankment than for a concrete dam.

1532. The test hole suggested in the last opinion as noted, was sunk to a depth of 190 feet. Broken and shattered lava of various dimensions was encountered practically the entire depth. The estimate for the structure includes an item for grouting this section of the foundation.

1533. Regarding the type of structure to be used at this site, Mr. Wiley recommended:

This forms the north or upper end of the Grand Coulee Reservoir and is about 70 feet in maximum height. It is planned to make this an earth embankment with downstream slope of loose rock. I suggest that the top width of the earth embankment be made not less than 20 feet and that its slope be 3 to 1 starting from the top, omitting the 1½ to 1 slope shown in the plan. Connections should

⁵² Appendix No. 3.

⁵³ Appendix no. 3.

be made with the earth foundation by a number of deep trenches with side slopes of $1\frac{1}{2}$ to 1 carried down to the relatively firm material. I think the material noted as black mud and wind blown sand should both be stripped from the foundation.

The material noted as no. 2, consisting of very firm volcanic ash and found about $1\frac{1}{2}$ miles south of the dam, as well as similar material found anywhere in the vicinity, though entirely free from clay and devoid of plasticity as pointed out by the geological report, will make a satisfactory dam when moistened and rolled in 4-inch layers.

The upstream face should be protected by rock paving as shown, but that part of the face which will be exposed to wave action by the possible drawdown of the reservoir should have hand-laid paving with a minimum thickness normal to the face of not less than 18 inches, and a maximum of 24 inches underlaid by 12 inches of gravel.

1534. This structure has been designed along the lines recommended above with the addition of one large Stoney gate and wasteway leading to the Columbia River.

1535. Feature no. 5. South Reservoir Dam—Grand Coulee Reservoir. See plate no. 139.² The proper location of this structure has been the subject of considerable study during the present investigation. Surveys were made of three possible sites; one at Coulee City, one at a point about $4\frac{1}{2}$ miles north of Coulee City, and a third about 1 mile still farther north. Drilling was done at the Coulee City site and the geological opinions, while generally agreeing that the site was a suitable one, favored the site located $4\frac{1}{2}$ miles above, because of conditions in the reservoir basin. About 4 miles above Coulee City, the Coulee Monocline crosses the basin and the geologists generally agree that that geological feature would introduce an element of doubt if included within the reservoir basin. For that reason the site located $4\frac{1}{2}$ miles above Coulee City and well above the monocline in question has been adopted for the present plan. No drilling was done at this dam site. For structures of the type proposed, the character of the upper 20 or 25 feet of soil is of most importance. In this case the upper strata was tested by hand augers and found to be satisfactory. Regarding the suitability of the site selected, Mr. Ransome⁸¹ rendered the following opinion:

With attention to the modification of position suggested and with fuller information concerning the material under the flat bottom of the Coulee, I am of the opinion that it will prove entirely feasible to construct a safe and effective dam, to the approximate height of 60 feet at the no. 2 Coulee City site.

The question of the character of dam suitable for this site is one for the engineers to decide. To the geologist it appears that the site is more appropriate for an earth-fill, or for a combination earth-fill and rock-fill embankment than for a concrete structure.

1536. Regarding the type and design of structure for this location, Mr. Wiley advised as follows:

The dam at Coulee City is to be located about $4\frac{1}{2}$ miles above Coulee City where there is a very uniform profile with a flat bottom formed by a dry lake bed. This dam is about 100 feet high with its base in the dry lake bed. There are no borings, so the undersurface conditions are unknown. The east end of the dam will be on a gentle slope composed of fine volcanic ash soil suitable for use in the embankment. The west end of the dam will close against solid rock spurs projecting beyond the regular side walls of the Coulee.

The flow line will be above the projecting spurs and it will be necessary to excavate the talus slopes to connect the top of the dam with the solid lava slope.

The section of the dam will be of the same dimensions and made in the same way in all respects as the dam at the upper end of the reservoir except that the base to which connection will be made at this site will have to be investigated by

² Not printed

⁸¹ Appendix no. 3.

boring before plans for cut-off trenches can be decided upon. From the information now available, it appears that the dam as shown will be satisfactory if the upstream slope and top width are changed to correspond with those recommended for the dam at the upper end of the Coulee.

1537. Below the Grand Coulee Reservoir the Main Canal, consisting of sections of canal, 1 siphon and 2 tunnels, extends a distance of 10.2 miles to the Bifurcation Works. Detailed description of the features constituting these portions of the plan will be found in appendix no. 5. The location of the entire Main Canal is based upon a projection made on line topographic sheets prepared in connection with the present report.

1538. *b''*. *Distributing system*.—Below the Bifurcation Works, the Main Canal is divided into the Main West and the Main East.

1539. The Main West extends in a southwesterly direction crossing Dry Coulee, and Grand Coulee at the upper end of Soap Lake. From the upper end of Soap Lake it extends in a southerly direction about 2.5 miles where it joins the Main North of plan no. 2-A, which has previously been described. Below this junction the Main West of plan no. 4 is identical in every respect with the Main North of plan no. 2-A.

1540. The Main West serves that portion of the project lying west of a line extended north from Moses Lake and north and west of that portion of Crab Creek extending from Moses Lake to Columbia River, consisting of an area of 370,710 acres including that to be covered by supplemental pumping.

1541. The Main East extends in a southerly and southeasterly direction from the Bifurcation Works along the eastern boundary of the project and serves all irrigable land within the project that is located east of a line extending north from Moses Lake and south and east of that portion of Crab Creek extending from Moses Lake to the Columbia River consisting of an area of 828,720 acres including that covered by supplemental pumping.

1542. The Main West and the Main East consist of a series of canal sections, tunnels, and siphons, more particularly described in appendix no. 5, which involve no special features other than the extremely large capacities and dimensions required.

1543. In considering the proposed system for plan no. 4, reference is made to certain office records, unpublished, which 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 water requirements for that area and capacities of all canals and laterals at strategical points.

1544. The location of the canals and the larger laterals was projected in the manner outlined in detailed description of the various features constituting the system as outlined in appendix no. 5. Laterals having a capacity of less than 100 second-feet are covered by a blanket estimate based upon the area served.

1545. *c''*. *General project items*.—Above has been given a brief description of the system as proposed for plan no. 4. The entire system is described feature by feature in geographic order in appendix no. 5. The following items pertain to the general project rather than to any one of the subdivisions mentioned above.

1546. *a'''*. *Drainage*.—A blanket estimate is included to cover this item. The question of drainage is one that will 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 drainage systems while others will require little or none. For the purpose of the present estimate \$5 per acre throughout the entire project is included to cover this item. In the plan of stage development it is assumed that this expenditure will be required 5 years after the first application of water to the land.

1547. *b'''*. *Wasteways*.—For the plan under consideration no detailed estimate was prepared for the system of wasteways that would be required on the project. The system as proposed in the Gault report for the pumping plan of development seemed to be adequate, and that estimate was adopted without modification.

1548. *c'''*. *Supplemental pumping*.—As outlined in the discussion of this phase of the study in plan no. 2-A, a considerable amount of power could be developed on the project and used to pump water to desirable lands located above the gravity canal system. In the plan now under consideration there are also possibilities of developing power on the project, but to a somewhat less extent. The decrease in power possibilities is due to a material change in the location of the distributing system, particularly on the upper side of the project. Some of the power sites considered under plan no. 2-A will be eliminated entirely in the present plan; one new power site is available, and those on the lower portion of the project are common to both plan no. 2-A and plan no. 4. The power possibilities on the project under the present plan are all located on the Main East Canal and its distributing system; none are available on the Main West.

1549. In table no. 213 is given a list of available power. These power plants retain the same numbers as those used in the discussion of this subject in plan no. 2-A. Of the plants proposed under plan no. 2-A, nos. 1, 4, 6, and 7 will be eliminated in the present plan; plant no. 2 will be modified; plants nos. 3, 5, 8, and 9 will remain the same, and plant no. 10 is available only under the present plan.

TABLE NO. 213.—*Available power, plan no. 4*

Power plant no.	Location ¹	Quantity second- feet	Net head	Pen- stock ²	Capacity	
					Horse- power	Kilowatts
2	Lateral E-13	392	80		3,040	2,270
3	Main East	320	85		3,000	2,240
5	Lateral E-5	130	138		1,850	1,380
8	Lateral E-8	926	100		8,400	6,270
9	Lateral E-5-5	85	255		2,100	1,570
10	E-5	1,801	156		25,800	19,240
Total					44,190	32,970

¹ For location see map no. 131.

² Penstocks included as a part of canal.

1550. In the proposed power developments under this plan the penstock pipes have been included as a part of the canal system. Some are of considerable length, and some sacrifice of power has been made in their design in the interest of economy. As the power possi-

bilities exceed the requirements for pumping to lands within the limit of a 100-foot lift, it appears that this sacrifice in the design of the penstock pipes is advisable.

1551. The total area for which water is to be provided through supplemental pumping amounts to 219,090 acres in tracts of various areas. The seasonal water requirement is 627,227 acre-feet; the average gross head through which the water is to be pumped is 70 feet; the acre-feet to be pumped per season is 43,905,890. These areas vary from 20 to 15,000 acres and are scattered throughout the project as indicated on plate no. 131.

1552. Estimates of cost for pumping installations to cover these tracts are taken from graphs. The cost of the installation includes all electrical equipment from the low side of the step-down transformers, pumping equipment, valves, pipe lines, etc. It is evident that the unit cost of these installations will depend upon the size of the development.

1553. To meet the requirements of supplemental pumping, it has been shown that the total installation required amounts to 43,905,890 acre-feet per season, requiring the following installations:

- 50 percent, or 21,952,940 acre-feet feet, 1,000 kilowatt installation.
- 30 percent, or 13,171,770 acre-feet feet, 500 kilowatt installation.
- 10 percent, or 4,390,590 acre-feet feet, 250 kilowatt installation.
- 5 percent, or 2,195,295 acre-feet feet, 100 kilowatt installation.
- 5 percent, or 2,195,295 acre-feet feet, 10-50 kilowatt installation.

1554. The cost of these installations was determined by applying the unit prices as shown on the graph to the unit quantities as given above.

1555. The power installation required to operate the units necessary for the above supplemental pumping units amounts to 19,000 kilowatts. These amounts are based upon the seasonal requirements for water, as outlined elsewhere in this report, and upon an over-all efficiency of 65 percent in the power and pumping system.

1556. Plans were not developed for the various power plants. Estimates for each were prepared upon the following unit cost basis:

	<i>Per kilo- watt</i>
Hydraulic equipment.....	\$13
Electrical equipment.....	27
Power house and miscellaneous ⁸⁵	20
Total.....	60

1557. The following estimate for plan no. 4 includes only the cost of the development of 19,000 kilowatts, the requirement to meet the demand for supplemental pumping on the project. The disposition of the balance of the power to be developed on the project, amounting to about 14,000 kilowatts, will be discussed later in the report.

1558. Included in the estimate for supplemental pumping is the cost of the system of transmission lines required to deliver the power from the generating station to the points of use at various locations on the project. This item includes the construction of 180 miles of primary line (66,000 volts) and 150 miles of secondary line (11,000 volts). The transmission lines as proposed would make power available to 95 percent of the land to be reclaimed through supplemental

⁸⁵ Penstocks included as a part of the cost of canal.

pumping, the remaining 5 percent, representing small isolated areas, would be unreclaimed until such time as commercial transmission lines on the project made available the small amount of power required for that purpose. The estimate of the cost of the transmission lines includes the cost of the step-down transformers necessary to deliver the current to the pumping units at the proper voltage.

1559. *d'''*. *Telephone system*.—Included in the estimate is an item covering the cost of the telephone system that will be required in the operation of the canal system. No details have been developed regarding this section of the work, but an approximate estimate was made of a system that was thought to be adequate to cover the project upon its completion.

1560. *e'''*. *Wells*.—This item, discussed more fully in plan no. 2-A, is to provide water for construction purposes. The estimate represents the cost of the development, less salvage value, that may exist after the completion of the construction work.

1561. *f'''*. *Permanent buildings*.—This item covers the buildings, offices, shops, warehouses, quarters, etc., required in the operation of the canal system. No detailed estimate has been prepared, but a lump estimate was based upon a percentage of the requirements as given in the estimate for plan no. 2.

1562. *g'''*. *Preliminary work*.—Included in the project items is an allowance of \$1,000,000 for preliminary work, and for testing of Grand Coulee Reservoir Basin.

1563. *h'''*. *Other features*.—Included in the estimate are items for fencing all canals in the systems, and for providing highway crossings over all canals and ditches that will cross existing highways. Where bridges are required, standard types of the Washington State Highway Department with a H-15 loading have been used. The fences, bridges, etc., are included in the estimate of the particular feature of which they form a part.

1564. *d''*. *Estimate*.—Following are the estimates of the various features that constitute the irrigation system as designed for plan no. 4. The estimate for the plan includes no item for power development on the Columbia River at Grand Coulee. The operating cost includes the purchase price of power required for pumping purposes.

Feature no.	<i>Main Canal</i>	
1. Grand Coulee Dam, not included as a part of the irrigation system.		
2. Pumping plant and pipe line.....		\$15, 631, 300
3. Canal.....		2, 101, 080
4. North Reservoir Dam.....		1, 085, 560
5. South Reservoir Dam.....		3, 977, 270
6. Canal.....		4, 474, 330
7. Bacon siphon.....		403, 320
8. Bacon Tunnel, first bore.....		2, 688, 030
Bacon Tunnel, second bore.....		2, 585, 050
9. Canal.....		1, 089, 060
10. Trail Lake Tunnel, first bore.....		793, 670
Trail Lake Tunnel, second bore.....		617, 680
11. Bifurcation works.....		99, 200
	Total Main Canal.....	35, 545, 550

Feature
no.*Main West*

1. Canal.....	\$1, 057, 520
2. Dry Coulee Tunnel No. 1.....	423, 440
3. Dry Coulee Tunnel No. 2.....	294, 610
4. Canal.....	309, 120
5. Dry Coulee siphon.....	634, 490
6. Canal.....	1, 742, 800
7. Soap Lake siphon.....	1, 622, 090
8. Canal.....	3, 123, 690
9. Canal.....	380, 460
10. Great Northern siphon.....	200, 040
11. Canal.....	780, 720
12. Potholes siphon.....	2, 156, 850
13. Canal.....	771, 230
14. Frenchman siphon.....	880, 750
15. Canal.....	1, 211, 620
16. Low Gap Tunnel.....	855, 040
17. Canal.....	1, 418, 820
W-1. Lateral W-1.....	1, 238, 050
W-1-1. Lateral W-1-1.....	141, 250
W-2. Lateral W-2.....	1, 138, 600
W-2-1. Lateral W-2-1.....	190, 130
W-2-2. Lateral W-2-2.....	216, 590
W-2-3. Lateral W-2-3.....	83, 440
W-3. Lateral W-3.....	737, 150
W-3-1. Lateral W-3-1.....	253, 090
W-4. Lateral W-4.....	93, 000
W-5. Lateral W-5.....	90, 130
W-6. Lateral W-6.....	567, 400
W-7. Lateral W-7.....	31, 510
18. Sublaterals.....	7, 784, 910
Total Main West.....	<u>30, 428, 540</u>

Main East

1. Canal.....	876, 800
2. Long Lake Tunnel No. 1, first bore.....	543, 260
Long Lake Tunnel No. 1, second bore.....	410, 050
3. Canal.....	444, 000
4. Long Lake Tunnel No. 2, first bore.....	396, 530
Long Lake Tunnel No. 2, second bore.....	259, 370
5. Canal.....	1, 698, 520
6. Stratford Tunnel, first bore.....	1, 014, 360
Stratford Tunnel, second bore.....	846, 270
7. Canal.....	586, 610
8. Crab Creek siphon.....	2, 760, 270
9. Canal.....	2, 083, 830
10. Broken Rock siphon.....	3, 556, 350
11. Canal.....	2, 299, 510
12. Black Rock siphon.....	1, 588, 990
13. Canal.....	567, 380
14. Long Ridge Tunnel, first bore.....	682, 400
Long Ridge Tunnel, second bore.....	527, 770
15. Canal.....	741, 200
16. Sand Coulee siphon.....	258, 160
17. Canal.....	1, 901, 750
18. Rocky Branch siphon.....	525, 140
19. Canal.....	246, 160
20. Rocky Coulee siphon.....	1, 833, 790
21. Canal.....	2, 034, 440
22. Weber Branch siphon.....	2, 410, 620
23. Canal.....	417, 950
24. Weber Coulee siphon.....	1, 718, 500
25. Canal.....	3, 314, 510
26. Lind Coulee siphon.....	1, 328, 760
27. Canal.....	1, 213, 840
28. Providence Tunnel, single bore.....	3, 253, 030

Feature
no.*Main East—Continued*

29. Canal.....	\$449, 300
30. E-8 bifurcation works.....	37, 940
31. Canal.....	667, 470
32. Provi ence branch siphon.....	127, 020
33. Canal.....	597, 150
34. Hatton Coulee siphon.....	317, 450
35. Canal.....	1, 074, 650
36. Rattlesnake Tunnel, single bore.....	389, 000
37. Canal.....	87, 040
38. Rattlesnake siphon.....	107, 790
39. Canal.....	281, 920
40. Reeder Tunnel, single bore.....	566, 060
41. Canal.....	815, 760
42. Washtucna siphon.....	1, 345, 030
43. Canal.....	150, 610
44. Canal.....	1, 224, 560
45. Dunnigan Tunnel, single bore.....	83, 660
46. Canal.....	652, 720
47. Rye Grass Tunnel, single bore.....	63, 530
48. Canal.....	489, 930
49. Rye Grass siphon.....	257, 310
50. Canal.....	473, 990
51. Smith siphon.....	121, 920
52. Canal.....	608, 000
E-1. Lateral E-1.....	605, 320
E-2. Lateral E-2.....	52, 580
E-3. Lateral E-3.....	253, 700
E-4. Lateral E-4.....	433, 780
E-4-1. Lateral E-4-1.....	113, 480
E-5. Lateral E-5.....	12, 803, 860
E-5-1. Lateral E-5-1.....	637, 250
E-5-2. Lateral E-5-2.....	16, 220
E-5-3. Lateral E-5-3.....	33, 280
E-5-4. Lateral E-5-4.....	90, 690
E-5-5. Lateral E-5-5.....	317, 960
E-6. Lateral E-6.....	51, 380
E-7. Lateral E-7.....	2, 041, 570
E-7-1. Lateral E-7-1.....	26, 700
E-8. Lateral E-8.....	6, 946, 060
E-8-1. Lateral E-8-1.....	55, 920
E-8-2. Lateral E-8-2.....	257, 350
E-8-3. Lateral E-8-3.....	285, 190
E-8-4. Lateral E-8-4.....	29, 080
E-8-5. Lateral E-8-5.....	219, 980
E-8-6. Lateral E-8-6.....	116, 700
E-9. Lateral E-9.....	42, 210
E-10. Lateral E-10.....	149, 280
E-11. Lateral E-11.....	139, 340
E-12. Lateral E-12.....	352, 120
E-13. Lateral E-13.....	1, 211, 460
53. Sublaterals.....	17, 403, 120
Total Main East.....	98, 015, 510
<i>Project items</i>	
Supplemental pumping.....	6, 049, 270
Drainage.....	5, 997, 150
Wasteways.....	2, 162, 710
Permanent buildings.....	1, 201, 600
Wells.....	200, 000
Telephone system.....	225, 000
Preliminary work.....	1, 000, 000
Total.....	16, 835, 730

Recapitulation

Main Canal.....	\$35, 545, 550
Main West.....	30, 428, 540
Main East.....	98, 015, 510
Project items.....	16, 835, 730
Project total.....	180, 825, 330

1565. *e''*. *Stage development*.—The necessity of a stage development is outlined in plan no 2-A. The same necessity exists for a stage development in the plan now under consideration. The stage development outlined below is predicated upon (a) the colonization of 50,000 acres per year, (b) the construction stages to be developed as required by the colonization of the land and the demand for water, (c) the land to be placed under irrigation where the irrigation supply is made available, (d) that interest on all unpaid balances be at the rate of 4 percent per annum, and (e) that repayments be made beginning at the end of the third year of crop from the land.

1566. To meet the above requirements the system has been divided into 14 construction stages. Because of limitations fixed by local topographic and other conditions, most of the individual stages include an area requiring 2 or even 3 years to colonize. Table no. 214 gives the proposed stage development for the present plan. The first stage brings no land under cultivation, but is devoted to preliminary work and a portion of the main canal.

1567. This development is based upon the construction of the high dam in the Columbia River at Grand Coulee, with the power development possible at that point. This phase of the development is considered in the "Power" section of this report, and is of interest in connection with the stage development of the present plan of irrigation development, because of the fact that power for pumping purposes is to be obtained from that source.

1568. It is estimated that 6 years will be required for the construction of the dam in the Columbia River; and in order to be able to deliver water to the first unit on the irrigation project at the beginning of the seventh year, the first stage should be begun during the third year of construction on the dam.

1569. The second stage includes the construction of a portion of the pumping plant and the installation of two pumping units, each of 1,600 second-foot capacity, the completion of that portion of the main canal that is not susceptible of a stage development, and the first unit of those features that may be developed by stages, and also that portion of the distributing system that is required to reclaim the area in the first unit.

TABLE NO. 214.—*Stage development, plan no. 4*

Year	Stage	Capital expenditure	Area reclaimed	Area colonized	Area beginning repayment
			<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
1.....	1	\$500,000			
2.....		2,122,000			
3.....	2	13,500,000	108,750		
4.....		18,949,010			
5.....	3	4,831,000	98,980	54,370	
6.....		5,770,260		54,380	
7.....	4	3,500,000	110,510	49,490	54,370
8.....		5,419,180		49,490	54,380
9.....	5	10,883,750	98,440	55,250	49,490
10.....		16,204,510		55,250	49,490
11.....	6	10,494,900	98,420	49,220	55,250
12.....		12,973,250		49,220	55,260
13.....	7	8,790,680	64,790	49,210	49,220
14.....		2,550,000		49,210	49,220
15.....	8	5,644,040	99,730	64,790	49,210
16.....		6,860,000		64,790	49,210
17.....	9	12,290,820	82,580	49,870	64,790
18.....		5,523,450		49,870	64,790
19.....	10	2,300,000	58,540	41,290	49,880
20.....		5,240,890		41,290	49,870
21.....	11	6,555,740	114,000	38,200	41,290
22.....		6,040,500		38,200	41,290
23.....	12	3,124,000	45,000	38,200	58,540
24.....		2,505,000		38,200	38,200
25.....	13, 14	2,808,550	100,000	50,000	38,200
26.....		4,541,110		50,000	38,200
27.....				50,000	50,000
28.....				69,090	50,000
29.....					50,000
30.....					50,000
31.....					69,090
32.....					69,090

1570. Under the plan of development as outlined in the table Stage development—plan no. 4, the first land will be brought under cultivation in the seventh year and repayments will begin at the end of the ninth; the last area would be placed under cultivation in the thirtieth year and repayments begin on that area at the end of the thirty-second year.

1571. Carrying all capital expenditures to the end of the thirty-second year, with interest at the rate of 4 percent, and deducting an annual repayment of \$7.39 per acre per year, which will also bear interest at the rate of 4 percent from the time repayment is made to the end of the thirty-second year, gives the following results:

Capital cost plus interest.....	\$221,722,180 or \$184.86	<i>Per acre</i>
Capital cost.....	180,825,330 or	150.76
Interest.....	40,896,850 or	34.10
Annual interest charge after completion.....		7.39
Annual cost of operation and maintenance.....		1.52
Annual depreciation charge.....		1.28
Total annual charge less power.....		2.80
Annual cost of power.....		1.20
Total annual charge.....		11.39

1572. *f''*. *Elimination of Grand Coulee Reservoir.*—The above plan is based upon the use of the Grand Coulee Reservoir as a part of the main canal system. Should tests demonstrate that the site at Grand Coulee be unfit for reservoir purposes, a modification of the main canal system would be required to eliminate that feature. If the

reservoir is eliminated, the north and south reservoir dams, together with the right-of-way in the basin, would be replaced by a section of canal 24.5 miles in length, including 3 tunnels and 1 siphon. A portion of this canal is located over an area favorable to canal construction while a portion will encounter a large percentage of solid rock excavation. The elimination of the reservoir from the main canal system will require some modification in the plan for the pumping plant. As stated earlier in this discussion, the substitution of a canal for the reservoir increases the pumping head 50 feet. On the other hand, the use of the canal eliminates the requirement for pumping 1,000 second-feet to care for reservoir loss. Plan no. 4 provided an excess installation at the pumping plant to provide water for storage in the reservoir during periods favorable for the use of secondary power for that purpose. The additional expense due to the increase in pumping head necessary if the reservoir be eliminated is practically balanced by the decrease in the number of pumping units required.

1573. If the Grand Coulee Reservoir is replaced by a canal through the basin, an additional capital expenditure of \$17,656,220 would be required. Carrying this capital expenditure through the stage development as outlined for plan no. 4, gives the following as the final cost of the project.

		<i>Per acre</i>
Capital cost plus interest.....	\$248, 378, 010 or	\$207. 08
Capital cost.....	198, 481, 550 or	165. 08
Interest.....	49, 896, 460 or	41. 60
		<hr/>
Annual interest charge after completion.....		8. 28
Annual cost of operation, depreciation, and maintenance.....		2. 80
Annual cost of power.....		1. 31
		<hr/>
Total annual charge.....		12. 39

1574. *n'. Plan no. 4-A.*—This plan for the development of the Columbia Basin irrigation project contemplates the reclamation of the tract in two divisions. The first, or division A, is identical with plan no. 4 less the Priest Rapids area. The sum of the areas reclaimed under these two divisions is equal to and identical with the area reclaimed in plan no. 4, except as noted in the discussion of the Priest Rapids project.

1575. *a'. Division A.*—Division A is covered by a modification of the system proposed for plan no. 4. In that plan lateral E-5, a diversion from the main east, extended in a southwesterly direction to a point near Scootency Lake, where a long siphon was required to carry the lateral to the high ground on the west side of the lake. From that high point lateral E-5 continued westward along the south slope of the Saddle Mountains and covered the Priest Rapids area. In the plan now under consideration, the Priest Rapids area is eliminated from division A, and lateral E-5 ends at the site of the Scootency siphon. The portion of lateral E-5, extending from the main east to the Scootency siphon site, which is retained in the present plan, is reduced in dimensions and capacity to meet the requirements of the area served. This reduction in the capacity of lateral E-5 also requires a like reduction in capacity of the main east and the main canal from the bifurcation works to the Grand Coulee Reservoir. The main canal above the Grand Coulee Reservoir and the Columbia River pumping plant remain as outlined for plan no. 4. In plan no. 4

this portion of the system was given excess capacity for the purpose of utilizing secondary power for pumping purposes as explained in discussing that plan. The same excess capacity between the river and the Grand Coulee Reservoir is retained in the plan now under consideration.

1576. Other than this modification in the dimensions and capacity of that section of the main canal system, and the reduction in the dimensions and capacity of lateral E-5 to the Scootney siphon site beyond which point it is abandoned, the system for division A is identical in all respects with the system as outlined for plan no. 4.

1577. *a'''*. *Main canal*.—The salient figures relating to the main canal are given in the following tabulation:

Area reclaimed by gravity.....	acres	834, 860
Area reclaimed by supplemental pumping.....	do	199, 250
Total area reclaimed.....	do	1, 034, 110
Capacity of main canal, pumping plant to Grand Coulee Reservoir.....	second-feet	16, 000
Grand Coulee Reservoir to bifurcation works.....	do	9, 760
Rediverted water on project.....	do	610
Requirement at head of irrigable area.....	do	10, 370

1578. As in plan no. 4, the main canal has a capacity of 16,000 second-feet for reasons that concern the use of secondary power. The main canal below the Grand Coulee Reservoir has a capacity of 9,760 second-feet, which is based upon the requirements of the area served with the same water duty and seasonal distribution as outlined for these areas under the plans previously discussed.

1579. The main canal system of the plan now under consideration is made up of the same features as described under plan no. 4, modified where necessary to meet the reduction in capacity.

1580. *b'''*. *Distributing system*.—The distributing system is the same as described and outlined for plan no. 4, except as noted above.

1581. *a''''*. *Main west*.—The main west is identical in all respects with the main west and its lateral system as described in plan no. 4.

1582. *b''''*. *Main east*.—The main east for the plan now under consideration is reduced in capacity to meet the requirements of the reduced area served. This reduction extends from the bifurcation works at the head of the main east to and including the turnout for lateral E-5. Below the turnout for lateral E-5, the main east is identical in all respects with the main east as described for plan no. 4. The laterals diverting from the main east, as described for plan no. 4, will remain the same for the plan now under consideration, except lateral E-5, which is modified in length and capacity to meet the water requirements of the reduced area which it serves.

1583. The following lateral system diverts from the main east. For convenience, these laterals are presented in table no. 215.

TABLE NO. 215.—Laterals diverting from main east, plan no. 4-A

Lateral No.	Canal		Siphons or penstocks				
	Length	Section	Barrel	Number of pipes	Length	Diameter	Maximum head
	<i>Miles</i>				<i>Feet</i>	<i>Feet</i>	<i>Feet</i>
E-1	4.77	(1)					
	3.56	(1)					
	4.70	(2)					
E-2	2.60	(2)					
E-3	12.20	(2)					
E-4	10.20	(2)	Concrete	1	200	4.58	² 13
E-4-1	4.20	(2)	Steel penstock	1	2,640	7.83	⁴ 163
E-5	34.30	(1 ²)	Concrete	1	2,800	5.83	⁶ 26
E-6	2.20	(2)					
E-7	25.80	(2)	Concrete	1	1,200	7.08	³ 25
E-7-1	1.70	(2)					
E-8	31.00	(2)	Steel penstock	2	1,200	10	⁶ 102
E-8-1	2.10	(2)					
E-8-2	7.60	(2)					
E-8-3	6.50	(2)	Steel	1	9,240	4	⁵ 207
E-8-4	1.80	(2)					
E-8-5	6.60	(2)					
E-8-6	4.30	(2)					
E-9	1.80	(2)					
E-10	5.60	(2)					
E-11	7.10	(2)					
E-12	10.50	(2)					
E-13	29.10	(2)	Steel penstock	1	535	9	⁷ 80

¹ Projected on line topographic sheets. (See plate no. 136 (not printed) for sections.)

² Projected on U. S. Geological Survey quadrangle sheets.

³ Unnamed siphons.

⁴ Penstock, power plant no. 10.

⁵ Northern Pacific siphon.

⁶ Penstock, power plant no. 8.

⁷ Penstock, power plant no. 2.

1584. *c'''*. *Project items*.—The project items appurtenant to plan no. 4-A will differ to some extent from those of plan no. 4.

1585. *a''''*. *Drainage*.—This item is covered by a blanket estimate of \$5 per acre and the estimate for the present plan differs from plan no. 4 only as to the acreage involved.

1586. *b''''*. *Wasteways*.—The item of wasteways for the present plan was treated in the same manner as in plan no. 4. The present estimate is the same as that for plan no. 4, less the Gault estimate for the Hanford and Othello, and Lind Coulee wasteways.

1587. *c''''*. *Supplemental pumping*.—Sites on the canal system favorable for the development of power for use in supplemental pumping differ to some extent from those enumerated for development in plan no. 4. Under the present plan, power plant no. 10 as listed for plan no. 4 will be reduced in capacity due to the reduction in the water requirements for land under lateral E-5 upon which the proposed power plant is located. Power plants nos. 5 and 9 will be eliminated entirely.

1588. Table no. 216 gives the available developments of the present plan under this division.

TABLE NO. 216. Available developments, plan no. 4-A, division A. For location see plate no. 131

Power plant no.	Location	Quantity	Net head	Penstock	Capacity	
			Feet		Horse-power	Kilo-watts
2.....	Lateral East 13.	392	80	Penstocks included as part of canal.....	3,040	2,270
3.....	Main East.....	320	85	do.....	3,000	2,240
8.....	Lateral East 8.	926	100	do.....	8,400	6,270
10.....	Lateral East 5.	391	156	do.....	5,600	4,180

1589. The total area to which water is to be supplied by supplemental pumping under the present plan is 199,250 acres, with a seasonal water requirement of 564,935 acre-feet. As in plan no. 4, the average head (gross) through which this water is to be pumped is 70 feet. The total power requirements for the season expressed in acre-feet feet is 39,545,450.

1590. The extent of the areas to be reclaimed by supplemental pumping are as noted for plan no. 4, and the costs of pumping and electrical equipment for the various pumping units were determined in the manner described in that plan.

1591. To meet the requirements of supplemental pumping for the plan under consideration, the size of installations required would be as follows:

50 percent or 19,772,725 acre-feet feet, 1,000 kilowatts installation.

30 percent or 11,863,635 acre-feet feet, 500 kilowatts installation.

10 percent or 3,954,545 acre-feet feet, 250 kilowatts installation.

5 percent or 1,977,270 acre-feet feet, 100 kilowatts installation.

5 percent or 1,977,270 acre-feet feet, 10-50 kilowatts installation.

1592. The cost of these installations was determined by applying the unit prices as shown on graph to the unit quantities as given above.

1593. The power installation required to operate the units necessary for the above supplemental pumping units amounts to 17,000 kilowatts. These requirements are based upon a seasonal water requirement as outlined earlier in this report, and upon an over-all efficiency of 65 percent.

1594. Plans were not developed for these individual power plants, but the estimated cost was determined in the manner outlined in the discussion of this feature in plan no. 2 and plan no. 4. Included in the cost for supplemental pumping is an item covering cost of transmission line necessary to deliver power from the generating plant to the various pumping plants on the project. This item is the same as for plan no. 4. Transmission lines for this division will be the same as for plan no. 4. The location will be changed somewhat, but the length and capacity will remain the same.

1595. *d''''*. Telephone system.—The estimate includes an item covering the cost of a telephone system considered adequate to meet the operation requirements. This estimate was prepared as outlined in plan no. 4.

1596. *e''''*. Wells.—This item is discussed fully in plan no. 2-A, and with some modification due to the decreased acreage in the project now under consideration, is included in the present estimate.

1597. *f'''*. *Permanent buildings*.—This item covers the buildings, offices, shops, warehouses, quarters, etc., required in the operation of the canal system. Estimates for this item in the present report are a modification of that noted in plan no. 2-A for the same item.

1598. *g'''*. *Preliminary work*.—Included in this estimate is an item of \$900,000 which has been arbitrarily allowed for preliminary work.

1599. *h'''*. *Other features*.—All fences, bridges for highways and railroads, etc., are included with the feature of the system of which they form a part.

1600. *d'''*. *Estimate*.—Following are the estimates of the various features that constitute the irrigation system of division A of plan no. 4-A. The estimate for this plan includes no item for power development in Columbia River at Grand Coulee. The operating cost includes the purchase price of power for pumping purposes.

Feature no.	<i>Main Canal</i>	
1. Grand Coulee Dam (not included as part of the irrigation system).		
2. Pumping plant.....		\$15, 631, 300
3. Canal.....		2, 101, 080
4. North reservoir dam.....		1, 085, 560
5. South reservoir dam.....		3, 977, 270
6. Canal.....		4, 150, 570
7. Bacon siphon.....		374, 830
8. Bacon tunnel.....		4, 783, 060
9. Canal.....		976, 380
10. Trail Lake tunnel.....		1, 300, 610
11. Bifurcation works.....		99, 200
Total main canal.....		<u>34, 479, 860</u>

Main West

The main west is identical in all respects with plan no. 4..... 30, 428, 540

Feature no.	<i>Main East</i>	
1. Canal.....		766, 080
2. Long Lake, tunnel no. 1.....		865, 820
3. Canal.....		363, 800
4. Long Lake, tunnel no. 2.....		655, 280
5. Canal.....		1, 460, 390
6. Stratford tunnel.....		1, 743, 010
7. Canal.....		493, 140
8. Crab Creek siphon.....		2, 632, 690
9. Canal.....		1, 818, 480
10. Broken Rock siphon.....		3, 203, 260
11. Canal.....		2, 027, 080
12. Black Rock siphon.....		1, 469, 760
13. Canal.....		493, 580
14. Long Ridge tunnel.....		1, 096, 490
15. Canal.....		670, 180
16. Sand Coulee siphon.....		206, 980
17. Canal.....		1, 805, 800
18. Rocky Branch siphon.....		477, 590
19. Canal.....		230, 950
20. Rocky Coulee siphon.....		1, 609, 300
21. Canal.....		1, 955, 110
22. Weber Branch siphon.....		2, 410, 620
23. Canal.....		417, 950
24. Weber Coulee siphon.....		1, 718, 500
25. Canal.....		3, 314, 510
26. Lind Coulee siphon.....		1, 328, 760
27. Canal.....		1, 213, 840

Feature no.	<i>Main East—Continued</i>	
28. Providence tunnel.....		\$3, 253, 030
29. Canal.....		449, 300
30. Bifurcation works, lateral E-8.....		37, 940
31. Canal.....		667, 470
32. Providence Branch siphon.....		127, 020
33. Canal.....		597, 150
34. Hatton Coulee siphon.....		317, 450
35. Canal.....		1, 074, 650
36. Rattlesnake tunnel.....		389, 000
37. Canal.....		87, 040
38. Rattlesnake siphon.....		107, 790
39. Canal.....		281, 920
40. Reeder tunnel.....		566, 060
41. Canal.....		815, 760
42. Washtucna siphon.....		1, 345, 030
43. Canal.....		150, 610
44. Do.....		1, 224, 560
45. Dunnigan tunnel.....		83, 660
46. Canal.....		652, 720
47. Rye Grass tunnel.....		63, 530
48. Canal.....		489, 930
49. Rye Grass siphon.....		257, 310
50. Canal.....		473, 990
51. Smith siphon.....		121, 920
52. Canal.....		608, 000
E-1. Lateral E-1.....		605, 320
E-2. Lateral E-2.....		52, 580
E-3. Lateral E-3.....		253, 700
E-4. Lateral E-4.....		433, 780
E-4-1. Lateral E-4-1.....		113, 480
E-5. Lateral E-5.....		1, 875, 650
E-6. Lateral E-6.....		51, 380
E-7. Lateral E-7.....		2, 041, 570
E-7-1. Lateral E-7-1.....		26, 700
E-8. Lateral E-8.....		6, 946, 060
E-8-1. Lateral E-8-1.....		55, 920
E-8-2. Lateral E-8-2.....		257, 350
E-8-3. Lateral E-8-3.....		285, 190
E-8-4. Lateral E-8-4.....		29, 080
E-8-5. Lateral E-8-5.....		219, 980
E-8-6. Lateral E-8-6.....		116, 700
E-9. Lateral E-9.....		42, 210
E-10. Lateral E-10.....		149, 280
E-11. Lateral E-11.....		139, 340
E-12. Lateral E-12.....		352, 120
E-13. Lateral E-13.....		1, 211, 460
53. Sublaterals.....		13, 931, 400
Total Main East.....		<u>79, 882, 040</u>
<i>Project items</i>		
Supplemental pumping.....		5, 234, 270
Drainage.....		5, 170, 550
Wasteways.....		1, 941, 370
Permanent buildings.....		1, 061, 600
Wells.....		155, 000
Telephone system.....		195, 000
Preliminary work.....		900, 000
Total project items.....		<u>14, 657, 790</u>
<i>Recapitulation</i>		
Main Canal.....		34, 479, 860
Main West.....		30, 428, 540
Main East.....		79, 882, 040
Project items.....		14, 657, 790
Project total.....		<u>159, 448, 230</u>