cally included in future protected districts. The remainder is in such small, isolated parcels that it could not be economically protected that is, the cost of the necessary protective works would exceed the value of the land when protected (pls 120, 121). For the 23 square miles which could be economically protected, approximately 38 miles of new levees would be required. Plate 120 shows the location and acreage, with estimated costs of protective works for these areas. The cost estimates are based upon heights of levees 2 feet above the 1894 flood crest. This conforms to maximum height of existing levee construction for areas already protected and is used in order to make comparisons with existing protected areas. Plate 121 shows the estimated capital values per acre of unprotected areas when protected and used for general and dairy farming.

(B) USE, PRESENT AND FUTURE

1110. Low unprotected land is generally covered with brush and is used to a small extent for pasturage; clear portions are used more extensively for pasturage. Values range from $10 to $50 per acre. When protected, these areas would be used for dairying and general farming, and would be valued at approximately $390 per acre. (Pl. 121.)

(C) DEMAND FOR PROTECTION

1111. There is at this time no demand for additional flood protection or new levee construction, though there is a growing demand for bank protection of existing works from wave action and scour. It is desired by many and requests have been made in the past, that the sand removed in channel dredging be placed along the river face of levees to form a flat slope and thus protect the levees from wave action and erosion. In some cases this has been practicable and has been done where the cost of dredging was not materially increased, but in the great majority of cases it is impracticable to place material along the levees in connection with channel dredging. The lengths of pipe line involved would usually be excessive and the quantities of material removed from the channel in any one place and season are too small to be effective in the work desired. If such work is to be done as a means of protecting banks, it would be much more economical and practical to do it as an independent operation, by placing the dredge close to work to be done, rather than to do it in connection with channel maintenance. In many cases there is no pipe line dredging being done within a distance of several miles. The benefit from bank protection would be chiefly to relieve the interested parties of a portion of the present maintenance charges.

1112. Maintenance consists of spur-dike construction, riprapping, ditching, and replacing levees washed out by river currents and wave action. The average annual maintenance costs per acre are about $1.77 for districts with pumps and $1.32 for districts without pumps. Plate 122 shows the annual maintenance costs for several typical districts.

UNPROTECTED AREAS – COSTS OF PROTECTIVE WORKS

Location	Area Acres	Original Value Per Acre	Original Value Total	Levees – Slopes 1½ – Top Width 10 Lin. Ft.	Height Ft.	Cost Per Lin. Ft.	Cost Total	Pump Cost @ $406 per Acre	Tide Gates No	Tide Gates Cost of	Protected Cost Per Acre	Protected Cost Total	Use Present	Use Future	Remarks
Bachelor Island, Clark County, Wash.	1800	35	63,000	39,000	22	12.10	471,900	7,308	1	1,593	302	543,801	Pasture	General Dairy	Uneconomical
Carlson Island, Clatsop County, Ore.	400	10	4,000	10,000	7	1.86	18,600		2	3,186	64	25,786	"	" "	
Clark Co. Diking Dist. No. 3 (Proposed) near Vancouver, Wash.	4,200	20	84,000	51,000	12	4.53	231,030	17,052	2	3,186	79	335,268	"	" "	
Clark Co. Diking Dist. No. 8 (Proposed) near Washougal, Wash.	1,800	50	90,000	26,000	8	2.31	60,060	7,308	3	4,779	90	162,147	"	" "	
Clatsop Diking Dist. No. 2, West of.	400	50	20,000	4,000	5	1.11	4,440		2	3,186	69	27,626	"	" "	
Clatsop Diking Dist. No. 3, East of.	1,000	50	50,000	11,000	8	2.31	25,410		2	3,186	78	78,596	"	" "	
Columbia Drainage Dist. No. 1, West of.	2,200	25	55,000	66,000	16	7.44	491,040	8,932	1	1,593	253	556,565	"	" "	Uneconomical
Cowlitz Diking Imp. Dist. No. 2, South of.	1,400	30	42,000	18,000	5	1.11	19,980	5,684	2	3,186	50	70,850	"	" "	
Cowlitz Diking Imp. Dist. No. 15, South of.	500	20	10,000	8,000	9	2.79	22,320	2,030	1	1,593	71	35,943	"	" "	
Crims Island, Columbia County, Ore.	300	10	3,000	9,000	7	1.86	16,740	1,218	2	3,186	80	24,144	"	" "	
Deep River, Wash., near mouth.	470	10	4,700	14,000	12	4.53	63,420		2	3,186	151	71,305	None	" "	
Grays River, Wash., near mouth.	400	10	4,000	4,500	11	3.90	17,550		1	1,593	57	23,143	"	" "	
Kalama River, Wash., near mouth.	1,300	20	26,000	8,000	12	4.53	36,240	5,278	1	1,593	53	69,111	Pasture	" "	
Lindsey Ranch, near Ridgefield, Wash.	1,310	10	13,100	19,300	16	7.44	143,592	5,318	2	3,186	126	165,206	"	" "	
Peninsula Drainage Dist. No. 1, West of.	4,000	50	200,000	82,000	24	14.44	1,184,080	16,240	1	1,593	350	1401,313	None	" "	Uneconomical
Warrenton Diking Dists. No. 1-2-3, South of.	300	10	3,000	3,000	5	1.11	3,330		1	1,593	26	7,923	Pasture	" "	
Westland Drainage Dist. (Proposed) West of Webb Drainage Dist.	1,100	10	11,000	14,000	12	4.53	63,420	4,466	2	3,186	74	82,072	None	" "	
Economical Areas – Pumping – Average	11,910	23			11	3.87	49. Per A.	48,354	15	2. Per A.	79				
Economical Areas – Pumping – Total			279,100	153,300			593,382			23,895		944,741			
Economical Areas – Non Pumping – Average	2,970	28			9	2.85	44. Per A.		10	5. Per A.	78				
Economical Areas – Non Pumping – Total			85,700	46,500			132,750			15,930		234,380			
Economical Areas – Total – Average	14,880	24			10	3.63	48. Per A.		25	2. Per A.	79				
Economical Areas – Total – Total			364,800	199,800			726,132	48,354		39,825		1,179,121			

Note: Levees computed with tops at elevation 2 feet above equivalent of uncontracted 1894 flood crest.

PLATE 120

UNPROTECTED AREAS - CAPITAL VALUES PER ACRE - GENERAL DAIRY FARMS

Location	Land x	Levees x	Pumps x	Tide Gates f	Buildings f	Working Capital f	Clearing Leveling Ditches Fences f	Capital	Gross Income f	Production Costs f	Net Return	Interest on Capital @ 6%	Surplus	Remarks
Bachelor Island, Clark County, Wash.	35	262	4.06	.88	45	66	45	458	74.84	51.38	23.46	27.48		Uneconomical-Excessive Levee Constr.
Carlson Island - Clatsop Co. Ore.	10	46		7.96	45	66	45	220	74.84	51.38	23.46	13.20	10.26	
Clark Co. Diking Dist. No. 3. (Proposed) near Vancouver, Wash.	20	55	4.06	.75	45	66	45	236	74.84	51.38	23.46	14.16	9.30	
Clark Co. Diking Dist. No. 8. (Proposed) near Washougal, Wash.	50	33	4.06	2.65	45	66	45	246	74.84	51.38	23.46	14.76	8.70	
Clatsop Diking Dist. No. 2., West of.	50	11		7.96	45	66	45	225	74.84	51.38	23.46	13.50	9.96	
Clatsop Diking Dist. No. 3, East of.	50	25		3.18	45	66	45	234	74.84	51.38	23.46	14.04	9.42	
Columbia Drainage Dist No. 1, West of.	25	223	4.06	.72	45	66	45	409	74.84	51.38	23.46	24.54		Unenocomical-Excessive Levee Constr.
Cowlitz Diking Imp. Dist. No. 2, South of.	30	14	4.06	2.27	45	66	45	206	74.84	51.38	23.46	12.36	11.10	
Cowlitz Diking Imp. Dist. No. 15, South of	20	44	4.06	3.18	45	66	45	227	74.84	51.38	23.46	13.62	9.84	
Grims Island, Columbia County, Ore.	10	55	4.06	10.62	45	66	45	236	74.84	51.38	23.46	14.16	9.30	
Deep River, Wash., near mouth.	10	134		6.77	45	66	45	307	74.84	51.38	23.46	18.42	5.04	
Grays River, Wash., near mouth.	10	43		3.98	45	66	45	213	74.84	51.38	23.46	12.78	10.68	
Kalama River, Wash., near mouth.	20	27	4.06	1.22	45	66	45	208	74.84	51.38	23.46	12.48	10.98	
Lindsey Ranch, near Ridgefield, Wash.	10	109	4.06	2.43	45	66	45	281	74.84	51.38	23.46	16.86	6.60	
Peninsula Drainage Dist. No. 1, West of.	50	296	4.06	.39	45	66	45	506	74.84	51.38	23.46	30.36		Uneconomical-Excessive Levee Constr.
Warrenton Diking Dists. No. 1-2-3. South of.	10	11		5.31	45	66	45	182	74.84	51.38	23.46	10.92	12.54	
Westland Drainage Dist. (Proposed) West of Webb Dr. Dist.	10	51	4.06	2.89	45	66	45	230	74.84	51.38	23.46	13.80	9.66	

Note:

x Figures in this column are based on quotations of land owners in the vicinity of the areas considered. The variations in value are due primarily to the locations of the tracts. For example, Peninsula Drainage District No. 1 is near Portland and is worth more than Deep River, Wash., areas which are not so favorably located.

f Figures in these columns correspond to those for irrigated general and dairy farms on Columbia River.

ANNUAL MAINTENANCE COSTS

District	Area Acres	Cost in Dollars											
		Levees		Ditches		Tide Gates		Pumps		Other Items		Grand Total	
		Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre
Beaver Drainage District.	5,702							8,553	1.50			8,553	1.50
Carlson Island.	333	1,292	3.88									1,292	3.88
Clatsop Diking Dist. No. 2.	280	500	1.78									500	1.78
Clatsop Diking Dist. No. 3.	1,000	500	0.50									500	0.50
Cowlitz Consolidated Diking Imp. Dist. No. 1.	10,000	14,000	1.40									14,000	1.40
Cowlitz Diking Imp. Dist. No. 2.	1,146	50	0.04	50	0.04	5	0.01	5	0.01			110	0.10
Cowlitz Diking Imp. Dists. No. 5 & 11.	7,300	6,000	0.82	500	0.07	400	0.05	100	0.01	500	0.07	7,500	1.02
Cowlitz Diking Imp. Dist. No. 15.	845	422	0.50									422	0.50
Deep River.	1,180	1,000	0.84									1,000	0.84
Grays River.	1,750	1,000	0.57									1,000	0.57
John Drainage Dist.	153							300	1.96			300	1.96
Magruder Drainage Dist.	592							592	1.00			592	1.00
Marshland Drainage Dist.	1,033							400	0.38			400	0.38
Midland Drainage Dist.	1,302							95	0.07			95	0.07
Multnomah County Drainage Dist. No. 1.	8,417	4,800	0.57	3,000	0.36	100	0.01	1,000	0.11	4,000	0.48	12,900	1.53
Peninsula Sewer Dist.		1,490		5,675						650		7,815	
Peninsula Drainage Dist. No. 1.	951	250	0.26	220	0.23			2,340	2.46	1,182	1.24	3,992	4.19
Peninsula Drainage Dist. No. 2.	1,425	462	0.32	1,035	0.72							1,497	1.05
Rainier Drainage Dist.	1,325							1,500	1.13			1,500	1.13
Sandy Drainage Dist.	1,556	2,460	1.58	200	0.12							2,660	1.70
Scappoose Drainage Dist.	5,800	3,000	0.52	1,000	0.17	100	0.02	300	0.05	500	0.08	4,900	0.84
Tenasillahe Island.	1,596	500	0.31	500	0.31	50	0.03					1,050	0.65
Warrenton Diking Dists. No. 1-2-3.	6,300	4,000	0.63									4,000	0.63
Woodson Drainage Dist.	353							353	1.00			353	1.00
Excluding Peninsula Sewer Dist. Total		40,236		6,505		655		15,538		6,182		69,116	
Average			0.80		0.23		0.02		0.45		0.27		1.77
Including Peninsula Sewer Dist. Total		41,726		12,180						6,832		76,931	

Note: Average cost per acre for each item is obtained by dividing total cost of each item by the number of acres in the districts for which costs are shown under that item.

PLATE 122

E. IRRIGATION

(1) General Considerations

(a) present status

1113. The drainage basin of the Columbia below the mouth of Snake River totals approximately 46,500 square miles, of which about 1 percent is irrigated. Approximately 28,000 square miles of the basin lie to the east and 18,500 square miles to the west of the main divide of the Cascade Range. The portion lying to the west in general has a high average annual precipitation, enabling the production of fair crops without irrigation. Irrigation has become a factor in crop production in this area, however, owing to the fact that the growing season in parts of the area, notably the Willamette Valley, is often marked by a long period of drought, and maximum crop production can be assured only by the use of water. The portion of the basin lying to the east of the Cascades is arid in character and contains the major part of the irrigated lands of the basin. These irrigated lands lie on small benches along the main stream and in the basins of Walla Walla, Umatilla, John Day, Deschutes, Hood, Willamette, Klickitat, and White Salmon Rivers and other tributaries.

1114. Crop production in the basin accompanied the occupation of the land by the early settlers. As population increased in the arid sections, due to the development of mining, stock raising, and other industries, a greater need for agricultural products arose. These products could be secured only by the agricultural development of the lands of the area through the use of water for irrigation. Initiated on small tracts to serve local markets, irrigation was extended to larger areas and crops produced for export. Markets arose by reason of increased settlement in the Northwest and by the development of transportation, connecting the basin with distant centers of population. Extensive areas well adapted to irrigation were found in the basins of tributaries. These were level or gently rolling in topography, crossed by deep washed streambeds providing natural drainage. The vegetation consisted principally of sagebrush and bunch grass, enabling the preparation of the land for crop production at a low cost. The soil was fertile and the climate mild, with a long growing season. Except for the production of grain by dry-farming methods, crops could not be grown on these areas without the use of water. With the assurance of demand for products and favorable natural conditions, the use of water soon became a factor in the agricultural development of the basin. The use of water was fostered by the fact that since the first settlements were along the banks of the many streams of the region little effort was required for diverting the waters of the streams to adjacent tracts of land by small ditches.

1115. Irrigation in the Columbia Basin below Pasco probably was practiced first in Walla Walla River Valley, the earliest water rights in that area, as determined by State adjudication, dating as far back as 1859. In the John Day, Umatilla, and Hood River Basins adjudicated rights date from the early sixties. Early development was by individual effort and progress was slow, so that by 1889 only about 400,000 acres were irrigated in the entire Columbia River Basin. As irrigation development progressed, early methods were discarded as

cumbersome and wasteful. Individual effort was succeeded by cooperative action through private organizations and projects organized under Federal and State law. Water was conserved by improved methods of delivery. Laws assisting irrigation development were enacted. At the present time approximately 4,000,000 acres are irrigated in the entire Columbia Basin, the estimated ultimate irrigable area being approximately 9,000,000 acres. About 277,000 acres of the 4,000,000 acres now irrigated lie in the portion of the basin below the mouth of the Snake.

1116. The following summary shows the general location and acreage of irrigated lands in the Columbia Basin below Pasco:

Basin	*Acres irrigated*
Walla Walla River	48, 523
Umatilla River	39, 600
Willow Creek	6, 500
John Day River	62, 000
Deschutes River	82, 218
Hood River	22, 933
Willamette River	4, 360
Klickitat River	4, 200
White Salmon River	2, 384
Columbia River, direct	1, 500
Small tributaries	3, 070
Total	277, 288

1117. The gradual development of irrigation was accompanied by important Federal and State legislation, the principal enactments being as follows:

Name of law	Date of enactment		
	Federal	Washington	Oregon
Act of 1866	July 26, 1866		
Desert Land Act	Mar. 3, 1877		
Raley Act			Feb. 18, 1891.
Irrigation District Law		1890	1895.
Carey Act	Aug. 18, 1894		
Acceptance of Carey Act		1895	Feb. 28, 1901.
Reclamation Act	June 17, 1902		
Irrigation District Act	Aug. 11, 1916		
Water code		Mar. 4, 1917	Feb. 24, 1909.

1118. The act of 1866 related to the right of diversion of water and transportation to the land on which it was to be used. Rights acquired under local customs, laws, and the decisions of courts were recognized and the right to construct ditches across public lands was established. This law was later confirmed in the Reclamation Act (1902).

1119. The Desert Land Act, passed in 1877, provided for the securing of title to arid public land by conducting water upon it for irrigation use and paying $1.25 per acre. Water could be secured through a canal constructed by the applicant or from an irrigation project covering many acres.

1120. The passage of the Raley Act (1891) marked the beginning of irrigation on a large scale in Oregon. This act permitted the organization of corporations with adequate powers of condemnation for canal right of way and other purposes for the appropriating of water for

general rental and sale. Some progress was made under this act, especially in Umatilla County, where fairly large projects were instituted.

1121. Irrigation district laws were enacted by both Oregon and Washington in the early nineties. These laws have suffered many modifications but are still in force. They have been the means of effecting the organization of a large portion of the irrigated areas of the two States into operating units. Irrigation district laws are explained in greater detail in paragraphs 1122 to 1129 of this report. In the Columbia Basin below the mouth of the Snake in Oregon there was little activity under the irrigation district law until 1912, only two districts having been organized before that date, Hood River irrigation district in 1905, and Hermiston irrigation district in 1906. The latter includes the lands of the Umatilla project of the United States Bureau of Reclamation. From 1912 to 1923, 23 additional districts were organized. The 25 districts cover an irrigable area of about 678,000 acres. Of this total about 99,000 acres in 15 districts are actually irrigated at the present time. In Washington 17 districts were organized in the Columbia Basin below the mouth of the Snake from 1912 to 1924, with a total irrigable area of about 276,000 acres. Out of this total about 3,500 acres in 15 districts are irrigated at the present time. The only large district, the Horse Heaven, included over 250,000 acres. This district is in process of legal dissolution. The tables following list irrigation districts organized in the two States, with pertinent facts concerning each district.

TABLE 56.—*Irrigation districts, Columbia Basin below mouth of the Snake*

OREGON

[From Second Biennial Report of State Reclamation Commission, Oregon]

No.	Name of district	Date organized	River basin	Source of water	Acres irrigable	Acres irrigated	Status
1	Hood River irrigation	1905	Hood	Hood River	4,177	2,822	Active.
2	Hermiston irrigation	1906	Umatilla	Umatilla River	10,857	7,700	Active (U.S. Bureau of Reclamation).
3	Teel irrigation	1912	do	John Day River	16,000	0	Inactive.
4	Paradise irrigation	1912	do	Umatilla River	42,000	0	Do.
5	Starlight irrigation	1913	John Day	Canyon Creek	20,000	0	Do.
6	Suttle Lake irrigation	1913	Deschutes	First Creek	10,669	0	Do.
7	East Fork irrigation	1913	Hood	Hood River	11,261	9,800	Active.
8	Jefferson water conservatory[a]	1916	Deschutes	Deschutes River	105,653	0	Inactive.
9	Ochoco irrigation	1916	do	Ochoco Creek	18,501	10,215	Active.
10	Westland irrigation	1917	Umatilla	Umatilla River	8,788	4,500	Do.
11	Central Oregon irrigation	1918	Deschutes	Deschutes River	43,350	35,000	Do.
12	West extension irrigation	1918	Umatilla	Umatilla River	5,923	4,200	Active (U.S. Bureau of Reclamation).
13	Squaw Creek irrigation	1918	Deschutes	Squaw Creek	7,206	5,932	Active.
14	Powell Butte irrigation	1918	do	Deschutes River	12,700	0	Inactive.
15	Deschutes County municipal improvement [b]	1919	do	Deschutes River and Tumalo Creek.	14,555	6,926	Active.
16	Bear Creek irrigation	1919	do		4,000	0	Inactive.
17	Crook County improvement no. 1 [c]	1919	do	Deschutes River	2,438	1,800	Active.
18	John Day irrigation	1919	Columbia	John Day River	285,000	0	Inactive.
19	Snow Creek irrigation	1919	Deschutes		2,000	250	Active.
20	Middle Fork irrigation	1921	Hood	Hood River	7,600	3,900	Do.
21	Dee irrigation	1922	do	do	1,414	1,000	Do.
22	West side reclamation	1922	Deschutes	Deschutes River	20,225	0	Inactive.
23	South unit improvement	1922	do	do	14,500	0	Do.
24	Stanfield irrigation	1923	Umatilla	Umatilla River	8,240	3,400	Active.
25	Sisters irrigation		Deschutes		1,385	1,385	Inactive.
	Total				678,442	98,830	

[a] Formerly North unit irrigation district.
[b] Formerly Tumalo irrigation district.
[c] Formerly Lone Pine irrigation district.

TABLE 57.—*Irrigation districts, Columbia Basin below mouth of the Snake*

WASHINGTON

No.	Name of district	Date organized	River basin	Source of water	Acres irrigable	Acres irrigated	Status
1	Hearn irrigation	1912	Walla Walla	Touchet River	42	42	Active.
2	West End Ditch Co.	1912	do	do	238	238	Do.
3	Underwood irrigation	1916	White Salmon	Little Buck Creek	242	84	Inactive.
4	Horse Heaven irrigation	1916	Columbia	Klickitat River	256,400		Inactive (dissolved 1931).
5	Lowden irrigation	1918	Walla Walla	Walla Walla River	409	409	Active.
6	Burbank irrigation no. 4	1919	Columbia	Snake River	8,500	75	Inactive.
7	Blalock irrigation no. 3	1919	Walla Walla	Mill Creek	883	789	Active.
8	Touchet east side irrigation no. 6	1919	do	Touchet River	800	480	Do.
9	Alder irrigation		Columbia	Alder Creek	180	20	Inactive.
10	Attalia irrigation	1920	do	Walla Walla River	4,000	40	Do.
11	Mud Creek irrigation no. 7	1920	Walla Walla	Mud Creek	409	409	Active.
12	Artesian irrigation no. 8	1921	do	Well	50	50	Do.
13	Orchard irrigation no. 10	1922	do	do	110	110	Do.
14	Hydro irrigation no. 9	1922	do	do			Active, domestic use.
15	North Dalles irrigation	1923	Columbia	Columbia River	3,500	360	Active.
16	White Salmon irrigation	1923	White Salmon	Buck Creek	600	300	Do.
17	Green Tank irrigation no. 11	1924	Walla Walla	Wells	100	100	Do.
	Total				276,463	3,506	

1122. The Carey Act is section 4 of an act of Congress approved August 18, 1894, entitled "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1895, and for other purposes." The act granted to each State named in it such desert land within the State, not to exceed 1,000,000 acres, as the State would cause to be irrigated and cultivated, to the extent of not less than 20 acres out of each 160 acres, within 10 years of the passage of the act. Under this act, upon application by the State for certain lands, accompanied by a plan of reclamation, the lands are withdrawn from entry under the general land laws of the United States. A contract is then executed between the State and Federal Government providing for reclamation of the area covered by the contract. The withdrawal is generally made at the request of some construction company which desires to reclaim the land. The construction company is reimbursed from the sale of the land to settlers after reclamation, payment being secured by the previous making of a lien on the land by the State in favor of the company.

1123. The legislative act of February 28, 1901 (Oregon), accepting the Carey Act, placed the responsibility of supervising reclamation work upon the State land board. Many projects were initiated soon after 1901, little State supervision being exercised until 1907. This law was repealed in 1909 and a new law of acceptance enacted. The legislative (Oregon) act of February 24, 1909, placed administrative responsibility upon the desert land board, which was created by the act and was composed of the Governor, secretary of state, State treasurer, attorney general, and State engineer. This law provided for the transfer of the irrigation system to the settler, after payment of the construction lien and for the payment to the State by the irrigation company, at whose request the withdrawal of arid lands for irrigation was made, of not less than $1 per acre, as the lands were sold. It also contained many other provisions protecting the rights of the settler and of the public as well as those of the construction companies.

1124. The duties of the desert land board pertaining to irrigation were later transferred to the State reclamation commission, created in 1927 (ch. 434, General Laws of Oregon). The commission is composed of the Governor, the secretary of state, and the State treasurer, the State engineer acting as secretary.

1125. Development of land in the Columbia Basin below the mouth of the Snake in Oregon under the Carey Act is shown in tabulation below. This tabulation shows that of 15 segregations 2 were completed, 6 partially completed and 7 relinquished or canceled. About 318,567 acres were withdrawn, of which 44,695 acres in the active projects are now irrigated. Segregations nos. 6, 19, and 29, classed in the tabulation as active, are now included in central Oregon irrigation district. Numbers 13 and 37, also active, are included in Deschutes County Municipal Improvement District. Segregation list no. 11 is operated by Walker Basin Irrigation Co.

Segregation list no.	County	Applicant for withdrawal	Date	Withdrawn acres	Irrigated acres	Status
[1] 3	Umatilla	Brownell Desert Reclamation Association.	1901	240	240	Completed. Title to settlers.
[1] 4	Deschutes	Deschutes Reclamation & Irrigation Co.	1903	1,280	1,280	Do.
[1] 6	do	Pilot Butte Development Co.	1903	84,708	[2]	Included in central Oregon project.
[1] 7	do	Little Deschutes Irrigation Co.	1901		0	Included in segregation list no. 11.
[1] 11	Deschutes and Klamath.	Oregon Development Co.	1902	31,082	175	Morson project of Walker Basin Irrigation Co.
[1] 13	Deschutes	Three Sisters Irrigation Co.	1902	27,005	5,000	Included in Tumalo irrigation project.
14	Crook	Lillard & Jacobs	1902	2,800	0	Canceled, 1903.
[1] 19	Deschutes and Crook.	Deschutes Irrigation & Power Co.	1905	56,007	[2]	Included in central Oregon project.
20	do	do	1905	74,198	[2]	Relinquished, 1917.
21	Deschutes	Davis Lake Irrigation Co.	1904	2,849	0	No segregation made.
23	do	Squaw Creek Irrigation Co.	1905	11,767	0	Canceled, 1907.
[1] 29	Deschutes and Crook.	Deschutes Irrigation & Power Co.	1910	12,470	38,000	Included in central Oregon project.
32	Deschutes	Columbia southern project.	1910	7,401	0	Relinquished, 1912.
34	do	do	1912	4,761	0	Do.
[1] 37	do	Tumalo irrigation project.	1919	1,999	[3]	Included in Tumalo project.
	Total			318,567	44,695	

[1] Active (totally or partially irrigated). [2] See no. 29. [3] See no. 13.

1126. The Carey Act was accepted in the State of Washington in 1895, but no Carey Act projects have been initiated in the State, in the Columbia Basin below Pasco.

1127. The Federal Reclamation Act (act of June 17, 1902) provided for the creation of a revolving fund from the receipts of the sale and disposal of public lands in certain named States for the construction of irrigation projects by the Federal Government in the contributing States. Only one, the Umatilla project, has been developed in the area under consideration under this law. This project was first investigated by the Government in 1903, construction was authorized in 1905, and the first of its lands were irrigated in 1908. Water was obtained from Umatilla River. Large areas have been reclaimed in Washington under the Reclamation Act, but none of these is included in the area considered in this report.

1128. The Federal Irrigation District Act of 1916 provided for the inclusion of public lands in irrigation districts organized under State laws. As State laws provided that lands in an irrigation district were subject to taxation for the payment of irrigation costs, inclusion of public lands subjected them to similar taxation. The act provided that the Federal Government would assume no responsibility for payment of the taxes, which were to be paid by the person acquiring the land.

1129. Oregon and Washington enacted water codes in 1909 and in 1917, respectively. The appropriation and use of water in the two States are governed by these codes as subsequently amended and modified. The water codes are treated in detail in paragraphs 1147 to 1151 of this report.

(B) SOURCES OF WATER

1130. Water for irrigation use in the Columbia Basin below the mouth of the Snake is obtained from the normal flow of Columbia River and its tributaries, supplemented by the retention of a portion of nonirrigation season flows of tributaries in storage reservoirs, and from subsurface sources—wells and springs. Future increase of irrigation requirements of the Columbia Basin below the mouth of the Snake will be provided for by pumping from Columbia River and additional storage on tributaries. Possible development by pumping from Columbia River is described in paragraphs 1262 to 1313 of this report.

1131. Stream flows of the basin are described in paragraphs 73 to 110. The main river is characterized by a high irrigation season flow. While flood stages on the main river generally occur during May, June, and July, about 30 percent of the annual flow occurs during the months, July, August, and September (table 10, par. 107). This assures an abundant water supply for irrigation without recourse to storage or material interference with possible power development.

1132. The normal annual discharge of Columbia River just below the mouth of the Snake is about 137,500,000 acre-feet. This flow is increased by the flows of tributaries between this junction and the mouth of the main river, amounting to about 62,500,000 acre-feet, resulting in an annual flow of about 200,000,000 acre-feet at the mouth of the Columbia. These figures represent the natural flow of the river reduced by the net demands of existing irrigation. The average annual flow at The Dalles, above which point practically all irrigation diversion will occur, is about 145,000,000 acre-feet. Without existing irrigation, the flow at The Dalles would be about 157,500,000 acre-feet. The reduction of the natural flow of the river due to irrigation demands amounts to about 8 percent. Return flow compensates in part for loss by irrigation diversion. In general from 35 to 65 percent of water diverted for irrigation use is returned to the river through surface and subsurface drainage channels. The net loss to the flow at The Dalles, due to existing irrigation of about 4,000,000 acres, has been, as indicated above, about 12,500,000 acre-feet. While future irrigation may add an acreage greater than the present irrigated area, higher costs of construction and operation of future irrigation developments will tend to a more conservative use of water and the additional loss to the river due to diversion for the added acreage will probably not be greater than above figures. The maximum ultimate irrigation demand, then, will probably not reduce the natural flow at The Dalles in excess of 25,000,000 acre-feet, which would be a reduction of about 16 percent.

1133. For topographic reasons, the waters of the Columbia are not available for gravity diversion. Although there is sufficient water in the river for the irrigation of large irrigable areas that lie adjacent to the river, only a limited acreage is at present irrigated, by pumping. With the advent of lower cost power for pumping and greater demand for additional agricultural lands, many of these pumping areas may be developed. The ultimate demand for water for pumping will have only a proportionally small effect on the normal flow of the main river.

1134. Irrigation use of tributary waters tends to exercise a regulatory effect on the natural flow of Columbia River. Diversion from normal flow for irrigation decreases the flow during the high months, which occur during the irrigation season, while return flow following the irrigation season increases the low-water flow which occurs in the winter months (table 5).

1135. The principal source of water supply for existing irrigation use is gravity diversion of the flow of tributaries. Tributaries of Columbia River below the mouth of Snake River (see table 9, par. 101) may be grouped in two classes, with reference to characteristics of normal flow. The first class, including Deschutes, Hood, Klickitat, and White Salmon Rivers, is characterized by a fairly uniform seasonal flow, approximately one fourth of the annual discharge occurring in July, August, and September. The second class, including Walla Walla, Umatilla, and John Day Rivers, is characterized by a proportionally low flow in the 3 months mentioned.

1136. Early irrigation was accomplished by utilization of the normal flow of tributary streams. Development proceeded rapidly in basins favored by fairly large stream flows and sufficient lands suitable for irrigation. At the present time large areas are irrigated in tributary basins (see pars. 1188 to 1208), using the entire low-water flow at certain points of some streams, as Deschutes River, Willow Creek, Umatilla River, John Day River, and Walla Walla River. The low-water flow of other tributaries, as Hood, Klickitat, and White Salmon Rivers, has not been completely utilized on account of absence of need for irrigation water or scarcity of suitable irrigable lands in the basins. Irrigation in Willamette Basin, although advantageous has had only partial development, due mainly to lack of interest.

1137. After complete utilization of the normal stream flows during the irrigation season, further development can be promoted by storage of surplus flows for release when required. Many storage sites have been examined in tributary basins by various public and private interests. (See pars. 111 to 134.) Partial regulation by storage has been carried out on Deschutes and Umatilla Rivers, permitting the addition of several thousand acres to the irrigated area of those basins. Use of the water of Klickitat and John Day Rivers has been proposed on land outside of their basins with regulation of flows by storage reservoirs. (See pars. 114 and 117.)

1138. The use of subsurface water supply for irrigation on the area under consideration has not been practiced to any considerable extent. Small tracts are using ground water through individual pumping plants, but the development of a large area by this method has not been attempted. Flowing springs are found throughout the basin. Some of these assist in building up stream flows, thus contributing to the water supply of the basin available for irrigation, and others are used directly on adjacent lands. The total area served directly is not large.

1139. The use of ground water from wells for irrigation probably will not be increased materially in future agricultural development. Deep wells furnish an assured water supply, but the burden of cost of installation and operation is too great to be borne by irrigated lands. Such installations are economic only for domestic use. Shallow wells will serve in particular cases but the uncertainty of a continuous water supply will preclude general use over large areas.

(C) DUTY OF WATER

1140. The net irrigation requirements for principal crops suited to the Columbia Basin below the mouth of the Snake are shown in tabulated form below, for various soil types encountered. Requirements are based on past use in the area, on similar soils, and on experiments conducted by various governmental agencies.

Net irrigation requirement in Columbia Basin below the mouth of Snake River

[Figures denote acre-feet per acre per year]

Crop	Soil type			Crop	Soil type		
	Coarse sandy	Medium and fine sandy	Sandy loam		Coarse sandy	Medium and fine sandy	Sandy loam
Alfalfa	6.0	4.8	3.0	Grain	3.5	2.8	1.75
Fruit	4.0	3.2	2.0	Truck and root crops	5.0	4.0	2.5
Potatoes	5.0	4.0	2.5	Pasture	7.0	5.8	4.0

(D) WESTERN SYSTEM OF WATER APPROPRIATION

1141. Before the adoption of water codes by the States of the West rights of property owners to irrigation water were assigned according to the doctrine of appropriation or the doctrine of riparian rights as modified to fit the needs of irrigation. The doctrine of appropriation arose from early mining practices in California. According to this doctrine, the first claim to the use of water of a stream or lake belonged to the one who made the first beneficial and continuous use of the water. The right was forfeited with discontinuance of use. The doctrine was upheld in California as early as 1851, recognized by the United States in 1866 in the act authorizing the sale of mining lands, and included in modified form in the Reclamation Act of 1902. The Reclamation Act limited the amount of water used according to acreage, with proportional rights in case of water shortage. The common-law doctrine of riparian rights, suitable for use in humid climates, was modified in the courts of various States to fit irrigation requirements of arid and semi-arid countries. Originally water was tied to the land located on the stream. Under the modified doctrine courts held that even lands in another watershed were riparian for irrigation purposes. The principle of returning the stream undiminished in volume, a part of the riparian doctrine, was interpreted to permit a reasonable detention and use. Other modifications were also made.

1142. The two doctrines described above differ essentially in the status of ownership of the waters of a stream and in the relation of the water to the land on which it is used. Under the doctrine of appropriation the water is held to be the property of the public but subject to appropriation, and to belong to the first individual who appropriates it. Its ownership is held to be separate from the land. The doctrine of riparian rights assumes that water is incident to the land through which it flows, never having been the property of the public. Disputes and litigation over water rights, resulting in part, at least, from the conflict between these two methods of acquiring water

rights, led to the adoption of water codes in the States of the West where irrigation was an important factor in agricultural development. Oregon adopted its code in 1909 (sec. 5722 et seq., Oregon Laws) and Washington in 1917 (sec. 5715 et seq., Washington Laws).

1143. The water codes of Oregon and Washington are based on the doctrine that all waters within the State from all sources belong to the public, thus tending to render the riparian doctrine of no effect. Water is subject to appropriation by the individual for beneficial use, with certain limitations, according to the laws of the State. The appropriation is initiated by an application with the State engineer (sec. 5722, Oregon Laws; sec. 5721, Washington Laws). This application must precede the commencement of construction of control works. It must contain the name and address of the applicant; the source of water supply; the nature and amount of the proposed use; the location and description of the proposed ditch, canal, or other work; the time within which it is proposed to begin construction; the time of completion of construction; and the time of complete application of the water to the proposed use. Additional details are required, contingent upon whether the purpose of the proposed development is for agricultural, power, reservoir, domestic, or mining use. The application must be accompanied by sufficient maps, drawings, and other data to demonstrate the feasibility of the proposed plan. Granting of a permit based on the application is subject to the approval of the State engineer.

1144. At the time when water codes were adopted each State was confronted with the task of establishing water rights initiated previously. These rights were in a chaotic condition, giving rise to long and costly litigation. The code established a method of securing title to water by a system of adjudication and survey conducted by the State engineer. Rights thus established under the law are forever defined. Progress has been made in both Oregon and Washington in the adjudication of State waters, but some streams are yet to be adjudicated. Adjudication is initiated by petition to the State engineer in accordance with the code. Other important subjects dealt with in the code are underground waters, unlawful use and waste, withdrawals for specific purpose, and distribution of the State's waters.

1145. Three important principles set forth in the Oregon code are found in sections 5717, 5807, and 5799 of Oregon Laws. Section 5717 deals with the application of water to beneficial use prior to the adoption of the code. It states that actual beneficial use, or proposed beneficial use under certain conditions, by or under authority of any riparian proprietor or his predecessors in interest shall be deemed to create a vested right to the extent of such beneficial use, providing beneficial use has not been abandoned for a continuous period of more than 2 years. Section 5807 authorizes and requires the State engineer to withdraw from appropriation any waters which may be required for any project being investigated or proposed for investigation under provisions of the act authorizing such investigations. Section 5799 states that when the waters of any natural stream are not sufficient for the service of all those desiring the use of the same, those using the water for domestic purposes shall, with certain limitations prescribed by law, have the preference over those claiming such water for any

other purpose, and that agricultural use shall have the preference over manufacturing use.

(E) FORMATION OF IRRIGATION DISTRICTS

1146. The original irrigation district laws of Oregon and Washington date back to the early nineties. The present irrigation district codes of the two States were adopted in 1917 (sec. 7305 et. seq., Oregon Laws, and sec. 7417 et seq., Washington Laws, with subsequent amendments). Progress under the irrigation district code is shown in paragraph 1121 above.

1147. An irrigation district may be proposed for organization when 50 or a majority of landowners in an area susceptible of irrigation desire to provide for the construction of irrigation works, or for betterment and operation and maintenance of existing works, or for the assumption of indebtedness to the United States under the Federal reclamation laws (sec. 7417, Washington Laws; sec. 7305, Oregon Laws). Initiation of irrigation district organization is by petition to the board of county commissioners or county court, setting forth the boundaries of the district and the number of directors desired. After due investigation in accordance with the law, the county board will issue an order outlining the plan of the proposed district organization and will call for an election to be held in the district to determine whether or not the district shall be organized. If the election results in an affirmative vote, the county board issues an order declaring that a duly organized district exists. At the time of this election a board of directors, under whose direction the affairs of the district are conducted in accordance with the provision of the law, is selected by vote.

1148. One of the most important sections of the irrigation district law enables the district to issue and sell bonds for the purpose of securing money to carry out the provisions of the act. Money thus secured can be applied to construction of irrigation works, acquisition of property, and to other purposes authorized by law. Under the code as adopted in 1917 bonded indebtedness is an obligation of the district as a whole. Default in payment of its obligations by a portion of the lands of a district results in an increase of the unit indebtedness of the remaining portion, sometimes discouraging payment by lands able to pay. This situation has proved unsatisfactory in some cases, and a law has been passed by the Oregon Legislature (1929), permitting irrigation districts to include in their provision an individual liability clause whereby each parcel of land in the district is liable only for its own share in the total bonded indebtedness. Under the individual liability plan the individual landowner is not responsible for delinquent assessments or taxes of other landowners and for this reason is satisfactory on proved and colonized lands but probably would not be successful in districts organized for the development of raw lands.

1149. Certification of irrigation district bonds is provided for in the code. Under this procedure, after investigation of the water supply, soils, irrigation works, and legality of the district by authorized agencies, the secretary of state may certify that the district has been investigated and approved; that the bonds have been legally issued; and that the expenditure of the proceeds of the bond issue

may be under the supervision of the State. Irrigation district bond certification by the State has assisted in the marketing of such bonds, having made them a legal investment for trust funds and for the funds of insurance companies, banks, trust companies, bonding companies, and any funds which may be invested in county, municipal, or school district bonds. After certification, they may be deposited as security for the performance of any act whenever the bonds of any county, city, school district, or other municipality may be so deposited and may also be used as security for the deposit of public money in the banks of the State, the market value, however, being determined by the State bank examiner.

1150. The State of Oregon amended its constitution in 1920 to provide for payment of interest on irrigation district bonds by the State for a period not exceeding 5 years. Oregon has advanced over $2,000,000 for this purpose, secured by certificates of indebtedness which do not become due until after the last due date of the district bonds. The amendment was repealed in 1930. Practically all districts have defaulted in payment of interest to State on interest money so advanced. The State legislature in 1929 authorized the State reclamation commission, under certain conditions, to cancel the certificates of indebtedness.

1151. Provisions for facilitating cooperation between irrigation districts and the Federal Government were included in the irrigation district code.

(2) Irrigable Areas

(a) location

1152. Irrigable lands of Columbia Basin below the mouth of the Snake (see pl. 123 and table 58) may be divided into four classes, according to location:

First. Bottom lands along the main stream.

Second. Bench lands adjacent to the main stream.

Third. Bottom lands of tributaries.

Fourth. Bench lands of tributary basins.

1153. The irrigable lands of the first class are found in the immediate river bottom of Columbia River throughout its length. Between the mouth of the Snake and Vancouver, Wash. (mile 104.5), the irrigable tracts are small. Those now irrigated are served by low lift pumping from the main river and by gravity diversion from tributaries near their mouths. Below Vancouver the tracts are larger, often requiring the building of dikes for protection against high waters. In some cases drainage by pumping is required. After such protection these tracts may be irrigated by low lift pumping from the main river or subirrigated by manipulation of drainage outlets. Many acres of this lower stretch have been diked, though little irrigation of the diked lands has been attempted. (See pars. 1085 to 1094.)

1154. Lands of the second class, bench lands adjacent to Columbia River, lie from 100 to 1,000 feet in elevation above the river and extend from 1 to 15 miles inland. The major portion of these lands is found on both sides of the river between Umatilla, Oreg. (mile 289), and Arlington, Oreg. (mile 241). These areas are all within reach of pumping from Columbia River. Gravity irrigation of two large

tracts in the above areas is also possible. The area in Oregon between Umatilla and Arlington might be irrigated by gravity diversion from John Day River and that in Washington, across the main river, from Klickitat and Cispus Rivers. Projects mentioned above are described later in this report. (Pars. 1244 to 1316.) Only a small portion of this class of irrigable lands is now irrigated. Irrigation is mainly by pumping from Columbia River and from wells, with a small acreage served by gravity through short ditches from tributaries.

TABLE 58.—*Irrigable lands, Columbia Basin below mouth of the Snake*

Area	Irrigated	Not irrigated		Total	State	Date of earliest water right	Net seasonal irrigation requirement
		In constructed projects	In proposed projects				
	Acres	*Acres*	*Acres*	*Acres*			*Acre-feet per acre*
Columbia River bottom lands	1,500	0	0	1,500	Washington		2.5–4.8
Walla Walla River Basin	28,000	0	50,000	78,000	do	1859	2.5–4.8
Do	20,523	0	50,000	70,523	Oregon	1861	2.5–4.8
Umatilla River Basin	39,600	15,008	0	54,608	do	1864	2.5–4.8
Willow Creek Basin	6,500	0	0	6,500	do	1885	2.5–4.8
John Day River Basin	62,000	0	25,000	87,000	do	1862	2.5–4.8
Deschutes River Basin	82,218	45,614	210,710	338,542	do	1865	2.5–4.8
Klickitat River Basin	4,200	0	16,525	20,725	Washington		2.5
Hood River Basin	22,933	10,896	0	33,829	Oregon	1862	1.5–2.5
White Salmon River Basin	2,384	458	0	2,842	Washington		1.5–2.5
Willamette River Basin	4,360	0	0	4,360	Oregon		1.0
Miscellaneous stream basins	2,570	0	0	2,570	do		1.5–4.8
Do	500	0	0	500	Washington		1.5–4.8
Cold Springs	0	0	50,000	[1] 50,000	Oregon		2.8–4.3
Horse Heaven	0	0	142,000	[1] 142,000	Washington		2.8–4.3
Do	0	0	140,000	140,000	do		2.8
Arlington and Willow Creek	0	0	184,560	[1] 184,560	Oregon		2.8–5.3
John Day project	0	0	115,440	[2] 115,440	do		2.8
Roosevelt	0	0	1,500	[1] 1,500	Washington		2.8
Total	277,288	71,976	985,735	1,334,999			

[1] Pumping from Columbia River.
[2] John Day project total acres, 300,000.; 184,560 acres of total also included in Arlington and Willow Creek pumping areas.

1155. Lands of the third class, bottom lands of tributaries, were the first areas in the basin to be irrigated. They have the smallest area of the four classes of irrigable lands. Their development is practically complete. Irrigation is accomplished by direct gravity diversion of normal flows.

1156. Irrigable areas of the fourth class, bench lands adjacent to tributaries, consist of compact bodies of land so situated that they can be watered by gravity diversion. In most of the tributary basins there is an abundance of such lands, development being limited only by demand for agricultural lands and the amount of water available. Maximum development can be attained only with complete regulation of stream flow by means of storage reservoirs.

(B) CHARACTER

1157. In the portion of the Columbia Basin below the mouth of Snake River and east of the Cascades irrigable lands along the main river and on adjacent benches generally have wind-blown sandy soils of sedimentary origin and comparatively flat topography. Bench lands have a decided slope toward the river and are provided with many

natural drainage channels. The higher lands are rolling, with deep cut, steep-sided drainage streams. Soils of the higher lands are loamy in character. Soils of the lower lands are more porous and less fertile. They require more water than the tighter loamy soils of the higher lands, but the smaller cost of pumping for the lower lifts will permit the agricultural use of at least the better part of such lands. Soils of these areas are fairly well supplied with lime, potash, and phosphorous, but like those in most arid regions are low in organic matter and nitrogen. Vegetation consists principally of sagebrush and bunch grass. The latter provides forage for stock during a part of the year. The value of the lands is low, generally not over $5 per acre.

1158. Bottom lands along tributaries east of the Cascades are flat, with alluvial soils of the sandy loam type. Higher irrigable lands adjacent to tributaries vary in topography from flat to rough rolling. Their soils are loessial in character. Surface soils are dark in color and contain fairly high percentage of organic matter. Lime and other soluble matter have been removed from the weathered soil material by leaching due to precipitation. These areas include lands of central and eastern Oregon and southern Washington now devoted to producing wheat by dry-farming methods. Natural vegetation consists of sagebrush, bunch grass, and short prairie grasses. The best of these lands are valued as high as $25 per acre.

1159. West of the Cascades bottom lands of the main river are generally flat, with fertile soils of alluvial silt. Natural vegetation consists of native grasses, brush, and small trees, such as scrub oak, cottonwood, and maple. These lands generally need protection from high water for efficient agricultural use. This report (pars. 1085 to 1094) lists 170,500 acres of arable lands below the crest elevation of the 1894 flood in the bottoms of the Columbia and the lower reaches of the tributaries, Cowlitz, Lewis, and Willamette Rivers. About 76,000 acres of this area have been diked and are producing good crops, mainly without irrigation, sufficient moisture for crop production being secured through subirrigation from river waters. In one district, Multnomah County improvement district no. 1, subirrigation is regulated by manipulation of the drainage flood gates, the gates being closed during the wet season, shutting out the flow of the Columbia and Willamette, and opened during the dry season. This procedure permits backwater of the river to fill the drainage channels during the months with low precipitation and raise the level of ground water to a point where capillary action will conduct the moisture to the growing plant. Pumping is required for drainage during high-water periods. Subirrigation affects only that portion of the river bottom land below an elevation about 10 feet above low water. The remainder of the bottom areas produces fair crops under natural conditions but would require irrigation for the highest efficiency of agricultural production. In general the best source of water is the Columbia River, which is available for low lift pumping, although in some cases consideration must be given to irrigation from tributaries. Bench lands along the main river west of the Cascades lie in small areas, rolling to rough rolling in topography. Natural vegetation consists of fir timber, small trees and brush, and native grasses. Soils are silty loam or silty clayey loam and are highly productive.

1160. Bottom lands of tributaries west of the Cascades are flat, with sandy and silty loam soils of great fertility. Higher irrigable

lands of tributary basins are flat to rolling in topography. The major part of lands of this class is found in Willamette Valley. Report on Willamette River by this office dated August 15, 1929, lists about 500,000 acres of irrigable land in the basin, with detailed description of irrigable areas. Fair crops are produced on some of these lands, but owing to the dry summer the highest efficiency of production can be attained only by means of supplemental irrigation during the summer months. Soils of these areas are of the silty loam type and have a very high degree of fertility. Generally they are well drained, both on the surface and beneath. Some areas, however, locally known as "white land", being flat and underlain by heavy clays, have inadequate drainage. They can be reclaimed by fertilization and artificial drainage.

(c) OWNERSHIP

1161. Lands, aside from those held in other reservations described in paragraph 135, are vacant Federal lands, reserved Federal lands, and patented lands belonging to the State, to railroads, to school districts, and to individuals.

1162. Unreserved vacant public lands in Oregon total about 13,000,000 acres (2.14 percent of the State area) and in Washington about 950,000 acres (0.21 percent of the State area). In the basin of the Columbia below the mouth of Snake River there are about 1,000,000 acres of lands of this class. Acreages by counties are shown in tabulation below, extracted from circular no. 1197, General Land Office, dated July 1, 1929.

County	State	Acres	Character
Yakima	Washington		
Columbia [1]	do	200	Grazing.
Walla Walla [1]	do	1,500	Grazing, timbered.
Benton [1]	do	30,000	Semiarid, mountainous.
Klickitat	do	18,786	Grazing, desert.
Skamania	do	360	Mountainous.
Lewis [1]	do	2,000	Do.
Cowlitz	do	2,994	Rough.
Clark	do	1,248	Rough, burnt over.
Wahkiakum	do	220	Rough.
Umatilla	Oregon	14,453	Grazing, hilly, mountainous.
Grant [1]	do	150,000	Do.
Morrow	do	5,000	Do.
Gilliam	do	15,000	Do.
Wheeler	do	91,000	Do.
Sherman	do	11,600	Do.
Wasco	do	15,600	Do.
Jefferson	do	22,000	Do.
Crook	do	349,480	Do.
Deschutes	do	120,640	Do.
Clackamas	do	39,995	Grazing, hilly, timber, agricultural.
Marion	do	8,080	Do.
Linn	do	13,620	Grazing, hilly.
Lane [1]	do	35,000	Grazing, timber, mineral.
Douglas [1]	do	10,000	Do.
Columbia	do	1,463	Grazing, hilly, agricultural.
Washington	do	1,880	Grazing, hilly, agricultural, timber.
Yamhill	do	12,466	Do.
Polk [1]	do	2,500	Do.
Benton [1]	do	20,000	Grazing, agricultural, timber.
Clatsop [1]	do	1,500	Grazing, hilly.
Total		998,583	

[1] Partly in basin, acreage estimated.

1163. Ownership of lands in the irrigable areas considered in this report is analyzed below.

1164. *Cold Springs area.*—About 1,500 acres of this area are vacant Federal land. Some of this land has been withdrawn from entry under the Reclamation Act of 1902. Sections 16 and 36 of each township were originally patented to school districts and a large acreage patented to the Northern Pacific Railway Co. Some of the school and railroad holdings have been sold in small tracts. The remainder of the area has been patented to individuals under the Homestead Act (1862).

1165. *Horse Heaven area.*—There is a large acreage of unpatented Federal land in this area. Some of this land has been occupied by settlers under the Government Desert Land Act (1877), but final proof has not been made, as the requirement of a water supply cannot be fulfilled. Sections 16 and 36 of each township have been set aside as school lands.

1166. *Willow Creek and Arlington areas.*—About 96,000 acres of these areas are vacant Federal land. This vacant land is not open to entry, being withdrawn under the Reclamation Act of 1902. Of the remaining 129,000 acres, alternate sections were originally patented to the Northern Pacific Railway Co. and sections 16 and 36 of each township to school districts. Some of the railroad and school land has been sold to individuals. The remaining lands of the area are in private ownership, having been patented directly to individuals by the Federal Government.

1167. *Roosevelt area.*—The lands of Roosevelt area are patented lands.

(D) ECONOMIES OF PUMPING

1168. Irrigable area which may be economically served by pumping may be determined by a comparison of the cost of irrigation and the net returns from crops produced. The cost of irrigation must be at such level that, when charges for production costs are added, a comparison with returns from agricultural effort will show a profit to the producer.

1169. The cost items of pumping and distribution of water for irrigation use are—

Electric energy.

Plant. Interest on investment in pumping plant, pipe lines, canals, and other construction features; taxes; insurance; cost of financing and interest during construction; depreciation; amortization.

Maintenance. Charge for maintenance and operation other than electrical energy.

1170. Maximum demand for electrical energy for pumping for irrigation purposes from Columbia River will occur during the season of maximum discharge of the river. During the maximum discharge period a large quantity of secondary power is available under the proposed power development. It is assumed that this secondary power, which can be produced at a low cost, will be available for irrigation pumping at a cost of 1 mill per kilowatt-hour measured at the low voltage side of the substation transformers.

1171. The total charge for electrical energy for lifting 1 acre-foot of water to various heights can be readily determined from plate 124 [1] below. In the left portion kilowatt-hours required with varying efficiency factors are shown. The right portion of the chart shows cost in dollars per acre-foot for various costs of power. For example, if the total pumping head is 500 feet, and the efficiency factor 70 percent, follow the broken line on the chart to efficiency factor 70 percent, thence to cost of power at the pump, say, 1 mill per kilowatt-hour, which indicates a cost per acre-foot of approximately $0.72. Power charges at other unit costs and under other conditions as to head and efficiency can be obtained from the chart in a similar manner.

1172. The efficiency factor for electrically operated pumping plants includes motor losses, hydraulic losses in pumps and conduits, and transformer and transmission losses between the point where power is measured and the point where used. This factor will vary somewhat among projects, but for purposes of estimates is taken to be about 67 percent. For a typical pumping project the factor is obtained as shown below:

Feature	Losses	Feature	Efficiency
	Percent	*Percent*	*Percent*
Point of delivery of power			100.00
Transmission line	2	98	98.00
Step-down transformer	2	98	96.04
Motors	10	90	86.44
Pumps	20	80	69.15
Pipe lines	3	97	67.08

Generating losses are not included, but are taken care of in price of power at the delivery point. Figures for percent of loss shown for various features will vary for different projects from these shown in the table, but in general the final factor for any well-designed large project will rarely depart materially from the 67 percent assumed. The total cost of lifting 1 acre-foot 1 foot, based on 67 percent efficiency and cost of 1 mill per killowatt-hour will be 1.53 mills.

1173. An analysis of estimated construction costs for the pumping areas described later in this report discloses a wide variation in unit costs (see pl. 125). [2] Figures show a decided trend toward a decrease in unit costs as capacity is increased, up to a development of about 55,000 kilowatts. Beyond that figure unit costs apparently increase. For the 55,000 kilowatt installation the cost of all construction works per acre-foot per foot of lift will be $0.06375. Interest on this investment is assumed at 4 percent and depreciation at 1.783 percent, with a sinking fund which provides one complete renewal of the plant each 30 years, and amortization at 1.783 percent, which pays off the principal in 30 years. The total of 7.56 percent applied to investment cost determines the cost per acre-foot per foot of lift as $0.004823. It is believed that unit costs of large pumping projects along Columbia River will not depart materially from the above figures. Costs for smaller projects can also be obtained from the curves of plate 125.

[2] Not printed.

1174. Cost of operation and maintenance of construction works, other than cost of electrical energy, is estimated at $2 per acre for areas considered in this report. Total costs of operations and maintenance, including electrical energy, per acre-foot per foot of lift, will be $0.00233 for the large plants (see pl. 125),[2] with increasing costs as plant capacity decreases.

1175. A recapitulation of unit costs of irrigation by pumping, per acre-foot per foot of lift, for large projects, under assumptions made in preceding paragraphs is given below:

Electrical energy (1.53 kilowatt-hours, at $0.001)	$0. 0015300
Interest on investment ($0.06375, at 4 percent)	.0025500
Depreciation (30 years life, 1.783 percent)	.0011365
Amortization (30-year period, 1.783 percent)	.0011365
Operation and maintenance other than electrical energy	.0008000
Total	.007153

1176. Figures for returns from irrigated lands show wide diversity. Returns vary from year to year on the same piece of ground, from farm to farm in any section, and differ consistently in different sections. Variations are due mainly to climatic and soil conditions, farming methods, and prices. Annual variations result largely from price variation and climatic conditions. Soil fertility is a direct factor in determining amount of yield. The method of handling the farming operations, including selection of type of products and efficiency of production and marketing, are perhaps of the greatest importance in the determination of returns from agricultural effort.

1177. Figures showing gross returns from irrigated lands are available for Federal irrigation projects. Annual returns for 15 projects for the period 1920 to 1929, inclusive, vary from $12.50 to $385 per acre. Unweighted averages for the projects for the period varied from $15 to $238 per acre per year. Average annual returns from the six better projects were $238, $129, $94, $83, $72, and $69. Similar figures for the three poorer projects were $15, $24, and $30. Average annual returns for all Federal projects varied from $43 to $63 per acre, with an average for the period of about $53. Projects with large returns were those devoting a large percentage of the area to special crops such as fruit, cotton, potatoes, livestock, and dairy products. Such a project is Sunnyside division of Yakima project in eastern Washington. Annual returns on this project varied from $67 to $119 for the period 1920 to 1929, with an average of about $94. Returns in 1929 were $100.51 per acre, with 37 percent of the area in hay, 15 percent in fruit, 18 percent in grain, 18 percent in pasture, and 12 percent in fruit and miscellaneous crops. Climatic conditions and soil of the Sunnyside division are similar to those of the areas considered in this report, and similar returns might be expected. However, complete records of production costs are not available and net returns essential to this study would have to be estimated. Complete records are available for lands in Twin Falls County, Idaho, irrigated by gravity. These districts have soil and climatic conditions somewhat similar to the areas considered below. For both regions the summer precipitation is slight and the growing season long. Water requirements are similar. Marketing conditions are more favorable for the Columbia River areas, the Idaho district being more remote from large cities and from manufacturing centers

[2] Not printed.

of the Pacific coast. Crops produced in the Idaho district are believed to be admirably adapted to the lands considered in this report. The principal crops grown were wheat, alfalfa, clover, beans, sugar-beets, potatoes, and corn. Barley and oats were grown in limited quantities for feed. Small fruits, apples, and other tree fruits were grown commercially.

1178. Data were secured for the years 1919 to 1922, inclusive. Crop yields varied but little during the period but gross returns and costs of production varied widely. Returns from the sales of farm products were high in 1919. Cost of production had not reached the highest level in the Twin Falls area in that year, so the year shows a high net return from agriculture. Returns dropped sharply in 1920, but costs of production mounted, net return dropping to about one third the 1919 figure. The years 1921 and 1922 were marked by a sharp decline in prices paid for produce. The costs of production fell more slowly. Net returns for 1921 and 1922 were about the same as for 1920. Average prices paid to producers for the 4 years show about 50 percent above the average for the pre-war period 1909 to 1914, while average costs were about 80 percent greater than for the pre-war period. However, while net returns as high as the average of the period 1919 to 1922 may be obtained in the future, it is believed they are the maximum that may be reasonably expected over an extended period in the area under consideration in this report. Hence, application of these returns to irrigation costs will determine the probable maximum economic lift for pumping projects. It is to be noted that lifts determined are feasible only when the combination of gross returns and costs of production are as favorable to producers as they were in the period 1919 to 1922.

1179. For comparative purposes data were secured for farms grouped in accordance with three classifications, based on the types of crops produced. Farms devoted entirely to the production of the field crops common to the district were classified as "general crop" farms. Those carrying on a dairy enterprise in addition to field-crop production were classed as "dairy" farms. Those having commercial orchards were classed as "orchard" farms. Essential conclusions related to the three farm groups are presented in tabular form below:

	Per acre		
	General crop farms	Dairy farms	Orchard farms
Capital	$350.00	$386.00	$431.00
Gross income	56.15	74.84	85.56
Production costs	41.42	51.38	59.48
Net returns	14.73	23.46	26.08
Percent return to capital	4.2	6.1	6.0

1180. Capital values stated in the table above include the value of real estate, comprising land and buildings, based on the sales price, and the value of working capital, comprising livestock, machinery, food, supplies, and cash necessary to operate the farm. In determining capital values for this study, buildings and working capital are

considered to be the same as for the Idaho lands. Land values, however, consist of the current price of raw or range land. The cost of irrigation works including operation and maintenance has been included under the estimate of the cost of irrigation by pumping, and evaluated as a charge against the pumping operation (pars. 1168 to 1175). Taxes and insurance are included in costs of production in the Idaho data. Costs of clearing, leveling, fencing, and ditching are added for Columbia River lands. An additional allowance of $40 per acre is made in the case of orchard farms for Columbia River lands to cover costs of labor and material, less temporary crops, required to bring the orchard, which comprises about one fourth of the farm, into bearing. The tabulation below shows the various items pertaining to capital value for the Idaho lands, with corresponding values to be used for the purpose of this report:

Capital values per acre

	General crop farms		Dairy farms		Orchard farms	
	Idaho lands	Columbia River lands	Idaho lands	Columbia River lands	Idaho lands	Columbia River lands
Land	$276	$5	$275	$5	$339	$5
Allowance for orchard						40
Buildings	37	37	45	45	54	54
Working capital	37	37	66	66	38	38
Clearing, leveling, ditches, fences, etc		45		45		45
Total	350	124	386	161	431	182

1181. With capital values as above for Columbia River lands proposed for irrigation by pumping, costs, and returns to capital are given in the tabulation below. Gross income is assumed to be the same as for the Idaho lands. Production costs are Idaho costs less irrigation water charges. Before determining the amount available from net returns for irrigation charges, an allowance for interest of 6 percent on the capital investment is made.

	Per acre		
	General crop farms	Dairy farms	Orchard farms
Capital	$124.00	$161.00	$182.00
Gross income	56.15	74.84	85.56
Production costs	38.42	48.38	56.48
Net return	17.73	26.46	29.08
Interest on capital at 6 percent	7.44	9.66	10.92
Maximum allowable for irrigation costs	10.29	16.80	18.16

1182. Assuming the above maximum amounts available to cover the costs of irrigation by pumping and using $0.007153 per acre-foot per foot of lift as the cost of pumping, economic limits of pumping are determined for various irrigation requirements. In determining the irrigation requirements for the areas considered in this report

utilization of land is assumed to be the same as given for the Idaho lands, as follows:

Type of farm	Percentages of farm in—				
	Hay	Orchard	Grain	Truck, root crops, and forage	Pasture
General crop	26	2	38	24	10
Dairy	32	2	28	17	21
Orchard	21	36	18	16	9

1183. The percentages of an area used for various crops will vary from year to year and will depend upon economic conditions, individuality of the producer, and many other factors. However, net irrigation requirements derived by use of the above percentages are believed to be conservative. In addition to the normal requirement applicable to the three farm types, 0.5 acre-foot per acre was added to the orchard requirement to cover irrigation of crops grown between tree rows. An allowance of 15 percent for leakage, seepage, evaporation, and other distribution losses has been used in computing the diversion irrigation requirement, all canals to be concrete lined above 50 second-feet capacity. The tabulation below shows approximate maximum permissible lifts for the three farm types under different soil conditions.

	Coarse sandy soil			Medium and fine sandy			Sandy loam soil		
	Net irrigation requirement	Diversion irrigation requirement	Maximum lift	Net irrigation requirement	Diversion irrigation requirement	Maximum lift	Net irrigation requirement	Diversion irrigation requirement	Maximum lift
	Acre-feet	*Acre-feet*	*Feet*	*Acre-feet*	*Acre-feet*	*Feet*	*Acre-feet*	*Acre-feet*	*Feet*
General crop	4.9	5.8	250	3.9	4.6	310	2.5	3.0	480
Dairy	5.3	6.2	380	4.3	5.0	470	2.8	3.3	710
Orchard	4.8	5.7	445	3.8	4.5	565	2.4	3.0	845

1184. These maximum lifts are applicable to projects of large size having average construction costs. Unusually expensive siphons, pipe lines, feed canals, and other construction works will result in a higher cost, decreasing the allowance for pumping and consequently the maximum lift. It is to be noted that the lifts will be economic only when the cost of electrical energy for pumping is 1 mill per kilowatt-hour and net returns are as shown for the Idaho lands. Higher costs of electrical energy and lower net returns will decrease the amount available for payment of irrigation costs and render the stated lifts unjustifiable from an economic standpoint.

(3) Existing Irrigation Development

1185. There are about 1,335,000 acres of irrigable land in the Columbia River Basin below the mouth of the Snake, of which about

277,300 acres are now irrigated. About 72,000 acres of the portion not irrigated are included in constructed projects. About 71 percent of the irrigable land is found in Oregon and 29 percent in Washington.

1186. There are no irrigation projects of consequence utilizing the water of the Columbia River, such use being restricted to occasional small areas near the river, irrigated by privately owned pumping plants. In some tributary basins, however, especially in Oregon, irrigation projects are numerous and waters of the tributaries have been extensively developed. The major districts in which irrigable lands exist are listed above (table 58) with pertinent facts. The irrigable areas are shown on plate 123 of this report. Brief descriptions of the districts follow the table.

1187. *a. Columbia River bottom lands.*—The irrigated lands of this area include a number of tracts along Columbia River between the mouth of the Snake and The Dalles, irrigated mainly by pumping from the river. The tracts are small, ranging in size from 10 to 100 acres, with one area of 700 acres on Blalock Island, in Benton County, Wash. The major portion of the lands classed as "Columbia River bottom lands" are found in the lower 120 miles of the river and are not irrigated. These lands are subject to inundation during periods of high flows. Many tracts are protected by dikes. They are described in greater detail in paragraphs 1085 to 1087.

1188. *b. Walla Walla River Basin.*—The basin of Walla Walla River lies partly in Oregon and partly in Washington. The irrigated portion of the basin lies in the valley of the main river and its tributaries. The total area irrigated comprises about 48,500 acres, of which 20,500 acres are in Oregon and 28,000 acres in Washington.

1189. Walla Walla River rises in Wallowa County, Oreg., near the western boundary of Grande Ronde River Basin. It flows in a northwesterly direction through the northern part of Umatilla County into Walla Walla County, Wash., entering the Columbia near Wallula, Wash. The main branches in Oregon are North Fork, South Fork, Birch Creek, Pine Creek, Mud Creek, and Couse Creek. A branch of the main river diverting in sec. 12, T. 5 N., R. 35 E., is known as Little Walla Walla River. It runs northwesterly about 1 mile, dividing to form Crockett and Ford branches which continue in a northerly direction to enter the State of Washington. The portion of the main river north of the point of diversion of Little Walla Walla River is known as Tum-a-Lum River. These designations are of interest in a consideration of irrigation diversions in the basin. The main branches in Washington are Touchet River and Mill, Garrison, Stone, Yellowhawk, Russel, Cottonwood, and Mud Creeks. Garrison and Yellowhawk Creeks are branches of Mill Creek, connecting that stream with the main river above the mouth of Mill Creek. The sources of the various streams are in Oregon, with the exception of Touchet River and Mill Creek, which rise in Washington.

1190. The soils of Walla Walla Valley are loam and sandy loam. A portion of the area is underlain with gravel, causing excessive seepage. Much of this seepage returns to the surface at lower levels and is available for further irrigation use. The soils are very fertile, the greater part of the area producing valuable fruit and truck crops, as well as alfalfa and grains.

1191. The climate of Walla Walla Valley is mild and favorable for growing crops, with an average frost-free season of about 200 days.

Normal annual precipitation varies from 10 to about 17 inches, occurring largely in the winter months.

1192. The sources of supply of water for irrigation in the valley are the surface and subsurface flows of Walla Walla River and its numerous tributaries and branches. The normal annual flow at the mouth is about 500,000 acre-feet. The normal flow of the main river at Milton, Oreg., above practically all irrigation diversions, is about 200,000 acre-feet. About 105,000 acre-feet of this flow occurs during the irrigation season, April to September, inclusive. Nearly all of this summer flow is used on portions of the 48,000 acres of irrigated land of the valley. Without storage, there is not sufficient water in ordinary years to supply the entire area during the low water season. Additional water for irrigation use could be secured by storage of surplus waters in the upper reaches of Walla Walla River and its tributaries. (See par. 116.) It is probable that 100,000 acres of additional irrigable land (one half in Oregon and one half in Washington) can be found in the valley and adjacent thereto which would utilize the greater part of the surplus flow of 500,000 acre-feet if storage were provided.

1193. Irrigation in Walla Walla Valley is accomplished by diversion through natural channels and canals, from the main river and its tributaries and branches, by pumping from wells, and by subirrigation. Canal systems are generally small, the largest serving about 6,000 acres. The tabulation lists the various streams of the basin and shows the irrigated area for each.

Source of water:	*Acres irrigated*	
OREGON		
Walla Walla River	12,425	
Pine Creek	5,282	
Spring Branches	1,440	
South Fork	514	
Miscellaneous springs, wells, and subirrigation	317	
North Fork	219	
Couse Creek	199	
Birch Creek	127	
		20,523
WASHINGTON		
Walla Walla River	8,000	
Touchet River	5,000	
Creeks, springs, and branches	15,000	
		28,000
Total		48,523

1194. *c. Umatilla River Basin.*—The basin of Umatilla River is situated in Umatilla and Morrow Counties, Oreg. The irrigated lands of the basin lie in the valleys of the main river and its tributaries and on bench lands adjacent to the main stream near its mouth. About 39,600 acres are irrigated. The river rises in eastern Umatilla County near the Grande Ronde watershed, flows westerly and northerly to enter Columbia River near Umatilla, Oreg., mile 289. The main tributaries are Butter, Birch, McKay, and Meacham Creeks.

1195. The soils in the irrigated areas are generally sandy loam. The bench lands of lower elevation are sandy. They are rolling and shallow, and often are underlaid by a deposit of coarse sand and gravel. The principal products are alfalfa, grains, fruits, berries, and vegetables. The climate is arid. Temperatures range ordinarily

from about zero to 100° above zero. Precipitation averages about 9 inches per year, with very little occurring during the growing season.

1196. Water for irrigation is secured from Umatilla River and its tributaries. The low-water flow of the main stream is increased by the use of storage. The normal flow at the mouth, occuring mainly during the nonirrigation season, is about 425,000 acre-feet. The entire flow could be used on desirable lands now uncultivated if additional storage facilities were provided (par. 115). The main part of the irrigated area lies along the lower reaches of the river and on benches adjacent to that portion of the stream. Four large districts organized under the State law are found in this area. Two, the Umatilla (Hermiston irrigation district) and Umatilla west extension (West extension irrigation district) projects have been developed by the United States Bureau of Reclamation. The other two were built by private interests and are known as the Furnish (Stanfield irrigation district) and the Western Land & Irrigation Co. (Westland irrigation district) projects. The tabulation below lists the various irrigated areas, showing number of acres irrigated.

Name of area	Irrigable	Irrigated	Source of water
	Acres	*Acres*	
Hermiston irrigation district	10,857	7,700	Umatilla River.
West extension irrigation district	5,923	4,200	Do.
Westland irrigation district	8,788	4,500	Do.
Stanfield irrigation district	8,240	3,400	Do.
Umatilla Meadows	6,000	5,000	Do.
Miscellaneous	3,000	3,000	Do.
Do	3,200	3,200	Birch Creek.
Do	900	900	McKay Creek.
Do	7,700	7,700	Butter Creek.
Total	54,608	39,600	

1197. *d. Willow Creek Basin.*—Irrigated areas of Willow Creek Basin lie in scattered tracts along the creek. A total of 6,500 acres is irrigated in this basin. Willow Creek rises in the Blue Mountains, flowing in a northerly direction to enter Columbia River at mile 252.5. The basin lies in Umatilla, Morrow, and Gilliam Counties. Willow Creek is the largest of several waterways in the area between Umatilla and John Day River Basins that lead directly to Columbia River.

1198. Water has been used for irrigation in this basin since about 1885. The principal crop produced under irrigation is alfalfa. Irrigation is by direct diversion from the main stream through small canals. Due to lack of regulation by storage, the water supply for the acreage developed is inadequate during the low-water season. The normal flow of Willow Creek at the mouth is about 50,000 acre-feet. If suitable storage could be developed, this flow could be made available for use on additional irrigable lands.

1199. *e. John Day River Basin.*—The basin of John Day River includes portions of Umatilla, Grant, Morrow, Gilliam, Wheeler, Sherman, and Jefferson Counties, Oreg. The irrigated portions of the basin lie in the valleys of the main stream and its tributaries and amount to a total of about 62,000 acres. The main river rises in eastern Grant County, at the western boundary of the Malheur

River Basin, and flows in a generally northwestern direction, joining Columbia River at mile 216.5. The important tributaries of John Day River are North, Middle, and South Forks. Many small streams flow into these tributaries and into the main river. Among these are Strawberry, Indian, Pine, Canyon, Bridge, Butte, Thirty Mile, Hay, and Rock Creeks, tributary to the main river; Cable, Camas, and Cottonwood Creeks, tributary to North Fork of John Day River; and Long Creek, tributary to Middle Fork.

1200. The soils of the irrigated areas are alluvial deposits of sandy and silty loam, generally underlaid by gravel beds. They are very fertile, the principal crops produced being alfalfa, fruit, and truck. As the main industry of the region is stock raising, alfalfa is the most important crop grown. The climate in the valleys of John Day Basin is such that irrigation is required for the successful growing of crops. The summers are hot and dry and the winters cold.

1201. The source of water supply for irrigation is the normal flow of the streams of the basin. The entire flow of most of the streams is used for irrigation during the summer months. The summer flows are unequal to the demand in most years. The normal annual discharge of John Day River at the mouth is about 1,600,000 acre-feet. Storage sites exist that would impound and make available for additional lands at least two thirds of this discharge. There are enough suitable irrigable lands in the basin and on benches adjacent to the basin to utilize the entire surplus flow of the river. Irrigation is by direct diversion through small ditches. A single ditch rarely serves more than three or four tracts.

1202. John Day River is the subject of a separate report to be submitted by this office at a later date.

1203. *f. Deschutes River Basin.*—The Deschutes River, lying between the Cascade Range on the west, the John Day drainage basin on the east, Columbia River on the north, and the Central Oregon Basin on the south, drains an area of 9,180 square miles. The river has its source in a number of lakes near the summit of the Cascades just across the divide from the headwaters of the Willamette, and flows northward entering the Columbia at mile 203, about 15 miles above The Dalles. The principal tributaries are the West Fork and Metolius, Warm Springs, and White Rivers, which drain the east slope of the Cascades; and Crooked River, which drains a large area in the southeast corner of the basin. The Deschutes is remarkable for the uniformity of its flow, the result of natural storage due to the porosity and water retentive qualities of the pumice and lava formation underlying the greater part of the basin. The normal annual discharge at the mouth is about 4,600,000 acre-feet. From its mouth to Crooked River, a distance of approximately 112 miles, it flows through a deep canyon from 1,000 to 2,000 feet in depth. From the junction of Crooked River upstream on the Deschutes, the canyon still exists, but the depth below the tablelands gradually lessens until at Aubrey Falls, approximately 154 miles from the Columbia River, the walls are about 200 feet high. The elevation at its mouth is slightly less than 150 feet above sea level; at mouth of Crooked River, 1,600 feet above sea level; and at Aubrey Falls, 3,080 feet above sea level. Above Aubrey Falls the canyon formation changes until, in the vicinity of Bend, the banks are such that water may be diverted from the river by means of low-diversion dams.

Deschutes Basin is rough and mountainous, with the exception of a large plateau some 70 miles in length and from 6 to 20 miles wide, to the south and east of Bend. The agricultural area consists largely of high tablelands.

1204. Along the summit of Cascade Range, the precipitation varies from about 70 inches at the south end to over 100 inches at the north end. The area of heavy precipitation, however, is small compared with the total area of the basin. The precipitation on the remaining area is very light, ranging from 9 to 18 inches, with an average of probably 10 inches on the greater part of the area under cultivation. The range in temperature varies from $-40°$ to $+112°$ Fahrenheit. The number of days between killing frosts also varies widely; for instance, at Bend, the records show a minimum of 53 days and a maximum of 143 days.

1205. The most important towns in the basin are Bend, on Deschutes River, with a population of 8,848, and Prineville, at the junction of Crooked and Ochoco Rivers, with a population of 1,027. Both Bend, with an elevation of 3,629 feet above sea level, and Prineville, with an elevation of 2,864 feet, are in the upper-plateau region, and both are centers for the greater part of the agricultural development which has taken place within the basin.

1206. There are many first-class roads and highways within the basin, particularly in the region south of Madras. The principal highways are The Dalles-California and Prineville-Lakeview Highways, running north and south, and the Ochoco and Central Oregon Highways, running east and west. The Oregon-Washington Railroad & Navigation Co. and Oregon Trunk Railroad, which practically parallel the Deschutes River, afford transportation between the towns of Bend and Prineville and the main line of the Oregon-Washington Railroad & Navigation Co., along the south bank of the Columbia. The Oregon-Washington Railroad & Navigation Co. also operates a short line along the eastern edge of the basin, connecting the town of Shaniko with Biggs, on the main line. The Great Northern recently completed the construction of a railroad system between Bend and Klamath Falls, which affords easy access to the California market.

1207. The general type of soil of value for agricultural use found in the basin is a sandy loam of volcanic origin, varying somewhat in texture and underlain with a porous basalt lava, or occasional tuff. The poorer type of soils, which is not adaptable for farming, is a coarse sand, or disintegrated lava. The rocks of the entire region are volcanic in origin. The principal crops grown upon the irrigated lands are alfalfa, clover, wheat, barley, oats, rye, potatoes, and all kinds of the hardier vegetables. Berries and all of the hardier fruits which can be grown in the northern climate are successfully grown on the irrigated lands along the streams in the lower altitudes. Wheat has been successfully grown by dry farming on a large part of the area.

1208. The irrigated area in the Deschutes Basin comprises about 82,000 acres. Most of the irrigation development has taken place in the plateau region around the towns of Bend, Prineville, Redmond, and Tumalo. This area extends from the foot of Cascade Range on the west to John Day Basin on the east, and from about 10 miles

south of Bend to 30 miles north of Bend. There are other districts in which irrigation development is taking place, but the areas involved are comparatively small. Many irrigation districts and companies have been formed and are at present operating. A list showing irrigable and irrigated areas of the most important districts and companies follows:

Name	Area (acres)	
	Irrigable	Irrigated
Deschutes Reclamation & Irrigation Co	6,638	2,700
Walker Basin Irrigation Co	9,646	175
Central Oregon irrigation district	43,350	35,000
North Canal Co	20,000	591
The Arnold Irrigation Co	9,392	3,700
Deschutes County municipal improvement district	14,555	6,926
Crook County improvement district no. 1	2,438	1,800
Ochoco irrigation district	18,501	10,215
Jefferson water conservancy district	105,653	0
Suttle Lake irrigation district	10,669	0
Squaw Creek irrigation district	7,206	5,032
Snow Creek irrigation district	2,000	250
The Sisters irrigation district	1,385	1,385
Cline Falls Power Co	800	400
Odin Falls Land Co	1,057	400
Wapinitia Irrigation Co	12,000	2,000
Oregon Land Corporation	8,083	0
Powell Butte irrigation district	12,700	0
South unit improvement district	14,500	0
West side reclamation district	20,225	0
Lost & Boulder Ditch Co	1,233	1,233
Miscellaneous [1]	16,511	9,511
Total	338,542	82,218

[1] This item includes several minor companies, such as the Wamic Water Ditch Co. and Tygh Valley High Line Ditch Co. These companies are all small farmers' organizations, controlling the particular ditch which furnishes water to their lands.

1209. *g. Klickitat River Basin.*—The basin of Klickitat River lies in southern Washington, in Klickitat and Yakima Counties. A total of 4,200 acres is irrigated in the basin. The main river rises in Yakima County, in the snowclad Cascade Range, and flows in a southerly direction, joining Columbia River, at mile 179.5, in southern Klickitat County. The main tributaries of Klickitat River are Diamond Fork, Big Muddy, White, Hellroaring, Bird, Frazier, and Little Klickitat Creeks.

1210. In some portions of the basin the summer rainfall is sufficient to mature crops, but in other portions irrigation is required. Water for irrigation use is obtained from Klickitat River and from tributary streams. Some of the streams are of glacial origin, having a well-sustained summer flow which provides a water supply for irrigation of an appreciable area without storage. Complete use of waters of the streams can be made only by means of storage reservoirs. Many storage sites exist in the basin. (See par. 117.) The average flow of the river available for additional irrigation is about 450,000 acre-feet.

1211. Existing irrigation is by small diversions from the streams of the basin, without recourse to storage. The largest development is Glenwood project, near Glenwood, Wash., in T. 6 N., R. 12 E., Willamette meridian. In this locality an irrigable area of about 5,500 acres is being developed, with about 3,800 acres now irrigated. An enlarged project of 20,000 acres, with storage on Hellroaring Creek, is contemplated. Water for the present project is obtained from Bird

and Frazier Creeks. The principal crop is alfalfa, largely used locally to feed cattle and other stock. In Goldendale Valley, on Little Klickitat Creek, there are about 8,000 acres producing good alfalfa crops without irrigation. There are, however, a few small irrigated tracts along Little Klickitat Creek. Some additional development is contemplated. Storage is necessary for further development.

1212. Use of water from Klickitat River for lands outside of the basin has been considered. (See par. 117.) The following is a summary of irrigated areas in Klickitat River Basin:

Area	Irrigable	Irrigated	Source of water
	Acres	*Acres*	
Glenwood project	20,000	3,800	Bird, Frazier, Hellroaring Creeks.
Goldendale project	500	175	Bowman Creek.
Miscellaneous	225	225	Various streams.
Total	20,725	4,200	

1213. *h. Hood River Basin.*—Hood River drainage basin lies in Hood River County, in north-central Oregon. It has an area of 366 square miles. The normal flow of Hood River at its mouth is about 786,000 acre-feet. The basin is bounded on the north by Columbia River, on the south by the slopes of Mount Hood, on the east by a spur of the Cascade Mountains, and on the west by the main Cascade divide. Originally, the entire drainage basin was covered with a heavy growth of pine and fir timber. Lands adjacent to the river, however, have been cleared and are devoted to agricultural use. The agricultural portion of the basin is known as Hood River Valley. There are about 23,000 acres under irrigation in the valley.

1214. The three main branches of Hood River—East Fork, Middle Fork, and West Fork—rise on the slopes of Mount Hood and flow in a northerly direction, uniting to form the main river about 20 miles above its mouth. These streams flow generally in deep channels cut in basalt. The valley consists of a series of plateaulike, comparatively level terraces lying from 100 to 500 feet above the river bed. A rough mountain spur separates it into two major sections, known as Upper Hood River Valley and Lower Hood River Valley. East of this spur and about 3 miles from the river is a third and smaller section known as Middle Valley. Upper Valley lies between Middle and East Forks and east of East Fork, extending several miles above their confluence. Lower Valley is bisected by the main river, extending from the mouth about 10 miles upstream. Middle Valley consists of a few hundred acres of gently sloping land lying between Upper and Lower Valleys.

1215. Irrigation has been practiced in Hood River Valley for many years. Agricultural activities of the early settlers were, on account of the absence of accessible markets, limited to the production of hay and grain in connection with the raising of stock. The first attempt at producing a commercial crop by irrigation was made in the early eighties, when strawberries from irrigated tracts were shipped to Portland. This was shortly after the completion of the Union Pacific Railroad connecting Hood River with that city. Previous to that time access to markets was only by boats on the Columbia River. The main agricultural products are strawberries and apples. A small

acreage produces soft fruits, such as peaches, pears, and plums. Many of the strawberry beds are planted in the young orchards. It is probable that the strawberry acreage will decrease as the orchards mature. Some alfalfa, timothy, clover, and other hay is grown, but mainly in small tracts to meet the needs of the individual farm. A large part of the forage used is shipped in from outside producing areas.

1216. The population of Hood River Valley is about 9,000. The principal city is Hood River, situated at the junction of Hood River and the Columbia. It has a population of 2,757. Other towns in Lower Valley are Odell and Wyeth, and in Upper Valley Doe and Parkdale. The valley has many miles of excellent surfaced highways, including Mount Hood Loop Highway, extending from Hood River southwesterly throughout its length. Mount Hood Railway runs from Parkdale to Hood River, a distance of 23 miles, carrying freight which is transferred to the Union Pacific at the latter point. Water transportation is available from Hood River to Portland, via Columbia River.

1217. The climate of Hood River Valley is characterized by long, cool summers, and fairly moderate winters, with comparative freedom from killing frosts during the growing season. Heavy snowfalls are often experienced on the upper levels of the valley in January, February, and March. A long growing season, with an abundance of sunlight, insures the successful production of deciduous fruits, berries, and other crops adapted to a cool, temperate climate. Temperature records secured at the city of Hood River, 1884 to 1930, inclusive, show a maximum temperature of 106°, minimum of −27°, and mean of 50°. The average number of days between killing frosts for the same period is 182; the average frost-free period extends from April 21 to October 20. Precipitation records for the above station for the period 1884 to 1927, inclusive, show a maximum of 54.17 inches (1893), a minimum of 16.66 inches (1930), and a mean of 32.2 inches. The average yearly snowfall at the station is 53.5 inches. The soils encountered are loams and silty loams, underlaid with Columbia lava. They are the result of glacial and alluvial deposits and rock weathering.

1218. The following is a summary of the various irrigated areas of Hood River Valley:

Area	Irrigable	Irrigated	Source of water
	Acres	*Acres*	
East Fork irrigation district	11,261	9,800	East Fork.
Glacier Irrigation Co.	2,510	562	Sand Creek.
Mount Hood Water Co.	1,423	545	East Fork.
Middle Fork irrigation district	7,600	3,900	Middle Fork.
Dee irrigation district	1,411	1,000	West Fork.
Farmers Irrigation Co.	5,000	3,860	Hood River.
Hood River irrigation district	4,177	2,822	Green Point Creek and Spring.
Stanley Smith Lumber Co.	144	144	Green Point Creek.
Neal Creek	300	300	
Total	33,829	22,933	

1219. *i. White Salmon River Basin.*—The basin of White Salmon River is situated in Klickitat, Skamania, and Yakima Counties, Wash. The irrigated areas lie along the steams of the basin and on adjacent benches. The total area irrigated is about 2,400 acres. The largest

town in the basin is Stevenson; population 400. White Salmon River heads in the glaciers of Mount Adams and flows in a southerly direction, joining Columbia River near Underwood, Wash. (mile 167). The principal tributary is Trout Creek, which drains the high slopes and spurs of Mount Adams. Other tributaries are Rattlesnake and Gilmer Creeks, entering the main river from the east, and Big Springs, Buck, and Little Buck Creeks, from the west. The normal annual flow at the mouth is about 763,000 acre-feet.

1220. The climate in the basin is characterized by moderate winters, long cool summers, and comparative freedom from damaging spring frosts. The precipitation is moderate, the annual average being about 30 inches, with less than one fifth occurring during the growing season, April to September. Soils are principally silty loam, resulting from alluvial deposits and from rock weathering.

1221. Water for irrigation is secured from the normal flows of streams, without recourse to storage. Irrigation is by direct diversion from streams through numerous small ditches. Irrigated areas are listed below, with pertinent facts:

Area	Irrigable	Irrigated	Source of water
	Acres	*Acres*	
White Salmon irrigation district	600	300	Buck Creek.
Underwood irrigation district	242	84	Little Buck Creek.
Trout lake area	2,000	2,000	Trout Creek and White Salmon River.
Total	2,842	2,384	

1222. *j. Willamette River Basin.*—Willamette River has been made the subject of a separate report submitted by this office under date of August 15, 1929. Details pertinent to irrigation in Willamette Valley are included in the report.

1223. Willamette River Basin has an area of about 11,200 square miles. It lies in northwestern Oregon, extending north and south between the Coast and Cascade Ranges. The basin is drained by Willamette River, which is formed by the junction, near Eugene, Oreg., of three branches—Coast Fork, Middle Fork, and McKenzie River. About one seventh of the tillable acreage of 3,000,000 acres in the valley is considered irrigable and about 4,000 acres are actually irrigated.

1224. Willamette River flows northerly from its origin, entering Columbia River at mile 99. The main tributaries, in addition to the three branches named in the preceding paragraph, are Callapooya, Santiam, Molalla, and Clackamas Rivers in the eastern portion of the basin, with sources in the Cascade Range, and Long Tom, Marys, Luckiamute, Rickreall, Yamhill, and Tualatin Rivers in the western portion, rising in the coast range.

1225. The soils of the valleys of Willamette Basin are in the main highly fertile alluvial deposits. Subsoils vary from gravel to compact clay. Surface drainage is good except for the silty loam type which have inadequate surface and subsurface drainage. The soils are satisfactory for the production of fruit, truck, hay, and grains. The climate of the valley is mild. Precipitation is high, ranging from an annual average of 70 to 150 inches in the mountain ranges to 40 inches in the lower levels. However, the rainfall in the valleys occurs prin-

cipally during the winter months, the summers having very little rainfall, and efficient crop production can be attained only by means of irrigation.

1226. Irrigation in Willamette Valley is accomplished by diversion of normal stream flows, by subirrigation, and by pumping from wells. Some of the streams of the basin have well-sustained summer flows sufficient for the irrigation of large areas. Complete utilization of the waters of the basin on the 428,000 acres of irrigable land included therein can be attained only through storage. Storage sites are found in the valleys of tributary streams and are listed in the report mentioned above. The following are the principal irrigated areas:

Name of area	Acres irrigated	Source of water
Lake Labish	1,500	Subirrigation from drainage canals.
Fullacres project	1,300	North Santiam River.
Canby	1,000	Molalla River.
Eugene-Springfield no. 1 irrigation project	285	McKenzie River.
Stayton project	200	North Santiam River.
Portland area	75	
Total	4,360	

1227. *k. Miscellaneous stream basins.*—A total of 3,070 acres is listed above, paragraph 1154, as irrigated from various small tributaries of the Columbia River. The areas are given in detail in the tabulation following:

Area	Acres irrigated	State	Source of water	Enters Columbia River at mile—
Fifteen Mile Creek Basin	1,819	Oregon	Fifteen Mile Creek	192
Mill Creek Basin	393	do	Mill Creek	188
Mosier Creek Basin	200	do	Mosier Creek	175
Chenowith Creek Basin	130	do	Chenowith Creek	186
Three Mile Creek Basin	28	do	Three Mile Creek	191
Artesian Coulee	500	Washington	Wells	261
Total	3,070			

1228. Reclamation by irrigation in the basin, whether by individual effort or by combination of efforts, has on the whole attained a measure of success. Usually applied to an area sparsely populated or without population, irrigation has developed thickly settled communities on the area itself and augmented nearby population centers already in existence. Lands producing crops limited in quantity or totally unproductive have been placed in the efficiently productive class.

1229. Many developments, however, have at some period experienced difficulty in meeting their financial obligations, and some have definitely defaulted. The reasons for these failures have been numerous and varied. The specific causes of failures have been engineering mistakes and difficulties, faulty financing and colonization difficulties, or combination of these elements.

1230. Important engineering mistakes and difficulties have been overestimation of the water supply, underestimation of the irrigation requirement, inadequacy of the irrigation works for serving all land bearing construction charges, inclusion of marginal areas unsuited for agricultural production on account of unfavorable soil and topographic conditions, disaster to irrigation works, underestimation of the costs of construction and operation, and defects in storage reservoirs.

1231. Faults in plans of financing have resulted from overcapitalization due to desire of promotors for excessive profits or to overestimation of the value of improved lands. The plan of liability of each landowner for delinquencies of every owner, originally intended to make investment in irrigation securities more attractive, by pyramiding assessments, actually encouraged landowners who were able to pay to refuse payment. In some cases amortization periods were unduly brief and not based on the ability of the land to earn the amount required to meet the annual payments.

1232. Lag in settlement of irrigation projects has been a leading cause of failure to meet financial obligations. Delay in the utilization of irrigation works to their full capacity, accompanied by delinquencies of owners of idle land, in time imposes an obligation greater than can ever be met by the land. Some causes for delay of settlement are lack of adequate colonization program, high construction costs, and unfavorable climatic, farming, and marketing conditions, all tending to render the development unattractive.

1233. Only two projects, and these minor ones, in the basin of the Columbia below the mouth of the Snake can be classed as total failures, the Alder irrigation district, with an irrigable area of about 200 acres, and the Attalia irrigation district, with 4,000 acres irrigable. Lands of these districts were developed to a highly productive stage, but both land and irrigation works have been abandoned. The main cause of abandonment in each case was failure of the water supply due to a succession of low-flow years. In the case of the Attalia District the trouble was intensified by the loss of the main diversion works during a freshet.

1234. In Oregon, investigation and reorganization of defaulting irrigation districts have been made a function of the State reclamation commission (Oregon Laws, ch. 434, 1927). The second biennial report of this body, covering the period October 1, 1928, to September 30, 1930, lists 13 projects which have been examined. Of these only one was found to be in sound financial condition. The others have been in default in payment of principal and interest on their bonds for varying periods, ranging from 6 months to several years. The investigations of the commission include the following elements: Surveys of the physical conditions, including water-supply studies, and estimates of cost of necessary improvements or betterments, made by the State engineer department; soil surveys made by experts from the State agricultural college experiment station; and economic studies made by irrigation economists of the United States Department of Agriculture. The commission has been actively engaged in assisting 11 of the defaulting districts to reorganize and refinance their bonded indebtedness. These efforts have been attended with a fair measure of success.

(4) Possible Irrigation Development

I. EARLIER INVESTIGATIONS

1235. Engineering and economic problems of the more important irrigable areas in the Columbia Basin below mouth of the Snake have been subjected to study and investigation by various Federal, State, and private interests. Many reports have been published covering these investigations, which have been available for the purposes of this study. The most important are listed in table 58, page 1672.

II. PRESENT INVESTIGATION

(A) TRACTS CONSIDERED

1236. Irrigable areas considered in this section include lands of the Columbia Basin below the mouth of the Snake susceptible to irrigation by pumping from the main river. (See pl. 126.) Use of water of tributaries is considered only when such use provides an alternate source of water supply.

1237. Maximum pumping lifts stated in paragraph 1183 are based on the study of an area of which 88 percent was devoted to general crop farming, 7 percent to dairy farming, and 5 percent to orchard farming. The figures show that the greatest net returns and consequently the greatest permissible lifts, if net returns were used to cover pumping costs, accompany the use of orchard farms. However, considering that only a small portion of the lands studied were thus used, it is believed that it would be unsafe to assume that the same unit net return would have been obtained if the whole area had been in orchard farms. The area in dairy farms was likewise small. Statistics show, however, that the trend in agricultural development is toward the production of feed for stock, the highest return for farm products being realized when the products are used on the farm and not sold in the open market.[28]

1238. The agricultural plan believed to be best adapted to present-day conditions of demands and markets would include devoting some of the farm lands to general crops, but the major portion to feed crops and pasture, with sufficient dairy stock, cattle, sheep, or hogs on the farm to utilize the stock feed produced. The irrigation requirements and maximum permissible lifts for lands thus utilized would be similar to those of dairy farms (par. 1180), with maximum lifts of 380 feet for coarse sandy soils, 470 feet for medium and fine sandy soils, and 710 feet for sandy loam soils. The maximum available amount for annual charges for irrigation by pumping is estimated to be $16.80.

1239. Net irrigation requirements used are 5.3 acre-feet for the coarse soils, 4.3 acre-feet for the medium and fine sandy, and 2.8 acre-feet for the loamy, with diversion requirements of 6.2, 5, and 3.3 acre-feet, the allowance for all transportation losses being 15 percent. Canals with 50 second-feet capacity or more are concrete lined. On some tracts marginal areas are eliminated on account of steepness, roughness, or other undesirable characteristics.

[28] Better Iowa, vol. XIII, no. 22, p. 1, states that the average return (238 farms surveyed) from agricultural products worth $100 in the open market was $197 when fed to livestock.

1240. The tabulation following lists the irrigable areas considered, with pertinent facts. Descriptions of the areas follow the tabulation. A plan of irrigation development of each area is described in paragraphs 1274 to 1313 below:

No.	Name of area	State	Area, acres		Water supply	
			Gross	Irrigable	Pumping from—	Gravity from—
1	Cold Springs	Oregon	67,000	50,000	Columbia River	
2	Horse Heaven	Washington	200,000	142,000	do	
3	Willow Creek	Oregon	207,000	173,000	do	John Day River.
4	Arlington	do	18,000	11,500	do	Do.
5	Roosevelt	Washington	2,000	1,500	do	
	Total		494,000	378,000		

1. COLD SPRINGS AREA

1241. This is an area of about 67,000 acres in Umatilla County, Oreg., lying east of the Hermiston and Stanfield irrigation districts, of which 50,000 acres is considered irrigable. The area extends about 15 miles southward from Columbia River. It slopes generally downward to the west from its eastern boundary, which lies at about elevation 1,000 feet above sea level. The climate is comparable to that of Umatilla (par. 65), and is marked by long, hot, dry summers and cold winters. Agricultural production is not possible without irrigation.

1242. As the result of a soil examination, soils of 4,000 acres are classed as medium and fine sandy, and 46,000 acres as sandy loam. Below elevation 750, medium sandy soil predominates north of Cold Springs Canyon, and fine sandy south of Despain Gulch. In this section, between the two canyons, the soil is largely sandy loam. Above 850 elevation, the soils are principally sandy loam. The diversion irrigation requirement for the sandy soils is 5 acre-feet per acre and for the sandy loam soils 3.3 acre-feet. The following tabulation shows the acre-feet required for the area:

Type of soil	Area	Diversion irrigation requirement, acre-feet per annum	
		Per acre	Total
	Acres		
Medium and fine sandy	4,000	5.00	20,000
Sandy loam	46,000	3.30	151,800
Total and average	50,000	3.41	171,800

1243. The only means of irrigating this area is by pumping from Columbia River. The diversion of the 573 second-feet required for the area will not materially affect the flow of the river.

2. HORSE HEAVEN AREA

1244. This is an area of about 200,000 acres north of Columbia River in Benton and Klickitat Counties, Wash., of which about 142,000 acres are considered irrigable. The area is bounded on the north by elevation about 1,000 above sea level, and on the south by

elevation 350, near Columbia River. It extends from Spaw Canyon (mile 303, Columbia River) on the east to Alder Creek (mile 257, Columbia River) on the west. The extreme width east and west is about 40 miles, and the greatest north and south about 18 miles.

1245. The area has a gradual slope from north to south varying from about 40 feet to the mile in the widest part to 250 in the narrowest. Most of the area is cut by deep canyons leading from the north toward Columbia River. Between the canyons the benches are fairly level. The sides of the canyons are too steep to permit successful irrigation. Estimates of irrigable area exclude all lands with slopes greater than 15 percent. The eastern portion of the area is cut by high ridges extending from the northeast to the southwest. Portions of these ridges would produce high yields under irrigation and are below the 1,000-foot contour. However, as expensive siphons would be required for the irrigation of these lands they have been excluded from the irrigable area. About 6,000 acres of comparatively high land in the southwestern part of the area were excluded for the same reason.

1246. The climatic conditions for most of the Horse Heaven area are such that successful agricultural production is absolutely dependent upon irrigation. The summers are long and hot and practically without precipitation. Some areas between elevations 750 and 1,000 have produced fair wheat crops in wet years, but these lands have not been farmed recently. The growing season extends from March to October. The irrigation season begins about March 15 and ends about October 15 in ordinary years. There are no weather stations in the area, but records obtained at Umatilla, Oreg., are comparable (par. 65 of this report).

1247. Soils of Horse Heaven area vary from sandy loam to sandy. Sandy loam soils predominate in the higher northern portions of the area, the sandy soils occurring nearer the Columbia. Of the 142,000 acres considered irrigable, 130,500 acres are classed as sandy loam, and 11,500 acres as fine sandy soil. The annual diversion irrigation requirement for the sandy loam soils is 3.3 acre-feet per acre, and for the sandy soils 5.0. The coarse sands requiring a larger amount of water have been excluded from the irrigable area. The average annual diversion irrigation requirement for the entire area is 3.43 acre-feet per acre. The total acre-feet required are shown below in tabulated form.

Type of soil	Area	Diversion irrigation requirement, acre-feet per annum	
		Per acre	Total
	Acres		
Fine sandy	11,500	5.0	57,500
Sandy loam	130,500	3.3	430,650
Total and average	142,000	3.43	488,150

1248. The largest monthly requirement will be 97,630 acre-feet occurring in June, necessitating a continuous flow of 1,635 second-feet during that month. The best source of water supply for the

Horse Heaven area is the Columbia River, water to be supplied by pumping. Diversion for irrigation will not be greater than one half of 1 percent of the average flow of the river at The Dalles at any time during the irrigation season.

1249. A gravity water supply has been considered for a part of Horse Heaven area from Klickitat River. Extensive surveys have been conducted and reports published covering the proposed development.[29] Irrigation was originally proposed by the Klickitat Development Co., organized in 1904. This company was absorbed by the Klickitat Irrigation & Power Co. in 1905. In 1916 the Horse Heaven irrigation district was organized, the district including the lands considered by the Klickitat Irrigation & Power Co. The district included 360,000 acres of irrigable land. Bonds, amounting to $18,250,000, were issued by the district. The proceeds were to be used for the construction of the irrigation works, excepting $222,000 in bonds which were assigned to the Klickitat Irrigation & Power Co. for their rights, surveys, and holdings. Owing to financial conditions the bonds were never disposed of, those given the Power Co. being still outstanding and bearing interest. Current newspaper reports indicate that an agreement has been reached with bondholders to make settlement by the use of funds to be raised by assessment on the land and by sale of delinquent lands, and that the district will soon be dissolved.

1250. The irrigable area considered for the district under the gravity plan is 225,000 acres, for which the net water supply was estimated at 470,800 acre-feet or about 2.1 acre-feet per acre. Diversion from Cispus River in the Cowlitz drainage basin was included. The irrigation plan includes several storage reservoirs on the Klickitat River and tributaries, 25 miles of feed and intercepting canals, and a main canal 111 miles in length between the diversion point in Klickitat River and the nearest portion of the area. The main canal is located through a rough, mountainous, heavily timbered area and includes over 7 miles of siphons and 7½ miles of tunnels. A feature of the development is the possibility of developing hydroelectric power at two points in the main canal where the canal grade falls rapidly in very short distances. Estimates of output gave quantities varying from 25,700 horsepower in October to 100,600 horsepower in June, with no power available in December, January, and February. The total cost of the project, including interest during construction, was estimated in 1920 to be $139 per acre for the 225,000 acres.

1251. Additional information available since 1920 leads to the conclusion that the water supply is less and the irrigation requirement higher than considered in the foregoing estimates. It is believed that about 460,000 acre-feet is the maximum gross amount available for the irrigation of Horse Heaven area from Klickitat and Cispus Rivers in average years. This amount is adequate for the irrigation of about 140,000 acres during average years, but there would be annual periods of shortage. In view of the high cost of storage reservoirs and main canal, and the reduced acreage, it is believed that the unit cost for irrigation of Horse Heaven area from Klickitat River would be higher than the figure given above.

[29] Report on Horse Heaven irrigation district irrigation project by O. Laurgaard, Dec. 18, 1916. Report of the consulting engineers and attorneys with reference to the Horse Heaven irrigation project by Thompson, Wiley, Kane, Williamson, and Laurgaard, Jan. 18, 1917. Report on the Horse Heaven irrigation project by Lars Langloe, Dec. 31, 1920.

1252. Diversion of the flow of Klickitat River was covered by adequate filings by the Klickitat Irrigation & Power Co., whose rights were sold to the Horse Heaven irrigation district. These rights have lapsed through nonuse. It is probable that rights claimed by power companies and the United States Bureau of Indian Affairs would interfere with the reestablishment of the irrigation district rights.

1253. It is to be noted that of the irrigable area considered by the district, under the gravity plan, more than 140,000 acres, the amount of land for which an adequate water supply is available from Klikitat and Cispus Rivers, lies without the boundaries of the pumping project proposed in this report. It is therefore concluded that there is no conflict between the two schemes—gravity irrigation from Klickitat and Cispus Rivers, and pumping from Columbia River.

3. WILLOW CREEK AREA

1254. This is an area of about 207,000 acres in Umatilla, Morrow, and Gilliam Counties, Oreg., of which 173,060 acres are considered irrigable. The area is bounded on the north by elevation about 350 near Columbia River, on the south by elevation 1,000, on the east by Butter Creek, Umatilla River, and the Westland irrigation district, and on the west by Willow Creek and Eightmile Canyon. The greatest width of the area from north to south is about 17 miles.

1255. The irrigable lands slope gradually from the south downward toward Columbia River. Between elevations 750 and 1,000, a strip 4 to 6 miles in width, the lands are rolling and cut by many steep sided deep canyons. Areas between the canyons are fairly level. Below elevation 750 the slopes are gentler and water courses less plainly marked. Parts of this section are covered by hummocks and sand dunes. Land with slopes greater than 15 percent and those excessively rough are excluded from the irrigable area.

1256. The climate of Willow Creek area is such that irrigation is necessary for the successful growing of crops. The summers are hot and practically without precipitation. The growing season is long. Records at Umatilla Weather Station, near the eastern border of the area, are applicable to the entire area (par. 65).

1257. A soil survey of the area has been made by Dr. Powers, professor in soils, Oregon State College.[30]

Dr. Powers notes three general classes of soils, coarse sandy, medium and fine sandy, and sandy loam. The sandy-loam type predominates above 700 feet elevation and coarse sandy below elevation 400. Between these two elevations are found the medium and fine sandy soils.

1258. A field examination of the area, consideration being given Dr. Powers' soil survey, resulted in the classification of the 173,060 irrigable acres as follows: Sandy loam, 94,760 acres; medium and fine sandy, 31,050 acres; coarse sandy, 47,250 acres. The average annual diversion requirement is 4.4 acre-feet per acre. The tabulation following shows the total amount of water required for the irrigation of the area:

[30] Report, Soil and Agricultural Survey, John Day Irrigation District, June 1915.

Type of soil	Area	Diversion irrigation requirement, acre-feet per annum	
		Per acre	Total
	Acres		
Course sandy	47,250	6.2	292,950
Medium and fine sandy	31,050	5.0	155,250
Sandy loam	94,760	3.3	312,708
Total and average	173,060	4.4	760,908

1259. The largest monthly requirement will be 152,182 acre-feet in June, necessitating a continuous flow of 2,537 second-feet during that month. The best source of water for Willow Creek area is Columbia River, by pumping. Diversion for irrigation will amount to less than 1 percent of the flow at The Dalles during the period of lowest seasonal flow in average years.

4. ARLINGTON AREA

1260. This is an area of about 18,000 acres in Gilliam County, Oreg., of which 11,500 acres is considered irrigable. It is located on a high bench near Arlington, Oreg., and extends south from Columbia River about 7 miles. It is bounded on the east by Willow Creek and Eightmile Canyon, and on the west by Alkali Canyon. Climatic and topographic conditions are similar to those of Willow Creek area (par. 1256). The soil is a sandy loam, with an annual diversion irrigation requirement of 3.3 acre-feet per acre. The total annual requirement is 37,950 acre-feet. The maximum monthly requirement is 7,590 acre-feet, during June, which necessitates a pipe-line capacity of about 130 second-feet. Diversion from Columbia River for this area would have no appreciable effect on proposed power developments on the river.

5. ROOSEVELT AREA

1261. This is an area adjacent to Columbia River in Benton County, Wash., near Roosevelt, Wash. (mile 242, Columbia River). The total area of the tract is about 2,000 acres of which 1,500 acres are considered irrigable. The climate is similar to that of the Willow Creek area (par. 1256). Successful crop production is impossible except under irrigation. The surface of the area is fairly smooth sloping gently from the northern boundary, elevation about 450, to near the river, elevation 330. The soil is practically all sandy loam. The annual diversion irrigation requirement is 4,950 acre-feet. The June demand is 990 acre-feet, necessitating a continuous flow of 17 second-feet during that month. Diversion of this amount would have no appreciable effect on the flow of Columbia River at the diversion point. Pumping from Columbia River is the only possible source of water supply for the area.

(B) IRRIGATION OF INDIVIDUAL AREAS

1262. Plans for irrigation of the foregoing areas with estimates of construction costs and annual charges are given below. Topographic surveys were conducted to the extent necessary for making accurate detailed estimates of the cost of major features. In some cases minor

features, as distributing and drainage canals, were estimated on an acreage basis, such estimate being based on the cost of those features on existing projects with comparable conditions.

1263. The total cost estimate of each development considered is made up of the following elements:

1. Per acre construction costs as determined by the estimates of cost.

2. Interest compounded annually at 4 percent during construction period (assumed as 3 years) on funds used in payment of construction costs.

3. Interest at 4 percent compounded annually, on costs under 1 and 2 above for the period, estimated to be 2 years, during which the lands are being brought to the point of efficient crop production.

4. Interest at 4 percent compounded annually on the costs under 1, 2, and 3, above, for the period required for settlement. It is assumed that the length of the settlement period will be more or less independent of the size of the tract and will be spread over a period of years. The settlement period for all tracts in each area is estimated to be 10 years. Interest charges during the periods for construction, bringing the lands into production and for settlement, as outlined above, add 37.58 percent to the net construction costs. For purposes of comparison, charges during the settlement period are also based on a settlement rate of 50,000 acres per year, the rate determined possible in paragraph 1333. Under this assumption, projects considered below would be settled in from 1 to 3 years. The charge during settlement would add 16.95 percent for a 1-year period, 19.24 percent for a 2-year period, and 21.53 percent for a 3-year period.

1264. Annual charges pertaining to irrigation are made up of interest and depreciation on the total cost of the project, and operation and maintenance of the pumping plant and distribution system, including cost of electrical energy.

1265. Annual charges covering interest and depreciation are estimated as follows:

	Percent
Interest on investment	4.000
Depreciation (30 years life)	1.783

1266. It is estimated that the annual cost of operation and maintenance exclusive of electrical energy of all irrigation works, will be about $2 per acre. In determining this figure consideration was given to costs for existing projects, especially for Federal projects comparable to those described herein.

1267. Electrical energy is estimated to cost 1 mill per kilowatt-hour at the low voltage side of the substation transformer at the pumping plant.

1268. The size of canal required for any given development is determined by the maximum monthly irrigation requirement. Monthly requirements adopted are based on average use on lands of Umatilla project. This Federal project has climate, soil, and other characteristics similar to those of the areas described in this report. Figures following state the monthly use, in percentage of total seasonal use and monthly unit requirements, on the three types of soil considered.

Month	Percent	Delivered to farms, acre-feet per acre			Diversion requirement, acre-feet per acre		
		Soil type			Soil type		
		Coarse sandy	Medium and fine sandy	Sandy loam	Coarse sandy	Medium and fine sandy	Sandy loam
March	2.1	0.11	0.09	0.06	0.13	0.105	0.07
April	13.0	.69	.56	.36	.81	.65	.43
May	15.8	.84	.68	.44	.98	.79	.52
June	20.0	1.06	.86	.56	1.24	1.00	.66
July	20.0	1.06	.86	.56	1.24	1.00	.66
August	17.8	.94	.76	.50	1.10	.89	.59
September	9.2	.49	.40	.26	.57	.46	.30
October	2.1	.11	.09	.06	.13	.105	.07
Total	100.0	5.30	4.30	2.80	6.20	5.00	3.30

1269. Items considered and range of unit prices used in estimating costs are given below. Unit costs are taken sufficiently high to provide for contractors profit.

1270. *Pumping plants.*—The cost of buildings and equipment for the various plants was estimated by comparison with costs of similar existing plants or with published estimates for proposed developments.

1271. *Discharge pipe and siphons.*—

Steel	per pound	$0.07
Expansion joints	each	$1,000–1,500
Manholes	do	100
Flap valves		800–1,000
Air and drain valves	each	250–1,000
Anchors	do	1,000–5,000
Excavation—piers and pipe	per cubic yard	0.25–1.25
Outlet structure	each	2,500–3,000
Concrete in piers	per cubic yard	15–30
Creosoted wood staves	per 1,000 feet board measure	70

1272. *Canals.*—

Excavation, earth	per cubic yard	$0.20
Excavation, rock	do	1.20

Costs for canal excavation assumes that powered excavating machines will be used when conditions warrant. Unit costs include costs of machine operation, hand labor, drilling, blasting, explosives, plant and equipment depreciation, liability insurance, and field overhead.

Concrete lining	per cubic yard	$13

Unit costs of concrete lining for canals include the following items:

Crushed rock	$1.40
Sand	1.30
Cement	4.25
Mixing and placing	1.50
Water	.15
Forms	1.50
Trimming banks	.50
Plant depreciation	.25
Miscellaneous and field overhead at 20 percent	2.15
Cost per cubic yard	13.00

1273. Administration, engineering, and contingencies, 20 percent. Estimated field costs are increased 20 percent to cover general supervision, office expense, examination and surveys, engineering during construction, legal services, and unforeseen items of expense.

1. Cold Springs area

1274. This area is described in paragraph 1241 above and shown on plate 126. Irrigation of the area is possible by pumping from Columbia River. The pumping plant would be located in section 35, T. 6 N., R. 30 E., Willamette meridian. Engineering and economic facts of interest are shown below.

1275. *Data*—

Gross area	acres	67, 000
Irrigable area	do	50, 000
Average annual diversion irrigation requirement	acre-feet per acre	3. 44
Total annual diversion irrigation requirement	acre-feet	171, 000
Low water surface in river, elevation above sea level	feet	330
Water surface at head of main canal, above sea level	do	1, 040
Lift	do	710
Friction head	do	16
Pumping head	do	726
Acre-feet feet		124, 000, 000
Kilowatt-hours required		190, 000, 000
Kilowatt-hours per acre		3, 800
Pipe-line capacity	second-feet	573
Plant installed capacity	kilowatts	53, 000

1276. *Construction costs*—

Main canal, length 64 miles	$1, 661, 000
Distribution system	1, 000, 000
Drainage	200, 000
Pumping plant	1, 216, 000
Discharge pipe, length 5,250 feet	753, 000
Administration, engineering, and contingencies at 20 percent	966, 000
50,000 acres at $115.92 per acre	5, 796, 000

1277. *Total cost*—

10-year settlement period, $115.92×1.3758	per acre	$159. 50
1-year settlement period, $115.92×1.1695	do	135. 60

1278. *Annual charges* [31]—

	10-year settlement period	1-year settlement period
Interest on investment (4 percent)	$6. 38	$5. 42
Depreciation (30 years average life 1.783 percent)	2. 84	2. 42
Operation and maintenance	5. 80	5. 80
Total	15. 02	13. 64

2. Horse Heaven area

1279. This area is considered in three units for pumping from Columbia River—division A, between elevations 350 and 575 feet above sea level; division B, between elevations 575 and 800; and

[31] Amortization not included.

division C, between elevations 800 and 1,040. Divisions A and B would be served by pumping plants located in section 4, T. 5 N., R. 23 E., Willamette meridian, and division C by a plant located in section 27, T. 6 N., R. 30 E., Willamette meridian. Separate developments have been considered for divisions A and B, although the two plants would be located at the same point. If the plants were constructed under one roof, there would be a consequent reduction in unit cost of construction. The area is described in paragraph 1244 and is shown in plate 126. Engineering and economic facts of interest are shown below.

a. Division A

1280. *Data*—

Gross area ..... acres	40,000
Irrigable area ..... do	28,500
Average annual diversion irrigation requirement ..... acre-feet per acre	4
Total annual diversion irrigation requirement ..... acre-feet	113,600
Low water surface in river, elevation above sea level ..... feet	330
Water surface at head of main canal, above sea level ..... do	575
Lift ..... do	245
Friction head ..... do	4
Pumping head ..... do	249
Acre-feet feet	28,300,000
Kilowatt-hours required	43,300,000
Kilowatt-hours per acre	1,520
Pipe-line capacity ..... second-feet	385
Plant installed capacity ..... kilowatts	12,000

1281. *Construction costs.*—

Main canal, length 48.3 miles	$1,215,000
Distribution system	570,000
Drainage system	114,000
Pumping plant	388,000
Discharge pipe, length 925 feet	94,000
Administration, engineering, and contingencies, at 20 percent	476,000
28,500 acres, at $100.25 per acre	2,857,000

1282. *Total cost.*—

10-year settlement period $100.25×1.3758 ..... per acre	$138.00
1-year settlement period $100.25×1.1695 ..... do	117.25

1283. *Annual charges.*[31]—

	10-year settlement period	1-year settlement period
Interest on investment (4 percent)	$5.52	$4.69
Depreciation (30-year average life 1.783 percent)	2.46	2.09
Operation and maintenance	3.52	3.52
Total	11.50	10.30

[31] Amortization not included.

b. Division B

1284. *Data.*—

Gross area—acres	70,000
Irrigable area—do	47,500
Average annual diversion irrigation requirement—acre-feet per acre	3.3
Total annual diversion irrigation requirement—acre-feet	156,750
Low water surface in river, elevation above sea level—feet	330
Water surface at head of main canal, elevation above sea level—feet	800
Lift—do	470
Friction head—do	5
Pumping head—do	475
Acre-feet feet	74,500,000
Kilowatt-hours required	114,000,000
Kilowatt-hours per acre	2,400
Pipe-line capacity—second-feet	525
Plant installed capacity—kilowatts	31,600

1285. *Construction costs.*

Main canal, length 79 miles	$2,050,000
Distribution system	950,000
Pumping plant	774,000
Discharge pipe, length 1,450 feet	209,000
Administration, engineering, and contingencies, at 20 percent	796,000
47,500 acres, at $100.62 per acre	4,779,000

1286. *Total cost.*—

10-year settlement period, $100.62×1.3758	$138.40
1-year settlement period, $100.62×1.1695	117.70

1287. *Annual charges.*[31]—

	10-year settlement period	1-year settlement period
Interest on investment (4 percent)	$5.54	$4.71
Depreciation (30-year average life 1.783 percent)	2.47	2.10
Operation and maintenance	4.40	4.40
Total	12.41	11.21

c. Division C

1288. *Data.*—

Gross area—acres	90,000
Irrigable area—do	66,000
Average annual diversion irrigation requirement—acre-feet per acre	3.3
Total annual diversion irrigation requirement—acre-feet	217,800
Low-water surface in river, elevation above sea level—feet	330
Water surface at head of main canal, above sea level—do	1,040
Lift—do	710
Friction head—do	10
Pumping head—do	720
Acre-feet feet	157,000,000
Kilowatt-hours required	240,000,000
Kilowatt-hours per acre	3,630
Pipe-line capacity—second-feet	725
Plant installed capacity—kilowatts	67,000

[31] Amortization not included.

1289. *Construction costs.*—

Main canal, length 91 miles	$2, 716, 000
Distribution system	1, 320, 000
Pumping plant	1, 387, 000
Discharge pipe, length 4,300 feet	689, 000
Administration, engineering, and contingencies at 20 percent	1, 223, 000
66,000 acres at $111.14 per acre	7, 335. 000

1290. *Total cost.*—

10-year settlement period, $111.14×1.3758	152. 90
2-year settlement period, $111.14×1.1924	132. 53

1291. *Annual charges.*[31]—

	10-year settlement period	2-year settlement period
Interest on investment (4 percent)	$6. 12	$5. 30
Depreciation (30-year life, 1.783 percent)	2. 72	2. 36
Operation and maintenance	5. 63	5. 63
Total	14. 47	13. 29

3. Willow Creek Area

1292. This area is considered in three units for pumping from Columbia River: Division A, between elevations 350 and 616 feet above sea level; division B, between elevations 616 and 861; and, division C, between elevations 861 and 1,000. Division A would be served by a plant located in section 16, T. 5 N., R. 28 E., W.M. For divisions B and C, a plant in section 13, T. 3 N., R. 22 E., W.M. would lift water for the entire 135,120 acres, 547,033 acre-feet, from elevation 330 to elevation 610; a plant in section 28, T. 2 N., R. 23 E., would lift 482,033 acre-feet for 122,120 acres from elevation 598.5 to elevation 800; and a plant in section 22, T. 1 N., R. 23 E., would lift 103,455 acre-feet for division C, 31,350 acres, from elevation 786 to elevation 1,000. Although served by the same main plant, costs for divisions B and C are shown separately. Construction of division C would be contingent upon construction of division B. The area is described in paragraph 1254 and shown on plate 126, page 1692. Engineering and economic data are shown below.

a. Division A

1293. *Data.*—

Gross area—acres	55, 000
Irrigable area—do	37, 940
Average annual diversion irrigation requirement—acre-feet per acre	5. 64
Total annual diversion irrigation requirement—acre-feet	213, 875
Low water surface in river, elevation above sea level—feet	330
Water surface at head of main canal, above sea level—do	616
Lift—do	286
Friction head—do	19
Pumping head—do	305
Acre-feet feet	65, 000, 000
Kilowatt-hours required	100, 000, 000
Kilowatt hours per acre	2, 640
Pipe-line capacity—second-feet	713
Plant installed capacity—kilowatts	27, 700

[31] Amortization not included.

1294. *Construction costs.*—

Main canal, length 47.8 miles	$1, 241, 000
Distribution system	534, 000
Drainage	190, 000
Pumping plant	687, 000
Discharge pipe, length 6,500 feet	500, 000
Administration, engineering and contingencies at 20 percent	630, 000
37,940, acres at $99.80	3, 782, 000

1295. *Total costs.*—

10-year settlement period, $99.80×1.3738	137. 30
1-year settlement period, $99.80×1.1695	116. 72

1296. *Annual charges.*[31]—

	10-year settlement period	1-year settlement period
Interest on investment (4 percent)	$5. 49	$4. 67
Depreciation (30 years' life—1.783 percent)	2. 45	2. 08
Operation and maintenance	4. 64	4. 64
Total	12. 58	11. 39

b. Division B

1297. *Data.*—

Gross area, acres	117, 000
Irrigable area, do	103, 770
Average annual diversion irrigation requirement, acre-feet per acre	4. 27
Total annual diversion irrigation requirement, acre-feet	443, 578
Low water surface in river, elevation above sea level, feet	330
Water surface at head of supply canal above sea level, do	610
Lift for main plant, do	280
Friction head, do	9
Pumping head, do	289
Acre-feet feet for main plant	128, 200, 000
Kilowatt-hours required for main plant	196, 000, 000
Water surface at end of supply canal, elevation above sea level, feet	598. 5
Water surface at head of main canal, elevation above sea level, feet	800
Lift for auxiliary plant, do	201. 5
Friction head, do	7. 5
Pumping head, do	209
Supplied by auxiliary plant, acre-feet	378, 578
Acre-feet feet for auxiliary plant	79, 100, 000
Kilowatt-hours for auxiliary plant	121, 000, 000
Total kilowatt-hours, both plants	317, 000, 000
Kilowatt-hours per acre	3, 060
Pipe-line capacity, main plant, second-feet	1, 479
Plant installed capacity, two plants, kilowatts	88, 000

1298. *Construction costs.*—

Main canal, length 66.8 miles	$2, 988, 000
Distribution system	2, 075, 000
Drainage	415, 000
Pumping plant	1, 901, 000
Discharge pipe, length 3,325 feet	662, 000
Administration, engineering, and contingencies at 20 percent	1, 608, 000
103,770 acres at $93 per acre	9, 649, 000

[31] Amortization not included.

1299. *Total cost.*—

10-year settlement period, $93×1.3758	$127.95
3-year settlement period, $93×1.2153	113.03

1300. *Annual charges.*[31]—

	10-year settlement period	3-year settlement period
Interest on investment (4 percent)	$5.12	$4.52
Depreciation (30 years' life, 1.783 percent)	2.28	2.02
Operation and maintenance	5.06	5.06
Total	12.46	11.60

c. Division C

1301. *Data.*—

Gross area—acres	35,000
Irrigable area—do	31,350
Average annual diversion irrigation requirement—acre-feet per acre	3.3
Total annual diversion irrigation requirement—acre-feet	103,455
Low water surface in river, elevation above sea level—feet	330
Water surface at head of main canal, elevation above sea level—feet	1,000
Lift—do	670
Friction head—do	22.5
Loss of head in supply canals—do	22.5
Pumping head—do	718
Acre-feet feet	74,300,000
Kilowatt-hours required	113,600,000
Kilowatt-hours per acre	3,630
Pipe-line capacity—second-feet	345
Plant installed capacity—kilowatts	31,600

1302. *Construction costs.*—

Main canal, length 53.9 miles	$1,131,000
Distribution system	627,000
Drainage	125,000
Pumping plant	777,000
Discharge pipe, length 4,525 feet	217,000
Administration, engineering, and contingencies at 20 percent	576,000
31,350 acres at $110.15 per acre	3,453,000

1303. *Total cost.*—

10-year settlement period, $110.15×1.3758	$151.54
1-year settlement period, $110.15×1.1695	128.82

1304. *Annual charges.*[31]—

	10-year settlement period	1-year settlement period
Interest on investment (4 percent)	$6.06	$5.15
Depreciation (30 years' life, 1.783 percent)	2.70	2.30
Operation and maintenance	5.63	5.63
Total	14.39	13.08

[31] Amortization not included.

4. Arlington area

1305. This area would be served by a pumping plant on Columbia River in sec. 21, T. 3 N., R. 21 E. Willamette meridian. The area is described in paragraph 1260 and shown on plate 126, p. 1692. Engineering and economic facts of interest are shown below.

1306. *Data.*—

Gross area	acres	18,000
Irrigable area	do	11,500
Average annual diversion irrigation requirement	acre-feet per acre	3.3
Total annual diversion irrigation requirement	acre-feet	37,950
Low water surface in river, elevation above sea level	feet	330
Water surface at head of main canal, elevation above sea level	do	861
Lift	do	531
Friction head	do	10
Pumping head	do	541
Acre-feet feet		20,500,000
Kilowatt-hours required		31,450,000
Kilowatt-hours per acre		2,730
Pipe-line capacity	second-feet	130
Plant installed capacity	kilowatts	9,000

1307. *Construction costs.*—

Main canal, length 11.4 miles	$195,000
Distribution system	230,000
Drainage	46,000
Pumping plant	276,000
Discharge pipe, length 2,750 feet	117,000
Administration, engineering and contingencies, at 20 percent	173,000
11,500 acres, at $90.18 per acre	1,037,000

1308. *Total cost.*—

10-year settlement period, $90.18×1.3758	124.07
1-year settlement period, $90.18×1.1695	105.47

1309. *Annual charges.*[31]—

	10-year settlement period	1-year settlement period
Interest on investment (4 percent)	$4.96	$4.22
Depreciation (30-year life, 1.783 percent)	2.20	1.88
Operation and maintenance	4.73	4.73
Total	11.89	10.83

5. Roosevelt area

1310. This area is considered as a single unit for pumping from Columbia River. The pumping plant would be located in sec. 23, T. 3 N., R. 20 E., Willamette meridian. The area is described in paragraph 1261 and shown on plate 126. Engineering and economic facts of interest are shown below.

1311. *Data.*—

Gross area	acres	2,000
Irrigable area	do	1,500
Average annual diversion irrigation requirement	acre-feet per acre	3.3
Average annual diversion irrigation requirement	acre-feet	4,950

[31] Amortization not included.

Low-water surface in river, elevation above sea level, feet	330
Water surface at head of main canal, elevation above sea level, do	505
Lift, do	175
Friction head, do	3
Pumping head, do	178
Acre-feet feet	880, 000
Kilowatt-hours required	1, 350, 000
Kilowatt-hours per acre	900
Pipe line capacity, second-feet	17
Plant installed capacity, kilowatts	375

1312. *Construction costs.*—

Main canal, length, 5.7 miles	$41, 000
Distribution system	15, 000
Pumping plant	29, 500
Discharge pipe, length 1,400 feet	17, 500
Administration, engineering and contingencies at 20 percent	20, 600
1,500 acres, at $82.40 per acre	123, 600

1313. *Total cost.*—

10-year settlement period, $82.40×1.3758	113. 37
1-year settlement period, $82.40×1.1695	96. 40

1314. *Annual charges.*[31]—

	10-year settlement period	1-year settlement period
Interest on investment (4 percent)	$4. 53	$3. 86
Depreciation (30 years life, 1.783 percent)	2. 04	1. 72
Operation and maintenance	2. 92	2. 92
Total	9. 49	8. 50

(C) IRRIGATION OF COMBINED AREAS

1315. Two of the areas considered in preceding paragraphs 1279 to 1304 include three divisions each. These are Horse Heaven and Willow Creek areas. The divisions are treated as separate projects, although in both cases they are so situated geographically as to form a single area. If the areas were each treated as a single project, an economic plan of development, consideration being given to construction costs and settlement possibilities, would be by units, as described, and total construction costs would not differ from those given. Spreading of division construction costs over the entire area would, however, affect unit costs as set forth for the divisions. Horse Heaven area, with estimated construction costs per acre for division A of $100.25, for division B, $100.62, and division C, $111.14, would average, under the plan of combination of divisions, $105.43 per acre. Willow Creek area, with costs of $99.80 for division A, $93, for division B, and $110.15 for division C, would average $97.56 per acre for the entire area.

1316. It is believed, however, that divisions should be developed as separate projects. This would enable the selection of projects with lowest cost and better lands for first development. The above factors would tend to render the projects more attractive to settlers, thus

[31] Amortization not included.

reducing the settlement period and consequently the total construction cost. Settlement of these projects would build up communities with accompanying school, highway, and other developments. This would in turn attract settlers to the projects of higher construction costs as demand arose and tend to produce an economic parity for all projects.

(5) Probable Rate of Future Irrigation Development

1317. In general, the advisability of irrigating agricultural land is determined by the analysis of five major factors, viz, topography and soil conditions; crop production, including costs and returns; marketing possibilities; construction costs; and probable rate of settlement attainable. Preceding paragraphs describe the topography and soil condition, production features, and construction possibilities of certain areas in Columbia Basin below the mouth of Snake River, for which irrigation from Columbia River is feasible from a physical or construction standpoint, and necessary for efficient agricultural production on account of climatic conditions. Paragraphs following present a survey of marketing and settlement possibilities for those areas.

1318. Estimates as to future needs for additional agricultural land in the United States have been made by various authorities. In the United States Department of Agriculture Year Book for 1923 it is estimated that by 1950 the cropped area in the United States required for the support of the 150,000,000 estimated population, with allowance for some export, will be 403,000,000 acres; an increase of 38,000,000 acres over the 1920 acreage, and a figure 33,000,000 acres greater than the 1930 acreage. A more pessimistic stand is taken by O. E. Baker, of the United States Bureau of Agricultural Economics,[32] who states that the United States is not likely to need, for domestic consumption, much more crop land than there is in crops at present, and that the problem of disposing of the export surplus seems likely to continue. Mr. Baker's estimates are based on the assumptions that the population of the United States will reach its maximum about 1960, and may remain stationary or actually decline thereafter.

1319. It is believed that even though the cropped acreage of the country as a whole may increase rather slowly for the next three decades, that of the Northwest will continue to increase faster than the average. This belief is based on consideration of the factors that tend to make agricultural development in this area more attractive than in many other sections. Such factors include fertile lands, a long growing season, a climate comparatively free from destructive storms, numerous recreational features, and for the irrigated lands a certainty of water supply. The tendency for more rapid development is shown in plate 127,[2] the curves for cropped acreage indicating that while the figure for the United States as a whole has remained practically stationary since 1918, the acreage in the Northwest has experienced a marked increase. It is assumed that the 1930 acreage for the Northwest is about normal, which assumption is supported graphically by the curve of the above plate.

1320. It is believed that of the remaining lands suitable for agriculture, lands which can be irrigated will, in general, be the most desirable

[2] Not printed.

[32] Population Trends in Relation to Land Utilization, O. E. Baker. Proceedings of the International Conference of Agricultural Economists, second conference, 1930.

to develop. It is also believed that the irrigable areas considered in this study can be made to produce as efficiently as other irrigated land. Additional land which can be irrigated in the portion of the basin of Columbia River within United States is estimated at 5,000,000 acres.

1321. The method adopted in making the market study is outlined below:

(*a*) The major crops best suited to the area covered in this report are listed.
(*b*) There is determined for each crop the market areas in which the present Oregon, Washington, and Idaho production of that crop is now sold.
(*c*) For areas in the United States it is assumed that the quantities now marketed will increase in the same proportions as the population of the area in which the particular crop is marketed.
(*d*) For foreign markets it is assumed that there will be no increase over the quantities now marketed.
(*e*) The increase as determined in (*c*) is translated into acres of land required to produce it.
(*f*) The sum of the number of acres thus derived for each product gives the maximum amount of additional irrigable land in Oregon, Washington, and Idaho, from which crops can be expected to be profitably marketed during the period indicated.

1322. While the area covered by this report is limited to Columbia Basin below the mouth of the Snake and includes only about one third of the area of Oregon, one eighth of the area of Washington, and no part of Idaho, the local market area for the lands studied is considered as indicated above to include all of the three States mentioned, viz, Oregon, Washington, and Idaho. California is given separate consideration as a consumer as that State affords a special market for certain products and also differs materially in rate of population increase from the remainder of the United States. Results are shown in tabulated form below, the total required increase over the 1930 acreage being shown for each commodity by 10-year periods, from 1930 to 1960. The additional acreage required for the products shown by 1960 totals about 2,170,000 acres, or an average annual increase of about 70,000 acres.

1323. Yields per acre used are applicable to the better grade of irrigated land, and are markedly higher than the average for the United States for all cropped lands. It is to be noted that the use of the higher yields tends to conservatism in determining the additional acreage required. Specific yields adopted are a composite of various studies conducted by Federal and State agencies dealing with the commodities considered and covering areas comparable to those under consideration.

1324. The 1930 consumption for each commodity is the consumption in the trade area considered of Oregon, Washington, and Idaho production. Production figures were obtained from the yearbooks of the United States Department of Agriculture and are usually averages of selected years. Distribution of the commodities to market areas was determined by analysis of estimates obtained from various Federal bureaus. Disposition of commodities is considered through four channels: The Pacific Northwest, California, the remainder of the United States, and foreign shipments. Exceptions occur in the cases of pork, wool, clover seed, and prunes.

1325. There is at present a deficiency in pork production in the Northwest. It is assumed that the shortage can be economically made up by production from new lands in the Northwest. No exports

of pork or pork products are considered for the area. Acreages for wool are included in figures for mutton. No exports of wool to California or foreign markets are considered. Consumption for Oregon, Washington, and Idaho includes wool used both in manufacture in the three States and in products shipped in from other States. Although about half the wool used in the United States is imported from abroad, no consideration is given possible encroachment on the import trade by Northwest products. Clover seed is not exported to foreign markets, as there is a shortage of this commodity in the United States greater than the total production of the Northwest. It is assumed that the three States could find a market for an amount equal to this shortage, as the area is especially favorable to the economic production of the commodity. In the case of prunes, there apparently is an overproduction of this commodity at present, evidenced by an existing unmarketable surplus. An acreage corresponding to this surplus is presented in the table, which is deduced from the estimated permissible increase due to increased population.

Estimated additional acreage,[1] Oregon, Washington, and Idaho, by 10-year periods, 1930–60

Item	1930, consumption [2] (tons)	1930–40, additional acres	1940–50, additional acres	1950–60, additional acres	Total additional acres required by 1960
Beef, [3] veal [3]	104,775	157,000	166,000	185,000	508,000
Pork [3]	103,974	[4] 360,000	132,000	149,000	641,000
Mutton, [3] lamb, [3] wool	56,833	59,000	57,000	53,000	169,000
Milk	1,833,000	138,000	137,000	137,000	412,000
Eggs	92,438	65,000	67,000	72,000	204,000
Potatoes	1,063,290	24,000	22,000	19,000	65,000
Truck	200,000	7,100	7,500	8,000	22,600
Clover seed	9,960	[5] 48,000	5,500	5,500	59,000
Alfalfa seed	3,660	[6] 6,300	3,000	3,300	12,600
Beans, dry	62,113	16,100	15,100	12,800	44,000
Apples	1,080,401	7,200	7,000	6,800	21,000
Pears	153,308	1,000	1,000	1,000	3,000
Prunes	134,000	0	500	1,000	1,500
Peaches	38,294	500	550	600	1,650
Strawberries	20,585	900	950	1,000	2,850
Other berries	35,000	900	900	1,000	2,800
Total		891,000	623,000	656,000	2,170,000

[1] Number of acres based on probable yields of irrigated lands.
[2] Consumption of Oregon, Washington, and Idaho production.
[3] Dressed.
[4] Includes 1930 deficiency of 29,517 tons.
[5] Includes 1930 imports to United States, 5,490 tons.
[6] Includes 1930 imports to United States, 409 tons.

1326. It is to be noted that there is little evidence pointing to the desirability of a large increase in lands devoted to fruit production. The estimated acreage which should be devoted to increased fruit production by 1960 amounts to but 2 percent of the acreage estimated for all crops. Hay, grain, and forage crops are not considered in the above study, as it is assumed that such crops will be utilized as food for livestock, and that lands to be devoted to their production are accounted for in the studies of livestock products.

1327. The results obtained by the foregoing study are shown graphically in plate 127.[2] Population and total and per capita cropped acreages are shown for the United States and for Oregon, Washington,

[2] Not printed.

and Idaho for the years 1909 to 1930, inclusive. The curves are extended to 1950 for the United States, in accordance with the estimate of the United States Department of Agriculture. The curves for the three States are extended to 1940, 1950, and 1960, through points determined in this study. It is noted that the per capita acreage for Oregon, Washington, and Idaho is about 3.7 in 1930, and that the estimate for the future shows a decrease until a figure of 3.2 is reached in 1960. This difference of 0.5 acre per capita is due to the greater proportion of irrigated land in 1960 than in 1930. It is realized that a complete economic study of agricultural development should include estimates of quantity and value of crop production, but it is believed that an analysis of the trend of acreage cropped as presented above may serve as a measure of the rate of development that may be reasonably anticipated.

1328. The history of irrigation settlement throughout the entire west shows that for the majority of the irrigation projects a part, generally between 10 and 20 percent, has remained unsettled. A study [33] of the projects shows that, while 100 percent settlement is rarely attained, for the average project, 70 percent of the irrigable acreage for which water could be supplied is settled at the end of the first 15 years after the beginning of construction work.

1329. Factors retarding settlement may be divided into two general classes, namely, incorrect estimation of physical characteristics and insufficient attention to the economics of the development. The most important factors included in the first class are inclusion of undesirable lands in the irrigable area and overestimation of the water supply. In the second class are the failure to properly estimate the total costs of irrigation construction, including carrying charges during the settlement period, and the failure to determine the feasibility of the project with relation to demand for its products.

1330. Statistics show that irrigation development follows the trend of other industries in that it passes through cycles of prosperity and adversity. During times of agricultural prosperity development is at its maximum. During adversity it declines and sometimes ceases. The following tabulation shows the total irrigated acreage in Oregon and Washington by 10-year periods between 1890 and 1930. The period 1900 to 1920 may be taken as one of reasonably prosperous agricultural conditions. During this period the total irrigated area in the States of Washington and Oregon increased at the rate of about 50,000 acres per year.

Acres irrigated

Year	Oregon	Washington	Total	Average annual increase	Remarks
1890	177,944	48,799	226,743		
1900	388,310	135,470	523,780	29,700	Reclamation Act, 1902.
1910	686,129	334,378	1,020,507	49,672	
1920	986,162	529,899	1,516,061	49,545	
1930	937,068	503,458	1,440,526	7,553	Decrease.

1331. This tabulation shows that the actual average annual increase of irrigated lands reached the maximum of 49,672 acres during the period 1900 to 1910, or about 6.4 percent of the total area

[33] Economics of Land Reclamation, Ray P. Teele (1927).

irrigated. Such expansion did not continue during later years, but it is reasonable to assume that similar cycles of increased demand for irrigable land will return.

1332. Using the States of Washington and Oregon and the period of 1900 to 1920 as a basis in estimating future settlement for irrigable land and bearing in mind also the increase of the population of the United States and of the basic agricultural market, it is believed that upon the return of agricultural prosperity additional irrigable land for the States of Washington and Oregon could be settled at the rate of 50,000 acres per year. This may be divided over several localities or concentrated in any one section of the two States as economics may dictate.

1333. Marginal lands in all projects considered have been eliminated and an adequate water supply provided. The largest area considered in this report has an irrigable area of 103,000 acres. It has been shown that due to population increases in the market areas considered there may be a market for products of an additional 70,000 acres per year for the next 30 years, and that a reasonable rate of settlement, which may be expected, for the States of Oregon and Washington is 50,000 acres per year. The rate of settlement is, then, the limiting factor in the rate of development of the areas considered. If the rate of settlement as determined above could be applied to any one area, exclusively, the area of 103,000 acres would be 100 percent colonized in less than 3 years. Past experience shows that for various reasons such will not be the case. It is not likely that any one large area in any one locality will be developed and all other areas excluded until that particular area is 100 percent colonized. Living and climatic conditions in one locality will attract one family and repel another.

1334. The rate of settlement in the past generally has been rapid in early years and slow after the project was about 75 percent colonized, due, as previously stated, to the inclusion of marginal lands, to increasing construction costs, and to failing water supply. There is no reason why these troubles generally should be encountered in the future. During periods of agricultural depression settlement may stop, and actually recede, conversely, during periods of expansion, settlement may be very rapid. In view of the study of the market for agricultural products and the probable rate of settlement for the area as a whole, it has been assumed that for any one of these projects, 100 percent settlement could be attained in 15 years after the beginning of the construction period. However, construction of any of these projects should not be commenced until all the unoccupied irrigable land under existing projects is settled.

F. EFFECT OF FUTURE IRRIGATION AND POWER DEMANDS ON FLOW OF COLUMBIA RIVER AT THE DALLES, OREG.

1335. In considering the effect of future irrigation and power demands on the flow of the Columbia at The Dalles, Oreg., the area of the basin above The Dalles has been divided into three sections: Section 1, Columbia Basin above the mouth of Snake River; section 2, Snake River Basin; and section 3, area between mouth of Snake River and The Dalles, Oreg.

(A) SECTION 1. COLUMBIA BASIN ABOVE THE MOUTH OF SNAKE RIVER

1336. The effect of future development within this area is discussed in part 2 (Seattle district section) of this report. Under the comprehensive plan for the development of the Columbia above mouth of Snake River, as proposed in part 2, the ultimate storage of 14,100,000 acre-feet is provided in the interest of power and irrigation. The effect on the flow of Columbia River above the mouth of Snake River of regulating this storage and the irrigation of 2,226,000 acres is shown in table 59.

(B) SECTION 2. SNAKE RIVER BASIN

1337. The Milner Dam in sec. 29, T. 10 S., R. 21 E., Boise meridian, 642 miles above the mouth of Snake River, is the farthest point downstream from which water of Snake River can be diverted for irrigation purposes. The flow now passing this dam and reflected by the discharge records of the gaging station maintained at Milner, below the dam, is not sufficient to furnish water to all the irrigable areas which can be served by diversions at this point and by diversions farther upstream. Ultimate irrigation demands will therefore necessitate the full use of this flow with the exception of occasional flood discharges for which it would not be economical to provide storage. In the study of the ultimate effect on the flow of the Snake of future development within the basin, the assumption has been made that all flow now passing Milner Dam, accepting excess flood discharges mentioned above, will be used for purposes of irrigation. Distribution of the water to be diverted for future irrigation in percent of the total amount diverted was estimated from average results found on the Umatilla, Yakima, Boise, and King Hill projects (see tables by E. B. Debbler, hydraulic engineer, U.S.B.R., in Proceedings of American Society of Civil Engineers for March 1929), preference being given to the results for the last two projects. (See table 60.) The assumed figures for the Columbia Basin project as used by the Seattle district office are also shown.

1338. Return flow has been assumed at one third of the total amount diverted and the distribution of this return flow by months expressed in percent of the total has been taken as the average of the figures used by the Seattle district office in considering the Columbia Basin project, the results of observations by the United States Reclamation Bureau on the Hermiston Drain, Umatilla County, Oreg., and the average of four observations by R. I. Meeker, irrigation engineer, on the South Platte, North Platte, Carmol drainage district and Rio Grande drainage district. (See table 61.)

1339. Discharge records, as published in the several water-supply papers to and including 1926 and since then as obtained from advance sheets furnished by the Idaho, Washington, and Oregon, United States Geological Survey offices, have been used in making computations. The record of the Snake at Milner is continuous since April 1918, while at Whitebird that of the Salmon, an important tributary, is continuous since October 1919. In order to eliminate as much as possible the interpolation of missing figures, the 12-year period October 1, 1919, to October 1, 1930, has been used. Where individual records do not include this period or only part of it, the average effect

for the actual period of the record has been determined in each instance and these figures used for the missing months. Flow records for the Columbia at The Dalles show that during this period the discharge was approximately 90 percent of normal. Unquestionably the discharge of the Snake and its tributaries during the same time has also been, on an average, below normal. The period, however, includes years of high discharge, such as 1921, 1927, and 1928, and years of low discharge, 1924, 1926, 1929, and 1930. Taken as a whole, computations as to flow and effect thereon of future diversion should give satisfactory results. The fact that during the last 7 years the discharge has been low during 4 years and 2 of these years in succession, namely, 1929 and 1930, results in storage requirements which represent as adverse conditions as may be expected in the future.

1340. Using the assumed values for demand and return flow, computations as to the effect of future irrigation on the flow of the Snake and all of its principal tributaries have been made covering the period October 1, 1919, to October 1, 1930. The regulation of flow by storage in the interest of power has also been considered. All computations are based on the average monthly flow of the several streams. Many tables have been prepared but only table 62, which shows the total effect of all future regulations on the flow at the mouth of Snake River, is here given.

1341. The results of the study show a total diversion for irrigation of 6,090,000 acre-feet a year and storage of 10,100,000 acre-feet. Of this total storage, 5,800,000 acre-feet is for irrigation alone and the remainder, 4,300,000 acre-feet, is in the interest of power.

(C) SECTION 3. AREA BETWEEN MOUTH OF SNAKE RIVER AND THE DALLES, OREG.

1342. In this area the four streams considered are the Walla Walla, Umatilla, John Day, and Deschutes. The figures for the John Day River have been taken from the flow study made in connection with the report now being prepared on the John Day project. For the other streams the same assumptions as to rate of demand and return flow were made as for the Snake.

1343. Each stream was studied separately and consideration given to storage available and irrigable area which could be served. Table 63 shows the total effect that future development on these streams will have on the flow of the Columbia. The results of the study show a total diversion for irrigation of 2,200,000 acre-feet a year and a total storage of 1,920,000 acre-feet.

(D) SUMMARY

1344. Table 64 is a summary of tables 59, 62, and 63 and shows total effect of estimated future development on the flow of the Columbia at The Dalles, Oreg. The estimated acreage to be irrigated and storage for each section is as follows:

	Acreage to be irrigated	Storage in acre-feet
Sec. 1. Columbia Basin above mouth of Snake	2,226,000	14,100,000
Sec. 2. Snake Basin	[1] 1,522,000	10,100,000
Sec. 3. Columbia Basin between mouth of Snake and The Dalles	[2] 555,000	1,920,000
Total	4,303,000	26,120,000

[1] Estimated for a gross diversion of 4 acre-feet per acre.
[2] Same allowance as (1), except for John Day River. The figures for the John Day have been taken from the John Day project report.

1345. Table 65 gives the average monthly observed flow of the Columbia at The Dalles for the period April 1, 1913, to October 1, 1930. Table 66 gives the average monthly flow of the Columbia at The Dalles as regulated by figures in table 64. On account of the shorter record used for the Snake flow study the record is for the period October 1, 1919, to October 1, 1930. Table 67 shows the duration relation for observed and regulated flow of Columbia at The Dalles, Oreg. Tables 64 to 67, inclusive, show that ultimate future development will tend to regulate the flow of Columbia River. Although the effect will vary from month to month and year to year, the past records show that in each instance the low flows have been increased while the high flows occurring during April, May, June, or July have been materially decreased.

TABLE 59.—*Effect on flow of Columbia River of regulating 14,100,000 acre-feet of storage and irrigating 2,226,000 acres in Columbia Basin above mouth of Snake River*

[Increase or decrease in second-feet]

Calendar year	January	February	March	April	May	June
1913				−16,000	−114,000	−57,100
1914	+33,200	+35,100	+19,200	−25,200	−122,000	−59,500
1915	+36,300	+40,100	+31,000	−22,900	−116,000	−41,900
1916	+39,000	+35,400	+1,600	−40,600	−87,100	−46,700
1917	+33,300	+34,100	+34,800	+4,200	−110,000	−45,500
1918	−11,500	+25,000	+31,900	−18,200	−107,000	−59,900
1919	+33,000	+25,300	+25,700	−16,500	−127,000	−63,700
1920	+29,300	+27,900	+25,500	+7,500	−83,900	−94,700
1921	+30,800	+30,600	+13,800	−14,700	−116,000	−72,400
1922	+25,700	+34,000	+34,900	+7,100	−105,000	−74,400
1923	+21,000	+34,700	+33,100	−18,200	−119,000	−56,900
1924	+34,500	+15,600	+17,100	+9,500	−136,000	−57,700
1925	+29,000	+8,000	+14,400	−62,100	−82,300	−56,100
1926	+30,400	+26,300	+21,700	−17,400	−121,000	−50,100
1927	+28,700	+30,200	+25,600	−3,200	−132,000	−35,900
1928	+30,800	+41,000	+30,900	−11,600	−105,000	−61,100
1929	+28,400	+32,700	+30,600	+13,600	−60,300	−122,000
1930	+34,400	+32,100	+27,500	−19,200	−100,000	−88,400

Calendar year	July	August	September	October	November	December
1913	−50,000	−15,500	+3,000	+9,900	+19,300	+31,200
1914	−31,100	−6,500	+7,500	+10,700	+3,100	+19,800
1915	−27,800	−9,100	+600	+19,100	+19,700	+27,500
1916	−55,500	−27,300	−6,900	+2,700	+13,900	+26,400
1917	−60,900	−15,300	+4,400	+19,900	+40,000	+33,300
1918	−45,200	−8,600	+3,700	+11,500	+22,900	+29,700
1919	−34,500	−7,500	+1,400	+10,700	+23,800	+29,400
1920	−42,900	−5,900	+7,300	+6,600	+15,500	+32,400
1921	−42,800	−11,700	+2,300	+12,100	+16,100	+8,600
1922	−39,100	−9,600	+2,700	+10,500	+21,100	+32,700
1923	−41,600	−13,000	+1,000	+12,000	+25,300	+28,300
1924	−28,400	−3,300	+5,900	+27,100	+27,300	+29,500
1925	−39,000	−12,600	+1,600	+12,700	+21,600	+26,300
1926	−13,100	+1,600	+9,400	+12,400	+9,400	+9,500
1927	−52,200	−4,300	+10,900	+7,300	+900	+1,000
1928	−39,500	−19,600	−2,000	+8,600	+13,700	+21,200
1929	−32,500	−11,100	+2,200	+14,300	+24,200	+28,200
1930	−23,900	−9,000	+4,000			

TABLE 60.—*Distribution of water diverted for irrigation in percent of total amount diverted during season (percent)*

	Umatilla project	Yakima project	Boise project	King Hill project	Columbia Basin project	Assumed figures for Snake Basin
April	10	10	4	4	12	4
May	19	18	20	17	16	20
June	21	18	22	19	18	20
July	19	19	25	22	18	22
August	9	18	20	21	17	20
September	1	12	8	14	12	12
October		5	1	3	7	2

TABLE 61.—*Distribution of return flow, by months, expressed in percent of total return flow (percent)*

	Columbia Basin	Hermiston	Average of observation by I. R. Meeker, irrigation engineer	Assumed for study of Snake Basin
October	12	11	10	11
November	10	8	9	9
December	6	7	7	7
January	4	6	5	5
February	3	5	6	4
March	2	4	6	4
April	3	5	7	5
May	8	8	8	8
June	12	10	11	11
July	13	12	11	12
August	14	12	10	12
September	13	12	10	12

TABLE 62—*Effect on flow of Columbia River of regulating 10,100,000 acre-feet of storage and the diversion of 6,090,000 acre-feet a year in Snake River Basin*

[Increase or decrease in second-feet]

Calendar year	January	February	March	April	May	June	July	August	September	October	November	December
1918										+7,000	+1,800	+2,900
1919										+600	−4,100	−2,300
1920	−800	−1,000	−3,000	−6,900	−36,900	−28,400	+1,700	+8,000	+7,500	+3,500	−1,800	−3,800
1921	−6,900	−9,700	−29,000	−22,400	−40,400	−17,500	−600	+5,600	+6,300	+5,500	−1,400	−1,300
1922	−400	−1,800	−15,800	−6,300	−36,300	−30,100	+700	+5,600	+7,300	+6,900	−700	−2,100
1923	−3,800	−1,600	−5,100	−11,100	−35,500	−23,000	−2,800	+5,000	+6,900	−700	−2,100	−400
1924	−300	−7,600	−1,300	−2,900	−22,700	+2,200	+7,900	+10,900	+10,900	+8,900	+2,500	+3,000
1925	−1,200	−17,100	−9,400	−27,900	−63,000	−13,100	−5,700	+6,300	+5,000	−1,500	−2,000	−2,400
1926	+500	−6,800	−7,900	−7,900	−19,100	−800	+7,300	+10,100	+9,300	+7,400	+3,400	−700
1927	+500	−9,000	−8,500	−17,700	−47,400	−30,900	−9,900	+4,200	+3,100	+200	−9,800	−11,900
1928	−9,700	−7,600	−10,600	−7,200	−31,700	−10,600	+200	+6,500	+6,100	+2,500	+1,100	+2,000
1929	+1,600	+1,900	−9,200	−13,900	−23,000	−19,000	+1,900	+7,700	+6,900	+5,200	−500	−1,800
1930	+1,000	−4,300	−500	−3,500	−24,800	−10,000	+4,900	+7,000	+7,100			

NOTE.—The 10,100,000 acre-feet of storage includes 5,800,000 acre-feet regulated for irrigation only and 4,300,000 acre-feet regulated for power.

TABLE 63.—*Effect on flow of Columbia River of regulating 1,920,000 acre-feet of storage for the diversion of 2,220,000 acre-feet a year from tributaries between mouth of Snake River and The Dalles, Oreg.*

[Increase or decrease in second-feet]

Calendar year	January	February	March	April	May	June	July	August	September	October	November	December
1918				−3,000	−3,100	−1,200	+100	+500	+400	−400	−1,100	−1,200
1919	−1,800	−1,600	−4,000	−10,700	−5,000	−900	+500	+800	+500	−100	−1,800	−4,000
1920	−4,000	−2,400	−2,000	−6,000	−6,000	−1,600	+400	+900	+500	−200	−1,700	−2,300
1921	−6,000	−7,100	−2,500	−2,400	−3,800	−2,500	−200	+100	+100	−300	−2,500	−3,100
1922	−1,000	−1,900	−2,900	−6,700	−4,100	−2,600	0	+500	+500	−200	−1,000	−2,500
1923	−2,900	−1,900	−3,300	−7,200	−4,800	−2,200	−400	+700	+800	+100	−500	−1,900
1924	−2,200	−6,100	−3,000	−3,100	−1,800	+400	+900	+1,000	+700	+500	−1,300	−1,900
1925	−3,600	−7,400	−3,800	−7,600	−5,600	−1,400	+600	+700	+400	0	−600	−1,400
1926	−1,400	−4,600	−4,700	−3,100	−900	+600	−1,000	+1,100	+900	+300	−800	−2,500
1927	−3,400	−5,700	−5,700	−6,200	−5,500	−3,400	+300	+800	+100	−1,000	−4,300	−3,900
1928	−6,200	−3,400	−6,200	−4,900	−2,700	−400	+600	+900	+800	+400	−700	−900
1929	−1,100	−1,300	−5,100	−4,800	−4,500	−1,300	+700	+1,000	+1,000	+400	−400	−1,200
1930	−1,300	−4,000	−3,300	−2,200	−1,100	0	+800	+1,000	+900			

TABLE 64.—*Total effect of future development on flow of Columbia River at The Dalles, Oreg.*

[Increase or decrease in second-feet]

Calendar year	January	February	March	April	May	June
1918						
1919						
1920	+24,400	+24,400	+20,500	−5,400	−126,800	−124,800
1921	+17,900	+13,800	−17,700	−39,500	−160,300	−92,400
1922	+24,200	+30,300	+16,200	−5,900	−145,400	−107,100
1923	+14,200	+31,300	+24,800	−36,500	−159,200	−82,100
1924	+32,700	+1,900	+12,800	+3,500	−160,500	−55,100
1925	+24,200	−16,400	+12,000	−97,600	−150,900	−70,500
1926	+29,500	+14,900	+9,100	−28,300	−141,000	−50,200
1927	+25,800	+15,500	+11,400	−27,100	−184,900	−70,200
1928	+14,900	+29,900	+14,200	−23,700	−139,500	−72,100
1929	+28,900	+33,300	+16,200	−5,000	−87,700	−142,200
1930	+34,100	+23,800	+23,700	−24,900	−125,800	−98,400

Calendar year	July	August	September	October	November	December
1918						
1919				+17,500	+23,800	+28,300
1920	−40,900	+2,900	+15,300	+8,000	+9,700	+27,800
1921	−43,600	−5,900	+8,700	+14,200	+5,800	+1,700
1922	−38,400	−3,500	+10,500	+15,800	+18,700	+28,800
1923	−38,400	−7,400	+8,700	+11,400	+22,800	+26,000
1924	−19,600	+8,500	+17,400	+36,500	+28,400	+30,600
1925	−44,000	−5,600	+7,000	+11,200	+22,000	+22,500
1926	−4,800	+12,700	+19,600	+20,100	+12,000	+6,300
1927	−61,800	+700	+14,100	+6,500	−13,300	−14,800
1928	−38,700	−12,200	+4,900	+11,500	+14,100	+22,300
1929	−29,900	−2,300	+10,100	+19,800	+23,300	+25,200
1930	−18,200	−900	+12,000			

Area to be irrigated, 4,303,000 acres. Storage for power and irrigation, 26,120,000 acre-feet.

TABLE 65.—*Average monthly flow of Columbia River at The Dalles, Oreg.*

[Observed flow, second-feet]

Calendar year	January	February	March	April	May	June	July	August	September	October	November	December
1913				228,000	376,000	694,000	392,000	210,000	141,000	110,000	101,000	82,600
1914	95,300	89,800	150,000	218,000	375,000	423,000	316,000	168,000	109,000	104,000	121,000	89,500
1915	70,300	71,100	84,100	167,000	253,000	266,000	224,000	185,000	122,000	77,200	84,300	85,600
1916	70,700	133,000	198,000	268,000	390,000	532,000	599,000	259,000	156,000	101,000	84,600	74,200
1917	66,500	68,300	69,900	178,000	391,000	657,000	478,000	204,000	123,000	101,000	77,200	129,000
1918	216,000	132,000	127,000	208,000	344,000	476,000	339,000	182,000	121,000	103,000	85,000	75,400
1919	82,000	92,000	106,000	214,000	336,000	403,000	285,000	170,000	109,000	72,000	66,100	65,000
1920	78,700	76,800	77,900	118,000	252,000	362,000	376,000	214,000	120,000	133,000	111,000	98,500
1921	125,000	129,000	193,000	219,000	450,000	661,000	347,000	182,000	109,000	86,300	99,700	124,000
1922	78,600	74,300	87,200	164,000	329,000	579,000	292,000	161,000	119,000	86,500	77,100	70,000

TABLE 65.—*Average monthly flow of Columbia River at The Dalles, Oreg.*—Continued

Calendar year	January	February	March	April	May	June	July	August	September	October	November	December
1923	108,000	71,400	84,000	176,000	321,000	507,000	352,000	174,000	121,000	85,500	73,400	75,200
1924	67,400	119,000	94,000	103,000	301,000	292,000	195,000	132,000	103,000	74,000	85,700	78,700
1925	95,200	159,000	126,000	270,000	467,000	472,000	315,000	167,000	106,000	84,100	71,700	73,500
1926	66,900	91,000	97,300	140,000	245,000	181,000	164,000	108,000	91,800	85,100	102,000	123,000
1927	97,800	121,000	120,000	147,000	329,000	598,000	401,000	193,000	153,000	156,000	201,000	184,000
1928	150,000	121,000	164,000	204,000	495,000	504,000	314,000	173,000	104,000	84,000	77,900	67,400
1929	61,000	60,800	82,900	99,300	205,500	373,700	210,300	129,700	90,300	69,400	62,700	62,900
1930	48,700	83,200	75,600	147,000	248,000	297,000	231,000	149,000	101,000			

TABLE 66.—*Average monthly flow of Columbia River at The Dalles, Oreg., regulated by total effect of future development as shown in table 64*

[Second-feet]

Calendar year	January	February	March	April	May	June	July	August	September	October	November	December
1918										89,500	89,900	93,300
1919										100,500	105,500	125,700
1920	103,100	101,200	98,400	112,600	125,200	237,200	335,100	216,900	135,300	141,000	120,700	126,300
1921	142,900	142,800	175,300	179,500	289,700	568,600	303,400	176,100	117,700	100,500	105,500	125,700
1922	102,800	104,600	103,400	158,100	183,600	471,900	253,600	157,500	129,500	102,300	95,800	98,800
1923	122,200	102,700	108,800	139,500	161,800	424,900	313,600	166,600	129,700	96,900	96,200	101,200
1924	100,100	120,900	106,800	106,500	140,500	236,900	175,400	140,500	120,400	110,500	114,100	109,300
1925	119,400	142,600	138,000	172,400	316,100	401,500	271,000	161,400	113,000	95,300	93,700	96,000
1926	96,400	105,900	106,400	111,600	104,000	130,800	159,200	120,700	111,500	105,200	114,000	129,300
1927	123,600	136,500	131,400	119,900	144,100	527,800	339,200	193,700	167,100	162,500	187,700	169,200
1928	164,900	150,900	178,200	180,300	355,500	431,900	275,300	160,800	108,900	95,500	92,000	89,300
1929	89,900	94,100	99,100	94,300	117,800	231,500	180,400	127,400	100,400	89,200	86,000	88,100
1930	82,800	107,000	99,300	154,900	161,900	165,000	204,200	146,000	111,200			

TABLE 67.—*Duration relation for average monthly flow Columbia River at The Dalles, Oreg.*

[Discharges in second-feet]

Percent of time (months)	Period of record, Oct. 1, 1919, to Apr. 1, 1930			Period of record, Apr. 1, 1913, to Apr. 1, 1930		
	Observed flow at The Dalles, Oreg.	Flow regulated by Columbia River projects above mouth of Snake River	Flow regulated by all future projects	Observed flow at The Dalles, Oreg.	Flow regulated by Columbia River projects above mouth of Snake River	Flow regulated by all future projects (figures estimated from comparing discharges in other columns)
5	495,000	409,000	390,000	495,000	417,000	398,000
10	362,000	306,000	295,000	390,000	324,000	313,000
15	315,000	236,000	232,000	336,000	255,000	251,000
20	252,000	202,000	180,000	285,000	214,000	192,000
25	201,000	179,000	171,000	219,000	197,000	189,000
30	181,000	167,000	161,000	204,000	182,000	176,000
35	164,000	159,000	141,000	181,000	168,000	154,000
40	150,000	151,000	140,000	164,000	160,000	149,000
45	126,000	136,000	130,000	140,000	144,000	138,000
50	121,000	129,000	125,000	125,000	133,000	129,000
55	110,000	123,000	120,000	120,000	126,000	123,000
60	103,000	118,000	114,000	108,000	122,000	118,000
65	97,000	112,000	109,000	101,000	117,000	114,000
70	87,000	108,000	106,000	92,000	113,000	111,000
75	84,000	104,000	103,000	85,000	110,000	109,000
80	78,000	102,000	100,000	83,000	105,000	103,000
85	75,000	98,000	97,000	77,000	102,000	101,000
90	71,000	96,000	95,000	72,000	98,000	97,000
95	66,000	91,000	90,000	67,000	94,000	93,000
99	61,000	83,000	87,000	61,000	84,000	88,000
100	49,000	83,000	83,000	49,000	83,000	83,000