REVIEW REPORT ON
COLUMBIA RIVER AND TRIBUTARIES

APPENDIX L
COLUMBIA RIVER BELOW YAKIMA RIVER

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APPENDIX L—MAIN COLUMBIA RIVER BELOW YAKIMA RIVER

PART I—SUB-BASIN DATA

CHAPTER I—SUB-BASIN DATA

SECTION I—DESCRIPTION

GEOGRAPHY

1. This sub-basin, as delineated on plate 36, extends along Columbia River from the mouth of Yakima River, at about mile 335, to the Pacific Ocean. It includes the narrow strip of adjacent lowlands constituting the flood plain of Columbia River from the mouth of Yakima River downstream to Cowlitz and Willamette Rivers, which enter Columbia River from the north and south, respectively; the lands in the Horse Heaven and Umatilla projects which may be irrigated from Columbia River; and the northern and southern drainage areas directly tributary to Columbia River downstream from Cowlitz and Willamette Rivers.

2. Of the 335 miles of Columbia River within the sub-basin, the upper 25 miles are entirely within the State of Washington, and the lower 310 miles form a portion of the boundary between Washington and Oregon.

3. The total land area of the sub-basin is about 1,970 square miles, of which about 600 square miles lie in the State of Washington and about 1,370 square miles lie in the State of Oregon. The area of the water surface of Columbia River within the sub-basin is about 430 square miles.

TOPOGRAPHY

4. With the exception of the proposed Horse Heaven and Umatilla irrigation project areas, which lie at elevation 450 to 700 feet above the river, the lands within this sub-basin area, upstream from Cowlitz and Willamette Rivers, are confined to the Columbia River flood plain and are generally low and flat. From the mouth of Yakima River to Wallula, Wash., mile 314, the river banks slope gently, and areas on each side are irrigated. From Wallula downstream to McNary dam site, mile 292, the flood plain lies in a gorge generally about 1 mile in bottom width and approximately 750 feet deep. Elevations a short distance from the river are nearly twice as high on the Washington side as those on the Oregon side. From McNary dam site to Canoe Encampment Rapids, mile 264, the flood plain is bordered by rolling hills to the north and a gently undulating plain to the south. From Canoe Encampment Rapids to a point about 3 miles upstream from Arlington, Oreg., mile 241, the terrain gradually changes and from that point to Celilo, Oreg., mile 201, the subbasin lies within a rocky gorge. In the stretch from Celilo to Bonneville

Dam, about mile 145, Columbia River cuts through Cascade Range. From Bonneville Dam downstream to Cowlitz and Willamette Rivers, which enter from the north and south at about miles 68 and 102, respectively, at the foothills of the Coast Range, the hills adjoining the sub-basin become less rugged and areas of flat land are found at the mouths of tributary valleys. This reach of the river is very flat and subject to tidal action. From Cowlitz and Willamette Rivers to the Pacific Ocean, the sub-basin includes the relatively wide drainage area formed predominantly by the cross-cutting of the Coast Range by Columbia River. These mountains rise about 2,500 feet above mean sea level on both sides of the river and slope irregularly to the ocean beaches.

GEOLOGY

5. A few miles below the mouth of Yakima River, Columbia River leaves the Pasco Basin and cuts through Horse Heaven Plateau at Wallula Gap. Horse Heaven Plateau consists of Miocene Columbia River basalt which has been uplifted and sharply folded into a monocline trending west-northwest. The boundary between the Pasco Basin and the plateau is, in places, a series of normal faults, approximately parallel to the plateau axis.

6. Downstream from Wallula Gap, Columbia River flows through Umatilla Basin, a broad, shallow, structural trough in the Columbia River basalt. The axis of the trough trends approximately east and west and is closely followed by the river. The basalt is overlain, more or less throughout the basin, by lake beds, outwash gravels, and stream alluvium probably of Pleistocene age, and by miscellaneous aluvium and windblown deposits of Recent age.

7. In the western portion of Umatilla Basin, Columbia River flows nearly parallel to the large, east-west trending, normal Columbia Fault. This fault lies along the north limit of the basin downwarp and extends westward for a distance of about 80 miles from the vicinity of Umatilla, Oreg. Between Arlington and The Dalles, Oreg., the river has cut a canyon through the Pliocene Dalles and Shuttler Lake beds formations and into the underlying, relatively horizontal basalt flows. In the area between Celilo and The Dalles, near the western extremity of the Columbia Fault, much subsidiary faulting has occurred in the basalt. This action has resulted in numerous falls and rapids in the river. No sharp, folds, however, are known to be present in the basalt in this area.

8. Cascade Range consists of pyroclastic deposits and lava flows ranging in age from Oligocene to Recent. The lavas are superposed on a broad anticlinal fold in the older formations. The oldest rocks in the Columbia Gorge area are the Eagle Creek formation of Oligocene age, consisting of tuff, tuff breccia, and miscellaneous pyroclastics. This formation is unconformably overlain by the Miocene Columbia River basalt, which is overlain, in turn, by gravelly sediments of Pliocene age. The coarse materials have been derived from explosive volcanic activity in the Cascade Range area during early Pliocene times. The ejected material has been subsequently reworked by water. These materials are represented east of the present Cascade Range by The Dalles formation and west of the Cascades by the Troutdale gravel. Throughout the central part of Cascade Range, the Cascade andesite overlies the Columbia River

basalt and The Dalles-Troutdale beds. The Cascade andesite is late Pliocene and Pleistocene and forms the highest portions of the present Cascade Range.

9. A series of northeast-southwest trending anticlines and synclines in the Columbia River basalt occur between The Dalles and the axis of the present Cascade Range. These structures probably predate the outpouring of the Cascade andesite.

10. Downstream from Cascade Range, Columbia River flows across the Puget Sound downwarp which is locally occupied by the valleys of Willamette, Sandy, and Cowlitz Rivers. The Puget Sound downwarp is a north-south structural trough between the Cascade and Coast Ranges. The Columbia River basalt and associated Tertiary formations underlying the valley have been downwarped below sea level in places and subsequently have been covered by thick deposits of Pleistocene gravel and Recent alluvium. Columbia River turns northward at the confluence of Willamette River, and flows parallel to the axis of this trough for about 50 miles to its junction with Cowlitz River, where it turns westward and cuts through the Coast Range to the ocean.

11. Where it is crossed by Columbia River, the Coast Range consists of marine sandstone and shale beds and some intercalated lava flows and pyroclastics, ranging in age from Eocene probably through Pliocene. The river flows in a relatively narrow valley through this series of gently folded, low, broad, anticlines and synclines. Flat lying Pleistocene deposits of sand, clay, and gravel are found on the ocean side of the Coast Range. Some submergence of the lower Columbia Valley is indicated by the fact that the river flows at about sea level for approximately 150 miles.

CLIMATE

12. The climate ranges from humid in the areas where the river cuts through the Cascade and Coast Ranges to nearly arid east of the Cascades. Although the entire area is dominated by maritime climate controls, continental influences are significant east of Cascade Range, which forms a topographic barrier to the prevailing west winds. Plate 2 shows the location of representative climatological stations and the periods of record are shown on plate 3. Table 8 lists the recording precipitation gages located immediately adjacent to Columbia River. Table 9 is a summary of pertinent climatological data for selected stations.

13. Normal annual precipitation is generally in excess of 40 inches to the west of the Cascade Range and less than one-fourth of that value along the eastern half of the sub-basin. The wide variation in normal annual precipitation is illustrated by the isohyetal map on plate 4 and by the precipitation profile on plate 5. As shown, annual depths range from a minimum of about 7 inches near Boardman, Oreg., to maxima in excess of 75 inches in the vicinity of the Cascade and Coast Ranges. The effect of topography in determining the geographical variation of precipitation is clearly shown. The annual depths shown in the profile on plate 5 are those which occur along the river proper. Much greater annual depths, well in excess of 100 inches in some areas, occur over the contiguous mountainous regions.

14. The percentage of annual precipitation normally occurring as snow at river level varies from less than 1 percent on the coast to about 20 percent at Kennewick, Wash. These proportions, however, are exceeded to a considerable extent in the higher levels of the Coast Range and particularly in the Cascade Range. Although seasonal distribution of precipitation varies somewhat with geographical location, the entire area is characterized by dry summers and a maximum occurrence of precipitation during the winter months. Plate 6 contains isopercentual maps illustrating the distribution of precipitation for selected seasons. Shown also on plate 6 are certain results of precipitation trends analysis, of which a discussion appears in part II of this appendix.

15. Temperature characteristics generally vary with elevation and distance from the coast, and reflect the tempering influence of the Pacific Ocean. Seasonal temperature variation, small in the western portions, increases with distance from the ocean. At North Head, Wash., near the mouth of Columbia River, the normal difference between January and July mean temperatures is only 15°, whereas at Kennewick, Wash., a typical inland station, the difference is 44°. Mean monthly maximum and minimum temperatures for other selected stations are shown on plate 5. Temperatures above 90° are common during the summer months at inland stations but decrease in frequency toward the coast. Subfreezing temperatures, though common east of the Cascade Range during winter, occur only occasionally at river level west of the Cascades, and are rare on the coast. Extreme temperatures of record were 117° at Umatilla and minus 30° at The Dalles. As shown in table 9 and by the horizontal bars on plate 5, the growing season west of the Cascade Range generally decreases with increasing distance from the ocean, and is more or less uniform to the east.

16. Because of the proximity of the Pacific Ocean and the consequent prevalence of moist air masses, relative humidity is high over the entire area during winter months. Nocturnal cooling occasionally produces fog during the morning hours, particularly west of the Cascade Range. Strong winds occur frequently, especially in the Columbia River Gorge, and usually blow parallel to the river. Destructive, gale-force, easterly winds in the gorge, induced by a polar anticyclone, occur nearly every winter.

STREAMS

17. Within this subbasin, Columbia River varies in width from a minimum of a few hundred feet at some of the rapids to 6½ miles at the tidal estuary, and has an average width of about 2,000 feet. Approximately 103,000 square miles, or 40 percent of the area of Columbia River Basin, is tributary to Columbia River above the mouth of Snake River. The remaining 60 percent of the basin area, or 156,000 square miles, drains into lower Columbia River below the mouth of Yakima River.

18. During low-water periods, the river between the mouth of Snake River and Celilo Falls contains 16 rapids which have a total length of 20 miles, comprising 16.2 percent of the total distance between these two points. These rapids are listed in downstream order in the following tabulation:

Rapid	Reach, river mile	Length in miles
Homly	319.5 to 317.9	1.6
Bull Run	309.9 to 309.2	.7
Juniper	308.3 to 307.4	.9
Mill Rock	298.4 to 297.2	1.2
Umatilla	294.3 to 291.3	3.0
Devils Bend	285.9 to 284.3	1.6
Canoe Encampment	265.4 to 264.2	1.2
Owyhee	240.9 to 238.2	2.7
Blalock	235.4 to 234.2	1.2
Four O'Clock	232.8 to 232.1	.7
Rock Creek	228.7 to 228.2	.5
Squally Hook	223.8 to 223.0	.8
Indian	220.2 to 219.8	.4
John Day	218.1 to 215.8	2.3
Schofield	215.2 to 214.8	.4
Biggs	207.8 to 207.0	.8
Total length		20.0

These 20 miles of rapids have a total low-water fall of 90.4 feet and average slopes varying from 2 to 8 feet per mile. The low-water slope between rapids in this reach of the river is about 0.9 foot per mile. Velocities in the rapids vary from 9 feet per second to more than 15 feet per second. From Bonneville Dam to the mouth, a distance of 145 miles in which low-water profiles are affected by tides, the average slope of Columbia River is 0.08 foot per mile.

19. Downstream from Cowlitz and Willamette Rivers, the sub-basin includes the drainage areas of numerous minor water courses. In downstream order, the larger of these streams are Clatskanie, Elokomin, Klaskanine, Youngs, and Lewis and Clark Rivers.

20. Streams are delineated on plate 36. Physical features of the main stream are discussed in detail under "Problems and solutions" in chapter II of this appendix.

STORMS

21. This sub-basin is subjected to general winter storms of the cyclone type and occasional convective-type storms of local importance which generally occur during the warmer months. The latter usually are confined to the area east of the Cascade Range.

22. The typical winter storm is the result of the southward displacement of the Aleutian low pressure area and accompanying frontal systems. The more intense storms usually originate over the northwestern Pacific Ocean and have had a long trajectory over relatively warm water where a high moisture charge is acquired. The frontal activity of these storms usually consists of a series of mature occlusions moving eastward, or a quasi-stationary front with minor active waves moving along the general east-west orientation of the front. After crossing the coastline of Oregon and Washington, this frontal activity is supplemented by orographic lifting. Resulting precipitation is particularly heavy along the west slopes of the mountain ranges. The higher areas along Columbia Gorge through the mountain ranges normally have a much greater precipitation than do areas at river level.

23. Durations of general winter storms vary from less than 1 day to about 1 week. Storm intensities vary greatly with location along the river, but usually reach a maximum near Cascade Locks, Oreg., and

decrease rapidly east of Cascade Range to become of little significance at river level east of The Dalles. Duration and precipitation amounts for intense storms affecting this area, as recorded at Cascade Locks in Columbia Gorge, are shown in the following tabulation:

Date of storm	Duration, days	Cascade Locks precipitation, inches
Jan. 30–Feb. 4, 1890	6	18.6
Jan. 10–14, 1901	5	7.7
Nov. 28–Dec. 1, 1917	4	6.8
Jan. 4–7, 1923	4	11.8

DISCHARGE AND STAGE RECORDS

24. The longest record of Columbia River stream flow has been maintained at Umatilla and The Dalles. These are the only discharge records for stations on the lower river. Observations of river stages at Umatilla were initiated by the Corps of Engineers in June 1878 and in February 1892 at The Dalles. The United States Weather Bureau has obtained gage readings in the vicinity of Umatilla since 1892. At present, the United States Geological Survey operates a gaging station at Celilo, Oreg. The stream-flow records for these stations have been adjusted to a common basis and made into a composite 68-year record, published by the United States Geological Survey, for Columbia River near The Dalles, where the drainage area is 237,000 square miles. Daily hydrographs for this period are shown on plates 7 through 10.

25. Ocean tides influence daily river stages downstream from Warrendale, Oreg., at the head of the tidal reach about 140 miles above the mouth of Columbia River. The average daily tidal fluctuation, about 8 feet in Columbia River estuary, gradually decreases to zero at Warrendale. The lowest tide observed at Fort Stevens, mile 8, was estimated to be 3.0 feet below mean lower low water, and the highest was 11.6 feet above mean lower low water. The highest stage resulted from a combination of storm activity and tidal action. For a distance of 41 miles, between the mouth and Cathlamet, Wash., tides generally have more influence on river stages than do flows in the river. Upstream from Cathlamet, the river stages become increasingly a function of the flow in the river, a fact illustrated by plate 12, which shows the daily maximum and minimum stages observed during 1933 at Cathlamet, Wash., mile 40.7; Longview, Wash., mile 66.3; St. Helens, Oreg., mile 86.1; and Vancouver, Wash., mile 106.3. Tidal effect makes the correlation of stages and discharges impractical throughout the reach downstream from Warrendale.

26. During floods, the tidal effect diminishes in distance upstream from the estuary and with increasing magnitude of the flood crest. For example, at Vancouver the normal tide range at low water is approximately 2 feet, but diminishes to an insignificant amount at a gage height of 11 feet, which can be expected to occur about 20 percent of the time. Flood flows have only a 2- to 5-foot effect on the high tide in the estuary as compared with a 20- to 30-foot effect at Vancouver.

STREAM-FLOW CHARACTERISTICS

27. The annual discharge pattern of lower Columbia River is quite regular; low flows occur from September through March and high flows from April through August. Plates 11 and 13 illustrate these general flow characteristics. The general stream-flow pattern does not follow the yearly rainfall pattern, since a large percent of the annual precipitation over the tributary area occurs during the winter in the form of snow and does not contribute to surface run-off until the following spring and summer. Large changes in flows are gradual, and extend over a period of several months. Minor fluctuations in run-off occur during the high-water period as the result of day-to-day temperature variations. Occasionally, a winter storm will result in a flash flood which is small in comparison to the annual snow-melt flood. Ninety-five percent of the maximum annual discharges have occurred during May and June.

28. Low temperatures in December, January, and February cause ice to form almost every year in Columbia River, particularly east of the Cascade Range. In most years, the icing conditions are confined to shore and running ice, but occasionally an extremely cold period causes the stream to freeze over. The coldest period of record, which occurred in January 1937, caused the river to freeze over as far downstream as mile 30.

29. At The Dalles gaging station, which records the run-off from about 92 percent of the area in Columbia River Basin, the mean annual run-off is 140,500,000 acre-feet, or 11.12 inches, on the basis of the 68-year record, 1878 through 1946. Observed extremes in the annual runoff were 225,000,000 acre-feet, or 160 percent of normal, in water year 1894, and 85,500,000 acre-feet, or 61 percent of normal, in water year 1926. The annual run-off of Columbia River over the period of record has shown a definite downward trend, in excess of that which can be attributed to increased upstream irrigation depletions. Chart 3 shows the annual run-off in acre-feet at The Dalles and the long-term trend, which has been progressively downward since the start of the twentieth century. During the last 25 years, which is the normal length of record at most of the gaging stations within the sub-basin, the average run-off was only 86 percent of the average for the long-term record of 68 years at The Dalles. Extremes in mean daily discharge were 1,240,000 second-feet in June 1894 and 36,000 second-feet in January 1937. The extreme low flow occurred following a long period of subzero weather, which froze many of the headwater tributaries in Columbia River Basin. Based upon this low-water year, existing power storage in Columbia River Basin assures minimum a regulated flow of about 70,000 second-feet at The Dalles. The average discharge through a normal low-water season from November through February is approximately 90,000 second-feet.

30. Below The Dalles gaging station, 22,000 square miles of area with a relatively high unit run-off drains into Columbia River. Though gaging stations are located on the major tributaries, none exist through this reach of Columbia River. However, stages are observed regularly at a number of stations in this reach. Table 1 lists river stations between Pasco and the mouth of Columbia River and the corresponding periods of record. Estimates of mean annual

run-off below The Dalles are made by adding to the run-off at The Dalles the run-off from downstream tributaries. At the mouth, Columbia River has an estimated 50-year normal annual run-off of 180,100,000 acre-feet, or 13.0 inches. Records indicate that 8.5 percent of Columbia River Basin, located downstream from The Dalles, contributes 25.8 percent of the total run-off.

FLOOD CHARACTERISTICS

31. Floods on Columbia River occur annually as the result of melting snow cover in the mountainous headwater areas. Run-off from this source generally commences in March with the melting of snow from the foothills and increases gradually to flood proportions, both east and west of the Cascade Range, with the higher spring temperatures. The floods usually crest in May or June. Both magnitude and duration of these snow-melt floods are a function of the depth of snow cover over Columbia River Basin and of the temperature sequence before and during the snow-melt period, which is from 60 to 120 days in length. During a normal high-water season, the flow gradually increases to a peak and then recedes to base flow by late September. In this period, several minor secondary peaks may be caused by alternate periods of high and low temperatures. Daily hydrographs on plate 7 through 10 illustrate the flood run-off of Columbia River at The Dalles for the period of record. Ground-water storage is the main source of run-off during the low-water season, but, occasionally, during this period winter rains accompanied by above-freezing temperatures will result in minor freshets east of the Cascade Range. West of the Cascades, where the average winter temperature is above freezing, the frequent rainstorms cause flood run-off from such tributaries as Sandy, Willamette, Lewis, and Cowlitz Rivers. These high rates of discharge produce flood stages on Columbia River downstream from Camas, Wash., mile 120, on an average of once in 5 years. Such periods of high water are of short duration and not as extreme as the norml spring and summer snow-melt freshets. Downstream from Vancouver, these rain floods have a correspondingly higher water surface profile than do similar snow-melt floods, because of the larger inflow from downstream tributaries and the storm tides which are greatest during this season.

PAST FLOODS

32. The largest-known flood on Columbia River occurred in June 1894 and reached a maximum discharge of 1,240,000 second-feet at The Dalles, Oreg. A discharge of 600,000 second-feet is approximately the average of the maximum annual floods during the period 1858 through 1946. Based on flood frequency studies, and as shown on chart 7, the average recurrence interval of an 1894-magnitude flood on lower Columbia River is about once in 75 years. Records of maximum annual stages are available from 1858 to date, whereas the continuous record of daily discharges did not begin until 1878.

33. During the 89 years, 1858 through 1946, floods exceeded 900,000 second-feet in each of the years 1862, 1876, 1880, and 1894. In the 36 years preceding the 1894 flood, 24 floods exceeded 600,000 second-feet, of which 8 exceeded 800,000 second-feet. From 1894

to 1948, only 21 floods have exceeded 600,000 second-feet. From 1926 to 1948, the highest discharge observed at The Dalles was 1,010,000 second-feet in 1948. Only four other floods in this period exceeded the average maximum annual flood of 606,000 second-feet. Chart 1 shows the maximum annual discharge frequency curve for Columbia River at The Dalles for the period 1876 through 1948. The following tabulation lists, in order of magnitude, the 24 largest floods of record at The Dalles and the number of days that flows exceeded 600,000 second-feet:

Order of magnitude	Year	Month	Day	Maximum discharge, cubic feet per second	Number of days discharges exceeded 600,000 cubic feet per second
1	1894	June	6	1,240,000	52
2	1876	do	23	1,020,000	
3	1948	May	31	1,010,000	36
4	1862			919,000	
5	1880	July	1	914,000	57
6	1887	June	19	896,000	49
7	1882	do	13-14	883,000	35
8	1859			874,000	
9	1871			856,000	
10	1866			839,000	
11	1899	June	22	787,000	36
12	1903	do	18-19	787,000	29
13	1896	do	22	785,000	46
14	1897	May	24	780,000	23
15	1863			777,000	
16	1870			777,000	
17	1921	June	11	773,000	31
18	1928	May	29	766,000	16
19	1913	June	12	759,000	30
20	1872			737,000	
21	1916	July	1	727,000	29
22	1917	June	20	727,000	34
23	1933	do	19	722,000	18
24	1865			714,000	

Eight of the above 24 ranking floods occurred since the turn of the century.

34. During the last 40 years, large irrigation developments have taken place, particularly in Snake River Basin. Storage and diversions from Columbia River and its tributaries during the normal flood season have resulted in some reduction in the magnitude of the maximum annual floods. Future irrigation and power developments within the basin will tend further to reduce flood flows.

35. On the basis of records up to the year 1948, the recurrence of floods of certain magnitudes may be expected at The Dalles as shown in the following tabulation.

Average recurrence interval:	*Maximum discharge in second-feet*
5 years	720,000
10 years	820,000
20 years	940,000
50 years	1,150,000
100 years	1,350,000

36. East of Cascade Range, high water resulting directly from rainfall is infrequent on Columbia River and insignificant as compared with the annual spring and summer freshet. The largest rain flood on Columbia River, with a peak discharge of 368,000 second-feet, occurred in December 1933. This flood reached a 22.3-foot stage at

Vancouver, about that of a 3-year snow-melt flood, and in the estuary, combined with storms and high tides, reached a stage about equal to that which occurred during the 1894 flood. Other notable winter floods occurred in February 1881, January 1909, and in December 1917.

1894 FLOOD

37. By far the largest recorded flood on Columbia River was that of June 1894, at which time the flow at The Dalles reached an estimated peak of 1,240,000 second-feet. No flood since that time has equaled that magnitude, although the historical flood of 1849 may have been equally large. The 1894 flood had a maximum water surface profile roughly 30 to 35 feet above the mean low water profile from the mouth of Snake River to Celilo, a distance of 124 miles. At Big Eddy, 9 miles below Celilo, the water surface was 60 feet above mean low water. This stage difference gradually decreased to 50 feet in the 45-mile reach downstream to the head of Cascade Rapids. In the 7-mile reach between Cascade Rapids and Warrendale, which is at the head of the tidal reach, the water surface dropped to 43 feet above mean low water. Between Warrendale and the mouth of Columbia River, a distance of 140 miles, the maximum water surface gradually decreased to about 12 feet above mean low water. At The Dalles, the flood discharge exceeded 600,000 second-feet for 52 days.

38. Little information is available as to snowfall depths and water content of snow in the tributary areas preceding the 1894 flood, since much of the region was sparsely settled and the records kept were generally for locations in the lower valleys of the main watercourses. Available climatological and meteorological records show that conditions during the winter and spring preceding the flood were favorable for a high run-off. Excessive precipitation in the fall thoroughly saturated the soil and continued heavy precipitation in the winter and spring resulted in the accumulation of a deep snow cover over all of the mountainous areas. A cold period, starting early in the season and continuing later than normal, was followed by an unusually warm period. Consistently cool temperatures from early fall until the middle of May caused precipitation to fall as snow, and, at the same time, greatly retarded the run-off and losses that normally would have occurred. Precipitation was about 160 percent of normal during the winter and spring of 1893–94.

39. Sudden and prolonged warm weather in the latter part of May and early in June caused rapid melting of the snow cover. Nearly all of the tributary streams throughout Columbia River Basin east of Cascade Range rose to unprecedented flood stages at that time.

1948 FLOOD

40. During the last of May and the first part of June 1948, a disastrous flood occurred on Columbia River. A maximum discharge of about 1,010,000 second-feet occurred on May 31, 1948, at The Dalles. On June 1, and again on June 14, Columbia River at Vancouver, mile 106, reached a maximum elevation of 32.4 feet above mean sea level, or about 15 feet above flood stage. Between these dates, the river remained within a foot of the crest stage. On Willamette River at Portland, backwater from Columbia River produced a crest stage of

31.2 feet above mean sea level, or about 12 feet above flood stage. Although the 1876 flood was of greater magnitude, only the June 1894 flood exceeded the 1948 flood stage at Portland. Nine-foot tides occurred during the flood and added to the magnitude of crest stages downstream from St. Helens, Oreg. The following tabulation compares the maximum water surface elevations of the 1894 and 1948 floods at several representative points between Pasco and the mouth of Columbia River:

Station	River mile	Drainage area, square miles	Flood stage, elevation, feet above mean sea level	Maximum elevation in feet (mean sea level).		Stage difference, feet
				1894 flood	1948 flood	
Pasco	328	103,500	338	349.6	344.2	5.4
Umatilla	292	213,500	272	281.9	277.9	4.0
Vancouver	106		17	35.6	32.4	3.2
Portland [1]			19	34.2	31.2	3.0
St. Helens	86	255,000	15	31.1	27.3	3.8
Longview	66		12	23.0	19.6	3.4
Wauna	42			12.2	10.6	1.6

[1] Located on Willamette River and affected by Columbia River backwater.

41. Climatic and meteorological conditions contributing to the 1948 flood can be discussed only in general terms, since detailed records and studies are not yet available. In April 1948, the water content of the accumulated snow at the numerous snow courses throughout Columbia River Basin varied from 100 to 140 percent of normal. In the areas making a major contribution to the flood run-off in lower Columbia River, the average snow pack was about 120 percent of normal. Spring was abnormally late and the heat supply measured at four index stations was about 15 days behind normal. Probably the most significant factors that contributed to the extreme magnitude of the flood were the subnormal temperatures and the greater than normal precipitation in both April and May. Subnormal temperatures prevailed until May 15, which permitted the snow cover to remain on the basin to a much lower elevation than normal for that date. On May 15, temperatures rose and, after 2 weeks of warm weather, the run-off from the abnormally large snow-melt area caused near record floods on all major tributaries with the exception of Snake River above the mouth of Salmon River. General rains on May 28 and 29 were extremely intense in several localities and added to the seriousness of the flood in lower Columbia River. Weather conditions favorable to a high rate of snow melt prevailed until June 10 and resulted in the flood remaining near crest discharges for a 2-week period.

GROUND WATER

42. As major withdrawals are not made from the ground-water table immediately adjacent to Columbia River below Pasco, the levels generally fluctuate with those of the river. This characteristic fluctuation is particularly noticeable in the lowlands between the mouth of Yakima River and Arlington, river miles 335 to 242, and between the mouth of Sandy River and the Coast Range, river miles 123 to 30, where the river valley is underlain with an alluvium strata. The

Columbia River Gorge is cut through practically impervious basalt. Ground water returns to the river in the vicinity of Umatilla, Oreg., from a number of small artesian wells. Longview, Wash., obtains its entire domestic water supply from wells, and The Dalles and Portland, Oreg., and Camas and Vancouver, Wash., use wells to supplement other water supplies.

WATER RIGHTS

43. Numerous small irrigation pumping installations are now in operation along both banks of the river, but the aggregate demand does not appreciably affect the flow during the irrigation season, which coincides with the period of normal high discharge. Nonconsumptive water rights are now exercised by the Federal Government at Bonneville Dam and will be exercised in the future at McNary Dam and at proposed dams at other sites. The present use of water for irrigation does not seriously affect the required flow at the various Federal power plants, as the period of maximum demand for water for power generation does not occur during the irrigation season.

PREVIOUS REPORTS, MULTIPLE-PURPOSE PROJECTS

44. House Document No. 704, Seventy-fifth Congress, third session, prepared in 1937, is the latest report covering the development of Columbia River below the mouth of Yakima River by multipurpose dams and reservoirs. That report is a review of dam and reservoir proposals contained in House Document No. 103, Seventy-third Congress, first session, dated 1931, which presented the first comprehensive basin plan formulated to guide the development of individual projects. Principal subject of each of these reports consisted of development of the main stem of Columbia River by means of dams and reservoirs providing both navigation and power facilities. The comprehensive plan proposed in House Document No. 103 for the reach consisted of two dams; one at Warrendale with normal pool elevation 54 feet, mean sea level, and one at The Dalles with normal pool elevation 330 feet, mean sea level. The Board of Engineers for Rivers and Harbors, in its report to the Chief of Engineers, stated that an alternate plan consisting of four dams of moderate height would be better suited to the progressive development of this reach of the river. The Chief of Engineers concurred with the views of the Board.

45. At the time House Document 704 was prepared, construction of the Bonneville project was in progress. As the result of detailed engineering studies, Bonneville Dam, with a pool elevation 72 feet above mean sea level, was constructed in lieu of the Warrendale development proposed in House Document 103. House Document 704 recommended that lower Columbia River be further developed by a series of four dams located upstream from Bonneville Dam. The recommendations were concurred in by the Board of Engineers for Rivers and Harbors and by the Chief of Engineers. These recommended projects were at The Dalles site, with pool elevation 150; at John Day site, with pool elevation 210; at Arlington site, with pool elevation 258; and at Umatilla site (later renamed McNary Dam), with pool elevation 310.5. A previous report entitled "Interim

Report No. 1, Columbia River and Tributaries Review Report, The Dalles Dam," and dated March 21, 1946, was submitted to the Chief of Engineers and Board of Engineers for Rivers and Harbors for review.

PREVIOUS REPORTS, FLOOD CONTROL

46. Flood control and bank protection on the tidewater section of Colombia River have been the subject of several reports submitted since 1918. Those submitted since 1925 are itemized in appendix R. Existing Federal flood control projects have been constructed on the basis of authorizations resulting from an unpublished report dated December 24, 1935.

47. House Document No. 631, Seventy-seventh Congress, second session, favorably reported the provision of a flood channel in Alkali Canyon at Arlington, Oreg., to protect that city from floods as a result of storms originating in the small drainage basin above it.

PREVIOUS REPORTS, NAVIGATION

48. Consideration of improvement of Columbia River below Yakima River in the interests of navigation began in 1879 when studies in connection with a report recommending certain channel work through the bar at the mouth of the river were initiated. Since that date, many other reports have been submitted, and the entire river length has been divided into authorized navigation projects. In addition to the main channel improvement and the multipurpose projects previously mentioned, these navigation reports have covered auxiliary channels, harbors, and turning basins. Appendix R lists all such reports subsequent to 1925. Table 35 itemizes all minor navigation improvements, in addition to main channel projects, that have been constructed or authorized. Most recent reports forming the bases of the main river projects are as follows:

(*a*) House Document No. 94, Fifty-sixth Congress, first session, covers the present project at the mouth of the river which was authorized by the River and Harbor Act of 1905. Some revisions in the original plan have been made.

(*b*) House Document No. 195, Seventieth Congress, first session, covers Columbia River between Vancouver and the Pacific Ocean, and Willamette River between Portland and the confluence with Columbia River.

(*c*) House Document No. 704, Seventy-ninth Congress, second session, covers the reach between Vancouver, Wash., and The Dalles, Oreg.

(*d*) House Document No.16, Seventy-third Congress, second session, covers improvement between The Dalles, Oreg., and Wallula, Wash.

SECTION II—ECONOMIC DEVELOPMENT

POPULATION

49. The population of this sub-basin in 1947 was estimated at 338,350 persons, approximately two-thirds of whom resided in Oregon. Population increased from about 154,000 in 1920 to about 210,000 in 1940. The rapid increase between 1940 and 1947, amounting to over 50 percent of the 1940 population, was occasioned by an influx

of people to take jobs in shipbuilding and other industries which mushroomed during and since World War II. Much of this war-induced growth in population has been retained in the postwar period. Moreover, as shown on chart 4, a definite trend toward a continued population increase to about 435,000 by 1970 appears to be consistent with the anticipated regional development of industries, agriculture, and natural resources. Population, distribution by counties, and the increase since 1920 are shown in table 10 and summarized by States in the following tabulation:

State	Percent of 1940 population of State within sub-basin	Sub-basin population			
		1920	1930	1940	1947 [1]
Washington	4	42,780	57,030	69,230	125,900
Oregon	13	111,210	129,460	140,630	212,450
Sub-basin		153,990	186,490	209,860	338,350

[1] Estimated.

50. The population is largely urban in character. In 1940, 75 percent of the people lived in cities of 2,500 population or over; 10 percent resided in small towns and suburban areas; and 15 percent lived on farms. Excluding Portland, only four cities had population in excess of 4,500 in 1940. In 1947, eight cities exceeded 4,500 in population and showed an average growth of more than 41 percent in the preceding 7-year period. The population of Portland, which is partly within the sub-basin, increased from 305,394 in 1940 to more than 405,000 in 1947. The portion of the population of Portland residing within the sub-basin has not been estimated. The estimated 1947 populations of the Portland and Vancouver metropolitan areas are about 500,000 and 52,000, respectively. Cities in the subbasin with estimated population in excess of 4,500 in 1947, excluding Portland, are shown in the following tabulation:

City	State	Population	
		1940	1947 [1]
Astoria	Oregon	10,389	16,900
Hood River	do	3,280	4,700
St. Helens	do	4,304	6,000
The Dalles	do	6,266	8,400
Camas	Washington	4,433	5,200
Longview	do	12,385	17,500
Pasco	do	3,913	6,000
Vancouver	do	18,788	26,000

[1] Estimated.

51. The distribution of population is nonuniform. More than 85 percent of the people live in the lower area between Portland and the sea, where the river lowlands widen. Population density over the whole sub-basin in 1940 was 106 persons per square mile. The estimated 1947 population of 338,000, with a density of 171 persons per square mile, represents increases of 61 and 120 percent over 1940 and 1920, respectively.

52. Population distribution is indicated in tables 10 and 11 and on plate 14, and changes from 1920 to 1947 are summarized in the following tabulation:

Year	Population					Percent increase during 10-year period				
	Rural			Urban	Total	Rural			Urban	Total
	Farm	Non-farm	Total			Farm	Non-farm	Total		
1920	(1)	(1)	44,980	109,010	153,990	-------	-------	-------	-------	-------
1930	25,310	17,400	42,710	143,780	186,490	-------	-------	−5	32	21
1940	31,190	22,710	53,900	155,960	209,860	23	30	26	8	12
1947	33,650	38,700	72,350	266,000	338,350	8	70	34	71	61

[1] Rural farm and nonfarm populations were not reported separately in 1920.

RESOURCES AND INDUSTRIES

53. Columbia River, with the present and potential water-borne commerce, power production, and extensive fishery, is the most important natural resource within the sub-basin. Natural resources of the surrounding area are processed in this sub-basin for distribution to regional, national, and world markets. The river and adjacent area form the major avenue of commerce for Columbia River Basin and the tributary trade area. Transporting raw materials, processing and distributing goods, and providing services account for nearly nine-tenths of the employed workers. Table 14 shows the 1940 distribution of employed workers by the type of industry.

54. The land area of the sub-basin, about 1,260,000 acres, is fairly evenly divided between forests and existing or potential agricultural lands, with small areas of open grazing or waste lands, as shown on plates 16 and 17. Compared with the demands of the heavy concentration of industry, the raw-material resources of the area are relatively insignificant.

55. More than 99 percent of the land is privately owned. Distribution of land by use and counties is shown in table 12 and summarized by States in the following tabulation:

Land use	Acres		
	Oregon	Washington	Total
Agriculture	410,653	182,158	592,811
Range	7,760	----------	7,760
Forest	401,590	227,072	628,662
Waste and miscellaneous [1]	21,736	11,143	32,879
Total area	841,739	420,373	1,262,112

[1] Inaccessible waste land, town sites, etc.

56. The areas of farm land support only a minor portion of the population. Forests were extensively cut over during the early settlement period and now supply only a small portion of the raw materials utilized by the local forest products industries.

57. The increase in value of taxable property within counties is shown in table 13 and is summarized by States in the following tabulation:

State	Actual value of taxable property in thousands of dollars [1]					
	1920	1925	1930	1935	1940	1946
Oregon	$331,550	$394,130	$419,340	$335,170	$328,570	$426,220
Washington	72,120	76,360	82,170	64,010	66,117	105,840
Sub-basin	403,670	470,490	501,510	399,180	394,687	532,060

[1] Based on assessed valuations multiplied by appropriate factors for each county to determine representative average values.

AGRICULTURE

58. Farms generally are small units. About one-half are part-time farms producing food primarily for family use. Only 15 percent of the people lived on farms in 1940. About three-fourths of the farm families live in the area, consisting principally of lowlands, below the mouth of Willamette River. In 1940, 45 percent of the farmers in this area operated primarily to produce food for the farm family and 60 percent of the farm operators worked off the farm. The predominance of part-time farms is even greater where the land is adjacent to industrial centers. Full-time farm units west of the Cascades are devoted primarily to dairy, poultry, vegetable, and fruit farming, and supply local fresh markets and processors. A number of farmers obtain a good income from small-tract farms producing specialty products such as mint, flower bulbs, seed, and nursery stock. East of the Cascade Range, farms lying within the sub-basin are principally full-time dairy, poultry, vegetable, and fruit types, which are in contrast to the usual large-scale dry-land grain and stock farms on the adjoining lands and in other areas through which the river passes. Farm acreages and values, as of 1945, are shown in table 15, and employment in agriculture is shown in table 14.

IRRIGATION

59. Approximately 30,000 acres of land are irrigated at present. In Oregon, near Irrigon, 14,000 acres are irrigated with water from Umatilla River. In Washington, near Pasco, 11,600 acres are irrigated with water from Yakima River. Private interests irrigate the remaining 4,400 acres with water obtained by pumping from Columbia River and wells in the flood plain. The acreages of farms under irrigation in 1939 are listed in table 16.

FORESTRY

60. Forests along the lower reaches of Columbia River generally were depleted early in the settlement of the area. Although almost half the area within the lower portion of the sub-basin is now forested by second-growth timber, the heavy concentration of forest industries requires more logs than present commercial stands can supply. A log of old-growth Douglas fir, the species on which the timber industry of this area has been based, is shown in figure 1. The forests are esti-

mated to contain approximately 5.5 billion feet of saw timber, almost all of which is privately owned. The unreserved saw timber still remaining, distributed by counties, is shown in table 18. Unreserved saw timber within the sub-basin, by ownership as of January 1, 1945, is shown in table 17. Plate 17 shows the distribution of forested areas within the sub-basin.

MINERALS AND MINING

61. No mineral occurrences of commercial importance are known to exist but such deposits as have been found are shown on plate 18.

MANUFACTURING

62. In 1940, about 82 percent of the employees in manufacturing were in industries processing wood, food, metals, and textiles. Most of the remaining 18 percent were employed in printing and publishing concerns; sheet metal works; foundries, stone, clay, and glass products factories; machine shops; and ship-repair yards. The distribution of workers in 1940 in extractive and processing industries is shown in table 14.

63. The industrial distribution and payrolls of employees in manufacturing industries covered by unemployment compensation for the year ending September 30, 1946, are shown in table 20. Data on distribution of manufacturing in 1939 by counties, including number of establishments; wages earned; number of employees; value of product; value added by manufacture; and cost of materials, fuel, and power, are shown in table 19. These data are summarized by States in the following tabulation:

State	Number of establishments	Wage earners (average for year)	Wages	Value of product
Washington	108	5,633	$7,517,000	$36,561,000
Oregon	356	10,721	13,546,000	73,058,000
Total for sub-basin	464	16,354	21,063,000	109,619,000

64. Processing timber products, the principal industry, employed an average of nearly 12,000 persons and had an annual payroll of nearly $30,000,000 in the year ending September 30, 1946. Timber from adjacent areas and logs purchased on the Columbia River log market support this industry. The bulk of the sawmill industry is concentrated in the vicinity of Portland, Longview, and Vancouver. For several years, Cowlitz County, Wash., has led the Nation in lumber production. Most of the output has been from two large mills located in Longview, which have a combined capacity in excess of 2,000,000 feet, board measure, per 8-hour shift. These mills each cut from 300 to 400 million board feet annually and have been doing so since about 1927. The view of the Longview waterfront, figure 2, shows two major timber-products plants, a pulp mill in the left foreground and one of the two large sawmills in the right foreground. Lumber production in the counties lying partially within the sub-basin is shown in table 27. Maximum production was 2,311,000,000 feet, board measure,

in 1941, and the minimum was 1,474,000,000 feet, board measure, in 1945. Plywood plants, located at Longview and Portland, have a combined annual capacity of 160,000,000 square feet of ⅜-inch, 3-ply, plywood.

65. Pulp and paper mills employed nearly 5,000 of the 12,000 workers in the forestry products industries in 1946, and had an annual payroll of nearly $13,000,000. Mills are located at Camas, Longview, and Vancouver, Wash., and St. Helens, Oreg. The pulp mills have a combined capacity of 1,860 tons of pulp each 24 hours, of which 1,010 tons are sulfate, 650 tons are sulfite, and 200 tons are chemical pulp. The paper mills have a combined capacity of 1,261 tons of paper each 24 hours, of which 997 tons are sulfates and 264 tons are sulfites. Products of these plants are bleached paper, envelopes, specialties, wrapping papers, fruit wraps, toweling, tissues, waxed and gummed paper, bags, paperboard, paperboard products, and newsprint.

66. In addition to the major wood-processing plants mentioned above, the sub-basin contains a minor furniture and millwork industry which employed 1 percent of the total workers in 1940. Products of the wood processing industry are sold in both national and international markets.

67. Farm lands are limited in area, and plants processing agricultural products must depend primarily upon outside areas for raw materials. This condition will probably continue as products from new irrigation projects and more intensive cultivation of existing acreages are likely to be absorbed by the expanding fresh market.

68. In Portland, Astoria, Vancouver, and Longview, plants process most of the milk from the counties making up the lower portion of the sub-basin. Practically the entire output of these plants is consumed by the expanding market created by the increased population in the sub-basin and adjacent areas.

69. Vegetables and fruits are shipped to processing plants in the Portland-Vancouver areas from points as far distant as Yakima, Wash., and Eugene, Oreg. Chief products from these plants are canned and frozen berries, beans, pears, sauces, relishes, jellies, preserves, pickles, vinegar, fruit juices, sirups, fruit confections, and other specialty foods. Much of the produce from the upper part of the sub-basin is processed in plants at Kennewick and Pasco, Wash. Grape-juice production at Kennewick is an important and expanding industry and has a nation-wide market. Other products of the upper sub-basin are canned and frozen peaches, asparagus, peas and lima beans, canned and brined cherries, and other canned fruits and vegetables. Meat packing is an important industry in Portland and in Kennewick.

70. Metal refining became important in this sub-basin after 1939 with the availability of large amounts of cheap power. At present, nearly 30 percent of the Nation's primary aluminum capacity, or 373,000,000 pounds annually, is concentrated in three plants located at Vancouver and Longview, Wash., and Troutdale, Oreg. Shown in figure 3 is the Vancouver plant of the Aluminum Co. of America, the first aluminum reduction plant in the Pacific Northwest. The basic raw material, alumina, is shipped from outside sources, and the product in the form of pig and ingot aluminum is shipped east for processing.

SERVICE INDUSTRIES

71. In 1940, 66 percent, or 50,999, of the employed workers were in service industries. Portland is a wholesale, trade, and transportation center for both this sub-basin and large areas lying outside the sub-basin. Smaller cities along the river are major trading centers for adjacent areas. The distribution of service workers in 1940 is shown in table 14.

PUBLIC LANDS AND RESERVATIONS

72. Of approximately 1,260,000 acres of land area, about 12,200 are included in public lands and reservations. These lands are made up of public domain, reservations of the Department of the Army, State parks, other State lands, and county lands. The distribution of these lands is shown by counties in table 21 and by ownership in table 22.

FISH

73. For more than 80 years salmon runs in Columbia River have supported an extensive commercial fishery, which, at its peak, reached an annual production of more than 49,000,000 pounds. In addition to the river fishery, the salmon have contributed to an ocean troll fishery extending along the Pacific coast from California to southeastern Alaska.

74. Astoria, Oreg., the home port and marketing point for most of the Columbia River fishing fleet, has, with its many canneries, icing plants, and reduction works, a heavier per capita investment in fishing than any other city along the Pacific coast. Figure 4 shows one of the larger Astoria fish-packing plants.

75. The first cannery on Columbia River, established by Hapgood, Hume & Co. at Eagle Cliff, Wash., canned 4,000 cases in 1866. The industry, thus initiated, developed with amazing rapidity. The number of canneries and the annual salmon pack and its value has fluctuated from year to year. The highest annual Columbia River salmon pack value was recorded in 1947 and amounted to $11,457,000 at the packing plant. The values of the annual Columbia River canned pack of the various species of salmon for the 25-year period, 1922 to 1947, inclusive, are shown in table 23 and summarized in the following tabulation:

Year	Annual pack [1]		Year	Annual pack [1]	
	Cases	Value at plant		Cases	Value at plant
1922	392,174	$5,206,993	1935	332,730	$3,405,282
1923	480,925	6,730,924	1936	316,445	3,833,055
1924	500,872	6,219,404	1937	416,830	5,437,294
1925	540,452	7,468,468	1938	307,990	3,893,755
1926	479,723	6,744,064	1939	322,472	4,666,141
1927	519,809	7,028,705	1940	386,999	5,379,326
1928	446,646	5,903,462	1941	513,712	7,727,984
1929	422,117	5,905,024	1942	464,401	8,156,445
1930	429,505	5,658,177	1943	167,660	3,669,451
1931	353,699	4,191,000	1944	196,762	4,259,433
1932	296,191	2,474,586	1945	[2] 175,670	3,723,456
1933	336,711	3,329,178	1946	209,471	7,274,930
1934	362,721	3,462,919	1947	347,306	11,457,000

[1] Data from Pacific Fisherman Yearbook.
[2] Includes 1,044 cases of pinks canned from Puget Sound fish.

76. The pack of mild-cured salmon, a product treated to prevent deterioration and usually packaged in barrels, has declined since World War I, whereas, the frozen-fish pack has increased. Europe, where Germany purchased most of the pack, was the principal market for mild-cured salmon. The Columbia River production of canned, mild-cured, and frozen salmon from 1866 to 1946, inclusive, is shown in table 24 and summarized in the following tabulation:

Period	Annual average [1]			
	Canned, pounds [2]	Mild-cured, pounds [3]	Frozen, pounds	Total, pounds
1866-75	11,730,000			11,730,000
1876-85	35,222,600			35,222,600
1886-95	29,577,273			29,577,273
1896-1905	27,561,678	4,010,160		31,571,838
1906-15	29,693,952	6,768,300	987,317	33,449,569
1916-25	33,942,193	2,800,160	1,417,522	38,159,875
1926-35	27,063,054	1,718,970	1,370,775	30,152,799
1936-45	22,228,799	463,430	909,738	23,601,967
1946	14,244,028	105,600	3,390,293	17,739,921
1947	23,616,808	108,900	1,167,863	24,893,571

[1] Data from Pacific Fisherman Yearbook.
[2] Converted on basis of 68 pounds of round fish per case.
[3] Converted on basis of 1,100 pounds of round fish per tierce.

77. According to a survey made by the Oregon Fish Commission in 1945, fish processors and dealers have an investment of about $8,250,000 in plants, machinery, boats, trucks, and other items of operating equipment. The more than 1,200 fishermen who operate on the river have been estimated to have more than $5,000,000 invested in their docks, boats, nets, and other items of gear.

78. The Columbia River salmon and steelhead trout support also an important sport fishery. The estimated annual sport catch from Columbia River, including tributary streams, is about 2,000,000 pounds. The value of sport-caught fish is usually based on the cost to the fisherman of catching the fish, including transportation, lodging, meals, equipment, and licenses. On this basis, using a value of $1.75 per pound, the annual sport catch has a value of about $3,500,000.

79. The Indians are known to catch large numbers of salmon; some they consume, the remainder are sold to canneries and retail customers. The commercial sales of salmon by Indians to fish dealers are recorded by the Oregon Fish Commission, but the poundage consumed by the Indians or disposed of locally to individuals has not been definitely determined. The total unrecorded catch probably will average about 600,000 to 700,000 pounds annually. The recorded Indian salmon take on the Oregon side of the river was 2,100,000 pounds in 1946.

WILDLIFE

80. Migratory waterfowl is the principal wildlife resource. Some of the islands and river banks afford a good nesting habitat for ducks and geese; and the river, being on a flyway, is used for resting during periods of migration. Hunting is prohibited on portions of the upper river. Some wild game, including deer, elk, and black bear, are found in the lower portion of the sub-basin in Clatsop County, Oreg., and vicinity.

RECREATION

81. The natural beauty and intricate geologic structure of Columbia River Gorge form the major recreational assets of the region. Although highways, railroads, and Bonneville Dam exist in the area, the Gorge remains virtually undisturbed, and the remarkable natural features are still dominant.

82. The land structures near the upper end of the sub-basin are characterized by smooth plateaus and basaltic cliffs in step formation adjacent to the river. Numerous striking panoramic views of this section of the gorge are obtained from vantage points along the highway. Farther downstream, where Columbia River cuts through the Cascade Range, the streams flowing into the river have cut the original mountain mass into a succession of ridges which terminate near the river in towering escarpments. The cliffs, measuring hundreds of feet in height, are sculptured by erosion into domes, pinnacles, and palisades of great variety. Numerous waterfalls, including the 620-foot Multnomah Falls, highest in the Northwest, are visible from the highway while others are accessible by trails. The mountain peaks flanking Columbia River Gorge within this section are nearly 5,000 feet above the river and Mount Hood, adjacent to the sub-basin in Oregon, reaches an elevation of 11,245 feet, mean sea level.

83. Climatic conditions have an effect upon the gorge by reason of the transition from the arid to the humid area. Plant growth varies from sagebrush and scattered clumps of juniper in the upper section, through sweeping, open meadows with pines and oaks growing singly or in clusters, to dense, moist forests of Douglas fir, hemlock, spruce, and maple in the Cascades and lower river area.

84. Excellent transportation facilities providing easy access to Columbia Gorge, a wide variety in climatic conditions, and excellent river conditions have resulted in extensive recreational use of the subbasin for touring, local day-use, boating, and fishing. The famed Columbia River Highway, a portion of the Old Oregon Trail regarded as the most historic and one of the most scenic routes of motor travel in the Northwest, carries the greatest share of the east-west tourist traffic. The numerous scenic vistas, waterfalls, parks, waysides, forest camps, and features of Bonneville Dam provide opportunity for a sightseeing, hiking, picnicking, and camping that attract considerable attendance from the densely populated Portland-Vancouver area.

85. Sport fisheries in the vicinity of Astoria attract thousands of fishermen each year from all parts of the country. Other fisheries are found along short reaches of Columbia River at the mouths of such tributaries at Cowlitz, Lewis, Kalama, Sandy, Little White Salmon, White Salmon, and Klickitat Rivers and just below Celilo Falls. Multnomah channel, Sauvie Island, and numerous shallow arms of Bonneville Reservoir are considered fair fisheries for bass, crappie, and catfish. Sturgeon are caught in limited numbers. Although some hunting for deer, elk, and black bear occurs, hunting generally is confined to that for migratory waterfowl. Reclamation of lowlands, establishment of refuges, and reservation of large areas by private hunting clubs, have left comparatively few good shooting grounds available to the general public.

86. Because of the almost ideal conditions extending from the mouth of Columbia River upstream to The Dalles, boating has been extensively developed. Numerous moorages have been established by private yacht clubs to provide facilities for maintenance and servicing. A survey conducted in 1945 revealed that more than 1,200 craft, 25 documented yachts, and more than 100 sailboats were registered in the vicinity of Portland alone. These boats in large number visit both the upper and lower reaches of the river as well as points on the Oregon and Washington coasts. Most popular cruises are through the Bonneville lock to The Dalles, and down river to Astoria for the annual Salmon Derby and Regatta. Numerous yacht clubs have been organized along the shoreline, at points such as The Dalles and Hood River, Oreg., Bingen, Wash., and Bonneville and Astoria, Oreg. One commercial line advertises boat trips from Portland through Bonneville lock and return. At present, trips to eastern Oregon are possible in a small cruiser, and, upon completion of the authorized McNary and lower Snake River dams, a 300-mile trip by boat from Portland, Oreg., to Lewiston, Idaho, will be possible.

87. The development of recreational facilities has been concentrated largely within the more scenic part of Columbia Gorge, extending from Portland upstream to The Dalles. Development has been accomplished for the most part by Federal and State agencies. The Columbia Gorge recreation area has been set aside by the United States Forest Service. The State of Oregon maintains more than 25 parks and waysides, most of which are in the Cascade section of Columbia Gorge, to preserve particularly scenic areas and to provide convenient picnicking spots for motorists. The State of Washington maintains three parks, one in the vicinity of Pasco, Wash., one near Bonneville Dam, and one near the mouth of Columbia River.

POWER DEVELOPMENT

88. Bonneville Dam project, the only existing hydroelectric power development in the sub-basin, has a total name-plate rating of 518,400 kilowatts but can safely develop 570,000 kilowatts for peaking operations of short duration. The installation produced 4,059 million kilowatt-hours, an average of more than 460,000 kilowatts, in calendar year 1947. A description of this multiple-purpose project, which is operated by the Department of the Army, is contained in subsequent paragraphs.

89. McNary Dam project, authorized in 1945, is now under construction near Umatilla, Oreg., and will be a multiple-purpose installation similar to that at Bonneville. Construction as presently planned will provide a powerhouse for 14 generating units with a total installed capacity of 980,000 kilowatts, leaving ample space for future expansion. A description of this project also is contained in subsequent paragraphs. The operation of the Bonneville and McNary projects in a unified power system is discussed in chapter IV of the main report and in appendix O.

90. Steam-generating capacity in the Pacific Northwest is not large since the fuel and hydroelectric supply situation in this area is practically the reverse of that in other parts of the country where fuel is the prime source of power. Large steam plants contributing to the public

power supply in the lower Columbia River area are listed in the following tabulation:

Owner	Location	Name-plate rating, kilowatts
Major steam plants over 10,000 kilowatts:		
Public utility district, Cowlitz County	Longview, Wash	27,000
Weyerhauser Timber Co	do	15,000
Pacific Power & Light Co	Astoria, Oreg	10,000
Subtotal		52,000
Steam plants 1,000 to 10,000 kilowatts:		
Crown-Zellerbach Co	Camas, Wash	6,750
Vancouver Plywood Co	Vancouver, Wash	2,250
Columbia River Paper Co	do	2,500
Westport Lumber Co	Westport, Oreg	2,750
Longview Fibre Co	Longview, Wash	8,000
Prouty Lumber & Box Co	Astoria, Oreg	1,250
Subtotal		23,500
Total		75,500

To this total should be added 129,000 kilowatts of steam-generating capacity in Portland. Portland is located principally within the geographical limits of Willamette River Basin, which is discussed in appendix J, but, from the standpoint of power market and supply, the city is an integral part of the heavy load area in the vicinity of Troutdale, Vancouver, and Longview. The load area is described in the discussion of the power problem.

TRANSPORTATION

91. Land, air, and water transportation facilities of the sub-basin are shown on plate 19 and discussed in the paragraphs which follow.

RAILROADS

92. Through a cooperative operating agreement, the Great Northern Railway and the Spokane, Portland & Seattle Railway make joint use, between Bend, Oreg., and Spokane, Wash., of tracks owned by the latter company. This railroad crosses the sub-basin in the eastern portion. The Union Pacific transcontinental main line reaches Columbia River 17 miles west of Umatilla and follows the south bank about 200 miles to Portland. From Portland the line proceeds northward to Seattle. The main line from Spokane, and branches from Yakima and Walla Walla, converge near Wallula, Wash., and proceed westward through Umatilla to a junction with the transcontinental line. The main line of Northern Pacific Railway provides transcontinental connections to the East at Pasco, Wash. At Pasco, the line crosses Columbia River and extends westward to Seattle, thence south to enter the sub-basin again at Longview and continues south to Vancouver, where it again crosses the river to Portland. Spokane, Portland & Seattle Railway parallels the north bank of Columbia River between Pasco and Vancouver, Wash. A branch leaves the main line at Wishram, Wash., crosses Columbia River, and extends to Bend, Oreg. After crossing the river at Portland, the main line con-

tinues down the south bank to Astoria and Seaside. Mount Hood Railroad operates freight service between Union Pacific Railroad at Hood River and Parkdale, Oreg. Numerous branch and short railroad lines connect with the main rail lines to serve populated areas or to transport raw materials to processing plants.

HIGHWAYS

93. This section of Columbia River Basin is served by United States Highways Nos. 30, 97, 99, 101, 395, 410, 730, and 830 and many primary and secondary State highways and county roads. On the south bank of Columbia River, United States Highway No. 30 parallels the river between Boardman, Oreg., and Pacific Ocean. Northeast of Boardman, United States Highway No. 730 extends to Pasco. United States Highway No. 830 borders the north bank downstream from Maryhill, Wash. State and county roads connect Maryhill with Kennewick and Pasco. Access roads from the highlands down to the river bank in this section are few and mostly unimproved.

AIRLINES

94. This section of the Columbia River Basin is served with regular scheduled airline flights, as shown below:

City	Flight	Number of daily flights each way	Line
The Dalles	Transcontinental	1	United Air Lines.
Do	Portland-Spokane	1	Do.
Portland and Vancouver	Transcontinental	4	Do.
Do	do	2	Northwest Airlines.
Do	Portland-Spokane	2	Do.
Do	Through coastwise	11	United Air Lines.
Do	Local coastwise	1	Do.
Do	do	4	West Coast Airlines.
Do	Through coastwise	3	Western Air Lines.
Astoria	Seattle-Portland	2	West Coast Airlines.

In addition, more or less improved landing fields at many other points are used for emergency purposes and nonscheduled or local service.

WATER TRANSPORTATION

95. Between the mouth of Columbia River and Vancouver, a distance of 106 miles, channel dimensions are adequate for the immediate needs of ocean and river commerce. Further improvement to provide a ship channel from Vancouver to The Dalles, a distance of 86 miles, has been authorized and is scheduled for completion in the near future. Between The Dalles and the Pasco-Kennewick area, 136 miles, lesser depths limit navigation to river craft. Barge transportation between the Portland-Vancouver and Pasco-Kennewick areas is firmly established in spite of the limiting dimensions of The Dalles-Celilo Canal and inadequate channel depths and widths through the numerous rocky rapids prevalent in The Dalles-Pasco section of the river. These difficulties, however, render navigation costly and hazardous, and definitely confine traffic to a fraction of the total potential commerce. Improvements in aid of navigation at the mouth of the river

were inaugurated by the Federal Government in 1884, the north and south jetties were completed by 1917, and a channel with minimum depth of 40 feet is maintained through the entrance at the present time. These improvements, together with dredging and construction of spur jetties to provide a depth of 35 feet upstream to Portland, on Willamette River, and dredging to provide a depth of 30 feet in the 5-mile stretch between the mouth of Willamette River and Vancouver, furnish safe and easy passage for ocean carriers to those ports. Wharves on or directly connected to the ship channel have been provided by local interests at many points, including Astoria, Westport, St. Helens, and Portland in Oregon, and Longview, Kalama, and Vancouver in Washington. One of these facilities, a grain elevator at Vancouver, which handles grain from the wheatlands of the upper Columbia River Basin, is shown in figure 5.

96. In 1945, the latest year for which comparative statistics are available, Portland ranked eleventh among the ports of the United States and second among the seaports of the Pacific coast for ocean and local commerce combined. During the calendar year 1946, a total of 1,191 in-bound and 1,081 out-bound vessels constituted the ocean carrier traffic on Columbia River. Agricultural products, logs and wood products, minerals, fuels, metals and metal products, and miscellaneous manufactured items made up the ocean commerce. In 1946, the total in-bound tonnage was 4,739,083 ,and the total out-bound commerce was 2,142,885 tons.

97. Coincident with construction of the ship lock at Bonneville Dam, extension of the ship channel from Vancouver upstream to The Dalles was authorized. The latter improvement was to be accomplished by dredging a channel to a low-water depth of 27 feet between Vancouver and Bonneville Dam. The depth of the pool above this point, with some rock removal and channel alinement, was considered to be sufficient to carry deep-draft vessels to The Dalles. Dredging was partially completed but was suspended during the war to await return of normal economic conditions and demand for ship service to and from the interior.

RIVER COMMERCE

98. Columbia River and the larger tributaries have been navigated by river craft from days of early settlement. River commerce developed and prospered until 1882, when construction of a railroad paralleling the south bank of Columbia River from Wallula to Portland interposed serious competition. Shortly afterward, river service was abandoned. Sporadic attempts to revive navigation above Celilo were made later, but the difficulties of navigating the river could not be overcome with profit to operators, although considerable work had been performed by the Federal Government to improve critical locations.

99. Interest in navigation on Columbia River above Vancouver was again revived in 1933. About this time construction was started on a lock and dam at Bonneville. This was followed by adoption by Congress of projects providing for: open-river improvements to secure a depth of 7 feet between Celilo and Wallula; a lock and dam at Umatilla (McNary Dam); and a series of locks and dams in Snake River to create a slack-water navigation channel to Lewiston, Idaho,

100. During the period 1926 through 1930, no freight traffic passed through The Dalles-Celilo Canal. Traffic was revived in 1932 when 400 tons transited the canal. Tonnage has increased rapidly since that time. In 1937, the year before Bonneville lock was opened to navigation, the total tonnage was 5,626, while in 1938, the year Bonneville lock was opened, the tonnage was 44,349. Since the opening of the lock at Bonneville Dam, traffic has increased manyfold and 834,923 tons passed through the canal in 1947. The tonnage through the canal in 1946 was 744,352 tons. Of this amount, 16,809, 34,938, and 300 tons originated at Port Kelly, Wash., Umatilla, Oreg., and Maryhill, Wash., respectively, destined for downstream points. That tonnage originating at downstream points and destined for Pasco, Wash., Attalia, Wash., and Umatilla, Oreg., was 118,272, 183,060, and 390,973 tons, respectively. Major commodity movement upstream was petroleum products, and that downstream was grain. Table 29 contains a year-by-year break-down of commodities moved up and down stream for the years 1932 through 1947. Three stretches of the river are listed—through The Dalles-Celilo Canal, through Bonneville and Cascade locks, and from Vancouver to Bonneville. The river past Richland and Hanford, Wash., and as far upstream as the site of Priest Rapids Dam, mile 397, is navigable for barge operation at medium and higher river stages, and is used irregularly as the occasion arises.

101. Further growth of river commerce is limited by adverse conditions as described in the text devoted to navigation problems.

FLOATING PLANT

102. Commercial navigation is conducted on Columbia River above Vancouver by four principal companies using a total of 17 towboats ranging from 200 to 4,000 horsepower, and 48 barges ranging from 400 to 2,000 tons capacity. Barge drafts range from 1½ feet when empty to 12 feet when loaded. Above The Dalles only barges with loaded draft of 7 feet or less are used. Port-to-port barge rates are shown in tables 31 and 32.

PORT DISTRICTS

103. In order to take full advantage of the benefits to be derived from navigating Columbia River, public port districts at the communities listed in the following tabulation have been created as agencies of the States:

State of Washington: Kennewick, Pasco, Klickitat, Wind River, North Bonneville, Camas-Washougal, Vancouver, Kalama, Longview, Ilwaco.
State of Oregon: Umatilla, Arlington, The Dalles, Hood River, Cascade Locks, Portland, St. Helens, Astoria.

In addition, a port district for Walla Walla County, Wash., has been considered by local interests and possibly will be established. Table 28 shows existing terminal facilities. Figure 6 shows the port facilities at Astoria, Oreg.

BRIDGES

104. Columbia River within this sub-basin is crossed by nine bridges, of which four are railroad and five are highway bridges. The struc-

tures are either of sufficient height to clear river traffic or may be opened to permit passage of vessels. Following is a tabulation of the bridges:

Owner	Nearest city	Miles above mouth	Type of bridge	Type of traffic
State of Washington	Pasco and Kennewick	340	Fixed	Vehicular.
Northern Pacific Ry	Pasco, Wash	339	Swing	Railroad
Union Pacific R. R. Co	Kennewick, Wash	323	do	Do.
Oregon Trunk Ry	Celilo, Oreg	198	do	Do.
Oregon-Washington Bridge Co	Hood River, Oreg	170	Vertical lift	Vehicular.
Wauna Toll Bridge Co	Cascade Locks, Oreg	148.3	Fixed	Do.
States of Oregon and Washington	Vancouver, Wash	104.5	Vertical lift	Do.
Spokane, Portland and Seattle Ry	do	103.5	Swing	Railroad.
Longview Bridge Co	Rainier, Oreg	64	Fixed	Vehicular.

Three of these bridges will be affected by the authorized McNary Dam and one by the proposed The Dalles Dam. Modifications are discussed in connection with the appropriate projects.

105. In addition to the 9 listed above, there are 41 bridges over navigable tributaries and sloughs. Most are in the lower river area and would not be affected by proposed improvements. Data on all bridges over navigable streams are shown in table 25.

EXISTING AND AUTHORIZED PROJECTS

106. Existing and authorized projects are discussed in the following paragraphs under open-river navigation projects, locks and lock and dam projects, and flood-control projects. The projects are shown on plate 36.

OPEN-RIVER NAVIGATION PROJECTS

107. Open-river navigation projects include improvement of the main river channel; construction of auxiliary channels to ports; and construction of turning basins, port developments, and small boat harbors. Since the first work was initiated in 1866, about $55,000,000 has been expended by the Corps of Engineers for construction and maintenance of navigation improvements, exclusive of The Dalles-Celilo Canal, Bonneville Dam and corollary bridge revisions, and McNary Dam. The existing and authorized open-river navigation projects extend from the mouth of Columbia River to Kennewick, Wash., a distance of about 328 miles. Detailed data on these projects are shown in table 35 and in appendix R and are summarized in the following paragraphs.

108. The existing project for lower Columbia River provides for a channel 40 feet deep and one-half mile wide at the mouth of the river. Above this point it provides for a channel 35 feet deep and 500 feet wide to the mouth of Willamette River and 12 miles up that stream to the Broadway Bridge in Portland. Between Broadway and Ross Island Bridges in Portland, a 30-foot by 300-foot channel is maintained by the local ports. From the mouth of Willamette River upstream along Columbia River to Vancouver, a distance of about 5 miles, the project provides for a channel 30 feet deep and 300 feet wide. From Vancouver to The Dalles, a distance of 85 miles, a channel 27 feet deep and 300 feet wide is authorized. The section above Bonneville utilizes the 47.5-mile pool created by Bonneville Dam. From The

Dalles, a project is authorized to provide shallow draft open-river improvement to the foot of The Dalles-Celilo Canal. This canal, which is 8.5 miles long and by-passes Fivemile Rapids and Celilo Falls, is discussed as a separate improvement. The authorized project includes improvement of 128 miles of Columbia River to provide a channel 7 feet deep and 150 feet wide from Celilo Falls to Wallula, Wash., and a channel with no specified depth or width from Wallula to Kennewick, Wash. McNary Dam, which is now under construction, will, when completed, obviate the necessity of channel improvement between the lower end of Umatilla Rapids and the mouth of Yakima River. Miscellaneous port approach channels, turning basins, and harbors shown in detail in table 35, have been constructed or authorized in addition to the projects on the main channel.

LOCKS AND LOCK AND DAM PROJECTS

109. Existing and authorized locks and lock and dam projects for Columbia River in this sub-basin include McNary Dam, The Dalles-Celilo Canal, and Bonneville Dam, each of which are described in the following paragraphs.

MCNARY DAM

110. McNary Dam, now under construction, is located at river mile 292, about 2 miles east of Umatilla, Oreg. The dam structures, which will be approximately 7,500 feet long, are shown in illustration 2. Natural low-water surface at the site is 250 feet. The proposed pool level, elevation 340 feet, will provide an initial maximum head of about 90 feet, but, because of overlap by the recommended John Day pool, the normal head ultimately would be about 85 feet. With level pool, McNary Reservoir will extend upstream a total distance of 59 miles, provide 19 feet of increased depth above adopted low water at the mouth of Yakima River, and extend 16 miles upstream from that point. A controlling depth of 9 feet will extend up Snake River about 10 miles. The position of McNary Dam in relation to existing and proposed developments on the river is shown in profile on plate 1.

111. Reservoir acquisition and utility relocations for McNary Dam will be performed to specified freeboards over the backwater profile for a flood similar to that of 1894 passing the dam at normal pool elevation. About 42,000 acres of land are involved. As shown on plate 36, several areas upstream from Wallula will be excluded from the reservoir by levees and appurtenant drainage facilities. About 90 miles of railroad will be revised and about 47 miles of highways and roads relocated. The Union Pacific Railroad bridge at mile 323, the Northern Pacific Railway bridge at mile 339, and the highway bridge at mile 340 will all be altered to clear the design backwater and provide clearance for navigation.

112. The dam site foundation and abutments are generally a massive flow of basalt of good quality and have little overburden in the river section. The foundation is underlain by a thick sedimantary interbed but at sufficient depth to have little effect upon design. Very little overburden exists on the Washington shore, but an extensive deposit of pervious material overlies the Oregon abutment. Special provisions for seepage cut-off will be made in this area.

113. The navigation lock will be located on the Washington shore, which is most easily accessible to river traffic. The lock chamber will be 86 feet by 675 feet in clear plan dimensions and will have a minimum depth of 14 feet over the miter sills. Guard walls approximately 1,400 feet long, both upstream and downstream from the lock chamber, will protect traffic from spillway discharges.

114. The spillway will extend to the south from the lock and will consist of a concrete ogee section controlled by 22 two-section vertical lift gates 50 feet wide and approximately 54 feet high. The gates will be operated by two gantry cranes travelling on a bridge supported by the gate piers. A concrete stilling basin with baffles will be provided downstream from the spillway to reduce overflow velocities.

115. The powerhouse, located south of the spillway, will extend south of the low-water shore and will require considerable excavation to provide an adequate tailrace. Space will be provided for 14 70,000-kilowatt generators driven by Kaplan turbines. An assembly bay will be located at the southern end of the powerhouse and, should future conditions require, construction of additional units south of the assembly bay will be possible. Appendix O contains detailed information on the characteristics, output, and economics of this plant.

116. Two fish ladders will convey migrating fish over the dam, and one fish lock, adjacent to the navigation lock, will serve a similar purpose. Continuing studies of fish habits and the operation of Bonneville Dam fish facilities will govern final design of fish facilities.

117. Recreational development will include the provision of facilities for the comfort and safety of sightseers and for boating and day-use facilities in the vicinity of the dam and at Sacajawea Park in the upper reservoir area.

118. Construction of McNary Dam was initiated April 15, 1947, and $7,288,501.44 had been spent to June 30, 1948, for new work. Estimated cost of the entire project, excluding interest during construction, and including 14 generators installed, is $227,028,000, as shown in the annual report of the Chief of Engineers for June 1948. Additional statistical data are shown in table 34.

THE DALLES-CELILO CANAL

119. The existing project provided for open-river improvements of the stretch of river (now part of Bonneville pool)extending from the foot of Threemile Rapids to the foot of The Dalles (Fivemile) Rapids, and for a continuous canal on the Oregon shore to the head of Celilo Falls. The canal has a depth of 8 feet, a bottom width of 65 feet, a length of 8.5 miles, and includes four locks with a total lift of 55 feet at low water. Controlling dimensions in the lock chambers are 45-foot widths, 265-foot lengths, and 7.8-foot depth over the sills. The canal and locks, completed in 1919, were designed for operation and use up to a discharge of 650,000 second-feet, a stage of 18 feet at the Celilo gage at the upstream end of the canal. This discharge is exceeded 1.3 percent of the time, during which periods navigation is suspended. The tandem lift locks at Big Eddy were converted to a single lift in 1941. Total costs under the existing project to June 30, 1948, have been $5,946,141.88, of which $4,669,092.33 was for new work and $1,277,049.55 for maintenance, operation, and care.

BONNEVILLE DAM

120. Bonneville Dam is located on Columbia River at the head of tidewater, 145.3 miles upstream from the ocean, and 42 miles east of Portland. A photograph of the dam is included as illustration 1. Normal tailwater at the dam is approximately 13 feet and the normal pool level is 72 feet, thus providing a normal head differential of 59 feet. The pool created by the dam extends upstream about 48 miles to Big Eddy, at the foot of The Dalles-Celilo Canal, just upstream from The Dalles. The pool affords a navigable channel with depths of 30 feet or more from the dam to The Dalles. A small area at Hood River, and, at The Dalles, an area as indicated on plate 36, have been excluded from the reservoir by diking and drainage works. Construction of Bonneville Dam was initiated in 1933 and was completed with two 43,200-kilowatt generating units in 1938. Between that time and 1943, eight 54,000-kilowatt generating units were added. The position of this dam in relation to existing and proposed developments on the river is shown in profile on plate 1.

121. Bradford Island divides the river at the site. The spillway, located in the north channel, consists of a concrete gravity ogee section controlled by 18 vertical-lift, fixed-wheel gates, 50 feet long and 50 to 60 feet high. The gates are operated by two gantry cranes of 350-ton capacity, which travel on a roadway supported by the gate piers. A concrete apron with baffles has been provided below the spillway to protect the toe of the structure against erosion. The spillway structure is founded on reworked pyroclastics.

122. The powerhouse and navigation lock are located in the channel south of Bradford Island, a short distance downstream from the spillway dam. These features of the project are founded on andesite. The powerhouse and headworks, constructed integrally, serve as a dam. The structure includes 10 main units spaced at 82-foot centers and has a 100-foot assembly bay at each end. The main generators have a total installed capacity of 518,400 kilowatts and include two rated at 43,200 kilowatts and eight rated at 54,000 kilowatts. The generators are driven by vertical-shaft Kaplan-type turbines, 280 inches in diameter. Appendix O contains detailed information on the characteristics, output, and economics of this plant.

123. The navigation lock, located south of the powerhouse, consists largely of a concrete faced chamber excavated in rock. Clear inside dimensions are 76 feet in width by 500 feet in length. Depth over miter sills at adopted low water is 24.2 feet. The lock chamber is filled and emptied through a central floor culvert. The Cascade Locks and Hood River highway bridges upstream from the lock in the pool area have been altered to provide vertical clearances for navigation. Provisions have been made in both channels of the river to pass anadromous fish. At the spillway dam, fish ladders and fish locks or elevators are located at each end of the structure. The fish are attracted to the entrances of these structures by artificially created favorable water currents. Fish arriving at the powerhouse tailrace are similarly attracted into a conveying channel over the draft tubes. The channel is parallel ot the powerhouse structure and is connected by a fish ladder to a similar ladder on Bradford Island serving the south end of the spillway. A fish elevator is located at the junction of the powerhouse and lock. Fingerling fish are passed downstream

through the dam by means of special channels to steep gradient located at strategic points, as well as through the turbines and under the spillway gates.

124. A recreation plan now being prepared for Bonneville Dam and Reservoir includes the development of sight-seeing facilities in the vicinity of the dam and the development of at least four areas for access to the reservoir by the general public. The development of authorized small boat harbors at Hood River and The Dalles and the authorized auxiliary channel at Bingen will encourage recreational use of the reservoir.

125. The existing project is considered 98 percent complete. Total costs to June 30, 1948, amounted to $86,917,680.30, of which $81,028,746.86 was for new work, and $5,888,933.44 for maintenance. Cost of alterations to the Cascade locks and Hood River Highway bridges amounted to $1,081,805.96. Table 34 summarizes princiapl data concerning the development.

FLOOD CONTROL PROJECTS

126. Sixty-five flood control projects exist or are authorized. With the exception of Alkali Canyon project, discussed subsequently, these projects are for the protection of flood plain areas along Columbia River downstream from Bonneville Dam. These areas, shown on plates 35 and 36, are not continuous but are broken at several points by tributaries and by high ground lying close to the river. The protection of intervening low lands by levees increases maximum flood heights only about 2 feet, as natural constrictions previously controlled the flood profile. It has been practicable to dike about 99,000 acres, or 58 percent of the total of 170,000 acres within the flood plain. Improvements made by the Federal Government were authorized in 1936 and consisted of rehabilitation of existing levees, construction of new levees, bank protection, and drainage facilities. This work was accomplished prior to 1942. The Department of the Army has participated in the construction of 42 of the 65 existing or authorized flood control projects. Monies so expended totaled about $7,350,000 as of June 30, 1947. Of the remaining 23 projects, 11 were constructed by local interests; 6, costing about $240,000, received the benefit of Federal funds as relief projects during the depression years of the 1930's; conditions of local cooperation required for Federal participation have not been met for 2; 3 have received about $250,000 for emergency repairs; and 1, the Alkali Canyon project, is under further study, as discussed subsequently. With the exception of the two projects for which the conditions of local cooperation have not been fulfilled, no projects are authorized for which funds have not been appropriated. Table 36 lists existing and authorized flood control projects.

127. Levees upstream from Cathlamet, Wash., are designed for various flood stages on Columbia River. Generally those protecting urban and improved industrial districts are designed for the higher flows. Levees protecting agricultural lands are designed for lesser stages, some being overtopped at relatively low flood flows. Downstream form Cathlamet, protection is generally afforded against the highest tide of record, 11.6 feet above low water at Astoria, combined with backwater from a flood such as that of December 1933. Run-off

within the leveed areas is, at a majority of the projects, discharged by tide boxes, although 16 existing projects have pumping plants.

128. The June 1948 flood, the largest since the levees were constructed, imposed a heavy strain. Some levees were overtopped and others failed without overtopping. In other instances, failure of railroad or similar embankments, incorporated into the levee systems, resulted in inundation. In some cases, failures were progressive as at diking districts Nos. 1 and 3, Wahiakum County. Water from a main levee break in district No. 3 overtopped a low cross levee separating this district from district No. 1 and the latter was consequently flooded. Eleven of the 42 districts which have had Federal assistance through the Corps of Engineers were affected and about 28 percent of the area originally protected was inundated. Seven other districts constructed by local interests or the combination of local interests and Federal relief agencies also were flooded and 53 percent of the protected area affected. The following tabulation lists the districts and areas suffering damage during the 1948 flood:

Name	County	Sponsor	Area, acres
1. Diking district No. 1	Wahkiakum, Wash	Local interests [1]	3,200
2. Diking district No. 3	do	do	740
3. Westport area, Diking district No. 15	Columbia and Clatsop, Oreg	do	233
4. Marshland drainage district	Columbia, Oreg	do	976
5. Rainier drainage district	do	do	1,287
6. Diking improvement district No. 11	Cowlitz, Wash	do	1,740
7. Diking improvement district No. 5	do	do	5,629
8. Columbia drainage district No. 1	Columbia, Oreg	do	1,602
9. Peninsula drainage district No. 1	Multnomah, Oreg	do	901
10. Peninsula drainage district No. 2	do	do	1,425
11. Multnomah drainage district No. 1	do	do	8,417
Subtotal			26,150
12. Clatskanie drainage district	Columbia, Oreg	Local interests [2]	300
13. John drainage district	do	do	153
14. Palm drainage district	do	do	28
15. LaCenter area	Cowlitz, Wash	do	400
16. Lewis River area	Clark, Wash	do	800
17. Bachelor Island area	do	do	2,100
18. Tomahawk Island area	Multnomah, Oreg	do	40
Subtotal			3,821
Total			29,971

[1] Assisted by Corps of Engineers.
[2] Assisted by Civil Works Administration.

129. A preliminary estimate of the cost of repairing levees and appurtenant installations damaged during the 1948 flood was made before the flood had completely receded. The cost of such repair work, as estimated at that time, was about $2,000,000. In addition, a sum of about $3,000,000 was expended during the flood period on strengthening the levees and on rescue work. Sufficient money was made available in the second deficiency appropriation of 1948 to defray the above costs. In this report, the existing levee system is assumed to have been rehabilitated to the original condition in considering future levee projects.

ALKALI CANYON

130. Alkali Canyon enters Columbia River at mile 242 through a channel traversing Arlington, Oreg. The drainage area of the

canyon, 53 square miles, is subject to cloudburst-type storms. The improvement, authorized in 1944, would be located in Arlington and would consist of a flood channel about 3,000 feet long designed to confine a flow of 6,500 second-feet. Portions of the funds necessary for construction were appropriated in 1947 and 1948, but no construction work has been initiated. Latest estimate of cost for the project is $490,000, of which $39,300 would be chargeable to local interests. The project would be inundated by the reservoir of the proposed John Day project and is further discussed under flowage items pertinent to that project.

IMPROVEMENTS BY OTHER AGENCIES

131. Navigation improvements by other agencies include navigation aids installed by the United States Coast Guard and terminal docks and facilities constructed by local interests. These latter improvements have been discussed under the section on transportation. Since navigation aids, which consist of lights, buoys, and other channel markers, would be required in about the same degree for any plan of improvement for Columbia River, and the cost of these aids is relatively low, revisions of these facilities can be easily accomplished if necessary.

132. As previously noted, 17 small flood-control projects protecting 7,170 acres of Columbia River flood plain have been constructed by local interests between Vancouver and the ocean. In some cases, Federal participation through the Civil Works Administration and Works Progress Administration was obtained. These projects are itemized in table 36 and appendix R. Improvements consist of levees, tide boxes, revetment, pumping plants, and related facilities. Cost of 12 of these projects, the only ones for which data are available, is estimated at about $410,000. Half of these, costing approximately $170,000, received no Federal funds.

133. About 30,000 acres of land adjoining Columbia River below Yakima River are irrigated by gravity systems from Yakima and Umatilla Rivers and, by small pumping plants, from Columbia River. These projects were constructed by private interests and no data are available as to costs. The locations of the irrigation projects are shown on plate 36.

134. The Bonneville Power Administration has constructed extensive 115-kilovolt and 230-kilovolt transmission facilities for marketing the energy from Bonneville Dam. Plate 21 shows existing generation and transmission facilities, and indicates the load centers.

CHAPTER II—PROBLEMS AND SOLUTIONS

SECTION I—GENERAL PROBLEMS

INTRODUCTION

135. *General.*—Four of the numerous problems to be considered in selecting projects for development of the water resources of the subbasin are basin-wide, or regional, in scope. The remainder are of local significance, although solutions thereto are, to some extent, dependent on solutions selected for the regional problems. Desires of local

interests have been considered in connection with both regional and local problems.

136. *Regional problems.*—The regional problems are those arising from need for through navigation on Columbia River, flood control, power production, and fishery maintenance. The regional aspects of these problems are discussed in subsequent text, and general solutions and specific projects considered are described. To some extent, each of the regional problems and the general solutions thereto are related to conditions, problems, and solutions in tributary areas outside this sub-basin.

137. *Local problems.*—Problems of local significance include drainage, irrigation, bank erosion, recreation, water supply, ground water, and the need for local navigation works such as auxiliary channels and harbors. Wildlife problems which would arise from construction of projects would be local in nature.

NAVIGATION PROBLEM

138. *General.*—Since the earliest exploration and settlement of the Pacific Northwest, Columbia River has been an outstanding factor affecting the development of the region. Because of the fact that it provides a low level route to the interior, the portion of Columbia River within this sub-basin is an important link in a waterway of great commercial importance to the entire Columbia River Basin in the United States. The water level in Bonneville pool, in the center of the Cascade Range, is about 72 feet above sea level. Important rail and highway routes pass through the range adjacent to the pool, thus avoiding the adverse grades encountered on other routes. In contrast, the lowest railroad and highway passes outside the sub-basin are at elevations 2,564 and 3,004, respectively. The presence of the mountain barrier accentuates the desirability of through navigation from Pacific Ocean to inland ports.

139. At present, the deep-water channel allows ocean carriers to reach Portland and Vancouver, 114 and 106 miles, respectively, from the ocean. Extension of ocean-carrier service to The Dalles, about 190 miles from the ocean, will be possible upon completion of the authorized project for 27-foot depth to Bonneville, as described in House Document 94. (See "Existing and authorized projects," in par. 104.) Existing 24-foot depth navigation locks at Bonneville Dam can pass ships to Bonneville pool and on to The Dalles, where ample terminals have been constructed. Penetration deep into the interior by such a major navigable waterway will be of great benefit in the transportation of exportable products and in the importation of commodities adaptable to movement by water.

140. Present navigation by river craft, though restricted by navigational difficulties above The Dalles, extends from the ocean to the present head of navigation on Columbia River at Pasco, Wash., 328 miles upstream. With completion of McNary Dam, the head of navigation on Columbia River will be extended about 24 miles farther upstream to within 10 miles of the Hanford Engineering Works. Restricted navigation is now possible on 140 miles of Snake River from the mouth to Lewiston, Idaho, a reach for which improvement by a series of dams to provide slack-water conditions for navigation has been authorized. The 92-mile stretch from Lewiston upstream to

Johnsons Bar is now navigated by light-draft launches in regular service.

141. The volume of commerce that moved on Columbia River in the year 1946, as shown in the following tabulation, is an indication of the present importance of navigation:

Section of river	Tonnage	Remarks
Mouth to Vancouver-Portland	6,900,000	Ocean traffic.
	8,900,000	River traffic.
Total	15,800,000	
Vancouver-Bonneville	2,570,000	Do.
Bonneville-The Dalles	1,019,000	Do.
The Dalles-Umatilla	744,000	Do.
Umatilla-upstream	318,000	Do.

142. In 1947, commerce on the Bonneville-The Dalles section was 1,300,000 tons and on The Dalles-Umatilla section it was 834,000 tons; increases of 28 and 12 percent, respectively, over 1946. A future annual average of nearly 5,000,000 tons of commerce probably will move on the river between Pasco and Bonneville to lower river ports upon the completion of authorized and proposed slack-water and other improvements.

143. *Problems affecting ship navigation.*—Existing and authorized projects provide for a main ship channel between Pacific Ocean and The Dalles, a distance of 190 miles, and for side channels to serve ports along both sides of the river. Other projects authorized, but for which sufficient funds have not been made available, are completion of the ship channel between Vancouver and Bonneville Dam, including improvement of the lower entrance to Bonneville lock; a turning basin at Camas, Wash.; and rock removal above Bonneville Dam. Completion of the foregoing incompleted projects will solve the problems in these stretches. Dimensions of the auxiliary ship channel at Westport, Oreg., for which the existing project makes provision, have been found inadequate for postwar ships. A survey has been made, and modification of the existing project was recommended in a report by the district engineer, Portland district, dated April 15, 1947.

144. The existing project at the mouth of Columbia River provides for a depth of 40 feet over a width of not less than one-half mile through the entrance. The project was completed in 1917 and was adequate, under normal sea conditions, for ships with load drafts common to Pacific coast harbors at that time. Post-World War II tankers and cargo ships are larger than earlier vessels, and draw 3 to 4 feet more water when fully loaded. Just inside the entrance, the channel was dredged to a minimum depth of 41 feet during the 1947 season, but complaint has been registered by pilots that it is frequently found necessary to veer to the north of the range and run close to the north jetty to find deeper water for heavily laden ships. Occasionally it is found inadvisable to proceed through the entrance and ships are delayed awaiting more favorable conditions. A minimum depth of 48 feet in the main entrance channel is requested by the Columbia River Bar pilots and other shipping interests to provide safe passage for ships in the rough seas that cause "sounding" as much as 10 to 15 feet deeper than normal ship draft.

145. *Navigation problems affecting river craft.*—The most pressing river craft problems occur in that stretch of the river between The Dalles and Pasco, which is a very important connecting link between the interior region and the centers of population and seaports of lower Columbia River. As a result of the full utilization of the water resources of the region, an estimated total of about 5,000,000 tons of commerce will become available annually in the future, for transportation over this stretch of river.

146. Navigation problems to be solved arise from swift currents; insufficient depth and width of channel during a large part of the year; narrow, rock-bound channels lined with points on the sides and pinnacles on the bottom; excessive length of time required for passage through The Dalles-Celilo Canal and locks; and shallow water between the main channel and shore installations where interchange of cargo between land and river takes place. Other conditions, such as high winds and occasional closure of the river by ice, add to the hazards and complicate the problems encountered. Increasing numbers of recreational and commercial fishing craft owners demand safe harbors and facilities in which this type of craft can be moored, stored, and serviced.

147. In the 36-mile stretch between McNary Dam (mile 292) and Pasco (mile 328) there are two major rapids, Umatilla and Homly, through which upstream tows are limited to one barge. Above Pasco, the present head of scheduled navigation, available depths are inadequate during a large part of each year. The present channel problems in the 60-mile stretch within the boundaries of McNary pool will be eliminated when McNary Dam, now under construction, is completed.

148. The 100-mile stretch of river between McNary Dam and the head of Bonneville pool, at The Dalles, presents the most serious remaining navigation problems, insofar as river craft are concerned. In this reach, 11 major rapids occur. The rapids have an aggregate length of 13 miles of narrow, rock-bound channel through which velocities range from 5.4 to 9.8 miles per hour at medium river stages. Under these conditions, the use of towboats of about double normal power is required, and the barge load and number of barges per tow are restricted. Four-barge tows can be handled only about 30 percent of the time, even with towboats of 4,000 horsepower.

149. From McNary Dam downstream to the head of The Dalles-Celilo Canal, the presently authorized project, when completed, will provide a channel 150 feet wide and 7 feet deep at low water. The uncompleted work consists of removal of a shoal 3 miles below McNary dam site, and channel rectification at Indian, Squally Hook, and Owyhee Rapids. The low-water fall in this reach of river is 123 feet, from elevation 250 at McNary Dam to elevation 127 at the head of Celilo Falls. Much of this fall is concentrated in the rapids, some of which, with current velocities, are shown in the following tabulation.

Rapid	Velocity in miles per hour [1]			
	Discharge of 105,000 second-feet		Discharge of 230,000 second-feet	
	Average	Maximum	Average	Maximum
Devils Bend	3.4	5.4	6.5	7.0
Canoe Encampment	4.6	7.0	7.4	7.8
Owyhee	4.3	7.3		8.7
Blalock	4.0			
Four O'Clock	4.8	8.0	5.7	6.3
Rock Creek	5.8	9.8	4.8	4.8
Squally Hook	4.3	7.5	6.4	7.2
Indian	3.7	6.5	8.2	9.6
John Day	4.0	7.5	6.2	7.8

[1] Velocities estimated from surface float measurements made in 1936. Some channel improvement work has been done since that time but velocities have not been affected appreciably.

In addition to the high velocities, ranging up to 9.8 miles per hour, the channels through the rapids are narrow and hazardous.

150. The Dalles-Celilo Canal has a controlling depth of 7 feet 8 inches over a bottom width of 65 feet, while the four single-lift locks have usable widths of only 45 to 50 feet, usable lengths of 265 feet, and controlling depths over the sills of 7 feet, at design stage. The 8.5 mile canal, with limited width and depth, small size locks, and exposure to wind and local silting, constitutes a serious handicap to economical navigation on Columbia River. Tows must be broken and barges passed singly through the locks and canals at slow speeds. As much as 15 hours are required to transit a four-barge tow between The Dalles and a suitable break-up and reassembly point above the canal, even with the assistance of a shuttle tug.

151. Navigation conditions through the downstream approach to The Dalles-Celilo Canal, from mile 191 to 192.8, have been improved considerably by the raising of the Bonneville pool, but still remain difficult because of cross currents and eddies at Sturgeon and Covington Points, and at the entrance to Big Eddy lock. The flow through this constricted zone is very swift and irregular, with velocities approaching 10 miles per hour at a discharge of 500,000 second-feet.

152. Under open-river conditions, winds which sweep this section of the river much of the time have discouraged two-way loading by the use of double deck barges with housing for dry cargo on main deck. The additional surface of a superstructure exposed to high winds adds much to the difficulty of maintaining position in narrow channels. All the navigation difficulties and hazards enumerated result in high insurance rates and abnormal barge-operating costs. Problems created by windstorms and ice, inherent by nature to middle Columbia River, are not susceptible to solution on a basin-wide scale, but ports of refuge can and should be provided.

153. Excepting wind and ice, Bonneville pool presents no navigational problems for which provisions are not made by authorized projects, but barge operators have stated that the present Bonneville lock is inadequate in size, and that it imposes burdensome cost and delay in having to break up tows for passage. The lock has a minimum depth of 24 feet over the sills and clear plan dimensions of 76 feet by 500 feet; sufficient to accommodate two barges 40 feet by 175 feet, four barges 36 feet by 175 feet, or five barges 36 feet by 150 feet,

all with accompanying towboats. One self-propelled barge of 3,000 horsepower now in operation on that section of the river is 190 feet long and can be accompanied through the lock by one of the larger barges mentioned above.

154. Conditions at the lock were the subject of investigation and report in 1946, published in House Document No. 704, Seventy-ninth Congress, second session. Altered circumstances, including a substantial increase in the tonnage passing through the locks, an increase in estimated future commerce, and the probability of use by ocean shipping after completion of the ship channel between Bonneville and Vancouver, indicate the subject to be worthy of further study.

155. For a distance of about 1 mile downstream from the lower end of the Bonneville lock, along Hamilton Island where the river is constricted to a width of 800 feet, natural current velocities range from 3.5 miles per hour at minimum flow to about 8.5 miles per hour at a flow of 400,000 second-feet. The latter flow is exceeded only about 45 days per year on an average. At 800,000 second-feet, the velocity would be about 12 miles per hour. This reach, through which four-barge tows can be handled without difficulty except at high stages, will be a controlling factor insofar as towboat power and size of ascending tows are concerned, and may present some difficulty in future ship navigation.

156. *Future problems.*—After construction of the proposed dams, higher water levels will be established, and problems will arise in connection with present or relocated terminal facilities at ports and landings where the augmented volume of commerce, expected to follow the completion of each project, will be interchanged between river and land. Provision of access channels and excavated harbors may become necessary for the safety and convenience of commercial navigation and for recreational and fishing craft. The location, nature, extent, and cost of such approach channels and harbor work can be determined only in a preliminary way at this time. Selection of sites must give consideration to such prime factors as highway and railroad intersection, topography, bottom contours, bridge interference, tributary tonnage, and protection from ice and wind.

FLOOD PROBLEM

157. *General.*—Major floods on Columbia River in this sub-basin inundate or adversely affect an area of about 300,000 acres, including agricultural lands, 15 cities, several towns, main- and branch-line railroads, highways, air terminals, and lines of communication. The flood problem is especially critical in the industrial and agricultural areas downstream from the confluence of Sandy River.

158. In addition to problems on Columbia River proper, backwater causes serious flood conditions on the lower reaches of tributaries. The industrial and urban areas along Willamette River in and downstream from Portland, and on the lower reaches of other tributaries, are considered in connection with study of the flood problem for Columbia River, as the major damage in those areas is caused by backwater. The heaviest damage is suffered along lower reaches of Columbia River because of the highly developed lands adjacent to the river and the inundation of part of the metropolitan areas of Portland and Vancouver. Existing upstream storage dams, as now

operated, do not provide peak stage reductions, and local levee and diking projects are, in many cases, inadequate to provide protection against major floods. Further, considerable areas of low-lying lands are not now leveed or otherwise protected against damage from floods.

159. *Past floods.*—Annual floods on Columbia River occur in the spring or early summer months, as a result of snow-melt. Winter floods, resulting from intense rainstorms, especially over the lower tributaries, also cause considerable damage. In the 90-year period since 1858, 24 floods have equaled or exceeded a discharge of 714,000 second-feet at The Dalles. Of that total, 10 floods exceeded 800,000 second-feet, and 3 floods exceeded 1,000,000 second-feet. Table 2 shows maximum floods of record from 1879 to 1946, and the tabulation in paragraph 33 shows order of magnitude, peak discharge, and duration above 600,000 second-feet for the 24 largest floods. A discharge of 600,000 second-feet at The Dalles corresponds to stages of about 22 feet at Vancouver and 21.5 feet at Portland.

160. The greatest known flood on lower Columbia River, which occurred in June 1894, reached a stage of 34.4 feet at Vancouver, and the backwater caused a stage of 33 feet on Willamette River at Portland. All the bottom lands along Columbia River, including all or parts of the towns of Kelso, Kalama, and Vancouver were flooded. The entire area where Longview is now located was inundated, as were more than 300 blocks in the downtown area of Portland. All railroads and highways leading north and east from Portland were closed. No estimate is available of the damage done at that time, but newspaper accounts listed extensive property damages. Should a flood of this magnitude occur under present conditions of economic development, the damages in this sub-basin would amount to about $213,000,000.

161. The second-largest known flood occurred in 1876. Data are not available as to duration or damages.

162. The third-largest flood of record occurred in late May and in June 1948 and reached stages of 30.2 feet at Vancouver, 29.95 feet at Portland, and 51.8 feet at The Dalles. The discharges recorded are almost identical with those determined for the flood of 1876 at The Dalles, but stages in the lower river from Camas to below Longview were from 0.8 foot to 1.5 feet higher because of constriction of the waterway by numerous levees, railroad and highway fills, bridges, docks, and other improvements, and because of the effect of a 9-foot tide.

163. Approximately 251,000 acres were inundated and 5,000 homes destroyed by the 1948 flood. Nearly 35,000 people were made homeless, and approximately 100,000 persons were evacuated. Enormous damage to crops, lands, industrial and commercial properties, and other improvements resulted from inundation and high velocities. All highways, railroads, and navigation facilities serving the Portland-Vancouver area from the east, north, and west were disrupted; the Portland and Vancouver airports were inundated; and transportation and lines of communication generally were seriously affected. Levees protecting 18 districts were overtopped or breached, and many other levees were maintained only with great effort. Failure of the levee protecting the Vanport housing project at Portland was one of the most disastrous occurrences. Throughout the sub-basin, at least 28

persons lost their lives, 8 persons are listed as missing, and large numbers were injured and affected by shock and exposure. General inoculation against typhoid and other infectious diseases prevented serious epidemics.

164. Detailed damage surveys are still in progress, but preliminary estimates, believed conservative, indicate that damages in this subbasin amount to about $79,000,000. Modification of the estimate may be required when surveys are completed.

165. Of particular importance in increasing damages due to this flood was the enormous volume of run-off and prolonged period of high stages. The river reached flood stage at Vancouver, 15 feet on the gage, on May 19, and first crested at 30.2 on June 1. Additional crests of over 30 feet occurred on June 8 and June 14, and the recessions between crests ranged from a few tenths to less than 1 foot. Following the final crest, the river dropped below flood stage on July 9. Thus, the river was in flood for 52 days, including 17 days during which it was above 29 feet at Vancouver. The total run-off passing The Dalles from May 15 to July 15, 1948, is estimated to have amounted to 91,700,000 acre-feet.

166. The most recent major flood prior to 1948 occurred in June 1933, when the river stage reached 25.5 feet at Vancouver. This flood inundated all unprotected lowlands, and, because the inadequate existing levees were breached, many areas protected against normal high waters were flooded, particularly at Kelso, Wash., and Sauvie Island, near the confluence of Columbia and Willamette Rivers. Many other agricultural areas were damaged because of seepage and inability to secure normal drainage. A flood of the magnitude of that of 1933 occurring under present conditions of economic development would result in damages of about $4,500,000.

167. *Existing conditions.*—Flood stage is normally considered as 15 feet on the Vancouver gage. Damages occur, however, at stages down to 12 feet, principally to low-lying pasture and agricultural lands along the river and to the several mills where log booming areas, docks, and other river commerce facilities are so located as to function at normal river stages. Stages of about 25 feet cause inundation of low-lying industrial areas and extensive seepage through and under levees, and generally disrupt river traffic. As stages increase above 25 feet, the damages increase rapidly. The June 1933 flood caused very serious damage to existing levees, industrial properties, and utilities. Levees have been raised and strengthened since that flood occurred, but additional development has taken place outside the levees and damage to such development tends to offset the reductions occasioned by increased levee protection.

168. Much of the lowland along lower Columbia River has been protected against normal high tides and floods by levees constructed by local interests. Levees have been raised and strengthened by the Corps of Engineers to protect 92,117 acres of the more valuable suburban and agricultural lands. Some urban and highly developed industrial areas are now protected against a flood equal to that of 1894, and less highly developed agricultural areas are protected against a maxi-

mum stage equal to that reached in 1948 or June 1933. The city of Portland has constructed a harbor wall to protect the main west-side commercial area. The flood wall, together with emergency measures such as construction of sand-bag levees and auxiliary pumping of seepage water, provided protection against the 1948 flood. The harbor wall is not adequate for protection against a flood of 1894 magnitude. Material dredged from the harbor has been used to raise some of the Portland industrial areas above flood stages ranging from 30 to 32 feet. Woodland, Kelso, and Longview and other urban areas have constructed levees and flood walls to give similar protection.

169. *Estimates of present and future damages.*—In estimating future damages, all levee systems, including railroad and highway embankments, were assumed restored at least to the state which existed prior to the 1948 flood. Without additional improvement to levee systems, substantially the same potentialities for damages would exist after restoration, except for the Vanport area. It is presumed that housing development in that area will be prohibited in the future, but industrial expansion, at least in the higher sections of the area, is imminent. Future damage potentialities, therefore, based on 1948 conditions of economic development after anticipated restoration of levee systems and properties, are estimated to be $4,497,000, $52,317,000, and $212,864,000, respectively, for floods similar to those of June 1933, 1948, and 1894. These floods were analyzed as representative annual summer floods, and data obtained were used as key points on damage curves for various river stretches.

170. Estimates of damages within this sub-basin that would result from repetition of the June 1933 and 1894 floods under 1948 conditions of economic development anticipated after restoration from the 1948 flood, and preliminary estimates of the actual damages within this sub-basin caused by the 1948 flood, are shown in part II of this appendix. The following tabulation summarizes estimated flood damages, by type of damage, for these floods:

Type of damage	Estimated amount of damages		
	1933 [1]	1948 [2]	1894 [1]
Agricultural	$1,502,000	$15,935,000	$27,925,000
Residential	64,000	25,805,000	18,062,000
Commercial	157,000	8,686,000	33,684,000
Industrial	1,137,000	11,437,000	94,335,000
Utilities	400,000	1,832,000	10,031,000
Municipal	75,000	3,105,000	3,185,000
Highways, roads, and bridges	290,000	2,848,000	4,200,000
Truck and bus facilities		84,000	345,000
Railroads	77,000	916,000	7,045,000
Air terminals		290,000	360,000
Navigation facilities	80,000	835,000	2,670,000
Dikes and protective works	715,000	3,500,000	7,100,000
Emergency expenses		3,545,000	3,922,000
Total	4,497,000	78,818,000	212,864,000

[1] Estimates based on 1948 economic development, and assuming restoration of properties and protective works as discussed in preceding text.
[2] Preliminary estimate of actual damages, exclusive of losses due to sedimentation of channels.

171. The preceding estimates of damage include both direct damages and indirect losses. Direct damages average about 76 percent of the total, the percent of indirect losses increasing as the total damages increase. Comparison of direct damages and indirect losses is shown in the following tabulation:

Item	Amount [1]		
	1933	1948	1894
Direct damages	$3,748,000	$59,644,000	$144,843,000
Percent of total	(83.4)	(75.7)	(68.1)
Indirect losses	$749,000	$19,174,000	$68,021,000
Percent of total	(16.6)	(24.3)	(31.9)
Total	$4,497,000	$78,818,000	$212,864,000

[1] Based on data from preceding tabulation.

172. Estimated damages for the flood of 1948 and floods similar to those of June 1933 and 1894, as determined for various zones on stretches of the river, are shown in the following tabulation:

Stretch of river	Estimated damages		
	1933 [1]	1948 [2]	1894 [1]
Yakima River to Bonneville (Washington and Oregon shores)	$67,000	$1,473,000	$3,462,000
Bonneville to Camas (Washington side) and to Sandy River (Oregon side)	228,500	1,943,000	5,266,000
Camas, Wash., to Lewis River	411,000	3,692,000	30,840,000
Sandy River to Willamette River	325,000	38,796,000	54,315,000
Willamette River backwater area	509,000	10,275,000	65,262,000
Lewis River to Baker Bay	1,858,000	14,978,000	34,334,000
Willamette River to Youngs Bay	1,098,500	7,661,000	19,385,000
Total	4,497,000	78,818,000	212,864,000

[1] Estimates based on 1948 economic development, and assuming restoration of properties and protective works as discussed in preceding text.
[2] Preliminary estimate of actual damages, exclusive of losses due to sedimentation of channels.

173. In view of the anticipated growth and development in this section of Columbia River Basin, neither the 1948 economic developments nor estimates of damages for actual or assumed 1948 conditions are representative of future conditions. In making a long-range forecast of future damages, consideration has been given to economic developments probable in 1975 as a result of normal growth and expansion without additional flood-control improvements. Although certain flood-control improvements probably will be constructed before 1975, complete control of floods by reservoirs and supplemental local protective works probably could not be realized before that date. Forecasts of economic development and potentialities for flood damage are made by weighted percentage factors for various zones or stretches of the river, based on trends of population, and agricultural, residential, commercial, industrial, and other growth. Supporting data as to the percentage factors used are shown in part II of this appendix. Consideration of economic developments reasonably expected by 1975 indicates the following probable damages for the three representative floods heretofore analyzed.

Stretch or zone	Estimated 1975 damages for floods similar to those of—		
	1933	1948	1894
Yakima River to Bonneville	$80,000	$1,841,000	$4,501,000
Bonneville to Camas, Wash., and to Sandy River	274,000	2,428,000	5,026,000
Camas, Wash., to Lewis River	740,000	7,264,000	65,648,000
Sandy River to Willamette River	481,000	19,640,000	95,142,000
Willamette River backwater area	692,000	14,899,000	100,503,000
Lewis River to Baker Bay	2,452,000	20,342,000	50,814,000
Willamette River to Youngs Bay	1,318,000	10,327,000	25,200,000
Total	6,037,000	76,741,000	346,834,000

174. *Winter floods.*—The lands along lower Columbia River, below the confluences of Willamette River in Oregon and Lewis and Cowlitz Rivers in Washington, are subject to flooding during winter months by reason of high discharges from these streams coinciding with normal or above-normal flows in Columbia River and the usual high tidal conditions prevailing during those months. During winter floods, stages at Vancouver frequently are above the 15-foot flood stage. These floods cause considerable damage, especially downstream from the mouth of Cowlitz River, by inundation of low-lying lands, erosion of levees and river banks, and crop and property losses. Duration is comparatively short and the highest stages normally last only 1 or 2 days. Stages are reached, however, that greatly increase seepage into and pumping from leveed areas. Agricultural crop damages in winter floods are somewhat lower than those suffered from comparable summer floods, because of the fact that large areas are fallow during the winter season.

175. The highest winter flood of record occurred in December 1933. At Cathlamet, Wash., the stage during this flood was only 2 feet lower than during the flood of June 1894. The December 1941 flood reached nearly the same stage on the lower river as did the December 1933 flood, but was lower above Longview and did much less damage because of the effect of levees and revetments constructed between 1933 and 1941. Surveys made following the December 1933 flood showed that about 75,000 acres were flooded, and that flood damages ranged from $2 to $11 per acre. About 20,000 acres of this land, however, had adequate protection against the 1941 flood, and suffered very little damage at that time.

176. A smaller flood, which had a stage of 18.7 feet at Vancouver, occurred in December 1946. Damages between Washougal, Wash., and St. Helens, Oreg., including the water-front area in Portland, amounted to about $140,000, including $70,000 to industries; $40,000 to utilities, commercial concerns, and residential properties; and $30,000 to agricultural properties.

177. From surveys and from a review of conditions existing in 1933 and 1941, a repetition of a flood similar to that of 1933 or 1941 would cause estimated damages of about $2,000,000 based on 1948 economic developments and assuming restoration of levees and properties as previously described. About $750,000 of these damages would be in Oregon and $1,250,000 would be in Washington.

178. *Annual damages.*—Average annual damages are estimated from stage-damage and stage-frequency relationships determined by

individual curves for The Dalles, Vancouver, Portland, and Longview for spring and summer floods and for Longview and Cathlamet for winter floods. Analytical computations have been made which substantially check values obtained by graphical analysis. An explanation of the method of analysis, together with frequency curves, mass diagrams, and analytical computations, is contained in part II of this appendix. The estimated average annual damages for the several zones or reaches of the river, reflecting probable 1975 economic development and current protective installations, are summarized in the following tabulation:

Zone or stretch	Average annual damages	
	1948 developments	1975 developments
Spring and summer floods:		
Yakima River to Bonneville	$173,000	$216,000
Bonneville to Camas, Wash., and Sandy River	241,600	302,000
Camas, Wash., to Lewis River	1,018,000	2,036,000
Sandy River to Willamette River	2,201,900	3,523,000
Willamette River backwater area	2,526,600	3,664,000
Lewis River to Baker Bay	1,993,900	2,791,000
Willamette River to Youngs Bay	1,009,200	1,262,000
Subtotal	9,164,200	13,794,000
Local winter floods:		
Vancouver, Wash., to Cowlitz River	65,200	98,000
Cowlitz River to Baker Bay	155,700	218,000
Willamette River to Rainier, Oreg	37,900	47,000
Rainier, Oreg., to Youngs Bay	98,400	123,000
Subtotal	357,200	486,000
Total	9,521,400	14,280,000

179. *General solution.*—General solution to the flood problem in this sub-basin would involve provision of local flood protective works and storage capacity for flood control on Columbia River and the major flood-producing tributaries. A main control plan, the units of which are discussed in appropriate sub-basin appendixes, is set forth in the main report and analyzed in detail in appendix M.

POWER PROBLEM

180. *General.*—The market for power generated in this sub-basin is concentrated in the vicinity of Portland, Vancouver, and Longview. The power load in these centers consists of well diversified domestic, rural, commercial, and industrial loads. The most important single load is that of the aluminum reduction industry which requires large amounts of firm power.

181. *Estimated power requirements.*—In 1947, the average and maximum requirements of two aluminum reduction plants located at Vancouver, Wash., and Troutdale, Oreg., both within 10 miles of Portland, and a third plant at Longview, Wash., totaled 319,000 kilowatts and 385,000 kilowatts, respectively. These totals are roughly equal to the average requirement, and over one-half the combined maximum demand, of other classes of consumers in the same area. Studies by Bonneville Power Administration, reproduced as appendix N to this report, indicate that by 1960 the aluminum

reduction load in the entire Pacific Northwest may be increased by a minimum of 2,000,000 kilowatts, provided the necessary low-cost energy is available. If reduction facilities should increase throughout the Northwest at the present rate, the total aluminum reduction load in the lower Columbia River area alone would be at least 1,500,000 kilowatts by 1960, an increase of more than 1,000,000 kilowatts.

182. Although the aluminum load is by far the largest single class of load in the area, its significance in the economic and social life of the community is overshadowed by the rural and domestic loads. Because of the prevailing low power rates, residential and rural consumption of electric energy is over twice the Nation-wide average, and costs are about one-half as much per kilowatt-hour. Most of this increased consumption is due to electric cooking and water heating, an increasing amount of electric house heating of various types, and expanding uses for electricity on the farm.

183. *Existing conditions.*—As listed by the Federal Power Commission, steam plants constitute over 68 percent of the generating capacity contributing to the public supply in the United States as a whole. In comparison, nearly 90 percent of the total capacity of the major utilities in the Pacific Northwest is in hydroelectric plants. The larger percentage of hydroelectric generation in the vicinity of Portland and in the Northwest is possible because many sites suited to the economical development of water power are situated within a few miles of the important load centers. With the exception of the Rock Island plant of the Puget Sound Power & Light Co., existing privately owned generating stations are located on tributaries of Columbia River or on relatively small rivers in the Puget Sound area. As few sites remain which can be developed with moderate capital expenditures, attention now is turning to large-scale development of Columbia River and major tributaries by agencies of the Federal Government.

184. A further characteristic of the Pacific Northwest is that supplies of coal and oil are not available in the quantity or at a price that would permit thermal-electric plants to compete with hydroelectric generation for the major portion of the load. Some coal is mined in the general vicinity of Seattle, but the ash and moisture content is usually so great that it cannot be considered a high-grade fuel. The only large sources of coal available to the area are the Montana, Wyoming, and Utah fields, which are over 500 miles by rail from Portland and Seattle. Most of the oil for this area comes from California by tanker. Economic studies, contained in appendix O, compare the relative costs of steam-electric and hydroelectric power and clearly show the high cost of steam power in this region.

FISH AND WILDLIFE PROBLEMS

185. *Salmonoid fish.*—The major fish problem resulting from present and proposed development of Columbia River in this sub-basin is the need for preservation of fish runs using the river both as a migratory route and as a spawning area. The salmonoid runs of the Columbia River system consist of Chinook, blueback, silver, and chum salmon, and steelhead trout. The Chinooks spawn in nearly all accessible tributaries of the river both above and below Bonneville Dam, and biologists believe also that some spawn in portions of the main stem.

Bluebacks, a large number of which are known to migrate up Snake River and past Rock Island Dam on Columbia River, spawn in tributaries above Bonneville Dam. A large proportion of the silver and chum salmon spawn in tributaries below Bonneville Dam. Steelhead trout spawn generally throughout the accessible tributaries but apparently are more abundant in the upper streams. The general distribution of the salmonoid population in the Columbia River system, as estimated by fishery interests, is tabulated as follows:

Species	Percentage in tributaries below Bonneville Dam	Percentage in Columbia River system between Bonneville and Rock Island Dams	Percentage migrating above Rock Island Dam
Spring Chinook salmon	15	81	4
Fall Chinook salmon	60	40	0
Blueback salmon	0	86	14
Silver salmon	70	30	0
Chum salmon	80	20	0
Steelhead trout		60-70	

186. The magnitude of Columbia River fish runs is indicated by the 798,336 salmonoid fish which were counted going over the Bonneville Dam fish ladders during 1947. Fish counts showing the annual migrations of the various species of salmonoid fishes past Bonneville Dam from 1938 to 1947, inclusive, are shown in table 26. A summary follows:

Calendar year	Fish passing Bonneville Dam		Calendar year	Fish passing Bonneville Dam	
	Salmonoid	Other		Salmonoid	Other
1938	471,144	614,897	1945	428,652	309,139
1939	497,091	464,684	1946	667,720	364,707
1940	739,138	364,210	1947	798,336	408,297
1941	668,455	269,820			
1942	623,084	245,029	Total	5,703,573	3,458,337
1943	448,436	187,277	1938-47 average	570,357	345,833
1944	361,517	230,277			

187. The natural propagation of salmonoid fish is supplemented by artificial propagation at numerous fish hatcheries operated by the Oregon Fish Commission, the Washington State Department of Fisheries, and the United States Fish and Wildlife Service. The location of hatcheries in the vicinity of Columbia River is shown on plate 20.

188. Fishways are included in plans for each of the proposed dams on Columbia River. The design of these fish-passage facilities involves both biological and engineering problems. As the heights of the dams are increased the problems become more complex. Fishery biologists believe that even with the best designed fish-passage facilities some upstream migrants will not attempt passage or may be unable successfully to negotiate the fishways. Another possible fish loss may be incurred because of inundation of spawning grounds located in the pool areas.

189. In view of the apparent necessity for restitution of any losses which may be incurred and for rehabilitation and maintenance of salmonoid fish runs now supported by Columbia River and tributaries, provisions for comprehensive development of the tributaries downstream from McNary Dam in the interest of fish life are proposed as part of the over-all plan of river development, as discussed in appendixes K and P.

190. *Indian fishing problem.*—By a treaty negotiated in 1855, certain Indian tribes retained the right in perpetuity to take fish at their usual and accustomed fishing places along Columbia River. About 5,000 Indians now claiming such rights frequent the principal and most productive remaining fishing location at Celilo Falls. The Indians are accustomed to take fish for sustenance, for retail sale of fresh food, and for sale to commercial canneries. In the commercial fisheries, the Indians abide by the regulations of the States of Oregon and Washington.

191. The proposed The Dalles Reservoir would inundate the Celilo Falls fishing grounds and partially inundate the Indian villages associated therewith. Although payment for lands and improvements affected may be made readily, and alternate locations to take fish for sustenance and for limited retail sale may be found, undoubtedly the Indians' commercial fishing cannot be continued under the usual methods. This situation is further complicated by the fact that certain Indians depend, to a large extent, upon this resource for a livelihood, and it would be desirable to preserve their economic independence.

192. *Wildlife.*—The principal wildlife problems would originate from the inundation of important waterfowl nesting areas. Some inundation of fur bearer habitat probably will take place, but most of the animals so affected are expected to move to areas on higher ground. Additional investigations and studies by the United States Fish and Wildlife Service are required to determine the extent and type of protective measures which would be needed to preserve the wildlife in this reach.

DRAINAGE PROBLEM

193. *General.*—Drainage problems along lower Columbia River are of two general types. Lands downstream from Cathlamet, Wash., are affected primarily by tidal action and may be drained effectively by use of tide gates, while those lands upstream from that city, being affected primarily by flood waters, require pumping to remove interior drainage and seepage during the flood season.

194. *Existing conditions.*—Present drainage for a major portion of the protected lands is limited to collection of surface run-off by open ditches. Existing tide gates and pumping installations are adequate to maintain water levels at elevations low enough for subsurface drainage facilities to function in some areas, which are so drained.

195. Existing drainage facilities on most of the cropped land generally hold the ground-water table a short distance below the surface during the winter and spring months when high surface run-off and low river stages are prevalent. Except under conditions of extreme high water, the ground-water table can be maintained at about the same level during the early summer, when high river stages, with

resulting high seepage and low surface run-off, are prevalent. During the late summer and early fall, however, as seepage decreases with decreasing river stages and surface run-off is a minimum, the ground-water surface may drop several feet. Partial control of the water-table elevation provides a degree of subsurface irrigation in some areas.

196. These ground-water conditions are favorable for the production of pasture grasses and spring seeded hay, grain, and truck crops. Inadequate root development, as a result of a relatively high ground-water table during the spring months, sometimes aggravates drought conditions in the late summer or early fall.

197. *Improvements desired.*—Installation of facilities for relatively complete drainage is considered very desirable by the majority of the owners of bottom lands. These owners have organized five soil conservation districts to aid in improving the surface drainage facilities, to secure more effective outlets, and to develop a relatively complete drainage program. Conservation districts cover Sauvie Island, Puget Island, and the majority of the low lands on both sides of the river. In addition to the lands on which partial drainage has been effected, about 70,000 acres in the flood plain outside of diked areas have had negligible improvement. About 27,600 acres in Washington, and 27,800 acres in Oregon, warrant investigation as to feasibility of protection and drainage. The remaining area is of submarginal character.

IRRIGATION PROBLEM

198. *General.*—The principal irrigation problem consists of the need for supplying water for irrigable lands which lie above possible gravity diversions from Columbia River. Preliminary investigations indicate that about 448,000 acres, lying at elevations up to 1,000 feet, may be irrigated by pumping from the pools which would be formed by proposed multipurpose dams in Columbia River, or possibly by diversion from certain tributaries. Further studies will be necessary to determine the most economical and dependable source of supply for all areas concerned. Preliminary investigations indicate that water may be delivered by pumping to lands adjacent to the river at costs as shown in the following tabulation:

Acres of land	Distance from river, miles	Lift in feet	Duty in acre-feet per acre	Annual cost per acre
55,200	1.5	200	4	$6.50
151,300	10.0	460	4	15.00
241,500	15.0	600-700	3.6	20.00

These costs include retirement of costs of plants in 40 years, operation and maintenance, and power at 1 mill per kilowatt-hour, but do not include interest or distribution system costs. The costs indicate that only the lower elevation lands near the river can be irrigated and utilized economically for ordinary field crops. Those lands with lifts above 400 feet apparently could support a diversified agricultural economy, including 50 percent or more intensified, high return crops. Where lifts of over 600 feet would prevail, only very high return crops, such as orchard or intensive truck crops, could be expected to pay irrigation costs.

199. Lands presently irrigated and those for which irrigation is considered possible are shown in the following tabulation:

Area	State	Area, acres	
		Presently irrigated	Considered for irrigation
Scattered areas, lower Columbia River	Oregon and Washington	4,000	40,000
Pasco-Kennewick area	Washington	11,600	
Horse Heaven	do		127,200
Irrigon area	Oregon	14,000	
Cold Springs	do		36,700
Arlington	do		11,500
Roosevelt	Washington		1,500
Willow Creek [1]	Oregon		135,100
Walla Walla [2]	Washington and Oregon		80,000
The Dalles	Oregon		16,000
Total		29,600	448,000

[1] Included in John Day project, considered by Bureau of Reclamation for irrigation from John Day River.
[2] Not considered by Bureau of Reclamation in comprehensive report dated June 1946.

200. Three of the irrigation projects listed above—the Horse Heaven area, Cold Springs area, and the Walla Walla area—would be supplied with water by pumping from the pool behind NcMary Dam. The Horse Heaven area, north of the river in Washington, would require pumping lifts of 700 and 460 feet. The higher lift would supply 66,000 acres and the lower lift 47,500. Return flow from these two higher areas would be utilized on 13,700 acres of lands below elevation 676 feet. The Cold Springs area in Oregon along Columbia River near Hermiston and Stanfield, would require a pumping lift of about 700 feet. The Walla Walla area, located along both sides of Walla Walla River in Washington and Oregon, would require a pumping lift of about 700 feet.

201. The Arlington, Roosevelt, and Willow Creek areas could be supplied with water by pumping from the pool behind the proposed John Day Dam. A pumping lift of about 603 feet would be required to supply the Arlington area east of Alkali Canyon and west of Willow Creek. The Roosevelt area, in the vicinity of Roosevelt, Wash., could be irrigated with a pumping lift of about 240 feet. The Willow Creek area, located in Morrow and Umatilla Counties, Oreg., could be served with a pump lift of about 550 feet.

202. The Dallas area would involve pumping to an elevation of 800 feet, or higher. Of approximately 6,000 acres now used for orchards and truck crops, only 400 acres are irrigated from Mill and Threemile Creeks. Local interests have formed an organization and propose to irrigate about 7,000 acres. The Bureau of Reclamation is now considering a 6,000-acre project, which includes part of these lands, to be irrigated by a pump lift of 925 feet to an elevation of about 1,000 feet. The previously recommended The Dalles project, west unit, is described in section IV of this chapter.

203. Other potentially irrigable lands on lower Columbia River are located within the existing diking and drainage districts along the lower river. These districts contain about 120,000 acres of irrigable lands, of which 90,000 acres are protected by levees. Abundant water is available from the river, drainage ditches, or wells, with

pumping lifts of less than 50 feet. Eventually, probably one-third of the irrigable lands, or 40,000 acres, will be irrigated by small pumping installations.

204. The present production of the areas considered for irrigation in eastern Oregon and Washington is limited to dry-land wheat and pasture. The normal annual precipitation on most of these lands is less than 10 inches. Water requirements would vary from 3 to 5 acre-feet per acre on the lands to which water would be pumped, although some lands with higher water requirements at lower elevations could be irrigated by waste water and return flow. Provision of water to these lands would allow production of hay, grain, potatoes, sugar beets, fruits, and vegetables equal to the production on the presently irrigated areas in this region.

BANK EROSION PROBLEM

205. *General.*—Damage from bank erosion along Columbia River in this sub-basin is confined to the 123-mile reach between Washougal, Wash., and the Pacific Ocean. At present, a total of about 94 areas, involving a length of about 40.1 miles, are affected and require protection. Upstream from Washougal, the river banks are either rocky or otherwise generally nonerosible, and the value of adjacent property is low. Erosion, therefore, causes no significant loss. About 50 percent of the flood plain downstream from Washougal is protected by levees and is high-value agricultural or industrial property. Many of the erosion areas occur at the levees.

206. Bank erosion results principally from high stream velocities and wave action induced by wind or the passage of watercraft. The erosion now taking place generally is located from 8 to 30 feet above low water and bears no consistent relationship to the adjacent water depth. While many areas are protected by revetment, additional protection is necessary.

207. The greatest single factor contributing to bank erosion during the war years was the trial runs of the many ships built in the Portland-Vancouver area. Each ship, prior to acceptance by the Navy or Maritime Commission, was put through exhaustive speed runs and turning tests. Protective vegetation was torn away in areas which had never been eroded before, and wave-wash from present ship and small-boat traffic has prevented natural rehabilitation.

208. The banks of minor tributaries in the tidal area also are eroding at a rapid rate in certain locations. This erosion is caused by wave-wash produced by passage of fishing craft, towboats drawing log rafts, and pleasure boats. The number of small boats plying the river is increasing, and the erosion from this cause may be expected to increase.

209. Many miles of channel now are lined temporarily by log rafts which, if secured away from the shore by dolphins, serve to protect the banks. A great number of rafts, however, are allowed to float against the bank and have a detrimental effect on natural protective cover. Banks also are attacked by the repeated shifting of local accumulations of driftwood under the influence of waves and wind which action generally is disregarded by local landowners.

210. The only apparent solution to the bank erosion problem would be to provide protective works, such as revetments, and encourage the growth of natural protective cover.

RECREATION PROBLEMS

211. *General.*—The increase in population within and adjacent to the sub-basin, together with increased tourist trade, has resulted in an increasing need for recreational development. Pleasure boating originally was confined largely to lower Columbia and Willamette Rivers. Construction of Bonneville Dam and Reservoir created about 50 additional miles of good cruising water and stimulated a greater boating interest in the population adjacent to the reservoir. As a result of this greater opportunity, a demand for boat launching, moorage, service, and repair facilities has developed. The need for such facilities will be increased by the completion of additional projects, because of the greater cruising range and increased attraction for boat owners.

212. Particularly in the upper sub-basin, a need exists for day-use park developments providing opportunity for picnicking and water-associated sports. Presently developed organized camps for youth and church organizations are inadequate in number and quality of development. Opportunities for boating, swimming, and fishing are particularly wanting.

213. Despite the heavy volume of tourist travel within the sub-basin, motor courts and hotels, for the most part, are inadequate, and hotel resorts equipped for a wide range of outdoor activities are particularly lacking. In consideration of the scenic qualities of Columbia River Gorge, together with the opportunities afforded for boating, swimming, fishing, hunting, and hiking, a considerable demand for resort development may be anticipated.

214. The fish ladders, navigation locks, and power houses at large multipurpose projects hold considerable interest for the local population and tourists alike, as evidenced by the more than one-half million sightseers at Bonneville Dam during 1947. Facilities will be required for the comfort and safety of the public at all existing and proposed reservoirs.

WATER SUPPLY PROBLEM

215. *General.*—The water supply in this sub-basin is adequate to serve all irrigable lands and still have a large excess for the production of hydroelectric energy. In order to determine both the prime and secondary potential capabilities of an integrated Northwest power system on Columbia River, an analysis of past run-off records from 1878 to 1946 was made. Within the period of record, the critical power production period would have been in either the low-water season of 1936–37 or in the period from 1929 through 1932, depending upon the amount of storage available.

216. *Water supply studies.*—Inasmuch as power studies should include a number of average and above-average run-off years, as well as critical years, studies were made of the period 1927 through 1942. From the standpoint of prime capability, a low-water season such as 1936 through 1937 would be critical if the available storage were less than 20 percent of the mean annual run-off for the period 1927 through 1942. Twenty percent of that mean annual run-off would be equivalent to an effective storage above The Dalles of about 23,000,000 acre-feet.

217. During the 1936–37 low-water season, minimum flows of record, varying from a duration of 1 day to 2 months, were recorded at prac-

tically all gaging stations within Columbia River Basin. These unusually low flows were the result of an extremely cold winter, particularly December and January, together with a deficiency in winter precipitation. The annual run-off in the 1936–37 water year was the fourth lowest of record, amounting to only 66.4 percent of the long-term mean. For effective storages greater than 20 percent of the mean annual run-off, the critical period for production of prime capability would have been from September 1929 to February 1932. This period would be critical for the maximum storage proposed for the basin. The mean-annual run-off of the water years 1929 to 1931, inclusive, is 66 percent of the long-term mean and is only 5 percent greater than the mean for the minimum year of record, 1926.

218. *Depletions.*—At the present time, the stream flows of Columbia River and several of the major tributaries are affected by irrigation diversions, the most notable of which are those from Snake and Yakima Rivers. A water supply study to determine the future power capability of lower Columbia River must consider not only existing irrigation requirements within the entire Columbia River Basin, but also the requirements of future irrigation projects.

219. Irrigation at the present time depletes the flow of Columbia River above the mouth about 5,900,000 acre-feet annually. Of the new lands to be irrigated, the largest single unit is the Columbia Basin project wherein ultimately 1,027,000 acres will be irrigated. An estimated area of approximately 4,000,000 acres of additional land are to be irrigated in the basin, and about 1,500,000 acres of presently irrigated lands would receive supplemental water. Diversions would average about 5 acre-feet per acre for new lands and 1 acre-foot per acre for the lands receiving supplemental water. Because of return flows, however, the average annual additional depletions occasioned by diverting water required would be only approximately 8,500,000 acre-feet. The ultimate depletion may increase to about 15,000,000 acre-feet annually. This ultimate irrigation depletion is about 10 percent of the average annual observed flow of the stream, leaving 90 percent for power production at the lower river power plants. Storage, however, would be essential for the development of maximum power potentialities in this reach. Appropriate stream-flow reductions to reflect future irrigation depletions were made in the observed 1927 through 1942 flows. Tables 3 through 7 show observed and modified mean monthly flows for existing and proposed projects on Columbia River.

220. A flow duration curve of observed Columbia River discharges at The Dalles, plate 13, shows that the extremes in mean daily discharges in the period 1879 through 1946 were 36,000 second-feet and 1,160,000 second-feet, on the basis of data published prior to the 1948 flood. Data obtained during that flood indicate that the maximum daily discharge should be 1,230,000 second-feet. The following tabulation shows discharges that have been equaled or exceeded 100, 90, 75, 50, and 25 percent of the time during the 69-year period, 1879 through 1946:

Flow equaled or exceeded—	*Percent of time*
36,000 second-feet	100
76,000 second-feet	90
91,000 second-feet	75
135,000 second-feet	50
250,000 second-feet	25

221. On the basis of past records, existing power storage will increase the minimum mean daily flow from 36,000 second-feet at The Dalles to an average of about 75,000 second-feet during the critical power production period. Storages proposed for early development would increase the present average dependable flow from 75,000 second-feet to about 110,000 second-feet. Reference is made to an average dependable flow, since the power studies are on a system basis and a uniform flow during the critical period is not necessarily maintained. This average flow is the mean during the critical power production months. Further development of storage in Columbia River Basin within the United States, as contemplated in present power studies in this report, would increase the minimum dependable flow to approximately 125,000 second-feet. This increased flow would result from the regulation of storage primarily in the interest of system power production.

GROUND-WATER PROBLEM

222. *General.*—No withdrawals of ground water, except for domestic water supply, are made in this sub-basin at the present time. Inasmuch as the river provides a continuous and ample means to recharge the ground-water supply, no present or future problems exist in this respect. Where low lands adjoining the river are protected from high river stages by levees, the problem of excluding ground water from the enclosed areas is considered as part of the problem of interior drainage.

STREAM POLLUTION PROBLEM

223. *General.*—Pollution of Columbia River within this sub-basin by sewage or industrial wastes generally is not serious at the present time. In some areas, purely local pollution by pulp and paper-mill wastes occasionally causes some difficulty for commercial fishermen, and certain side channels of the river, notably Multnomah and Camas sloughs, frequently contain insufficient quantities of dissolved oxygen to support fish life. These conditons usually occur during the low-water seasons of late summer and early fall and are aggravated by warm weather and the greater industrial activity prevailing at those times.

224. Unpolluted river water at summer temperatures has a normal dissolved-oxygen content of about eight parts per million. Allowing five parts per million as the minimum amount of oxygen content desirable for aquatic life, the remaining oxygen content of three parts per million may be considered available for the stabilization of sewage and industrial wastes. Oxygen requirements for natural stabilization of domestic sewage by river water average about 0.2 pound per capita of contributing population per day. A continuous flow of 1 cubic foot per second for 1 day, amounting to 5,400,000 pounds of water, will provide, in addition to the minimum requirements for aquatic life, about 16.2 pounds of available oxygen, or an amount sufficient to stabilize the sewage from the population equivalent of 80 people. In contrast to the natural stabilization of sewage by stream flow, primary, secondary, and complete treatment usually are capable of reducing the oxygen demand of raw sewage by 38, 80, and nearly 100 percent, respectively. The disposal capacity of a second-foot of water is

thereby increased from 80 persons to 115, 400, or almost infinity, respectively.

225. Mean low flows of Columbia River at several points, together with the population-equivalent sewage stabilizing capabilities of these flows, are shown in the following tabulation:

Location	Mile	Under present conditions, with regulation by Grand Coulee Dam		Under future conditions with regulation by existing and proposed dams [1]	
		Flow, second-feet	Population-equivalent capability	Flow, second-feet	Population-equivalent capability
Mouth of Yakima River	335	49,000	3,920,000	75,000	6,000,000
Bonneville	145	86,400	6,912,000	112,000	8,960,000
Vancouver	106	88,100	7,048,000	112,700	9,016,000
Barlow Point	61	110,100	8,808,000	124,100	9,928,000

[1] For illustrative purposes only. Flows shown are based on assumed storage approximately equal to that which may be proposed and, therefore, the stabilizing capability is only approximate.

226. Cities and towns along the river are the principal sources of domestic sewage pollution, while pulp and paper mills below Bonneville Dam are mainly responsible for pollution from industrial wastes. Estimated pollution caused by industrial wastes is indicated in the following tabulation, which shows pollution loads contributed by the above sources in terms of population-equivalents, under present conditions and with probable expansion by 1975.

Location	Source	Estimated population-equivalent	
		Under present conditions	Under probable future conditions [1]
Washougal	Domestic	1,400	2,000
Camas	Domestic and industrial	1,160,700	1,505,500
Vancouver	do	490,000	680,000
Portland	do	(2)	[3] 700,000
Subtotal		1,652,100	2,887,500
Willamette River	Domestic and industrial	2,000,000	1,000,000
St. Helens	do	116,500	181,000
Columbia City	Domestic	400	500
Kalama	do	1,100	1,500
Rainier	do	400	500
Longview	Domestic and industrial	912,000	1,520,000
Clatskanie	Domestic	800	900
Subtotal		3,031,200	2,707,400
Total		4,683,300	5,594,900

[1] Assuming developments as of 1975, improved partial treatment of industrial wastes, and primary treatment of domestic sewage.
[2] Portland's sewage is now discharged into Willamette River.
[3] Proposed sewage-treatment plant in Portland will discharge directly into Columbia River.

227. The lack of pollution problem on Columbia River above the mouth of Willamette River is clearly indicated by the above tabulation, which shows the present pollution load as having a population-equivalent of only 1,652,100, or about 23 percent of the pollution stabilizing capability of the present stream flow. With anticipated

future development of the area, this ratio apparently will become no greater than 41 percent under present flow conditions and would be reduced to about 32 percent by increased flows provided by regulation of proposed dams. Similarly, the present pollution load at Barlow Point, with population equivalent of 4,683,300, is only 53 percent of the present stabilizing capability of the stream flow. With loads introduced by estimated future growth, this ratio under present flow conditions would not exceed 64 percent and, with increased future flows expected to be available, would be reduced to 56 percent.

228. Generally, no pollution problem exists on Columbia River below the mouth of Yakima River, except for local difficulties caused by industrial wastes and the presence of visible solids and pathogenic organisms from domestic sewage. Even with the predicted development and growth of the area, the pollution problem is not anticipated to attain a serious magnitude in the future. Efforts of State agencies, in requiring that contributors of pollution make some effort toward reducing the amount of pollution, are expected to result in the future reduction of the present relatively minor degree of stream pollution. Local needs for removal of floating solids or pathogenic organisms will be satisfied, of necessity, through proper treatment by the contributing agency, whether municipal or industrial. Commercial uses for industrial wastes and modification of present methods of manufacture may aid in solution of these local problems.

DESIRES OF LOCAL INTERESTS

229. *General.*—In connection with the present investigations, public hearings have been held as listed below:

Date	Place	Subject	Held by
June 8, 1944	Walla Walla, Wash	Navigation	District engineers, Portland and Seattle.
June 15, 1944	Portland, Oreg	do	Do.
June 22, 1944	Boise, Idaho	do	Do.
Apr. 25, 1945	The Dalles, Oreg	Indian fishing rights	District engineer, Portland.
Sept. 22, 1945	do	The Dalles Dam	Do.
Mar. 28, 1947	Gravelly Point, Va	do	Board of Engineers for Rivers and Harbors.
May 25, 1948	Arlington, Oreg	John Day Dam	District engineer, Portland.

The hearings brought out that the desires of local interests were divided. Power and navigation proponents favor immediate development of the main stem of Columbia River by dams and reservoirs. Indian fishermen having treaty-accorded rights, together with commercial and sport fishermen, contend that such construction will deplete or destroy present fish runs. Irrigation interests desire that use of water for irrigation be given first priority without infringement by downstream power developments.

230. *Hearing of June 8, 1944.*—The hearing at Walla Walla was devoted to navigation. Estimates of tonnage of commodities susceptible to water movement were submitted by representatives of the Inland Empire Waterways Association, the Washington State Farm Bureau Federation, and the Lewiston, Idaho, Chamber of Commerce. A statement as to potential shipments from the Columbia Basin irrigation project was submitted by the Bureau of Reclamation. State-

ments endorsing improvement of navigation facilities were submitted by the Portland, Spokane, and Walla Walla Chambers of Commerce. Representatives of towboat operating companies joined in stressing the need for large-size locks and recommended chambers capable of passing three barges, each 40 feet in width, abreast. Representatives of Montana and Idaho interests expressed the belief that navigation use of water should be subordinated to irrigation use.

231. *Hearing of June 15, 1944.*—The hearing at Portland was devoted to navigation. Representatives of large grain and milling companies testified in favor of water transportation of wheat from the inland territory. Representatives of towboat and barge-line companies operating on the river stressed the need for larger locks, pointing out that the width of Bonneville lock has proved insufficient for the needs of river navigation. These representatives mentioned also the need for a better approach to the upper end of Bonneville lock and for facilities for tying barges and log rafts above and below the lock. The Columbia River basin operators endorsed the program of river development. A statement was filed by organizations of Flathead Valley, Mont., expressing the belief that navigation use of the river should be subordinated to power and irrigation use.

232. *Hearing of June 22, 1944.*—The hearing at Boise was devoted to navigation. Representatives of the Bureau of Reclamation presented data as to feasible projects for the development of new lands and stressed the need for irrigation, bringing out the fact that means could be found without difficulty to use available water resources without detriment to navigation or existing irrigation projects. Idaho irrigation district representatives had no objection to the development of navigation projects on lower Snake River, provided the use of water for such projects would not be allowed to encroach upon the water supply available for present or proposed irrigation projects on the upper Snake River. The Inland Navgation Co. stressed development of navigation in the upper river. The Governor of Idaho assured cooperation in developing reclamation and navigation. The Wenatchee, Wash., Chamber of Commerce favored development of navigation.

233. *Hearing of April 25, 1945.*—The hearing, held at The Dalles, was to obtain the views of Indians possessing fishing rights on Columbia River under the 1855 treaty as to the proposed construction of the Dalles Dam. Inundation of Celilo Falls, the best Indian fishing grounds on the river, was the principal subject discussed. The Yakima, Walla Walla, Cayuse, Umatilla, Warm Springs, and Columbia River Indians were opposed to construction of a dam at the Dalles site, and advocated in lieu thereof an alternate upstream location to preserve the present fishing grounds.

234. *Hearing of September 22, 1945.*—The hearing, held at The Dalles, was in connection with Interim Report No. 1 on the Dalles Dam, principally from the navigation standpoint. Fishing interests contended that the Dalles Dam would destroy the salmon runs and the large fishery industry based thereon, dislocate the Indians dependent upon fishing, and destroy a scenic attraction by inundating Celilo Falls. In lieu of construction of the Dalles Dam, they recommend prior construction of Foster Creek Dam and enlargement of the Dalles-Celilo canal. These interests cautioned that a pipeline might supplant present barge movements insofar as petroleum products are concerned, and that atomic power might render hydroelectric power

facilities obsolete. Representatives of 35 organizations were in favor of the Dalles Dam, and representatives of 13 organizations, including Indians and fisheries interests, presented testimony in opposition.

235. *Hearing of March 28, 1947.*—The hearing at Gravelly Point, Va., secured data in connection with the proposed The Dalles Dam. Arguments brought out the present need for improved transportation and the industrial potential of Columbia River when cheap transportation and cheap power are combined. The present waste of unused water was pointed out. In addition, arguments were offered to the effect that the potential industrial development along the river dwarfed the present fishery industry and should not be delayed because of possible adverse effect on the fishery.

236. Ten fishing organizations advocated deferment of construction of The Dalles Dam and other lower Columbia River dams until all other power sites have been developed, to permit development of more reliable facilities for passing fish runs and to permit investigation of the feasibility of transplanting fish runs to certain lower tributaries unaffected by dams.

237. *Hearing of May 25, 1948.*—The hearing at Arlington was in connection with the proposed John Day Dam with normal pool elevation 255 to supplant two dams previously recommended, one with pool elevation 210 at the John Day site, and the other with pool elevation 258 at the Arlington site. Views were desired from navigation, fishery, and other interests, and from owners of property between John Day and Arlington Dam sites that would be affected by the single-dam plan but not by the two-dam plan.

238. Opposition testimony was presented primarily by fishery interests who opposed construction of either one or two dams in the reach of river under consideration because of the uncertainty of passing fish over the dams and possible damage to main stream spawning grounds. The two-dam plan appeared to these interests as the lesser of two evils in regard to providing successful fish ladders of lifts. Suggestion was made that, if construction of a dam at the John Day site were determined to be necessary, consideration be given to locating it above the mouth of John Day River in order to make that stream more accessible to migratory fish. Other opinions favored deferment of John Day Dam until other upstream power sites such as Hungry Horse and Foster Creek were fully developed.

239. Testimony was given by Indians of the Warm Springs Confederated Tribes, by Yakimas, and by Nez Percé in opposition to all dams. The Indians' protests were based on inundation of fishing locations at which they were given fishing rights by a treaty executed in 1855. Navigation interests, the Mid-Columbia Chamber of Commerce, grain growers' associations, and various port districts and chambers of commerce were generally in favor of development by the single John Day Dam, although some advocates made their recommendations contingent upon acceptability to the majority of residents in the flowage area.

240. No objections were received from residents of Arlington, the principal community which would be affected by the single-dam plan and left unaffected by the two-dam plan. The brief filed by the Mid-Columbia Chamber of Commerce recommended provisions of a lock chamber 130 feet by 750 feet in clear plan dimensions. Other inter-

ests, however, concurred in the 86-foot by 675-foot dimensions currently planned for the lock at McNary Dam.

SECTION II—FIELD AND OFFICE STUDIES

GENERAL

241. *Field investigations.*—Surveys and field explorations undertaken by the Corps of Engineers in connection with previous reports furnished a portion of the data upon which studies for this report are based. Such data for Bonneville and McNary Reservoirs are quite complete. Hydrographic surveys were available for the remaining 248 miles of Columbia River within this sub-basin. In addition, limited drilling at seven dam sites was completed. A photogrammetric reservoir map to elevation 500 feet, mean sea level, of the river reach from the head of Bonneville pool to McNary Dam site was prepared. Plane table surveys of The Dalles and John Day dam sites also were completed. Other field investigations made at The Dalles site consisted of core drill holes, seismic lines, and diver inspection of the deep main river channel. Comprehensive exploration by seismic methods was undertaken in the John Day and Arlington dam site areas, in addition to exploration by 10 and 5 drill holes, respectively.

242. Field investigations for the local river and harbor projects discussed in this report (a mooring basin and channel enlargement in Baker Bay, channel enlargement in Westport Slough, channel improvement in Columbia Slough, and harbor improvement at Umatilla, Oreg.) included soundings, plane table surveys, cross sections, or combinations of these methods as warranted by local conditions. Probings were made where necessary to determine subsurface conditions.

243. A number of surveys were available from previous investigations for use in the analysis of proposed diking, drainage, and bank-protection projects downstream from Bonneville Dam. These surveys were supplemented by recent reconnaissance, and, in connection with bank-erosion studies, cross sections were taken and ranges for float-velocity measurements established over about 50 percent of the locations involved. Preliminary flood-damage appraisals also were made throughout this reach. Accumulation of field data on these projects was sufficient to permit preliminary analysis of economic qualifications. Investigations, however, will be completed and final results shown in an authorized separate comprehensive review of local flood-control projects which is to be submitted at a later date.

244. *Office studies.*—In connection with analysis of reservoirs, office studies were made for several alternative developments at The Dalles dam site. A two-dam plan, consisting of low dams at John Day and Arlington sites, as well as open-river improvement, was considered in lieu of the proposed high John Day development. Supporting studies included determination of stream-flow characteristics, flood-control storage capacities, tailwater rating curves, spillway design floods, and backwater profiles and elevations. Hydraulic and power studies were made to determine controlling dimensions and power installations. Flowage and utility relocation studies were completed from field data. Studies and field investigations of foundation geology

and construction materials, based on available data, were made, and construction cost data and methods of construction were analyzed in preparation of detailed cost estimates. Project benefits were analyzed, but those of basin-wide import are treated in appendix M, and only those of local nature are detailed in this appendix.

245. In connection with the previously recommended local navigation projects enumerated in following paragraphs, designs, estimates, and economic analyses were completed in considerable detail. Studies of diking, drainage, and bank revetment; the improvement of Oregon Slough in the interests of navigation; and the investigation of additional dredging at the mouth of Columbia River were preliminary in nature but somewhat more detailed than those made for approach channels to future harbors. Appendix R contains a summary of investigations performed and part II of this appendix contains detailed information on special studies made.

SECTION III—PREVIOUSLY RECOMMENDED PROJECTS

GENERAL

246. Previously recommended projects are: Local navigation developments for Umatilla Harbor, Columbia slough channel, Westport slough channel enlargement, and Baker Bay channel and mooring basin; all recommended by the Corps of Engineers; and the west unit of The Dalles irrigation project, recommended by the United States Bureau of Reclamation, and The Dalles Dam previously reported on by the district engineer, Portland, in an interim report dated March 21, 1946.

247. Construction of the local navigation projects would fulfill the immediate needs for such development on lower Columbia River, but would not constitute an ultimate development. Construction of The Dalles Dam and Reservoir would leave undeveloped only 75 miles of Columbia River between the mouth of Yakima River and Bonneville Dam. These previous recommendations are reiterated, and abstracts from the original reports follow. In all cases economic analyses are modified from the previous reports to reflect price levels and economic developments as of January 1, 1948.

UMATILLA HARBOR

248. *General.*—Improvement of the existing harbor on Columbia River at Umatilla, Oreg., was favorably recommended by the district engineer in a separate report entitled "Review Report on Columbia River at Umatilla, Oreg.," dated January 28, 1948, in which the division engineer, North Pacific Division, concurred May 11, 1948, and forwarded to the Chief of Engineers. The proposed improvement, shown on plate 27, would consist of an excavated harbor area to provide adequate navigable depth for barges. The harbor would be served by the existing river channel, which has a depth of 7 feet at low water and a minimum width of 150 feet.

249. *Description.*—The site of the proposed work is the harbor area at the Umatilla port dock, 289 miles above the mouth of Columbia River. The harbor depth at low water generally is less than 7 feet, and the river bottom consists of compacted gravel and small rock

ledges. Small areas of rock shoals occur throughout the harbor and restrict free access to docks along the water front during periods of low water. This stretch of the river is subject to ice jams, due to local and floating ice, which may block navigation for periods of 1 to 2 weeks and occasionally as long as 8 weeks. These occurrences are generally in January and February.

250. *Existing conditions.*—The trade area tributary to Umatilla includes some 60,000 square miles having a 1940 population of 362,000. In addition to eastern Oregon, it includes much of southern and western Idaho. The principal industries of the region are farming, stock raising, processing of farm products, logging operations, production of sawed lumber, mining, and operation of facilities for tourists and vacationists. Because of the location of existing highway and railway facilities, Umatilla is the natural point of interchange for most commodities which are adaptable to movement by water, and in 1946 about 426,000 tons were handled at this point. More than 90 percent of this traffic was petroleum products moving upstream, and most of the balance was wheat moving downstream. The trend of shipments by water carrier is definitely upward, as evidenced by statistics available for The Dalles-Celilo Canal, where tonnage in 1946 was 21 times that of 1938.

251. Private interests have constructed three tank farms, with a total capacity in excess of 14,000,000 gallons, for storage of petroleum products at Umatilla. Two of these have rail, truck, and water connections, and the third has truck and water connections only. Water connections in two instances consist of narrow pile trestles carrying pipelines and walkways to mooring facilities located in shallow water in the river. At the third terminal the barges are moored close in without benefit of a shore structure for unloading. A cooperative grain elevator of 350,000-bushel capacity is located adjacent the harbor. This elevator has truck, rail, and water connections, the latter consisting of a conveyor extending riverward about 200 feet beyond the low-water shore line to a loading point about 200 feet inshore from the 7-foot depth line. The port of Umatilla, organized in 1940, owns 1,775 linear feet of water frontage but owns no terminal or transfer facilities. Portions of this frontage are leased to the aforementioned private petroleum interests.

252. *Plan of improvement.*—The proposed project consists of clearing the harbor area of all shoals to a depth of 7½ feet below low water from the channel shoreward to a line which generally follows the present 7-foot depth contour and covers the greater part of the port frontage. This line would extend downstream channelward across the shoal area above the mouth of Umatilla River to provide a usable angle of approach to the dock area. Docks now constructed along the water front could be extended to the edge of the proposed improvement at small cost.

253. The proposed improvement would not provide shelter from ice flows or jams. The harbor is situated only 3 miles downstream from McNary Dam, which is now under construction, and that reservoir will trap most of the floating ice and, in addition, the lower lock approach will provide a safe harbor between the guide wall and river bank moorage.

254. The previously recommended Umatilla Harbor project fits in with John Day Reservoir as proposed for comprehensive development

of Columbia River. John Day Reservoir at normal pool elevation 255 would create slack water to McNary Dam. Natural low water at Umatilla Harbor is now elevation 247.41. Excavation to 7½-foot depth would place the harbor floor at elevation 240. With 3 feet of draw-down for power-plant operation at John Day Dam, Umatilla Harbor ultimately would provide a dependable minimum draft of 12 feet. In addition, the backwater effect of the John Day Reservoir would be beneficial in reducing velocities through the harbor, which would be fully exposed to present stream velocities.

255. The Federal Government would excavate the harbor area and assume the maintenance of project depth. Local interests would be required to furnish assurances satisfactory to the Secretary of the Army that adequate terminal facilities open to all on equal and equitable terms would be provided and that the United States would be held safe and free from all claims for damages which might result from execution of the work. Local interests have indicated a willingness to comply with these conditions. No rights-of-way are required for the proposed construction and rights-of-way are available for terminal facilities.

256. In connection with the harbor improvement, the port of Umatilla has proposed construction of dock and terminal facilities costing $196,700. In addition, pile trestles serving two of the present tank farms should be extended to the edge of the improved harbor, and the conveyor belt serving the grain elevator likewise should be extended. Cost of these extensions amounts to $3,000 and $5,000, respectively, and total $8,000.

257. *Costs and charges.*—Estimated costs to both Federal and local interests are detailed in part II of this appendix. The estimated total initial investment is $620,950, of which $416,250 and $204,700 would be Federal and non-Federal, respectively. Estimated annual charges are shown in the following tabulation:

	Annual charges
Federal:	
Interest and amortization	$16, 180
Maintenance and operation	1, 000
Subtotal	17, 180
Non-Federal:	
Interest and amortization	9, 585
Maintenance and operation	2, 365
Subtotal	11, 950
Total	29, 130

258. *Accomplishments.*—The proposed project would provide an improved depth from the main channel to dock facilities, thereby reducing maintenance costs that result from damage frequently inflicted on boats and barges by existing scattered shoals of rock and boulders. Barges could be loaded to full capacity during low-water stages on Columbia River. A 7-foot depth would provide unimpeded access to Umatilla port facilities at all stages of Columbia River, provide an area for breaking up barge tows, assure access to oil storage tanks and grain loading facilities, and provide for further expansion of port facilities. Considerable development in river transportation and port facilities is anticipated as a result of increased agricultural

development, mechanization, manufacturing, and population increases within the area served by Umatilla port.

259. Although the improvement proposed would be justified in the interest of safety and convenience of established navigation alone, monetary benefits were evaluated. Savings would be realized on commodities now moving entirely on land, but which could move by barge between Portland and Umatilla if navigation conditions at Umatilla Harbor were improved and suitable terminal facilities were provided by local interests. These savings would amount to about $47,610 annually, and would be the total evaluated benefits credited to the project.

260. Indirect benefits creditable to the proposed project would be of considerable importance. Navigation in general would be promoted by the elimination of hazards, causes of delay, and damage to equipment. Lowered cost of operating barges and of marine insurance would have a beneficial effect upon rate bases and in turn the general public would profit by a wider use of river transportation. No evaluation of indirect benefits was made.

261. *Economic justification.*—Evaluated direct annual benefits are $47,610 and estimated total annual charges are $29,130. The benefit-to-cost ratio would be 1.63 to 1 and the project would be economically justifiable.

THE DALLES DAM

262. *General.*—The Dalles Dam, as previously reported on, would be located at the head of Bonneville pool, 192.5 miles above the mouth of Columbia River, as shown in the subbasin map, plate 36, and the subbasin profile, plate 1. It would raise the natural low-water surface 87.5 feet at the site. A dam at this location was proposed in both of the prior comprehensive reports on development of Columbia River. In the latest of these, House Document No. 704, Seventy-fifth Congress, third session, prepared in 1937, normal pool at elevation 150 was proposed to create a reservoir extending to the mouth of John Day River at Columbia River, mile 218. The present report proposes pool elevation 160 in accordance with the report entitled, "Interim Report No. 1, Columbia River and Tributaries Review Report, the Dalles Dam, Oregon and Washington," dated March 21, 1946. The referenced report reviews previous reports; evaluates changed conditions with regard to commerce, power generation, and other uses of water at the Dalles site; compares alternative locations for a dam in the vicinity of The Dalles; and, with due regard to future development, compares alternative pool elevations for the site deemed most practical. In addition to material in the referenced report, this appendix contains descriptive data and information on the economic development and problems of the area.

263. *Hydrology.*—The run-off of Columbia River at The Dalles dam site is identical to that recorded at the United States Geological Survey station at The Dalles. Hydrological data for this station are described in chapter I.

264. The flow duration curve for Columbia River discharge at The dalles, plate 13, shows that the minimum mean monthly discharge was 42,430 second-feet. Fifty-six percent of the time the flow exceeded 120,000 second-feet, the average flow of the minimum year.

Upstream storage provided by reservoirs in the main control plan would increase the average dependable flow to about 110,000 second-feet. Plates 7 to 10 show daily discharge hydrographs for Columbia River at The Dalles, and plate 11 presents summary hydrographs at the same location. Plate 13 shows other stream-flow characteristics. A discussion of the derivation of the spillway design flood of 2,290,000 second-feet for The Dalles dam site is contained in part II of this appendix.

265. *Geology.*—The dam site is located on the east limb of The Dalles syncline, an asymmetrical fold trending about North 30° East. The site is underlain principally by Miocene Columbia River basalt, consisting of several series of superposed flows of varying individual thickness. The flows exhibit columnar structure, horizontal jointing, and vesicular to scoriaceous zones, but are primarily hard, sound rock excellent for foundations. Interbeds of sedimentary rock are rare, and most flow contacts are tight.

266. Three transverse faults are present in the area; one at the head of Fivemile Rapids, one at the foot of Threemile Rapids, and a third at Big Eddy. These faults trend northwest-southeast, nearly parallel to the strike of the basalt, and appear to be post Pliocene in age with no evidence of recent movement.

267. In adjacent areas south of the river, the basalt is overlain unconformably by the Pliocene Dalles formation consisting of semi-consolidated sandstones, conglomerates, tuffs, and tuff breccias. These occur well above the crest of the dam and normal pool elevation and do not affect the structure. Quaternary terrace deposits, composed of poorly consolidated silts, sands, and gravels, are present at elevations up to 300 feet in the area adjacent to the site. Recent deposits of silt, sand, and gravel of variable thickness, are present, to a limited extent, in the site area.

268. *Lay-out.*—Lay-out and details of The Dalles Dam are shown on plates 28 and 29. The dam would consist of a navigation lock, spillway, powerhouse, and nonoverflow dam sections totaling about 8,000 feet in length. The lock would be located on the Washington shore at the foot of Threemile Rapids, nearly alined with the river channel downstream. A 1,736-foot length of nonoverflow concrete dam would continue upstream on line with the riverward lock wall to connect with the west end of the spillway, located approximately at the midpoint of the basalt flat west of the main channel. The spillway would extend across the basalt to the main channel. The powerhouse would extend northeastward along the edge of the deep river channel. This channel would be closed by a rock and earth embankment which would tie to the powerhouse and would be connected to the Oregon shore by a concrete nonoverflow dam crossing the head of Big Eddy lock of The Dalles-Celilo Canal. Statistical data on the several features of the dam are contained in table 34.

269. The navigation lock for barges would be 86 feet by 675 feet in clear plan dimensions and would provide a 14-foot depth of water over the sills at 3-foot drawdown. Since the lock chamber would be excavated largely in rock, a filling and emptying system consisting of two floor culverts was adopted. Downstream from the chamber, a guard wall 1,000 feet long and a channel 250 feet wide would be provided to insure favorable entrance conditions. A portion of the upstream channel in the reservoir area must be excavated to provide

necessary depth and a width of 350 feet required for moorage space adjacent to the channel. Upstream from the lock chamber, the nonoverflow dam would extend on line with the riverward lock wall to the Washington end of the spillway, and a 1,400-foot guard wall would continue on the same tangent to protect boats and tows from currents toward the spillway.

270. The spillway, crest elevation 119, would be 1,848 feet long. Thirty two-section vertical lift gates 43 feet high and 50 feet wide are proposed to control the pool to normal elevation 160. The gates would be operated by means of two gantry cranes traveling on the spillway bridge. The spillway would pass the flowage design flood at approximate normal pool elevation, and the spillway design flood of 2,290,000 second-feet with pool elevation 16.5 feet over normal level. The spillway discharge would be spread over the entire spillway length, and a perforated sill would deflect and decelerate the overflow.

271. The power plant would be located upstream from the spillway section and along the deep main river channel. Under phase C–2 development, as described in appendix O, 14 units rated at 70,000 kilowatts each would be installed. The power plant structure would be 1,478 feet long and provide space for two additional units. Additional space would be provided between the powerhouse and spillway section by a nonoverflow concrete gravity dam section, or other barrier which could be removed or incorporated in the final structure, in order that the powerhouse could be extended to house a total ultimate installed capacity of 20 units to develop 1,400,000 kilowatts. Generating equipment would include automatically adjustable propeller-type turbines, spaced 83 feet on centers. These turbines would have 6-blade, 286-inch runners with mechanical ratings of 112,000 horsepower at 85-foot head and 83.7 revolutions per minute. Two station service units rated at 3,500 kilowatt capacity each would be installed in the 150-foot long assembly bay area to meet auxiliary equipment power requirements. Plate 31 illustrates approximate head and output characteristics of The Dalles power plant under phase C–2 development as related to river discharge conditions. Appendix O contains details of the power installation and generating capacity.

272. The main river channel, a rock gorge about 500 feet wide and 180 feet deep, crosses the dam axis just upstream from the upstream end of the powerhouse, and upstream from the lower entrance to The Dalles-Celilo Canal. Closure of this channel without cofferdams is proposed by dumping the embankment materials in the water. The initial closure would be made with large rock and the upstream deposits would grade to sand to produce an impervious barrier. This method of closure appears more economical and practicable than any other method considered. The embankment as shown has been designed for closure at a flow of 300,000 second-feet, although flows of this magnitude are unlikely during the closure period. About 1,500,000 cubic yards of quarry rock ranging to 10 tons in weight, and 1,520,000 cubic yards of blanket material, would be required. Completion of the embankment would require approximately 380 days.

273. *Fish facilities.*—Until such time as continuing studies, by various State and Federal agencies, of anadromous fish problems and fish facilities indicate material revisions, fish ladders and powerhouse

collecting systems similar to those used at Bonneville Dam and to those now being studied and designed for McNary Dam are proposed for this site. Gravity fish ladders with a width of 30 feet and a slope of 1 on 20 would be provided at each end of the spillway structure and near the south end of the dam, providing access to the pool near the Washington and Oregon shores and near the central portion of the dam. The powerhouse collecting system would be constructed so that it could be operated to lead the fish into either the central or the Oregon shore fish ladders, as desired. Downstream migrants would have access both to fish ladders and to fingerling bypasses. Inasmuch as the difference of elevation between forebay and tailwater normally would be about 88 feet, further study conceivably might indicate the need for one or more pairs of fish locks to supplement the gravity-type fish ladders.

274. Consideration has been given to the development of means to recover fish that might become exhausted below or in the fishways, but because of biological and other difficulties, no suitable facility has been devised. It is considered, therefore, more advisable to mitigate any possible losses by artificial propagation of fall Chinook salmon in lower Deschutes River. Inasmuch as the same problem of restitution exists at the proposed John Day Dam, and in the interest of economy, a joint two or more unit hatchery is proposed to compensate for possible losses at The Dalles and John Day Dams. The hatchery units would be constructed along lower Deschutes River, above backwater from The Dalles pool. These units combined would have a capacity to handle about 25,000 adult fish, which would require capacity for about 50,000,000 eggs. The costs of the proposed hatchery units would be borne jointly by The Dalles and John Day Dams.

275. *Flowage.*—The Dalles Reservoir is outlined on plate 30. At low water, before construction of the John Day project, 24.8 miles upstream, the reservoir would extend upstream a distance of 35.5 miles and would average about 3,500 feet in width. Flowage acquisition and utility relocations are based upon the computed backwater for the historical 1894 flood passing the dam at normal pool elevation. Fee title or flowage easements would be acquired to all lands and improvements within a taking line tentatively set at 5 feet above the 1894 backwater profile. The lands involved are listed below.

	Area in acres
Nontillable grazing and wastelands	5,039
Tillable	329
Industrial property	9
Indian lands	234
Federal reservation	326
Total	5,937

Wishram, Wash., and the Indian village at Celilo, Oreg., would be only slightly affected, but the Indian village at Spearfish, Wash., would be inundated.

276. Improvements within the proposed flowage area consist of The Dallas-Celilo Canal, which, with all appurtenant structures, is owned and operated by the United States; 10 commercial and industrial properties; schools; churches; 29 residences in the small towns; and 34 farm units.

277. Necessary relocations include 81.4 miles of railroad, raising of the Wishram yard, raising and revision of the Columbia River railroad bridge of the Spokane, Portland & Seattle Railway; reconstruction of 18.7 miles of United States Highway No. 30; miscellaneous power and telephone line revisions; and reconstruction of the approaches to the Maryhill Ferry. An interstate highway bridge is now proposed at the Seufert bridge site. This structure, crossing in the dam site area, should be planned so as not to conflict with the lay-out of the dam. Preliminary estimates indicate that construction of the dam would increase the cost of the bridge about $791,000. This additional cost is proposed as a Federal cost. Should the bridge be completed prior to construction of The Dalles Dam, the Corps of Engineers would realize benefits estimated at $488,000 from elimination of need for other facilities for transferring personnel and materials across the river during construction of the dam.

278. Estimates of cost for railroad and other relocations for the project are based upon construction of this project prior to initiation of construction on the John Day project upstream. When the latter is constructed, therefore, the new relocations in the upstream reaches of The Dalles project would again require revisions. Savings involved in concurrent relocation of railroads for both projects would justify concurrent relocation only if construction of the John Day project were anticipated to follow construction of The Dalles project by about 6 years or less.

279. The Indian fishing grounds at Celilo Falls, retained by the Indians under treaty with the United States; and the Indian village at Spearfish, Wash., would be inundated; and the Indian village at Celilo, Oreg., would be affected. The estimates of cost for The Dalles project include an allowance for construction of a new Indian village satisfactory to the Indians and the Bureau of Indian Affairs, and provision of suitable natural or artificial subsistence fishing sites near the dam. Further restitution or dispensation deemed fitting and proper by the Congress in consideration of treaty rights would be made a part of this project.

280. *Recreation facilities.*—Proposed development by the Corps of Engineers would include sightseeing facilities consisting of parking areas and public service buildings on either shore in the vicinity of the dam; a public boat dock and picnic area on the Washington abutment; and three public access areas at strategic points along the reservoir providing limited parking, picnicking, and boat-launching facilities. Dependent upon demand, moorage and service and repair facilities might be provided by local organizations or private capital.

281. *Construction materials.*—Columbia River sand and gravel are of suitable quality for concrete aggregates and exist abundantly in the area of The Dalles project. Some blending of sand to supply certain size deficiencies, however, may be necessary. Loessal soils for semi-pervious and impervious fills are available within short distances south and east of the site. Ample supplies of rock from excavations at the site would be available for riprap and a fair proportion of the large rock for the river closure embankment. Selective quarrying in the general area would provide the remainder.

282. *Construction schedule.*—Construction of The Dalles Dam with installation of 4 generating units could be accomplished in approximately 5 years and the 10 additional units, required under phase

C-2 power development, could be installed at the rate of 4 per year to complete the project in 7.5 years. Construction of the powerhouse and spillway behind cofferdams would be initiated immediately. Relocation of the Spokane, Portland & Seattle Railway, which would require about 1 year, likewise would be begun immediately to enable work on the navigation lock to proceed as early as practicable. Upon completion of these works with provisions for second step diversion through the partially completed powerhouse, the earth and rock embankment closing the main river channel, requiring slightly over a year to place, would be constructed. During this time navigation would be passed through the existing The Dalles-Celilo Canal. Final closure of the dam and subsequent raising of the pool would involve completion of the short section of nonoverflow dam immediately upstream from Big Eddy lock of the existing The Dalles-Celilo Canal. After completion of this section, The Dalles lock would be placed in operation.

283. *Costs.*—Costs of The Dalles project with 14 generating units installed, based on January 1948 price levels, in conformance with the plan proposed in this appendix, are summarized below. A detailed breakdown of quantities and unit prices involved are shown in part II of this appendix.

Item	Construction cost	Capital cost
Utility relocations	$33,148,000	$36,255,000
Lands and acquisition	728,000	796,000
Reservoir clearing	269,000	294,000
Cofferdams and diversion	9,719,000	10,630,000
Spillway	26,067,000	28,511,000
Nonoverflow concrete dam	8,975,000	9,816,000
Power facilities	145,541,000	159,186,000
Powerhouse structure for two future units	8,257,000	9,031,000
Rock and earth-fill dam	11,181,000	12,229,000
Navigation lock	13,190,000	14,427,000
Mooring facilities	245,000	268,000
Fish facilities	23,305,000	25,490,000
Buildings and grounds	3,189,000	3,488,000
Construction of Indian village and fishing facilities	613,000	670,000
Recreation facilities	255,000	279,000
Oregon-Washington highway bridge	791,000	865,000
Miscellaneous	741,000	811,000
Navigation aids	72,000	79,000
Total	286,286,000	313,125,000

284. Annual charges for The Dalles Dam, based on 3 percent financing and a project life of 50 years, are summarized below.

Feature		*Annual charges*
Interest ($313,125,000, at 3 percent)		$9,394,000
Amortization ($313,125,000, at 0.886 percent)		2,774,000
Interim replacements		634,000
Operation and maintenance		1,191,000
Navigation lock	$77,000	
Spillway	210,000	
Power facilities	714,000	
Buildings and grounds	98,000	
Fish facilities	64,000	
Recreation facilities	28,000	
Payments in lieu of taxes		4,000
Total annual charges		13,997,000

285. Interim replacement costs were computed on the basis of additional amortization charges on a 30-year basis to create a sinking fund to replace items or portions of items having an economic life of less than 50 years. Operation and maintenance costs were derived from past experience at Bonneville Dam. No annual cost for inundation of The Dalles-Celilo Canal or of open river improvements in the reservoir reach are charged against The Dalles project. Navigation benefits credited to the project elsewhere in this report are incremental over existing conditions.

286. *Accomplishments.*—Navigation would be benefited by the 25-mile slack-water pool which would inundate narrow barge channels, swift flowing rapids, and The Dalles-Celilo Canal, all of which constitute a bottleneck to through navigation traffic from upper Columbia River points to Portland and to world ports. The generation of power would benefit the local area and provide needed additional capacity to the Northwest power pool which is now operating with a load greater than considered safe. Increased water surface elevation would benefit irrigation along the pool by reducing the required pumping lift. Possibilities for recreation, of a type not now available to the residents of the area, would be provided as an incidental feature.

287. The proposed project would improve a vital link in the through navigation system from Lewiston, Idaho, to tidewater and world ports. The future average annual tonnage expected to move over the pool when through navigation to Lewiston becomes possible is estimated to be approximately 4,828,000 tons, of which about 80 percent consisting of grain, lumber, wool, limestone, mineral products, and miscellaneous merchandise and industrial products, would move downstream; and 20 percent consisting of petroleum products, lumber, and general merchandise would move upstream.

288. Navigation benefits for The Dalles slack-water pool are estimated on the basis of savings in the cost of water-borne commerce over the cheapest of other forms of transportation. This saving would benefit the upper Columbia River Basin as greater returns would be netted to the producer. Appendix M contains the derivation of navigation benefits.

289. The project, as an element of the Northwest power pool, would provide greatly needed additional power to the coastal load centers; however, the principal value would lie in proximity to coastal load centers and ability to contribute a large amount of power to meet part of the anticipated future load on the integrated Pacific Northwest power system. Low cost power can be expected to attract specialized electrometallurgical and electrochemical industries, for which expanding markets are in prospect, and to facilitate the profitable expansion of other existing industries. The project would produce approximately 701,000 kilowatts of prime power and have an installed capacity of 980,000 kilowatts. More complete power studies are contained in appendix O.

290. The Bureau of Reclamation estimates that 60,000 acres in scattered tracts might be developed ultimately by pumping from The Dalles pool. These include a number of scattered benches of a few hundred acres each which may be feasible of development if cheap power should become available. The Dalles Dam and pool would facilitate irrigation of 9,000 acres in the east unit of The Dalles irrigation project, and 1,000 acres along the right bank near North Dalles.

This area is exclusive of The Dalles irrigation project, west unit previously recommended by the Bureau of Reclamation and described separately in this appendix. The Dalles Dam would raise the level of the river surface from elevation 72 to 160 and reduce the pumping lift 88 feet.

291. The dam and powerhouse structures would attract many visitors. The pool would offer boating and fishing as the principal attractions; camping and picnic grounds would be made available along the shores. Boat-launching ramps, sanitary facilities, parking areas, and other supplemental installations would be required for the benefit and comfort of visitors.

292. Complete facilities of improved design are proposed for passage of migrating fish over The Dalles Dam. As a further safeguard to continuance of these migrations, hatchery facilities are proposed as a part of the project. The Indian fishing facilities inundated would be replaced to the extent found practicable, including provision of alternative fishing sites.

293. In addition to the tangible accomplishment, certain general intangible benefits would accrue from the proposed improvements. These comprise principally the expansion of industry and local business, enlargement of the tax base, and increased social security of residents in the trade area tributary to the proposed dam.

294. Appendixes M and O show the benefits to be derived from the coordinated development of Columbia River Basin, of which The Dalles Dam would be an integral part.

COLUMBIA SLOUGH CHANNEL

295. *General.*—Improvement of Columbia slough, near Portland, for shallow draft navigation was recommended in a report dated May 16, 1947, entitled, "Survey Report on Columbia Slough, Oregon." This report was concurred in by the division engineer, North Pacific Division, July 25, 1947, and forwarded to the Chief of Engineers. The proposed improvement would consist of widening and deepening the existing slough to provide improved water access to industrial establishments fronting the slough. (The proposed improvement is shown on plate 26.)

296. *Description.*—Columbia slough is a narrow back channel which roughly parallels Columbia River, skirts the north limits of Portland, and empties into Willamette River about one-half mile above the confluence of that stream with Columbia River. The upper end of the slough originally connected with Columbia River, but this connection was replaced by a controlled ditch, and the upper portion of the slough now serves only as an interior drainage ditch for Multnomah County Drainage District No. 1. Levees of Peninsula Drainage Districts No. 1 and No. 2 border the central section of the slough and protect some 2,400 acres of land and several large industrial plants against Columbia River floods. The lower section of the slough flows through river bottom land containing several lakes. The width between levees averages about 320 feet in that stretch extending southward from Columbia River. The width downstream from this channel averages about 200 feet. Depths in the slough are affected by backwater from both Columbia and Willamette Rivers and vary accordingly. At extreme low water, the controlling depth is about 5

feet in a narrow channel. Five highway bridges and two railroad bridges cross Columbia slough. Vertical clearances vary from 27 feet to 41.78 feet, at low water, and horizontal clearances vary from 60 to 149 feet. All but one of these bridges are considered for improvement.

297. *Existing conditions.*—The area immediately tributary to Columbia slough contains practically all of the widely varied industrial activity of North Portland. Present commerce consists almost entirely of the movement of logs from Willamette and Columbia River points to shingle and lumber mills along the slough, and amounts to from 180,000 to 210,000 tons annually. Under present conditions, however, impaired depths have, on numerous occasions, caused cessation of log movements and forced closure of mills. Even at higher stages standard size log rafts must be broken upon entering the slough because of the tortuous channel. Navigation is hindered by limited bridge clearances, snags, fallen trees, and other obstructions in the waterway. Wharves or docks have not been constructed along the slough, but booms, dolphins, and slips for storage and handling of logs have been privately constructed. Adequate space is available for additional terminal facilities.

298. Industries located in North Portland, particularly those along Columbia Boulevard west of Union Avenue, are connected with the Columbia waterway system through the facilities for potential water commerce offered by Columbia slough. Because of difficulties attending the movement of commerce through the present channel, these particular industries are forced to operate at a disadvantage, as evidenced by higher towing rates. Improvement of the slough to provide a channel adequate for barge navigation would eliminate this disparity in towing rates and also would enable other industries of the area to use the waterway for receipt and shipment of supplies and materials by barge at substantial savings over present transportation methods. Annual traffic of about 450,000 tons should develop following a reasonable improvement of the slough.

299. The greatest potential use of the slough would be to supply logs, lumber, steel, and concrete aggregates to existing and potential industries, and to barge certain products out of the slough to shipside or to local and regional markets. Industrial growth along the slough is to be expected.

300. *Desires of local interests.*—While not in complete agreement as to the dimensions of the improvement desired, local interests, with but few exceptions desire improved navigation facilities between the mouth of Columbia slough and Union Avenue in Portland. Objection was raised by one railroad company to any improvement which would require revision of its bridge spanning the channel. Local interests point out that in addition to providing direct navigation benefits, the improvement would enhance the value of adjacent low-lying lands filled by dredge spoil, would tend to alleviate the present pollution problem in the slough, and would be a stimulus to industry in general.

301. *Plan of improvement.*—The previously recommended plan of improvement would include 7.7 miles of improved channel, 100 feet wide and 10 feet deep at low water, in Columbia slough from Willamette River to the Union Avenue bridge. Turning basins 200 feet wide and 2,000 feet long would be provided downstream from Union

and Denver Avenues. The improvement would necessitate raising the Union Pacific Railroad bridge and lengthening the central span to provide 80-foot horizontal and 34-foot vertical clearances at low water. It is anticipated that five other bridges would require modification and that it would be necessary to move certain transmission line towers of the Bonneville Power Administration. Under terms of the previous recommendation on this project, local interests would be required to furnish, free of cost to the United States, all lands, easements, rights-of-way, and spoil disposal areas required for both new work and subsequent maintenance; to agree to construct, maintain, and operate adequate terminal and transfer facilities along the slough; to accomplish, in accordance with law, such bridge alterations as necessary for accommodation of traffic with clearances as specified; and to hold and save the United States free from all claims for damages which might result from execution of the improvement.

302. *Costs and charges.*—Estimated costs to Federal and non-Federal interests are detailed in part II of this appendix. The estimated total initial investment is $1,141,300, of which $905,100 and $236,200 are Federal and non-Federal costs, respectively. Of the $905,100 Federal costs, $5,400, the cost of establishing navigation aids and markers, would be required by the United States Coast Guard. The balance would be expended by the Corps of Engineers. Estimated annual charges are shown in the following tabulation:

	Annual charges
Federal:	
Interest and amortization	$35,200
Maintenance and operation, Corps of Engineers	16,200
Maintenance and operation, U. S. Coast Guard	500
Subtotal	51,900
Non-Federal:	
Interest and amortization	10,100
Local loss of taxes	400
Subtotal	10,500
Total	62,400

303. *Accomplishments.*—Direct benefits anticipated to develop from the previously recommended improvements would be principally savings in cost of transporting materials to and from industries located along the slough. Certain indirect benefits, such as enchancement of property values and stimulation of industry and business in general, also are anticipated. The direct annual benefits resulting from the channel improvement would be about $77,800 as measured by savings in transportation costs, and the indirect annual benefits would be $6,500, making the total $84,300 annually.

304. *Economic justification.*—Evaluated total annual benefits are $84,300, and estimated total annual charges are $62,400. The benefit-to-cost ratio would be 1.35 to 1 and the project would be economically justifiable.

WESTPORT SLOUGH CHANNEL ENLARGEMENT

305. Enlargement of the channel of Westport slough has been recommended in a previous report entitled, "Review Report on Westport Slough, Oreg.," dated April 15, 1947. The recommenda-

tions of that report were concurred in by the division engineer, North Pacific Division, April 1, 1948, and the report was submitted to the Chief of Engineers. The proposed improvement consists of enlargement of a channel, designed for deep draft navigation, extending from the main ship channel in Columbia River at river mile 43 to Westport, Oreg. The proposed improvement is shown on plate 25.

306. *Description.*—Westport slough is a side channel of Columbia River with a total length of 10 miles and a width which varies from 150 feet in the upper reaches to 500 feet at the mouth. It meanders through the bottom lands between Clatskanie and Westport. The flow in Westport slough is principally tidal, and, except during the annual Columbia River freshets, the current reverses at flood tide. During low river stages the tide ranges from minus 0.5 to plus 8 feet. During freshet periods stages vary from about plus 7 to plus 10 feet between low and high tides. Velocities in Westport slough are moderate at all stages and do not adversely affect navigation. No bridges cross the slough but United States Highway No. 30 and the Spokane, Portland & Seattle Railway parallel it and connect the area to both Portland and Astoria.

307. Lowlands between Clatskanie and Westport are protected by levees and devoted to agriculture and dairying. Agricultural products contribute no commerce to Westport slough. The principal industrial plant in the region is a large sawmill at Westport that employs 300 men and has an 8-hour plant capacity of 240,000 feet, board measure. This mill had, in 1946, a production of 76,000,000 feet, board measure. Investment in the plant amounts to more than a million dollars and plans are being formulated to insure a continuous log supply so that operations may continue indefinitely. During 1946, a total of 46 vessels loaded at the lumber dock for foreign, west coast, or east coast ports.

308. The existing Federal project, completed in 1939, provided for construction and maintenance of a channel 28 feet deep and generally 200 feet wide extending from the 35-foot-deep Columbia River channel to a point immediately downstream from the lumber company wharf, a distance of approximately 3,500 feet. Conditions of local cooperation, with which compliance has been made, required local interests to provide suitable spoil-disposal areas for the project and to dredge and maintain a channel 28 feet deep and 150 feet wide for an additional 1,300 feet upstream to the upper end of the lumber company wharf. The mill wharf has a frontage of 1,200 feet and is adequate to handle lumber shipments. No other terminal facilities appear to be necessary as general freight is moved by rail or truck lines.

309. *Existing conditions.*—Because the vessels now serving Westport are larger than were used prior to World War II, the existing channel is now inadequate for proper maneuvering, and much time is lost. In order to avoid striking bottom, practically all ships entering the slough drop anchor to aid in making the sharp turn at the junction of Westport slough and Columbia River. The operation requires at least 30 minutes extra time. The total average annual delay occasioned by the maneuver is estimated at 12 hours for all commerce. Vessels loaded to drafts of 26 feet or more must await a favorable tide for departure. About 12 such vessels annually are estimated to be so delayed an average of 6 hours each, and the average annual delay is estimated at 72 hours.

310. Operators of large vessels prefer daylight hours for movement in the slough because of the hazards involved in nighttime maneuvering in the narrow channel. An estimated average of five such vessels annually are delayed at least 10 hours each, waiting for daylight, and the average annual delay due to waiting for daylight is estimated at 50 hours. Because of lack of adequate depth at Westport, approximately 10 vessels annually are compelled to run upstream to Portland or Vancouver to complete loading lumber to full draft. The extra running time involved amounts to 10 hours per round trip, and the average annual delay in completing loading is estimated at 100 hours. Under existing conditions, the total loss of time for ships using Westport slough amounts to about 234 hours annually.

311. Further, ships with modern turbine engines reportedly do not respond as readily as did ships with the older type reciprocating engines, and wider channels are, therefore, necessary for safe handling. Inasmuch as turning places are not available in the slough, vessels must be backed out, a somewhat hazardous operation.

312. In view of the conditions described in the preceding paragraphs, local interests advocate enlargement of the channel in Westport slough in order to accommodate the larger vessels currently used in the lumber trade.

313. *Plan of improvement.*—The improvement would consist of deepening the existing channel to 32 feet and providing a width of 300 feet at the lower end of the channel and a width of 250 feet at the upper end. The improvement by the Federal Government would be 3,500 feet long, as under the existing project. Local interests would be required to construct a channel 32 feet deep and 200 feet wide from the upstream terminus of the Federal work to the upper end of the mill dock, an additional distance of 1,300 feet. Dredge spoil would be placed on the right bank of the slough. Further conditions, which have been favorably received, require that local interests furnish, free of cost to the United States, suitable areas for the disposal of spoil for new work and for subsequent maintenance. Such bulkheads as may be required to retain disposal areas would be constructed by local interests. Maintenance of only the lower 3,500 feet of channel would be at Federal expense.

314. *Costs and charges.*—Estimated costs to Federal and non-Federal interests are detailed in part II of this appendix. Estimated initial cost is $143,250, of which $111,750 and $31,500 would be Federal and non-Federal, respectively. Estimated annual charges are shown in the following tabulation:

	Annual charges
Federal:	
Interest and amortization	$4, 340
Maintenance	8, 400
Subtotal	12, 740
Non-Federal:	
Interest and amortization	1, 340
Maintenance	2, 100
Subtotal	3, 440
Total	16, 180

315. *Accomplishments.*—Construction of the improvements proposed in the previously recommended plan would enable large ships to enter the channel with greater speed and safety and would eliminate the delay to ships resulting from the necessity of waiting for favorable tides or for daylight. The saving in time, about 234 hours annually, is evaluated at $83.50 per hour, representing a total annual saving of $19,500. These savings would be the annual benefits creditable to the project. Other benefits to the community would undoubtedly result from the increased commerce moving through the port, and from the accompanying increase in payrolls and in the buying power of the local people. These indirect benefits are not evaluated.

316. *Economic justification.*—Evaluated annual benefits are $19,500 and total estimated annual charges are $16,180. The benefit-to-cost ratio would be 1.20 to 1 and the improvement would be economically justifiable.

BAKER BAY CHANNEL AND MOORING BASIN

317. *General.*—This improvement was recommended in a previous report entitled, "Review Report on Baker Bay, Columbia River, Wash.," dated April 20, 1948. The recommendations contained in the report were concurred in by the division engineer, North Pacific Division, July 26, 1948, and the report submitted to the Chief of Engineers. The improvement would consist of a mooring basin for small boats at Ilwaco, Wash., at about mile 2 on Columbia River. The basin would accommodate 400 boats and would have an area of 23 acres. Included are necessary breakwaters and mooring facilities and a connecting channel from the main ship channel in the estuary of Columbia River. A lay-out of the recommended improvement and details of design are shown on plate 24.

318. *Description.*—Baker Bay lies on the north side of the estuary of Columbia River, near the mouth. It is separated from the Pacific Ocean by a peninsula known as Cape Disappointment, and from the Columbia River channel by a low-lying sand bar known as Sand Island. Ilwaco Harbor, the principal port, is situated on the northwesterly side of Baker Bay and is the site of the proposed small-boat harbor. Two channels, one on each side of Sand Island, connect Baker Bay with the ship channel in Columbia River. The improved east passage provides a 200-foot channel with present controlling depth of 11 feet. If the West Channel were improved, thereby shortening the route to sea by 5 miles, Ilwaco Harbor would provide a strategically located harbor, readily accessible at all tides, for basing ocean fishing boats. Although a depth of 8 feet is presently authorized for West Channel, on the basis of studies made in 1939, the trend to larger boats of greater draft since that time now justifies increasing the depth to 10 feet. This is the greatest depth that can be maintained in this location because of the shoaling which accompanies winter storms. Fishing fleet operations and fish processing are the principal industries in the Baker Bay area. Other industries for which Ilwaco is the distributing point are lumbering, dairying, stock raising, and cranberry growing.

319. *Existing improvements.*—The port of Ilwaco has constructed and maintained the present mooring basin, west of the proposed improvement, which will accommodate a maximum of 50 fishing boats. It owns and operates a warehouse at the inner end of the basin and has provided wharves, floats, and ramps for the accommoda-

tion of tugs, barges, and fishing vessels. Expenditures to date for these improvements, including maintenance, amount to about $200,000.

320. *Plan of improvement.*—The previously recommended plan of improvement includes about 2,800 feet of breakwater, an approach channel 150 feet wide via the "Dalton" waterway, and an interior basin, generally 10 feet deep, east of the port dock of Ilwaco. Additional area protected by the breakwater would allow for expansion of mooring facilities in the future. The channel connecting the port dock to the main ship channel would be 10 feet deep and 150 feet wide to the southerly 2,000 feet where the width would increase to 200 feet.

321. *Local cooperation.*—The recommendation for the new improvement provides that local interests must furnish, free of cost to the United States, all lands, easements, rights-of-way, and spoil-disposal areas required; agree to maintain the project depth in the basin; construct, maintain, and operate mooring facilities and utilities; make necessary changes in existing sewers; maintain a public landing with suitable supply facilities, open to all on equal and equitable terms; and agree to hold and save the United States free from all claims and damages resulting from the improvement. These provisions are believed acceptable to local interests.

322. *Federal participation.*—Federal participation in the improvement would include initial dredging in the West Channel, the "Dalton" waterway, and in the mooring basin; construction and maintenance of a breakwater; and maintenance dredging in the West Channel and "Dalton" waterway.

323. *Costs and charges.*—Estimated costs, both to the Federal Government and to local interests, are shown in part II of this appendix, and summarized as follows:

	Initial cost
Federal:	
Breakwater	$252,000
"Dalton" waterway and mooring basin	130,000
West channel	60,000
Subtotal	442,000
Non-Federal:	
Lands and easements	5,000
Construction costs, pertinent facilities	107,000
Subtotal	112,000
Total	554,000

Estimated annual charges are shown in the following tabulation:

	Annual charges
Federal:	
Interest and amortization	$17,180
Maintenance	8,000
Subtotal	25,180
Non-Federal:	
Interest and amortization	6,030
Maintenance and operation	10,000
Subtotal	16,030
Return from rental charges	−13,000
Net non-Federal	3,030
Total	28,210

324. *Accomplishments.*—The proposed improvement would facilitate operation and expansion of the fishing industry, the principal economic resource of Ilwaco and vicinity. Benefits creditable to the proposed improvement would be those attributable to elimination of mooring hazards, decreased boat operating costs, additional moorage space and to increased catches of fish. Indirect benefits would arise from additional activity in the fishing industry and the related processing industries.

325. The proposed improvement would provide adequate mooring facilities for 200 boats of the offshore fleet and for about the same number of smaller boats operating in the lower river. Elimination of damages that occur to the boats when tied abreast in the present small basin would save boat owners approximately $3,250 annually.

326. Reduction of travel distance between Ilwaco and the fishing grounds, through use of the improved west channel, would save from 45 minutes to 2 hours in running time per round trip over travel time from other harbors located on lower Columbia River between the mouth and Astoria. With an 8-foot channel depth, an estimated 12,000 trips would be made annually by 200 boats of the troller class, both large and small, with an annual saving in operating cost of $42,000. With a 10-foot channel an estimated 7,500 trips would be made annually by 125 smaller trollers and 4,500 trips would be made by 75 larger boats. At operating costs of $3.50 and $6 per hour, respectively, total savings would amount to $53,250 or $11,250 additional for the 10-foot channel.

327. Elimination of congested conditions in the mooring basin would permit boats to be serviced and leave without delay for the fishing grounds, and, upon return, to deliver catches promptly and berth in regularly assigned slips. The time saved in the mooring basin would allow more time for active fishing and thus result in larger catches. The increase in catch is estimated at an average of one-half ton per boat for each of the 200 boats, or 100 tons per year, worth approximately $20,000 at the fisherman's level of prices. This benefit would be in addition to the savings in operating costs as described in the preceding paragraph.

328. A larger fishing fleet at Ilwaco would provide employment for more workers in fish-processing plants, increase property values in the community, and benefit business generally. The proximity of the proposed harbor to the Columbia River entrance renders it favorable to use by the Coast Guard in rescue work and as a refuge for small boats during storms. The benefits are difficult to evaluate, but important, as savings of property and of human lives would be involved. The intangible benefits are estimated to amount to $5,000 annually.

329. *Economic justification.*—As the total annual benefits directly creditable to the proposed improvement are estimated to amount to $39,500 and the sum of the Federal and non-Federal annual costs is $28,210, the benefit-to-cost ratio would be 1.4 to 1. The improvement, therefore, would be economically justified and warrants immediate construction.

THE DALLES IRRIGATION PROJECT, WEST UNIT

330. *General.*—The United States Bureau of Reclamation has proposed, in a report prepared by the regional director of region I, dated December 1947 and entitled, "The Dalles Project, West Unit, Oregon," the irrigation of 4,530 acres of land south of The Dalles, Oreg. This project is considered as a probable unit of the sub-basin development, and a digest of the salient features follows.

331. The area to be irrigated is shown on plate 36. The project lands occupy portions of the basins of five small streams, which lie within 5 miles of, and are tributary to Columbia River. The climate is semiarid, and the topography varies from level bottom land to hillside. Orchard crops are of major importance, with cherries, peaches, and apricots produced in quantity in that order. The orchards initially were successful but have not continued to prosper, and landowners have sought to develop local irrigation water supplies, principally from wells. As a result of these efforts, irrigation water was applied to 1,500 acres in 1946, but the supply proved inadequate. The attempted irrigation was undertaken as a temporary measure pending development of a permanent and adequate solution.

332. The proposed improvement consists of irrigation by sprinkler system, using water pumped from Columbia River near the head of Bonneville pool. An electrically powered pumping system would deliver water under pressure to the 4,530 irrigable acres of the unit. The average surface elevation of the river during the pumping season is 82 feet, and virtually all of the irrigable lands lie between elevations 400 and 900 feet. Pump capacity of 42 second-feet against a maximum head of 947.5 feet, including static head and friction losses, would be required. As a part of the pumping and distribution system, a concrete-lined equalizing reservoir with a capacity of 1.5 acre-feet would be constructed at elevation 957 feet. The distribution system would be of welded steel pipe varying in size from a maximum of 36 inches to a minimum of 4 inches. The sprinkler equipment would be acquired privately by the operators and would not be part of the project development by the Federal Government.

SECTION IV—PROPOSED PROJECTS

GENERAL

333. *Introduction.*—Proposed projects, combined with existing, authorized, and previously recommended projects, would complete development of main stem Columbia River in the interests of navigation and power and would provide the maximum feasible amount of flood control. Apparently only one major navigation project, in addition to those previously recommended, is required at the present time in the reach below Bonneville Dam. This project, deepening of Columbia River entrance, is described in preliminary scope and is proposed for further study at an early date. Upstream from Bonneville Dam to McNary Dam, a 100-mile reach of channel will remain relatively unimproved. Because of rapids and other conditions, this reach can be further improved, for navigation, only by slack-water methods. After development of proposed upstream multipurpose storage, the undeveloped power head in this reach would represent a

total firm power supply of more than 1,900,000 kilowatts. The proposed The Dalles and John Day projects would provide slack water for navigation, develop available head, and provide needed flood-control storage in this 100-mile reach. Provision of flood-control storage has been found to be feasible only at the John Day project. The physical aspects of this project are described in considerable detail, but, as all evaluation of system benefits are contained in appendix M, only general statements in regard to benefits are presented in this appendix.

334. The high John Day Dam, to provide flood-control storage, is proposed for the reach from The Dalles pool to McNary Dam. Alternative considerations consisting of John Day Dam without flood-control storage, a low John Day and Arlington Dams, and open-river improvements for navigation are discussed here briefly and in some detail in part II of this appendix, in review of plans presented in House Document No. 704, Seventy-fifth Congress, third session. Studies indicate that only a single dam without flood-control storage should be considered as an alternate to the proposed high dam with flood-control storage.

335. Other projects relating to harbor facilities in existing and proposed reservoirs, diking, and drainage of additional flood plain areas, and protection of river banks from erosion are discussed herein. Although data are not now complete on these projects, sufficient information is available to show the economic feasibility of each project or group of projects.

JOHN DAY DAM

336. *Introduction.*—The proposed John Day project would be a multiple-purpose development, primarily for flood control, navigation, and power. John Day Dam would be located 217.3 river miles above the mouth of Columbia River, 24.8 miles upstream from the previously proposed The Dalles Dam, and 75 miles downstream from McNary Dam. The location of John Day project is shown on plates 1 and 36. Siatuated at the head of The Dalles pool immediately downstream from the mouth of John Day River, it would raise the low-water surface to normal pool elevation 255 feet and provide for flood-control storage to a maximum pool elevation of 292 feet. The resulting reservoir would extend upstream to McNary Dam. House Document No. 704, Seventy-fifth Congress, third session, proposed a lower dam at this location with normal pool elevation 210 feet and another dam, 26 miles upstream at the Arlington site, to effect development of the same reach of the river. Studies undertaken for this report, however, indicate the single-dam plan to be more economical than the previously proposed two-dam development. An alternative plan of a single dam with normal pool elevation of 255 feet, but without flood-control storage, is briefly discussed following this discussion of the recommended project, and, for comparative purposes, brief mention also is made of the two-dam plan and a plan for open river improvement. More detailed discussion of these alternative plans is contained in part II of this appendix.

337. *Storage analysis.*—John Day Reservoir, shown on plate 33, would have a length of 75 miles, and would constitute the longest pool on the lower Columbia River. In view of the relative lack of develop-

ment at the lower levels along Columbia River, surcharge flood-control storage above normal pool elevation 255 appears feasible and desirable.

338. Chart 8 shows area and capacity curves for John Day Reservoir, based on flat-pool levels. At normal pool elevation 255 the reservoir would contain 1,720,000 acre-feet of water above the natural low-water profile and about 600,000 acre-feet of additional storage capacity would be available in each 10-foot increment above this level. Table 38 presents detailed storage data by short reaches of the reservoir, which permits evaluation of storage between backwater profiles as the sum of a succession of increments.

339. Economic justification is the limiting factor controlling the amount of storage that may be made available at John Day Reservoir. Analysis of the cost of several alternative amounts have resulted in the proposal of a gross flood-control storage of about 2,000,000 acre-feet which would be obtainable between normal pool elevation 255 and maximum flood-control pool elevation 292.

340. *Hydrology.*—Columbia River run-off at John Day dam site is equal to run-off at The Dalles gaging station less the run-off from Deschutes River, which enters Columbia River between these points. The drainage area tributary above The Dalles is 237,000 square miles; in comparison, the drainage area tributary above John Day dam site is 226,000 square miles. Run-off and flow characteristics at John Day site are similar to those for The Dalles site. The estimated average annual run-off at the former is 136,400,000 acre-feet on the basis of 68 years of record at The Dalles. Based on the published discharge at The Dalles for the period 1878–1946 with correction for flow during the 1948 flood and adjusted for Deschutes River flow, the estimated peak discharge of the 1894 flood at John Day dam site was about 1,230,000 second-feet. No record of Deschutes River discharge at the time of the 1894 flood on Columbia River is available, but the maximum discharge probably did not exceed 10,000 second-feet.

341. The daily discharge hydrographs (pls. 7–10); summary hydrographs (pl. 11); and stream-flow characteristics (pl. 13); compiled for The Dalles, also are closely applicable to the John Day site. For The Dalles, the minimum monthly discharge was 42,430 second-feet, and 56 percent of the time the flow exceeded 120,000 second-feet, the average flow of the minimum year (1926). Upstream storage ultimately will increase the minimum dependable flow. The derivation of the spillway design discharge of 2,250,000 second-feet for John Day Dam site is discussed in part II of this appendix.

342. *Geology.*—Columbia River at the John Day site flows in a canyon about 4,000 feet wide, flanked by rock cliffs. An island about 1 mile long divides the river channel slightly north of midstream. This island which remains exposed up to discharges of about 700,000 second-feet, is characterized at the upper end, near the dam axis, by bedrock pinnacles. Numerous pinnacles and islands of bedrock also are contained in the channel to the south of the island, but the north channel has no bedrock exposures except along the edge. Bedrock at the site is Columbia River basalt, which occurs as essentially flat-lying flows ranging in thickness from about 15 feet to about 70 feet. Soil zones or interbeds a few inches thick occasionally are found between the flows, but are not continuous throughout the site area. The basalt flows form an extremely broad, gentle arch, the crest of which is near the site axis. Overburden in the axis area consists of talus and blow

sand along the edges of the canyon and gravel alluvium in the river channel. The talus deposits are small and believed to be stable. The alluvium is concentrated in the north channel, where it occurs to a depth of about 200 feet. The south channel, studded with bedrock exposures, contains alluvium only in minor amounts. A detailed discussion of the geology of John Day dam site is included in part II of this appendix.

343. *Proposed plan.*—Plate 32 illustrates the lay-out proposed to provide flood-control storage capacity at John Day site, and plate 8, part II, illustrates several reservoir backwater profiles with the proposed maximum flood-control pool elevation 292. The dam normally would operate with pool elevation 255, and storage would be necessary only about once in 10 to 20 years. The maximum flood-control pool would be at elevation 292 and the top of the dam would be at elevation 297.

344. *Lay-out.*—The arrangement of the several features of John Day Dam is controlled largely by topographic and subsurface conditions. Because of the limited canyon width, essential structures, with a minimum of connecting nonoverflow dam, would completely fill the cross section. The powerhouse, requiring the greatest foundation depth for the draft tube structure, would be placed in the north channel where an overburden depth of 200 feet at some points may exist. Rock elevation in the south channel is suitable for the location of the spillway and the spillway apron. The navigation lock would be placed adjacent to the spillway and against the Oregon shore, which curves slightly and affords good visibility and approach conditions both above and below the dam. Approaches would be protected from cross currents and turbulence by long guard walls. The selected location would be subjected to a minimum of turbulence as periods of spillway overflow would be shorter than those during which the river flow would be confined entirely to the powerhouse. A further advantage of separating the lock location from that of the powerhouse is that such location would permit easy rail access to the latter structure thereby facilitating future maintenance and initial construction. The project lay-out is governed to some extent by the necessity for maintaining navigation during construction. This factor is discussed in connection with cofferdams and river diversion.

345. *Spillway.*—Control of surcharge flood control storage in John Day Reservoir would be accomplished by use of the spillway gates. The proposed spillway would consist of 22 50-foot gate bays separated by 10-foot piers. The spillway crest would be at elevation 223.5, and, with all gates raised, the hydraulic capacity would be 650,000 second-feet at normal pool elevation 255. This discharge, supplemented by an estimated 150,000 second-feet through the powerhouse, would permit passage of a total of 800,000 second-feet without accumulation of surcharge storage. As the river discharge increased above this amount, the increment flow would be stored by so operating the spillway gates that discharge would be limited to 650,000 second-feet. The smallest gate opening of 13.5 feet would occur at the maximum pool elevation of 292. Spillway gates 57 feet high, including 2 feet of freeboard, would be required. Spillway gates 70 feet high are proposed for the bays at each end of the spillway in the interest of operational flexibility and in facilitating the formation of currents attractive to fish migrating upstream. Spillway

discharge characteristics, assuming equal opening of all spillway gates, are illustrated on plate 5, part II. If the available storage space were filled and river discharges no longer controlled, the spillway gates would be opened to pass reservoir inflow and maintain maximum pool elevation 292, at which level the spillway design flood of 2,250,000 second-feet could be passed with some slight control, or all spillway gates could be removed and the spillway design flood passed at pool elevation 290.7. In the interest of early resumption of navigation, after passage of a flood peak, storage would be released as rapidly as practicable, but not at a rate to exceed 800,000 second-feet discharge.

346. A stilling basin, with apron at elevation 124.0, would extend 290 feet downstream for the full width of the spillway. The stilling basin would be designed to produce a hydraulic jump on the apron for the design discharge of 2,250,000 second-feet. Two rows of baffles and an end sill would be provided.

347. *Power facilities.*—The powerhouse, 1,298 feet in length, would extend from the spillway structure northward to the Washington shore. Under phase C–2 development, as discussed in appendix O, 13 units, rated at 85,000 kilowatts each, would be installed, and powerhouse structure would be provided for 1 additional unit. A nonoverflow concrete gravity dam section between the spillway and the initial powerhouse structure would provide a bulkhead section that could be removed to permit extension of the powerhouse to provide for four additional units. If thought expedient, another bulkhead could be incorporated in the structure of the extension.

348. The utlization of surcharge flood-control capacity between elevations 255 and 292 at John Day Dam would have an adverse effect on the power head at McNary Dam, thereby reducing power output when McNary discharges exceeded 800,000 second-feet. According to the plan of system power operation contemplated, however, when the discharges at McNary exceed 800,000 second-feet, it would not be necessary to maintain the firm capacity of the McNary plant or that of the power system. Although additional generating units need not be installed at John Day Dam to compensate for loss of power at McNary Dam at the higher discharges, the higher pool levels would require that the turbines and thrust bearings at John Day Dam be strengthened. With a discharge of 800,000 second-feet and with the reservoir level at normal pool elevation 255, the effective head on the John Day generating units would be 76 feet. Were John Day to store floodwater to the 292-foot maximum flood-control water-surface elevation, the head would be increased to 113 feet. As an additional safety factor, and in consideration of the possibility that at some future date control of outflows to 600,000 second-feet may be desirable (tailwater elevation 174 for 600,000 second-feet as compared to 179 for 800,000 second-feet), the cost estimates for this project include design of the John Day turbines and thrust bearings for a maximum head of 118 feet.

349. Thirteen automatically adjustable, 6-blade, propeller-type runners would be initially installed. An additional powerhouse unit, complete except for the installation of generating equipment, would be constructed. The lay-out of the powerhouse provides space for an ultimate expansion to house a total of 18 generating units.

350. The generators would have a name-plate rating of 85,000 kilowatts each, 89,500 kilovolt-amperes at 0.95 power factor, and a guaranteed continuous overload capacity 15 percent greater than name-plate rating. Turbine runners, by reason of the low elevation of the supporting rock stratum at this site, would be set at a more than adequate distance below tailwater to preclude the possibility of cavitation on the runner at maximum head and generator guaranteed overload. Station service would be provided by means of two 3,500-kilowatt hydroelectric generating units.

351. The power plant would be designed to produce, at a river discharge of 800,000 second-feet, the firm power available with minimum regulated flow. This upper flow limit would be exceeded only about 0.3 percent of the time after ultimate storage regulation was effected. Plate 9, part II, illustrates head and output characteristics of John Day power plant (normal pool elevation 255) (see appendix O) as related to river discharge conditions. Appendix O contains detailed data as to power installations and capabilities, and general data are shown in the following tabulation:

Item	Description
Nominal prime capability	735,000 kilowatts.[1]
Nominal firm capability [2]	980,000 kilowatts.[1]
Installed generator capacity	1,105,000 kilowatts.
Type of turbine	Automatic, adjustable 6-blade propeller.
Design head	85 feet.
Rated head	93 feet.
Maximum head [3]	118 feet.
Minimum head [4]	76 feet.
Turbine rated output	134,000 horsepower.
Revolutions per minute	85.7.
Diameter of turbine runner	280 inches.
Elevation of centerline of runner	117 feet above mean sea level.
Unit spacing	82 feet.
Generator rating at 0.95 power factor	89,500 kilovolt-amperes.

[1] Approximate. See appendix O.
[2] Computed on basis of 75-percent load factor.
[3] For river discharge of 600,000 second-feet.
[4] For river discharge of 800,000 second-feet.

352. During flood periods, overload generator capacity at John Day Dam would be utilized and the following comparative data are illustrative of conditions which would prevail if maximum flood-control pool elevation were attained at John Day.

Discharge	Power output, megawatts	
	Pool elevation 255	Pool elevation 292
800,000 second-feet	1,100	1,271
1,100,000 second-feet	930	1,271

353. A typical cross section of John Day powerhouse shown on plate 32 illustrates the design proposed. In the interests of economy, the generator floor elevation has been established 28.5 feet below maximum tailwater. A heavy watertight downstream wall, however, is proposed to protect generating equipment during periods of high discharge. Hydraulic requirements of the intake structure set the

elevation of the floor at elevation 130 about 122 feet below minimum pool.

354. With flood-control storage at John Day Reservoir, the maximum pool would be at elevation 292 and design for structural stability would be based on that pool level and applicable tailwater. Although initially, with regulation to 800,000 second-feet, the water-surface differential would not exceed 113 feet, provision would be made for ultimate regulation to 600,000 second-feet with a corresponding head of 118 feet.

355. The trash sluiceway would be designed to receive floating debris at all pool elevations, from normal to maximum, by addition of extra entrance gates. The powerhouse intake gates would be designed for maximum pool and for tailwater elevation 174 corresponding to a discharge of 600,000 second-feet, as the draft tubes would not be unwatered during periods of maximum floods.

356. *Navigational lock.*—The navigation lock chamber, on the Oregon shore, adjacent to the spillway, would be excavated about 50 feet into sound rock and would have clear inside dimensions of 86 feet by 675 feet. The depths over the upper sill would range from 14 feet at minimum pool elevation 252 to 17 feet at normal pool elevation 255. Depth over the lower sill would vary with tailwater elevation and would range from a minimum of 14 feet at minimum flow with The Dalles pool drawn down 3 feet to a maximum of 35.5 feet for a discharge of 800,000 second-feet, which is a practicable upper limit for navigation. The lock lift would vary from a maximum of 94.5 feet at low water to about 76 feet at 800,000 second-foot discharge.

357. Because of adverse conditions along the river at discharges in excess of 800,000 second-feet, it would not be necessary to raise the lock walls and gates to accommodate navigation at the maximum flood-control storage pool elevation 292. Such raising, in addition to substantially increasing the cost of flood-control storage at John Day Dam, would result in an initial lift of 113 feet, which at present would be unprecedented. Upon ultimate extension of upstream storage to control flows to 600,000 second-feet at John Day Dam, the lock chamber could be so altered that the maximum lift of 118 feet could be made. A preliminary estimate of the incremental initial cost involved, including that of constructing John Day lock and upstream guard wall and raising the downstream guard wall and moorage at McNary Dam to a pool elevation of 292, is about $7,900,000.

358. The upstream and downstream approaches to the lock would be 250 feet in width and each would be protected by 1,000 feet of guard wall. A nominal sum is included in the cost estimate for moorages in these channels, clear of the navigation way, which also may be used as safe harbors during flood or ice conditions. The lock chamber would be filled and emptied by means of intake ports in the wall extensions just above the upper sill, main longitudinal culverts located in the lock walls, transverse culverts in the central section of the lock chamber with necessary ports, and by similar culverts just below the lower sill which would empty into the lower approach channel. Filling and emptying of the lock would be controlled by tainter valves in the wall culverts. Miter gates designed for 2-foot freeboard above normal pool are proposed for the lower and upper ends of the lock. Stop logs would be provided both upstream and downstream from the miter gates for emergency closure. At the up-

stream end, special provisions would be made to effect closure when pool levels above normal prevail, corresponding to discharges above 1,400,000 second-feet. A bascule bridge would connect the service roadway over the dam to the left abutment. An earth-fill esplanade accessible from United States Highway No. 30 would be constructed along the south wall of the lock. This esplanade would provide parking and maintenance areas.

359. *Fish facilities.*—Provisions to pass adult anadromous fish upstream over John Day Dam would consist of two fish ladders, fish locks, and a powerhouse fish collecting system. One fish ladder would be located at the north end of the powerhouse section; the other at the south end of the spillway next to the Oregon shore line. The fish ladders would be of gravity type, having a width of 30 feet and slope of 1 on 20. The fish locks probably would be located between the powerhouse and spillway sections. The collecting system would provide for operation so that migrant fish picked up by the system could be led into either the north fish ladder or the fish locks, as desired.

360. To mitigate possible fish losses due to inundation of spawning and rearing areas, and losses which, in the opinion of aquatic biologists, occur at dams under the most favorable of artificial conditions, provision would be made for artificial propagation facilities in lower Deschutes River above backwater from The Dalles pool. These facilities would include salmon hatchery units which would be operated to make up for any possible fish losses at both The Dalles and John Day Dams.

361. In the interest of economical operation, the two or more hatchery units would have common administrative headquarters, water supply system, biological laboratory facilities, and supervision. As proposed, at least two hatchery units would be provided with a combined capacity adequate to handle about 25,000 adult salmon and about 50,000,000 eggs. Costs would be borne jointly by John Day and The Dalles Dams. These installations would supplement passage facilities at John Day and The Dalles Dams and would not be a part of the lower tributary fishery plan proposed by the United States Fish and Wildlife Service.

362. *Nonoverflow concrete dam.*—The nonoverflow concrete sections connecting the main structures would be of gravity type founded on sound rock and would support connecting links of the service roadway across the dam. About 1,192 feet of nonoverflow dam would be required.

363. *Recreation facilities.*—Because of location of the dam with regard to United States Highways No. 30, 830, and 97, it would be an attraction to sightseers. Because of the excellent views of the dam and the proximity of the navigation lock, the fish ladder and spillway, greater attendances are anticipated on the Oregon side. The power house and fish ladder would be the principal attractions on the Washington shore.

364. The reservoir created by John Day Dam would not only provide a stimulus to boating in the immediate vicinity, but would also result in a far greater basin-wide interest in extended pleasure cruises, both private and commercial.

365. Proposed development would include sightseeing facilities in the vicinity of the dam, consisting of necessary access roads, parking areas, public service building, and picnic areas on either shore; a

public boat dock on the Oregon shore; and five public access areas at strategic points along the reservoir shore line provided with limited parking, picnicking, and boat-launching facilities.

366. Dependent upon future demand, resorts, moorage, and service facilities and group camps might be developed by local organizations or private capital.

367. *Construction.*—Reconnaissance investigations to find suitable sand and gravel for concrete aggregates were confined to Columbia River Canyon. Materials from this general area were used in Bonneville Dam and are proposed for use in McNary Dam. A large bar lying 4 to 7 miles downstream from the dam site, between river miles 210 and 213, could furnish a sufficient quantity of sand and gravel aggregate for the entire project. A second source is a large bar between miles 227 and 228, 10 miles upstream, and a third is the bench near river mile 233 upon which the town of Blalock, Oreg., and considerable farm land is located. While the quality of Columbia River aggregates generally is satisfactory, the gradation may be such as to require processing in order to provide some sizes. Rock suitable for miscellaneous embankment, backfill, and cofferdam construction is available in abundance, and would be supplied from necessary excavations at the dam.

368. The cofferdam arrangement proposed for John Day Dam is predicated on prior completion of The Dalles project and on maintenance of a normal pool elevation at 160 during construction of John Day Dam. The Dalles pool would thus create a backwater effect of 14 feet at the John Day site under minimum flow conditions. This effect would diminish at higher discharges, but nevertheless would necessitate higher cofferdams at John Day than if that structure were built under natural river conditions prior to The Dalles project. Should the John Day project be constructed prior to The Dalles project, the total cost of cofferdams and diversion would be reduced slightly.

369. With The Dalles and McNary Dams constructed and in operation, river traffic would be heavier and could utilize larger tows than at present. Adequate provision for navigation through John Day dam site during construction of the dam, therefore, would be essential. The use of more than two major cofferdams to accomplish that purpose is not considered feasible.

370. The major cofferdams would be designed for overtopping but would provide protection against a flood of 620,000 second-feet, which, on the average, is exceeded only 1 year in 5. This degree of protection is believed justified to prolong the annual working season and to reduce the expense of clean-up following overtopping. A plan of the cofferdam arrangement is shown on plate 32.

371. The first-step cofferdam, against the Oregon shore and extending to the island in the center of the river, would enclose the entire spillway and navigation lock area. The major portion of the cofferdam would be constructed of steel pile cells driven to rock and filled with river gravel. That portion of the cofferdam protecting areas above low water would be constructed of rock and earth fill, and, to prevent overtopping, would be raised to an elevation 10 feet higher than that of the steel pile cells.

372. During first-step construction, the present navigation channel would be closed by the cofferdam, and the north channel, between the

island and the Washington shore, would be used for navigation. Making allowance for increased water depth in this channel due to prior construction of The Dalles project, removal of about 2,500,000 cubic yards of gravel would be required to reduce velocities in the interest of navigation. Average channel velocities, after the planned excavation, are tabulated below:

Discharge:	*Miles per hour*
600,000 second-feet	8.9
300,000 second-feet	6.8
200,000 second-feet	5.5
100,000 second-feet	4.1

This excavation also would be of future benefit to the powerhouse in that it would afford channel get-away capacity and increase effective head.

373. Unusual problems are not expected to arise in construction of the first-stage cofferdam. Overburden in the area is very light, and sealing off leakage would not be difficult. The top of the upstream leg of the cofferdam would be at elevation 180, and that of the downstream leg at elevation 178. The height would range from 18 to 75 feet and would average 35 feet. The length would be about 5,500 feet.

374. The second-step cofferdam, against the Washington shore, would enclose the powerhouse and the north end of the dam. Along the dam axis, between the Washington shore and the island, gravel overlies the rock to a depth of about 200 feet. Upstream, however, rock is nearer the surface. In order to reduce seepage from downstream, the downstream leg would be located 2,000 feet from the dam axis. In addition, a 200-foot impervious blanket beyond the cofferdam is planned. Along the island, steel cells would be driven to rock. The upstream cofferdam leg, top elevation 182, would be so located that the steel sheet pile cells could be driven to rock. The cofferdam would be about 6,400 feet long and would enclose an area of about 110 acres. Height would range from 12 to 62 feet and would average 35 feet. For protection against overtopping, embankment sections would be constructed 10 feet higher than the steel cells. During second-step construction the river would flow over the spillway, the ogee section of which, above elevation 140, would have been omitted from first-step construction.

375. Shipping during second-step construction would pass through the lock. The upper lock sill would be left at elevation 168, the upstream approach channel would be excavated to the same elevation, and a temporary upstream lock gate would be employed. The upper pool normally would be maintained at elevation 176 by control effected by the spillway gates set in temporary guides provided in the spillway piers for this purpose.

376. During second-step construction, temporary fish ladders of timber and steel would be provided. One would be supported on the south side of the cofferdam and the other on the outside face of the south spillway training wall. Provisions would be made to adjust the ladders as the upper pool fluctuates.

377. Third-step construction would consist of raising the spillway ogee section and the upper lock sill. The spillway bays would be cofferdammed individually for this construction. In order to mini-

mize interference with navigation, raising the upper lock sill would be deferred until all of the spillway bays were completed.

378. During construction of John Day Dam, navigation would be interrupted for two short periods. The first of these, possibly 3 months in duration, would occur when the second-step cofferdam was under construction and the first-step cofferdam being removed. The second interruption, of about 1 month duration, would occur when third-step construction neared completion, and it became necessary to raise the temporary low upstream lock sill.

379. Construction of John Day Dam, including installation of four generating units, probably could be accomplished in 6 years. Installation of 9 additional units at the rate of 4 per year would complete the development of 13 units in a total period of 8¼ years. The limited space available in the canyon requires that the Union Pacific Railroad be relocated prior to initiation of dam construction in order to provide access. One year is the estimated time required to relocate the railroad, and 2 years is the estimated time for completion of the spillway and navigation lock within the cofferdam. Construction of the powerhouse within the second-step cofferdam and installation of four generating units is estimated to require 3 years, at the end of which time the pool would be raised. Installation of subsequent units would be accomplished with the project in operation.

380. *Reservoir.*—The reservoir would be strategically located for the control of floods on lower Columbia River, and, especially, to provide protection to the principal damage area downstream from Bonneville Dam. Although storage at John Day alone would not be sufficient to effect a large stage reduction, the project, when operated as a unit in a system of flood-control reservoirs could be of major benefit to downstream areas. Storage at this site would be downstream from most of the major flood-producing tributaries and close to the area to be protected, and would be reserved for regulation of major floods only. Under such conditions, the storage capacity also could be utilized to eliminate possible operational difficulties resulting from concentrated local run-offs or uncontrolled run-off from areas below upstream system reservoirs. Although this storage capacity at John Day project would be utilized only infrequently, it would add greatly to the flexibility and efficiency of a system of flood-control storages in controlling major floods.

381. *Flowage and relocations.*—John Day Reservoir normally would operate at pool elevation 255. Initially, the available storage space would be used only when flows exceed 800,000 second-feet, as regulated by upstream storage. Under ultimate conditions, it is possible that this storage would be utilized at flows of 600,000 second-feet. Such conditions would occur, on the average, less frequently than once in 10 years. It would be necessary to relocate utilities above the design maximum flood-control pool, and to acquire flowage rights to the pool level. Pool elevation 292, therefore, with backwater profile resulting from the 1894 flood with freeboard superimposed thereon, was used as a basis for estimating cost of reservoir acquisition and relocations. Plate 8, part II, illustrates the 1894 flood profiles with levels at John Day Dam of both 255 and 292. The vertical difference of 37 feet at the dam would be decreased considerably by backwater effects in the upper reaches of the reservoir and would amount to only 15 feet at Umatilla and 13 feet at McNary Dam.

382. Because of the high pool level required for flood-control operation of John Day, normally a substantial difference in elevation between permanent facilities along the shore and the water level would exist. This difference, however, would not materially exceed the fluctuation under natural conditions. At Umatilla, near the head of John Day pool, the natural fluctuation is from low-water elevation 247 to elevation 281 for the 1894 flood, a difference of 34 feet. Under the proposed flood-control storage plan this variation would be from elevation 255 to elevation 297, a difference of 42 feet. The range between low water and the backwater elevation for 800,000 second-feet, at which storage would begin, is 20 feet. At Arlington, situated in the central portion of John Day Reservoir area, reservoir fluctuation prior to storage would be negligible and with storage would be, as at John Day Dam, about 37 feet. A benefit, incidental to provision of flood-control storage, would accrue to small-boat navigation on John Day pool during normal river discharges, in that greatly increased clearance under bridges spanning shore-line indentations would make such indentations potential harbor sites.

383. Acquisition of land for the John Day storage reservoir would be extended to a level 5 feet above the 1894 backwater profile with 292 water surface elevation at the dam, even though inundation would be infrequent. As a result, about 18,500 acres of land on the fringe of the normal pool would be Government-owned. Most of this area, as indicated on plate 33, would occur in a 15-mile reach from Castle Rock to Irrigon. Elsewhere the width of additional acquisition flanking the normal pool would vary from a negligible amount in the canyon section immediately above the dam to about 1,000 feet. Although no permanent structures which would be damaged by inundation could be constructed below maximum pool level, some of the lands between normal and maximum pool levels would have value for park sites and game refuges and much of it could be leased, subject to inundation, for agricultural purposes. It would be possible to predict the magnitude of summer flood by about May 1 so that, in the event of need for storage in John Day Reservoir, it is unlikely that crop-planting expense and effort would be lost.

384. *Towns affected.*—The incremental effect of flood-control storage at pool elevation 292, over that of normal pool 255, on the nine communities bordering John Day Reservoir would be confined to Arlington, Alderdale, Irrigon, and Umatilla. Other towns, including Boardman and several small railroad settlements, would require complete relocation even at normal pool. The dislocations at Alderdale and Irrigon, towns of about 40 and 125 population, respectively, would not be serious, as the interests affected could easily be relocated. Alderdale is primarily a railroad point, whereas Irrigon is the center of a small irrigated area.

385. Arlington is the principal trading center for an area of about 600 square miles south of Columbia River. In view of its strategic location with respect to present transportation routes, and the lack of an equally convenient area in the vicinity to which the town could be relocated, it is proposed to raise the entire town to elevation 302. The flowage estimates do not provide for acquisition of land in Arlington but, in lieu thereof, provide for construction of embankment and replacement of existing utilities. Revision of the authorized flood channel through the city also is included, on the assumption that this

channel would be constructed in the period prior to construction of John Day Dam. The estimates are based upon payment of fair market value for all affected private improvements, although it probably would prove more economical to raise some in place and remove others temporarily during filling operations, later replacing them on the completed embankment.

386. The above procedure would be subject to modification upon detailed study prior to construction but the cost estimates based thereon are believed to be ample. Maximum fill height at the railroad would be about 80 feet and about 3,400,000 cubic yards of embankment would be required. Inasmuch as suitable material for a gravelly fill is available in Alkali Canyon south of Arlington, no appreciable subsidence in the fill would be anticipated, and the canyon overburden, largely of outwash materials, should not consolidate unduly. The proposed freeboard of 10 feet above maximum water surface would provide adequate subdrainage.

387. Revision of the town of Arlington would unavoidably cause some loss of business during the construction period. The improvement in the topography of the town, however, from canyon type to that of a flat-lying, well-drained area, and the opportunity to replan the city along modern lines, would compensate in large measure for such loss.

388. Studies were made of a system of levees to protect north Umatilla, but, because of the height of levee required and problems of access, such a plan was rejected even though possible. Similarly, a plan of filling and raising north Umatilla was studied and rejected as infeasible.

389. Flowage estimates, therefore, are based upon acquisition of all lands and improvements in Umatilla which would be affected by the 1894 backwater superimposed on maximum flood-control storage-pool elevation 292. Facilities of the Umatilla port, now and potentially one of the primary points of cargo interchange, lie in the low area proposed for acquisition. Commerce at this port is discussed in the previous description of a proposed harbor at Umatilla. To adapt the port development to the utilization of surcharge storage space, a filled strip about 300 feet wide and 3,000 feet long is proposed along the normal pool shore at the site of existing port facilities. This area would have an access strip of similar width, constructed to elevation 305, to serve as a safe and convenient site for the present oil tank farms and grain elevators, and for future warehouses. Lay-out of this construction is illustrated on plate 33.

390. Present commerce at Umatilla consists of gasoline and oil, which are unloaded from inland-bound carriers, and wheat, which is loaded for shipment downstream. Port facilities include three storage tank farms for petroleum products, which are discharged by pumps from the barges, and one grain elevator, which loads barges by an overhead conveyor. One of the tank farms is located upstream where deep water exists close to shore. The tanks, however, are placed nearby on low ground subject to overflow during moderate floods. At the remaining port installations, the gently sloping beach does not provide navigable water depth within about 200 feet of the shore, hence wharves are required to serve the barges which are moored at rock-filled cribs in the river. The wharves are of light construction; those serving the tank farms carrying pipelines primarily and the

grain-elevator discharge being designed principally to support the conveyor. The two tank farms in this area are about 1,000 feet from shore whereas the grain elevator is much nearer the beach. Plate 27 illustrates these conditions and also the proposed position of a port facility to cost about $200,000 which is planned by local interests to handle general cargo.

391. Operation of facilities at Umatilla Harbor would not be handicapped significantly by the proposed flood-control storage plan, which would result in raising of port storage facilities to base elevation 305. Grain-loading operations would not be affected and pumping of petroleum products would benefit from reduced length of discharge line, although static pumping head would be increased but general cargo would normally require vertical movement of about 45 feet in addition to horizontal travel.

392. Within the reservoir area, the Union Pacific Railroad follows the Oregon shore of Columbia River and has four connections leading to the south. These occur at Arlington, river mile 242; Heppner Junction, river mile 252; Messner, river mile 271; and Umatilla, river mile 289. The Spokane, Portland & Seattle Railway, following the north shore, has no lateral lines. These railroads would be relocated to a grade 7.5 feet above the backwater profile of maximum pool (elevation 292 at the dam) and flow of 1894 flood as shown on plate 8, part II. This would involve 82.8 miles of Union Pacific Railroad and 81.8 miles of Spokane, Portland & Seattle Railway. Present standards of the individual railroads would be adhered to for the new work. The maximum grade of the Union Pacific Railroad is 0.40 percent compensated for curvature, and the maximum curvature is 8°. Similar figures for the Spokane, Portland & Seattle Railway are 0.20 percent and 3°. The projected relocation would be expensive because of the necessity of providing special treatment of rock bluffs and talus slopes to eliminate danger from slides and falling rocks. Objectionable material under embankments subject to inundation would be excavated and wasted. Provision for operational difficulties which would have to be overcome during construction of the railroad relocations at rock cuts adjacent to the existing lines and at junction points is included in the cost estimates.

393. Additional relocations necessary for construction of John Day project include 62.6 miles of United States Highway No. 30, 46.0 miles of county roads, and comparatively minor amounts of telephone and power lines. United States Highway No. 30 would be reconstructed to existing standards.

394. Consideration would be given to provision of sufficient clearance under bridge structures crossing shore-line indentations to accommodate pleasure craft, or, where practicable, to admit larger traffic units to safe harbors. The more important natural harbors warranting consideration in this respect are at John Day River, mile 218; Rock Creek, mile 229; and Willow Creek, mile 252.

395. *Effect on McNary Dam.*—The effect of surcharge flood-control storage in John Day Reservoir on power output at McNary Dam has been discussed in preceding paragraphs. Other effects, all of a minor nature would arise from increased tail-water heights as shown on chart 9. Such effects would be related to structural stability, stilling basin action and spillway crest submergence, dam operating levels in the tail-bay area, and use of land in the tail-bay area.

396. Surcharge storage at John Day would not be detrimental to stability of McNary Dam. Tail-water level at spillway design flood discharge would be increased about 7 feet and a corresponding reduction in total headwater pressure would ensue. The slight difference in uplift pressures would be negligible. The generating floor at McNary powerhouse will be situated at a lower level than natural spillway design flood tail-water elevation and protection against such tail-water height will be provided by a heavy concrete wall on the downstream face of the powerhouse. With flood control storage at John Day, it would be necessary to raise the top of this wall 7 feet.

397. McNary Dam stilling basin will be of the hydraulic-jump type, consisting of a flat apron with two rows of baffles and an end sill. With full flood-control storage in John Day Reservoir, tail-water depth on McNary Dam spillway apron would be increased by amounts varying from 40 percent at 800,000 second-feet to 10 percent at spillway design flow. This increased depth would be beneficial and would operate to insure formation of the desired jump. Operation of John Day storage would cause some submergence of McNary spillway crest, elevation 291.0. Data in the following tabulation are illustrative of conditions at various discharges:

Total discharge	Tail-water elevation, feet, mean sea level	Gate opening [1]	Elevation of bottom of gate, feet, mean sea level
600,000 second-feet	294.4	13 feet	304
800,000 second-feet	296	18 feet	309
1,500,000 second-feet	299.4	27.5 feet	318.5
2,200,000 second-feet	310.5	Gates removed	

[1] Equal openings at all 22 gates; 150,000 second-feet deducted for flow through powerhouse.

The preceding data show also that, if all gates were operated at equal openings, tail water would not inundate the lower portion of the spillway gates, a condition that has resulted in some damage to the spillway gates at Bonneville Dam.

398. Operating levels on McNary Dam in the tail-bay area are generally being designed for elevation 287 which is slightly above natural tail water for the 1894 flood. Facilities at these levels, however, may be removed or protected from damage up to elevations higher than 303, which is computed tail-water height for the spillway design flood under natural conditions. A part of these facilities have to do with passage of migrating fish, but the total number of migratory fish upstream is not believed significant when flows exceed about 600,000 second-feet. The foregoing facts indicate that more frequent attainment of high tail-water levels resulting from surcharge storage at John Day, amounting to inundation of tail-bay operating levels about once in 15 years instead of once in 75 years, would result in inconvenience rather than harm. To allow for possible revisions, and for addition of watertight closures at McNary Dam, the amount of $400,000 has been added to the John Day cost estimate.

399. *Initial costs.*—Costs, summarized below, are on the basis of January 1948 price levels and assume the prior construction of The Dalles Dam. Should the John Day project be constructed prior to The Dalles project, the total cost would be slightly reduced due to a

reduction in cost of cofferdams and diversions, as noted in paragraph 368. A detailed estimate showing quantities and unit costs is contained in table 2, part II, of this appendix.

Item	Construction cost	Capital cost
Utilities	$75,524,000	$83,596,000
Navigation aids	170,000	188,000
Lands and acquisition	11,305,000	12,513,000
Reservoir clearing	219,000	242,000
Cofferdams and diversion	13,927,000	15,415,000
Gate-controlled spillway section	37,830,000	41,873,000
Nonoverflow concrete dam	8,220,000	9,099,000
Power facilities	192,087,000	212,616,000
Navigation lock	17,605,000	19,487,000
Mooring facilities	245,000	271,000
Fish facilities	17,980,000	19,902,000
Permanent buildings and grounds	3,947,000	4,369,000
Recreation facilities	367,000	406,000
Provisions at McNary Dam	400,000	443,000
Total	379,826,000	[1] 420,420,000

[1] Includes interest during construction.

400. Based on the estimated construction cost of $379,826,000, the capital cost of the John Day project is $420,420,000. The latter figure includes interest during construction at 3 percent over one-half of an average construction period taken at 7⅛ years. The average construction period was determined on the assumption that four generating units would be installed and the project in operation at the end of 6 years. The remaining nine units would be installed subsequently at the rate of four per year in 2¼ years. During the latter period benefits would accrue from the initial power installations and expenditures would not be of the magnitude of those necessary during initial construction; for this reason the incremental construction time was reduced by 50 percent to 1⅛ years, for computation of interest.

401. *Annual charges.*—Annual charges for the John Day flood control, navigation, and power project, based on 3 percent financing and a project life of 50 years, are summarized on the following tabulation:

	Annual charges
Federal:	
Interest—$420,420,000, at 3 percent	$12,613,000
Amortization—$420,420,000, at 0.886 percent	3,725,000
Interim—replacements	688,000
Operation and maintenance:	
Navigation lock	80,000
Spillway	165,000
Power facilities	663,000
Buildings and grounds	114,000
Fish facilities	231,000
Recreation facilities	40,000
Maintenance of port of Umatilla embankment	19,000
Payments in lieu of taxes	19,000
Total annual charges	18,357,000

402. Interim replacement costs were computed on the basis of additional amortization charges, on a 30-year basis, to create a sinking fund to replace all items or portions of items having an economic life of less than 50 years. Operation and maintenance costs were derived on the basis of past experience at Bonneville Dam. Annual charges against completed open-river channel improvements were not assessed

against John Day project, as navigation benefits credited to the project elsewhere in the report are incremental benefits above present development.

403. *Accomplishments.*—John Day Dam, with appurtenant works, would be an important element in a coordinated plan for development of Columbia River. The flood-control storage capacity, approximately 2,000,000 acre-feet, would be of great value in reducing flood stages and damages downstream during major floods. As an example, discharges could be reduced by 50,000 second-feet for 20 days. If the flow at Vancouver were reduced from 850,000 second-feet to 800,000 second-feet, the stage reduction would amount to 1 foot. With a higher-peaked hydrograph of shorter duration, the stage downstream could be reduced 2 feet or more.

404. Inasmuch as John Day flood-storage capacity would be located only 100 miles above the major areas subject to flood damage, it would be operated to provide emergency flood storage in final regulation of major floods. In addition, the reservoir would permit control of localized floods and of floods arising in uncontrolled tributaries, and would thus render more effective any system of upstream flood storage reservoirs in the protection of the highly developed lower Columbia River area.

405. Further accomplishments would also include the substitution of 75 miles of slack water for a hazardous open-river channel, and the addition of a large amount of electric power to the Northwest power network. Irrigation of nearby lands would be rendered less expensive and the project would add materially to the recreation development of the area.

406. John Day Dam would inundate the present narrow, hazardous barge channel and the numerous rapids, between the dam site and McNary Dam, thus permitting a fuller utilization of this vital transportation corridor, and providing a greatly improved water transportation route for the export and import of bulk commodities from and to the interior areas. Rich agricultural lands contiguous to the pool are the annual source of millions of bushels of grain which are shipped to downstream points for processing and for export to foreign countries. Improved navigation through this reach of Columbia River would facilitate upstream movement of petroleum products, machinery, and consumer merchandise to an area which is expected to develop rapidly from an agricultural and industrial standpoint. The inland area is served by three competing rail lines but rail rates are too high to facilitate the development of mineralized ores and limestone. More economical water transportation would stimulate such development. The anticipated future average annual commerce which would move over the John Day pool is estimated at 4,600,400 tons. Bulk grain and limestone and other mineral products would be the principal commodities to be shipped downstream. Petroleum products would constitute the major portion of the future upstream commerce. A wide variety of other products, including heavy machinery, industrial products, masonry and ceramic products, heavy and light hardware, and numerous other manufactured goods, also could be transported up river.

407. Navigation benefits creditable to a savings in transportation would consist of the difference in transportation costs, as compared to costs over rail and highway routes, from the origin to destination of

commerce, based on savings per ton mile over existing transportation facilities. Other benefits would accrue from new commerce which would develop only when water access routes to mineralized areas along middle and lower Snake River are provided by the authorized lower Snake River dams and proposed projects on middle Snake River. Additional benefits would result from new trade potential attracted by the savings between inland points and the Portland area. Appendix M contains an analysis of system navigation benefits.

408. The project would provide additional dependable power to the existing Northwest grid system which serves the major load areas in Oregon, Washington, Idaho, and Montana. The project would be strategically located within this system so that present storage at Grand Coulee and additional storage on Columbia and Snake Rivers would increase the present low flows. After completion of the main control plan, operation of the project with 13 power units installed would provide a nominal prime capability of about 735,000 kilowatts during minimum runoff years, as shown by phase C-2 studies in appendix O. See appendix O for analysis of system power production. Expansion of the load area and growth of industrial enterprise in an area relatively young in development and rich in natural resources would provide an immediate outlet for the additional power. Present power shortages have restricted industrial expansion and installation of authorized power facilities will not meet the anticipated load. See appendix M.

409. Arable lands lying along Columbia River in the vicinity of John Day project are suitable for irrigation by pumping from the project pool. Areas lying at elevations of 800 to 1,050 feet above mean sea level are cropped by dry-farming methods and produce fair yields of grain when rainfall is sufficient to mature the crops. These irrigable areas are described in previous text dealing with irrigation problems. The Roosevelt and Arlington areas are largely comprised of raw sagebrush lands, while the upper benches of the area lying east of Willow Creek are dry farmed and therefore would not show as great an increase in agricultural returns when irrigated.

410. A plan considered by the United States Bureau of Reclamation for John Day irrigation project (designed herein as the Willow Creek area) would provide gravity diversion from a storage dam on John Day River for irrigation of those lands lying east of Willow Creek. Pumping to these lands from John Day pool would provide an alternate water supply and probably decrease the cost of project development. The reduction in lift from that required to pump from the present stream elevation would result in a saving directly creditable to the navigation and power project. The average reduction in pumping lift for each of the three areas is shown in the following tabulation:

Project	Area in acres	Reduction in pumping lift
John Day	135,100	55 feet.
Arlington	11,500	70 feet.
Roosevelt	1,500	75 feet.
Total	148,100	

411. The pool would be located in a thinly populated area between the States of Oregon and Washington, where the major population centers are several small trade centers scattered along the river and adjacent to highway and rail lines. The number of local people visiting the project would be small; however, the project would be of sufficient magnitude to attract many tourists. Minimum recreational facilities which would be provided are landscaped viewpoints, parking areas, comfort stations, and an administration building. Boat-launching ramps and access roads to the pool are desirable. The project pool undoubtedly would be utilized by yacht clubs as distant as Portland for traveling to points along Columbia and lower Snake Rivers.

412. Only tangible accomplishments have been described in previous paragraphs. Local, regional, and national benefits in the form of increased industrial expansion and potential industrial production through dependable power supply, enlargement of the tax base in many sections of the basin, and greater national security during critical world readjustment periods, also would result from the proposed plan of water use development. Power shortages due to droughts are of far reaching effect, often extending beyond the regions affected by the drought. Development of sufficient reserve power capacity to meet all loads in spite of climatological conditions leading to droughts in the Western States would help to relieve the threat of industrial paralyzation. This power reserve, therefore, would be an intangible value of paramount importance

413. *Discussion.*—Provision of surcharge flood-control storage capacity at John Day Reservoir in the amount of approximately 2,000,000 acre-feet is feasible from an engineering standpoint and such space could be obtained at an incremental cost of about $30 per acre-foot. Although provision for the space would cause incremental dislocations, principally at Arlington and Umatilla, items have been included in the project costs to insure continuance of these towns and river harbor facilities. No public hearing has been held relative to storage of floodwater in John Day Reservoir to pool elevation 292. No opposition by local residents, however, was voiced in the hearing of May 25, 1948, to operation of John Day Reservoir at normal pool elevation 255. A pool elevation of 255 would necessitate raising 35 percent of the town of Arlington.

414. Surcharge flood-control storage above normal pool elevation 255 is proposed as a part of an initial system to control the downstream flood discharge to a maximum of 800,000 second-feet, but integration into an ultimate system to effect control to 600,000 second-feet also was studied. Some conflicts between flood-control operation and the interests of navigation and power would occur. The power conflict attributable to increased tailwater depth at McNary Dam, as shown on chart 9, would not initially alter the system power design which is predicated on production of firm power at an upper flow limit of 800,000 second-feet. Although ultimate regulation of flood flows to 600,000 second-feet would cause power loss under present criteria, a future system probably could absorb any such loss at other plants, and no extra generating facilities are considered necessary. The advisability of raising the John Day navigation lock to accommodate water surface fluctuations above normal level also was studied and,

while not considered advisable or necessary under initial conditions, might be desirable under conditions of ultimate regulation.

415. From the standpoint of navigation, the adopted normal pool elevation would greatly improve operating conditions. This is illustrated in table 37, which shows average velocities at critical locations in the pools that would be formed by the ultimate ladder of dams and through the critical Hamilton Island reach immediately downstream from Bonneville Dam. While these average velocities do not necessarily bear any constant relationship to the maximum velocities at any of the cross sections, an index for comparison is furnished.

416. *Storage investigations.*—In arriving at the proposed maximum flood-control storage capacity of 2,000,000 acre-feet at pool elevation 292, consideration was given to other amounts of surcharge storage as well as to draw-down storage below normal pool elevation 255. The results of these studies are discussed in part II of this appendix in support of the proposed plan.

417. *Alternative project without flood-control storage.*—Lay-out and details of the alternative John Day Dam with normal pool elevation 255, without flood-control storage, are shown on plate 6, part II. The structure would be about 95 feet high from tailwater to headwater and would consist essentially of a spillway, a navigation lock, a power plant for generating hydroelectric energy, and facilities for passing anadromous fish. The tool would extend upstream from the dam over a reach of river defined at the upper and lower limits by McNary dam and The Dalles Reservoir, respectively. Normal pool elevation for The Dalles Reservoir, as discussed in the prior report, has been tentatively established at elevation 160, and extreme low-water elevation at McNary dam site is elevation 248. The design features of the dam would be essentially the same as for the proposed project providing flood-control storage.

418. The total capital cost of the alternative plan is estimated to be $354,805,000, and annual charges are estimated to be $15,724,000. Accomplishments would be the substitution of 75 miles of slack water for hazardous open-river channel in the reach of John Day pool, the providing of 735,000 kilowatts of prime power, and the facilitating of irrigation of about 150,000 acres of lands. The important flood-control benefits of the proposed project would be eliminated. Detail of description of this alternate project and a summary of costs and accomplishments are presented in part II of this appendix.

419. *Other plans considered.*—Two plans of development, alternative to the single-dam plans, described in the preceding paragraphs, have been considered for the reach of Columbia River between John Day dam site and McNary Dam. The first of these, open-channel improvement, would eliminate multiple-purpose aspects of the improvement and would provide only increased channel depth and width for navigation. The second alternative, called the two-dam plan in contrast to the single-dam plan previously described, would consist of a low dam with normal pool elevation 210 at the John Day site and an additional dam, at the Arlington site 26 miles upstream, with normal pool elevation 255. This plan of development was proposed in House Document No. 704, Seventy-fifth Congress, third session. The two-dam plan would cost about $150,000,000 more than a single development. The benefits from either a single or a two-dam development

without flood-control storage would be approximately equal. The alternative plans are described in greater detail in part II.

HARBOR PROJECTS

420. *Introduction.*—As outlined in connection with the navigation problems, the construction of harbor facilities along the reservoirs would be necessary upon completion of the proposed main river dams, to allow convenient interchange between river and land of the greatly augmented commerce which would develop. In addition to facilities presently available, harbor improvements at six locations previously have been found economically justifiable on the basis of the increases in river commerce that has occurred within the last decade since completion of Bonneville Dam. As slack-water navigation is provided through greater stretches of the river system, river commerce will continue to increase and the provision of further harbor facilities will be found economically justified by the savings in transfer and shipping costs that would result. Provision of approach channels and turning basins, which is the function of the Federal Government, has been included in the plan of improvement for this subbasin to meet these anticipated needs which are further discussed in appendix M. These facilities would permit river access to wharves and warehouses, the construction of which would be the responsibility of local interests. At present, two auxiliary channels above Bonneville Dam at Bingen and Kennewick, Wash., are authorized, and a channel at Arlington, Oreg., has been constructed by the Corps of Engineers. A mooring basin at Hood River, Oreg., and harbor improvements at The Dalles, Oreg., also have been authorized, but no construction has been performed. In addition, a harbor improvement at Umatilla, Oreg., has been previously recommended but has not as yet been authorized. Estimated costs to the Federal Government for these projects are shown in the following tabulation:

	Estimated cost
Bingen, Wash., channel	$141, 400
Arlington, Oreg., channel	115, 217
Kennewick, Wash., channel	30, 000
Hood River, Oreg., mooring basin	136, 800
The Dalles, Oreg., harbor	143, 600
Umatilla, Oreg., harbor	416, 250
Total	983, 267

These facilities would supplement eight existing port installations constructed upstream from Bonneville Dam by private interests. Many of these latter installations, however, would require drastic revision and enlargement after the main river dams were complete, in order to accommodate the new water levels and increased volume of commerce.

421. *Proposed improvements.*—At this time, only a tentative selection of points at which additional harbor facilities would be desirable can be made. As the additional dams are constructed, and as commerce increases, the locations and extent of required facilities will become determinable. Where savings would result thereby, necessary harbors would be included in detailed planning for construction prior to raising of the pools. Such planning would require coordination with railroad relocation studies in certain cases where communities would have to be moved, in order to secure an arrangement satisfactory to both land and river transport.

422. Following is a tentative listing of harbors now considered necessary for the efficient functioning of an ultimate navigation system, together with estimates of initial costs and annual charges to the Federal Government. Estimates are based on price levels as of January 1, 1948, and on previous experience on similar work.

Location	River mile	Pool	Initial cost	Annual charges
Ringold, Wash	352.0	McNary	$100,000	$6,000
Yakima River, Wash	335.0	do	200,000	12,000
Pasco-Kennewick, Wash	328.0	do	200,000	12,000
Burbank, Wash	323.0	do	100,000	6,000
Hover, Wash	317.0	do	100,000	6,000
Wallula, Wash	314.3	do	300,000	18,000
Walla Walla River, Wash	314.0	do	200,000	12,000
Cold Springs, Oreg	300.0	do	100,000	6,000
Umatilla, Oreg	289.5	John Day	200,000	12,000
Alderdale, Wash	258.0	do	60,000	3,600
Roosevelt, Wash	242.7	do	60,000	3,600
Arlington, Oreg	241.7	do	60,000	3,600
Blalock, Oreg	233.3	do	60,000	3,600
Biggs, Oreg	207.6	The Dalles	60,000	3,600
Maryhill, Wash	209.2	do	60,000	3,600
Totals			1,860,000	111,600

The locations of these points are shown on plate 36, as well as on the applicable reservoir maps.

423. *Conclusion.*—Present harbor facilities along Columbia River are not adequate to handle the volume of commerce ultimately expected. To rectify this condition, 15 harbors having a total initial cost of $1,860,000 and total annual charges of $111,600 are proposed. System and local benefits would be more than ample to justify such improvements. In addition, local harbors would provide moorage for pleasure craft and refuge for all river craft during periods of bad weather. As a prediction of the exact size or location of the facilities required is not possible at this time, the list of harbors presented is tentative only. The list, however, is believed representative of the actual requirements which will be determined upon later detailed study, and the estimated costs are believed to be adequate, subject to future changes in price levels, for construction of the necessary improvements.

BANK PROTECTION AND DIKING AND DRAINAGE PROJECTS

424. *Introduction.*—As discussed in section II of this appendix, about 70,000 acres of the 170,000-acre flood plain of Columbia River are not protected from overflow during flood periods. The principal flood-plain areas are located downstream from Bonneville Dam. Population density, the fertility of the soil, and the favorable climate combine to make these areas of considerable value.

425. An authorized separate survey report is being prepared to determine the advisability of protecting additional areas along the river and providing additional protection for areas now inadequately protected. That report will be submitted at a later date and will contain a complete analysis of the engineering and economic considerations involved, as well as recommendations for future work. The progress of studies is sufficient to enable a preliminary determination of the economic feasibility of the protection of several

particular areas. These areas and others, for which justification is not apparent or is uncertain, are discussed herein, following a summary of the general aspects of additional protection to Columbia River flood plain.

426. Columbia River flood-plain lands have been formed by the deposition of river silts. As shown on plate 35, the land areas which comprise the flood plain are not continuous and do not extend far from the stream. Levees have been adopted as the only feasible means of protection against flooding. The economic development of the extreme lower river area gave rise to the first such construction at Warrenton in 1899, subsequently, in the period 1915 to 1921, 11 or more drainage districts were organized and the areas protected by dikes provided with tide boxes and pumping plants. This development continued and was accelerated in the period 1935 to 1940, when new districts were organized and old ones reorganized in order to comply with the provisions of the 1936 Flood Control Act and thereby obtain Federal assistance.

427. *Existing conditions.*—Existing development along lower Columbia River may be classified as municipal, industrial, and agricultural. Towns on or adjacent to the Oregon shore include Warrenton, Astoria, Clatskanie, Rainier, St. Helens, Portland, and Troutdale. Along the Washington shore are Ilwaco, Chinook, Cathlamet, Longview, Kelso, Kalama, Woodland, Vancouver, Camas, and Washougal. Industrial developments centering at the mouth of the river and at Portland are, in the main, not protected by levees. Lands which, if protected, would be potentially of industrial importance exist in the Portland area and in areas near Washougal, Vancouver, and Kalama. The preponderance of the presently protected land and land worthy of future protection, however, is devoted to agriculture or dairying. The development of agriculture within those districts which have been improved is in sharp contrast to that within areas which are subject to annual flooding.

428. *Protection.*—Plate 18 of part II indicates the river stages below Bonneville Dam for the 1894 and 1948 floods. From Cathlamet, river mile 40.7, to the sea, the profile for the maximum tide of record combined with the flood of December 1933 to produce the highest stages of record. The 1876 and 1894 flood profiles were used as standards of protection in the past. Above Cathlamet, the majority of the existing drainage districts were protected against a flood of the magnitude of that which occurred in 1876 plus a limited freeboard varying from 1 to 3 feet, depending upon the size of, and upon development within, each district concerned. Two drainage districts immediately adjacent to Portland were protected against a stage equivalent to that of the 1894 flood, including the increased stage due to confining action of the levees.

429. The characteristics of the 1948 flood have been found to be similar to those of the 1876 flood, and, because data obtained during the 1948 flood are more complete, plate 18 of part II presents river stages for the latter. The 1948 flood provided much additional data on the effects of floods of major proportions. Subsequent to construction of the Spokane, Portland & Seattle Railway fill at Vancouver and the Sandy, Multnomah No. 1, and Peninsula Nos. 1 and 2 drainage district levees, the constricted channel had not been tested by a

major flood, nor had discharges greater than 740,000 second-feet actually been measured.

430. The degree of levee protection which should be afforded the various land areas lying along the main river and tributaries varies with the development and potential development of the area concerned, and with the regulatory effect of upstream storage on river stages at the time of construction of the projects. Those projects which are proposed for immediate construction generally would provide protection, with 3-foot freeboard, against a recurrence of the 1948 flood. The levees which protect existing highly developed and urban areas, such as Peninsula drainage districts Nos. 1 and 2, would be designed to withstand a flood of the magnitude of that of 1894 under confined conditions. The main control plan, discussed in appendix M and in the main report, would control a flood of the magnitude of that of 1894 to a flow of 800,000 second-feet in the lower river. This reduction probably would allow future protection of areas where improvement cannot be economically justified under present conditions, and would increase substantially the amount of freeboard at projects completed now or in the interim period. The additional freeboard, amounting to about 3 feet, would be definitely desirable, as it would relieve the water load on the levee seepage path and reduce the degree of saturation of the levee. It would, in addition, provide the increased protection which should accompany population increases and economic development that can be expected in protected areas.

431. *Effect of levees on flood stages.*—The observed profile for the 1948 flood is shown on plate 18, part II, of this appendix. Shown also on this plate is a profile for the 1948 flood based on the assumption that proposed and possible future levees were in place. Similar observed and computed profiles for a flow of 800,000 second-feet also are indicated. The observed 1894 flood profile is shown, together with computed profiles based on 1948 channel conditions with existing levees and with proposed and possible future levees. It should be noted that proposed construction of the Vancouver Lake area levee plus the possible future development of lower Peninsula area would raise the water surface elevation of the 1948 flood at the Interstate Bridge by only 0.8 foot. The cumulative effect of all proposed and possible future construction on the water stage at Washougal would be about 1 foot for each of the profiles shown.

432. *Local cooperation.*—Protective works on lower Columbia River, as listed in table 36, have been constructed or rehabilitated with Federal funds under the authority of the Flood Control Act of June 22, 1936. Local interests have not been required to contribute to the construction costs of these projects, but they have been required to furnish the necessary rights-of-way, and they are charged with maintenance of the completed works. It has been found that the districts are generally lax in prosecuting adequate maintenance. Experience during the 1948 flood especially brought out this condition. A question exists as to whether or not maintenance of levees, revetments, tide boxes, pumping plants, and drainage ditches, if neglected by local interests, should be performed by an agency of the State Government with the cost being borne by local interests through taxation. Amendment to present State law would be necessary to provide for this procedure.

433. In those districts where the benefits accrue to individual land owners and not to the general public, apparently the local owners should make a considerable cash contribution toward meeting construction costs. In many unprotected, undeveloped areas, the principal benefits to be expected would be in the form of increased land use which would be enjoyed solely by local people.

434. The entire problem of local cooperation will be analyzed in detail and definite recommendations made in the separate report now in preparation. In the estimates quoted subsequently, non-Federal costs include, where applicable, an approximate evaluation of land enhancement as a measure of local contribution toward construction costs, as well as charges for rights-of-way and maintenance.

435. *Unprotected areas.*—Following is a tabulation showing, for both Oregon and Washington, the land areas and acreages now protected and the areas physically susceptible to protection:

Land classification	Areas in acres		
	Oregon	Washington	Total
Protected:			
By local interests	986	6,186	7,172
By local interests and Corps of Engineers	61,436	30,681	92,117
Subtotals	62,422	36,867	99,289
Unprotected	27,874	27,633	55,507
Total	90,296	64,500	154,796

The above tabulation shows that 99,289 acres in both States are now protected and that 55,507 acres are not protected. Excluded from the latter category are about 15,000 acres of submarginal land for which economic justification cannot be foreseen within any reasonable period of time. Table 36 lists existing and authorized diking and drainage projects. The excluded 15,000 acres include two areas for which conditions of local cooperation required to obtain Federal participation have not been fulfilled. Brief discussions of individual unprotected areas are contained subsequently in this appendix.

436. *Inadequately protected areas.*—The 1948 flood provided a severe test of the efficacy of existing lower Columbia River levees. As discussed previously, several failures occurred which will be repaired with emergency funds to bring the levees to the original condition. The flood indicated that in several districts drainage provisions were not adequate and that in others the degree of protection now provided, based upon original conditions, should be increased because of increased economic development within the district. Those projects in this category, in which the Corps of Engineers has participated, have been determined and are discussed individually in later paragraphs.

437. *Improvements considered.*—To secure adequate protection of lands within the flood plain of lower Columbia River generally would require construction of levees or seawalls. Such structures would confine the floodwaters, and at the same time, increase stages slightly, and accelerate velocities of flow. These effects would subject the improvements and unprotected banks to increased erosive attack. Furthermore, lower Columbia River is used extensively by ocean-going vessels and river craft, the wave wash of which further increases

the bank erosion problem. Therefore, to assure the permanency of existing banks and the existing or proposed levees, bank protection of some type would be required.

438. *Bank protection.*—The bank erosion problem in the sub-basin, and the causes thereof, are outlined in previous sections of this appendix. This problem is existent only along the river reach downstream from Washougal, Wash. Complete surveys since the occurrence of the 1948 flood are not available. Prior to that time, however, damage was being incurred at 94 locations totaling about 40.7 miles in length. Detailed investigations of bank erosion and protection are now being initiated in connection with an authorized separate report, to be submitted at a later date, on flood control on lower Columbia River. Although neither sufficient field investigations nor office studies to permit final recommendations have been completed at this time, considerable bank protection work evidently is economically justified and is proposed herein. A discussion of the general factors involved is contained in following text.

439. *Methods of bank protection.*—In the past, two general methods have been employed to control bank erosion. Where water depth adjacent to the shore is great, pile jetties have been constructed, and in other locations revetment has been used. The jetties consist of lines of piling extending from the bank into the river and so spaced as to break the direct attack of the current and encourage the deposition of river silts. A dumped stone blanket is placed upstream and downstream from each jetty, both on the bank and along the bed of the stream, to protect the piling from scouring. Use of pile jetties combines bank protection with navigation improvement as the jetties serve to constrict the navigation channel, thus increasing velocities and reducing maintenance dredging.

440. The usual type of bank revetment employed in the past has been constructed of quarry stone which is available at six or seven locations along the river. The banks to be protected have been sloped to about 1 on 2, a blanket composed of local gravel has been spread, and a top layer of dumped quarry stone has been placed over the gravel.

441. *Proposed bank protection.*—The banks of the river and the principal tributaries were examined prior to the June 1948 flood. At that time about 94 areas were being eroded. Of this number, 66 erosion areas, with a total length of about 123,800 linear feet, were of such a critical nature that either levees and the drainage districts protected or high-value unprotected property were in danger of being lost. Waves set up by wind action and aggravated by heavy water traffic, both oceangoing and local, evidently cause more damage than do floods. Examination of the conditions as existing after the flood may reveal that new areas have been stripped of protective cover and erosion has begun. A summary of all locations examined to date is shown in tables 39 and 40, in which the 66 primary locations are grouped as proposed projects and 28 secondary locations are grouped as possible future projects. Expenditures at the 66 primary locations apparently would be economically justifiable, especially in view of the damages which might result from a levee failure caused by erosion. The expenditure involved would be about $4,900,000. Erosion at the remaining 28 secondary locations, while quite active, does not now threaten potentially valuable lands, and for that reason can be

deferred. Justification for work at these locations may develop, however, as the land areas adjacent to the erosion areas are developed more extensively. The locations of both the proposed and possible future protection projects are shown on plate 36.

442. *Project descriptions.*—Proposed and possible future diking and drainage projects are listed in tables 39 and 40 and shown on plate 35. The following paragraphs describe, in downstream order, the proposed and possible future projects which are considered economically justified under present or foreseeable future development, as well as a number of projects for which future justification is not foreseeable at this time.

443. *Washougal area.*—The Washougal area is situated at river mile 125.0, in the southeastern part of Clark County, Wash., and extends from Lawton Creek on the east to include a part of the town of Washougal. It is about 4½ miles long, averages three-quarters of a mile wide, and generally lies about 30 feet above mean sea level. An area of 2,260 acres lies below the 40-foot contour. Steigewald Lake, which extends through the greater portion of the area, is long and narrow and has an area of 350 acres during periods of normal rainfall. A relatively small creek, Gibbons Creek, drains 4,500 acres of adjacent hill lands and enters the area. The flow from the creek increases the problem of draining the lake, but can be handled through automatic drainage gates.

444. The district has been a dairy center for over 30 years, and has several large dairies adjacent to the landward limits. Prune and filbert groves, which formerly occupied about 3 percent of the area, are now being removed. About 150 persons reside in the flood area. The Washougal Woolen Mill also is located in the area and has become an important factor in the economic life of the community.

445. A total of 5½ miles of levee, two large tide boxes, drainage ditches, and a pumping plant, at a total cost of $800,000, would be required to protect the entire area. Of this amount, about $275,000 would be non-Federal costs. The protection proposed would encourage further industrial development of the town of Washougal and would allow a much higher agricultural development of the remainder of the area. This project apparently would be economically feasible.

446. *Sandy River east area.*—This area lies at river mile 121.0, to the east of Sandy River in Multnomah County, Oreg. It fronts along 3 miles of Columbia River and along 2 miles of Sandy River. Of the 1,280 acres in the area, about 1,120 acres are susceptible to reclamation. Approximately 210 acres are under cultivation; the remainder are used for grazing registered beef stock. The area is subject to partial annual flooding from Columbia River backwater which spreads out through the existing sloughs. Construction of about 3.4 miles of levees and several tide boxes would be required to provide adequate protection. The present state of development does not appear to justify protection against the 1948 flood. If the project were determined feasible upon more detailed study, local interests would be required to furnish rights-of-way and make a considerable contribution toward the estimated construction cost of $300,000.

447. *Sandy drainage district.*—This district is located at river mile 118.5 in Multnomah County, Oreg., on Columbia River between Sandy River on the east and Multnomah drainage district No.1 on the west. The district contains 1,556 acres which are used for truck

gardening, general farming, and dairying. A large aluminum reduction plant and the Troutdale Airport also are located within the district. The area is protected by about 19,000 feet of levee, which successfully withstood the 1948 flood. Seepage, however, was considerable. In order to provide adequate interior drainage, a complete system of toe drains with ditches leading to the pump house would be required, and additional pumping capacity would be necessary. Total estimated construction cost of this work is $242,000, of which about $165,000 would be Federal costs and $77,000 would be non-Federal. Preliminary studies indicate that the proposed improvements would be justified.

448. *Government Island area.*—Government Island is situated at river mile 115.0, in the channel of Columbia River about 7 miles upstream from Vancouver. It contains about 1,850 acres, of which 90 percent is assessed as tillable land. The raising of registered dairy and beef stock, as well as horses, has been developed to a large scale. Approximately 1,490 acres could be brought to a high state of cultivation or pasturage if protected by 7.3 miles of levee, 2.7 miles of hydraulic filled beach, and the necessary automatic drainage gates. Local interests are anxious to receive some degree of protection, at least from the normal annual flooding if protection against higher floods cannot be justified. Protection of the area against the 1948 flood is estimated to cost $800,000 exclusive of rights-of-way, while protection against a 15-year flood could be provided for $300,000. The justification of either program is doubtful at the present time, but, in any event, local interests would be required to contribute a considerable part of the construction cost.

449. *Multnomah drainage district No. 1.*—This district lies along Columbia River at mile 112, northeast of Portland, and contains 8,417 acres protected by about 69,000 feet of levees. At the time the levees were constructed, the land was used for general farming, truck farming, and grazing. At present, the area has become priarily residential. Four golf courses and the Portland-Columbia Airport also are within the district. One failure in the levee system, at the pumphouse, occurred during the 1948 flood. With the degree of development now existing in the area, seepage through the sand levees probably should be controlled to a greater degree than at present. This control would require the construction of a toe drainage system throughout the entire length of the levee, a system of interior drains leading to the pumphouse, and the installation of additional pumping capacity. Four cross levees would be constructed on existing roads, thus dividing the district into five areas to relieve the present situation in which a continuous area about 15 miles in length is vulnerable to damage from a break at any point in the levee. Total estimated construction cost, including new cross levees, is $1,500,000, of which about $1,005,000 would be Federal costs and $495,000 would be non-Federal. Preliminary studies indicate that the proposed improvements would be economically feasible.

450. *Hidden area.*—Hidden area, located at river mile 108.0, lies to the east of Vancouver, Wash., and contains 750 acres. Vancouver shipyard is located in the tract, approximately 50 percent of which was filled by hydraulic dredging, during the construction of the shipyard, to an average elevation of 29 feet above mean sea level. During the 1948 flood, water reached depths of from 2 to 4 feet over the filled

location and up to 12 to 15 feet over the remainder. The war caused a shift in land use from dairy farming toward industrialization. This trend no doubt will be upset temporarily by the recent floods.

451. Adequate protection would require construction of about 2¼ miles of levee and flood walls, a tide box, and a pumping plant. The lowest portion of the area should be filled with spoil from channel dredging. The cost of protection would be approximately $340,000, of which $240,000 would be Federal, and $100,000 non-Federal costs. In view of the development of the railroads, hard surfaced roads, housing facilities, and housing sites, the potential value of the tract is high and protection probably would be justified.

452. *Portland area.*—The 1948 Columbia River flood inundated a total of 2,600 acres within the city limits of Portland. An area equivalent to approximately 700 blocks adjacent to Willamette River in the central part of the city was flooded. The harbor wall, along the west bank of Willamette River in the city, protected an area 23 blocks in length and from 5 to 6 blocks wide. Upstream and downstream from the harbor wall a total of 360 blocks was flooded. On the east bank of the river, in the central commercial district, approximately 340 blocks were flooded.

453. Raising of streets and construction of levees, flood walls, tide boxes, and pumping plants would be required to protect adequately the most highly developed portion of the areas which were flooded. The cost of furnishing this protection is estimated to be $22,000,000, of which $14,000,000 would be Federal and $8,000,000 non-Federal cost. The estimated average annual damages within the Portland area are $2,415,000. Elimination of a large part of this damage could be credited to the improvement. The city probably would be willing to assume a fair share of the cost of the protective works. Although time prevented completion of studies necessary to determine all of the features in connection with this project, the benefit-to-cost ratio apparently would be favorable.

454. *Peninsula drainage district No. 2.*—This district is located at river mile 106.5, to the west of Multnomah drainage district No. 1, from which it is separated by Columbia slough and an artificial channel which connects Columbia slough with Columbia River. The tract contains 1,425 acres protected by a levee system 33,900 feet in length. The district has changed from an agricultural area to an urban and industrial area, and the degree of protection provided, which is 2 feet of freeboard over a flood of the 1876 magnitude, is not considered adequate. This district was inundated during the 1948 flood, primarily as a result of failure of a railroad fill which formed part of the protective works for Peninsula drainage district No. 1. Recurrence of a flood similar to that of 1948 would make the district inoperative because of seepage through the levees. To provide a system of protection considered adequate, the design criteria should be changed to provide protection to an elevation above a flood of 1894 magnitude. Adequate protection would require raising all exterior levees about 6 feet, installing a complete system of interior toe drains, and enlarging pumping facilities. Total estimated cost of this work, including costs of rights-of-way but excluding costs of highway reconstruction, is $853,000, of which $535,000 would be Federal and $318,000 would be non-Federal costs. The proposed work would be justified.

455. *Peninsula drainage district No. 1.*—This district is located at river mile 105, to the west of Peninsula drainage district No. 2, from which it is separated by the fill of the Denver Avenue approach to the Interstate Highway Bridge. The district contains 901 acres, and includes improvements consisting of a large packing plant and stockyards, a large stock pavillion, a broadcasting tower, railroad trackage, and farm land and pasture. The area is protected by about 20,000 feet of levee. A railroad fill, which formed part of the protective works, failed during the 1948 flood, causing inundation of Peninsula district No. 1 and destruction of Vanport City, Oreg. A ring levee around the underpass to Vanport City subsequently failed, causing inundation of Peninsula district No. 2. Preliminary plans of the Port of Portland comtemplated the acquisition of Peninsula district No. 1. Industrial sites would be provided by filling the area to about elevation 30 feet with sand pumped from the river. If the district were filled, the necessity for rehabilitation of the levees would not exist. Otherwise, renewed portection would be indicated. As the railroad fill is not reliable, a new levee on the inside and parallel with the railroad would be necessary. This levee would be constructed to such elevation as to protect the district against a flood of 1894 magnitude. A complete toe drainage system and pumping plant would be necessary. Estimated cost of this work would be $1,580,000, of which $1,125,000 would be Federal and $455,000 non-Federal costs.

456. *Hayden Island.*—Hayden Island, situated on the Oregon side of Columbia River at mile 105 opposite Vancouver, is separated from the Oregon mainland by North Portland Harbor. It is about 4 miles long and contains approximately 850 acres. A total of 292 acres of the eastern half of the island adjacent to United States Highway No. 99 has been developed by Hayden Island Amusement Co. In addition to the amusement park, 24 duplex houses containing 48 rental units, a supermarket, drug store, restaurant, riding academy, hunt club, and filling station are located on the island. The damage caused by the 1948 flood was slightly in excess of $110,000, exclusive of the loss of business during the flood. Protection of the east end of the island, which lies upstream from the Spokane, Portland & Seattle Railway, justifiably could be accomplished by provision of a 4-mile levee, an automatic drainage gate, and a small pumping plant. At a later date, if conditions justified, the levee system could be extended to protect the entire island. The cost of the initial project would be about $264,000, of which $140,000 would be Federal cost and $124,000 non-Federal cost.

457. *Lower Peninsula area.*—Lower Peninsula area is located at river mile 103, to the west of Peninsula drainage district No. 1. It is bounded by Oregon slough and Columbia River on the north, Willamette River on the west, and high ground and Columbia slough on the south. Columbia slough roughly bisects the major portion of the area. The area is served by, or is readily accessible to, three major railroads. In addition, the main transmission lines of the Bonneville Power Administration cross it. The services and the advantageous location of the tract make it suitable for development for industrial purposes. Future dredging of the necessary water approaches and turn-arounds would provide sufficient material to build the adjacent land area to a height above flood levels. Such improvement, rather than protection by levees, is logical for this area.

458. *Burlington district area.*—Burlington district area, at river mile 100, is situated in the northern part of Multnomah County, Oreg., across Multnomah Channel from Sauvie Island. The district is 5.8 miles long and ranges in width from 800 to 2,800 feet. Of the approximately 1,030 acres, 130 acres are swamp and slough, 250 acres have been cleared for agriculture or pasture, and 650 acres are covered with timber or heavy brush. Developments consist of 4 boathouse moorage sites, 10 log dumps, and 4 woodworking plants. The woodworking plants and five of the log dumps are served by railroad. All developments were flooded to varying depths during the 1948 flood. The highway connection to Sauvie Island crosses the area on a causeway. Two creeks with drainage basins of 4.5 and 4.2 square miles, respectively, and five small intermittent creeks enter and cross Burlington district. One of the large, and two of the small, creeks probably could be bypassed out of the area, but the run-off of remaining creeks would have to be accommodated. Protection of the area would require construction of 4 miles of levees, four tide boxes, and a pumping plant at an estimated cost of $800,000, excluding cost of rights-of-way. This expenditure apparently could not be justified under present conditions.

459. *Vancouver Lake area.*—This area is located at river mile 100 and extends from the corporate limits of Vancouver, downstream along Columbia River for a distance of about 9 miles. The total area of the 1948 flood plain is about 10,000 acres, of which about 4,000 acres normally are inundated annually. The area is essentially suburban and includes orchards, subsistence farms, a large aluminum reduction plant, and a highway and railroad. Several large dairy farms supplying milk products to the city of Vancouver are located in the area. The land is extremely rich and protection from flooding, combined with drainage of the low-lying areas, would open large areas for truck gardening, and for additional industrial sites for Vancouver and vicinity. The population within this area increased greatly during the war years and, as long as the war housing units are occupied, this population will be threatened by major floods. The area is so extensive that it could support a suburban population equal to the present city of Vancouver.

460. Plans for protection of this area were proposed in 1920 and again in 1923, but opposition arose to prevent development. The most feasible plan under present conditions and probable future development would require the construction of a levee, about 2.8 miles in length, along the river front of the industrial area, possibly constructed with material excavated from the Columbia River ship channel; a levee about 7.7 miles in length, extending from the Aluminum Co. of America property downstream along the river 6.9 miles, thence northerly to a closure of Lake River; a diversion ditch to empty Salmon Creek into Lake River; tide boxes; a pumping plant in connection with the Lake River closure; and a pumping plant at the outlet of Shillapoo Lake.

461. The estimated cost of the above work would be $1,820,000, of which $1,225,000 would be Federal and $595,000 non-Federal cost. At the present time, local interests are making plans to protect a portion of the undeveloped industrial area. The work which local interests have under consideration would reduce materially the cost of the project. The project is believed to be economically justified.

462. *Sauvie Island.*—Sauvie Island is located adjacent to the Oregon shore near river mile 97. A complete levee system with drainage canals and pumping plants was constructed in 1941–42. The levee grade was selected to protect against a flood similar to that of 1876. The 1948 flood in this area approximated the elevation of the 1876 confined profile. During the 1948 flood the upstream end of Sauvie Island levee had to be protected with sand bags for a distance of about 4 miles to prevent overtopping. Other reaches of the levee, totaling about 6 miles in length, had a freeboard of only 1 to 1½ feet at the crest of the flood. To give additional protection to the area, raising this low levee to provide a 3-foot freeboard above the 1948 flood profile is proposed. In the downstream reach of the levee system, where the levee is built of heavier material, the height is adequate. Very heavy seepage, however, endangers certain locations in this area. In that reach of levee above the pump house, the river face of the levee would be stripped and the lower portion of the slope recompacted. On the landside toe, drains would be installed to carry off the seepage water and to prevent a softening of the berm. The proposed improvements are estimated to cost $1,000,000, of which $750,000 would be Federal and $250,000 non-Federal cost. This expenditure is believed to be justifiable.

463. *Sturgeon Lake area.*—This area is situated at river mile 95, in Multnomah and Columbia Counties, Oreg., and embraces all of that part of Sauvie Island not included in other districts or existing projects. The total area is about 8,380 acres, of which 4,430 acres are in lakes, depressions, and sloughs. Sturgeon Lake, the largest, is a State game refuge. It has an outlet through Gilbert River into Multnomah Channel. The tract is subject to flooding during the yearly spring freshets. The lack of development and the use to which the greater portion has been dedicated indicate little chance for economical justification of protective works.

464. *Columbia drainage district No. 1.*—This district is located at river mile 95, on Sauvie Island in Multnomah and Columbia Counties. It lies on the east side of the island and borders Columbia River for a distance of 4.4 miles. The district first was organized under the laws of the State of Oregon in 1915 for the protection and improvement of 1,600 acres of land. A total of 9.3 miles of levee would be required to surround the district. A pumping plant built by the district is very much in need of reconstruction. The elevations of the top of the levee, prior to damage by the 1948 flood, were from 1 to 4 feet below the crest elevation of that flood. To provide adequate protection against a flood such as that of 1948 would require the raising and enlargement of the 9.3 miles of levee, together with the reconstruction of the pump house and the construction of a tide box. The cost of such work is estimated at $1,108,000, of which $800,000 would be Federal and $308,000 non-Federal cost. Such improvements apparently would be justified.

465. *Campbell Lake area.*—This area is situated in a narrow strip along Columbia River at mile 94, between Bachelor Island and Vancouver Lake areas. The length of levees required in porportion to the land area to be protected would be large. Of the 1,910 acres in the area, an estimated 1,450 are reclaimable at a cost of $2,300,000, excluding rights-of-way. At the present time, the project does not appear to be justifiable. During and since the war, the river bank

through this reach has suffered heavily from erosion. Local owners are anxious to receive some relief from this erosion, and they have expressed the opinion that bank protection is required. Such work is discussed elsewhere in this appendix.

466. *Warren area.*—Warren area, at river mile 91, is situated in Columbia County, Oreg., on the west side of Multnomah channel, about 2½ miles north of Scappoose. Of the 2,140 acres in the area, only 1,540 acres reasonably could be reclaimed by levees. Scappoose and Sly Creeks, with a combined drainage area of about 70 square miles, traverse the area from south to north. Construction of 4.7 miles of levee, a large tide-box installation, a pumping plant, and attendant drainage ditches, would be required to protect the area. Development at the present time is not believed sufficient to justify the estimated cost of $400,000, excluding cost of rights-of-way.

467. *Bachelor Island area.*—This area, containing about 3,330 acres, is located at river mile 90. It includes all of Bachelor Island and the lands lying between Lake River, Bachelor Island slough, and the mouth of Bowers slough. Two lakes and several sloughs and lagoons are included. Protection and development are possible for about 2,850 acres.

468. Local owners have constructed levees to provide partial protection to 2,360 acres of land at a cost of $100,000 and have plans to extend this protection to include another 500 acres. The present levees protect the area against floods equivalent to about 24 feet on the Vancouver gage, but the levee height should be increased to provide protection against the 1948 flood. An increase in the levee heights and the installation of tide boxes and two pumping plants would cost approximately $680,000, of which $500,000 would be Federal and $180,000 non-Federal costs. Preliminary investigations indicate that the protection proposed for the area would be justified.

469. *Sauvie Island area C.*—This area, located at river mile 90, lies wholly within the limits of Columbia County, Oreg. It is bordered on the east by Columbia River and on the west by Multnomah Channel. To protect approximately 1,180 acres of the 1,730 acres in the area would require 5.8 miles of levee. The construction cost of the levee, tide box, pumping plant, and drainage ditches would be about $700,000. The state of development and the annual damages apparently would not justify such an expenditure at the present time.

470. *Scappoose drainage district.*—This district, located about 20 miles north of Portland, lies between Multnomah Channel and the high ground to the west. It contains 5,763 acres of land, which are used for general and truck farming and pasture. The area is protected by about 52,200 feet of levee which successfully withstood the 1948 flood, and which is adequate to provide protection against a flood of the magnitude of that of 1876. During the 1948 flood, seepage developed at several locations in the levee, the most serious being at two pump houses. A toe drainage system should be installed with special attention to the trapped seepage behind the toe levees, and special provisions should be made to control seepage at the pump houses. Total estimated construction cost of $510,000, of which about $325,000 would be Federal costs and $185,000 would be non-Federal. The improvement would be justified.

471. *Lewis River area.*—This area, located at river mile 89, includes the land lying between the Great Northern Railroad and Lake and

Lewis Rivers, adjacent to the town of Ridgefield, Wash. Of the 1,600 acres within the area, approximately 1,400 acres could be fully protected by the construction of levees, tide boxes, and a pumping plant. A trend toward establishment of wood utilization plants in the area near Ridgefield is evident, and with protection this development would continue. Local interests have spent about $35,000 for levees along Lewis River and intend to spend additional money for flood protection, despite the recent flood. Benefits to be obtained in this area would justify protection against floods of a greater magnitude than that of 1948. The cost of completing this project would be approximately $340,000, of which $240,000 would be Federal and $100,000 non-Federal cost.

472. *Cowlitz County diking districts No. 5 and 11.*—These districts, situated at river mile 84, in Cowlitz County, Wash., lie between Columbia and Lewis Rivers. District No. 5 lies to the north and is separated from district No. 11 by the Northern Pacific Railroad embankment. The area totals 7,369 acres and is highly productive dairying district, which has become one of the important sources of supply of dairy products for the city of Portland. A large acreage has been planted to flower bulbs in the last 5 years, and, despite a total loss of the 1948 crop, this type of farming apparently will be continued on an increasing scale. Other than the town of Woodland, the area is not urban and probably will not become so in the foreseeable future. During the 1948 flood, the levees were overtopped in four places. The area should have a higher degree of protection than has been provided.

473. Raising the levees to provide protection against floods such as that of 1948 would cost about $1,222,000, of which $777,000 would be Federal and $445,000 non-Federal cost. Expenditure for this protection appears to be justified.

474. *Deer Island drainage district.*—Deer Island drainage district lies on the south side of Columbia River at mile 76.8 about 6 miles below St. Helens, Oreg., and is separated from the mainland by Deer Island slough. The district, containing 3,950 acres of land primarily used for grazing, is protected by about 36,000 feet of levees which successfully withstood the 1948 flood. Serious leakage, however, developed at a railroad fill, composed of a large percentage of rock, which is crossed by the north levee. Control of this seepage would require a cut-off through the fill at or near the levee centerline. This could be accomplished by grouting with a cement-clay mixture. Total estimated construction cost would be $5,000, and no non-Federal participation would be required. An expenditure of $5,000 would be justified.

475. *Kalama River, south area.*—This area is situated in the southern part of Cowlitz County, and extends along Columbia River from Kalama River on the north to and including the town of Kalama, Wash. The 1948 floodwaters inundated the main street of Kalama to a depth of from 2 to 4 feet. All business in the town was suspended for a 6-week period, and preliminary estimates indicate the damage to have been $350,000. This does not include the damage to the municipal dock, the railroad station, or to the fish dock facilities which lie outside of the area which would be protected by levees. The total area is about 610 acres, of which 520 acres would be protected. Construction of 3 miles of levee, a tide box, drainage ditches,

and a pumping plant would be required. The estimated cost of this work would be $520,000, of which $350,000 would be Federal and $170,000 non-Federal cost. From preliminary investigation, the project apparently would be justified. Protection to this area would enhance the value of all business property, create potential sites for small industries, and expand the diversified farming area. With full protection, the fringe area on the north side of town probably would be fully developed.

476. *Kalama River, north area.*—This area, situated on the north side of Kalama River, has a frontage of about 1.4 miles along Columbia River and 2.4 miles on Kalama River. The area is crossed by the main north-south highway and railroad, the fills of which were either inundated or awash at the crest of the 1948 flood. The total area is 860 acres, of which 760 acres could be protected. Protection would require construction of about 3.8 miles of levees, a tide box, and a pumping plant. The estimated cost of this protection is about $500,000, excluding right-of-way. Under present conditions the improvement could not be economically justified, but may be justified under conditions prevailing at some time in the future.

477. *Carrols area.*—Carrols area is separated from Kalama River north area by a high hill that juts out into the flood plain, and is bisected by a railroad embankment. The total area is about 980 acres. The district is subject to flooding by Columbia, Cowlitz, and Coweman Rivers, and by natural drainage from 7,000 acres of hillside. About 15,000 linear feet of levee together with a pumping plant and a tide box, would be required to protect an area of about 890 acres. At a construction cost of approximately $700,000, excluding right-of-way, the improvement probably could not be justified under present conditions.

478. *Cowlitz County diking improvement districts Nos. 2 and 13.*—These districts lie between Cowlitz and Coweman Rivers and are occupied by the city of Kelso, Wash., and suburban areas. The total area of 1,354 acres is protected by 30,822 feet of primary levees, including 8,400 feet of Northern Pacific Railroad grade. An additional 7,300 feet of Northern Pacific Railroad grade provides a secondary protection between the two areas. The system provides protection against a flood such as that of 1933, with 4-foot freeboard for district No. 2 and 3-foot freeboard for district No. 13.

479. During the 1948 flood, a few points on the district No. 2 levee and the lower section of the railroad grade, where failure was feared for some time, showed excessive seepage. The old borrow pits contribute to this adverse condition. Corrective measures proposed would consist of blanketing the railroad fill with dredged sand at a 1 on 6 slope and complete filling of the borrow pits. The cost of this improvement would be about $700,000, of which $450,000 would be Federal and $250,000 non-Federal costs. Limited studies indicate the work to be feasible.

480. *Rainier drainage district.*—This district is situated in Columbia County, Oreg., and extends for a distance of 4.8 miles along Columbia River downstream from the town of Rainier. It was organized in 1917 to protect 1,287 acres of land. With the protection now afforded, the district is steadily growing as a suburban home and small industrial area. The diversified farming originally practiced is gradually changing to subsistence farming. The area is fringed with dairy farms

and smaller mint-producing plots. Rainier drainage district was inundated during the 1948 flood.

481. The sum of $25,700 was authorized for this district in the Flood Control Act of June 1936. A total of $47,700 was spent in the district in 1941 for installation of tide gates, construction of hillside diversion drainage, and other appurtenant works. The supervisors of the district have petitioned that the hillside diversion ditch be extended and that the pumping plant be rebuilt. The proposed work, together with rehabilitation and raising of the levee would cost $1,160,000, including $335,000 of non-Federal expense. Economic justification appears doubtful.

482. *Consolidated diking improvement district No. 1.*—This area, which consists of 9,885 acres in Cowlitz County, Wash., extends downstream from Cowlitz River for about 7 or 8 miles and includes the cities of Longview and West Kelso. Flood protection is provided by about 15.2 miles of levees. About 5,300 acres are industrial and commercial areas in Longview and Kelso and the balance is devoted to farming and truck gardening.

483. At the height of the 1948 flood, the levees had 7 to 9 feet of freeboard and, except for heavy seepage along the eastern edge of the district, were never in apparent danger. The adverse seepage condition existed for about one-half mile along the base of the levee. The levee foundation should be investigated where the seepage occurred, and a cut-off provided if necessary. In addition, some of the levees directing hillside drainage out of the district should be raised and strengthened, toe drains should be installed in some areas, and seepage should be led to the pumping plant. This work is proposed at an estimated cost of $270,000, of which $175,000 would be Federal and $95,000 non-Federal costs.

484. *Cowlitz County diking improvement district No. 17.*—This district is situated along Columbia River at river mile 60, 6 miles northwest of Longview. It is bounded on the west by district No. 15, on the north by Coal Creek, and on the east by Consolidated diking district No. 1. Of the total of 500 acres within the area, about 440 may be protected and reclaimed. The road along Columbia River, although high enough to provide partial protection, would have to be raised for a distance of 3,750 feet. In addition, a levee 6,700 feet long would be needed along Coal Creek. The benefits which would accrue from this improvement probably would not justify the estimated cost of $250,000 excluding right-of-way. County and local interests, however, might be willing to share in the costs of this project, and further investigation will be made.

485. *Cowlitz County diking improvement district No. 15.*—This area is situated in Cowlitz County, Wash., at river mile 56.8, just east of Stella, and lies between Columbia River and Coal Creek slough. The improvement district, organized in 1921, constructed about 33,000 feet of levee to protect 845 acres of diversified farm land. The area, with proper protection, would furnish subsistence farmsteads for the city of Longview. As population increases, dairying may gradually replace present farm practices. At the present time, the district produces hay and small grains. The Works Progress Administration raised the greater portion of the existing levee, installed adequate pumping capacity, and did a considerable amount of bank stabilization. Because of erosion of the levee in the subsequent years,

a portion of levee about 1,500 feet long is in need of reconstruction. Such reconstruction would cost $32,000 and appears to be justified. Local interests probably would be required to contribute part of this amount.

486. *John drainage district.*—John drainage district is situated in Columbia County between Mayger, Oreg., and Beaver drainage district. The district, organized in 1915, contains 153 acres, which are held by about 30 owners. About 8,630 feet of levee, which has an elevation equal to or slightly below the 1948 flood height, surrounds the district. The district owners held the levee against the 1948 flood until the levee became saturated. One break, which will be repaired with emergency flood control funds, occurred along the west side of the district. Reconstruction to give adequate protection against the 1948 flood plus a normal freeboard is estimated to cost $60,000. The cost of the work would be economically justified; local interests, however, would be required to contribute toward construction costs.

487. *Crims Island.*—Crims Island is situated in Columbia County, about 1 mile downstream from Mayger, Oreg., at river mile 55. The island contains about 400 acres, of which approximately 350 could be protected by a levee. The land is highly productive, and at the present time is used for the raising of foodstuffs and grazing registered beef cattle. Protection of the island would require 4.6 miles of levee, from 5 to 11 feet in height. Estimated construction cost is $250,000 excluding rights-of-way. The project probably is not economically justified at the present time. Local interests probably would be required to make a considerable cash contribution to the project construction cost.

488. *Beaver drainage district.*—This district has a 6-mile frontage on the south bank of Columbia River, at a point about 57 miles below Portland. It contains 5,595 acres primarily of agricultural land protected by about 60,000 feet of levee which successfully withstood the 1948 flood. During the flood, however, heavy seepage occurred at several points along the levee and at the connection of the levee with a railroad fill. One of the main pumps failed and seepage water covered wide areas of cultivated land causing extensive damage to crops, particularly to mint fields. Corrective work required in this district and herein proposed would include strengthening of levee sections and construction of a cut-off at the junction of the levee with the railroad fill. Total estimated construction cost of $930,000, of which about $660,000 would be Federal costs and $270,000 would be non-Federal. Preliminary studies indicate that the project would be economically justifiable.

489. *Clatskanie drainage district.*—Clatskanie drainage district lies between Clatskanie River and Beaver slough, about 1 mile downstream from the town of Clatskanie. The district was organized in 1912, and contains 300 acres. The land is intensively cultivated, and the damage caused by flood water overtopping the levee in June 1948 was extensive. Local interests have purchased a new pump, but it had not been installed prior to the flood. The new pump, when installed with the old one, will provide adequate pumping facilities. Approximately 3 miles of levee will have to be raised by amounts ranging from 3 to 5 feet to provide adequate protection against a flood similar to that of 1948. The total cost of the work is

estimated to be $126,000, and the work apparently would be economically justified. Of the total estimated cost, $110,000 would be Federal cost and $16,000 non-Federal cost.

490. *Clatskanie River area.*—Clatskanie River flows through the town of Clatskanie to empty into Beaver sough. The river is navigable to the town of Clatskanie, and tidal effect extend to a point a short distance above the town. The river makes four very sharp bends within the town, and local interests have constructed bulkheads along the banks in order to prevent property damage. The main street and business establishments are located on a peninsula formed by an oxbow bend in the river, and the elevations of the stores range from 14 to 18 feet, mean sea level. During the flood of 1948, two blocks of the main street lying at a slightly lower elevation were flooded, and traffic on Columbia River Highway was suspended. Annual floods, which occur many times during the rainy season, cause damage principally through bank erosion. The land areas so affected are too small to justify protection. Local citizens are desirous that some form of flood protection be provided for the town. Construction of 1,500 feet of timber bulkhead and 500 feet of 10-foot levee would be required to protect the town. The estimated cost of such works is $75,000, of which $70,000 would be Federal and $5,000 non-Federal. Limited studies indicate that such an expenditure would be justified.

491. *Wallace Island.*—Wallace Island is in Columbia County, Oreg., near Clatskanie. It is about 3 miles long, and entirely covered with heavy brush and trees. Approximately 25 percent of the area is low and swampy, and no development of the land has been undertaken. Protection of about 510 acres would require 5.6 miles of levee, the cost of which would be approximately $300,000, exclusive of rights-of-way. That the area would justify such an expenditure within the foreseeable future is doubtful. Developments may justify improvement at some time in the future.

492. *Magruder drainage district.*—This district, 2 miles west of Clatskanie, is located at river mile 47.6, between Westport slough and the high ground to the south. It contains 592 acres of farm land. Existing protection consists of 18,500 feet of levee, which successfully withstood the 1948 flood. A portion of the east end of the levee, which joins with a railroad fill constructed mainly of rock, showed excessive saturation, and seepage appeared. Corrective work required and herein proposed would consist of a complete cut-off through the railroad embankment by cement-clay grouting. Estimated Federal cost is $20,000, and no non-Federal expenditure would be involved. These improvements would be justified.

493. *Midland drainage district.*—This district, organized in 1921, is located at river mile 47.4, in Columbia County, Oreg., between Wallace and Westport sloughs. It contains about 1,300 acres, mostly mint-producing farms, and is protected by about 35,500 feet of levee which successfully withstood the 1948 flood. The levees, tide boxes, and gravity drains were rehabilitated in 1938 under authorization of the 1936 Flood Control Act. During the 1948 flood, the tide box was held in place by sandbags, and several low places on the back levee were sandbagged. To secure the district against a similar flood, pumping facilities should be increased from the present 15,000 gallons per minute to 25,000 gallons per minute, a tide box should be recon-

structed, and a portion of the front levee should be rebuilt. This work is considered justifiable and is proposed at an estimated Federal expenditure of $130,000.

494. *Woodson drainage district.*—This district is situated at river mile 45, in the northwestern part of Columbia County, Oreg., between Columbia River and Westport slough. The original district was organized in 1915 to provide protection for 355 acres of agricultural land. It was reorganized in 1937, and approximately 3.4 miles of levee and appurtenant facilities were reconstructed, using funds authorized in the 1936 Flood Control Act. This district was not inundated during the 1948 flood. The pumping plant, which has a capacity of 6,000 gallons per minute, has proved to be inadequate. Provision of additional capacity of 7,500 gallons per minute is proposed. The estimated cost of the improvement, $25,000, would be borne by the Federal Government and the expenditure is believed to be economically justified.

495. *Kerry Island.*—This island is located in the northwestern part of Columbia County, and lies on the north side of the main channel of Westport slough near Kerry, Oreg. Local interests constructed about 10,000 feet of levee on the island in 1920 to furnish partial protection to 109 acres of land. The area is heavily wooded, and no development has taken place on the island to warrant consideration of further improvements at this time. Further development may justify improvement at some future time.

496. *Wauna area.*—This district is situated in Clatsop County, Oreg., and lies between Wauna Channel; Westport slough; the Spokane, Portland, and Seattle Railway; and Columbia River. It has a shore line of 3.6 miles and contains 550 acres. A number of large tide boxes and 3.8 miles of levee would be required to protect the area against a flood equivalent to that which occurred in June 1948. The cost of protection would be approximately $400,000, exclusive of rights-of-way. The project probably could not be justified under present conditions, but may be justified by future developments.

497. *Westport area diking district No. 15, Clatsop and Columbia Counties.*—This district near the town of Westport, Oreg., lies between the Spokane, Portland, and Seattle Railway and Westport slough, and contains 233 acres of land used for general farming and pasture. It is protected by about 11,000 feet of levee which was rehabilitated by the Government in 1941. At the time of rehabilitation, the inside borrow ditches from which the original levees were built were not refilled. The present owners contend that the levee cannot be properly maintained as long as water lies on both sides of the levee. The overgrown ditches are conducive to the growth of beaver and muskrat colonies, and these burrowing animals cause much damage to the levee. The possibility of clearing the inside of the levee and drainage ditch and backfilling the ditch with sand will be studied. Preliminary investigations indicate that the work is of doubtful economic justification at this time. Future development, however, may justify improvements in the area.

498. *Wahkiakum County diking districts No. 1 and 3.*—This area between Cathlamet, Wash., and Wauna and Westport, Oreg., is situated on Puget and Little Islands, which are separated by Bernie slough. The total area of 3,940 acres is used for general farming, specialty crops, and dairying. The length of protecting levees is

about 20.8 miles. These levees were constructed to provide from 1½ to 3 feet freeboard above the 1876 and 1933 flood planes, which intersect in this area. Roads occupy the tops of all levees. Along the inside toe of the levees, colonies of muskrats and beavers have burrowed from an old borrow pit into the embankment and created a serious seepage hazard.

499. The levee system, which failed in 1933 and in 1948, is considered to be inadequate. Only by complete rehabilitation could it be made adequate for protection against the design flood. The entire levee system would have to be raised and backed with a sand fill which would entirely cover the old borrow areas, thus reinforcing the embankment and destroying the homes of the rodents. This would be very difficult to accomplish. Widening the levee would require removal of most of the houses and other buildings on the island, as these improvements are built on the levee. The total cost of the improvement would amount to about $1,410,000, of which $835,000 would be Federal costs and $575,000 would be chargeable to local interests. Limited studies indicate that the improvement would be justified, and the work is proposed.

500. *Hunting Islands.*—These two islands have a combined area of 920 acres and lie along the right bank of Columbia River just downstream from Cathlamet, Wash. Elokomin slough separates the islands from the mainland, and several sloughs are found on the island. The land lies from 2 to 4 feet above low water, and local residents believe that considerable additional development is feasible. Construction of about 6 miles of levee from 9 to 13 feet in height, tide boxes, and a pumping plant would be required to provide protection. The estimated cost for protective works, exclusive of rights-of-way, is $550,000. The potential benefits apparently would not justify the expenditure. If the improvement were found justified, however, the few landowners on the island would be required to assume a considerable portion of the construction cost, as well as the costs of rights-of-way and maintenance. Increased development may justify protection in the future.

501. *Elokomin River area.*—This area, situated in Wahkiakum County, Wash., just northwest of Cathlamet, includes lower Elokomin River Valley and acreage adjacent to Elokomin slough. Dairy farming is the principal activity. One industrial establishment, a modern, progressive sawmill and box plant, furnishes seasonal employment to nonfarming residents. A logging railroad and United States Highway No. 830 traverse the area. Approximately $100,000, exclusive of rights-of-way, would be required to protect adequately the 750-acre area against a flood similar to that of December 1933. Contributions by local interests would be necessary because of the fact that increased land use would provide the major benefits. At the present time, this project is not economically feasible, but may become so, and is proposed as a possible future project.

502. *Tenasillahe Island diking district No. 6.*—This district is located at river mile 34.6, about 4 miles below Wauna, and lies between Columbia River and Prairie Channel. It contains 1,709 acres of land used for dairying, pasture, and general farming. About 35,000 feet of levee, reconstructed by the Federal Government in 1939, encircles the island. Because of lack of funds, all of the revetment considered necessary was not placed during the 1939 construction, and since that

time some sections of the levee have eroded. Correction of this condition is proposed, as described elsewhere in this report. A rehabilitation program is proposed that would require replacing about 1,500 feet of riverward slope of the levee, and raising about 3,000 linear feet of levees at an estimated Federal cost of $40,000. No non-Federal costs would be involved. The improvement would be economically justified and is proposed for construction.

503. *Wahkiakum County diking district No. 4.*—This area is situated between the mouth of Elokomin River and Skamokawa, Wash. The total area consists of 2,271 acres of pasture land which is used principally for dairy purposes. Protection is now provided by 9½ miles of levees constructed with a 2-foot freeboard above the 1933 flood plane. Continued settlement of the levees since construction has reduced the freeboard in certain locations to about one-half foot above the design flood plane. Although few adverse conditions appeared during the 1948 flood, seepage occurred in several places. The seepage is attributable to beaver or muskrat holes in the embankments.

504. Raising the levee to provide a freeboard of at least 3 feet above the 1933 flood plane and backing all the main levees with a sand fill on a slope of about 1 on 6 is proposed. This would add to the stability of the levees and destroy the home areas of the beavers and muskrats. Total cost of the improvement would be approximately $150,000, of which $265,000 would be Federal and $185,000 non-Federal cost. Limited studies indicate the project to be economically justified.

505. *Clatsop County diking district No. 4.*—This district, located at river mile 29, borders the left bank of Gnat Creek between the highway bridge and Blind slough. The district, containing 90 acres, was organized in 1918, at which time 7,000 feet of levees were constructed. The levee withstood the 1948 flood and is in fair condition. The tide box, which contains six wooden pipes, does not have sufficient capacity, and reconstruction is proposed. The estimated cost of $30,000 appears to be economically justified, and no non-Federal costs would be involved.

506. *Clatsop County drainage district No. 1.*—This district, located near Brownsmead, Oreg., lies between Blind slough; the Spokane, Portland & Seattle Railway; and Prairie Channel, a side channel of Columbia River. It contains 1,391 acres of land used for farming, dairying, pasture, and specialty crops. The area is protected by 36,800 feet of levee, which was reconstructed by the Federal Government in 1937, and which successfully withstood the 1948 flood. One section of railroad fill is included in the levee system, and an examination of this embankment is proposed. The cost of a sufficiently thorough exploration of the fill is estimated to be $2,000, and, if a blanketing program is found to be required, the estimated Federal cost would be about $12,000. No non-Federal costs would be involved. The improvement is proposed for such construction as may be found necessary.

507. *Knappa-Columbia slough area.*—This area is located in Clatsop County, Oreg., in the vicinity of the town of Knappa. It lies between the railroad grade, Warren slough, Knappa Channel, and Blind slough. The area contains 380 acres covered with heavy brush and timber. Columbia slough traverses about 70 percent of the length of the tract and two arms of the slough occupy a large part of the western end. This slough is navigable and is used for the storage of logs. Approxi-

mately 2 miles of levee, costing about $100,000 for construction alone, would be required to protect the area and economic feasibility is doubtful at this time. Opinion of local interests as to the development of the area is divided, and it is doubtful that any local contribution would be made available to help defray the project cost. Future development may make a project feasible.

508. *Karlson Island.*—Karlson Island is located in Clatsop County, Oreg., between Knappa and Prairie Channels of Columbia River. The total area of the island is about 1,100 acres, of which about 890 acres would be usable. Prior to 1936, local interests constructed about 3 miles of levee partially to protect 370 acres of higher land. The Flood Control Act of 1936 authorized the reconstruction of this levee and installation of a much-needed tide box. Officials of Clatsop County request that the remaining 520 acres of usable ground be protected if feasible. Construction of 3.2 miles of levee would be required at an estimated cost, exclusive of rights-of-way, of $200,000. The annual benefits to accrue probably would not justify the expenditure of such a sum at the present time, and further detailed studies would be necessary.

509. *Lower Grays River area.*—This area, at river mile 24, in the western part of Wahkiakum County, Wash., is located along both banks of Grays River. It includes the overflow area adjacent to Seal River and Crooked Creek. The principal activity is dairying, but in recent years production of cannery peas and cranberries has developed. The bottom lands along the lower reaches of Grays River range from 6 to 13 feet above sea level. About 1,740 acres in the district are subject to flooding from tides in Columbia River or from freshets from upper Grays River.

510. About 840 acres, lying in three separate tracts, have been partially protected. As the remaining acreage is divided into three distinct problem areas, no coordinated plan or organization on the part of the local owners exists. Reconstruction of the existing levees and tide boxes and construction of new levees and tide boxes in unprotected areas would be required to provide adequate protection. Local interests would move a number of houses and farm buildings. The construction cost, exclusive of rights-of-way, would be approximately $700,000 to improve the entire area. Justification at the present time is doubtful. Protection of that acreage which has benefited from partial protection and is in a relatively high state of development may be justified but would require more detailed study.

511. *Deep River area.*—Deep River area is located off Grays Bay on Columbia River, at mile 20, in the westernmost part of Wahkiakum County, Wash. An existing project protects a portion of the area, and some of the acreage has been afforded partial protection by individually constructed levees. Approximately 820 acres, however, still are subject to inundation. Protection could best be afforded to three separate areas. Tide boxes and encompassing levees would be required for each. The estimated cost is $225,000, exclusive of rights-of-way. This project probably is not economically feasible at present and, since the greatest benefits would be derived from increased land use, local interests would have to make a considerable contribution. At some future time, the project probably would be justified by increased development.

512. *Svensen Island improvement district.*—This district, about 12 miles east of Astoria, includes all of Svensen Island, which is located in Clatsop County, Oreg., between Prairie Channel and Svensen slough. The island contains 301 acres, which are protected by about 21,000 feet of levee. The levee along Prairie Channel has been subject to serious erosion, and bank stabilization is proposed for one location. In addition, rehabilitation of about 10,000 linear feet of levee and construction of a limited amount of timber bulkhead would be required. The estimated cost is $100,000, exclusive of rights-of-way. As the annual cost of this work has been estimated to be more than the annual benefits, the improvement probably could not be justified. Svensen Island improvement district, although small, has been a mint-producing area for many years. At present, some poultry, especially turkeys, is raised within the district. Full protection probably would tend to intensify the present development. Future development may make protection of the area justifiable.

513. *Upper Skipanon River and Cullaby Lake area.*—This district is situated at river mile 10, south of the town of Warrenton in Clatsop County, Oreg. It extends along Skipanon River for a distance of 6½ miles to a point 1 mile south of Cullaby Lake. Of the 2,850 acres of land in the area, 1,400 acres are subject to inundation or have poor drainage during the rainy season. Improvements to facilitate the drainage and to protect the low areas from inundation would include channel widening and the removal of snags and debris from upper Skipanon River and Cullaby ditch, construction of 32,200 feet of low levees, construction of eight tide boxes, reconstruction of two bridges, and construction of drainage ditches. The construction cost of this work would amount to about $250,000, excluding rights-of-way. Since present flood damages are not extensive, the greatest benefits would be derived from increased land use. Doubt exists as to whether local interests would make the necessary cash contribution and as to whether the project would be justifiable. Future study of a more detailed nature will be necessary.

514. *Summary.*—Improvements at 25 locations involving 28 existing diking and drainage districts and the protection of 7 new areas are proposed. Bank protection is proposed at 66 locations to insure the permanency of constructed improvements and to protect the natural bank of the stream. In addition, several projects were investigated that apparently would not be justified for improvement under present development. Serious erosion presents a problem at 28 additional locations where present development apparently would not justify the expenditure necessary for a permanent installation. Increased development, however, may justify improvement at some future time, and these locations are considered as possible future projects. Correction of erosion conditions at 66 primary locations by 123,800 lineal feet of stone revetment at a cost to the Federal Government of about $4,900,000 is proposed. The improvement of 28 existing diking and drainage districts and the protection of 7 new areas by diking and drainage is proposed at a total cost of about $39,094,000. The following tabulation shows the proposed diking and drainage projects, grouped by improvements to existing districts and by new areas proposed for protection:

PROPOSED IMPROVEMENTS TO EXISTING DIKING AND DRAINAGE PROJE

Project	Capital cost			Annual charges		
	Federal	Non-Federal	Total	Federal	Non-Federal	Total
Sandy Drainage District	$165,000	$77,000	$242,000	$6,400	$5,700	$12,100
Multnomah County Drainage District No. 1	1,005,000	495,000	1,500,000	39,000	36,100	75,100
Peninsula Drainage District No. 2	535,000	318,000	853,000	20,800	22,100	42,900
Peninsula Drainage District No. 1	1,125,000	455,000	1,580,000	43,700	35,200	78,900
Sauvie Island (Areas A and B)	750,000	250,000	1,000,000	29,100	20,700	49,800
Columbia Drainage District No. 1	800,000	308,000	1,108,000	31,100	16,200	47,300
Bachelor Island	500,000	180,000	680,000	19,400	14,500	33,900
Scappoose Drainage District	325,000	185,000	510,000	12,600	13,000	25,600
Lewis River area	240,000	100,000	340,000	9,300	7,700	17,000
Cowlitz County Diking Improvement Districts Nos. 5 and 11	777,000	445,000	1,222,000	30,200	31,200	61,400
Deer Island Drainage District	5,000	0	5,000	200	100	300
Cowlitz County Diking Improvement Districts Nos. 2 and 13	450,000	250,000	700,000	17,500	17,700	35,200
Consolidated Diking Improvement District No. 1	175,000	95,000	270,000	6,800	6,700	13,500
Cowlitz County Diking Improvement District No. 15	30,000	2,000	32,000	1,200	400	1,600
John Drainage District	42,000	18,000	60,000	1,600	1,400	3,000
Beaver Drainage District	660,000	270,000	930,000	25,600	20,800	46,400
Clatskanie Drainage District	110,000	16,000	126,000	4,300	2,000	6,300
Magruder Drainage District	20,000	0	20,000	800	200	1,000
Midland Drainage District	130,000	0	130,000	5,100	1,300	6,400
Woodson Drainage District	25,000	0	25,000	1,000	200	1,200
Puget Island area, Wahkiakum Diking Districts Nos. 1 and 3	835,000	575,000	1,410,000	32,400	38,600	71,000
Tenasillahe Island, Diking District No. 6	40,000	0	40,000	1,600	400	2,000
Wahkiakum Diking District No. 4	265,000	185,000	450,000	10,300	12,400	22,700
Clatsop County Diking District No. 4	30,000	0	30,000	1,200	300	1,500
Clatsop County Drainage District No. 1	12,000	0	12,000	500	100	600
Total for improvements to existing projects	9,051,000	4,224,000	13,275,000	351,700	305,000	656,700

PROPOSED NEW DIKING AND DRAINAGE PROJECTS

Washougal area	$525,000	$275,000	$800,000	$20,400	$19,700	$40,100
Hidden area	240,000	100,000	340,000	9,300	7,700	17,000
Portland area	14,000,000	8,000,000	22,000,000	544,000	561,000	1,105,000
Hayden Island	140,000	124,000	264,000	5,400	7,900	13,300
Vancouver Lake area	1,225,000	595,000	1,820,000	47,600	43,600	91,200
Kalama River, south area	350,000	170,000	520,000	13,600	12,400	26,000
Clatskanie River area	70,000	5,000	75,000	2,700	1,000	3,700
Total for new projects	16,550,000	9,269,000	25,819,000	643,000	653,300	1,296,300
Total for all improvements	25,601,000	13,493,000	39,094,000	994,700	958,300	1,953,000

Table 39 also contains a list of proposed diking and drainage districts, together with proposed bank protection locations. Table 40 contains a list of similar improvements considered as possible future projects.

515. *Justification.*—The estimated capital cost of bank protection, levee and drainage improvements proposed is $43,994,000. Of this amount, the estimated Federal and non-Federal costs are $30,501,000 and $13,493,000, respectively. The total annual cost is estimated at $2,193,400. The respective annual charges would be $1,185,100 and $1,008,300 to Federal and non-Federal interests.

516. Benefits would consist of reduction of flood damages and of increased land use. Local protective works and flood-control storage would reduce annual flood damages along Columbia River downstream from the mouth of Yakima River by $12,843,900, based on 1948 prices and on developments forecast for 1975. Increased land use

would result from the protection from flooding. Certain undeveloped or partially developed urban areas would be more fully utilized after protection and many arable areas would be used to grow crops yielding a higher return. Increased land use as a result of flood protection is estimated at $1,654,300 annually. Thus, the total benefit creditable to local protective works and flood-control storage is $14,498,200 annually. Of this amount $188,700 is on the lower river where control by storage would be relatively ineffective so that all of this benefit would be creditable to local works. As the balance of the benefits are partially creditable to storage, to new local protective works, and to works now existing as well as to strengthening of the existing works, a distribution becomes complex.

517. Initially, practically all reduction of flood damage and increase in land use would be creditable to local protective works. As each of the storage dams is added to the control system, the benefits would be creditable in proporation to the efficacy of the various units of the project in reducing flood stages. Therefore, benefits actually creditable to local projects would decrease with the addition of each storage project. In consideration of the many variable factors involved both in the interim and when the main control plan has been effected, an arbitrary distribution of benefits has been made with a resulting average benefit-to-cost ratio for the entire system of local protective works of 1.29 to 1. Appendix M contains a discussion of benefits and a distribution to various elements of the main control plan.

518. *Conclusion.*—Limited studies indicate that improvements to existing diking and drainage projects by expenditures in the amount of $13,275,000 and rehabilitiation of new areas by expenditures in the amount of $25,819,000 would be justified by the benefits to be derived. In addition, river banks and diking and drainage improvements require protective work to assure permanency to the river bank or to existing or proposed improvements. Such work is estimated to cost about $4,900,000. Improvements to other areas are not justified at this time but may, on the basis of increased development, be feasible at some future time.

519. These proposed and possible future projects would be required even with upstream flood control storage, to confine floods and provide the degree of flood protection considered desirable for flood plain areaswith in this sub-basin. These improvements aren ecessary for the security of residents of the sub-basin, and would permit orderly development of areas needed for the expanding economy of Columbia River Basin. The proposed improvements to existing projects and the rehabilitation of new areas are feasible and justified for immediate accomplishment. A separate report, authorized for submission at a later date, will cover these proposed and possible future projects in more detail.

DEEPENING COLUMBIA RIVER ENTRANCE

520. *History of the project.*—The original project for improvement of the navigation channel in this area, as described in Senate Document No. 13, Forty-seventh Congress, second session, and Annual Report for 1883, page 2011, was adopted by the River and Harbor Act of July 5, 1884. The improvement was to develop a channel across the bar 30 feet deep at mean lower low water by the construction

of a jetty 4.5 miles long, extending seaward from Point Adams, on the south side of the entrance, and terminating at a point about 3 miles south of Cape Disappointment. The jetty was completed in October 1895, including groins and shore protection, and 945,923 tons of stone were placed in the structures. The expenditure for new work was $1,968,753.14. As completed, the profile of the jetty was 10 to 12 feet above mean lower low water for a distance of 1.8 miles from shore, thence sloping to a height of 4 feet above mean lower low water at the outer end. By June 1896, the outer 1,500 feet had been beaten down to low water, and the jetty suffered further damage from time to time until rebuilt under the present project.

521. When work on the south jetty began, the best channel across the bar was 20 feet deep. As the jetty was extended, the channel deepened and shifted to the west and north. Controlling depths in succeeding years were as follows:

Year	Depth, in feet	Year	Depth, in feet
1890	24	1897	30
1891	28	1898	29
1893	29	1899	28
1894	29	1900	24
1895	29	1901	23
1896	30	1902	22

Between 1897 and 1898 a marked change occurred, and the channel moved through an arc of 60° to the northwest, and by 1902 all traces of a channel had disappeared and a controlling depth of only 20 to 22 feet was prevalent over the westerly and southerly portions of the bar.

522. The River and Harbor Act of March 3, 1899, authorized examination and survey of the mouth of Columbia River. Provision was made for "Survey and estimates with a view to obtaining a channel 40 feet deep at lowest water, and a report as to the desirability of such improvement." The report is contained in House Document No. 94, Fifty-sixth Congress, first session. A report of the Board of Engineers on the proposed deeper project, dated January 24, 1903, is published in the Annual Report of the Chief of Engineers for 1903, page 2275. These two reports form the basis for the existing project, authorized by the River and Harbor Act of March 3, 1905, which provides for a channel across the bar 40 feet deep at mean lower low water and of suitable width, not less than one-half mile, to be secured by dredging and by converging rubble-mound jetties, the south jetty being about 7 miles long, and the north jetty about 2.5 miles long, terminating 2 miles north of the end of the south jetty.

523. Work on extension of the south jetty was completed in August 1913. As then completed, the south jetty had an average top width of 25 feet and an elevation of 10 feet above mean sea level from the shore to the end of the original project, a distance of 4.5 miles, thence the height was increased by stages to a maximum of 24 feet at the outer end. The original jetty, including extension thereto and maintenance, required the placement of nearly 6,000,000 tons of stone at a cost of about $10,000,000.

524. Construction of the north jetty was begun in 1913 and completed in 1917. This jetty extends 2.35 miles seaward from Cape

Disappointment and required the placement of nearly 3,000,000 tons of stone at a cost of about 4½ million dollars. The north jetty was constructed with a top width of 25 feet, with the exception of the first 3,000 feet, to an elevation from 28 to 32 feet above mean lower low water.

525. During the progress of work on the north and south jetties, dredging of the bar channel was carried on with more or less success. As the jetties were extended, however, greater depths prevailed and upon completion of the north jetty the controlling depth was 40 feet in a channel 1,000 feet wide. In 1919 the channel width increased to 3,000 feet, and in 1930 to nerly 8,000 feet, with a controlling depth on the entrance range of 44 feet. Entrance depths in excess of the project depth of 40 feet have prevailed since that time, although in recent years the sands of Clatsop Spit, inside the jetties, have encroached on the channel so that full depths are not now available on the ranges and to the south. Project depth and width prevails to the north of the ranges, but on an undesirable alinement.

526. About 3.5 miles of the south jetty were rehabilitated in the years 1931 to 1936. Jetty A was constructed in 1938 to check the tendency of the channel to swing to the north, which tendency was threatening the outer portion of the north jetty, and creating an objectionable alinement.

527. The depth on the outer bar has been about 45 feet for several years, and the bar channel has shifted to the north, cutting away a large part of the outer end of the north spit. The natural deepening and narrowing of the bar channel, which is still in progress on the north side, allows the seas to "pile up" in the area near buoy No. 10, where most of the trouble has been experienced in recent years. Maintenance dredging is necessary each year to provide the project depth in this area for the one-half mile width. During the summer of 1947, over 1,000,000 yards of sand were removed from the vicinity of buoy No. 10, at the intersection of the inside and outside ranges.

528. Annual dredging in the entrance of Columbia River, inside the bar, for the past 10 years has been as follows:

Fiscal year	Cubic yards	Fiscal year	Cubic yards
1939	501,289	1944	
1940	88,602	1945	393,127
1941		1946	186,009
1942		1947	483,014
1943		1948	1,030,178

529. *Navigation difficulties.*—Though the project depth of 40 feet is adequate for normal sea conditions, greater depths apparently are necessary for navigation by large vessels, especially during periods of rough weather. The Columbia River bar pilots state that, despite dredging of the main channel to a minimum depth of 41 feet during the 1947 season, the condition remains unsatisfactory. They point out that most of the prewar tankers drew from 27 to 28 feet of water and that now such ships are larger and draw from 30 to 32 feet. The cargo ships, also, have generally greater drafts. To stay in deeper water, the ships must veer north of the range and run close to the north jetty. A depth of 48 feet in the entrance channel is requested

by the pilots, who feel that the need is urgent to avoid expensive weather delays for the larger and deeper-draft vessels. Because of the heavy seas which prevail in the entrance during the winter season, vessels sound from 10 to 15 feet, possibly more, so that a depth of 48 feet is desired.

530. The present project dimensions and the depth of 40 feet were based on navigation by ships with load drafts common to Pacific coast harbors at the time of authorization. The project dimensions were adequate until the larger ships of the late war period came into service. Ship drafts at present average 3 to 4 feet more than formerly and few of the older ships remain in service. This trend to larger, deeper-draft ships is shown in the following tabulation of vessels using the Columbia River entrance:

Item	Number of ships using entrance in years shown	
	1947	Average of 1920-22
Actual draft:		
33 feet	2	[1] 1
32 feet	28	None.
31 feet	133	[1] 5
28 to 30 feet	533	41
Total ships with drafts 28 feet or more	696	43
Total arrivals and departures of ships with drafts over 18 feet	3,383	2,395

[1] In the 3 years.

In 1947, approximately 21 percent of ships moving through the entrance had actual drafts of 28 feet or more, while the average for 1920-22 was slightly less than 2 percent.

531. *Commerce and vessel traffic.*—In the period 1937 through 1946, inclusive, a total of 66,720,271 tons of commerce crossed the bar at Columbia River entrance. Included were about 12,000,000 tons of foreign exports, about 1,000,000 tons of foreign imports, about 40,000,000 tons of coastwise receipts, about 12,000,000 tons of coastwise shipments, and about 2,000,000 tons of cargo in transit. Total annual tonnage did not vary appreciably during the period, but cargoes in transit were reduced sharply during the war years. In 1947, totals of 1,671 and 1,712 ships, inbound and outbound, respectively, passed through the entrance. Total net registered tonnage inbound was 7,458,013, and outbound, 7,607,870. Most of these vessels had drafts ranging from 18 to 28 feet, but a total of 533 ships had drafts ranging from 28 feet to 30 feet, and 164 ships had drafts ranging from 31 feet to 33.5 feet.

532. *Existing conditions.*—Depth on the outer bar is 44 feet in a wide channel, and depths in excess of 40 feet are available between Clatsop Spit (buoy 10) and the north jetty, but large vessels must veer to the north of the ranges when in this vicinity in order to take advantage of deeper water. This maneuvering brings the ships closer to the north jetty than navigators consider safe during periods of heavy weather.

533. *Proposed improvements.*—The removal of a large amount of material from Clapsop Spit would be required to remedy the condition.

Dredging for one-quarter mile south of the ranges to depths of 45 and 48 feet, respectively, would require the removal of 8,000,000 and 14,000,000 cubic yards of sand in initial work and an estimated 2 to 3 million yards for annual maintenance. Removal of such large quantities of material in these rough waters, where work can be done only in a few months of each year, would require at least two large hopper dredges, none of which are available on the Pacific coast at this time.

534. Increasing the depth on the outer bar from the present 44 feet might entail further work on the main jetties, and construction of an additional jetty between jetty A and the north jetty might aid considerably in directing the ebb flow farther to the south and prevent encroachment of Clatsop Spit on the marked navigation channel. Considerable study would be required to determine the most economical and practical method of maintaining greater depths in the entrance.

535. *Preliminary estimates of cost.*—Estimates were prepared for two plans of improvement which provide for dredging Clatsop Spit to depths of 45 and 48 feet below the plane of mean lower low water to a line parallel with the two entrance ranges and one-quarter mile southerly thereof, with widening at the turn. The proposed alinement is shown on plate 34. Provision for overdepth dredging of 2 feet is included in the cost estimates which are based on January 1, 1948, price levels. Quantities were determined from a survey made May 10, 1948, just prior to the June flood.

536. Under plan A, which includes dredging to 45 feet, approximately 8,000,000 cubic yards of material would be removed from Clatsop Spit, at a unit cost of $0.13 per cubic yard. The total first cost of improvement under plan A would be $1,040,000. Under plan B, which includes dredging to 48 feet, approximately 11,000,000 cubic yards of material would be removed from Clatsop Spit and 3,000,000 cubic yards from the bar channel, which at a unit cost of $0.13 would amount to $1,820,000.

537. Maintenance of such depths would be very costly if done by dredging alone. Construction of an additional jetty extending from Cape Disappointment southwesterly toward Clatsop Spit undoubtedly would aid considerably in maintaining depths in the troublesome area. Such a spur jetty would cost several million dollars. Development of a method for maintaining greater depths by construction of an additional jetty would require extensive further studies and investigations.

538. *Accomplishments.*—Improvement of the entrance to Columbia River would provide a more properly alined navigation channel with a depth adequate for the safe passage of the larger postwar vessels, reduce the time lost annually by large or deeply laden vessels awaiting safe navigating conditions, reduce the loss of ships and cargoes due to inadequate channel conditions, and protect the existing improvements from the shifting of the channel. Time lost annually by deeply laden ships, both incoming and outgoing, awaiting more favorable conditions under which to navigate the entrance safely, is not a matter of record, but a survey may show it to be substantial. Also, marine insurance rates might be favorably affected by the improvement. Six hundred and ninety-six ships used the entrance in 1947; thus, the net effect would be a considerable, but as yet undetermined, annual benefit creditable to the project.

539. *Conclusion.*—Rough estimates indicate that the proposed channel improvement and spur jetties would be economically justified, but further studies would be necessary to determine the exact extent and character of work to be performed. Further, in view of the fact that solution of the problem would facilitate navigation development essential to continued growth and expansion of the Pacific Northwest, the project warrants detailed consideration. A separate report covering this project will be submitted as soon as practicable, pursuant to resolution of the Committee on Public Works, United States Senate, and Committee on Public Works, United States House of Representatives, dated August 4, 1948, and August 6, 1948, respectively.

Section V—Possible Future Projects

GENERAL

540. Known possible future projects in the sub-basin include reclamation by diking and drainage of additional land in the lower Columbia River flood plain, and protection from erosion of additional riverbank areas, as described in section IV of this chapter, but exclusive of that indicated therein to be now feasible; and improvement of Oregon slough for shallow-draft navigation. These projects would be essentially local in scope, although the individual units of the diking projects would extend from Sandy River to the mouth of Columbia River and the construction required would be dependent upon flow regulation by proposed and possible future upstream storage. Inasmuch as possible future diking and drainage and bank protection projects were grouped for discussion with proposed projects of this nature, no further discussion is presented in this section.

OREGON SLOUGH

541. *Description.*—Oregon slough, a back channel of Columbia River separating Hayden and Tomahawk Islands from the Oregon shore, is shown on plate 36. The slough is about 6.5 miles long and extends from river mile 102 to river mile 108.5. The upper limit is about 2 miles above the Interstate Bridge which connects Portland and Vancouver. Tomahawk Island, about a mile long, was connected to Hayden Island, immediately downstream and about 4 miles long, by an old pile dike about 3,500 feet long. This connection has been broken and the remaining piles are inundated at high water. The channel has, in general, a depth of about 10 feet for a width of 200 to 300 feet, except at the upper end where shoaling has reduced the controlling depth to about 3 feet at low water.

542. Improvement of the upper entrance to Oregon slough by dredging to a minimum depth of 10 feet and width of 300 feet has been authorized, but no construction has been done. This improvement would provide an adequate depth at all stages to allow access to the moorages in Oregon slough. A project completed in 1914, but no longer active, provided for a channel 20 feet deep and 200 feet wide at low water, extending from the lower slough entrance upstream 4 miles to a point above the Union Stock Yards. Over the specified width the controlling depth is now 7 feet. A gap of about 3 miles remains between the inactive project and the authorized channel through the upper slough entrance. At the approximate midpoint of this reach,

access to the main river between Tomahawk and Hayden Islands is partially blocked by shoals and the remaining portion of the old dike previously mentioned. At present a towing company owning property and maintaining facilities on the Oregon shore uses Oregon slough for storage of log rafts in the lower stretch. Several fishing boats operate out of Oregon slough, and the Portland Yacht Club maintains moorage facilities in the upper reach. The section adjoining Tomahawk Island is constricted to a total width of about 400 feet by houseboat moorages on each shore. Miscellaneous other moorages also are in existence in the slough, and two fixed bridges cross it, one at Tomahawk Island and the other at the interstate highway crossing to Hayden Island. The railroad bridge downstream has a movable span.

543. Under present traffic conditions, the congestion in Oregon slough is such that navigation interests urge, in addition to construction of the authorized work at the upstream entrance, that an investigation be made to determine the feasibility of connecting the authorized section to the existing downstream project. Emergency funds have been allocated in the amount of $25,000 for channel clearing of the authorized section where unprecedented shoaling has recently occurred. This work will be a temporary expedient only, and $49,000 will be required for completion of the authorized project. A report will be prepared in answer to requests by the Senate Committee on Public Works by resolution adopted January 20, 1948, and a similar request by the Committee on Public Works, House of Representatives, resolution adopted April 13, 1948. That report will be submitted as soon as practicable and will cover all phases of the Oregon slough problem. Pending holding of a public hearing to determine the nature of the improvements desired by local interests, no work on this study has been initiated.

CHAPTER III—SUMMARY

SECTION I—SUMMARY OF PROJECTS

GENERAL

544. The previously recommended, proposed, and possible future projects discussed in this appendix were considered as units of an ultimate plan of development which would include, in addition, all existing and authorized Federal and non-Federal projects in the sub-basin, as well as similar projects of regional scope in the rest of Columbia River Basin. The major regional problems to be solved by improvements considered are navigation, flood control, and power production. Regional fishery problems would be solved by provision of hatchery facilities in connection with proposed dams and the Lower Columbia River Fisheries plan discussed in appendixes K and P.

545. Within this sub-basin local flood control, bank protection, and navigation problems would be solved, and incidental benefits would accrue to irrigation through reduction of pumping lift. Recreation needs of the sub-basin would be partially served by provisions at reservoir projects. Following paragraphs summarize the improvements considered for solution of each of the above problems, and mention, in general terms, the accomplishments which would result from construction thereof.

NAVIGATION

546. Table 35 lists existing and authorized navigation projects in the sub-basin. These projects may be divided broadly into main channel projects, supplementary auxiliary channels, and mooring basins. As proposed, ultimate development of the main channel would consist of open-river improvement to Bonneville Dam, river mile 145.3, and of slack-water navigation development on Columbia River within the sub-basin, upstream from Bonneville Dam. Authorized open-river improvement downstream from Bonneville Dam would be adequate, with few exceptions, to satisfy present and immediate future needs. At low water, only 13 feet of fall exists in the 145-mile distance from Bonneville Dam to the Pacific Ocean. At present, a deep-draft navigation channel to accommodate ocean-going vessels has been constructed from the mouth of Columbia River to Portland and Vancouver. From the latter point a 27-foot deep channel to The Dalles has been authorized and is now about 46 percent complete. Bonneville pool forms this channel for about 44 miles downstream from The Dalles. One possible exception to the general adequacy of the channel below Bonneville Dam exists at the mouth of the river where channel depth over the bar is considered inadequate at times. This problem, which is of regional importance, would be solved by a project for deepening the entrance channel. A separate report on that project is to be submitted at a later date.

547. Above Bonneville pool, due to the rapids and swift water, slack-water improvements would be required fully to develop potential commerce. This has not been accomplished, but interim channel improvements have been authorized and constructed to provide navigable depth. From The Dalles, near the head of Bonneville pool, The Dalles-Celilo Canal leads to an authorized channel, 7 feet deep and 150 feet wide, extending to Wallula, Wash., near the upper sub-basin limit. No specified depth or width between Wallula and Kennewick, Wash., a distance of 14 miles, is provided. This channel is 75 percent completed. From Kennewick upstream to the mouth of Yakima River, a distance of 7 miles, no work is authorized. In addition to the shallow channel and swift velocities existing above The Dalles, navigation is further restricted by The Dalles-Celilo Canal, the lock chambers of which are only 45 feet by 265 feet in plan and 7.8 feet deep over the sills.

548. Slack-water development of the 190-mile reach above Bonneville Dam has been furthered by construction of Bonneville Dam, with a reservoir about 47 miles long. McNary Dam, now under construction, will form a pool to eliminate 44 miles of swift water at the upstream limit of the sub-basin. Improvement of the intervening distance of about 100 miles, by means of two locks and dams, one at The Dalles site, river mile 192.5, and the other at John Day site, river mile 217.3, appears feasible. Locks at these structures would provide plan clearances of 675 feet by 86 feet and minimum water depth of 14 feet. These dimensions are similar to the dimensions adopted for McNary lock after a thorough investigation of the factors involved.

549. Supplementing the main navigation channel, and as shown in table 35, about 19 auxiliary side channels to river ports and landing points have been constructed and 7 additional have been authorized; 3 ship turning basins have been constructed and 2 are authorized; and

3 small boat mooring basins have been authorized. Additional projects of this character, which have been previously recommended and are proposed for construction as forming desirable units of a comprehensive plan of improvement, are the channel and small boat mooring basin in Baker Bay, Westport slough channel enlargement, Columbia slough channel, and Umatilla Harbor.

550. To facilitate the interchange of cargo from land to water along the reservoirs, construction or modification of harbor facilities along the McNary, John Day, and The Dalles pools is proposed. Construction of facilities at 15 locations is proposed.

551. Possible future navigation projects include construction of a shallow-draft navigation channel in Oregon slough, and supplementary navigation improvements to fulfill needs not now apparent. Such future projects, which would be local in character, could be added as justification therefor develops.

FLOOD CONTROL

552. Existing flood control projects in the sub-basin consist principally of permanent reclamation of local flood plain areas along the lower river for agricultural and industrial use by construction of dikes and drainage facilities. Of the total flood plain area of 170,000 acres, about 100,000 acres, as listed in table 36, are protected. Several other areas which may also be economically susceptible to protection have been discussed in a general way in this appendix and, although final studies are not complete, apparently warrant protection or additional protection. Thirty-two of these areas would be protected by proposed projects. The total cost of the improvements proposed is estimated to be about $39,094,000, of which Federal and non-Federal costs would be $25,601,000 and $13,493,000, respectively. The results of further studies, with possible recommendations for additional work, will be contained in a separate survey report to be submitted at a later date.

553. The above, referenced survey report also will contain a detailed analysis of the need for, and economic justification of, revetment to protect eroding banks along Columbia River. Prior to the 1948 flood, 66 locations along completed levees and high-value unprotected land evidently needed bank protection. This work, therefore, is proposed for immediate construction. The cost of improving these 66 locations is estimated to be about $4,900,000.

554. One local flood control channel project, at Arlington, Oreg., is authorized, but construction has not been initiated. No other problem areas of this type in the sub-basin, subject to damage from intense tributary run-off, are known where protection would be economically feasible at present. Should such areas develop, however, the problems would be local in nature and could be solved without effect on the comprehensive plan of development. Cost of the channel improvement through Arlington is estimated to be $480,000, of which $191,000 has been appropriated.

555. The proposed John Day Reservoir would provide appreciable flood control benefits, especially to the area downstream from Bonneville Dam. In connection with design of proposed dams and reservoirs, consideration was given to the feasibility of obtaining flood-control storage capacity to protect the lower river areas, either by

drawdown, provision of surcharge space, or both. Although no significant amount could be reasonably obtained at The Dalles Dam, surcharge storage capacity of about 2,000,000 acre-feet could be made available economically in John Day Reservoir and is proposed.

POWER

556. The sub-basin includes a 335-mile reach of Columbia River in which the river fall is about 330 feet. A part of the potential power available is at present developed at Bonneville Dam at the head of tidewater, where the power drop is about 55 feet and the power installation 518,400 kilowatts. McNary Dam, now under construction in the upper reach of the sub-basin, will develop another 90 feet of head and have an installed capacity of 980,000 kilowatts. Upon completion of McNary Dam, 183 feet of head from McNary tailwater to Bonneville Pool will remain undeveloped. The proposed The Dalles and John Day projects would complete the development of the potential power of the sub-basin and would utilize this head in steps of 88 feet and 95 feet, respectively. The power plants at these dams would be designed so that, as river flow was regulated by upstream storage, full use could be made of the increased firm flow. The proposed installed capacity of The Dalles and John Day Dams would be 980,000 and 1,105,000 kilowatts, respectively. See appendix O.

FISHERIES

557. Fish hatchery and rearing facilities would be included as part of John Day and The Dalles projects to offset any losses which might occur as a result of loss of spawning and rearing areas in the pools. Facilities for passage of anadromous fish would be incorporated in each of the dams to the extent considered necessary by responsible Federal and State fishery agencies.

IRRIGATION

558. Although some 30,000 acres of land are now under irrigation in the sub-basin, these existing areas are small and scattered. Larger potentially irrigable acreages, however, are located along the river at higher elevations, notably east of The Dalles, and the total irrigable area within the sub-basin is estimated at 480,000 acres. None of the larger irrigation projects are as yet authorized. The Bureau of Reclamation, however, has recommended construction of The Dalles project west unit, which would serve 4,530 acres of land at high elevations by pumping. The Dalles and John Day Reservoir projects would have a beneficial effect on irrigation projects yet to be developed, by reducing the pumping lift. Future irrigation diversions would have no appreciable effect on stream flow in the sub-basin, and such projects readily could be incorporated into the over-all sub-basin development.

RECREATION

559. The sub-basin is characterized by many scenic attractions, especially through Columbia Gorge. Furthermore, attractions are easily accessible by rail and highway, and camping and day-use facilities generally are available. In addition, boating on Bonneville

pool is gaining in popularity. The only proposed projects which would have bearing on recreation in the area are The Dalles and John Day Dams. The new pools created would provide water-associated recreational opportunities in the upper sub-basin, where most needed. These two projects would, in addition, provide points of interest at the dams which would be exceedingly attractive to tourists and local residents alike.

SECTION II—CONCLUSION

GENERAL

560. This sub-basin is an area through which a major part of the raw materials and products of Columbia River Basin will pass, either in transit to the ultimate consumer or for processing in the Portland-Vancouver industrial area. Supplies, especially petroleum, for the normal needs of the interior areas also pass through the sub-basin, moving upstream by barge, highway, and rail transport. Development of navigation, both ocean-going and river craft, is of paramount importance to the basin as a whole, and to the subbasin proper.

561. The previously proposed dams and reservoirs would complete slack-water development from Bonneville Dam to the upper end of the sub-basin. The previously recommended, proposed, and possible future open-river and local harbor projects would complete the development of navigation channels on the lower river and provide access from tributary areas to the ship and river-craft channels at points suited to rapid and economical transfer of commodities.

562. Flood problems in the sub-basin could best be solved by construction of levees and local protective works, both as an interim measure and to supplement the effect of proposed and necessary storage in upstream reservoirs. Provision of about 2,000,000 acre-feet of usable surcharge flood control capacity in John Day Reservoir would be physically and economically feasible, and would add materially to the flexibility and efficiency of an ultimate flood control plan.

563. Run-off from the entire basin of Columbia River and tributaries upstream from the Cascade Range is available for development of power to satisfy demands of the adjacent load centers and the Pacific Northwest. Proposed installations at The Dalles and John Day Dams, together with the existing and authorized installations at Bonneville and McNary Dams, would develop all the available head in the sub-basin and would be so situated as to take full advantage of all upstream flow regulation.

564. Columbia River in this sub-basin is the route by which salmonoid fish ascend to tributary streams to spawn and maintain the runs which support the Columbia River salmon fishery. Any problems which would be posed by construction of dams in the sub-basin could be solved by provision of fish passage facilities in accordance with proven design at Bonneville Dam and as dictated by the latest data available from fishery agencies, and by provision of adequate hatchery and rearing facilities to offset loss of natural spawning and rearing areas in the proposed pools.

565. Local problems, including flood control, drainage, bank protection, irrigation, and recreation, would be solved by the previously

recommended, proposed, and possible future projects discussed herein. The provision of 32 proposed local flood control projects, at an estimated total cost of about $39,094,000, would be economically justified by the benefits to be derived. Incidental irrigation benefits would accrue to The Dalles and John Day Dams from reduction of pumping lifts to adjoining irrigable lands, and recreation benefits would accrue as a result of minimum provision for accommodating the public at the reservoirs.

566. In view of the foregoing conclusions, it appears that the projects considered could be combined with existing and authorized projects, both Federal and non-Federal, in this sub-basin to solve sub-basin problems. Also, in combination with projects considered for an ultimate plan of improvement in other sub-basins, the projects considered herein would be of importance in solving major regional navigation, flood control, and power problems.

TABLE 1.—*Maximum and low-water data*

[Main Columbia River below Yakima River]

Map No.[1]	Station	Stream	River mile	Drainage area, square miles	Period of record	Maximum observed water surface elevation		1894 water surface elevation, feet, mean sea level	Adopted low-water surface elevation, feet, mean sea level
						Date	Feet, mean sea level		
1	Pasco	Columbia River	328	103,500	June 1, 1942, to Sept. 30, 1946	June 5, 1946	335.8	349.6	314.0
2	Umatilla	do	292	213,500	Feb. 1, 1892, to Sept. 30, 1946	June 5, 1894	281.9	281.9	254.0
3	The Dalles	do	200	237,000	June 1, 1878, to Sept 30, 1946	June 6, 1894	160.1	160.1	128.5
4	Cascade Locks	do	149	240,000	Oct. 1, 1878, to Sept. 30, 1938	do	92.9	92.9	[2] 42.5
5	Bonneville	do	145	240,000	Oct. 1, 1938, to Sept. 30, 1946	June 5, 1946	82.3	49.3	[2] 8.2
6	Warrendale	do	142		Oct. 9, 1940, to Aug. 3, 1942	May 29, 1942	26.7	48.3	5.80
7	Prindle	do	134		Nov. 1, 1940, to Aug. 3, 1942	June 19, 1942	25.7	44.6	5.02
8	Washougal	do	123		Oct. 15, 1940, to Aug. 2, 1942	May 29, 1942	23.1	41.4	3.49
9	Ellsworth	do	110		Nov. 1, 1940, to Aug. 3, 1942	do	20.5	37.7	2.10
10	Vancouver	do	106		April 1902, to Sept. 30, 1946	June 18, 1933	27.7	36.5	1.40
11	Kelley Point	do	102		Oct. 7, 1940, to Aug. 3, 1942	May 30, 1942	17.8	34.6	1.11
12	Willow Bar	do	96		Oct. 2, 1940, to Aug. 4, 1942	do	16.5	33.5	.85
13	St. Helens	do	86	255,000	Mar. 17, 1930, to Sept. 30, 1946	June 19, 1933	22.4	31.1	.42
14	Kalama	do	75		Sept. 27, 1940, to Aug. 4, 1942	May 30, 1942	12.7	27.5	−.17
15	Longview	do	66		Feb. 30, 1928, to Sept. 30, 1946	June 19, 1933	16.0	23.0	−.67
16	Stella	do	57		Sept. 24, 1940, to Aug. 1, 1942	Dec. 19, 1941	10.2	18.8	−1.21
17	Eagle Cliff	do	51		Sept. 26, 1940, to Aug. 3, 1942	do	9.8	16.3	−1.74
18	Wauna	do	42		Nov. 5, 1940, to Sept. 30, 1946	do	9.3	12.2	−2.27
19	Cathlamet	do	41		Oct. 30, 1930, to Aug. 1, 1942	Dec. 17, 1933	9.3	11.8	−2.38
20	Skamokawa	do	33		Nov. 1, 1930, to July 31, 1942	do	9.2	9.2	−2.78
21	Altoona	do	24		Sept. 19, 1940, to Aug. 1, 1942	Dec. 19, 1941	8.3		−3.46
22	Tongue Point	do	17		Aug. 26, 1940, to Feb. 28, 1943	do	8.4		−3.79
23	Fort Stevens	do	8	259,000	Aug. 26, 1931, to Sept. 30, 1946	Dec. 17, 1933	7.6		−4.03

[1] For location of stations see map of Hydrologic Stations, pl. 2.
[2] For natural conditions existing prior to construction of Bonneville Dam.

TABLE 2.—*Yearly discharge and run-off summary, Columbia River at The Dalles*

[Drainage area = 237,000 square miles]

Water year [1]	Run-off in—		Mean, cubic feet per second	Extremes in mean daily discharge			
	Million acre-feet	Inches		Maximum, cubic feet per second	Date	Minimum, cubic feet per second	Date
1879	175.0	13.85	242,000	643,000	June 18	59,600	Feb. 5
1880	192.0	15.18	264,000	914,000	July 1	68,300	Mar. 23
1881	183.0	14.46	252,000	598,000	June 17	73,800	Jan. 31
1882	168.0	13.30	232,000	883,000	June 14	65,300	Do.
1883	154.0	12.14	212,000	573,000	do	58,800	Jan. 22
1884	156.0	12.34	215,000	698,000	June 13	51,000	Feb. 14
1885	155.0	12.28	214,000	482,000	June 23	49,000	Dec. 20
1886	153.0	12.07	211,000	673,000	June 9	64,400	Jan. 22
1887	189.0	14.96	261,000	896,000	June 19	66,800	Dec. 1
1888	147.0	11.63	203,000	564,000	June 18	54,900	Jan. 16
1889	97.0	7.72	135,000	302,000	June 8	62,600	Feb. 20
1890	143.0	11.29	197,000	633,000	May 14	47,400	Jan. 7
1891	121.0	9.55	167,000	448,000	June 2	62,600	Mar. 5
1892	144.0	11.38	198,000	607,000	June 23	66,200	Feb. 4
1893	159.0	12.59	220,000	679,000	June 14	66,200	Feb. 5
1894	225.0	17.77	311,000	[2] 1,160,000	June 6	88,300	Feb. 26
1895	140.0	11.13	194,000	475,000	May 31	80,100	Feb. 17
1896	166.0	13.15	229,000	785,000	June 22	70,000	Feb. 5
1897	176.0	13.87	243,000	780,000	May 24	78,000	Nov. 1
1898	167.0	13.19	230,000	649,000	June 21	82,000	Nov. 5
1899	171.0	13.50	236,000	787,000	June 22	63,200	Dec. 18
1900	163.0	12.85	224,000	536,000	May 15	103,000	Feb. 21
1901	158.0	12.53	219,000	662,000	June 1	81,100	Feb. 12
1902	143.0	11.32	198,000	644,000	do	63,200	Feb. 4
1903	153.0	12.09	211,000	787,000	June 19	72,200	Dec. 24
1904	176.0	13.89	242,000	629,000	May 26	80,200	Feb. 11
1905	102.0	8.10	141,000	412,000	June 15	57,800	Feb. 16
1906	114.0	9.04	158,000	374,000	June 1	64,400	Jan. 12
1907	166.0	13.12	229,000	587,000	June 5	77,800	Jan. 31
1908	143.0	11.30	197,000	653,000	June 18	65,000	Feb. 5
1909	139.0	11.02	192,000	675,000	June 19	68,000	Jan. 11
1910	154.0	12.21	213,000	566,000	May 14	79,400	Feb. 24
1911	136.0	10.78	188,000	574,000	June 18	67,400	Mar. 5
1912	134.0	10.56	184,000	568,000	June 1	57,200	Jan. 9
1913	155.0	12.23	214,000	759,000	June 12	68,000	Feb. 13
1914	135.0	10.70	187,000	493,000	May 27	70,600	Jan. 3
1915	107.0	8.45	147,000	328,000	June 1	62,000	Jan. 8
1916	173.0	13.80	238,000	727,000	July 1	62,000	Jan. 17
1917	152.0	12.03	210,000	727,000	June 20	62,000	Jan. 20
1918	148.0	11.72	205,000	578,000	June 23	70,600	Nov. 27
1919	125.0	9.86	172,000	553,000	June 1	57,000	Jan. 8
1920	115.0	9.11	158,000	428,000	June 26	47,000	Dec. 7
1921	167.0	13.18	230,000	773,000	June 11	86,600	Dec. 27
1922	133.0	10.47	183,000	677,000	June 9	64,400	Mar. 2
1923	130.0	10.29	179,000	581,000	June 15	56,000	Dec. 19
1924	99.3	7.87	137,000	433,000	May 26	60,800	Jan. 22
1925	146.0	11.51	201,000	642,000	May 25	68,000	Oct. 27
1926	85.5	6.77	118,000	269,000	May 9	63,200	Jan. 27
1927	149.0	11.79	206,000	690,000	June 18	74,000	Oct. 5
1928	168.0	13.28	231,000	766,000	May 29	86,800	Sept. 30
1929	96.1	7.61	133,000	460,000	June 19	43,200	Jan. 31
1930	95.2	7.60	131,000	332,000	June 14	40,000	Jan. 21
1931	88.4	7.00	122,000	308,000	May 19	50,800	Jan. 2
1932	135.0	10.64	186,000	565,000	May 24	43,200	Feb. 4
1933	143.0	11.31	198,000	722,000	June 18	47,200	Feb. 14
1934	153.1	12.11	211,500	453,000	May 3	86,400	Sept. 30
1935	123.2	9.76	170,200	476,000	June 10	61,600	Jan. 22
1936	115.4	9.13	158,900	529,000	May 17	45,100	Feb. 11
1937	93.2	7.37	128,700	376,000	June 24	36,000	Jan. 12
1938	137.7	10.90	190,200	605,000	May 31	66,700	Oct. 20
1939	108.4	8.58	149,700	387,000	May 21	61,000	Dec. 31
1940	107.8	8.53	148,500	369,000	June 5	61,700	Feb. 2
1941	94.1	7.45	130,000	272,000	June 10	68,700	Jan. 16
1942	129.3	10.21	178,600	428,000	June 18	82,000	Mar. 4
1943	150.1	11.88	207,300	541,000	June 21	76,400	Jan. 23
1944	86.8	6.87	119,600	326,000	June 19	62,700	Feb. 22
1945	109.2	8.65	150,800	505,000	June 8	68,200	Dec. 18
1946	142.0	11.23	196,100	581,000	May 30	71,900	Oct. 17
Average	140.5	11.12	193,900	582,000		65,400	
Maximum	225.0	17.77	311,000	1,160,000	1894	103,000	1900
Minimum	85.5	6.77	118,000	269,000	1926	36,000	1937

[1] Water year begins on Oct. 1, and ends on Sept. 30.

[2] The studies shown on this table were completed prior to the 1948 flood in Columbia River; therefore, the published value of maximum discharge, 1,160,000 second-feet, has been used. Data obtained during 1948 flood indicate that this discharge should be revised to 1,230,000 second-feet.

NOTE.—The Columbia River discharge and run-off data for the years 1879-1939 were obtained from Water Supply Paper No. 884, p. 185 and for the years 1940-46 from the yearly Water Supply Papers, pt. 4, published by the U. S. Geological Survey.

TABLE 3.—*Mean monthly discharges in second-feet, Columbia River at John Day Dam site, Oregon*

[Drainage area=226,000 square miles]

Water year	Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified	
		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate
	October			November			December			January			February			March		
1928	151,010	149,770	148,470	194,700	191,120	184,750	177,630	170,120	167,220	142,890	144,630	144,060	114,420	119,380	122,680	154,970	167,570	164,160
1929	82,940	80,880	78,080	74,750	73,820	70,950	60,690	60,500	57,660	53,940	57,220	56,220	53,130	60,340	61,650	80,590	88,840	85,880
1930	65,520	65,780	65,110	58,460	60,910	57,090	57,680	61,080	56,760	44,140	46,160	41,860	76,290	82,270	79,670	70,250	77,020	76,900
1931	72,810	73,300	72,790	60,120	61,700	59,430	55,190	55,770	52,180	50,640	53,820	50,660	52,590	56,230	54,290	71,490	80,310	78,190
1932	67,190	69,290	69,260	62,000	68,400	67,360	55,120	59,180	57,330	60,210	60,590	57,840	54,610	59,280	55,600	151,490	157,530	148,310
1933	75,030	75,820	75,620	88,250	93,770	92,400	90,030	88,300	85,940	85,430	84,770	81,740	65,490	66,610	63,560	89,680	97,250	94,730
1934	99,240	107,020	106,540	141,610	145,310	144,120	184,620	197,360	194,920	207,800	199,290	195,490	150,680	145,870	142,540	150,690	133,270	130,120
1935	70,510	74,280	74,840	93,170	100,490	99,990	87,560	85,320	83,720	80,340	84,170	81,760	100,400	101,700	99,230	92,320	96,570	92,830
1936	73,240	74,360	74,650	60,430	65,440	64,770	52,320	56,660	55,170	57,600	60,750	58,070	50,430	53,540	50,270	84,730	91,270	88,430
1937	65,290	67,290	67,270	53,690	60,010	59,200	47,820	54,040	52,400	37,970	42,780	40,270	46,640	51,430	48,910	64,140	66,690	63,480
1938	68,830	73,830	73,700	87,880	93,290	92,160	92,400	90,630	87,260	89,410	90,590	87,270	80,030	80,090	76,450	125,230	131,290	125,540
1939	87,810	88,640	87,690	70,740	73,770	72,300	64,190	65,300	62,820	63,380	64,820	58,360	61,300	61,490	60,490	101,300	107,950	104,520
1940	73,050	76,460	76,170	82,090	83,580	82,590	76,870	78,140	76,070	68,740	68,500	65,550	82,680	83,030	79,850	131,190	134,770	129,320
1941	93,670	94,940	94,240	90,460	91,910	90,150	77,130	77,560	74,830	76,020	74,440	71,260	77,670	75,550	72,480	100,540	102,330	98,100
1942	118,740	119,610	118,520	114,710	115,740	113,110	148,880	145,000	140,650	106,630	93,460	89,940	105,670	100,030	98,680	92,230	91,290	89,060
Minimum	65,290	65,780	65,110	53,690	60,010	57,090	47,820	54,040	52,180	37,970	42,780	40,270	46,640	51,430	48,910	64,140	66,690	63,480
Maximum	151,010	149,770	148,470	194,700	191,120	184,750	184,620	197,360	194,920	207,800	199,290	195,490	150,680	145,870	142,540	154,970	167,570	164,160
Average	84,330	86,090	85,530	88,870	91,950	90,030	88,540	89,660	87,000	81,680	81,730	78,690	78,140	79,790	77,760	104,060	108,260	104,640
	April			May			June			July			August			September		
1928	196,660	193,700	188,610	488,820	504,390	497,720	499,350	449,140	443,350	309,780	276,640	276,120	168,950	143,130	143,720	99,900	85,700	86,740
1929	99,590	93,600	83,220	209,480	207,980	199,790	379,190	347,730	343,140	215,900	181,210	181,120	133,280	113,360	114,030	90,670	80,390	81,290
1930	142,310	141,460	135,330	243,890	224,930	218,380	293,100	264,050	261,780	227,280	199,190	199,560	145,400	127,770	128,180	97,360	87,720	89,000
1931	126,820	125,870	119,550	241,560	229,780	224,450	269,180	235,420	235,120	192,430	166,180	167,010	123,570	107,030	108,000	96,100	88,880	90,670
1932	230,110	220,080	207,550	435,770	425,010	412,040	475,120	440,160	432,660	303,910	263,100	262,750	161,250	139,980	140,500	109,310	96,470	97,570
1933	145,830	146,130	137,530	305,200	305,050	297,670	613,310	593,890	584,800	418,330	373,980	374,620	208,000	182,440	182,960	127,070	114,710	115,870
1934	291,140	305,560	298,170	418,760	399,500	395,010	375,960	330,540	329,880	213,130	183,420	183,880	144,590	126,560	127,830	99,230	90,080	92,130
1935	137,270	133,140	124,980	283,250	288,590	281,060	435,080	402,190	398,570	308,090	273,540	273,820	184,140	162,360	163,120	108,190	96,590	98,180
1936	193,360	190,530	176,040	425,080	410,080	394,990	409,650	358,880	351,530	208,710	178,500	178,700	133,510	115,450	115,950	93,900	87,140	88,220
1937	110,030	103,550	92,540	237,680	219,880	210,730	343,370	314,790	312,090	241,910	208,530	208,600	138,450	118,950	119,490	93,810	86,520	87,950
1938	217,940	207,680	190,570	388,440	376,170	359,000	508,410	468,860	460,130	307,400	270,660	266,620	136,690	119,590	119,990	100,030	90,200	91,180
1939	178,790	173,750	166,450	343,040	335,920	328,870	302,570	267,160	265,700	229,640	205,550	205,430	139,490	129,600	130,190	95,540	88,390	89,810
1940	203,600	189,120	177,480	300,460	285,730	279,100	308,380	277,100	274,480	201,750	182,600	182,760	124,420	116,440	116,890	103,850	98,010	98,990

TABLE 3.—*Mean monthly discharges in second-feet, Columbia River at John Day Dam site, Oregon*—Continued

[Drainage area=226,000 square miles]

Water year	Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified	
		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate
	April			May			June			July			August			September		
1941	149,350	139,080	131,240	236,470	219,000	211,750	280,050	253,400	249,120	175,600	156,390	155,930	121,650	117,610	117,960	119,190	113,900	114,500
1942	196,800	194,650	182,270	275,930	268,540	259,900	418,240	394,620	389,670	282,500	259,660	258,660	159,710	147,420	147,530	97,650	92,810	93,440
Minimum	99,590	93,600	83,220	209,480	207,980	199,790	269,180	235,420	235,120	175,600	156,390	155,930	121,650	107,030	108,000	90,670	80,390	81,290
Maximum	221,140	305,560	298,170	488,820	504,390	497,720	613,310	593,890	584,800	418,330	373,980	374,620	208,600	182,440	182,960	127,070	114,710	115,870
Average	174,640	170,530	160,770	322,260	313,370	304,700	394,060	359,860	355,470	255,760	225,280	225,040	148,210	131,180	131,760	102,120	93,170	94,370

NOTE.—(1) Observed discharges are those recorded for Columbia River near The Dalles by the U. S. Geological Survey, less inflow between The Dalles and John Day dam site, corrected for change in storage in Grand Coulee Reservoir. (2) Modified discharges are observed discharges corrected by initial and ultimate irrigation requirements for which data were obtained from the U. S. Bureau of Reclamation. (3) The initial irrigation requirements are the net depletions which are anticipated for the year 1960 when, it is assumed, half of the remaining potential irrigable lands in Snake River and lower Columbia River Basins and all in upper Columbia River Basin will have been developed.

TABLE 4.—*Mean monthly discharges in second-feet, Columbia River near The Dalles, Oreg.*

[Drainage area=237,000 square miles]

Water year	Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified	
		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate
	October			November			December			January			February			March		
1928	156,000	154,960	153,850	201,000	197,310	190,830	184,000	176,050	172,730	150,000	151,020	149,720	121,000	125,160	127,660	164,000	176,360	172,710
1929	87,200	85,340	82,730	79,700	78,660	75,680	65,600	64,980	61,700	58,800	61,360	59,640	58,100	64,480	64,960	86,600	94,610	91,420
1930	69,400	69,860	69,380	62,700	65,040	61,110	62,900	65,870	61,120	48,700	50,000	44,980	83,200	88,350	84,930	75,600	82,140	81,770
1931	76,500	77,180	76,870	64,400	65,870	63,490	59,400	59,550	55,530	54,900	57,360	53,470	56,900	59,710	56,940	76,200	84,790	82,430
1932	70,700	73,000	73,160	66,000	72,290	71,140	59,300	62,920	60,650	64,800	64,460	60,980	59,500	63,370	58,890	159,000	164,800	155,350
1933	78,800	79,790	79,780	93,200	98,610	97,130	95,000	92,840	90,040	90,500	89,120	85,360	70,200	70,490	66,610	94,700	102,040	99,280
1934	103,200	111,170	110,890	146,400	149,990	148,690	191,300	203,610	200,740	214,900	205,660	201,150	156,200	150,570	146,400	156,100	138,450	135,060

1935	74,480	78,440	79,200	97,960	105,170	104,560	93,170	90,500	97,870	85,800	88,910	85,770	105,800	106,270	102,980	97,650	101,670	97,690
1936	77,080	78,390	78,880	64,870	69,770	68,990	56,830	60,740	58,820	63,550	65,970	62,580	55,890	58,200	54,120	91,100	97,400	94,330
1937	70,130	72,330	72,500	57,830	64,040	63,120	52,350	58,170	56,100	42,430	46,510	43,280	51,420	55,380	52,030	69,820	72,130	68,690
1938	72,820	78,020	78,080	92,810	98,110	96,870	99,040	96,840	93,030	96,310	96,770	92,720	87,090	86,320	81,850	134,900	140,730	134,740
1939	92,110	93,130	92,620	75,710	78,630	77,050	69,290	69,970	67,050	68,270	66,100	61,800	66,360	65,720	63,890	107,630	114,050	110,380
1940	76,820	80,420	80,330	86,120	87,500	86,400	81,410	82,250	79,750	73,490	72,520	68,860	88,740	88,290	84,310	138,600	141,950	136,260
1941	97,450	98,920	98,410	94,660	96,000	94,140	81,670	81,670	78,510	80,810	78,500	74,600	82,640	79,690	75,790	106,220	107,780	103,310
1942	122,420	123,490	122,590	119,020	119,940	117,200	154,220	149,910	145,120	111,600	97,700	93,460	112,440	105,970	103,790	100,860	99,680	97,220
Minimum	69,400	69,860	69,380	62,700	64,040	61,110	52,380	58,170	55,530	42,430	46,510	43,280	51,420	55,380	52,030	69,820	72,130	68,690
Maximum	156,000	154,960	153,850	201,000	197,310	190,830	191,300	203,610	200,740	214,900	205,660	201,150	156,200	150,570	146,400	164,000	176,360	172,710
Average	88,340	90,300	89,950	93,490	96,460	94,430	93,700	94,390	91,920	86,990	86,130	82,560	83,700	84,530	81,680	110,600	114,570	110,710

	April			May			June			July			August			September		
1928	204,000	202,150	195,110	495,000	512,070	503,490	504,000	453,840	448,100	314,000	280,910	280,430	173,000	147,290	148,000	104,000	90,100	91,420
1929	105,000	98,590	87,790	215,000	213,300	204,900	384,000	352,590	348,050	220,000	185,360	185,320	137,000	117,200	117,980	94,400	84,410	85,600
1930	147,000	145,730	139,180	248,000	228,830	222,090	297,000	268,000	265,780	231,000	202,960	203,380	149,000	131,490	132,010	101,000	91,660	93,230
1931	133,000	131,620	124,880	246,000	234,020	228,480	273,000	239,290	239,040	196,000	169,790	170,680	127,000	110,570	111,660	99,500	92,580	94,660
1932	237,000	226,540	213,590	442,000	431,040	417,860	480,000	445,090	437,640	308,000	267,240	266,940	165,000	143,850	144,480	113,000	100,460	101,850
1933	152,000	151,880	142,860	311,000	310,640	303,070	620,000	600,630	591,590	423,000	378,700	378,390	212,000	186,550	187,190	131,000	118,930	120,390
1934	295,900	309,900	302,090	422,900	403,440	398,750	379,900	334,530	333,920	216,900	187,240	187,740	148,300	130,380	131,770	102,900	94,050	96,390
1935	143,600	139,050	130,460	289,100	294,240	286,500	440,000	407,160	403,590	312,300	277,800	278,130	188,000	166,330	167,210	112,000	100,690	102,580
1936	201,300	198,050	183,140	431,400	416,190	400,900	414,600	363,880	356,580	212,900	182,740	182,970	137,500	119,550	120,170	97,870	91,400	92,770
1937	117,600	110,700	99,270	244,000	225,990	216,650	348,900	320,370	317,720	246,200	212,860	212,990	142,300	122,920	123,570	97,670	90,680	92,400
1938	228,600	217,920	200,390	395,810	383,340	365,960	513,600	474,100	465,420	311,660	274,970	270,970	140,720	123,730	124,250	104,110	94,570	95,850
1939	184,530	179,070	171,350	347,720	340,400	333,150	305,660	270,300	268,890	233,480	209,440	209,370	143,210	138,430	134,140	99,290	92,430	94,150
1940	210,020	195,120	183,060	304,850	289,920	283,080	312,220	280,990	278,420	205,440	186,340	186,550	127,990	120,130	120,690	107,530	101,980	103,260
1941	154,050	143,360	135,100	240,750	223,070	215,630	283,900	257,300	253,070	179,200	160,040	159,630	125,220	121,290	121,760	122,870	117,870	118,770
1942	203,470	200,900	188,100	280,800	273,200	264,370	422,600	399,030	394,140	286,300	263,500	262,560	163,300	151,130	151,350	101,250	96,710	97,630
Minimum	105,000	98,590	87,790	215,000	213,300	204,900	273,000	239,290	239,040	179,200	160,040	159,630	125,220	110,570	111,660	94,400	84,410	85,600
Maximum	295,900	309,900	302,890	495,000	512,070	503,490	620,000	600,630	591,590	423,000	378,700	378,390	212,000	186,550	187,190	131,000	118,930	120,390
Average	181,140	176,710	166,480	327,620	318,650	309,660	398,630	364,470	360,130	259,760	229,330	229,070	151,970	135,060	135,750	105,890	97,240	98,660

NOTE.—(1) Observed discharges are those recorded for Columbia River near The Dalles by the U. S. Geological Survey corrected for change in storage at Grand Coulee Reservoir. (2) Modified discharges are observed discharges corrected by initial and ultimate irrigation requirements for which data were obtained from U. S. Bureau of Reclamation (3) The initial irrigation requirements are the net depletions which are anticipated for the year 1960 when, it is assumed, half of the remaining potential irrigable lands in Snake River and lower Columbia River Basins and all in upper Columbia River Basin will have been developed.

TABLE 5.—*Mean monthly discharges in second-feet, Columbia River at McNary dam site, Oregon*

[Drainage area—213,500 square miles]

Water year	Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified	
		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate
	October			November			December			January			February			March		
1928	149,530	147,430	145,270	190,400	186,810	180,430	173,880	166,930	164,590	135,600	137,730	137,550	110,040	115,020	118,340	145,920	158,630	155,320
1929	82,640	79,520	75,650	74,100	72,320	68,620	60,120	59,560	56,340	53,370	56,550	55,450	52,250	59,570	60,990	75,040	84,880	83,510
1930	65,210	64,370	62,600	58,010	59,550	54,820	56,950	60,050	55,430	43,630	45,560	41,160	72,520	79,370	77,650	67,220	74,780	75,440
1931	72,550	71,950	70,350	59,770	60,460	57,300	54,750	54,910	50,890	49,610	52,760	49,560	51,630	55,410	53,600	68,660	78,340	77,070
1932	67,090	68,050	66,870	61,800	67,280	65,330	54,120	57,790	55,570	59,380	59,870	57,220	52,220	57,490	54,410	139,010	148,870	143,470
1933	74,840	74,510	73,190	87,540	92,210	89,990	89,450	87,300	84,510	84,310	83,560	80,440	64,480	65,660	62,670	86,220	94,840	93,370
1934	98,980	105,660	104,080	141,100	143,950	141,910	182,640	195,190	192,550	204,640	196,500	193,080	149,060	144,670	141,750	148,200	131,530	129,120
1935	79,390	73,010	72,420	92,810	99,240	97,870	86,290	83,730	81,800	79,270	83,080	80,650	98,980	100,590	98,430	90,940	95,780	92,625
1936	73,140	73,100	72,240	60,060	64,150	62,550	51,920	55,820	53,890	56,220	59,400	56,760	48,840	52,330	49,440	80,190	88,050	86,530
1937	66,210	67,060	65,880	53,390	58,760	57,020	47,460	53,240	51,160	37,570	42,200	39,530	45,720	50,610	48,190	60,140	64,220	62,560
1938	68,550	72,460	71,250	87,170	91,780	89,850	89,800	88,450	85,500	87,470	89,060	86,140	77,260	78,240	75,520	118,190	126,550	123,080
1939	87,580	87,320	85,520	70,120	72,320	70,040	63,330	64,130	61,320	62,530	61,040	57,430	61,190	61,520	60,670	93,570	102,740	101,820
1940	72,930	75,200	73,780	81,640	82,220	80,310	76,360	77,240	74,780	67,900	67,670	64,750	78,500	79,910	77,790	123,800	129,880	126,920
1941	93,370	93,590	91,850	89,530	90,220	87,700	74,760	75,350	72,780	73,980	72,820	70,060	75,970	74,430	71,950	96,750	100,190	97,610
1942	117,760	117,730	115,730	112,200	112,950	110,030	144,420	141,400	137,890	103,560	90,580	87,260	100,160	94,450	93,030	88,440	87,600	85,480
Minimum	65,210	64,370	62,600	53,390	58,760	54,820	47,460	53,240	50,890	37,570	42,200	39,530	45,720	50,610	48,190	60,140	64,220	62,560
Maximum	149,530	147,430	145,270	190,400	186,810	180,430	182,640	195,190	192,550	204,640	196,500	193,080	149,060	144,670	141,750	148,200	158,630	155,320
Average	84,050	84,730	83,110	87,980	90,280	87,590	87,080	88,070	85,270	79,940	79,890	77,140	75,920	77,950	76,300	98,820	104,460	102,260

	April			May			June			July			August			September		
1928	185,960	183,810	179,530	482,250	498,360	488,820	497,950	447,560	441,600	309,310	275,430	274,170	168,800	141,890	141,410	99,710	84,350	84,230
1929	94,280	90,220	81,780	204,080	203,560	196,340	376,880	345,680	341,350	215,490	180,040	179,180	133,160	112,150	111,710	90,510	79,040	78,760
1930	139,940	140,060	134,910	242,620	223,810	217,420	292,270	262,770	260,050	227,100	198,140	197,620	145,270	126,540	125,840	97,270	86,440	86,520
1931	120,000	120,950	116,540	239,650	228,340	223,470	268,660	234,290	233,390	192,290	165,150	165,100	123,530	105,860	105,700	96,050	87,620	88,200
1932	218,020	211,610	202,700	427,150	416,940	404,510	473,130	438,300	430,920	303,550	261,950	260,810	161,140	138,780	138,200	109,220	95,200	95,100
1933	138,490	141,210	135,030	296,310	297,150	290,770	608,750	589,656	580,899	417,750	372,732	371,710	207,860	181,220	180,660	126,860	113,320	113,310
1934	289,690	304,760	298,020	418,210	398,760	394,070	375,310	329,360	328,170	212,930	182,370	181,970	144,530	125,380	125,520	99,170	88,810	89,651
1935	131,900	129,610	123,270	280,350	286,590	279,950	433,980	400,800	396,880	307,790	272,420	271,890	184,060	161,170	160,820	108,340	95,530	95,910
1936	185,340	185,200	173,400	421,500	407,670	393,750	408,640	357,530	349,830	208,500	177,440	176,760	133,460	114,270	113,660	93,830	85,880	85,760
1937	102,010	98,480	90,420	231,900	216,200	209,150	341,420	312,920	310,310	241,480	207,350	206,670	138,320	117,720	117,160	93,670	85,200	85,440
1938	207,940	198,490	182,180	383,150	371,420	354,800	506,360	466,970	458,400	306,910	269,440	264,680	136,540	118,350	117,680	99,910	88,900	88,710
1939	172,540	168,450	162,100	340,430	333,860	327,350	300,720	264,880	263,000	229,370	204,431	203,470	139,440	128,425	127,900	95,480	87,128	87,350
1940	196,810	184,180	174,390	298,150	283,970	277,880	307,710	275,910	272,770	201,600	181,560	180,820	124,350	115,260	114,590	103,700	96,700	96,520
1941	146,580	137,530	130,900	232,790	215,860	209,160	276,640	250,320	246,370	174,870	155,080	154,050	121,270	116,250	115,610	118,570	112,320	111,970
1942	186,640	185,300	173,730	268,370	261,520	253,430	414,320	391,030	386,410	281,210	257,930	256,500	159,420	146,120	145,210	97,380	91,410	90,900
Minimum	94,280	90,220	81,780	204,080	203,560	196,340	268,660	234,290	233,390	174,870	155,080	154,050	121,270	105,860	105,700	90,510	79,040	78,760
Maximum	289,690	304,760	298,020	482,250	498,360	488,820	608,750	589,656	580,899	417,750	372,732	371,710	207,860	181,220	180,660	126,860	113,320	113,310
Average	167,740	165,330	157,260	317,800	309,600	301,390	392,180	357,870	353,360	255,350	224,100	223,030	148,080	129,960	129,450	101,980	91,860	91,890

NOTES: (1) Observed discharges are those recorded for Columbia River near The Dalles by the U. S. Geological Survey, less inflow between The Dalles and McNary dam site, corrected for change in storage in Grand Coulee Reservoir. (2) Modified discharges are observed discharges corrected by initial and ultimate irrigation requirements for which data were obtained from the U. S. Bureau of Reclamation. (3) The initial irrigation requirements are the net depletions which are anticipated for the year 1960 when, it is assumed, half of the remaining potential irrigable lands in Snake River and lower Columbia River Basins and all in upper Columbia River Basin will have been developed.

TABLE 6.—*Mean monthly discharges in second-feet, Columbia River at Bonneville, Oreg.*

[Drainage area = 240,000 square miles]

Water year	October			November			December			January			February			March		
	Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified	
		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate
1928	161,350	160,040	158,670	213,000	208,910	202,040	191,150	182,900	179,260	157,450	158,150	156,540	125,900	129,810	132,060	175,500	187,380	183,260
1929	90,300	88,240	85,420	83,150	81,890	78,690	68,900	68,080	64,610	62,100	64,470	62,570	61,700	67,930	68,260	92,600	100,400	96,990
1930	71,650	71,980	71,370	64,850	67,050	62,970	66,550	69,330	64,390	51,300	52,440	47,250	92,860	97,660	93,890	81,130	87,350	86,670
1931	78,760	79,320	78,880	66,820	68,170	65,660	61,660	61,660	57,490	58,200	60,470	56,400	60,250	62,870	59,910	81,800	90,170	87,590
1932	73,050	75,230	75,280	69,170	75,320	74,020	62,250	65,730	63,310	70,400	69,890	66,240	66,060	69,710	65,020	171,020	176,380	166,490
1933	81,480	82,310	82,150	99,330	104,330	102,440	100,440	98,000	94,930	97,160	95,530	91,540	75,100	75,200	71,130	102,560	109,690	106,740
1934	107,430	115,140	114,590	151,000	154,300	152,720	216,350	227,560	223,570	232,750	222,600	217,170	165,120	158,860	154,080	165,630	147,240	143,110
1935	78,430	82,140	82,650	105,430	112,160	111,070	101,620	98,610	96,230	94,370	97,140	93,670	113,520	113,640	110,000	104,650	108,360	104,070
1936	79,640	80,800	81,150	67,560	72,310	71,380	60,050	63,800	61,730	73,590	75,830	72,260	60,100	62,250	58,020	99,100	105,190	101,910
1937	72,440	74,500	74,530	59,980	66,060	65,020	55,960	61,580	59,340	44,990	48,900	45,500	55,200	59,020	55,530	77,410	79,540	75,920
1938	75,290	80,330	80,230	100,040	105,060	103,540	110,770	108,230	104,090	108,650	108,690	104,230	94,300	93,260	88,520	147,450	152,950	146,640
1939	94,880	95,730	95,050	79,200	81,930	80,170	74,030	74,480	71,320	73,300	70,920	66,420	72,260	71,430	69,420	113,960	120,210	116,370
1940	78,950	82,430	82,220	88,190	89,440	88,220	86,510	87,090	84,340	77,570	76,370	72,480	99,860	99,110	94,820	149,670	152,540	146,370
1941	99,810	101,130	100,470	98,060	99,230	97,190	86,310	86,080	82,710	86,500	84,000	79,900	88,010	84,860	80,750	111,470	112,680	107,870
1942	125,040	125,960	124,910	122,790	123,520	120,590	163,870	159,090	153,830	115,680	101,550	97,070	120,630	113,950	111,560	103,310	101,900	99,200
Minimum	71,650	71,980	71,370	59,980	66,060	62,970	55,960	61,580	57,490	44,990	48,900	45,500	55,200	59,020	55,530	77,410	79,540	75,920
Maximum	161,350	160,040	158,670	213,000	208,910	202,040	216,350	227,560	223,570	232,750	222,600	217,170	165,120	158,860	154,080	175,500	187,380	183,260
Average	91,230	93,020	92,500	97,900	100,650	98,380	100,430	100,820	97,370	93,600	92,460	88,620	90,060	90,640	87,530	118,490	122,130	117,950

	April			May			June			July			August			September		
1928	214,350	210,480	204,470	503,950	518,610	507,610	508,850	458,100	451,780	320,350	286,860	285,990	175,550	149,570	150,010	107,000	92,890	94,020
1929	111,000	104,270	93,150	223,480	220,980	211,790	390,700	358,620	353,420	223,800	188,820	188,440	139,700	119,680	120,240	96,750	86,590	87,620
1930	153,700	151,820	144,670	253,200	233,550	226,330	299,070	269,740	267,200	233,800	205,530	205,710	151,250	133,570	133,930	103,060	93,580	95,020
1931	142,060	140,200	132,970	252,860	240,210	234,010	276,950	242,930	242,370	198,550	172,140	172,820	129,080	112,500	113,430	101,480	94,430	96,390
1932	246,400	235,310	221,720	451,780	439,830	425,660	486,000	450,350	443,160	312,280	271,150	270,470	167,960	146,600	147,030	115,500	102,790	104,020
1933	162,000	161,370	151,830	321,350	320,130	311,690	632,680	612,070	601,800	429,500	384,660	383,820	215,750	190,020	190,370	134,300	122,020	123,250
1934	304,600	317,740	309,080	428,580	408,580	403,350	384,800	339,070	338,100	220,360	190,420	190,640	151,420	133,290	134,450	105,760	96,720	98,880
1935	151,320	146,340	137,320	298,500	302,730	294,090	447,430	413,860	409,560	316,730	281,860	281,820	191,300	169,410	170,060	114,850	103,380	105,110
1936	210,340	206,460	190,920	441,320	425,070	408,740	421,540	370,160	362,190	216,550	186,060	185,950	140,220	122,070	122,480	100,360	93,730	94,930
1937	128,250	120,940	109,100	253,400	234,570	224,400	357,630	328,260	324,770	250,550	216,780	216,470	144,960	125,360	125,800	100,110	92,930	94,470
1938	241,090	229,620	211,300	407,030	393,180	374,440	521,210	480,780	471,180	316,030	278,920	274,500	143,860	126,620	126,890	106,920	97,180	98,260
1939	191,030	184,970	176,650	356,630	348,550	340,540	309,520	273,760	271,960	236,320	212,030	211,710	145,430	135,490	136,030	101,400	94,400	95,980
1940	218,360	202,720	189,930	311,610	295,950	288,390	315,910	284,320	281,380	208,070	188,750	188,750	130,220	122,200	122,600	109,770	104,070	105,190
1941	159,260	148,010	139,200	245,710	227,550	219,610	287,070	260,200	255,710	181,580	162,210	161,600	127,250	123,180	123,490	125,360	120,210	120,960
1942	209,890	206,700	193,270	286,670	278,410	268,900	427,270	403,260	397,920	289,270	266,220	265,020	165,580	153,240	153,290	103,190	98,520	99,330
Minimum	111,000	104,270	93,150	223,480	220,980	211,790	276,950	242,930	242,370	181,580	162,210	161,600	127,250	112,500	113,430	96,750	86,590	87,620
Maximum	304,600	317,740	309,080	503,950	518,610	507,610	632,680	612,070	601,800	429,500	384,660	383,820	215,750	190,020	190,370	134,300	122,020	123,250
Average	189,580	184,460	173,710	335,740	325,860	315,970	404,440	369,700	364,830	263,580	232,830	232,250	154,640	137,520	138,010	108,390	99,560	100,900

NOTES.—(1) Observed discharges are those recorded for Columbia River near The Dalles by the U. S. Geological Survey, plus inflow between The Dalles and Bonneville, corrected for change in storage in Grand Coulee Reservoir. (2) Modified discharges are observed discharges corrected by initial and ultimate irrigation requirements for which data were obtained from the U. S. Bureau of Reclamation. (3) The initial irrigation requirements are the net depletions which are anticipated for the year 1960 when, it is assumed, half of the remaining potential irrigable lands in Snake River and lower Columbia River Basins and all in upper Columbia River Basin will have been developed.

TABLE 7.—*Mean monthly discharge in second-feet, Columbia River at Arlington Dam site, Oregon*

[Drainage area=217,500 square miles]

Water year	Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified		Observed	Modified	
		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate		Initial	Ultimate
	October			November			December			January			February			March		
1928	150,010	148,610	147,150	191,700	188,700	182,910	174,750	168,080	166,030	137,510	139,720	139,620	111,060	115,990	119,260	147,630	160,220	156,790
1929	82,670	80,250	77,080	74,270	73,080	69,970	60,250	59,970	57,040	53,490	56,760	55,740	52,490	59,750	61,120	76,450	86,170	84,680
1930	65,290	65,150	64,080	58,150	60,280	56,140	57,080	60,460	56,130	43,720	45,730	41,410	73,530	80,330	78,550	68,110	75,550	76,090
1931	72,590	72,690	71,790	59,830	61,110	58,530	54,850	55,300	51,560	49,920	53,150	50,040	51,880	55,610	53,750	69,370	78,930	77,540
1932	67,100	68,760	68,280	61,840	67,910	66,550	54,500	58,450	56,520	59,420	59,990	57,420	52,760	57,980	54,850	141,830	151,570	146,050
1933	74,880	75,250	74,630	87,750	93,010	91,380	89,630	87,760	85,260	84,740	84,070	81,030	64,850	65,970	62,930	87,060	95,560	93,970
1934	99,030	106,410	105,530	141,200	144,640	143,190	183,360	196,200	193,840	205,700	197,640	194,310	149,370	144,930	141,950	148,830	132,030	129,500
1935	70,410	73,730	73,840	92,860	99,880	99,100	86,760	84,480	82,840	79,580	83,470	81,120	99,300	100,850	98,640	91,130	95,850	92,570
1936	73,160	73,820	73,650	60,170	64,840	63,830	52,020	56,200	54,560	56,660	59,920	57,360	49,180	52,620	49,670	81,350	89,090	87,440
1937	66,220	67,770	67,280	53,470	59,430	58,280	47,540	53,600	51,810	37,670	42,380	39,790	45,990	50,830	48,360	60,740	64,700	62,920
1938	68,600	73,210	72,700	87,330	92,530	91,180	90,170	89,100	86,440	87,800	89,470	86,630	77,650	78,580	75,810	119,300	127,540	123,940
1939	87,600	88,040	86,930	70,260	73,050	71,360	63,550	64,640	62,110	62,750	61,340	57,810	61,520	61,800	60,890	95,180	104,230	103,190
1940	72,950	75,920	75,200	81,780	82,950	81,630	76,470	77,640	75,460	68,050	67,900	65,060	79,540	80,900	78,720	125,230	131,190	128,110
1941	93,380	94,300	93,260	89,770	91,050	89,120	75,290	76,170	73,880	74,350	73,270	70,590	76,140	74,540	72,010	97,090	100,410	97,710
1942	118,000	118,670	117,370	112,800	114,140	111,810	145,200	142,470	139,240	104,160	91,260	88,020	101,100	95,340	93,860	89,190	88,230	85,990
Minimum	65,290	65,150	64,080	53,470	59,430	56,140	47,540	53,600	51,560	37,670	42,380	39,790	45,990	50,830	48,360	60,740	64,700	62,920
Maximum	150,010	148,610	147,150	191,700	188,700	182,910	183,360	196,200	193,840	205,700	197,640	194,310	149,370	144,930	141,950	148,830	160,220	156,790
Average	84,130	85,510	84,580	88,210	91,110	89,000	87,430	88,700	86,180	80,370	80,400	77,730	76,420	78,400	76,690	99,900	105,420	103,100

	April			May			June			July			August			September		
1928	188,370	186,150	181,800	482,590	499,050	489,860	498,000	448,190	442,810	309,340	276,100	275,480	168,820	142,640	142,880	99,750	85,150	85,800
1929	95,100	90,970	82,470	204,500	204,330	197,460	376,940	346,320	342,570	215,520	180,710	180,490	133,180	112,900	113,180	90,560	79,860	80,340
1930	140,180	140,230	135,010	242,640	224,180	218,140	292,310	263,390	261,250	227,120	198,810	198,930	145,310	127,300	127,330	97,290	87,230	88,070
1931	121,710	122,590	118,120	239,680	228,720	224,200	268,690	234,900	234,580	192,300	165,810	166,400	123,540	106,600	107,160	96,060	88,400	89,740
1932	220,520	214,040	205,070	428,190	418,330	406,250	473,160	438,910	432,110	303,570	262,610	262,110	161,160	139,520	139,660	109,240	95,990	96,650
1933	139,920	142,570	136,330	297,950	299,140	293,110	609,020	590,510	582,330	417,760	373,380	373,010	207,880	181,960	182,120	126,930	114,160	114,910
9134	289,780	304,780	297,970	418,220	399,120	394,780	375,320	329,950	329,340	212,940	183,020	183,260	144,540	126,120	126,980	99,190	89,590	91,200
1935	132,870	130,520	124,110	280,460	287,050	280,760	433,990	401,390	398,050	307,810	273,080	273,190	184,080	161,910	162,280	108,350	96,310	97,450
1936	186,850	186,650	174,780	421,680	408,200	394,630	408,650	358,120	351,000	208,510	178,100	178,060	133,470	115,000	115,120	93,840	86,660	87,300
1937	103,220	99,620	91,490	232,280	216,930	210,230	341,470	313,550	311,520	241,490	208,000	207,970	138,350	118,470	118,630	93,710	86,000	87,010
1938	209,120	199,600	183,230	383,250	371,870	355,600	506,390	467,580	459,590	306,940	270,110	265,970	136,560	119,090	119,140	99,930	89,690	90,260
1939	173,230	169,080	162,660	340,480	334,260	328,100	300,740	265,480	264,180	229,410	205,110	204,790	139,450	129,170	129,360	95,490	87,910	88,890
1940	197,590	184,890	175,030	298,170	284,340	278,600	307,730	276,510	273,950	201,620	183,230	182,130	124,360	116,000	116,050	103,720	97,480	98,070
1941	146,590	137,480	130,780	232,830	216,250	209,900	276,850	251,110	247,740	174,890	155,740	155,350	121,310	117,010	117,100	118,630	113,140	113,560
1942	187,630	186,230	174,590	269,230	262,730	254,990	414,770	392,060	388,020	281,360	258,720	257,930	159,450	146,870	146,690	97,440	92,230	92,490
Minimum	95,100	90,970	82,470	204,500	204,330	197,460	268,690	234,900	234,580	174,890	155,740	155,350	121,310	106,600	107,160	90,560	85,150	80,340
Maximum	289,780	304,780	297,970	482,590	499,050	489,860	609,020	590,510	582,330	417,760	373,380	373,010	207,880	181,960	182,120	126,930	114,160	114,910
Average	168,850	166,360	158,230	318,140	310,300	302,440	392,270	358,530	354,690	255,370	224,770	224,340	148,100	130,700	130,910	102,010	92,650	93,450

NOTE.—(1) Observed discharges are those recorded for Columbia River near The Dalles by the U. S. Geological Survey, corrected for change in storage in Grand Coulee Reservoir less the inflow between The Dalles and Arlington dam site. (2) Modified discharges are observed discharges corrected by initial and ultimate irrigation requirements for which data were obtained from U. S. Bureau of Reclamation. (3) The initial irrigation requirements are the net depletions which are anticipated for the year 1960 when, it is assumed, half of the remaining potential irrigable lands in Snake River and lower Columbia River Basins and all in upper Columbia River Basin will have been developed.

TABLE 8.—*Active recording precipitation gages*

[Main Columbia River below Yakima River]

Map No.	Station	Elevation, feet	Date established
	OREGON		
115	Arlington Airport	885	November 1940.
116	[illegible]	85	January 1940.
117	[illegible]	400	January 1940.
118	[illegible] Experiment Station	300	August 1941.
119	[illegible]	825	January 1948.
120	[illegible]	39	December 1940.
121	[illegible]	30	January 1940.
122	[illegible]	40	January 1940.
	WASHINGTON		
123	[illegible]	190	January 1940.
124	[illegible]	360	August 1941.

TABLE 9.—*Climatological data*

[Main Columbia River below Yakima River]

Map No.	Station	Elevation, feet	Years of record	Temperature, in degrees Fahrenheit					Precipitation, inches						Snowfall, inches		Growing season, days,	
				Annual mean	Absolute maximum	Absolute minimum	January mean	July mean	Average	Normal [1]	Wettest year	Amount	Driest year	Amount	Years of record	Unmelted average	Years of record	Average
101	Arlington, Oreg	885	37	54.1	114	−25	32.7	75.3	9.0	9.3	1940	13.5	1939	5.0	33	13.2	12	205
102	Astoria, Oreg	231	88	51.2	101	10	40.4	61.0	76.3	76.9	1933	114.0	1884	49.4	59	4.1	28	273
103	Cascade Locks, Oreg	100	68	52.4	107	−9	35.8	68.1	76.2	77.0	1887	100.6	1935	48.8	53	33.4	30	217
104	Cathlamet, Wash.[2]	476	10	------	------	------	------	------	83.8	84.7	1946	105.0	1944	67.0	6	3.9	------	------
105	Clatskanie, Oreg	80	12	51.2	101	9	38.2	63.8	54.0	62.6	1937	76.8	1944	39.2	11	6.3	12	219
106	Hood River Experiment Station, Oreg	300	63	50.3	106	−27	32.8	67.4	31.3	29.8	1893	54.2	1944	15.8	50	48.3	31	183
107	Kennewick, Wash	392	55	53.7	115	−29	31.8	75.8	7.1	7.7	1940	12.2	1898	3.6	49	13.6	37	181
108	Longview, Wash	12	22	51.5	105	−20	38.0	63.8	40.6	40.0	1933	58.0	1929	28.3	22	5.9	14	171
109	Mottinger, Wash	307	46	55.1	115	−24	33.4	76.6	8.6	9.2	1916	14.0	1936	5.5	44	8.7	39	213
110	North Head, Wash	196	60	50.0	97	15	42.1	57.2	51.4	52.8	1933	77.2	1929	30.6	60	4.7	36	297
111	Portland, Oreg	30	76	53.1	107	−2	39.4	66.7	41.6	40.2	1882	67.2	1929	26.1	75	12.5	40	263
112	Prindle, Wash	200	14	50.7	104	7	37.4	67.0	66.8	66.1	1937	88.6	1933	22.0	11	12.8	14	236
113	The Dalles, Oreg	98	88	53.1	115	−30	32.6	72.6	15.5	13.5	1858	43.6	1939	6.4	70	29.4	32	196
114	Umatilla, Oreg	285	59	54.2	117	−23	32.8	76.2	7.9	7.7	1881	11.7	1934	4.1	45	6.6	28	197

[1] Obtained by adjusting data to long period values.
[2] Includes only those records of present location.

TABLE 10.—*Population, 1920–47*

State and county	Percent of 1940 population within sub-basin	Population				Percent increase		
		1920	1930	1940	1947 (estimate)	1920–30	1930–40	1940–47 (estimate)
Washington	4	42,780	57,030	69,230	125,900	33	21	82
Oregon	13	111,210	129,460	140,630	212,450	16	9	51
Total for sub-basin	.....	153,990	186,490	209,860	338,350	21	13	61
COUNTIES WITHIN SUB-BASIN								
Washington:								
Benton	30	3,180	3,040	3,610	12,000	−4	19	232
Clark	68	22,310	27,410	33,960	75,000	23	24	121
Cowlitz	41	4,830	13,080	16,320	22,000	171	25	35
Franklin	63	3,400	3,540	3,970	6,000	4	12	51
Klickitat	29	2,160	2,720	3,310	3,300	26	22	.....
Skamania	47	1,110	1,370	2,170	2,000	23	58	−8
Wahkiakum	100	3,470	3,860	4,290	4,000	11	11	−7
Small areas in Lewis, Pacific, and Walla Walla	.....	2,320	2,010	1,600	1,600	−13	−20	.....
Oregon:								
Clatsop	66	15,200	13,900	16,260	22,900	−9	17	41
Columbia	78	10,900	14,900	16,280	20,600	37	9	26
Hood River	42	4,320	3,670	4,890	6,300	−15	33	29
Multnomah	26	71,730	87,940	93,530	150,000	23	6	60
Wasco	52	6,170	6,230	6,770	9,000	1	8	40
Small areas in Gilliam, Morrow, Sherman, and Umatilla	.....	2,890	2,790	2,900	3,650	−3	4	26

Source: U. S. Census, "Population" 1920, 1930, and 1940; Washington State Census Board; Bonneville Power Administration. Population for parts of counties estimated on basis of these data.

TABLE 11.—*Urban and rural population 1920-47*

State and county	1920		1930				1940				1947 (estimate)			
	Urban	Rural [1]	Urban	Rural			Urban	Rural			Urban	Rural		
				Total	Nonfarm	Farm		Total	Nonfarm	Farm		Total	Nonfarm	Farm
Washington	15,990	26,790	34,140	22,890	12,970	9,920	39,510	29,720	17,850	11,870	86,000	39,900	26,500	13,400
Oregon	93,020	18,190	109,640	19,820	4,430	15,390	116,450	24,180	4,860	19,320	180,000	32,450	12,200	20,250
Total for sub-basin	109,010	44,980	143,780	42,710	17,400	25,310	155,960	53,900	22,710	31,190	266,000	72,350	38,700	33,650
COUNTIES WITHIN SUB-BASIN														
Washington														
Benton	----------	3,180	----------	3,040	1,520	1,520	----------	3,610	1,920	1,690	5,500	6,500	2,800	3,700
Clark	12,630	9,680	20,000	7,410	6,000	1,410	23,220	10,740	9,000	1,740	57,000	18,000	16,000	2,000
Cowlitz	----------	4,830	10,650	2,430	940	1,490	12,380	3,940	1,030	2,910	17,500	4,500	1,500	3,000
Franklin	3,360	40	3,490	50	----------	50	3,910	60	----------	60	6,000	----------	----------	----------
Klickitat	----------	2,160	----------	2,720	1,160	1,560	----------	3,310	1,580	1,730	----------	3,300	1,900	1,400
Skamania	----------	1,110	----------	1,370	400	970	----------	2,170	1,210	960	----------	2,000	1,400	600
Wahkiakum	----------	3,470	----------	3,860	2,200	1,660	----------	4,290	2,450	1,840	----------	4,000	2,300	1,700
Small areas in Lewis, Pacific, and Walla Walla	----------	2,320	----------	2,010	750	1,260	----------	1,600	660	940	----------	1,600	600	1,000
Oregon:														
Clatsop	14,030	1,170	10,350	3,550	----------	3,550	10,390	5,870	----------	5,870	16,900	6,000	----------	6,000
Columbia	----------	10,900	3,990	10,910	2,470	8,440	4,310	11,970	2,330	9,640	6,000	14,600	4,600	10,000
Hood River	3,200	1,120	2,760	910	240	670	3,280	1,610	700	910	4,700	1,600	700	900
Multnomah	69,980	1,750	86,660	1,280	490	790	92,200	1,330	520	810	144,000	6,000	5,000	1,000
Wasco	5,810	360	5,880	380	190	190	6,270	500	220	280	8,400	600	300	300
Small areas in Gilliam, Morrow, Sherman, Umatilla	----------	2,890	----------	2,790	1,040	1,750	----------	2,900	1,090	1,810	----------	3,650	1,600	2,050

[1] Rural farm and nonfarm not separately reported.

Source: U. S. Census, "Population," 1920, 1930, and 1940; Washington State Census Board; and the Bonneville Power Administration. Population for parts of counties and for rural arm and nonfarm, 1947, estimated on basis of these data.

TABLE 12.—*Land use, as of approximately 1940 (in acres)*

State and county	Total land area within sub-basin [1]	Agricultural land				Range			Forest area	Waste and miscellaneous uses [2]
		Total	Irrigated	Non-irrigated	Permanent pasture	Total	Open range	Forest range		
Oregon	841,739	410,653	16,029	371,323	23,301	7,760	7,760	.....	401,590	21,736
Washington	420,373	182,158	13,600	87,732	80,826	.....	.....	.....	227,072	11,143
Total for subbasin	1,262,112	592,811	29,629	459,055	104,127	7,760	7,760	.....	628,662	32,879
COUNTIES WITHIN SUB-BASIN										
Oregon:										
Clatsop	226,391	18,850	20	11,250	7,580	7,581	7,581	.....	199,960	.....
Columbia	230,510	46,520	350	38,650	7,520	.....	.....	.....	183,990	.....
Gilliam	60,000	60,000	.....	60,000	.....	.....	.....	.....	.....	.....
Hood River	1,500	286	.....	143	143	.....	.....	.....	.....	1,214
Morrow	200,200	200,200	3,810	196,390	.....	.....	.....	.....	.....	.....
Multnomah	77,240	41,640	1,440	32,700	7,500	.....	.....	.....	17,640	17,960
Sherman	731	552	92	26	434	179	179	.....	.....	.....
Umatilla	43,267	42,231	10,167	32,064	.....	.....	.....	.....	.....	1,036
Wasco	1,900	374	150	100	124	.....	.....	.....	.....	1,526
Washington:										
Benton	89,980	89,980	11,590	40,100	38,290	.....	.....	.....	.....	.....
Clark	34,473	24,530	500	23,630	400	.....	.....	.....	.....	9,943
Cowlitz	70,690	13,010	280	9,000	3,730	.....	.....	.....	57,680	.....
Franklin	1,000	.....	.....	.....	.....	.....	.....	.....	.....	1,000
Klickitat	7,500	7,500	100	400	7,000	.....	.....	.....	.....	.....
Lewis	3,920	.....	.....	.....	.....	.....	.....	.....	3,920	.....
Pacific	66,100	13,100	30	6,070	7,000	.....	.....	.....	53,000	.....
Skamania	2,700	2,500	1,100	1,000	400	.....	.....	.....	.....	200
Wahkiakum	144,010	31,538	.....	7,532	24,006	.....	.....	.....	112,472	.....

[1] Composed of agricultural land, open range land, forest area, and waste and miscellaneous uses.
[2] Inaccessible wasteland, townsites, etc.

Source: Data derived from statistics of Bureau of Census, U. S. Department of Agriculture, U. S. Department of Interior, and other sources.

TABLE 13.—*Actual value of taxable property, 1920–46*

[In thousands of dollars]

State and county	1920	1925	1930	1935	1940	1946
COUNTIES WITHIN SUB-BASIN [1]						
Washington:						
Benton	1,600	1,500	1,000	600	700	1,200
Clark	27,890	25,170	25,130	22,530	24,205	38,980
Cowlitz	16,370	24,860	31,670	22,200	22,613	30,000
Franklin	10,090	10,020	10,070	7,170	7,529	9,000
Klickitat	1,260	1,270	1,140	920	1,070	1,200
Pacific	2,250	1,980	2,010	1,660	1,440	16,000
Skamania	6,580	6,160	5,710	4,040	3,810	4,300
Wahkiakum	6,080	5,400	5,410	4,890	4,750	5,160
Subtotal	72,120	76,360	82,170	64,010	66,117	105,840
Oregon:						
Clatsop	30,720	31,940	26,860	20,370	18,190	22,100
Columbia	13,710	18,110	17,520	13,920	12,780	17,400
Gilliam	1,210	1,240	1,200	950	890	1,000
Hood River	3,920	4,920	5,420	5,080	5,600	9,000
Multnomah	272,730	326,020	354,930	283,070	278,300	360,500
Umatilla	900	990	1,650	1,400	1,440	1,720
Wasco	8,360	10,910	11,760	10,380	11,370	14,500
Subtotal	331,550	394,130	419,340	335,170	328,570	426,220
Total for sub-basin	403,670	470,490	501,510	399,180	394,687	532,060

[1] Small portions of the following counties lie within the sub-basin: Lewis and Walla Walla in Washington; Morrow and Sherman in Oregon.

Source: State of Washington, Minutes and Official Proceedings of the State Board of Equalization, 1921–42; Oregon State Tax Commission, Biennial Reports, 1921–47. Figures for parts of counties estimated from these data.

TABLE 14.—*Industrial distribution of employed workers, 1940*

Industry	Number employed	Percent of total
Extractive industries:		
Agriculture	7,500	10
Logging	1,910	2
Forestry	423	(1)
Mining	47	(1)
Total extractive industries	9,880	12
Processing industries:		
Saw and planing mills	6,150	8
Other woodworking	1,060	1
Paper and allied products	3,524	4
Food and kindred products	2,213	3
Iron and steel products	680	1
Textile products	554	1
Other manufacturing	3,153	4
Total processing industries	17,334	22
Service industries:		
Construction	4,581	6
Transportation	4,707	6
Wholesale and retail trade	16,228	21
Professional and government	11,475	15
Other services	14,008	18
Total service industries	50,999	66
Industries not classified	425	(1)
Total employed	78,638	100

[1] Less than 1 percent.

Source: U. S. Census "Population," 1940. Employment for parts of counties estimated on basis of these data.

TABLE 15.—*Land in farms and farm values, 1945*

State and county	Percent of county area within sub-basin	Number of farms	Average size of farms	Percent of land area in farms	Land in farms within sub-basin (in acres)					Value of land and buildings	
					Total	Crop land		All other uses		Total	Per acre
						Area	Percent of land in farms	Area	Percent of land in farms		
			Acres							*Thousands*	
Washington	------	1,727	105	43	182,158	111,022	61	71,136	39	$15,871	$87
Oregon	------	2,253	98	26	221,663	99,194	45	122,464	55	25,501	115
Total for sub-basin	------	3,980	101	32	403,821	210,216	52	193,605	48	41,372	102
COUNTIES WITHIN SUB-BASIN [1]											
Oregon:											
Clatsop	43	220	86	8	18,850	11,270	60	7,580	40	2,162	115
Columbia	56	750	62	20	46,520	39,000	84	7,520	16	6,226	134
Gilliam	8	15	4,000	100	60,000	296	(2)	59,704	99	296	5
Hood River	(2)	8	36	19	286	143	50	143	50	49	171
Morrow	15	114	95	5	10,810	3,810	35	7,000	65	1,174	109
Multnomah	29	875	48	54	41,640	34,140	82	7,500	18	12,867	309
Sherman	(2)	11	50	76	552	118	21	434	79	44	80
Umatilla	2	250	171	99	42,631	10,167	24	32,464	76	2,602	61
Wasco	(2)	10	37	20	374	250	67	124	33	81	217
Washington:											
Benton	8	756	119	100	89,980	60,980	68	29,000	32	3,777	42
Clark	9	94	261	71	24,530	24,130	98	400	2	5,519	225
Cowlitz	10	197	66	18	13,010	9,280	71	3,730	29	1,624	125
Klickitat	(2)	27	278	100	7,500	500	7	7,000	93	97	13
Pacific	11	70	187	20	13,100	6,100	47	7,000	53	1,048	80
Skamania	(2)	125	20	93	2,500	2,500	100	------	------	500	200
Wahkiakum	84	458	69	22	31,538	7,532	24	24,006	76	3,306	105

[1] Small areas in Franklin and Lewis Counties, Wash., lie within the sub-basin.
[2] Less than 1 percent.

TABLE 16.—*Farms under irrigation, 1939*

Item	Total sub-basin	Columbia River		
		Direct	Yakima River	Umatilla River
Irrigated farms ..... number	1,133	25	756	352
Area irrigated ..... acres	20,629	4,062	11,590	13,977
Crop harvested ..... do	25,161	3,778	11,590	9,793
Crop failure ..... do	1,653	36	.....	1,617
Pasture ..... do	2,815	248	.....	2,567
Irrigable area in enterprises ..... do	36,478	5,705	11,590	19,183
Difference, irrigable-irrigated ..... do	6,849	1,643	.....	5,206
Area works, could supply ..... do	34,597	4,892	11,590	18,115
Difference, capacity-irrigated ..... do	4,968	830	.....	4,138

TABLE 17.—*Unreserved saw timber by ownership as of Jan. 1, 1945*

[Millions of board feet, log scale, Scribner rule]

Species	Privately owned	National forest	Other publicly owned and managed	Total
Douglas fir	2,356	108	82	2,546
Western hemlock	1,742	43	330	2,115
Cedars	153	12	29	194
Balsam firs	163	32	69	264
Sitka spruce	266	.....	47	313
Other softwoods	12	3	.....	15
Hardwoods	34	.....	6	40
Total saw timber	4,726	198	563	5,487

Source: Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., Power Markets and Developments in the Pacific Northwest, Forest and Forest Products Industries, 1947. Figures for parts of counties estimated on basis of these data.

TABLE 18.—*Unreserved saw timber by counties as of Jan. 1, 1945*

[Millions of board feet, log scale, Scribner rule]

State and county	Percent of county within sub-basin	Douglas fir	Western hemlock	Cedars	Balsam firs	Sitka spruce	Other softwood	Hardwoods	Total
Washington	.....	2,120	1,774	160	176	235	12	35	4,521
Oregon	.....	417	341	34	88	78	3	5	966
Total for sub-basin	.....	2,546	2,115	194	264	313	15	40	5,487
COUNTIES WITHIN SUB-BASIN [1]									
Washington:									
Cowlitz	10	600	25	.....	.....	.....	.....	.....	625
Lewis	(2)	880	.....	.....	.....	.....	5	.....	885
Pacific	11	350	528	48	.....	.....	7	.....	933
Wahkiakum	84	299	1,221	112	176	235	.....	35	2,078
Oregon:									
Clatsop	43	83	295	22	55	78	.....	5	538
Columbia	50	217	.....	.....	.....	.....	.....	.....	217
Multnomah	29	117	46	12	33	.....	3	.....	211

[1] Parts of the following counties lie within the basin, but contain no significant volume of saw timber: Benton, Clark, Franklin, Klickitat, and Skamania in Washington; Gilliam, Hood River, Morrow, Sherman, Umatilla, and Wasco in Oregon.
[2] Less than 1 percent.

Source: U. S. Department of Agriculture, Forest Service, Power Markets and Developments in the Pacific Northwest, Forest and Forest Products Industries, 1947. Figures for parts of counties estimated on basis of data in this report.

TABLE 19.—*Manufacturing, 1939*

State and county	Percent of county area within sub-basin	Number of establishments	Wage earners (average for year)	Wages	Value of products	Value added by manufacture	Cost of materials, fuel and power
				Thous.	*Thous.*	*Thous.*	*Thous.*
Washington	.....	108	5,633	$7,517	$36,561	$18,138	$18,423
Oregon	.....	356	10,721	13,546	73,058	31,713	41,345
Total for sub-basin	.....	464	16,354	21,063	109,619	49,851	59,768
COUNTIES WITHIN SUB-BASIN [1]							
Washington:							
Benton	8	15	100	74	1,186	324	862
Clark	9	33	1,810	2,285	14,715	6,279	8,436
Cowlitz	10	35	3,030	4,231	16,975	9,586	7,389
Franklin	(2)	4	13	16	91	52	39
Klickitat	(2)	8	50	186	462	301	161
Skamania	(2)	3	110	127	514	317	197
Wahkiakum	84	10	420	598	2,618	1,279	1,339
Oregon:							
Clatsop	43	70	2,930	3,688	19,792	8,263	11,529
Columbia	56	40	2,350	3,264	13,258	6,672	6,586
Hood River	(2)	21	506	513	1,799	885	914
Multnomah	29	205	4,640	5,746	34,945	15,112	19,833
Wasco	(2)	20	295	335	3,264	781	2,483

[1] Small portions of the following counties lie within the basin, but have no significant amount of manufacturing: Lewis and Pacific in Washington; Gilliam, Morrow, Sherman, and Umtilla in Oregon.
[2] Less than 1 percent.

Source: U. S. Census, Manufactures, 1939. Figures for parts of counties estimated on basis of census data.

TABLE 20.—*Employees and payrolls in manufacturing, 1945–46* [1]

Type of manufacturing	Number of workers		Wages paid	
	Monthly average	Peak month	Total for year	Average monthly wage
Food and kindred products	3,630	5,871	$6,622,613	$152
Lumber and timber basic products	6,256	9,113	15,649,342	208
Furniture and finished lumber products	514	577	1,089,423	177
Printing, publishing, and allied products	422	477	916,373	181
Nonferrous metals and their products	2,037	2,054	7,289,759	298
Stone, clay, and glass products	97	107	191,298	165
Iron and steel and their products	445	517	1,244,736	233
Chemicals and allied products	116	120	260,853	186
Paper and allied products	4,914	5,253	12,697,862	215
Miscellaneous manufacturing	10,124	.....	33,557,648	276
Total	28,555	.....	79,519,907	.....

[1] For year ending Sept. 30, 1946. Includes only covered employment and paid wages reported under Unemployment Compensation and Placement.

TABLE 21.—*Public lands and reservations by counties (in acres)*

State and county	County area within sub-basin		All public lands within sub-basin		Public domain	Other Federal lands	State parks	Other State lands	County lands
	Percent	Area	Percent of area within sub-basin	Area					
Oregon:									
Clatsop	43	226,391							
Columbia	56	230,510	(1)	907		846	2	59	
Gilliam	8	60,000	1	761	761				
Hood River	(1)	1,500	1	11			11		
Morrow	15	200,200	2	3,539	1,791			7	1,741
Multnomah	29	77,240	(1)	369		330	39		
Sherman	(1)	731	(1)	17	17				
Umatilla	2	43,267							
Wasco	(1)	1,900	31	588	92	496			
Subtotal		841,739	(1)	6,192	2,661	1,672	52	66	1,741
Washington:									
Benton	8	89,980	1	1,333	320				1,013
Clark	9	34,473	2	640		640			
Cowlitz	10	70,690							
Franklin	(1)	1,000	2	19			19		
Klickitat	(1)	7,500	19	1,447	311	629		313	194
Lewis	(1)	3,920							
Pacific	11	66,100							
Skamania	(1)	2,700	41	1,112		1,112			
Wahkiakum	84	144,010	(1)	1,419		1,419			
Subtotal		420,373	1	5,970	631	3,800	19	313	1,207
Total for sub-basin		1,262,112	(1)	12,162	3,292	5,472	71	379	2,948

[1] Less than 1 percent.

Source: U. S. Forest Service; U. S. Bureau of Reclamation; Oregon State Land Board; Oregon State Highway Commission; State of Washington Park Service.

TABLE 22.—*Public lands and reservations by ownership*

[As of Jan. 1, 1948]

Name	Area, square miles	Purpose	Agency
Oregon:			
Public domain	4.15	Public lands	U. S. Land Office.
Other Federal lands	.50	Bonneville Dam	Corps of Engineers.
Do	.77	The Dalles-Celilo Canal	Do.
Do	1.32	Beaver Back-up storage point	Transportation Corps.
State parks	.08	Recreation	State.
Other State lands	.13	Miscellaneous	Do.
County lands	2.70	do	Counties.
Subtotal	9.65		
Washington:			
Public domain	1.00	Public lands	U. S. Land Office.
Other Federal lands	2.72	Bonneville Dam	Corps of Engineers.
Do	1.14	Fort Columbia	War Assets Administration.
Do	.06	do	Corps of Engineers.
Do	.26	Fort Canby	Do.
Do	.76	do	U. S. Coast Guard.
Do	1.00	U. S. Army Post	War Assets Administration.
State parks	.03	Recreation	State.
Other State lands	.50	Miscellaneous	Do.
County lands	1.88	do	Counties.
Subtotal	9.35		
Total for sub-basin	19.00		

Source: U. S. Forest Service, U. S. Bureau of Reclamation, Oregon State Land Board, Oregon State Highway Commission, and Washington State Park Service.

TABLE 23.—*Pack of canned salmon on the Columbia River 1922–47* [1]

Year	Number of canneries	Chinook		Blueback		Silver	
		Cases	Value	Cases	Value	Cases	Value
1922	23	237,230	$3,724,393	30,743	$614,860	90,437	$633,935
1923	23	289,586	4,967,657	38,309	766,180	101,554	673,954
1924	22	293,716	4,508,236	7,366	129,840	112,308	992,865
1925	21	350,809	5,423,129	5,650	106,220	113,554	1,488,855
1926	21	295,302	4,744,131	21,736	434,720	97,142	1,027,597
1927	22	339,446	5,559,202	6,887	147,378	74,879	585,816
1928	24	251,404	4,355,218	4,814	100,131	49,136	478,355
1929	21	242,938	4,234,214	10,072	181,296	90,684	917,561
1930	21	281,346	4,092,810	9,823	194,460	110,430	1,156,042
1931	20	294,798	3,754,929	4,125	66,000	39,268	247,878
1932	15	216,511	2,023,390	2,795	33,540	46,492	280,853
1933	14	251,157	2,719,303	6,921	96,894	36,430	263,190
1934	13	251,068	2,630,152	6,869	82,428	65,428	536,731
1935	10	205,870	2,479,450	1,302	17,619	95,184	725,868
1936	11	220,188	2,964,058	9,837	137,718	36,541	303,263
1937	11	291,343	4,256,819	7,526	126,436	69,801	725,996
1938	10	173,892	2,707,267	13,889	260,369	67,257	630,364
1939	----------	207,595	3,336,209	5,301	102,359	69,082	730,549
1940	11	244,570	3,785,681	23,974	471,530	59,737	623,681
1941	11	328,609	5,558,254	33,070	661,400	35,727	481,834
1942	12	274,750	5,692,920	23,256	625,230	26,541	497,070
1943	11	130,373	3,094,505	2,880	77,586	5,707	61,065
1944	10	163,047	3,714,591	758	20,342	12,210	137,072
1945	8	132,014	3,095,228	112	3,001	22,154	244,060
1946	11	159,872	5,940,740	9,726	369,588	6,883	206,490
1947	10	250,318	8,613,000	15,079	661,000	42,789	1,278,000

Year	Number of canneries	Chum		Steelhead trout		Total	
		Cases	Value	Cases	Value	Cases	Value
1922	23	8,844	$47,130	24,920	$186,675	392,174	$5,206,993
1923	23	25,508	135,108	25,968	187,965	480,925	6,730,924
1924	22	57,748	303,356	29,734	285,107	500,872	6,219,404
1925	21	55,812	272,398	14,637	177,866	540,452	7,468,468
1926	21	32,853	181,216	32,690	356,418	479,723	6,744,004
1927	22	68,449	425,240	30,148	311,070	519,809	7,028,705
1928	24	124,953	747,619	16,339	222,139	446,646	5,903,462
1929	21	54,619	314,928	23,804	257,025	422,117	5,905,024
1930	21	11,371	43,324	16,535	171,541	429,505	5,658,177
1931	20	3,518	11,764	11,990	110,429	353,699	4,191,000
1932	15	17,261	44,879	13,132	91,924	296,191	2,474,586
1933	14	24,398	107,351	17,805	142,440	336,711	3,329,178
1934	13	24,455	92,608	14,901	121,000	362,721	3,462,919
1935	10	15,495	59,499	14,888	122,846	332,739	3,405,282
1936	11	30,597	110,149	19,282	317,867	316,445	3,833,055
1937	11	30,592	138,309	17,568	189,734	416,830	5,437,294
1938	10	37,704	143,275	15,248	152,480	307,990	3,893,755
1939	----------	15,201	75,416	25,293	320,025	322,472	4,666,141
1940	11	25,282	125,420	33,436	373,514	386,999	5,379,826
1941	11	83,144	572,094	33,162	453,502	513,712	7,727,984
1942	12	118,051	911,538	21,803	429,678	464,401	8,156,445
1943	11	12,439	112,421	16,261	323,874	167,660	3,669,451
1944	10	1,525	11,590	19,222	375,838	196,762	4,259,433
1945	8	1,032	8,848	19,314	363,068	[3] 175,670	3,723,456
1946	11	[3] 15,617	247,392	17,373	510,720	209,471	7,274,930
1947	10	17,121	252,000	21,999	650,000	347,306	11,457,000

[1] Data from Pacific Fisherman Yearbook.
[2] Includes 1,044 cases of pinks canned from Puget Sound fish.
[3] Includes 1,873 cases of pinks canned from Puget Sound fish.

TABLE 24.—*Columbia River salmon production, 1866–1947* [1]

[All species, including steelhead trout]

Year	Canned [2]	Mild-cured [3]	Frozen	Total	Year	Canned [2]	Mild-cured [3]	Frozen	Total
	Pounds	*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*	*Pounds*
1866	272,000	.....	.....	272,000	1907	22,043,628	6,677,000	.....	28,720,628
1867	1,224,000	.....	.....	1,224,000	1908	18,884,892	5,456,000	.....	24,340,892
1868	1,904,000	.....	.....	1,904,000	1909	18,441,328	6,094,000	.....	24,535,323
1869	6,800,000	.....	.....	6,800,000	1910	26,616,220	8,714,200	.....	35,330,420
1870	10,200,000	.....	.....	10,600,000	1911	37,626,508	9,003,500	2,850,000	49,480,008
1871	13,600,000	.....	.....	13,600,000	1912	19,449,768	6,406,400	1,674,030	27,530,198
1872	17,000,000	.....	.....	17,000,000	1913	18,120,572	6,320,600	2,115,000	26,556,172
1873	17,000,000	.....	.....	17,000,000	1914	30,914,228	5,725,500	1,861,575	38,501,303
1874	23,800,000	.....	.....	23,800,000	1915	37,980,312	4,485,800	1,372,568	43,838,680
1875	25,500,000	.....	.....	25,500,000	1916	37,250,740	5,121,600	374,000	42,746,340
1876	30,600,000	.....	.....	30,600,000	1917	37,627,528	2,074,600	745,858	40,447,986
1877	25,840,000	.....	.....	25,840,000	1918	40,213,908	1,984,400	1,927,115	44,125,423
1878	31,280,000	.....	.....	31,280,000	1919	39,441,904	3,660,800	1,831,793	44,934,497
1879	32,640,000	.....	.....	32,640,000	1920	32,745,060	2,502,500	1,064,000	36,311,560
1880	36,040,000	.....	.....	36,040,000	1921	21,962,028	3,356,100	1,394,419	26,712,547
1881	37,400,000	.....	.....	37,400,000	1922	26,667,832	1,783,100	1,701,725	30,152,657
1882	36,808,400	.....	.....	36,808,400	1923	32,702,900	1,945,900	1,018,450	35,667,250
1883	42,799,200	.....	.....	42,799,200	1924	34,059,296	2,552,000	1,555,758	38,167,054
1884	42,160,000	.....	.....	42,160,000	1925	36,750,736	3,020,600	2,562,107	42,333,443
1885	37,658,400	.....	.....	37,658,400	1926	32,621,164	1,160,500	1,784,995	35,566,659
1886	30,498,000	.....	.....	30,498,000	1927	35,347,012	1,046,100	1,295,303	37,688,415
1887	24,208,000	.....	.....	24,208,000	1928	30,371,928	1,435,500	1,319,638	33,127,066
1888	25,328,436	.....	.....	25,328,436	1929	28,703,956	2,165,900	1,451,425	32,321,281
1889	21,072,180	.....	.....	21,072,180	1930	29,206,340	1,174,800	1,542,259	31,923,399
1890	29,632,632	.....	.....	29,632,632	1931	24,051,532	1,376,100	1,604,108	27,031,740
1891	27,128,804	.....	.....	27,128,804	1932	20,140,988	2,213,200	976,029	23,330,217
1892	33,138,984	.....	.....	33,138,984	1933	22,896,348	2,674,100	1,276,352	26,846,800
1893	28,279,568	.....	.....	28,279,568	1934	24,665,028	2,040,500	1,250,888	27,956,416
1894	33,326,800	.....	.....	33,326,800	1935	22,626,252	1,903,000	1,206,754	25,736,006
1895	43,159,328	.....	.....	43,159,328	1936	21,518,260	1,251,800	758,518	23,528,578
1896	32,755,396	.....	.....	32,755,396	1937	28,344,440	664,400	736,996	29,745,836
1897	37,585,028	440,000	.....	38,025,028	1938	20,943,320	1,421,200	638,767	23,003,287
1898	33,180,192	770,000	.....	33,950,192	1939	21,928,096	771,100	559,984	23,259,180
1899	22,628,632	1,375,000	.....	24,003,632	1940	26,315,932	36,300	270,943	26,623,175
1900	24,396,496	1,402,500	.....	25,798,996	1941	34,932,416	251,900	160,121	35,344,437
1901	26,532,444	3,300,000	.....	29,832,444	1942	31,579,268	22,000	700,464	32,301,732
1902	21,565,724	4,634,300	.....	26,200,024	1943	11,400,880	23,100	943,719	12,367,699
1903	23,091,236	7,397,500	.....	30,488,736	1944	13,379,816	17,600	1,907,042	15,304,458
1904	26,867,072	9,996,800	.....	36,863,872	1945	11,945,560	174,900	2,420,832	14,541,292
1905	27,014,564	10,785,500	.....	37,800,064	1946	14,244,628	105,600	3,390,293	17,739,921
1906	26,853,064	8,800,000	.....	35,653,064	1947	23,616,808	108,900	1,167,863	24,893,571

[1] Data from Pacific Fisherman Yearbooks.
[2] Converted on basis of 68 pounds of round fish per case.
[3] Converted on basis of 1,100 pounds of round fish per tierce.

TABLE 25.—*Data on bridges over navigable streams*

Miles above mouth	Stream and nearest town	Owner	Channel spans: Type of bridge	Number of spans	Clear width normal to channel	Clear height of lowest point of superstructure (in feet) above— Mean low water	High water	Date of completion	Purpose for which bridge is used
	COLUMBIA RIVER, OREG. AND WASH.								
64	Rainier, Oreg	Longview Bridge Co	Fixed	5	1,120	185	167	May 1930	Highway.
103.5	Vancouver, Wash	Spokane, Portland & Seattle Ry	Swing	9	200	39.25	14.25	1908	Railroad.
104.5	do	State of Oregon and State of Washington.	Vertical lift	13	250	[1] 175	[1] 154	February 1917	Highway.
148.3	Cascade Locks, Oreg	Wauna Toll Bridge Co	Fixed	3	656	135	124	September 1940	Do.
170	Hood River, Oreg	Oregon-Washington Bridge Co	Vertical lift	16	255	[1] 149	[1] 135	April 1940	Do.
198	Celilo, Oreg	Oregon Trunk Ry	Swing	9	[2] 65	[3] 56	[3] 43	1912	Railroad.
323	Kennewick, Wash	Union Pacific R. R. Co	do	8	113.25	32.75	6	October 1923	Do.
339	Pasco, Wash	Northern Pacific Ry	do	13	98.55	39.5	12	1907	Do.
340	Pasco and Kennewick, Wash	State of Washington	Fixed	5	420	75.2	44.5	December 1922	Highway.
	BIRNIE SLOUGH, WASHINGTON (PUGET ISLAND)								
1.5	Cathlamet, Wash	Wahkiakum County, Wash	do	1	25	23	13.5	August 1919	Do.
1.5	do	Public Utility District No. 1	do	1	25	22.5	12	June 1942	Pipeline.
	CATHLAMET CHANNEL, WASH.								
2.75	do	Wahkiakum County, Wash	do	13	215	74.6	60.7	August 1939	Highway.
	GRAYS RIVER, WASH.								
4.5	Roseburg, Wash	State of Washington	do	3	60	33	25	Under construction.	Do.
5.0	do	Wahkiakum County, Wash	Swing	1	48	18	10	November 1930	Do.
	SVENSON SLOUGH, OREG.								
1	Svenson, Oreg	Clatsop County, Oreg	Fixed	1	60	17.5	8	1916	Do.

[1] Lift span raised.
[2] Width of Celilo Canal.
[3] Above canal level.

TABLE 25.—*Data on bridges over navigable streams*—Continued

Miles above mouth	Stream and nearest town	Owner	Channel spans						
			Type of bridge	Number of spans	Clear width normal to channel	Clear height of lowest point of superstructure (in feet) above—		Date of completion	Purpose for which bridge is used
						Mean low water	High water		
	BEAVER SLOUGH, OREG.								
2	Clatskanie, Oreg	Columbia County, Oreg	Bascule	1	50	14.3	9.3	January 1944	Do.
3	do	do	do	1	50	14.3	9.3	May 1931	Do.
	WESTPORT SLOUGH, OREG.								
4.25	Woodson, Oreg	do	Removable span	1	48	16	11	February 1942	Do.
6.75	Marshland, Oreg	do	Fixed	1	98	20	15	December 1934	Do.
9.5	Clatskanie, Oreg	do	Vertical lift	1	50	20	14	September 1928	Do.
	SKIPANON RIVER, OREG.								
0.8	Warrenton, Oreg	Spokane, Portland & Seattle Ry	Swing	2	33	10	2.5	1916	Railroad.
0.9	Warrenton, Oreg	Clatsop County, Oreg	Bascule	1	33.3	15	3	1916	Highway.
2.5	do	State of Oregon	do	3	34	10	4	December 1929	Do.
	OREGON SLOUGH, OREG.								
3	Portland, Oreg	Spokane, Portland & Seattle, Ry	Swing	8	125	39.25	19.25	1908	Railroad.
4	do	Multnomah County, Oreg	Fixed	11	100	34	14	February 1917	Highway.
4.75	Faloma, Oreg	Columbia Beach Amusement Co	do	1	60	29	7.5	1929	Do.
	COLUMBIA SLOUGH, OREG.								
2.5	Portland, Oreg	City of Portland	do	1	83.75	41.78	21.78	January 1940	Do.
4.45	do	State of Oregon	do	1	80	40	19	May 1933	Do.
4.5	do	Spokane, Portland & Seattle Ry	do	1	149	39.25	14.25	1908	Railroad.
5	do	Union Pacific R. R. Co	do	1	60	27	7	1909	Do.
6.5	do	Multnomah County	do	3	66	34	13	April 1929	Highway.
7.25	do	do	do	1	70	34	14	August 1935	Do.
7.5	Portland, Oreg., Union Ave. approach to Interstate Bridge.	do	do	1	60	35	14	February 1917	Do.

	WELCOME SLOUGH, WASH.								
0.5	Wauna, Oreg	Wahkiakum County, Wash	do	1	25	23	13.5	August 1918	Do.
	SKAMOKAWA CREEK, WASH.								
0.25	Skamokawa, Wash	State of Washington	Swing	1	65	20.2	12.1	December 1939	Do.
0.5	do	Wahkiskum County, Wash	do	2	61.7	15	8	1913	Do.
	WHITE SALMON RIVER, WASH.								
0.01	Underwood, Wash	Spokane, Portland & Seattle Ry	Fixed	1	145.2	28.2	3	1908	Railroad.
0.02	do	State of Washington	do	1	184	26.2	1	1919	Highway.
	LITTLE WHITE SALMON RIVER, WASH.								
0.005	Cooks, Wash	Spokane, Portland & Seattle Ry	do	3	139.2	27.3	3	1908	Railroad.
0.01	do	State of Washington	do	4	274.3	25.1	1	1935	Highway.
	YOUNGS BAY, OREG.								
0.5	Astoria, Oreg	Spokane, Portland & Seattle, Ry	Swing	2	130	18	10.5	September 1896	Railroad.
2.4	do	State of Oregon	Bascule	1	120	27	20.6	November 1921	Highway.
	KLASKANINE RIVER, OREG.								
1.5	Olney, Oreg	Clatsop County, Oreg	Fixed	8	20	12	2	1923	Do.
	JOHN DAY RIVER, OREG.								
0	Astoria, Oreg	Spokane, Portland & Seattle Ry	Swing	2	60	11.3	4	1896	Railroad.
1	do	State of Oregon	do	2	40	25	18.7	October 1933	Highway.
	CLATSKANIE CREEK, OREG.								
0.75	Clatskanie, Oreg	Spokane, Portland & Seattle Ry	do	1	61	16	10.5	November 1898	Railroad.
	DEEP RIVER, WASH.								
3.5	Deep River, Wash	State of Washington	do	2	60	20	10	June 1933	Highway.
4.25	do	Whakiakum County, Wash	Bascule	1	38.3	18.5	11	1900	Do.
	KLICKITAT RIVER, WASH.								
0.02	Lyle, Wash	Spokane, Portland & Seattle Ry	Fixed	1	134.8	27.4	0	1908	Railroad.
0.05	do	State of Washington	do	1	154.7	58.6	34		Highway.

TABLE 26.—*Bonneville Dam fish counts*

Calendar year	Chinook	Blueback	Silver	Chum	Humpback	Steelhead	Total	Fish other than salmonoid
1938 [1]	271,799	75,040	15,185	2,117	.....	107,003	471,144	614,897
1939	286,236	73,382	14,383	1,168	.....	121,922	497,091	464,684
1940	391,573	148,805	11,870	1,729	.....	185,161	739,138	364,210
1941	461,443	65,741	17,011	5,269	4	118,087	668,455	269,820
1942	401,998	55,464	12,401	1,865	11	151,345	623,084	245,029
1943	313,123	39,845	2,547	790	.....	92,131	448,436	187,277
1944	240,763	15,071	4,207	954	1	100,521	361,517	230,277
1945	297,488	9,501	791	727	1	120,144	428,652	309,139
1946	445,743	74,354	3,897	1,176	2	142,548	667,720	364,707
1947	480,377	171,139	11,174	199	3	135,444	798,336	408,297
Total	3,590,543	728,342	94,366	15,994	22	1,274,306	5,703,573	3,458,337
1938-47 average	359,054	72,834	9,437	1,599	2	127,430	570,357	345,833

[1] Fish counting began at Bonneville, May 7, 1938.

TABLE 27.—*Lumber production, 1936–46*

[Thousands of feet, board measure]

State and county	Percent of county area within sub-basin	1941	1942	1943	1944	1945	1946
Washington	.....	983,517	994,458	826,712	837,583	673,271	721,937
Oregon	.....	1,327,019	1,249,359	1,117,897	1,112,490	800,543	848,759
Total for sub-basin	.....	2,310,536	[2] 2,243,817	[2] 1,944,609	[2] 1,950,073	[2] 1,473,814	[2] 1,570,696
COUNTIES WITHIN SUB-BASIN [3]							
Washington:							
Skamania	1	(3)	108,237	26,697	22,853	21,595	23,711
Clark	9	130,178		94,704	93,329	78,720	137,226
Cowlitz	10	853,339	886,221	705,311	721,401	572,956	560,053
Wahkiakum	84	(3)					947
Oregon:							
Clatsop	43	190,137	186,332	172,925	147,049	111,978	134,227
Columbia	56	336,183	371,278	371,143	342,493	244,651	263,316
Gilliam	8	(3)	17,368	12,558	.....	.....	.....
Morrow	15	14,561			22,502	18,753	20,086
Hood River	(4)	66,681	60,177	57,080	58,172	39,039	50,763
Multnomah	29	684,190	606,284	466,648	484,530	335,579	303,830
Umatilla	2	21,043	(3)	24,524	29,244	24,522	29,823
Wasco	(4)	14,224	[1] 7,920	[1] 13,010	[1] 28,500	[1] 26,021	[1] 46,714

[1] Includes production in Jefferson County, Oregon.
[2] Small areas of Benton, Franklin, Klickitat, Lewis, and Pacific Counties in Washington; and Sherman County in Oregon, lie within the sub-basin.
[3] Not separately reported and not included in sub-basin total.
[4] Less than one percent.

Source: Department of Commerce, Census of Forest Products, 1941–43, and Facts for Industry, 1944–46. Production for parts of counties estimated on basis of census data.

TABLE 28.—*Existing terminal facilities*

Location	Type	Number of facilities	Unit	Capacity or size	Berthage, linear feet		Ownership	Connections
					Ship	Barge		
Pasco, Wash.	Oil	1	Gallon	5,000,000			Private	Rail, highway, and river.
	Grain elevator	1	Bushel	500,000			Public	Do.
	Open wharf	1	Foot	28 by 125		125	do	Do.
Kennewick, Wash.	Grain elevator	1	Bushel	50,000			Private	Rail and river.
Attalia, Wash.	Oil	1	Gallon	5,500,000			do	Highway and river.
Port Kelley, Wash.	Grain warehouse	1	Bushel	84,000			do	Do.
Umatilla, Oreg.	Oil	2	Gallon	6,300,000			do	Do.
	Grain elevator	1	Bushel	9,275,000			do	Rail, highway, and river.
Blalock, Oreg.	do	1	do	340,000			do	Do.
Celilo Canal, Oreg.	Grain warehouse	2	do	20,000			Public	Highway and river.
The Dalles, Oreg.	Pile timber wharf	1	Foot	375,000			Private	Rail, highway, and river.
	Transit and storage warehouse	2	do	125 by 1,000	1,000		Public	Rail, highway, river, and ocean.
	Grain elevator	1	Bushel	94 by 461			do	Do.
	Grain warehouse	1	do	868,000			do	Do.
	Grain elevator	1	do	300,000			Private	Rail, highway, and river.
	Oil	1	Gallon	40,000			do	Do.
	Marine elevator	2	Ton	2,300,000			do	Rail, highway, river, and ocean.
	Wharf	1	Foot	10			Public	Do.
Camas-Washougal, Wash.	do	2	do	27 by 193		193	do	Do.
	Transit shed	1	do	100 by 528		528	do	Highway and river.
	Marine elevator	1	Ton	100 by 418		418	Private	Rail, highway, and river.
Vancouver, Wash.	Outfitting wharf	1	Foot	60 by 120			Public	Highway and river.
	Open wharf	1	do	7½			do	
	Sand, gravel wharf	1	do	3,150	3,150		do	Rail, highway, river, and ocean.
	Wharf, with	1	do	25 by 105			do	River and no rail connection.
	Transit shed	1	do	100 by 166		166	Private	Do.
	Open wharf, with	1	do	150 by 1,327	1,327		Public	Rail, highway, river, and ocean.
	Oil tank	1	do	100 by 320			do	Do.
	Grain elevator, with	1	Gallon	100 by 510	510		Private	Do.
	Wharf	1	Bushel	3,000,000			do	Do.
	Open wharf	1	Foot	2,700,000			do	Do.
	Open lumber wharf	1	do	30 by 587	587		do	Do.
	Whirley crane	1	do	100 by 350	350		do	Do.
	Stiff-leg derrick	6	Ton	80 by 460	460		do	Do.
	Mono-rail hoist	1	do	40			Public	
	Marine elevator	1	do	10			do	
		1	do	8			do	
		1	do	10			do	

TABLE 28.—*Existing terminal facilities*—Continued

Location	Type	Number of facilities	Unit	Capacity or size	Berthage, linear feet		Ownership	Connections
					Ship	Barge		
Portland, Oreg.	Oil	10	Barrel	4,364,000	7,930		Private	Rail, highway, river, and ocean.
	Grain warehouse and elevator	6	Bushel	4,440,000	3,880		do	Do.
	Grain elevator	1	do	2,000,000			Public	Do.
	Special facilities:							
	Coal	1	Ton	10,000			do	Do.
	Bulk liquids	1	Barrel	33,500			do	Do.
	Cold storage	1	Cubic foot	360,000			do	Do.
	Fruit warehouse	1	Box	250,000			do	Do.
	Lumber wharves	9			1,100		do	Do.
					5,170	390	Private	Do.
	General cargo	19			7,050		do	Do.
					9,682		Public	Do.
	Industry wharves	14			3,605	1,600	Private	Do.
	Sand and gravel plants	9				1,730	do	Do.
	Ship outfitting and repair plants	3			2,600		do	Do.
		12			13,269		Public	Do.
	Dry docks:							
	Floating	1	Ton	1,000			Private	Do.
	Graving	1	do	1,000			do	Do.
	Floating	2	do	8,000			Public	Do.
				12,000			do	Do.
	Self docking	1	do	16,700	500		Private	Do.
	Marine elevators	10	do	10			do	Do.
		3	do	10			Public	Do.
	Marine railways:							
	Side haul and shunt	1	Linear foot	165			Private	Do.
	do	1	do	380			do	Do.
	Roller type	1	do	140			do	Do.
	Skid type	2	do	140			do	Do.
	Hoisting cranes and derricks:							
	Shore	23	Ton	10 to 125			Public	Do.
	Floating	1	do	75			do	Do.
	Shore	17	do	10 to 60			Private	Do.
	Floating	15	do	12 to 250			do	Do.
	Diving outfit	1					do	Do.
St. Helens, Oreg.	Open lumber wharf	1	Foot	100 by 1,500	1,500		do	Do.
Kalama, Wash.	Open wharf	2	do	12 by 150		150	do	Rail, highway, and river.
				Length, 590	590		Public	Rail, highway, river, and ocean.
Rainier, Oreg.	Open lumber wharf	1	do	200 by 580	580		Private	Do.
	Wharf	1	do	160 by 100			do	Rail, highway, and river.

Prescott, Oreg.	Open lumber wharf	1	do	Length, 700	700		do	Rail, highway, river, and ocean.
Longview, Wash.	Wharf with oil tanks	1	do	Length, 2,000	2,000		Public	Do.
			Gallon	3,700,000			Private	Do.
	Grain elevator	1	Bushel	975,000			Public	Do.
	Long Bell Lumber Co. dock	1	Foot	Length, 2,000	2,000		Private	Do.
	Weyerhauser Timber Co. dock	1	do	140 by 1,760	1,760		do	Do.
	Locomotive cranes	3	Ton	25			Public	
	Shear leg derrick	1	do	40			do	
	Cranes	2	do	5			Private	
	Lift trucks	3	do	7			do	
	Bridge crane	1	do	7½			do	
	Gantry crane	1	do	7½			do	
Beaver, Oreg.	Open lumber wharf	1	Foot	60 by 1,200	1,200		Public	
West Port, Oreg.	do	1	do	Length, 1,200	1,200		Private	Highway, river, and ocean.
Wauna, Oreg.	do	1	do	200 by 1,050	1,050		do	Rail, highway, river, and ocean.
Bradwood, Oreg.	do	1	do	150 by 400	400		do	Do.
Astoria, Oreg.	Pier No. 1, with	1	do	Length, 1,723	1,723		Public	Do.
	Grain elevator	1	Bushel	1,250,000			do	Do.
	Pier No. 2	1	Foot	Length, 3,178	3,178		do	Do.
	Pier No. 3	1	do	Length, 2,121	2,121		do	Do.
	Locomotive cranes	2	Ton	35 to 50			do	
Warrenton, Oreg.	Open lumber wharf	1	Foot	200 by 650	650		Private	Highway, river, and ocean.
	Open wharf	1	do	Length, 300		300	do	Do.

TABLE 29.—*River commerce 1932–1947*

Item	Tonnage for year shown															
	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
THROUGH THE DALLES-CELILO CANAL																
Upstream:																
Petroleum products	--------	--------	100	--------	300	4,392	26,253	120,011	294,483	363,346	317,448	422,726	541,123	550,667	692,278	742,293
Other commodities	100	1,200	2,300	500	500	44	6,323	610	1,894	765	675	8,599	16,251	330	27	707
Subtotal	100	1,200	2,400	500	800	4,436	32,576	120,621	296,377	364,111	318,123	431,325	557,374	550,997	692,305	743,000
Downstream:																
Grain	300	14,400	21,000	3,100	6,500	1,190	11,765	18,921	29,523	28,752	5,890	1,820	1,965	25,115	51,747	91,915
Other commodities	--------	--------	--------	--------	--------	--------	8	--------	--------	--------	--------	--------	--------	[1] 22,868	300	8
Subtotal	300	14,400	21,000	3,100	6,500	1,190	11,773	18,921	29,523	28,752	5,890	1,820	1,965	47,983	52,047	91,923
Total, upstream and downstream	400	15,600	23,400	3,600	7,300	5,626	44,349	139,542	325,900	392,863	324,013	433,145	559,339	598,980	744,352	834,923
THROUGH BONNEVILLE LOCK																
Upstream:																
Petroleum products	35	264	273	626	2,818	8,007	51,703	216,926	357,284	409,917	379,404	529,213	585,497	598,617	744,722	809,004
Other commodities	1,082	5,010	5,896	3,786	3,575	106	5,221	5,097	13,190	218,899	131,078	16,521	24,648	15,955	19,250	87,223
Subtotal	1,117	5,274	6,169	4,412	6,393	8,113	56,924	222,023	370,474	628,816	510,482	546,734	610,145	614,572	763,972	896,227
Downstream:																
Grain	5,160	23,472	33,608	18,734	10,192	1,385	27,642	42,420	43,493	38,844	7,497	1,820	1,965	25,726	52,167	104,964
Logs	47,456	49,093	46,172	43,691	45,012	5,730	9,265	133,785	283,148	249,443	170,565	127,875	174,409	161,584	202,186	255,472
Other commodities	9,700	7,876	4,436	9,235	2,827	--------	7,866	11,586	10,329	6,530	3,477	5,236	3,404	1,019	444	8,340
Subtotal	62,316	80,441	84,216	71,660	58,031	7,115	44,773	194,791	336,970	294,817	181,539	134,931	179,778	188,329	254,797	368,776
Total, upstream and downstream	63,433	85,715	90,385	76,072	64,424	15,228	101,697	416,814	707,444	923,633	692,021	681,665	789,923	802,901	1,018,769	1,265,003
LOCAL COMMERCE, VANCOUVER TO BONNEVILLE																
Petroleum products	47,000	53,000	48,000	52,000	45,000	48,000	--------	21,000	26,000	36,000	48,000	61,000	92,000	36,000	31,000	--------
Rafted logs	296,000	271,000	371,000	438,000	447,000	230,000	483,000	560,000	463,000	765,000	746,000	829,000	740,000	710,000	646,000	--------
Hogged fuel	89,000	229,000	82,000	108,000	131,000	180,000	222,000	253,000	334,000	217,000	305,000	229,000	208,000	137,000	193,000	--------
Pulp and paper	89,000	106,000	95,000	125,000	89,000	111,000	122,000	156,000	190,000	220,000	232,000	211,000	188,000	197,000	148,000	--------
Sand and gravel	15,000	58,000	57,000	--------	34,000	54,000	209,000	274,000	135,000	255,000	279,000	262,000	--------	103,000	528,000	--------
Other commodities	40,000	59,000	39,000	62,000	55,000	29,000	16,000	29,000	28,000	54,000	127,000	7,000	50,000	30,000	5,000	--------
Total	576,000	776,000	692,000	785,000	803,000	652,000	1,052,000	1,293,000	1,176,000	1,527,000	1,737,000	1,599,000	1,278,000	1,213,000	1,551,000	--------

[1] Consisted of rafted pine logs towed from Maryhill, Wash., to Portland, Oreg.

TABLE 30.—*Estimated available, future, and average annual commerce, Columbia River between head of McNary pool and head of Bonneville pool, exclusive of Snake River commerce*

Commodities	River stretch in miles from mouth			Total
	McNary pool, 352-292	John Day pool, 292-217	The Dalles pool, 217-192	
DOWNSTREAM				
Wheat:	*Tons*	*Tons*	*Tons*	*Tons*
Available [1]	780,200	436,400	98,700	1,315,300
Future [2]	780,200	436,400	98,700	1,315,300
Average [3]	780,200	436,400	98,700	1,315,300
Barley:				
Available	2,000	23,340	4,100	29,440
Future	2,000	23,340	4,100	29,440
Average	2,000	23,340	4,100	29,440
Wool:				
Available	100	5,200	650	5,950
Future	100	5,200	650	5,950
Average	100	5,200	650	5,950
Hay:				
Available	----------	10,000	10,000	20,000
Future	----------	10,000	10,000	20,000
Average	----------	10,000	10,000	20,000
Ore:				
Available	----------	----------	----------	----------
Future	----------	30,000	----------	30,000
Average	----------	15,000	----------	15,000
Industrial products:				
Available	4,500	----------	----------	4,500
Future	25,500	500,000	----------	525,500
Average	15,000	250,000	----------	265,000
Peas and beans:				
Available	2,400	----------	----------	2,400
Future	2,400	----------	----------	2,400
Average	2,400	----------	----------	2,400
UPSTREAM				
Petroleum products:				
Available	93,600	277,500	91,200	462,300
Future	364,000	391,500	134,600	890,100
Average	228,800	334,500	112,900	676,200
Lumber:				
Available	12,000	1,750	150	13,900
Future	43,000	3,250	250	46,500
Average	27,500	2,500	200	30,200
Farm supplies:				
Available	1,000	700	----------	1,700
Future	5,000	700	----------	5,700
Average	3,000	700	----------	3,700
Groceries:				
Available	----------	2,000	150	2,150
Future	----------	3,500	250	3,750
Average	----------	2,750	200	2,950
Building materials:				
Available	2,800	2,750	300	5,850
Future	18,200	3,570	500	22,270
Average	10,500	3,160	400	14,060
Carbide:				
Available	400	----------	----------	400
Future	1,000	----------	----------	1,000
Average	700	----------	----------	700
Total:				
Available	899,000	759,610	205,250	1,863,890
Future	1,241,400	1,407,460	249,050	2,897,910
Average	1,070,200	1,083,550	227,150	2,380,900

[1] "Available" tonnage is that which would be moved immediately or shortly after improvements are completed.
[2] "Future" tonnage is the estimated commerce that would be developed over a 50-year period after improvement.
[3] "Average" tonnage is the 50-year average of immediately available and future tonnage.

TABLE 31.—*Port-to-port barge rates on bulk petroleum products as of Dec. 31, 1947*

[Pacific Inland Tariff Bureau, Inc., tariff No. 4-H, effective Oct. 13, 1947]

Ports		Minimum quantity, gallons	Transportation, per ton	Miles	Rate per ton-mile, mills	Storage at destination per ton	Total per ton	Rail rate per ton [1]
Between—	To—							
Portland	Astoria, Oreg	66,000	$2.10	98	21.4		$2.10	$3.08
Do	do	190,000	1.30	98	13.3		1.30	3.08
Do	Ilwaco, Wash		3.00	108	27.8		3.00	
Do	Longview, Wash	66,000	1.80	44	40.9		1.80	2.20
Do	do	190,000	1.10	44	25.0		1.10	2.20
Do	The Dalles, Oreg	150,000	1.48	96	15.4		1.48	3.74
Do	Umatilla, Oreg	150,000	2.03	196	10.4	$0.50	2.53	4.18
Do	Attalia, Wash	150,000	2.03	223	9.1	.50	2.53	4.62

[1] North Pacific Coast Freight Bureau Tariff No. 14-O, including increases to Dec. 31, 1947.

TABLE 32.—*Port-to-port barge rates on grain, bulk or sacked as of Dec. 31, 1947*

[Pacific Inland Tariff Bureau, tariff No. 30-A, effective Nov. 27, 1947]

Ports		Minimum, tons	Rate per ton	Average, mills	Rate per ton-mile, mills	Rail rate per ton
Between—	To—					
Portland, Oreg. Vancouver, Wash. Longview, Wash.	Lyle, Wash	300	$1.70	95	17.9	$1.87
	The Dalles, Oreg	300	1.70	104	16.3	1.87
	North Dalles, Wash	300	1.70	104	16.3	1.98
	Big Eddy, Oreg	300	1.70	108	15.7	2.31
	Maryhill, Wash	300	2.30	125	18.4	2.64
	Rufus, Oreg	300	2.30	129	17.8	2.53
	Goodnoe, Wash	300	2.60	141	18.4	2.64
	Quinton, Oreg	300	2.60	142	18.3	2.64
	Blalock, Oreg	300	2.60	149	17.4	2.64
	Sundale, Wash	300	2.60	152	17.1	2.64
	Arlington, Oreg	300	2.60	158	16.5	2.64
	Roosevelt, Wash	300	2.60	159	16.4	2.64
	Alderdale, Wash	300	2.60	174	14.9	3.08
	Boardman, Oreg	300	3.30	185	17.8	4.07
	Paterson, Wash	300	3.30	194	17.0	4.07
	Plymouth, Wash	300	3.30	205	16.1	4.51
	Umatilla, Oreg	300	3.30	205	16.1	4.07
	Port Kelley, Wash	300	3.60	227	15.9	
	Hover, Wash	300	3.60	234	15.4	4.51
	Pasco, Wash	300	4.50	244	18.4	4.51
	Kennewick, Wash	300	4.50	244	18.4	4.51

NOTE.—All above rates include increases effective on Dec. 31, 1947.

TABLE 33.—*Estimated flood damages by types and zones*

[Estimates based on 1948 prices, economic developments, and channel conditions]

1894 FLOOD MAGNITUDE

Type of damage	Yakima River to Bonneville	Bonneville to Camas and Sandy River	Camas to Lewis River	Sandy River to Willamette River	Portland area, Willamette River backwater	Lewis River, Washington to Baker Bay	Willamette River, Oregon to Youngs Bay	Total
DIRECT DAMAGES								
Agricultural	$25,000	$150,000	$1,430,000	$3,550,000	$25,000	$11,000,000	$9,250,000	$25,655,000
Residential	25,000	315,000	2,200,000	8,000,000	100,000	4,600,000	.....	15,465,000
Commercial	435,000	19,000	738,000	4,775,000	18,240,000	1,780,000	430,000	26,417,000
Industrial	180,000	1,725,000	9,900,000	15,000,000	16,260,000	4,310,000	4,530,000	51,905,000
Utilities	325,000	286,000	1,125,000	1,115,000	4,240,000	860,000	20,000	7,971,000
Municipal	25,000	325,000	715,000	60,000	1,950,000	100,000	10,000	3,185,000
Highways, roads, and bridges	150,000	65,000	725,000	900,000	50,000	700,000	140,000	2,730,000
Trucks and busses and terminal facilities	5,000	.....	15,000	25,000	150,000	150,000	.....	345,000
Railroads	30,000	.....	135,000	150,000	1,200,000	650,000	125,000	2,290,000
Air terminals	.....	.....	35,000	150,000	.....	50,000	.....	235,000
Navigation facilities	650,000	10,000	50,000	.....	800,000	25,000	10,000	1,545,000
Dikes and protective works	.....	.....	100,000	2,000,000	.....	2,500,000	2,500,000	7,100,000
Subtotal, direct damages	2,300,000	2,895,000	17,168,000	35,725,000	43,015,000	26,725,000	17,015,000	144,843,000
INDIRECT LOSSES								
Agricultural	.....	.....	320,000	200,000	.....	1,000,000	750,000	2,270,000
Residential	25,000	35,000	10,000	1,600,000	27,000	900,000	.....	2,597,000
Commercial	140,000	6,000	272,000	725,000	5,760,000	244,000	120,000	7,267,000
Industrial	120,000	1,650,000	11,900,000	13,740,000	11,600,000	2,740,000	680,000	42,430,000
Utilities	25,000	620,000	230,000	285,000	760,000	140,000	.....	2,060,000
Traffic interruptions:								
Highways	350,000	35,000	125,000	450,000	150,000	300,000	60,000	1,470,000
Railroads	140,000	.....	65,000	125,000	3,200,000	1,150,000	75,000	4,755,000
Navigation	350,000	.....	175,000	.....	600,000	.....	.....	1,125,000
Air terminals	.....	.....	25,000	100,000	.....	.....	.....	125,000
Emergency expenses	12,000	25,000	550,000	1,365,000	150,000	1,135,000	685,000	3,922,000
Subtotal, indirect losses	1,162,000	2,371,000	13,672,000	18,590,000	22,247,000	7,609,000	2,370,000	68,021,000
Total damages	3,462,000	5,266,000	30,840,000	54,315,000	65,262,000	34,334,000	19,385,000	212,864,000

1948 FLOOD MAGNITUDE

DIRECT DAMAGE								
Agricultural	$200,000	$40,000	$480,000	$2,180,000	$10,000	$7,850,000	$3,325,000	$14,085,000
Residential	150,000	270,000	185,000	21,040,000	40,000	1,057,000	.....	22,742,000
Commercial	222,000	22,000	135,000	2,780,000	3,120,000	367,000	205,000	6,851,000
Industrial	45,000	450,000	820,000	960,000	2,250,000	443,000	740,000	5,708,000
Utilities	15,000	61,000	95,000	223,000	76,000	520,000	10,000	1,000,000
Municipal	25,000	3,000	15,000	2,010,000	975,000	75,000	2,000	3,105,000
Highways, roads and bridges	100,000	32,000	460,000	750,000	30,000	125,000	115,000	1,612,000
Trucks, busses and terminal facilities	4,000	.....	5,000	50,000	25,000	.....	.....	84,000
Railroads	16,000	.....	50,000	85,000	75,000	76,000	65,000	367,000
Air terminals	.....	.....	10,000	150,000	.....	.....	.....	160,000
Navigation	210,000	10,000	50,000	.....	125,000	25,000	10,000	930,000
Dikes	.....	.....	100,000	1,000,000	.....	1,400,000	1,000,000	3,500,000
Emergency expenses	.....	.....	.....	.....	.....	.....	.....	.....
Subtotal, direct damage	987,000	888,000	2,405,000	31,228,000	6,726,000	11,938,000	5,472,000	59,644,000

TABLE 33.—*Estimated flood damages by types and zones*—Continued

1948 FLOOD MAGNITUDE—Continued

Type of damage	Yakima River to Bonneville	Bonneville to Camas and Sandy River	Camas to Lewis River	Sandy River to Willamette River	Portland area, Willamette River backwater	Lewis River, Washington to Baker Bay	Willamette River, Oregon to Youngs Bay	Total
INDIRECT LOSSES								
Agricultural			$140,000	$135,000		$900,000	$675,000	$1,850,000
Residential		$18,000		3,000,000		45,000		3,063,000
Commercial	$15,000		90,000	400,000	$1,100,000	185,000	45,000	1,835,000
Industrial	80,000	435,000	705,000	1,519,000	1,800,000	370,000	820,000	5,729,000
Utilities	3,000	560,000	25,000	80,000	24,000	140,000		832,000
Traffic interruption:								
Highways	250,000	30,000	193,000	378,000		300,000	85,000	1,236,000
Railroads			50,000	65,000	375,000	24,000	35,000	549,000
Navigation	130,000		50,000		225,000			405,000
Air terminals			5,000	125,000				130,000
Emergency expenditures	8,000	12,000	29,000	1,866,000	25,000	1,076,000	529,000	3,545,000
Subtotal, indirect losses	486,000	1,055,000	1,287,000	7,568,000	3,549,000	3,040,000	2,189,000	19,174,000
Total damages	1,473,000	1,943,000	3,692,000	38,796,000	10,275,000	14,978,000	7,661,000	78,818,000

JUNE 1933 FLOOD MAGNITUDE

Type of damage	Yakima River to Bonneville	Bonneville to Camas and Sandy River	Camas to Lewis River	Sandy River to Willamette River	Portland area, Willamette River backwater	Lewis River, Washington to Baker Bay	Willamette River, Oregon to Youngs Bay	Total
DIRECT DAMAGE								
Agricultural	$10,000		$194,000	$120,000		$650,000	$405,000	$1,379,000
Residential	5,000		3,000	25,000	$21,000	10,000		64,000
Commercial	10,000		79,000	10,000	33,000	10,000	15,000	157,000
Industrial	10,000	$73,000	85,000	73,000	242,000	98,000	216,000	797,000
Utilities					17,000	215,000	7,000	239,000
Municipal					50,000	25,000		75,000
Highways, roads, and bridges	10,000		5,000			210,000	25,000	250,000
Trucks, busses, and terminals								
Railroads	2,000					35,000		37,000
Air terminals								
Navigation	5,000				15,000	15,000		35,000
Dikes			15,000	75,000		350,000	275,000	715,000
Emergency expenses								
Subtotal, direct damage	52,000	73,000	381,000	303,000	378,000	1,618,000	943,000	3,748,000
INDIRECT LOSSES								
Agricultural						78,000	45,000	123,000
Residential								
Commercial								
Industrial	5,000	50,000	30,000	22,000	96,000	27,000	110,000	340,000
Utilities		106,000				55,000		161,000
Traffic interruption:								
Highways						40,000		40,000
Railroads						40,000		40,000
Navigation	10,000				35,000			45,000
Air terminals								
Emergency expenditures								
Subtotal, indirect losses	15,000	156,000	30,000	22,000	131,000	240,000	155,000	749,000
Total damages	67,000	229,000	411,000	325,000	509,000	1,858,000	1,098,000	4,497,000

TABLE 34.—*Pertinent data—Constructed and proposed dams*

Item	Unit	Bonneville (constructed)	The Dalles (proposed)	John Day, navigation, flood storage and power (proposed)	McNary (under construction)
General data:					
Height (normal headwater to minimum tailwater).	Feet	65	87.5	94.5	84.5
Over-all length	do	2,477	8,420	4,000	8,300
Stream mile (from mouth)	Mile	145.3	192.5	217.3	292.0
Drainage area	Square mile	240,000	237,000	226,000	213,500
Distance from Portland (airline)	Mile	36	80	96	168
Distance from Spokane (airline)	do	256	240	205	150
Distance from Boise (airline)	do	283	275	262	218
Discharge:					
Mean annual (1878 to 1946)	Second-feet	201,000	193,900	188,000	185,000
Minimum of record	do	38,000	35,000	30,500	30,000
Average regulated [1]	do	112,950	109,250	105,080	103,580
Maximum of record (June 1894).	do	1,170,000	1,170,000	1,160,000	1,150,000
Spillway design	do	1,600,000	2,290,000	2,250,000	2,220,000
River elevation (power plant tailwater):					
Discharge:					
Minimum of record	Feet mean sea level.	6.0	72.1	160.2	[2] 255.0
Average regulated	do	14.0	73.2	161.0	[2] 256.0
800,000 second-feet	do	39.5	103.5	179.0	[2] 279.0–296.0
Maximum of record (June 1894).	do	52.7	110.0	188.0	[2] 299.4
Spillway design	do		124.0	208.5	[2] 311.1
Reservoir:					
Elevation:					
Drawn down pool	do	69.0	157.0	252.0	337.0
Normal pool	do	72.0	160.0	255.0	340.0
Maximum pool (free discharge).	do	82.5	176.5	290.7	356.5
Maximum controlled pool	do	72.0	160.0	292	340.0
Flood control storage	Acre-feet	0	0	[3] 1,927,000	0
River discharge at start of storage	Second-feet			800,000	
Length at normal pool	Mile	47.2	31.3	74.7	59.2
Area at normal pool	Acre	20,300	11,000	44,000	37,900
Pondage—3-foot drawdown	Acre-feet	60,000	33,000	130,000	105,000
Highway revision (State and county).	Mile		18.7	108.6	47.47
Railroad revision	do		81.4	164.6	89.49
Land acquisition	Acres		5,937	47,832	41,963
Spillway dam:					
Length—over-all	Feet	1,070	1,848	1,310	1,310
Elevation:					
Crest	Feet mean sea level.	24.0	119.0	223.5	291.0
Bridge deck	do	97.0	185.0	297.0	361.0
Height—maximum (foundation to deck).	Feet	197	115	200	158
Gates:					
Type (vertical lift)		(4)	(4)	(4)	(4)
Number		18	30	22	22
Size (width by height including 2 feet freeboard	Feet	12-50x50 6-50x60	50x43	50x57	50x53
Gate operation		(5)	(5)	(5)	(5)
Discharge capacity at normal pool	Second-feet		1,200,000	650,000	1,430,000
Stilling basin type		(6)	(7)	(8)	(8)

[1] Average regulated flow during critical power period (1929–32).
[2] With John Day Reservoir as proposed for navigatin, flood storage, and power.
[3] Between backwater curves, discharge=800,000 second-feet.
[4] Fixed wheel.
[5] 2 gantry cranes.
[6] 2 level apron with baffles and end sill.
[7] Bucket with perforated end sill.
[8] Horizontal apron with baffles and end sill.

TABLE 34.—*Pertinent data—Constructed and proposed dams*—Continued

Item	Unit	Bonneville (constructed)	The Dalles (proposed)	John Day, navigation, flood storage, and power (proposed)	McNary (under construction)
Power facilities:					
Powerhouse length—over-all	Feet	1,027	1,478	1,298	1,403
Maximum height—foundation to intake deck.	do	145	192	357	180
Number of units installed		10	14	13	14
Number of additional units provided for in powerhouse structure.		0	2	1	0
Number of additional units for which space reservation is made.		0	4	4	6
Total installed capacity [9]	Kilowatts	518,400	980,000	1,105,000	980,000
Head:					
Maximum	Feet	65.0	87.5	[10] 113	84.5
Rated	do	58.0	85.0	93.0	83.0
For discharge of 800,000 second-feet.	do	39.5	56.5	76.0	62.0
For discharge of 600,000 second-feet.	do		60.0	81.0	66.0
Nominal prime capability	do	476,000	689,000	722,000	621,000
Nominal firm capability at 75 percent load factor.[11]	do	570,000	919,000	963,000	832,000
Navigation lock:					
Type		(12)	(12)	(12)	(12)
Normal lift	Feet	66	87.5	94.5	[2] 84.5
Net clear length	do	500	675	675	675
Net clear width	do	76	86	86	86
Depth over lower sill (minimum)	do	24	14	14	[13] 19
Depth over upper sill at normal pool elevation.	do	32	17	17	20
Non-overflow dam:					
Concrete—total length	do		3,466	1,252	339
Embankment—total length	do		583	0	4,885
Fish facilities:					
Ladders—number of units		3	3	2	2
Fish locks—number of units		6		2	1
Total construction time	Years		7½	8¼	

[9] In accordance with phase C development, appendix O.
[10] Initial flood storage regulation to 800,000 second-feet at pool 292, with ultimate regulation to 600,000 second-feet maximum head will be 118 feet.
[11] Dependable peaking capability, winter season.
[12] Single lift.
[13] With John Day Reservoir at normal pool elevation 265.

TABLE 35.—*Existing and authorized navigation projects*

Feature	River miles, Columbia River	Depth at low water	Width or other controlling dimensions	Status
MAIN CHANNEL				
At the mouth	0	40 feet	2,700 feet	Completed.
Portland (Broadway Bridge) to the sea.	[1] 0-101.0	35 feet	500 feet	Do.
Portland—Broadway Bridge to Ross Island Bridge.	(2)	30 feet	300 feet	Completed.[2]
Mouth Willamette to Vancouver.	101.0-106.0	30 feet	300 feet	Completed.
Vancouver to The Dalles	106.0-191.1	27 feet	300 feet	46 percent completed.
Celilo Falls to Wallula	201.1-314.3	7 feet	150 feet	75 percent completed.
Wallula to Kennewick	314.3-328.0	None specified	None specified	
Mouth of Snake River to Kennewick.	324.2-328.0	Obstruction removal		
AUXILIARY CHANNELS				
Baker Bay, Wash.:				
Westerly channel	3.0	8 feet	200 feet	33 percent completed.
Easterly channel	4.0	10 feet	200 feet	Completed.
Sand Island to Chinook, Wash.	7.0	8 feet	150 feet	Do.
Youngs Bay, Oreg	10.0	10 feet	150 feet	Do.
Skipanon, Oreg	10.7	30 feet	200 feet	Do.
Deep River, Wash	20.0	8 feet	100 feet	Do.
Grays River, Wash	21.0	Snag removal		Do.
Skamokawa (Steamboat slough), Wash.	33.0	24 feet	150 feet	No construction.
Skamokawa Creek, Wash	33.3	6.5 feet	75 feet	Completed.
Elokomin slough, Wash	35.8	10 feet	100 feet	Do.
Cathlamet, Wash	38.0	10 feet	300 feet	Do.
Westport slough, Oreg	43.5	28 feet	200 feet	Do.
Clatskanie, Oreg	50.0	6 feet	40 feet	Do.
Longview, Wash	64.0	28 feet	250 feet	No construction.
Rainier, Oreg.	67.4	24 feet	200 feet	Completed.
Old mouth of Cowlitz River, Wash.	67.7	8 feet	150 feet	No construction.
Cowlitz River, Wash	67.7	4 and 2.5 feet	50 feet	Completed.
St. Helens, Oreg	86.0	30 feet	500 feet	Do.
Multnomah channel, Oreg	86.5	25 feet	300 feet	Do.
Lake River, Wash	87.6	6 feet	100 feet	Do.
Lewis River, Wash	87.6	6 feet	50 feet	Do.
Oregon slough, Oreg	102.3	20 feet	200 feet	Do.
Oregon slough (upper entrance), Oreg.	108.0	10 feet	300 feet	No construction.
Bingen, Wash	171.0	10 feet	200 feet	Do.
Arlington, Oreg	242.0	6 feet		Completed.
Kennewick, Wash	328.0	6 feet		No construction.
HARBORS AND BOAT MOORING BASINS				
Warrenton small boat harbor, Oreg.	10.7	12-foot draft	700 by 800 feet	Do.
Astoria mooring basin, Oreg	14.0	18-foot draft	1,000 boats	Do.
Hood River mooring basin, Oreg.	169.0	10 feet	500 by 1,300 feet	Do.
The Dalles Harbor, Oreg	190.0	8 feet	400 by 800 feet	Do.
TURNING BASINS				
Skipanon (Warrenton), Oreg	10.7	30 feet	450 by 450 feet	Completed.
Skamokawa (Winters wharf), Wash.	33.3	24 feet	250 by 250 feet	No construction.
Vancouver (2 basins), Wash	106.0	30 feet	800 by 2,000 feet and 800 by 3,000 feet.	Completed.
Camas-Washougal, Wash	122.0	27 feet	1,000 by 3,000 feet.	No construction.
LOCKS				
Bonneville Dam	145.3	24.2 feet	76 by 500 feet	Completed.
The Dalles-Celilo canal (4 chambers).	192.8-201.1	7.8 feet	45 by 265 feet	Do.
McNary (Umatilla Dam)	292.0	12 feet	86 by 675 feet	Under construction.

[1] 11 miles additional in Willamette River.
[2] 3 miles in Willamette River. Maintained by Port of Portland.

TABLE 36.—*Existing and authorized flood-control projects*

Project	County	State	Location mile on Columbia River	Area protected, acres	Description of improvement	Status
CORPS OF ENGINEERS AND LOCAL INTERESTS						
Diking improvement district No. 1	Pacific	Washington	3.0	1,538	Pile and stone dike	Completed.
Warrenton diking district No. 1	Clatsop	Oregon	8.0	1,915	Levees, drainage, and revetment	Do.
Warrenton diking district No. 2	do	do	10.2	996	do	Do.
Warrenton diking district No. 3	do	do	10.7	945	do	Do.
Diking district No. 2	do	do	11.3	248	do	Do.
Lewis and Clark River area, diking district No. 8.	do	do	13.0	1,181	do	Do.
Lewis and Clark River area, diking district No. 11.	do	do	13.0	325	do	Do.
Diking district No. 3	do	do	13.0	485	Levees and drainage	Awaiting local cooperation.
Diking district No. 5	do	do	13.3	535	Levees, drainage, and revetment	Completed.
Youngs River area, diking district No. 9	do	do	14.0	2,528	do	Do.
Walluski River area, diking district No. 13	do	do	15.0	610	Levees and drainage	Do.
John Day River area, diking district No. 14	do	do	18.5	246	do	Do.
Svensen Island District Improvement Co	do	do	19.5	301	Emergency repairs to dike	Do.
Deep River area	Wahkiakum	Washington	20.0	425	Levees and drainage	Do.
Upper Grays River area	do	do	24.0	2,100	Channel clearing and revetment	Do.
Karlson Island diking district No. 10	Clatsop	Oregon	25.5	370	Levees, drainage, and revetment	Do.
Knappa area diking district No. 12	do	do	26.6	69	Levees and drainage	Do.
Drainage district No. 1	do	do	29.0	1,391	Levees, drainage and revetment	Do.
Diking district No. 5	Wahkiakum	Washington	30.0	1,500	Levees, diversion canal	Do.
Blind slough diking district No. 7	Clatsop	Oregon	31.0	928	Levees, drainage, and revetment	Do.
Diking improvement district No. 4	Wahkiakum	Washington	33.7	2,271	Levees and drainage	66 percent complete.
Tenasillahe Island diking district No. 6	Clatsop	Oregon	34.6	1,709	do	Completed.
Diking district No. 1	Wahkiakum	Washington	38.8	3,200	Levees, drainage, and revetment	Do.
Diking district No. 3	do	do	38.8	740	do	Do.
Westport diking district No. 15	Columbia and Clatsop	Oregon	43.4	233	Levees and diversion canal	Do.
Westland District Improvement Co	Columbia	do	44.0	1,091	Levees, drainage, and revetment	Do.
Woodson drainage district	do	do	45.0	355	Levees and drainage	Do.
Marshland drainage district	do	do	45.6	976	do	Do.
Webb District Improvement Co	do	do	46.0	720	Levees, drainage, and revetment	Do.
Midland drainage district	do	do	47.4	1,300	do	Do.
Magruder drainage district	do	do	47.6	592	Levees and drainage	Do.
Beaver drainage district	do	do	50.0	5,595	Levees, drainage, and revetment	Do.
Diking improvement district No. 15	Cowlitz	Washington	56.8		Repairs—flood damage to local interests levee.	Do.
Consolidated diking improvement district No. 1	do	do	60.7	9,885	Levees and drainage	Do.
Rainier drainage district	Columbia	Oregon	62.6	1,287	do	Do.
Diking improvement district No. 2	Cowlitz	Washington	68.8	1,146	Stone revetment	Do.
Diking improvement district No. 13	do	do	68.8	208	Levee and revetment	Do

Drainage improvement district No. 1	do	do	68.8	269	Drainage	Do.
Prescott area	Columbia	Oregon	72.4	500	Levee and drainage	Awaiting local cooperation.
Deer Island drainage district	do	do	76.8	3,950	Levees, drainage, and revetment	Completed.
Diking improvement district No. 5	Cowlitz	Washington	84.0	5,629	Revetment and diversion canal	Do.
Diking improvement district No. 11	do	do	84.0	1,740	Revetment and channel improvement	Do.
Scappoose drainage district	Columbia	Oregon	90.0	5,763	Levees, drainage, and revetment	Do.
Columbia drainage district No. 1	do	do	95.0	1,602	Emergency repairs	Do.
Sauvie Island drainage district	Multnomah	do	97.0	11,376	Levees and revetment	Do.
Peninsula drainage district No. 1	do	do	105.0	901	Levees and drainage	Do.
Peninsula drainage district No. 2	do	do	106.5	1,425	Levees, drainage, and revetment	Do.
Multnomah drainage district No. 1	do	do	105.0	8,417	Levees and revetment	90 percent complete.
Sandy drainage district	do	do	118.5	1,556	Levees and drainage	Completed.
Alkali Canyon, Arlington, Oreg	Gilliam	do	241.6		Channel improvement	No construction.
Subtotal				[1] 92,117		
LOCAL INTERESTS AND CIVIL WORKS ADMINISTRATION						
Deep River area	Wahkiskum	Washington	20.0	820	Levees	Completed.
Lower Grays River area	do	do	24.0	840	do	Do.
Clatskanie drainage district	Columbia	Oregon	50.0	300	do	Do.
John drainage district	do	do	56.0	153	Levees and bulkheads	Do.
District No. 17 area	Cowlitz	Washington	60.0	381	Levees	Do.
Subtotal				2,494		
LOCAL INTERESTS, CIVIL WORKS ADMINISTRATION, AND WORKS PROGRESS ADMINISTRATION						
Diking improvement district No. 15	Cowlitz	Washington	56.8	845	Levees and revetment	Do.
LOCAL INTERESTS						
Upper Skipanon River area	Clatsop	Oregon	10.5	127	Levees	Do.
Svensen miscellaneous areas	do	do	19.5	150	do	Do.
Gnat Creek, Blair area	do	do	29.0	18	do	Do.
Diking district No. 4	do	do	29.0	90	do	Do.
Clatskanie slough area	Columbia	do	48.0	80	do	Do.
Palm drainage district	do	do	49.2	28	do	Do.
Clatskanie River area	do	do	50.0		Piling and timber bulkheads	Do.
LaCenter area	Cowlitz	Washington	86.0	400	Levees	Under construction.
Lewis River area	do	do	89.0	800	do	Completed.
Bachelor Island area	Clark	do	90.0	2,100	do	Under construction.
Tomahawk Island area (Lotus Isle)	Multnomah	Oregon	106.7	40	do	Completed.
Subtotal				3,833		
Total				99,289		

[1] Excluding 985 acres authorized for protection for which local cooperation has not been fulfilled.

TABLE 37.—*Navigation channel velocities at critical locations under proposed slackwater development* [1]

Flow at The Dalles, second-feet [2]	Average velocities in miles per hour							Percent of time velocity is equaled or exceeded [2]
	Hamilton Island, mile 142.7	Sheridan Point, mile 147.8	The Dalles, mile 189.7	Hell Gate Rapids, mile 205.9	Scho-field Rapids, mile 215.0	Mile 289.3	Pasco Bridge, mile 328.5	
100,000	2.9	1.2	0.9	0.5	1.0	1.7	0.8	100.0
125,000	3.3	1.5	1.1	0.6	1.2	2.0	1.1	52.0
200,000	3.8	2.3	1.8	0.9	1.9	2.7	1.7	17.0
300,000	4.3	3.3	2.5	1.4	2.5	3.4	2.4	12.0
400,000	4.6	4.1	3.1	1.8	3.2	3.9	3.0	7.0
500,000	4.8	4.9	3.7	2.1	3.7	4.4	3.6	4.0
600,000	5.2	5.9	4.4	2.4	4.1	4.8	4.0	2.5
800,000	5.7	7.7	5.6	3.0	4.8	5.4	4.7	0

[1] Open river mile 0 to mile 145.3; Bonneville Dam mile 145.3 normal pool elevation 72 (existing); The Dalles Dam mile 192.5 normal pool elevation 160 (proposed); John Day Dam mile 217.3 normal pool elevation 255 (proposed); McNary Dam mile 292.0 normal pool elevation 340 (under construction).

[2] Conditions as for main control plan. (See appendix M.)

TABLE 38.—*Storage capacity data, John Day Reservoir*

Reach and low-water elevation	Storage in acre-feet between elevations—														
	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
Mile 217.3 to 219.03, elevation 144	3,790	8,950	15,340	23,420	34,845	51,520	68,195	84,870	101,545	118,220	140,540	162,860	185,180	207,500	229,820
Mile 219.03 to 223.0, elevation 148	5,520	16,030	28,485	42,030	56,790	73,665	90,540	107,415	124,290	141,165	160,190	179,215	198,240	217,265	236,290
Mile 223.0 to 227.22, elevation 152	--------	2,440	9,735	22,365	36,300	51,945	69,905	90,115	112,415	136,530	163,280	190,030	216,780	243,530	270,280
Mile 227.22 to 231.37, elevation 160	--------	--------	10,700	22,760	36,840	54,130	72,955	93,995	116,820	140,660	166,475	192,240	218,005	243,770	269,535
Mile 231.37 to 235.65, elevation 164	--------	--------	7,500	19,175	33,760	49,625	67,615	88,145	108,675	129,205	151,400	173,595	195,790	217,985	240,180
Mile 235.65 to 239.70, elevation 172	--------	--------	--------	9,620	21,015	34,475	48,490	63,040	77,975	93,185	110,470	127,755	145,040	162,325	179,610
Mile 239.70 to 242.86, elevation 178	--------	--------	--------	5,315	14,655	24,790	35,630	47,490	60,940	76,320	94,880	113,440	132,000	150,560	169,120
Mile 242.86 to 247.15, elevation 182	--------	--------	--------	5,050	19,100	35,525	53,935	74,525	97,090	121,105	147,670	174,235	200,800	227,365	253,930
Mile 247.15 to 251.30, elevation 189	--------	--------	--------	260	9,820	24,975	42,325	61,835	83,640	108,145	136,030	163,915	191,800	219,685	247,570
Mile 251.30 to 255.18, elevation 195	--------	--------	--------	--------	2,810	15,045	28,925	44,650	63,040	84,620	108,385	133,490	160,445	189,620	220,875
Mile 255.18 to 258.74, elevation 197	--------	--------	--------	--------	1,590	13,390	27,035	41,940	58,180	75,585	95,790	116,725	138,430	160,915	184,290
Mile 258.74 to 261.75, elevation 203	--------	--------	--------	--------	--------	3,480	13,845	25,050	37,440	51,585	67,725	85,585	104,755	125,170	146,800
Mile 261.75 to 264.45, elevation 207	--------	--------	--------	--------	--------	485	5,650	13,325	22,050	32,865	48,140	68,850	93,890	122,175	180,540
Mile 264.45 to 267.33, elevation 208	--------	--------	--------	--------	--------	--------	5,490	15,795	27,710	45,540	70,605	100,935	137,750	180,540	229,235
Mile 267.33 to 272.11, elevation 216	--------	--------	--------	--------	--------	--------	--------	12,775	36,565	71,215	121,680	187,990	263,760	347,720	438,385
Mile 272.11 to 276.28, elevation 223	--------	--------	--------	--------	--------	--------	--------	--------	13,810	31,560	56,185	96,385	153,110	220,335	293,960
Mile 276.28 to 278.91, elevation 225	--------	--------	--------	--------	--------	--------	--------	--------	6,545	16,265	28,235	48,280	78,355	114,795	154,815
Mile 278.91 to 281.05, elevation 232	--------	--------	--------	--------	--------	--------	--------	--------	2,045	7,660	14,015	25,000	46,185	79,460	120,685
Mile 281.05 to 283.56, elevation 232	--------	--------	--------	--------	--------	--------	--------	--------	3,005	10,880	19,580	31,375	47,950	69,555	96,810
Mile 283.56 to 286.11, elevation 234	--------	--------	--------	--------	--------	--------	--------	--------	1,385	8,470	18,630	29,940	42,680	58,325	79,125
Mile 286.11 to 288.70, elevation 245	--------	--------	--------	--------	--------	--------	--------	--------	--------	2,385	12,450	23,690	36,565	53,245	74,580
Mile 288.70 to 292.00, elevation 247	--------	--------	--------	--------	--------	--------	--------	--------	--------	1,265	10,815	22,370	36,720	55,980	79,185
Total	9,310	27,420	71,760	149,955	267,525	433,050	630,535	864,965	1,155,165	1,504,430	1,943,170	2,447,900	3,024,230	3,667,820	4,368,640

TABLE 39.—*Proposed diking and drainage and bank-protection projects*

DIKING AND DRAINAGE

River mile	Location	State	Area, acres
125.0	Washougal area [1]	Washington	2,260
118.5	Sandy drainage district [2]	Oregon	1,556
112.0	Multnomah County drainage district No. 1 [2]	do	8,417
108.0	Hidden area	Washington	750
107.0	Portland area	Oregon	2,600
106.5	Peninsula drainage district No. 2 [2]	do	1,425
105.0	Peninsula drainage district No. 1 [2]	do	901
105.0	Hayden Island	do	850
100.0	Vancouver Lake area	Washington	10,000
97.0	Sauvie Island (areas A and B) [2]	Oregon	11,376
95.0	Columbia drainage district No. 1 [1]	do	1,602
90.0	Bachelor Island area [1]	Washington	3,330
90.0	Scappoose drainage district [2]	Oregon	5,763
89.0	Lewis River area [1]	Washington	1,600
84.0	Cowlitz County dike-improvement districts Nos. 5 and 11 [2]	do	7,369
76.8	Deer Island drainage district [2]	Oregon	3,950
74.0	Kalama River-South area	Washington	610
68.8	Cowlitz County diking improvement districts Nos. 2 and 13 [2]	do	1,354
60.7	Consolidated diking improvement district No. 1 [2]	do	9,885
56.8	Cowlitz County diking improvement district No. 15 [2]	do	845
56.0	John drainage district [1]	Oregon	153
50.0	Beaver drainage district [2]	do	5,595
50.0	Clatskanie drainage district [1]	do	300
50.0	Clatskanie River area	do	Town
47.6	Magruder drainage district [2]	do	592
47.4	Midland drainage district [2]	do	1,300
45.0	Woodson drainage district [2]	do	355
38.8	Puget Island area, Wahkiakum County diking districts 1 and 3 [2]	Washington	3,940
34.6	Tenasillahe Island diking district No. 6 [2]	Oregon	1,709
33.7	Wahkiakum diking improvement district No. 1 [2]	Washington	2,271
29.0	Clatsop County diking district No. 4 [1]	Oregon	90
29.0	Clatsop County drainage district No. 1 [2]	do	1,391

BANK PROTECTION

River mile	Name of area	State	Bank	Length, feet
	WILLAMETTE RIVER			
2.0	Sauvie Island	Oregon	Left	500
1.7	do	do	do	400
1.4	do	do	do	400
1.2	do	do	do	200
1.0	do	do	do	300
	MULTNOMAH CHANNEL			
16.6	Sauvie Island, Rau location	Oregon	Right	1,500
15.3	Sauvie Island, Cline location	do	do	6,000
9.9	Scappoose drainage district, Chapman location	do	Left	4,500
7.5	Scappoose drainage district, Whites location	do	do	100
	COLUMBIA RIVER			
123.0	Washougal area	Washington	Right	3,000
118.0	Multnomah drainage district No. 1, Crosby location	Oregon	Left	200
117.7	Multnomah drainage district No. 1, Pullen location	do	do	500
116.9	Multnomah drainage district No. 1, Wilmot location	do	do	1,200
115.0	Multnomah drainage district No. 1, Hamilton location	do	do	1,000
114.1	Multnomah drainage district No. 1, Powell location	do	do	2,000
112.3	Multnomah drainage district No. 1, 96th Ave. location	do	do	500
111.4	Multnomah drainage district No. 1, Holtgreive location	do	do	500
111.0	Multnomah drainage district No. 1, Carson location	do	do	1,000
109.4	Multnomah drainage district No. 1, Airport location	do	do	1,000
108.2	Multnomah drainage district No. 1, Col. Marina location	do	do	2,000
107.8	Peninsula drainage district No. 2, Portland Yacht Club location	do	do	1,000
107.5	Tomahawk Island	do	Island	1,000
106.1	Peninsula drainage district No. 1, Stock Show location	do	Left	200
105.8	Vancouver Mill	Washington	Right	300
105.7	Peninsula drainage district No. 1, Swift location	do	do	200
103.0	Vancouver Lake area, Mathew D.L.C. location	do	do	1,000
102.7	Vancouver Lake area, Mathews Point	do	do	500
101.3	Sauvie Island, Belle Vue Point	Oregon	Left	500
101.3	Vancouver Lake area, Hatten D.L.C. location	Washington	Right	500
100.8	Vancouver Lake area, Blurock Landing	do	do	1,000
100.5	Sauvie Island, Morgan D.L.C. location	Oregon	Left	1,400

[1] Existing diking and drainage projects, local.
[2] Existing diking and drainage projects, Corps of Engineers participation.

TABLE 39.—*Proposed diking and drainage and bank-protection projects*—Continued

BANK PROTECTION—Continued

River mile	Name of area	State	Bank	Length, feet
	COLUMBIA RIVER—continued			
100.4	Vancouver Lake area, Hewlett Point	Washington	Right	500
98.4	Vancouver Lake area, Sturgess D.L.C. location	do	do	1,000
98.0	Sauvie Island, Hutchinson location	Oregon	Left	500
97.4	Sauvie Island, Reeder Point	do	do	2,500
97.3	Beatty D.L.C. location	Washington	Right	1,500
95.0	Knapp Point	do	do	5,000
94.2	Sauvie Island, Willow Point	Oregon	Left	2,400
87.5	Bachelor Island area	Washington	Right	11,500
82.5	Cowlitz County diking district No. 5	do	do	1,000
79.7	Deer Island drainage district	Oregon	Left	9,000
73.0	Kalama River area south	Washington	Right	5,000
60.0	Cowlitz County diking-improvement district No. 17, Fisher Island Channel.	do	do	1,000
59.5	Cowlitz County diking-improvement district No. 15, Fisher Island Channel.	do	do	500
59.1	Cowlitz County diking-improvement district No. 15, Fisher Island Channel.	do	do	600
58.8	Cowlitz County diking-improvement district No. 15, Fisher Island Channel.	do	do	600
56.7	Crims Island South End	Oregon	Island	1,000
55.2	John drainage district Bradburg Slough	do	Left	2,000
49.7	Beaver Slough, Magruder drainage district	do	do	600
49.7	Beaver Slough, Beaver drainage district	do	do	10,400
49.7	Clatskanie drainage district	do	do	3,200
49.3	Midland drainage district	do	do	1,000
45.5	Westland District Improvement Co	do	do	600
44.1	Westland District Improvement Co	do	do	300
40.8	Wahkiakum diking district No. 1	Washington	Island	4,000
39.1	Wahkiakum diking district Nos. 1 and 3	do	do	5,500
38.3	Wahkiakum diking district No. 3	do	do	1,000
36.2	Tenasillahe Island diking district	Oregon	do	200
34.4	Tenasillahe Island diking district, east side	do	do	1,500
34.1	Wahkiakum diking district No. 4	Washington	Right	400
27.9	Blind Slough, right bank	Oregon	Left	3,000
27.8	Blind Slough, left bank	do	do	4,000
27.5	Brownsmead diking district	do	do	2,000
27.1	Karlson Island diking district	do	do	2,000
23.9	Svensen Island improvement district	do	do	2,000
9.0	Hammond waterfront	do	do	2,100
	Total			123,800

TABLE 40.—*Possible future diking and drainage and bank protection projects*

DIKING AND DRAINAGE

River mile	Location	State	Area, acres
121.0	Sandy River, east area	Oregon	1,280
115.0	Government Island area	do	1,850
103.0	Lower Peninsula area	do	
100.0	Burlington district area	do	1,030
95.0	Sturgeon Lake area	do	8,380
94.0	Campbell Lake area	Washington	1,910
91.0	Warren area	Oregon	2,140
90.0	Sauvie Island, area C	do	1,730
72.0	Kalama River, north area	Washington	860
70.0	Carrols area	do	980
62.6	Rainier drainage district [2]	Oregon	1,287
60.0	Cowlitz County diking improvement district No. 17 [1]	Washington	500
55.0	Crims Island	Oregon	408
49.0	Wallace Island	do	510
45.0	Kerry Island	do	100
44.0	Wauna area	do	550
43.4	Westport area diking district No. 15 [2]	do	233
38.0	Hunting Island	Washington	920
37.0	Elokomin River area	do	750
26.6	Knappa-Columbia slough area	Oregon	380
25.5	Karlson Island [2]	do	520
24.0	Lower Grays River district [2]	Washington	1,740
20.0	Deep River area [2]	do	820
19.5	Svensen Island District Improvement Co.[2]	Oregon	301
10.0	Upper Skippanon and Cullaby Lake [1]	do	2,850

BANK PROTECTION

River mile	Name of area	State	Bank	Length, feet
	WILLAMETTE RIVER			
3.5	Lower Peninsula area	Oregon	Right	500
	MULTNOMAH CHANNEL			
15.4	Burlington area, Tomlenson location	do	Left	4,500
8.5	Sauvie Island, east bow location	do	Right	8,000
8.4	Scappoose drainage district, Reasoner location	do	Left	1,000
7.6	Sauvie Island, Fargher location	do	Right	1,500
4.8	Sauvie Island, Horst location	do	do	3,500
3.2	Hoyt D. L. C. location	do	Left	4,200
0.9	Lower Peninsula area	do	Right	500
	COLUMBIA RIVER			
115.9	Government Island, Bartlet Landing	do	Left	1,000
115.6	Government Island, south side	do	Island	4,500
115.2	Punkin Center location	Washington	Right	1,000
114.8	Government Island, north side	Oregon	Island	1,000
114.7	Government Island, south side	do	do	2,000
113.4	Government Island, south side	do	do	2,000
112.7	Taylor D. L. C. location	Washington	Right	1,000
112.6	Government Island, south side	Oregon	Island	1,000
112.4	Lemon Island	do	do	1,000
110.8	Image location	Washington	Right	800
110.6	Leiser Point	do	do	800
105.3	Hayden Island area	Oregon	Left	1,000
104.0	Lower Peninsula area	do	do	300
101.3	Sauvie Island, Belle Vue Point	do	do	500
95.3	Sauvie Island	do	do	5,000
91.3	Campbell Lake area	Washington	Right	17,000
89.3	Sauvie Island, Henrici landing	Oregon	Left	6,000
71.6	Kalama River area, north	Washington	Right	4,300
57.3	Cowlitz Co. diking imp. dist. No. 15, Coal Creek slough	do	do	13,300
35.0	Tenasillahe Island diking Dist., north end	Oregon	Island	1,000
	Total			88,200

[1] Existing diking and drainage projects, local.
[2] Existing diking and drainage projects, Corps of Engineers participation.

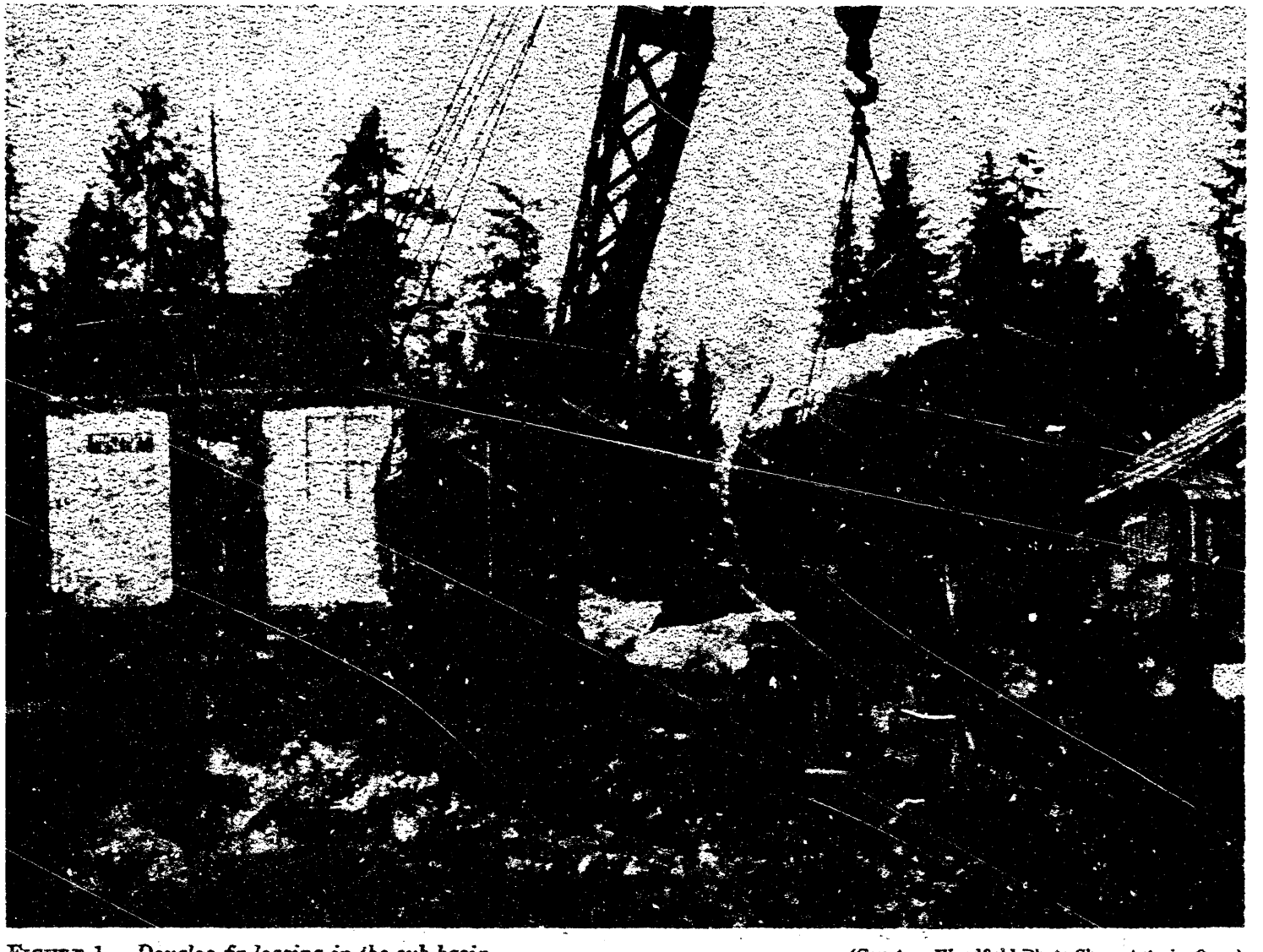


FIGURE 1.—*Douglas fir logging in the sub-basin.* (Courtesy Woodfield Photo Shop, Astoria, Oreg.)

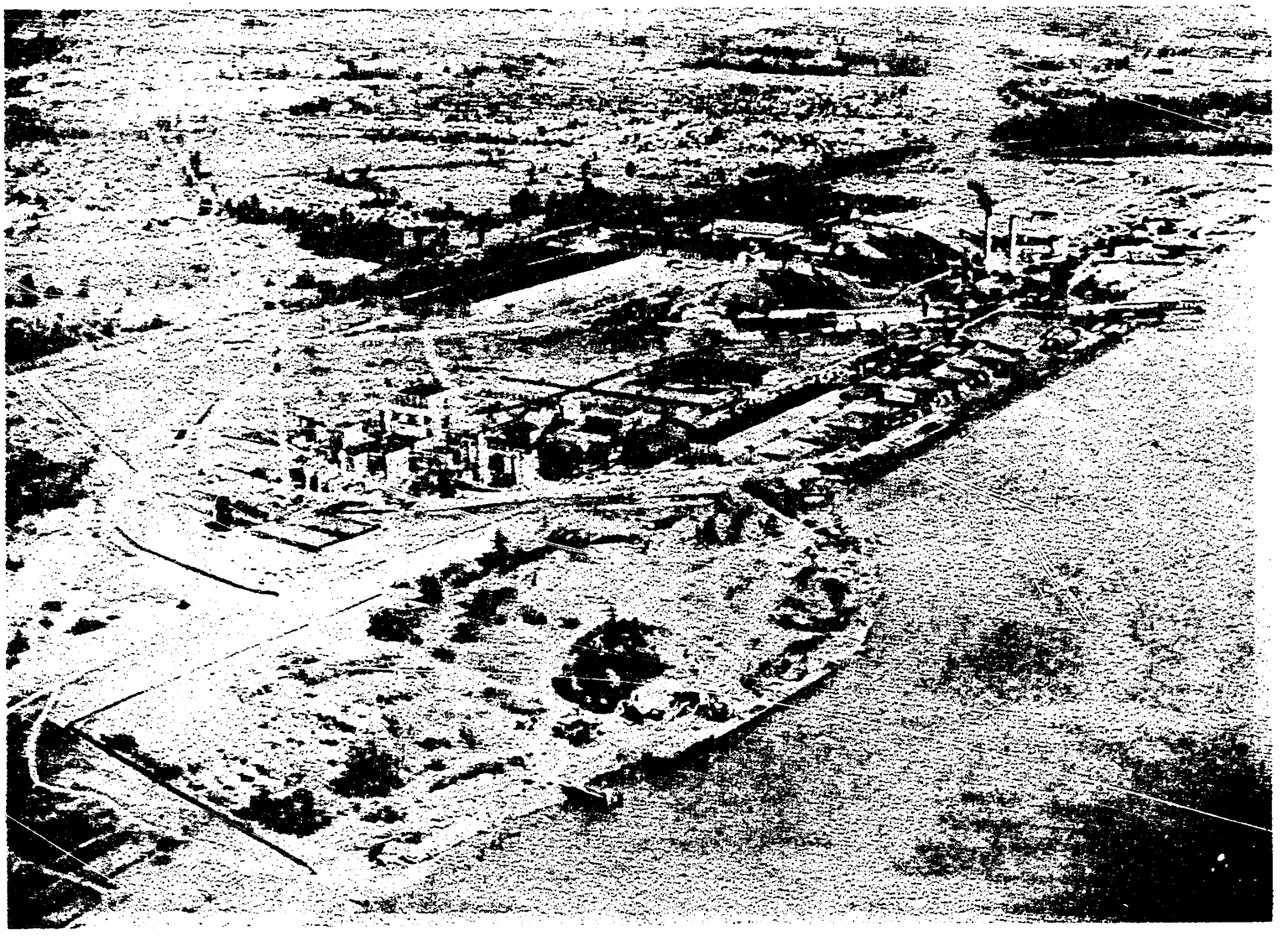


FIGURE 2.—*Timber products plants at Longview, Wash.* (Courtesy Rankin's Studio, Kelso, Wash.)

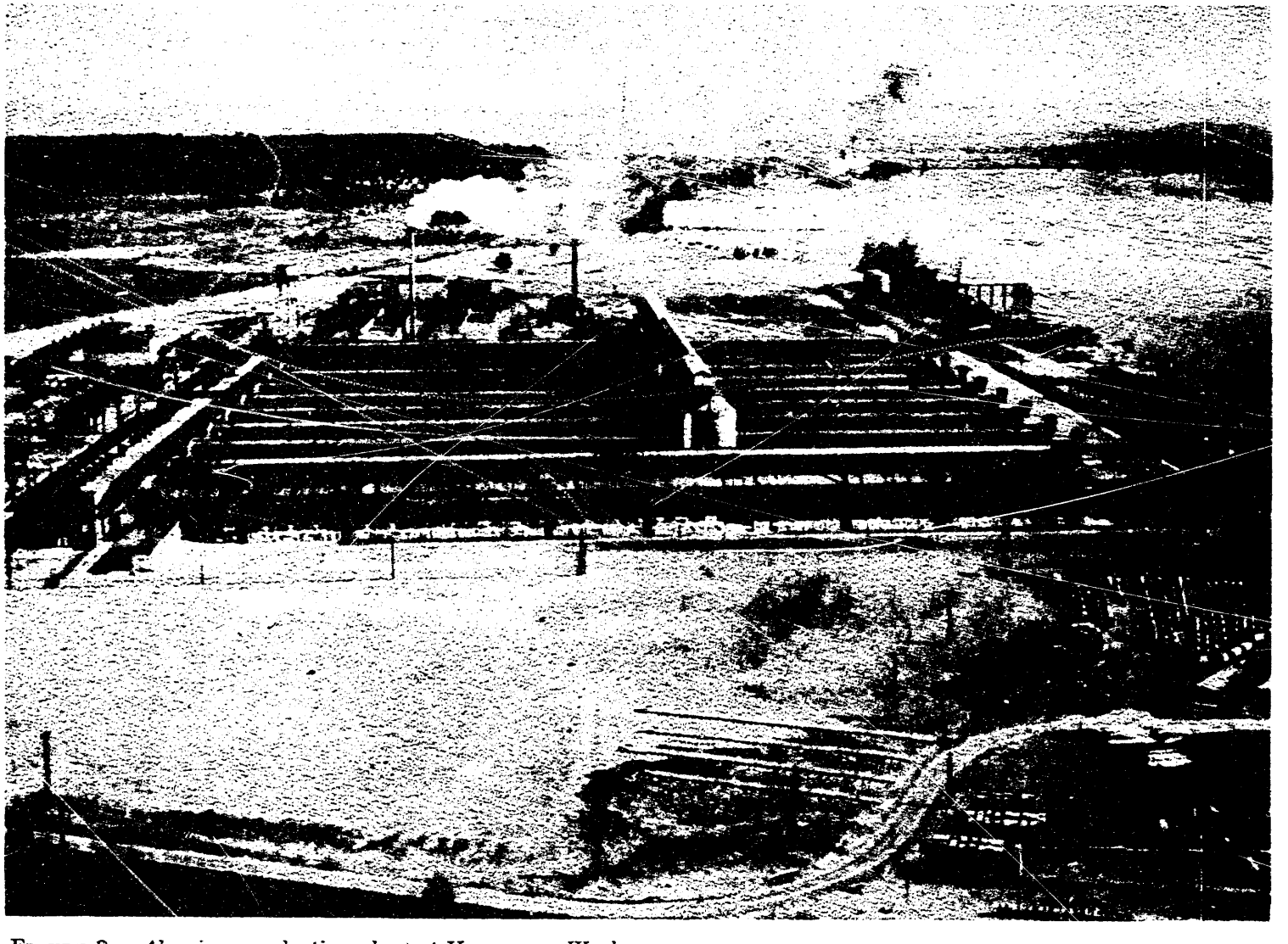


FIGURE 3.—*Aluminum reduction plant at Vancouver, Wash.* (Courtesy Chamber of Commerce, Vancouver, Wash.)

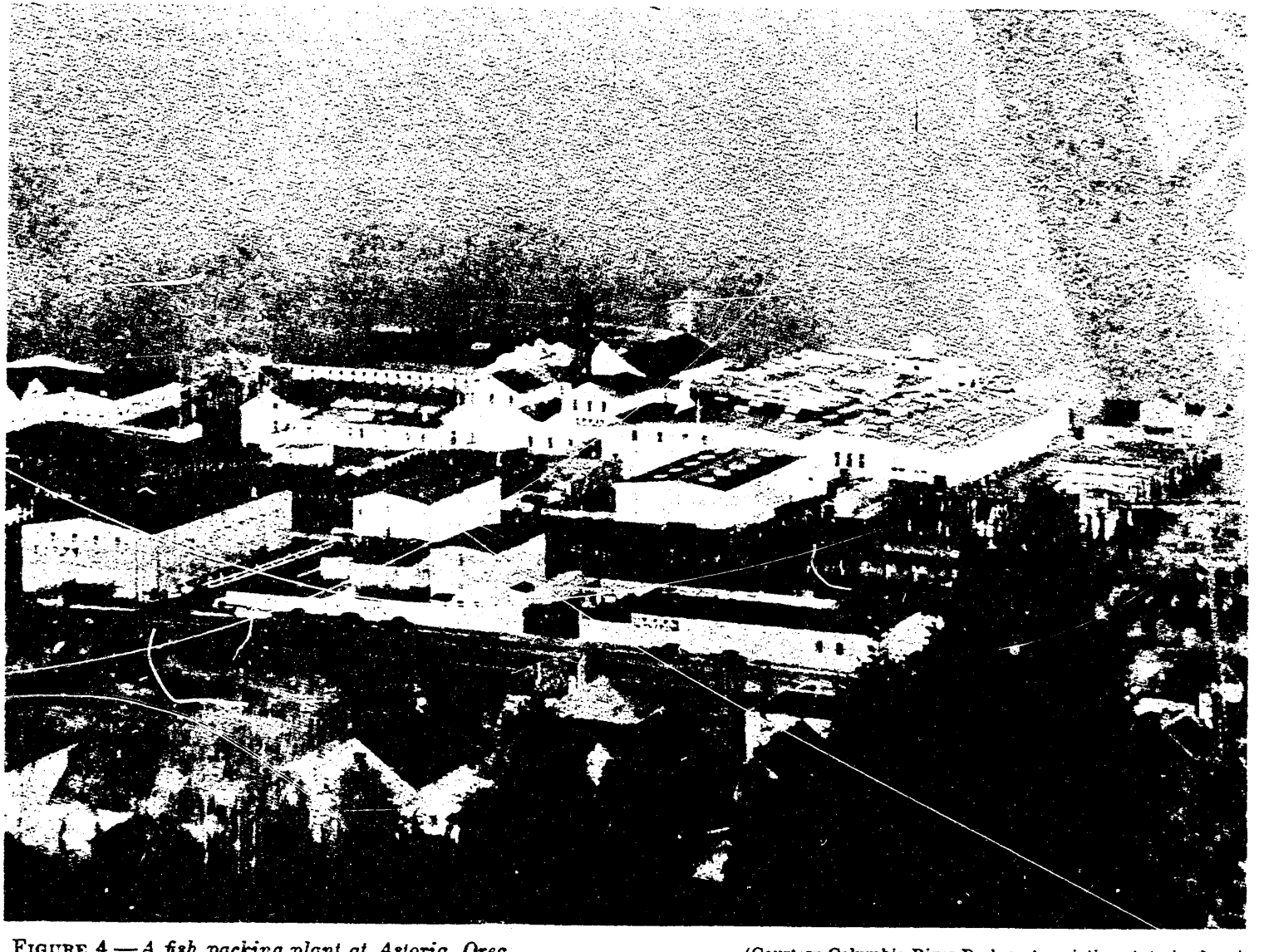


FIGURE 4.—*A fish packing plant at Astoria, Oreg.* (Courtesy Columbia River Packers Association, Astoria, Oreg.)

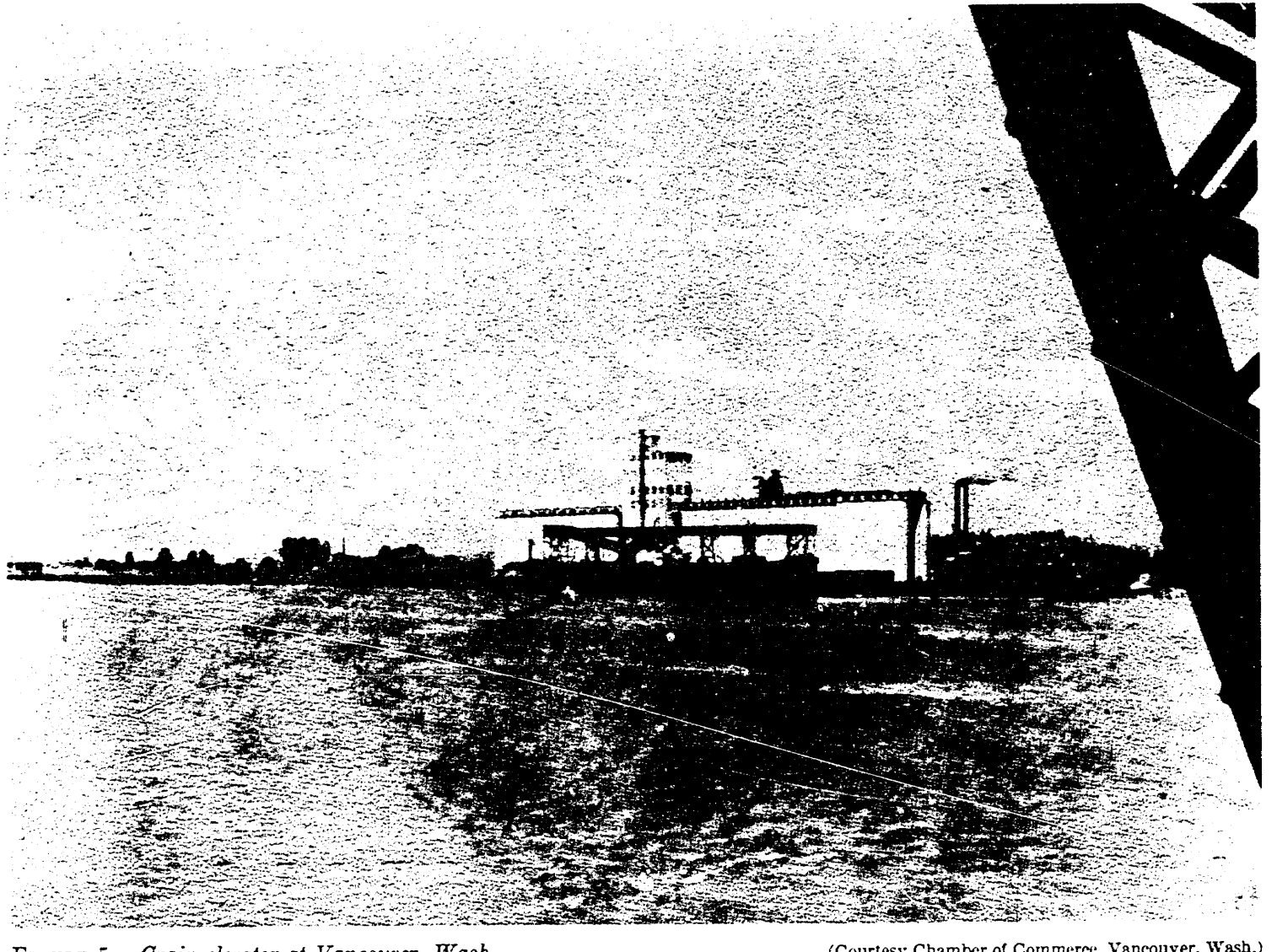


FIGURE 5.—*Grain elevator at Vancouver, Wash.* (Courtesy Chamber of Commerce, Vancouver, Wash.)

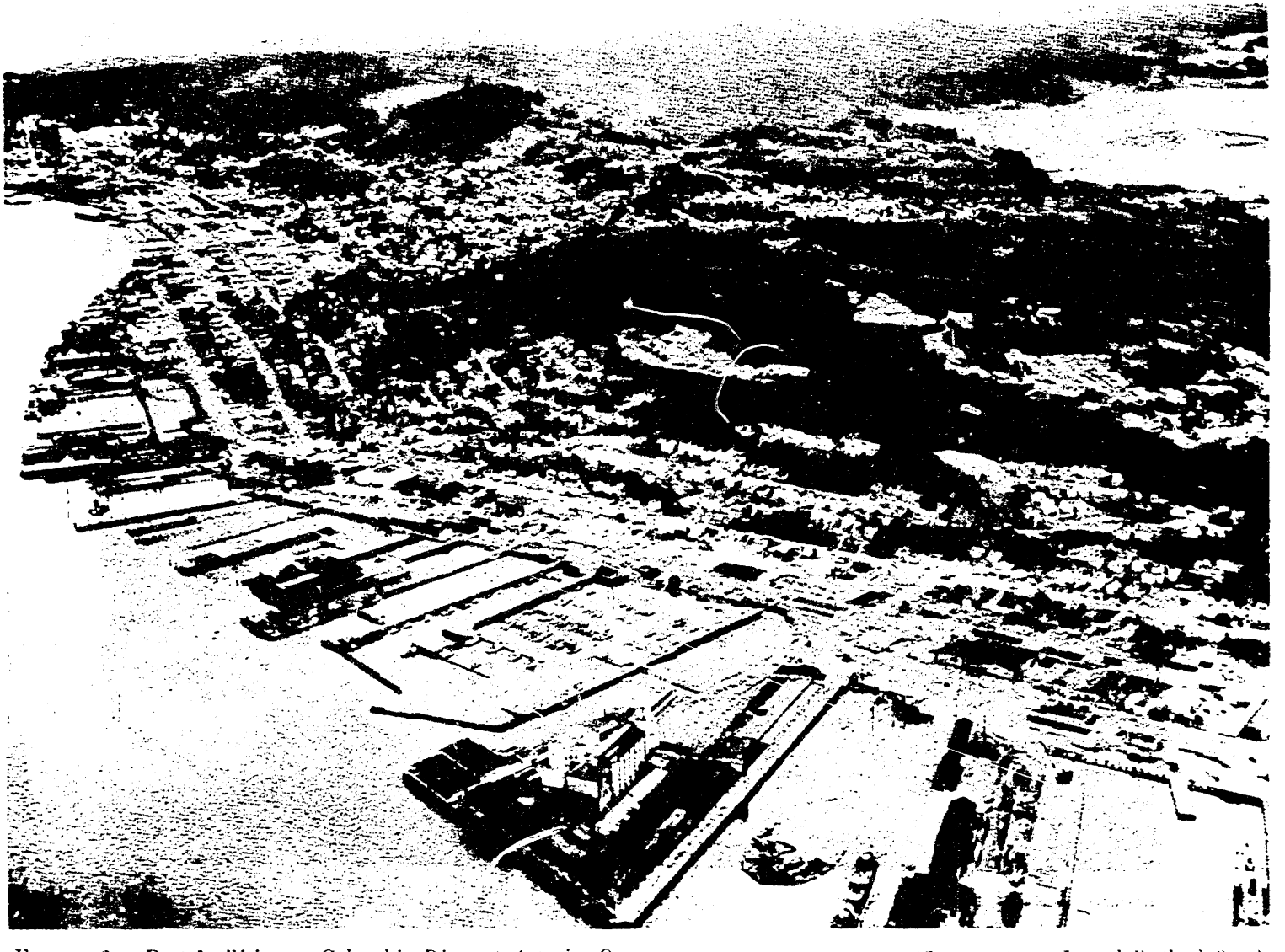


FIGURE 6.—*Port facilities on Columbia River at Astoria, Oreg.* (Courtesy Oregon Journal, Portland, Oreg.)

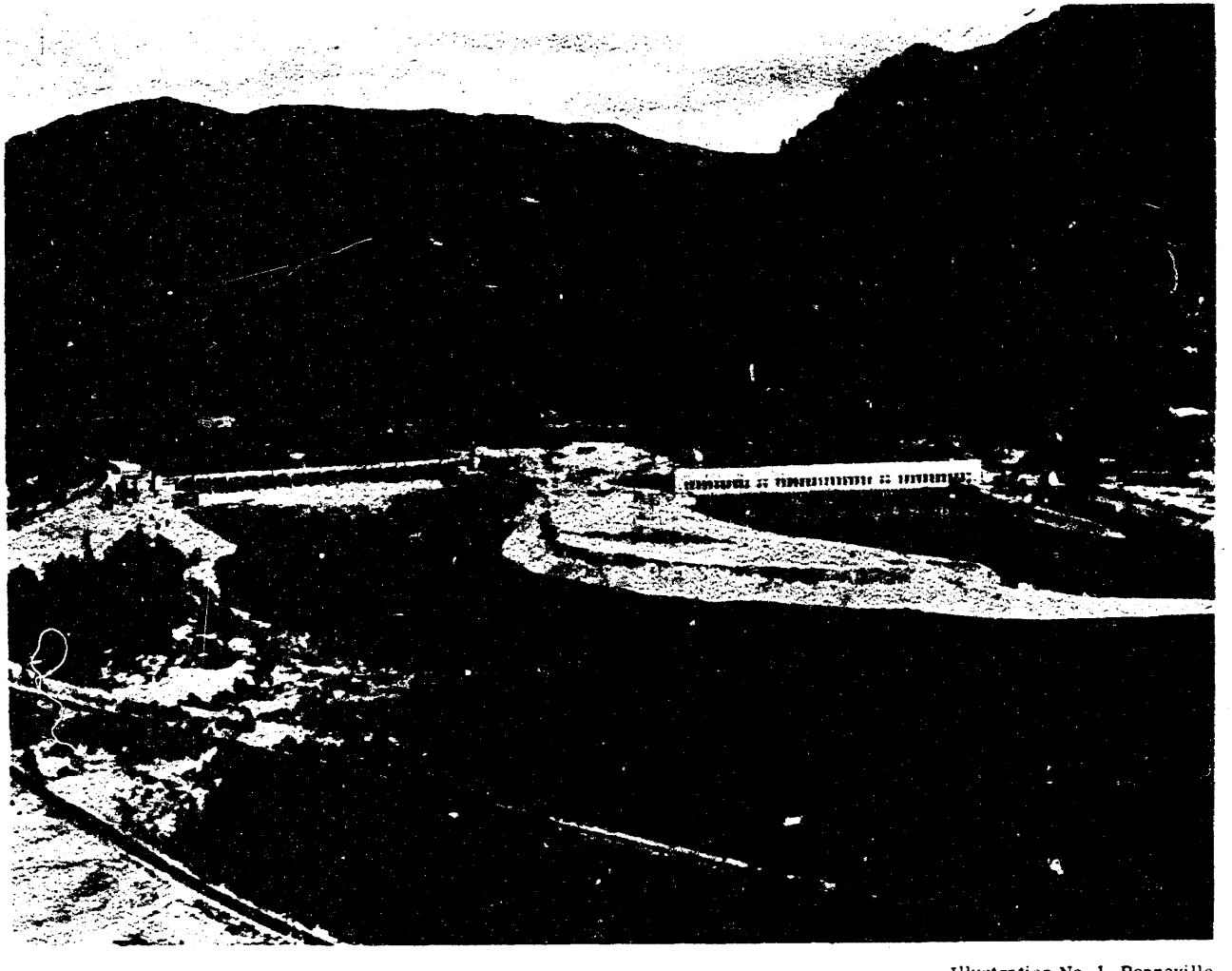
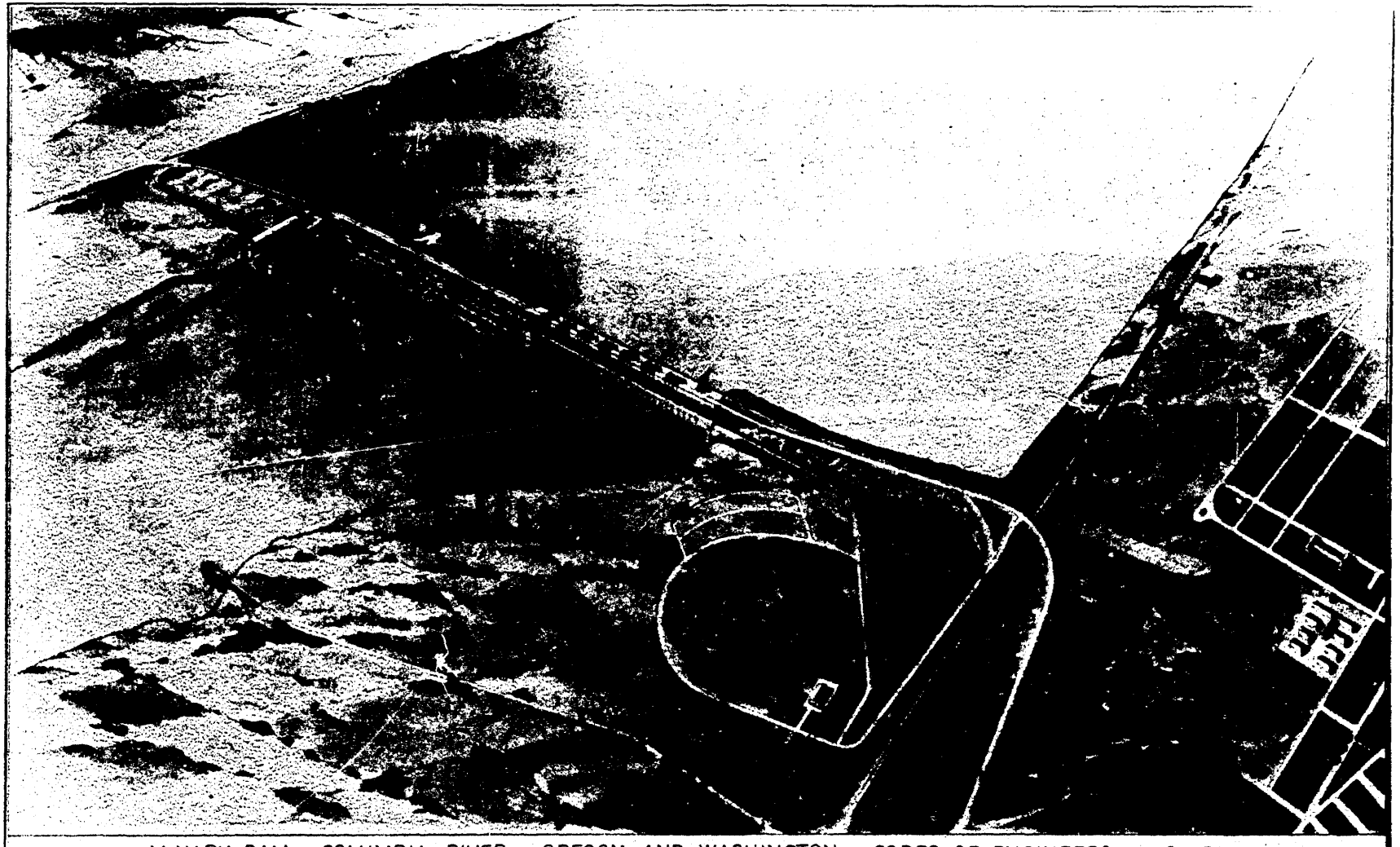


Illustration No. 1, Bonneville

01275 O—51—vol. VI



McNARY DAM — COLUMBIA RIVER — OREGON AND WASHINGTON — CORPS OF ENGINEERS — U.S. ARMY

Illustration No 2. McNary

91275 O—51—vol. VI

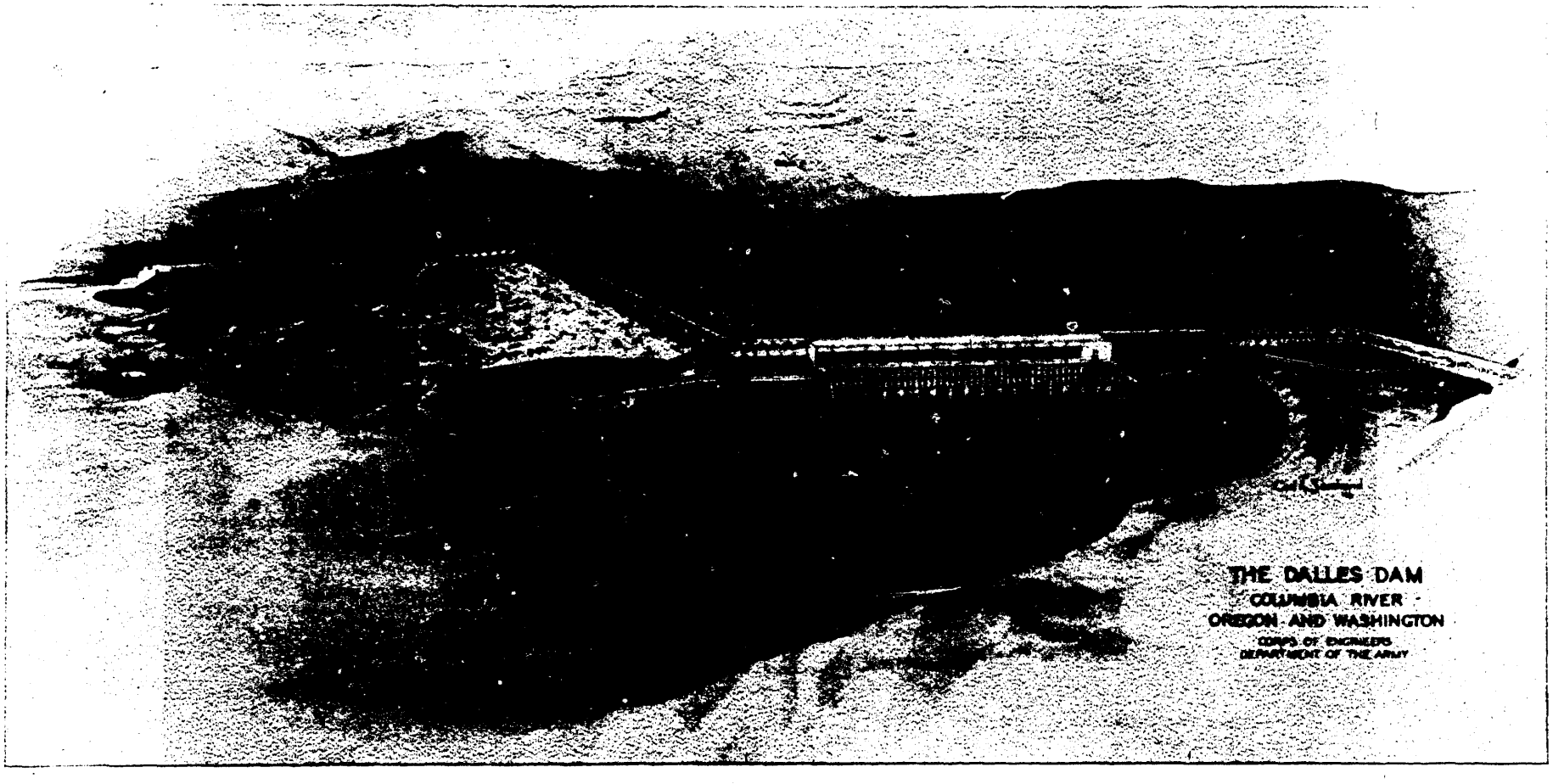


Illustration No. 3. The Dalles

91275 O—51—vol. VI

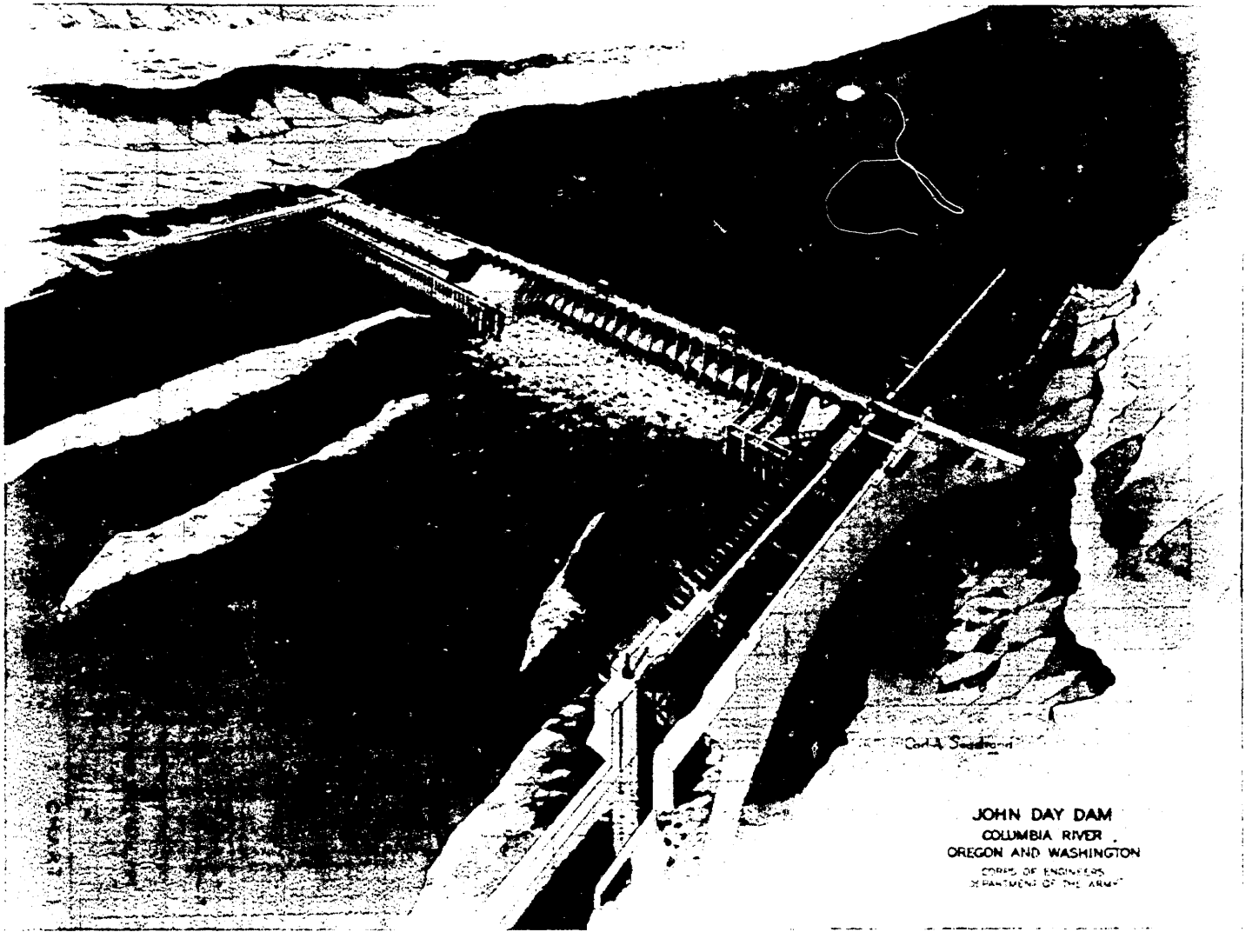


Illustration No. 4. John Day

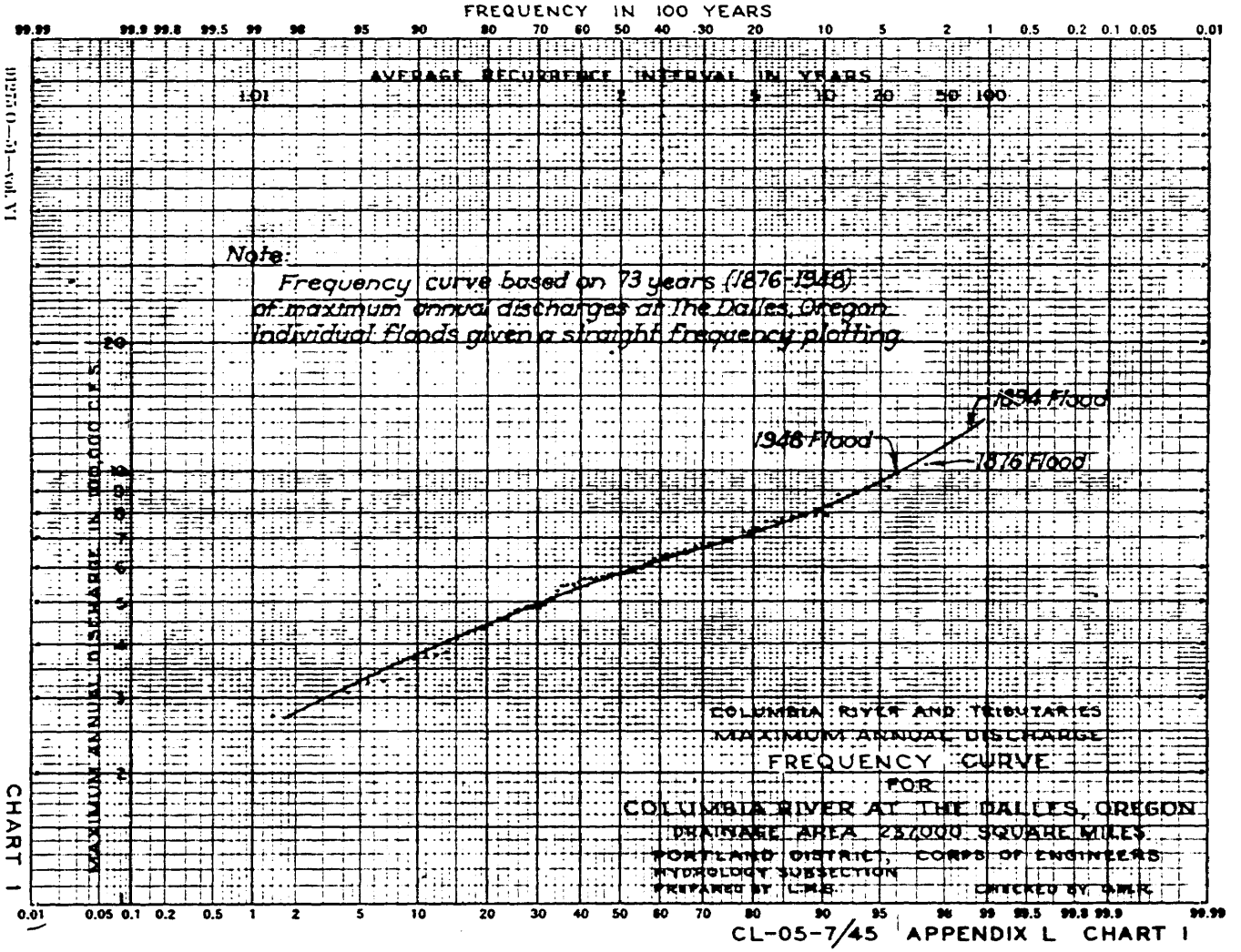
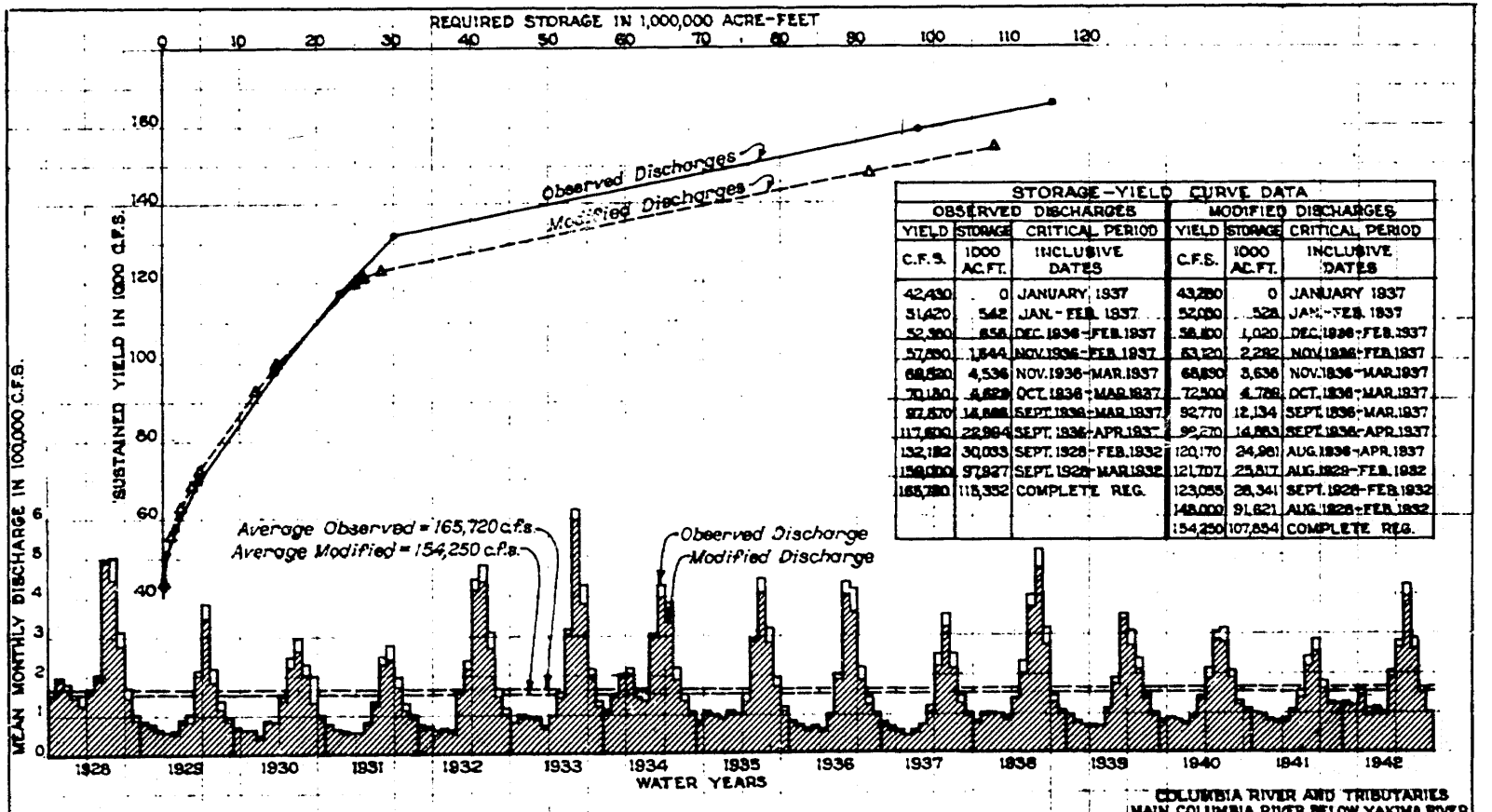


CHART 1

112510—51—vol. VI



STORAGE-YIELD CURVE DATA					
OBSERVED DISCHARGES			MODIFIED DISCHARGES		
YIELD C.F.S.	STORAGE 1000 AC.FT.	CRITICAL PERIOD INCLUSIVE DATES	YIELD C.F.S.	STORAGE 1000 AC.FT.	CRITICAL PERIOD INCLUSIVE DATES
42,430	0	JANUARY 1937	43,280	0	JANUARY 1937
51,420	542	JAN.-FEB. 1937	52,000	528	JAN.-FEB. 1937
52,390	856	DEC. 1936-FEB. 1937	56,100	1,020	DEC. 1936-FEB. 1937
57,890	1,844	NOV. 1936-FEB. 1937	63,120	2,282	NOV. 1936-FEB. 1937
68,520	4,536	NOV. 1936-MAR. 1937	68,830	3,636	NOV. 1936-MAR. 1937
70,180	4,829	OCT. 1936-MAR. 1937	72,300	4,788	OCT. 1936-MAR. 1937
97,870	14,888	SEPT. 1936-MAR. 1937	92,770	12,134	SEPT. 1936-MAR. 1937
117,600	22,984	SEPT. 1936-APR. 1937	99,270	14,883	SEPT. 1936-APR. 1937
132,182	30,033	SEPT. 1928-FEB. 1932	120,170	24,981	AUG. 1936-APR. 1937
159,000	97,827	SEPT. 1928-MAR. 1932	121,707	25,817	AUG. 1928-FEB. 1932
165,720	115,352	COMPLETE REG.	123,055	28,341	SEPT. 1928-FEB. 1932
			148,000	91,621	AUG. 1928-FEB. 1932
			154,250	107,854	COMPLETE REG.

Notes:

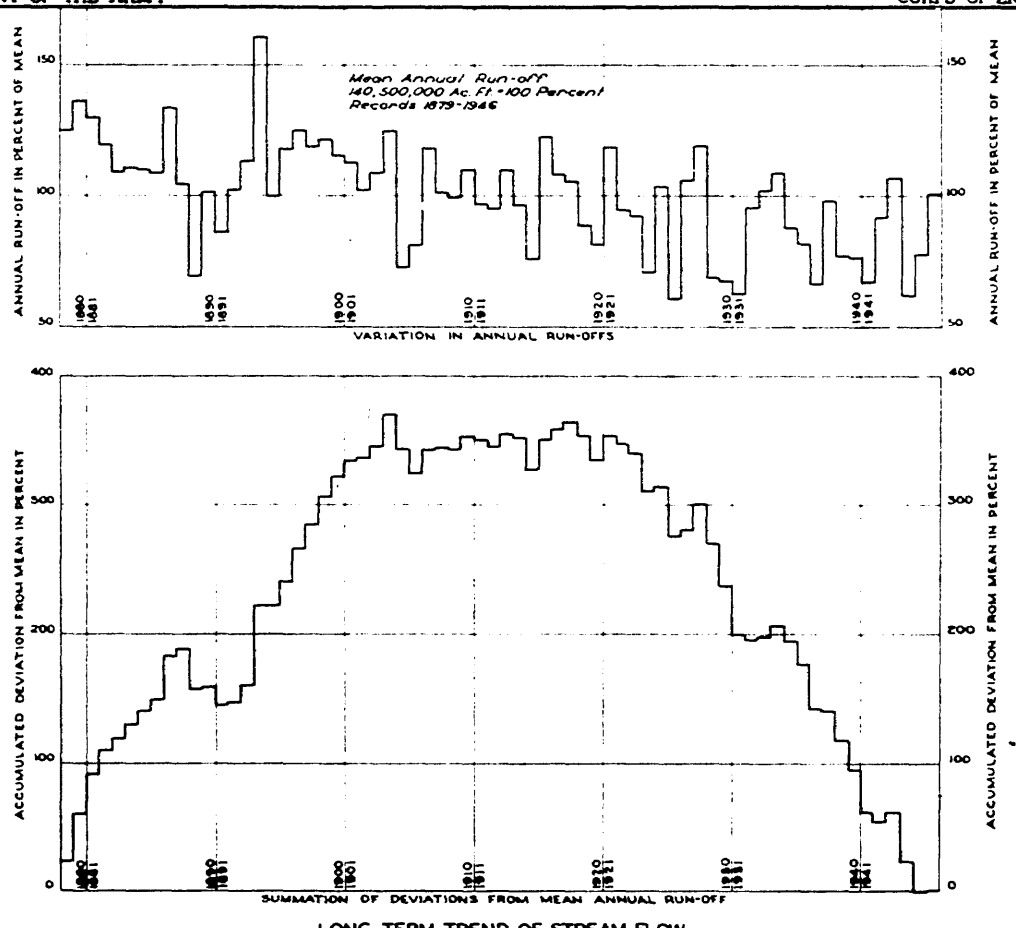
1. The observed discharge curve and hydrograph are based on the recorded flows at The Dalles corrected only for Grand Coulee storage effects since 1938.
2. The modified discharge curve and hydrograph are based on the observed flows modified by the ultimate irrigation requirements of the Columbia Basin.
3. Cyclic repetition of the critical 15 year period, October 1927 to September 1942, is assumed for the purpose of this study.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

STORAGE-YIELD CURVES
AND
MONTHLY DISCHARGE HYDROGRAPHS
COLUMBIA RIVER AT THE DALLES
DRAINAGE AREA=237,000 SQ. MI.

PORTLAND DISTRICT, CORPS OF ENGINEERS
HYDROLOGY SUBSECTION FEB. 28, 1948
PREPARED BY: G.L.G. CHECKED BY: J.S.

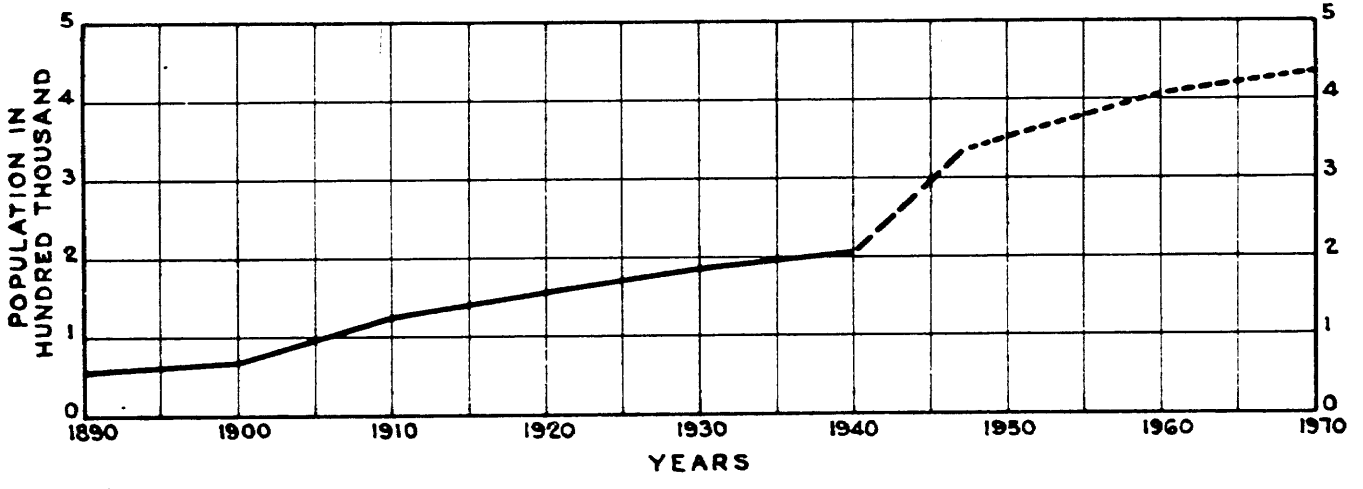
CL-05-7/48 APPENDIX L CHART 2



LONG TERM TREND OF STREAM FLOW
COLUMBIA RIVER AT THE DALLES, OREGON
DRAINAGE AREA = 237,000 SQ. MI.

CHART 3

112755 O—51—Vol. VI.



LEGEND

U.S. Census

Estimated

Increase based on adjusted trend

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

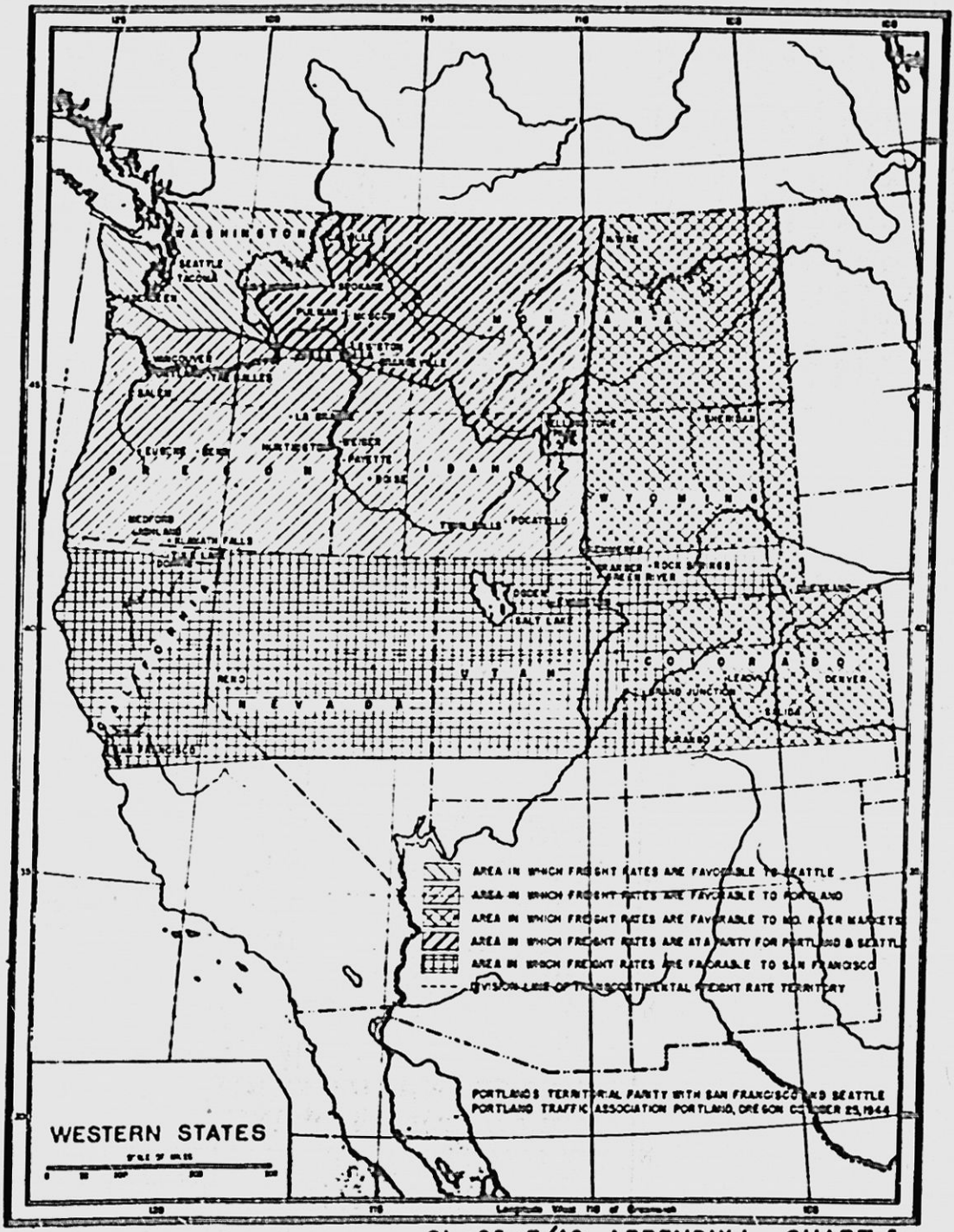
POPULATION GROWTH AND TREND

PORTLAND DISTRICT, CORPS OF ENGINEERS
ECONOMICS STUDIES SECTION MAY 1948

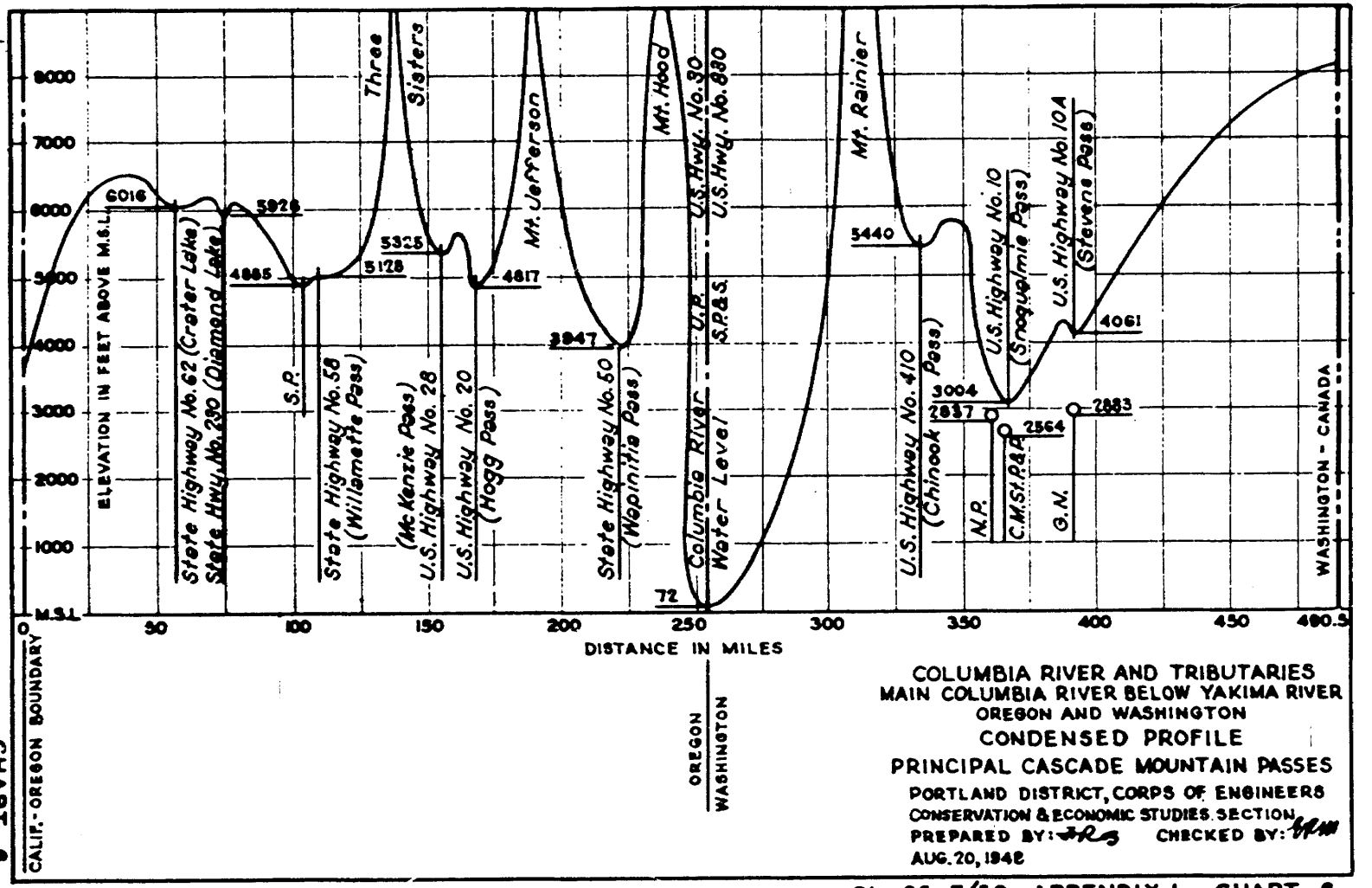
CL-05-7/48 APPENDIX L CHART 4

CHART 4

01275 O—51—vol. VI



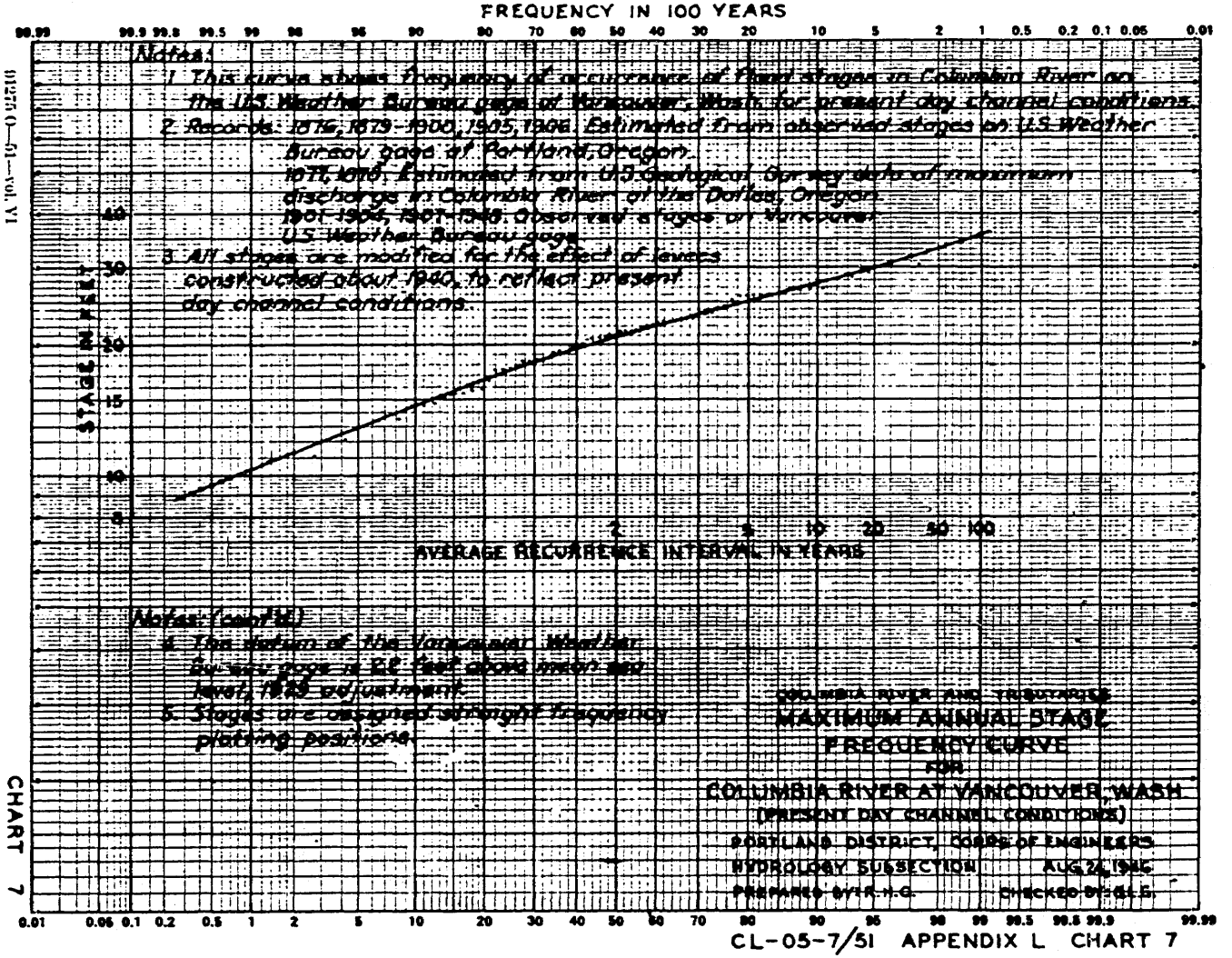
CL-05-7/49 APPENDIX L CHART 5



COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
CONDENSED PROFILE
PRINCIPAL CASCADE MOUNTAIN PASSES
PORTLAND DISTRICT, CORPS OF ENGINEERS
CONSERVATION & ECONOMIC STUDIES SECTION
PREPARED BY: JRS CHECKED BY: [illegible]
AUG. 20, 1948

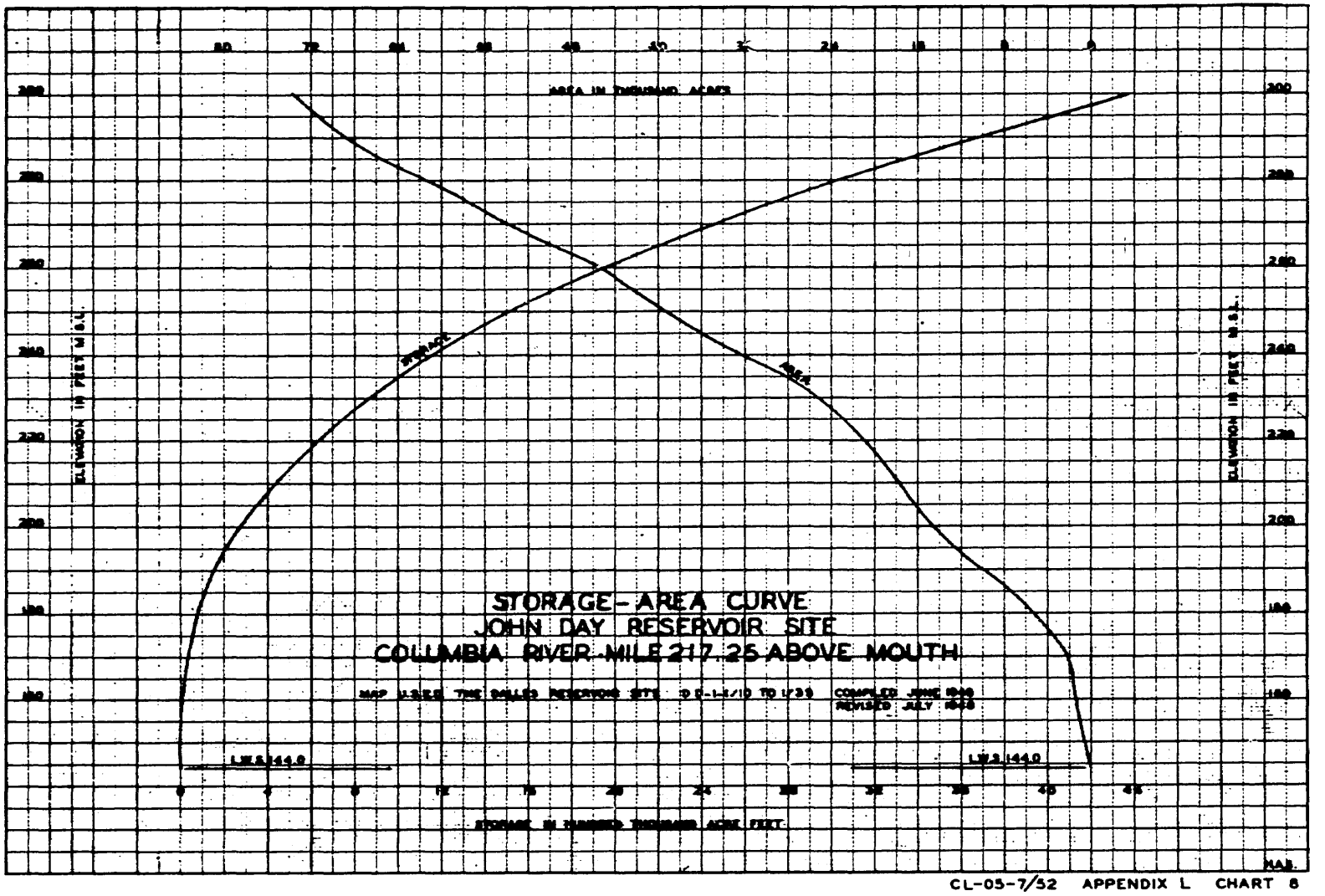
CHART 6

81275 O—51—vol. VI—

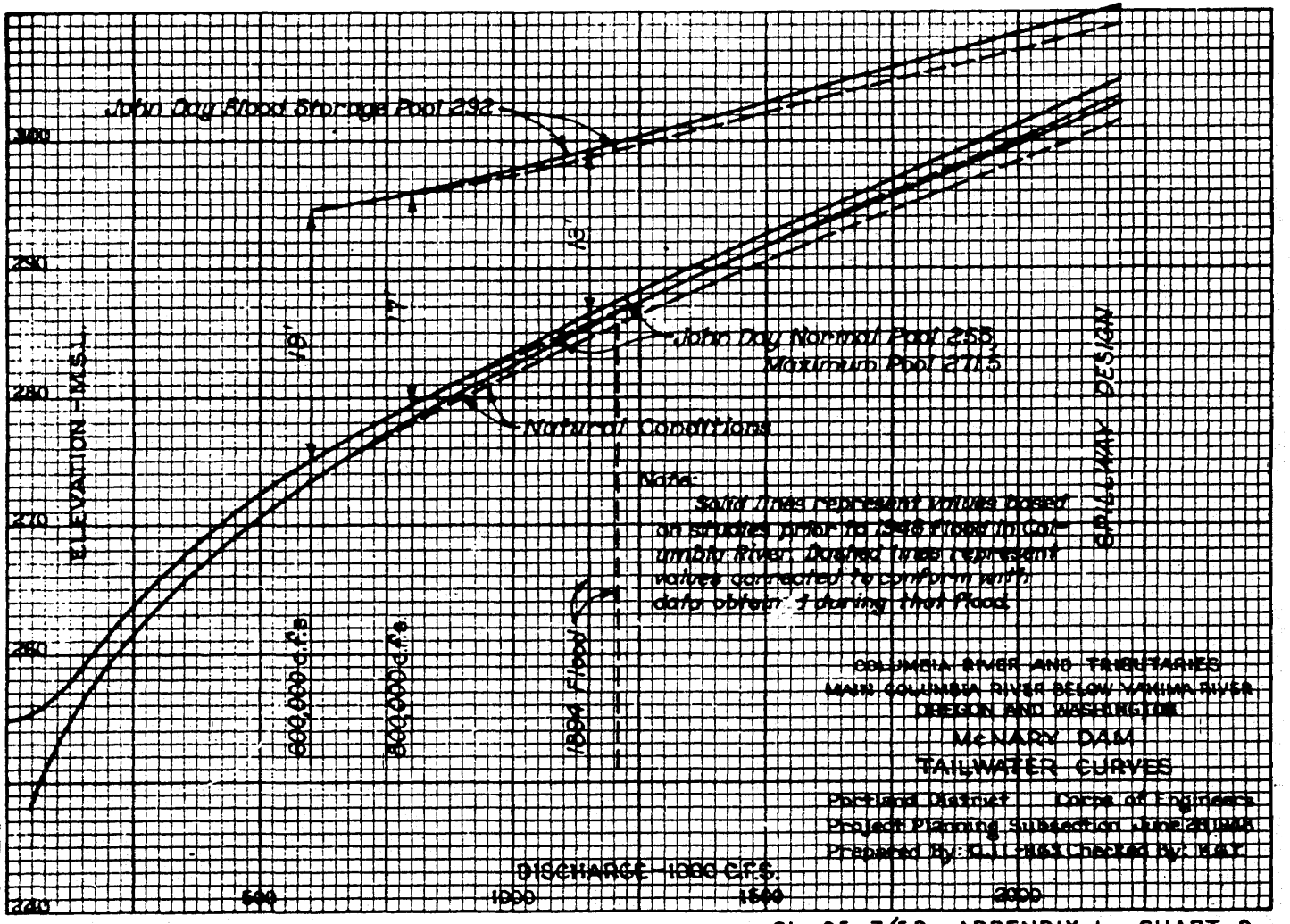


CL-05-7/51 APPENDIX L CHART 7

91275 O—51—Vol. VI



CL-05-7/52 APPENDIX L CHART 8



CL-05-7/53 APPENDIX L CHART 9

CHART 9

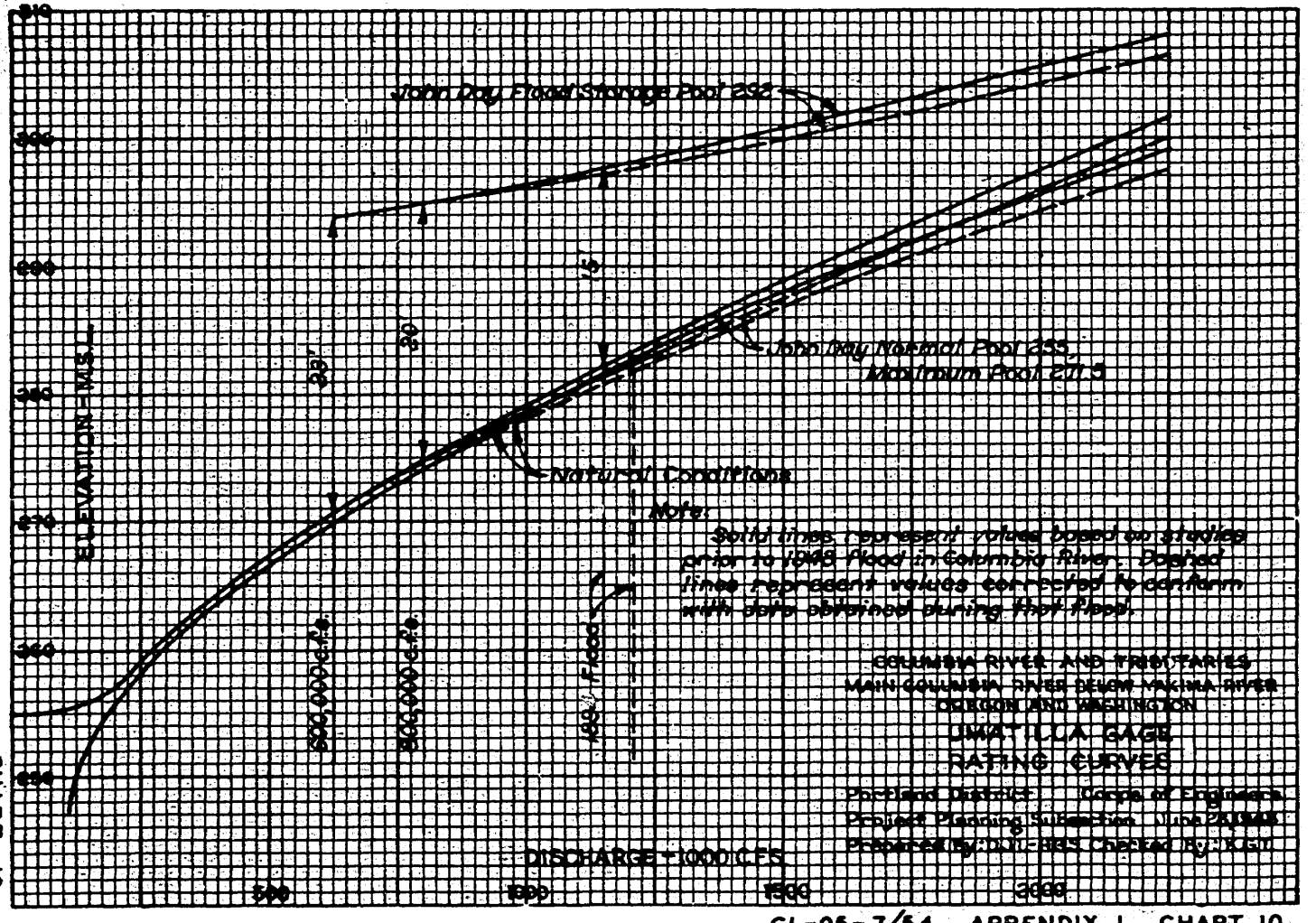
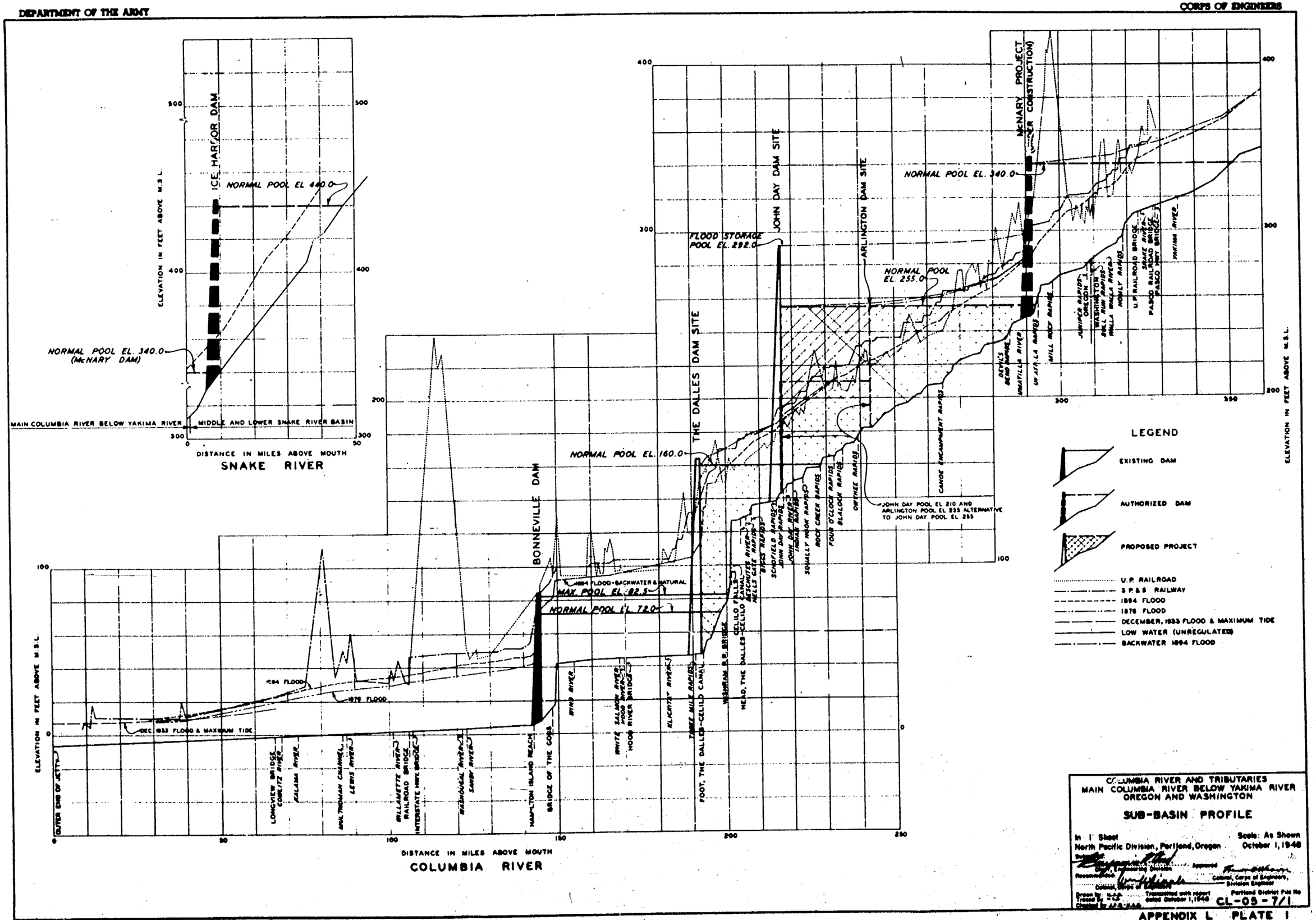


CHART 10

012710 O—51—vol. VI



COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

SUB-BASIN PROFILE

In 1 Sheet — Scale: As Shown
North Pacific Division, Portland, Oregon — October 1, 1948

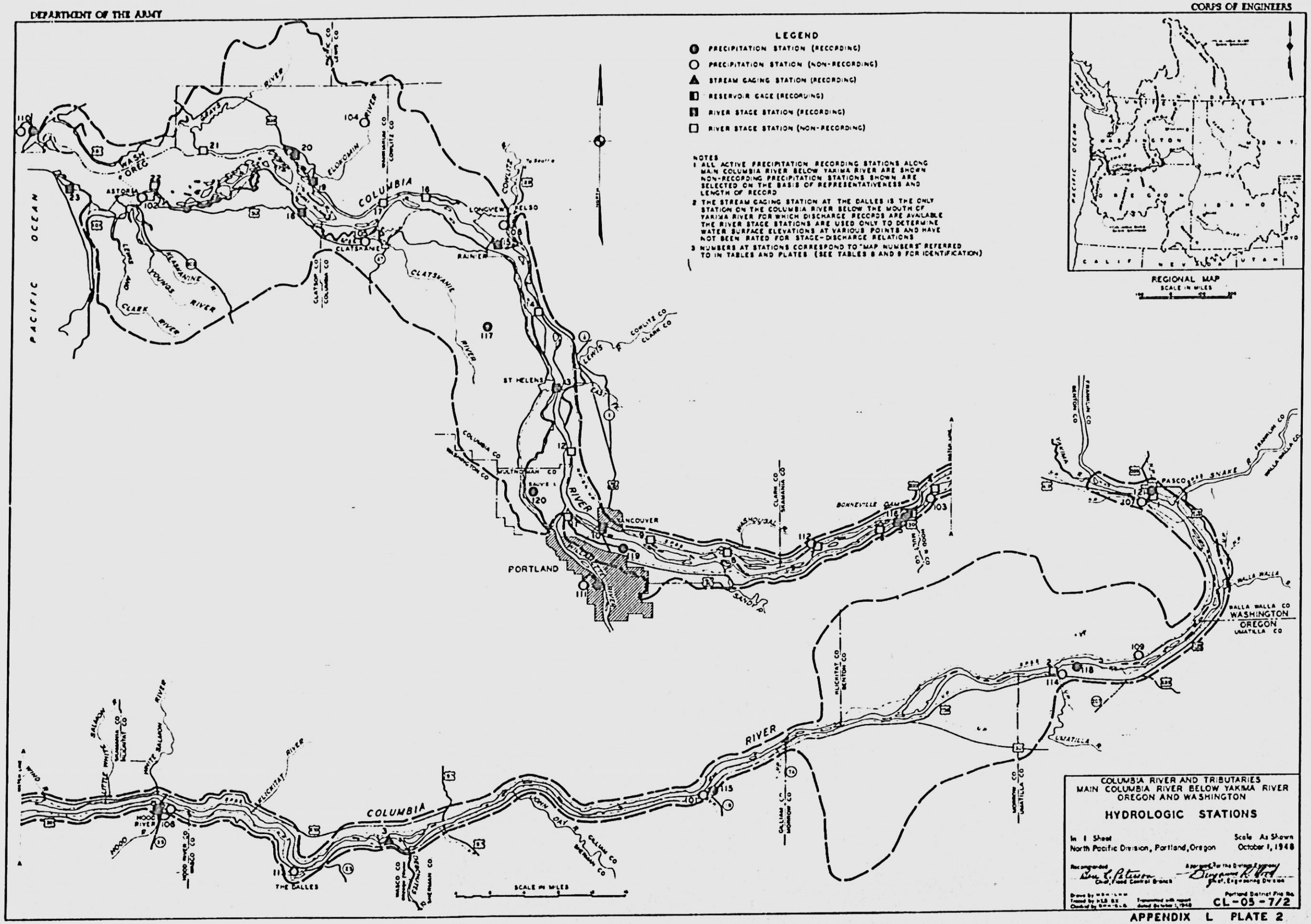
Chief, Engineering Division — Approved: Colonel, Corps of Engineers, Division Engineer

Recommended: Colonel, Corps of Engineers

Drawn by: H.E.P. — Transmitted with report dated October 1, 1948 — Portland District File No. CL-05-7/1

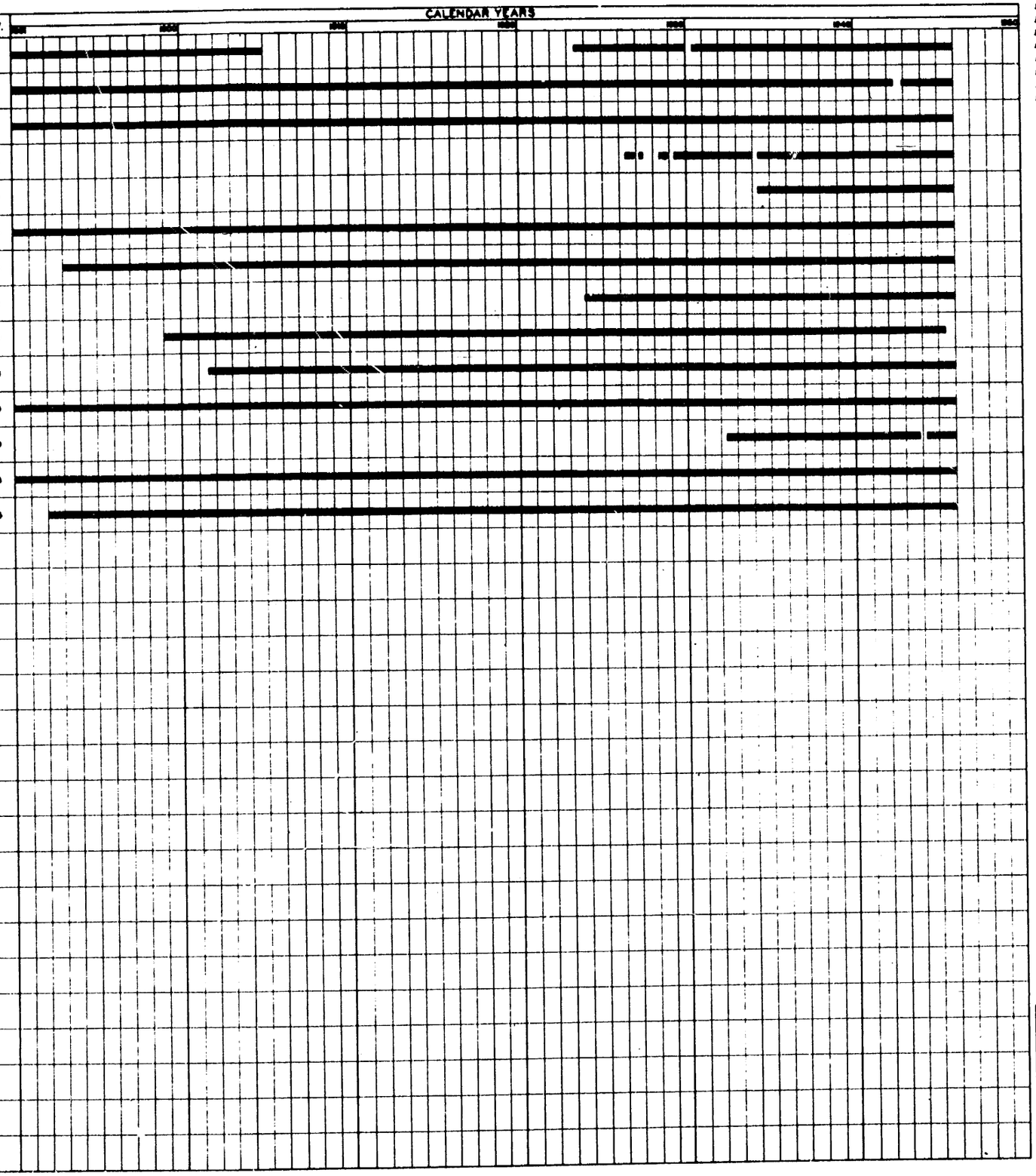
Traced by: H.E.P.

Checked by: J.F.S.-R.A.R.



APPENDIX L PLATE 2

MAP NO.	STATION	WATERSHED	ELEV.
101	ARLINGTON, ORE.[1]	COLUMBIA RIVER	668
102	ASTORIA, ORE.[2]	COLUMBIA RIVER	231
103	CASCADE LOCKS, ORE.[2]	COLUMBIA RIVER	180
104	CATHLAMET, WASH.	COLUMBIA RIVER	478
105	CLATSKANIE, ORE.	COLUMBIA RIVER	80
106	HOOD RIVER, ORE.[2]	COLUMBIA RIVER	300
107	KENNEWICK, WASH.[2]	COLUMBIA RIVER	392
108	LONGVIEW, WASH.	COLUMBIA RIVER	12
109	MOTTINGER, WASH.	COLUMBIA RIVER	307
110	NORTH HEAD, WASH.	COAST	196
111	PORTLAND, ORE.[2]	WILLAMETTE RIVER	30
112	PRINDLE, WASH.	COLUMBIA RIVER	200
113	THE DALLES, ORE.[2]	COLUMBIA RIVER	88
114	UMATILLA, ORE.[2]	COLUMBIA RIVER	265



1 RECORD AFTER JUNE, 1943 FOR ARLINGTON AIRPORT.
2 PARTIAL RECORD FROM 1880
3 PARTIAL RECORD FROM 1879.
4 COMPLETE RECORD FROM 1884.
5 PARTIAL RECORD FROM 1884.
6 PARTIAL RECORD FROM 1871.
7 PARTIAL RECORD FROM 1885
8 PARTIAL RECORD FROM 1877

NOTES
1-SELECTED STATIONS AND THEIR RESPECTIVE RECORDS SHOWN ARE REPRESENTATIVE OF THE CLIMATE OF THIS AREA
2-MAP NUMBERS IN FIRST COLUMN REFER TO STATION NUMBERS SHOWN ON MAP OF HYDROLOGIC STATIONS, PLATE 2

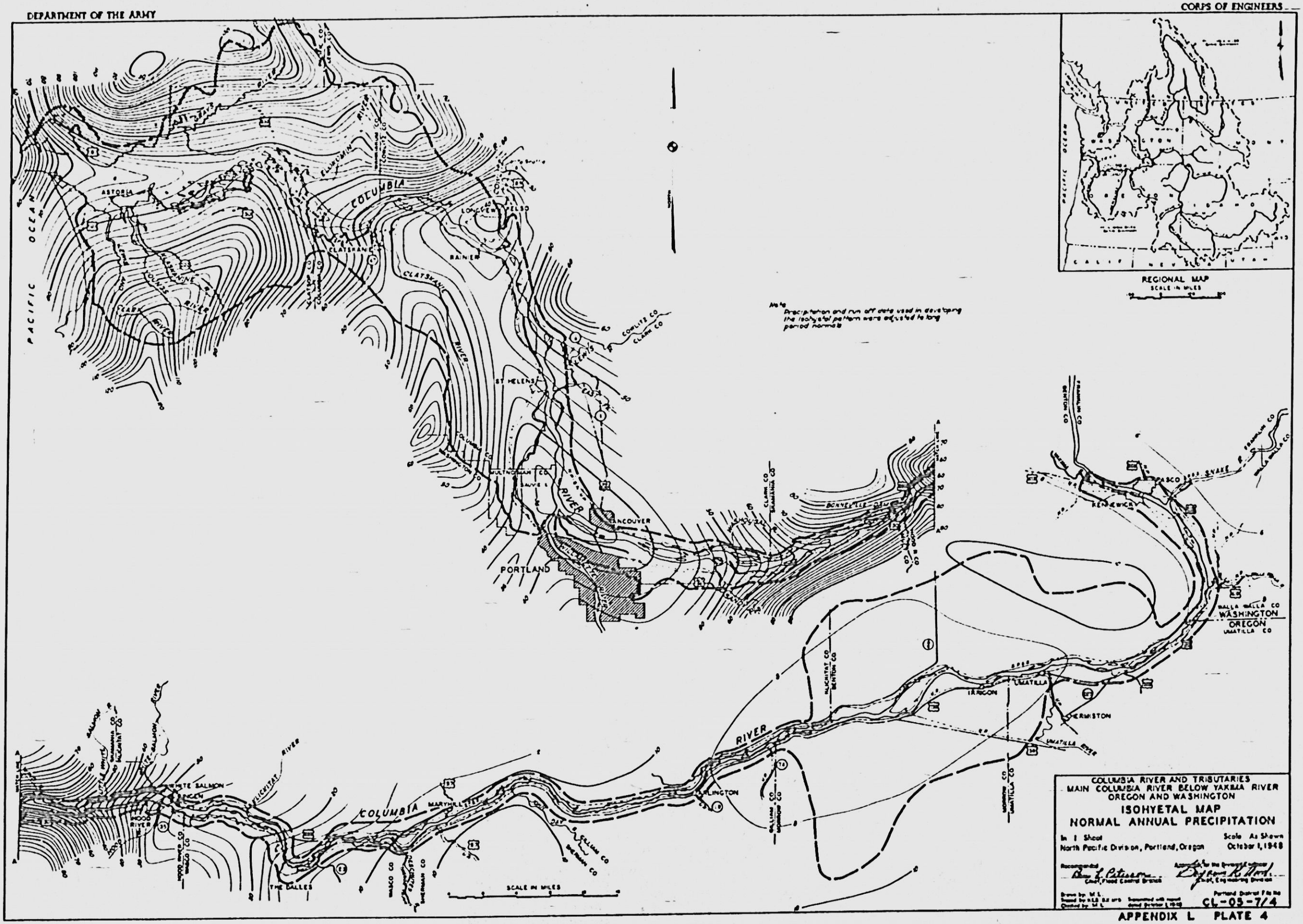
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

PRECIPITATION STATIONS
PERIOD OF RECORD

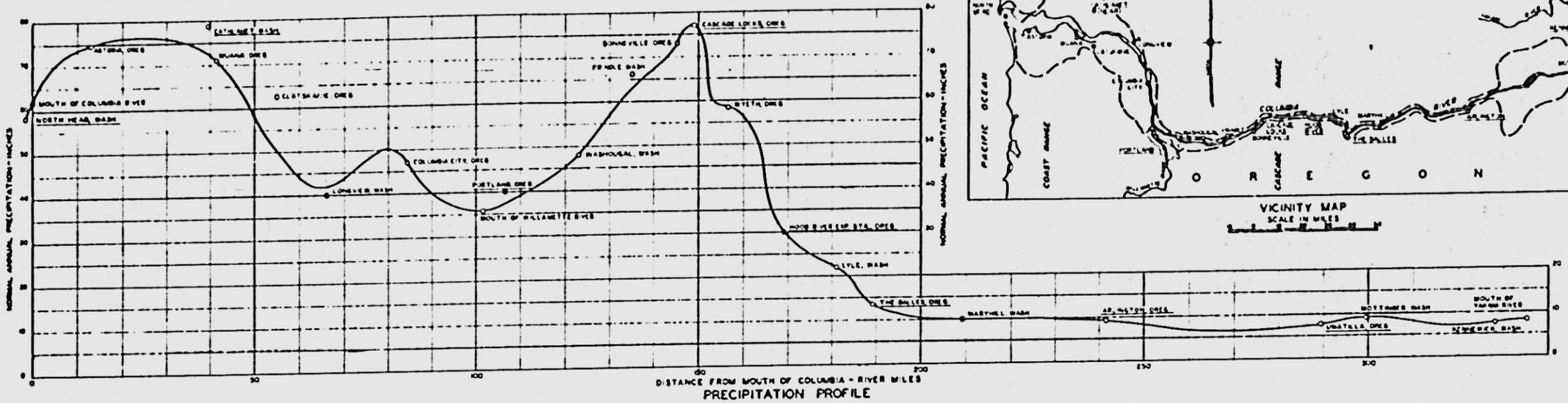
In 1 Sheet — Scale: As Shown
North Pacific Division, Portland, Oregon — Oregon 1, 1948

Recommended: Chief, Flood Control Branch
Approved for the Division Engineer: Chief, Engineering Division

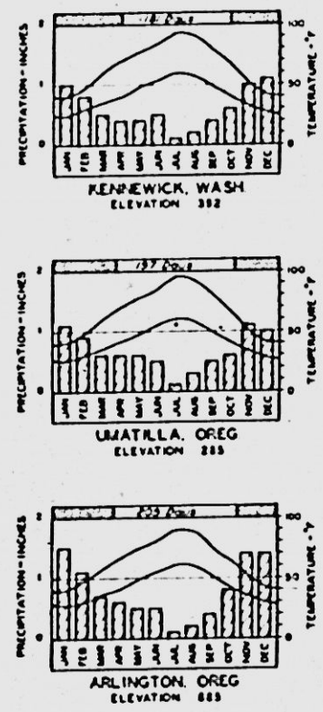
Drawn by: D.M.
Traced by: H.E.B.
Checked by: M.A.
Transmitted with report dated October 1, 1949
Portland District File No. CL-05-7/3



APPENDIX L PLATE 4



PRECIPITATION PROFILE



Notes

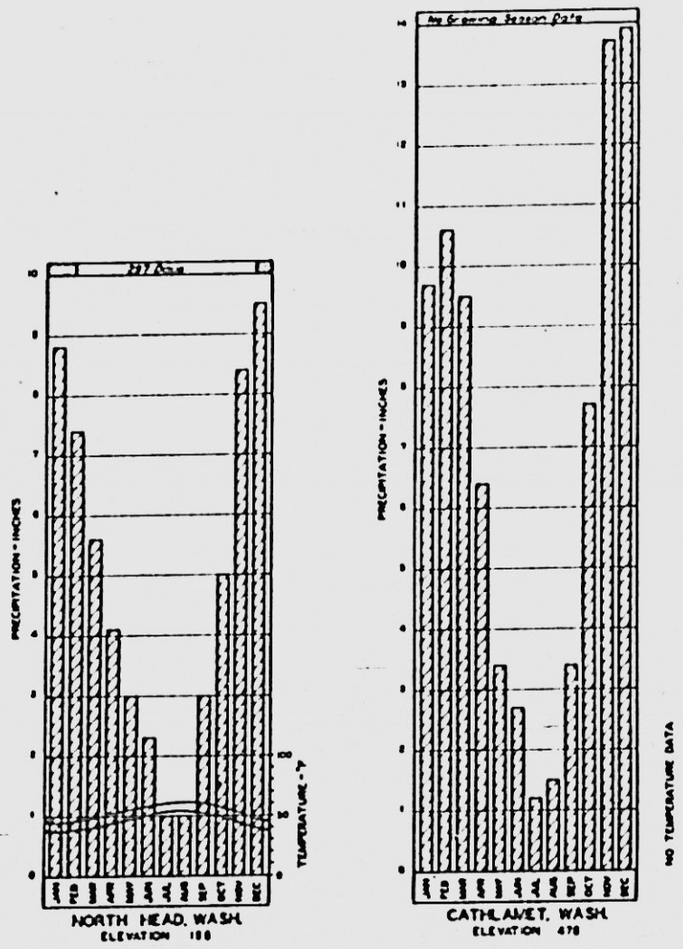
1 Normal precipitation shown on profile obtained by adjusting data to long-period normals

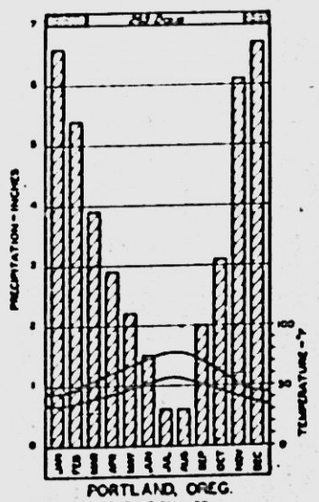
2 Stations adjacent to profile line are off-river stations, coordinates are normal annual precipitation and approximate distance from mouth in river miles

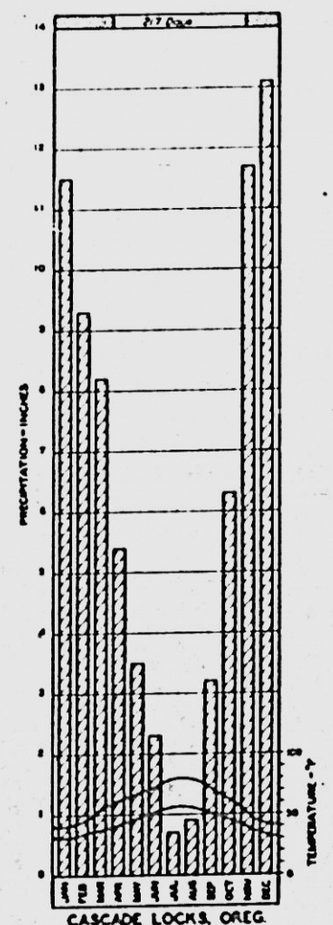
3 Bar charts show average precipitation by months at stations underlined on above profile. Averages are unadjusted arithmetic means

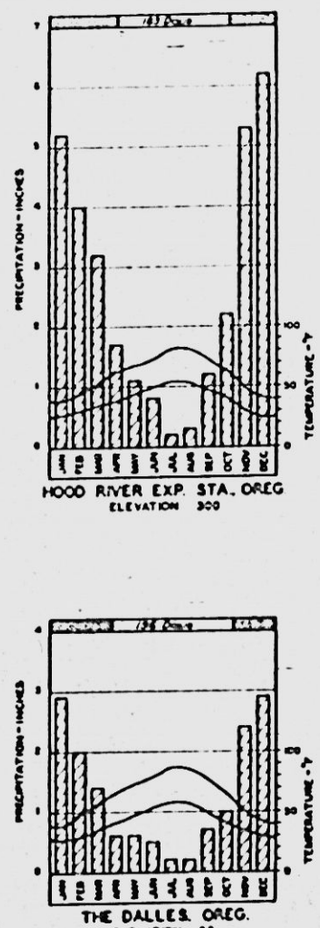
4 Curves on bar charts give average maximum and average minimum temperatures based on USWB Climatological Summaries

5 Open portion of horizontal bar at top of bar charts indicates average growing season









COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

CLIMATIC CHARACTERISTICS

In 1 Sheet — Scale: As Shown

North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch

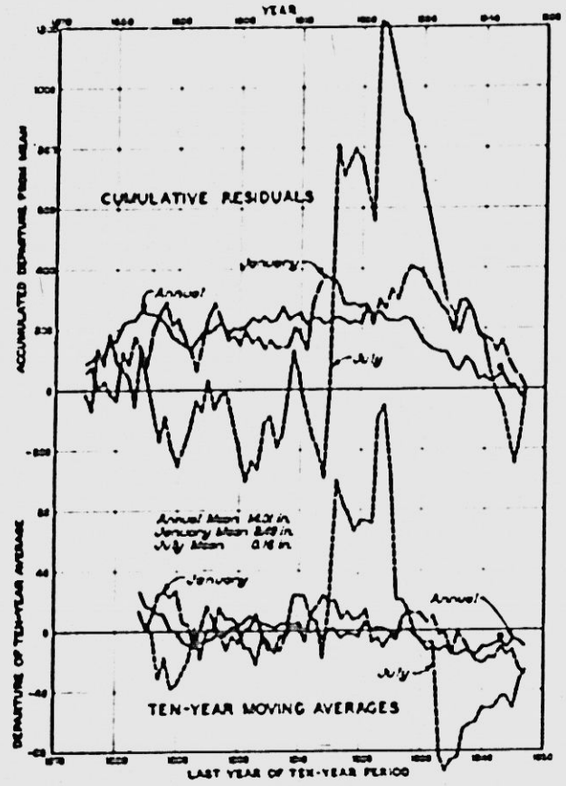
Approved: Chief, Engineering Division

Drawn by: Checked by:

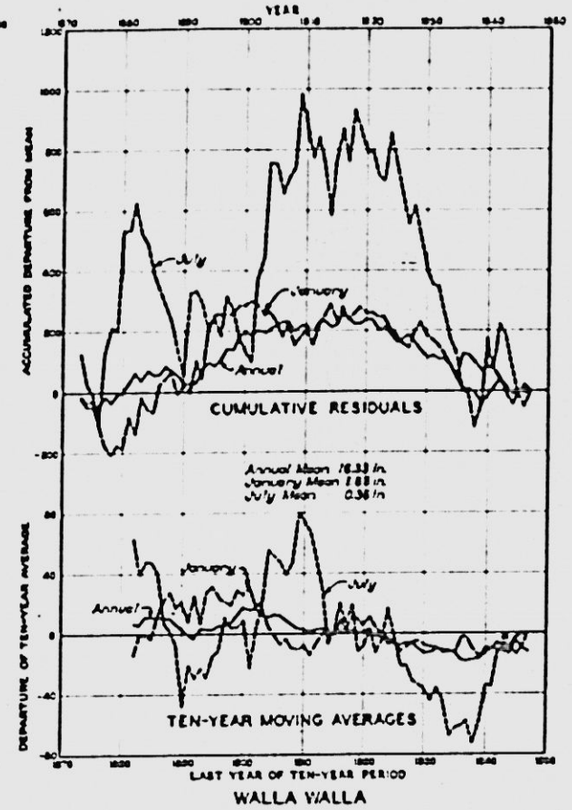
Submitted with report Army Engineer U.S.E.D.

Portland District File No. CL-05-7/5

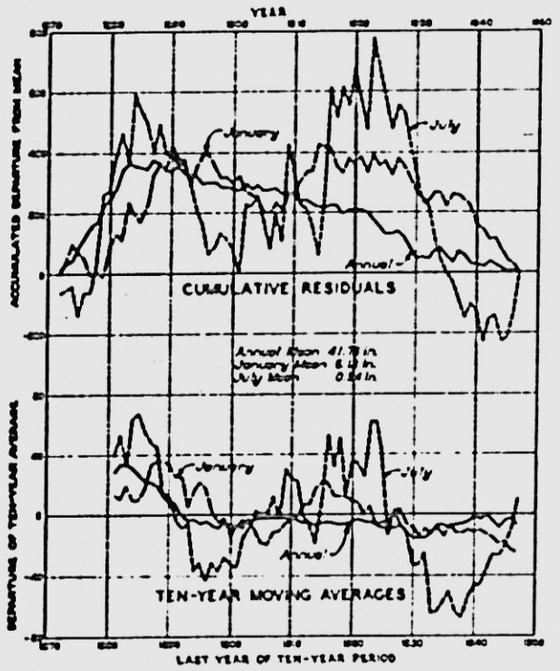
APPENDIX L PLATE 5



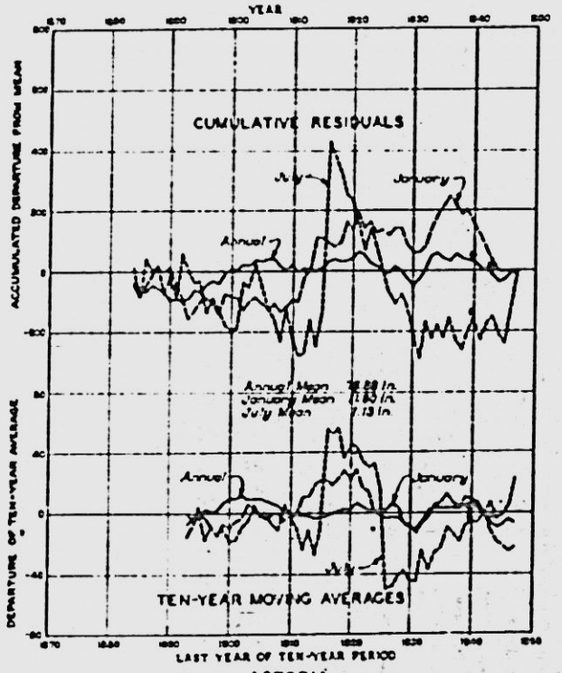
THE DALLES



WALLA WALLA

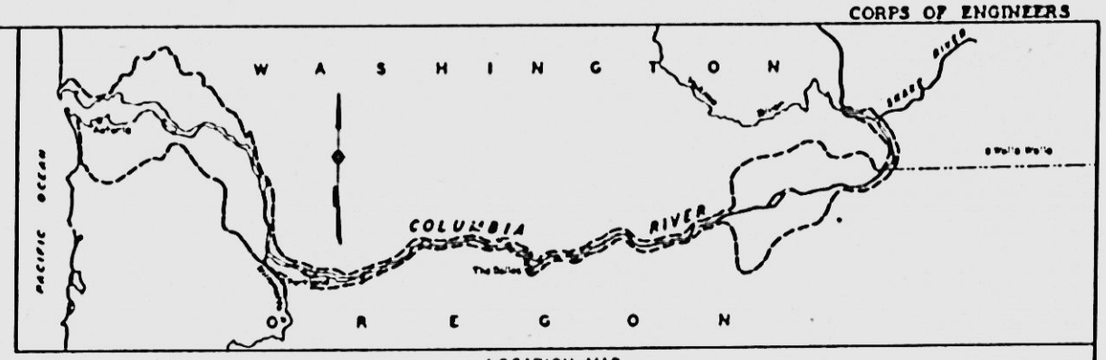


PORTLAND

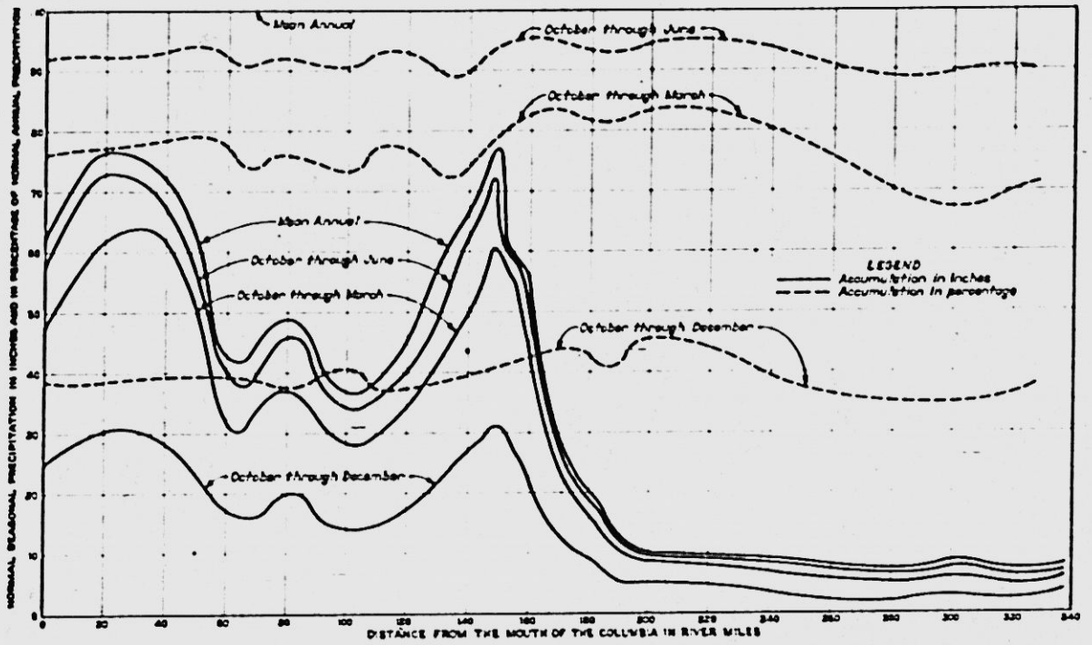


ASTORIA

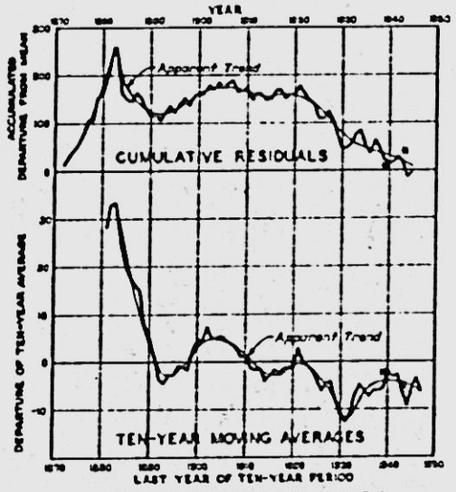
PRECIPITATION TRENDS



LOCATION MAP
SCALE IN MILES



PRECIPITATION PROFILES



AVERAGES OF PORTLAND, ASTORIA, THE DALLES AND WALLA WALLA

Notes

1. The curve which incorporates data from all four stations for the period subsequent to 1884 utilizes only Portland data for 1878, Portland and Walla Walla data between 1873 and 1878, and Portland, Walla Walla, and The Dalles data between 1873 and 1884.
2. Both accumulated departures from mean and departures of ten-year moving averages are expressed as percentage of mean.
3. Because arithmetic means of the actual period of record are used, all accumulated departure curves terminate at the zero departure line.
4. Asterisks denote missing basic data; values indicated were computed by comparison with records of nearby stations.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

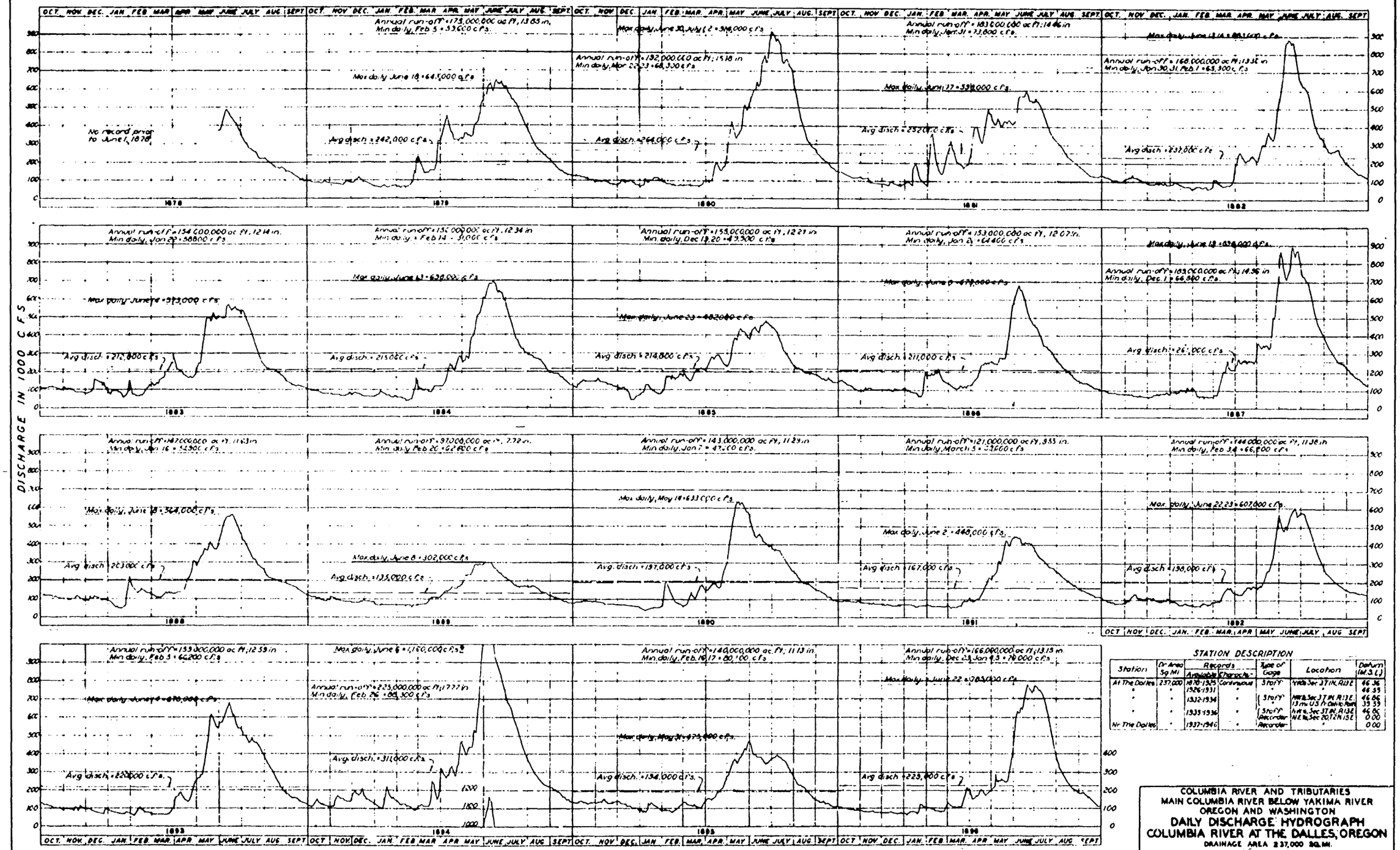
PRECIPITATION CHARACTERISTICS

In 1 Sheet — Scale As Shown
North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch
Approved: Chief, Engineering Division

Drawn by: M.L. — Traced by: S.K. — Checked by: J.M.
Transmitted with report dated October 1, 1948
Portland District File No. CL-05-7/6

01275 O—51—vol. VI



STATION DESCRIPTION

Station	Dr Area Sq Mi	Records Available	Records Character	Type of Gage	Location	Datum (M.S.L.)
At The Dalles	237,000	1878-1925	Continuous	Staff	Y Hdq Sec 37 1N, R13E	46.36
"	"	1926-1931	"	"	"	46.35
"	"	1932-1934	"	Staff	NW¼ Sec 3 T 1N R13E 13 mi US 1 from Dalles Bridge	46.06
"	"	1935-1936	"	Staff Recorder	NW¼ Sec 37 1N, R13E	46.06
Nr The Dalles	"	1937-1946	"	Recorder	NE¼ Sec 20 T2N 15E	0.00
						0.00

* Note:
The studies shown on this plate were completed prior to the 1948 flood in Columbia River, therefore the published value of maximum discharge, 1,180,000 second-feet, has been used. Data obtained during 1948 flood indicate that this discharge should be revised to 1,240,000 second-feet.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
DAILY DISCHARGE HYDROGRAPH
COLUMBIA RIVER AT THE DALLES, OREGON
DRAINAGE AREA 237,000 SQ. MI.

In 4 Sheets Sheet No. 1 Scale: As Shown
North Pacific Division, Portland, Oregon October 1, 1948

Recommended, Chief, Flood Control Branch
Approved for the Division Engineer, Chief, Engineering Division

Drawn by A.H.B.
Traced by H.A.
Checked by B.A.B.
Transmitted with report dated October 1, 1948
For Head District File No. CL-09-7/7

STATION DESCRIPTION

Station	Drainage Sq. Mi.	Records Available	Records Continuous	Type of Gage	Location	Datum (M.S.L.)
At The Dalles	237,000	1878-1925	Continuous	Staff	Near sec 37 T1N, R13E	46.34
"	"	1926-1931	"	"	"	46.33
"	"	1932-1934	"	Staff	Near sec 37 T1N, R13E 13 mi US of Dalles Bridge	46.84
"	"	1935-1936	"	Staff	Near sec 37 T1N, R13E	46.84
				"	Near sec 20-2N-R13E	0.00
Nr The Dalles	"	1931-1934	"	Recorder	"	0.00

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

DAILY DISCHARGE HYDROGRAPH
COLUMBIA RIVER AT THE DALLES, OREGON

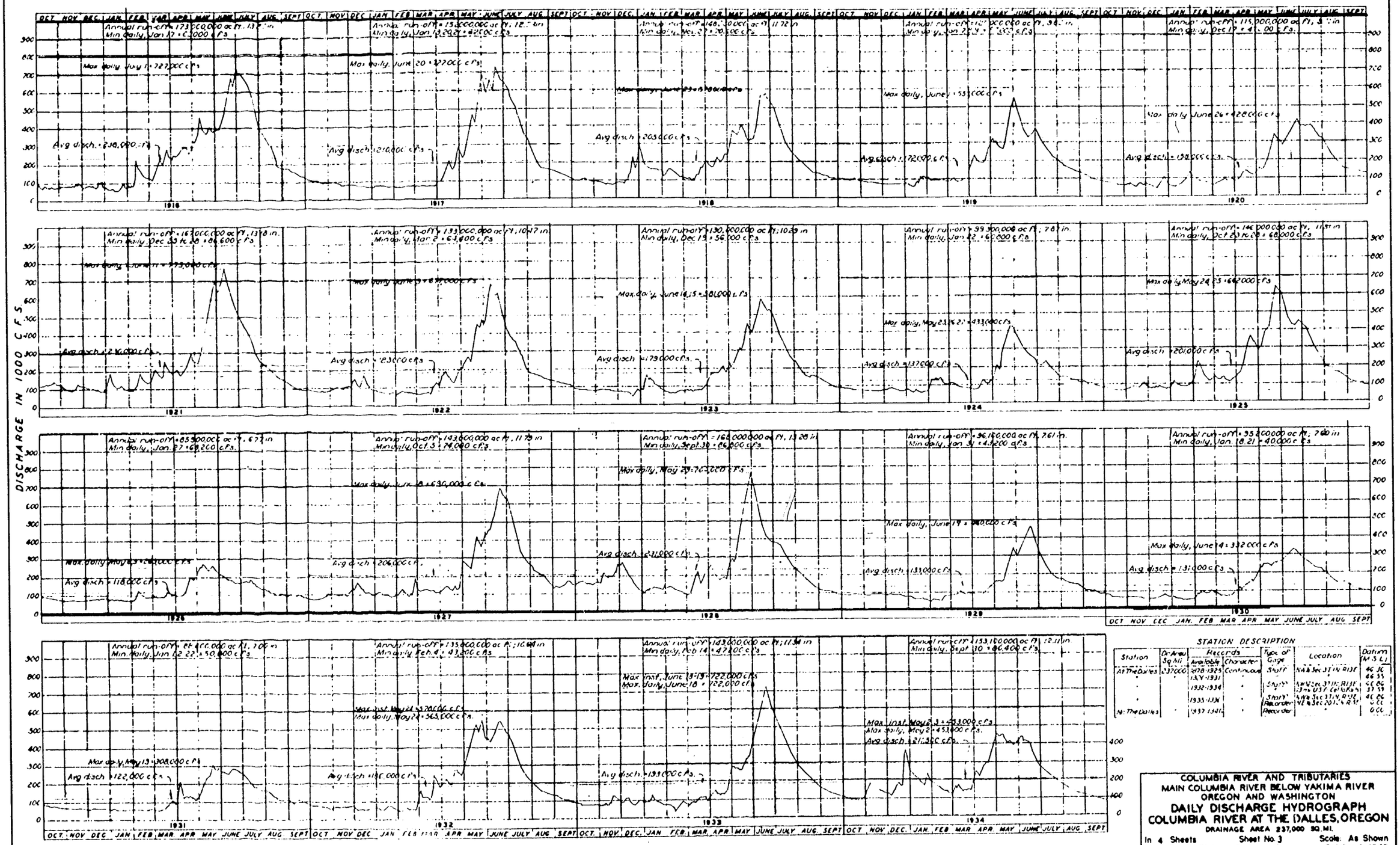
DRAINAGE AREA 237,000 SQ. MI.

In 4 Sheets Sheet No. 2 Scale: As Shown
North Pacific Division, Portland, Oregon October 1, 1948

Recommended: Chief, Flood Control Branch
Approved for the Division Engineer: Chief, Engineering Division

Drawn by: R.J.B.
Traced by: H.O.
Checked by: P.R.B.
Transmitted with report dated October 1, 1948

Portland District File No. CL-05-7/8



STATION DESCRIPTION

Station	Drainage Area Sq. Mi.	Records Available	Records Character	Type of Gage	Location	Datum M.S.L.
At The Dalles	237000	1878-1925	Continuous	Staff	NW¼ Sec 37 1N R13E	46.56
		1929-1931				46.55
		1932-1934		Staff	NW¼ Sec 37 1N R13E	45.86
				Recorder	1.2 mi. U.S. Gage (Staff)	37.59
		1935-1936		Staff	NW¼ Sec 37 1N R13E	46.86
				Recorder	NE¼ Sec 20 1S R13E	0.00
N. The Dalles		1937-1941		Recorder		0.00

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

DAILY DISCHARGE HYDROGRAPH
COLUMBIA RIVER AT THE DALLES, OREGON

DRAINAGE AREA 237,000 SQ. MI.

In 4 Sheets — Sheet No. 3 — Scale: As Shown

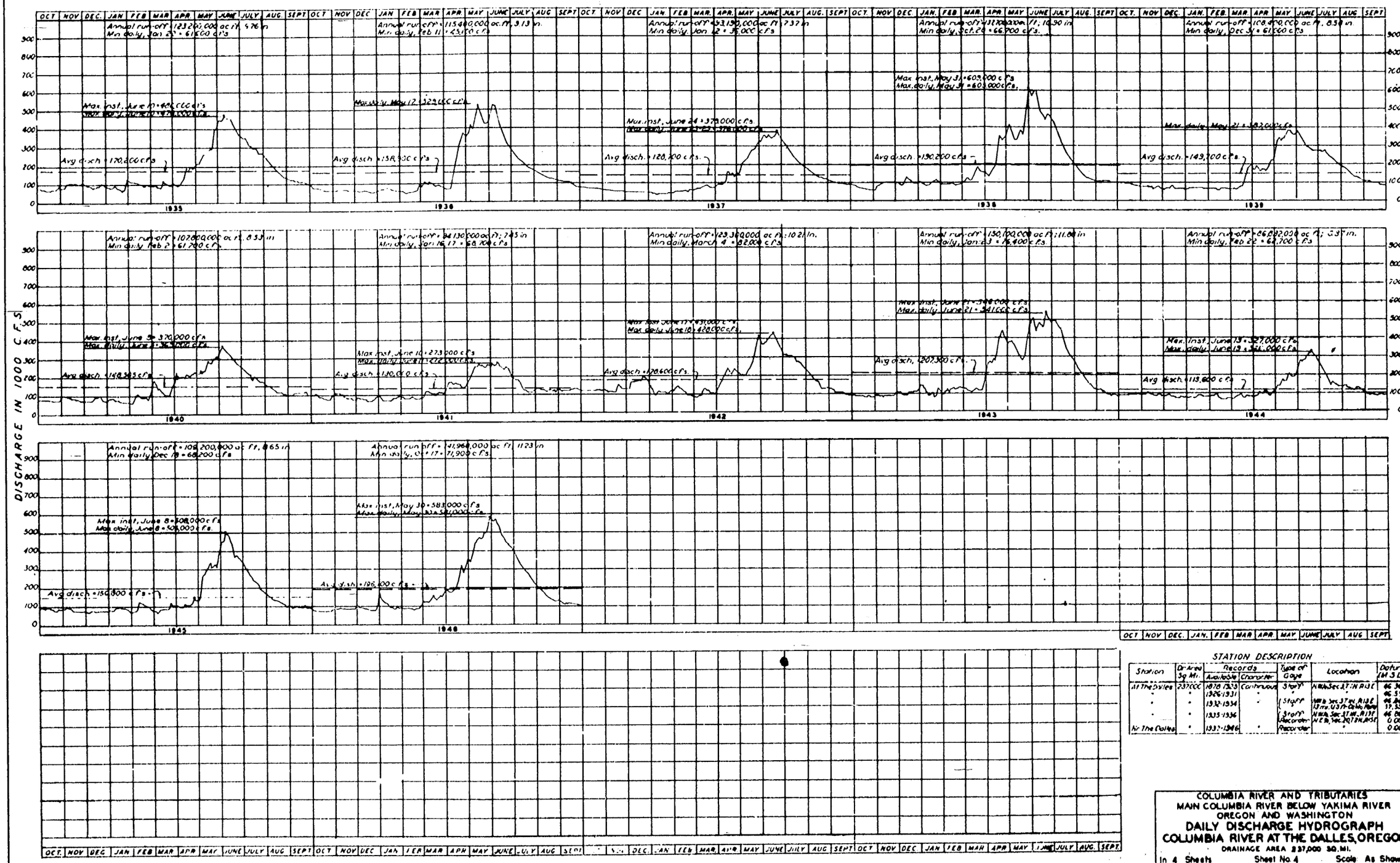
North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch

Approved for the Division Engineer: Chief, Engineering Division

Drawn by: A.J.B. Checked by: J.A.B. Traced by: R.E.B. Transmitted with report dated October 1, 1948

Portland District File No. CL-05-7/9



STATION DESCRIPTION

Station	Drainage Sq. Mi.	Records Available	Records Character	Type of Gage	Location	Datum (M.S.L.)
At The Dalles	237,000	1878-1933	Continuous	Staff	NW¼ Sec. 27 N, R13E	46.36
"	"	1926-1931	"	"	"	46.55
"	"	1932-1934	"	Staff	NW¼ Sec. 27 N, R13E	46.86
					13 mi. U.S. 99 Oak Ridge	37.33
"	"	1935-1936		Staff	NW¼ Sec. 27 N, R13E	46.86
				Recorder	NE¼ Sec. 20 T2N, R15E	0.00
Nr. The Dalles	"	1937-1946	"	Recorder	"	0.00

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

DAILY DISCHARGE HYDROGRAPH
COLUMBIA RIVER AT THE DALLES, OREGON

DRAINAGE AREA 237,000 SQ. MI.

In 4 Sheets — Sheet No. 4 — Scale: As Shown

North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch

Approved for the Division Engineer: Chief, Engineering Division

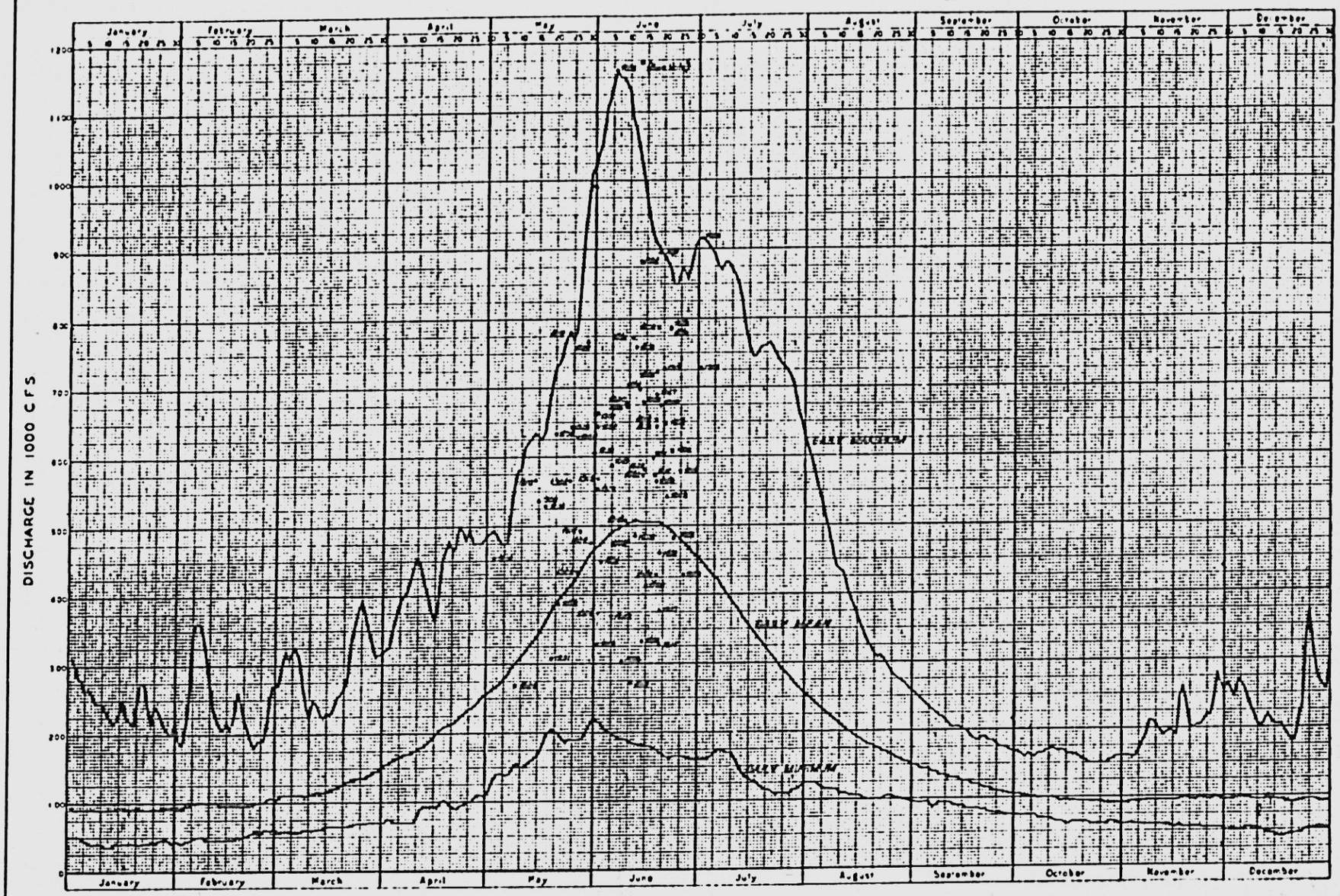
Drawn by: R.J.B. - A.H.B.
Traced by: H.B.
Checked by: P.R.B.

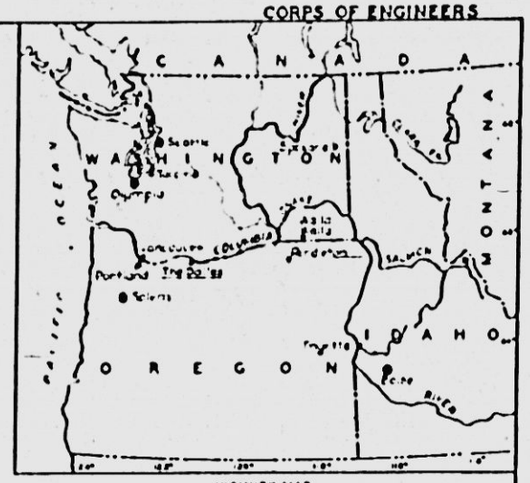
Transmitted with report dated October 1, 1948

Portland District File No. CL-05-7/10

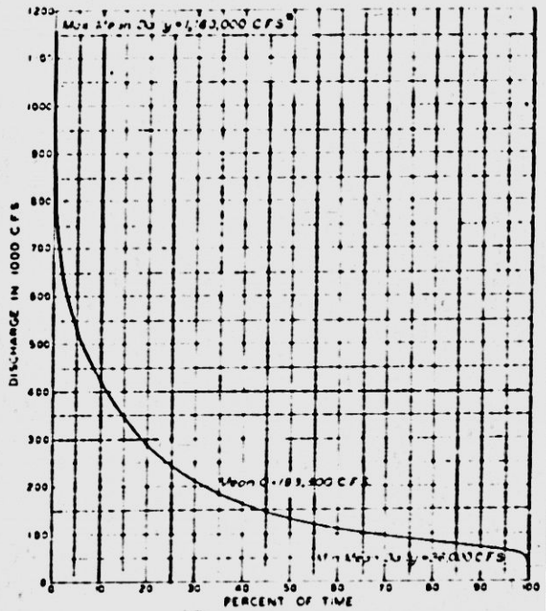
DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS





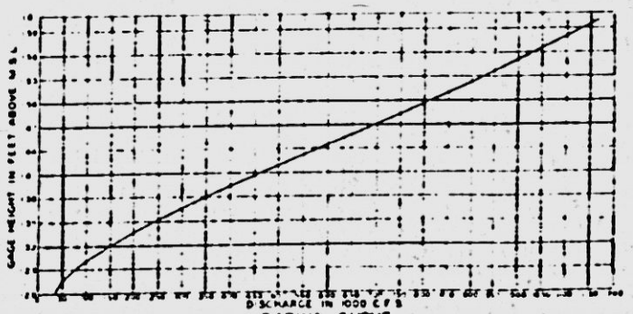
VICINITY MAP
SCALE IN MILES



FLOW-DURATION CURVE
COLUMBIA RIVER AT THE DALLES, ORE
JUNE 1878 - SEPT 30 1948

MAXIMUM ANNUAL MEAN DAILY Q. COLUMBIA RIVER, THE DALLES, OREGON

YEAR	DAY	CFS	YEAR	DAY	CFS	YEAR	DAY	CFS	YEAR	DAY	CFS	YEAR	DAY	CFS
1878	12 JUNE	485,000	1893	14 JUNE	6[illegible],000	1908	18 JUNE	639,000	1923	4-5 JUNE	581,000	1938	31 MAY	605,000
1879	9 JUNE	641,000	1894	8 JUNE	760,000*	1909	19 JUNE	675,000	1924	25-27 MAY	433,000	1939	21 MAY	487,000
1880	1 JULY	574,000	1895	31 MAY	475,000	1910	14 MAY	566,000	1925	24-25 MAY	642,000	1940	9 JUNE	365,000
1881	12 JUNE	558,000	1896	22 JUNE	783,000	1911	17-18 JUNE	574,000	1926	8 MAY	669,000	1941	11 JUNE	472,000
1882	13-14 JUNE	883,000	1897	24 MAY	760,000	1912	1 JUNE	568,000	1927	15 JUNE	650,000	1942	18 JUNE	428,000
1883	14 JUNE	573,000	1898	30 JUNE	649,000	1913	12 JUNE	759,000	1928	29 MAY	766,000	1943	21 JUNE	541,000
1884	13 JUNE	638,000	1899	26 JUNE	7[illegible],000	1914	22 MAY	433,000	1929	19 JUNE	600,000	1944	13 JUNE	3[illegible],000
1885	30 JUNE	485,000	1900	15 MAY	530,000	1915	1 JUNE	520,000	1930	18 JUNE	332,000	1945	5 JUNE	507,000
1886	9 JUNE	673,000	1901	8 JUNE	682,000	1916	1 JULY	727,000	1931	19 MAY	508,000	1946	30 MAY	581,000
1887	19 JUNE	8[illegible]6,000	1902	1 JUNE	6[illegible],000	1917	20 JUNE	727,000	1932	30 MAY	563,000	1947	----	----
1888	19 JUNE	564,000	1903	18 JUNE	707,000	1918	25 JUNE	578,000	1933	16 JUNE	[illegible]	1948	----	----
1889	30 JUNE	592,000	1904	26 MAY	679,000	1919	1 JUNE	553,000	1934	2 MAY	553,000	1949	----	----
1890	6-10 MAY	633,000	1905	15 JUNE	610,000	1920	26 JUNE	468,000	1935	10 JUNE	476,000	1950	----	----
1891	3 JUNE	440,000	1906	1 JUNE	5[illegible],000	1921	1 JUNE	[illegible],000	1936	7 MAY	521,000	NOTE	Mean Annual	Mean June
1892	22-23 MAY	607,000	1907	5 JUNE	58[illegible],000	1922	1 JUNE	[illegible],000	1937	3-4 MAY	576,000	Only	Mean Annual	[illegible] 1880



RATING CURVE
COLUMBIA RIVER AT THE DALLES, ORE

* Note
The gages shown on the plate were completed prior to the 1948 flood in Columbia River. Therefore the published value of maximum discharge, 620,000 second-feet has been used. Data obtained during 1948 flood indicate that the discharge should be revised to 1,240,000 second-feet

REVISED DEC. 15, 1948

COLUMBIA RIVER AND TRIBUTARIES
UNITED STATES AND BRITISH COLUMBIA
SUMMARY HYDROGRAPHS
COLUMBIA RIVER AT THE DALLES, OREGON

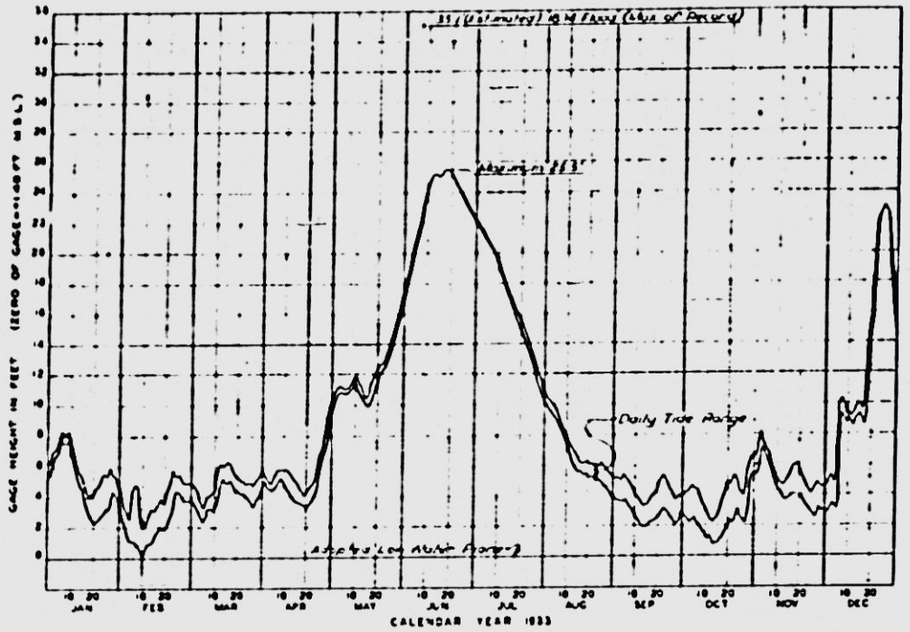
In 1 Sheet — Scale As Shown
North Pacific Division, Portland, Oregon — October 1, 1948

Submitted: Chief, Engineering Division
Recommended: Colonel, Corps of Engineers, Chief of Engineers
Approved: Colonel, Corps of Engineers, Division Engineer

Drawn by: E.S.B.
Traced by: W.F.B.
Checked by: H.M.; E.R.
Supplement with report dated October 1, 1948

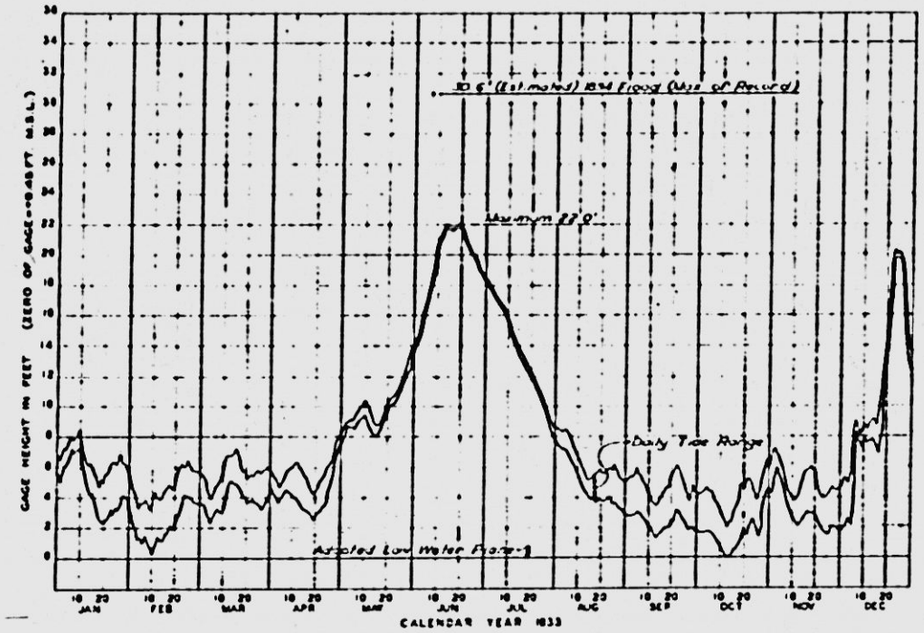
Portland District File No. CL-05-7/11

APPENDIX L PLATE II



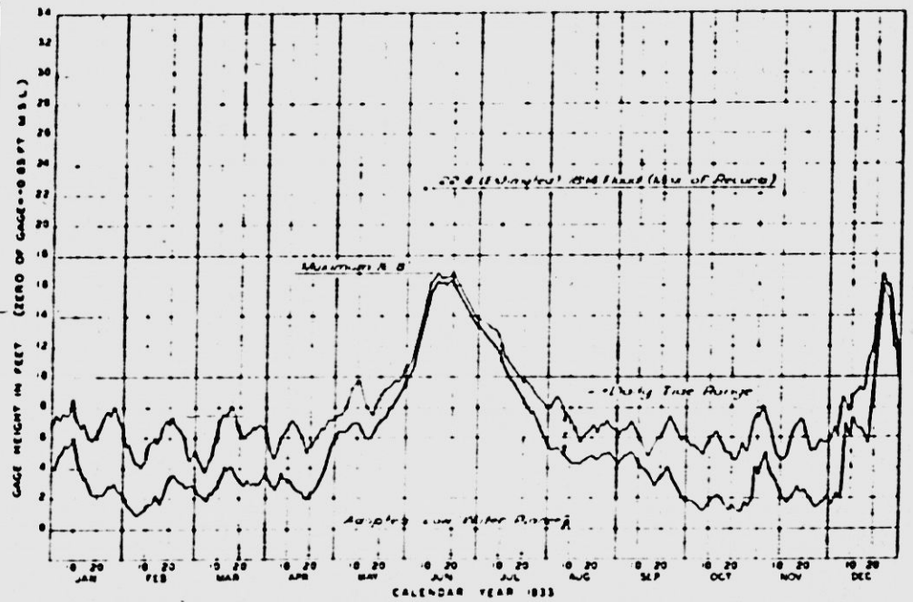
VANCOUVER, WASHINGTON

CORPS OF ENGINEERS GAGE



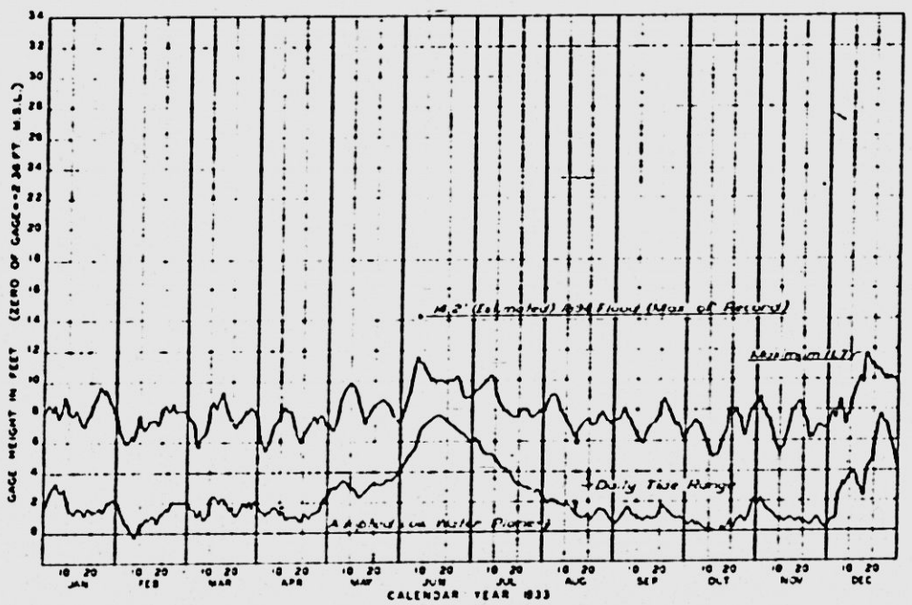
ST. HELENS, OREGON

CORPS OF ENGINEERS GAGE



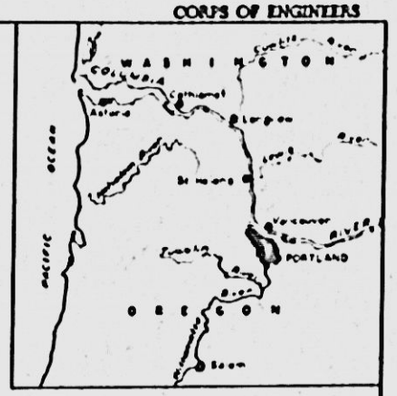
LONGVIEW, WASHINGTON

CORPS OF ENGINEERS GAGE



CATHLAMET, WASHINGTON

CORPS OF ENGINEERS GAGE



VICINITY MAP

SCALE IN MILES

MAXIMUM ANNUAL WATER SURFACE ELEVATIONS

YEAR	ELEVATION IN FEET - M.S.L. VANCOUVER	LONGVIEW
1902	23.1	
1903	26.3	
1904	23.3	
1905		
1906		
1907	20.9	
1908	23.2	
1909	22.8	
1910	20.4	
1911	20.5	
1912	20.8	
1913	23.9	
1914	18.3	
1915	14.1	
1916	24.0	
1917	24.0	
1918	21.6	
1919	20.8	
1920	16.1	
1921	24.1	
1922	24.8	
1923	22.1	
1924	16.8	
1925	23.8	
1926	11.83	
1927	25.43	
1928	26.93	16.0
1929	19.23	10.2
1930	13.33	7.4
1931	12.1	10.45
1932	23.0	12.55
1933	27.7	16.15
1934	19.3	10.65
1935	20.2	10.85
1936	22.6	12.95
1937	18.9	10.85
1938	24.0	13.15
1939	16.5	9.45
1940	15.55	8.75
1941	11.45	11.33
1942	18.65	11.13
1943	22.15	12.23
1944	13.55	8.43
1945	20.65	11.83
1946	23.65	13.73

Note
U.S. Weather Bureau and Corps of Engineers tide records combined

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

MAXIMUM & MINIMUM DAILY RIVER STAGES
VANCOUVER, LONGVIEW, & CATHLAMET, WASH
AND ST. HELENS, OREGON

In 1 Sheet — Scale As Shown

North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch

Approved for the Division Engineer: Chief, Engineering Division

Drawn by L.W.S.
Traced by H.E.B.
Checked by J.B.

Submitted with report dated October 1, 1948

Portland District File No. CL-05-7/12

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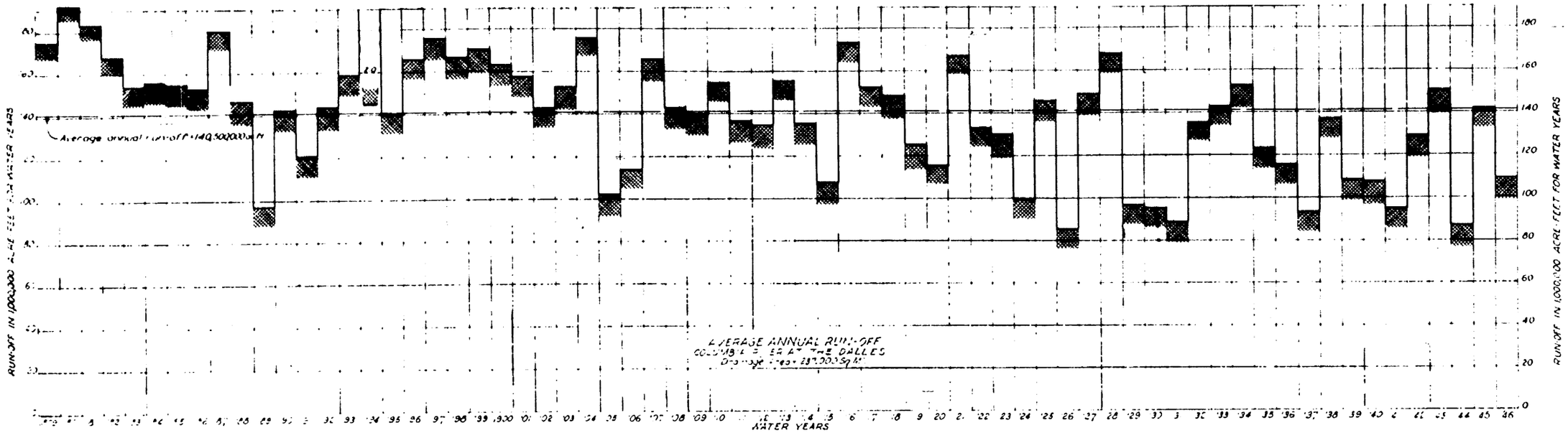

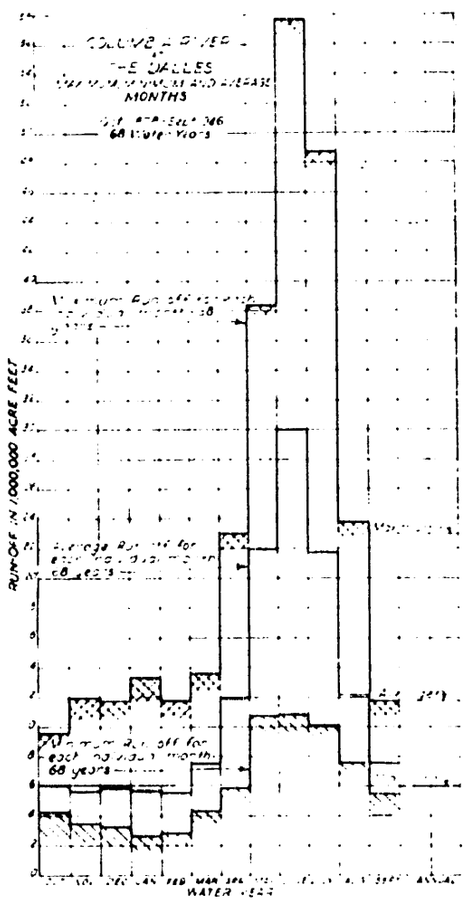

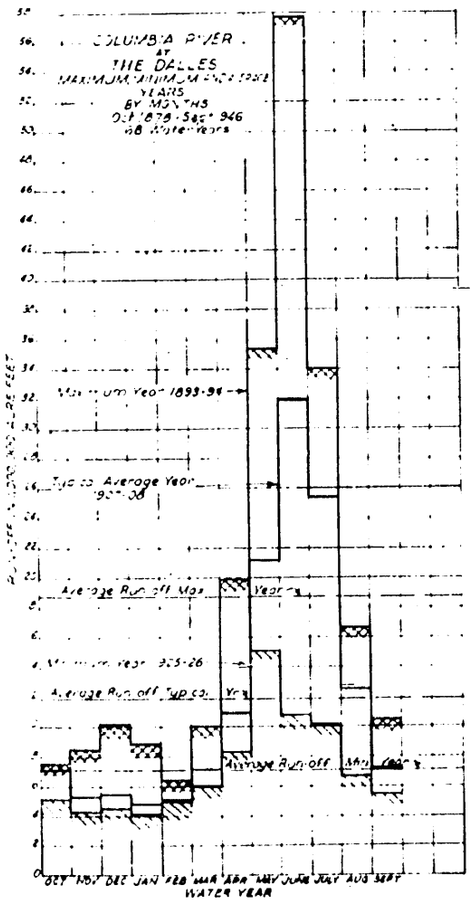

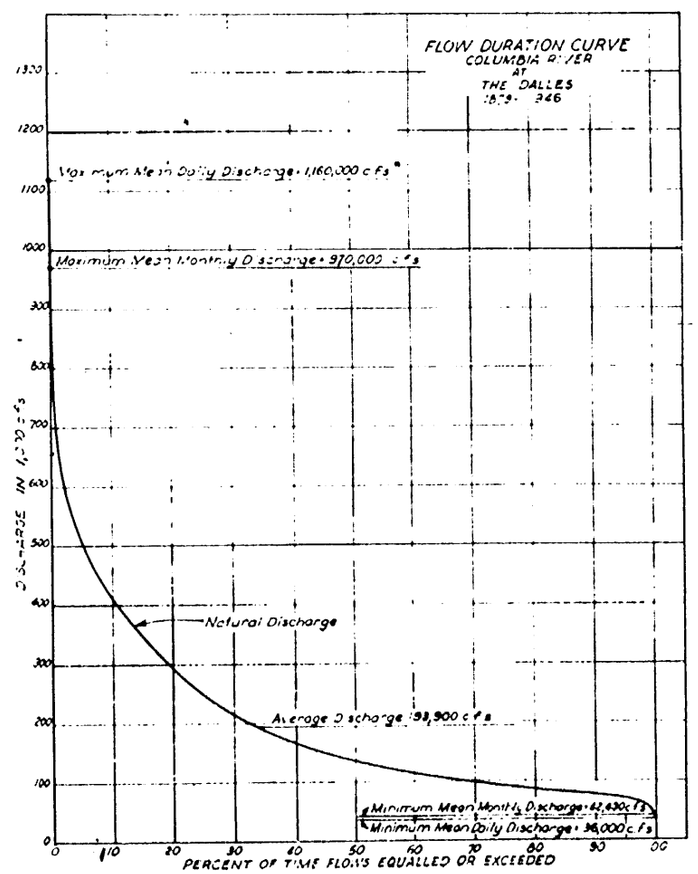

*Note:
The studies shown on this plate were completed prior to the 1948 flood in Columbia River. Therefore the published value of maximum discharge 1,160,000 second-feet, has been used. Data obtained during 1948 flood indicate that this discharge should be revised to 1,240,000 second-feet.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

STREAM FLOW CHARACTERISTICS
COLUMBIA RIVER AT THE DALLES, OREGON

In 1 Sheet — Scale As Shown
North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch
Approved for the Division Engineer: Chief, Engineering Division

Drawn by W.A.H. Traced by A.J.B. Checked by R.E.C.-C.P.
Transmitted with report dated October 1, 1948
Portland District File No. CL-05-7/13

REVISED DEC. 15, 1948

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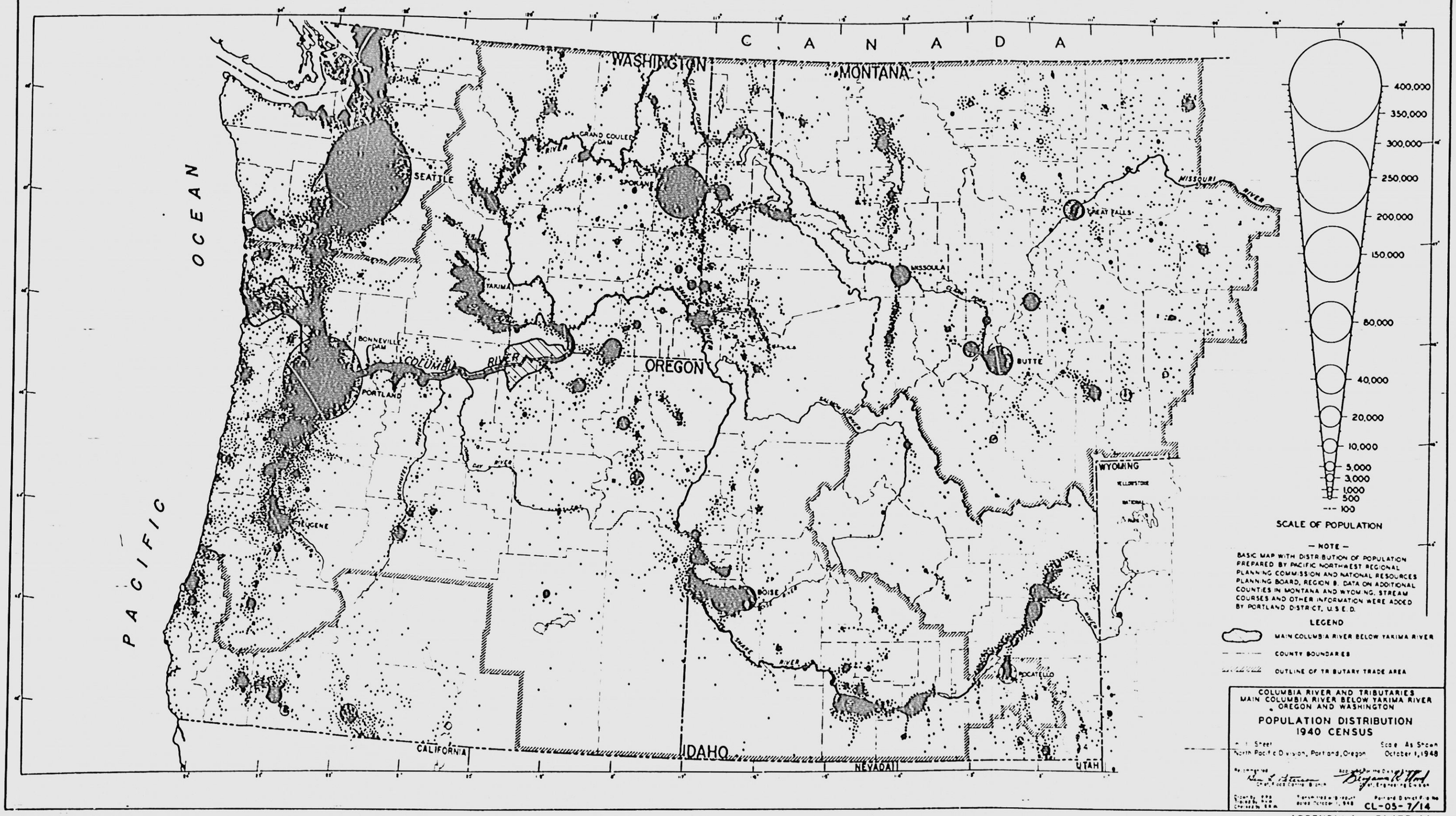
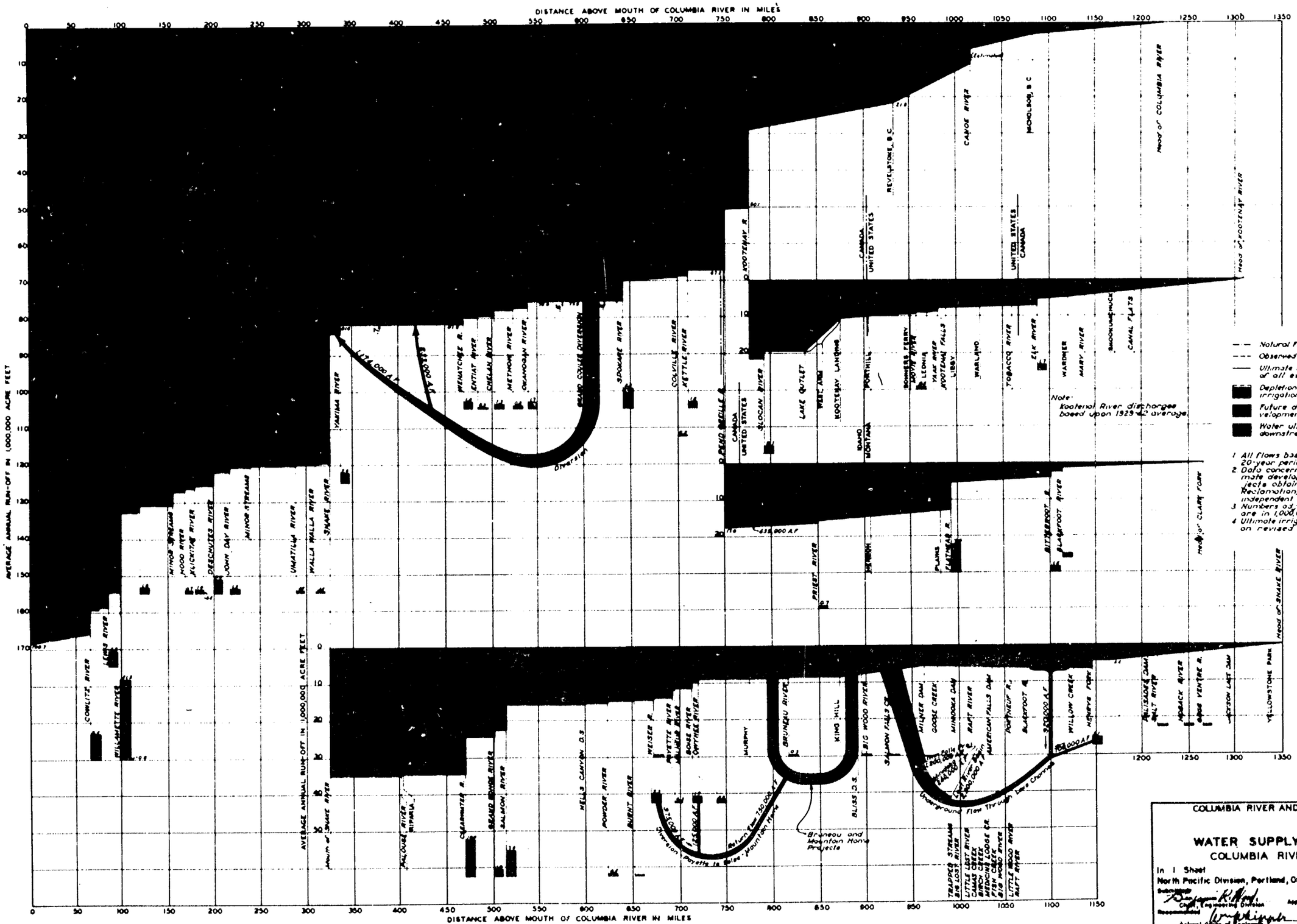
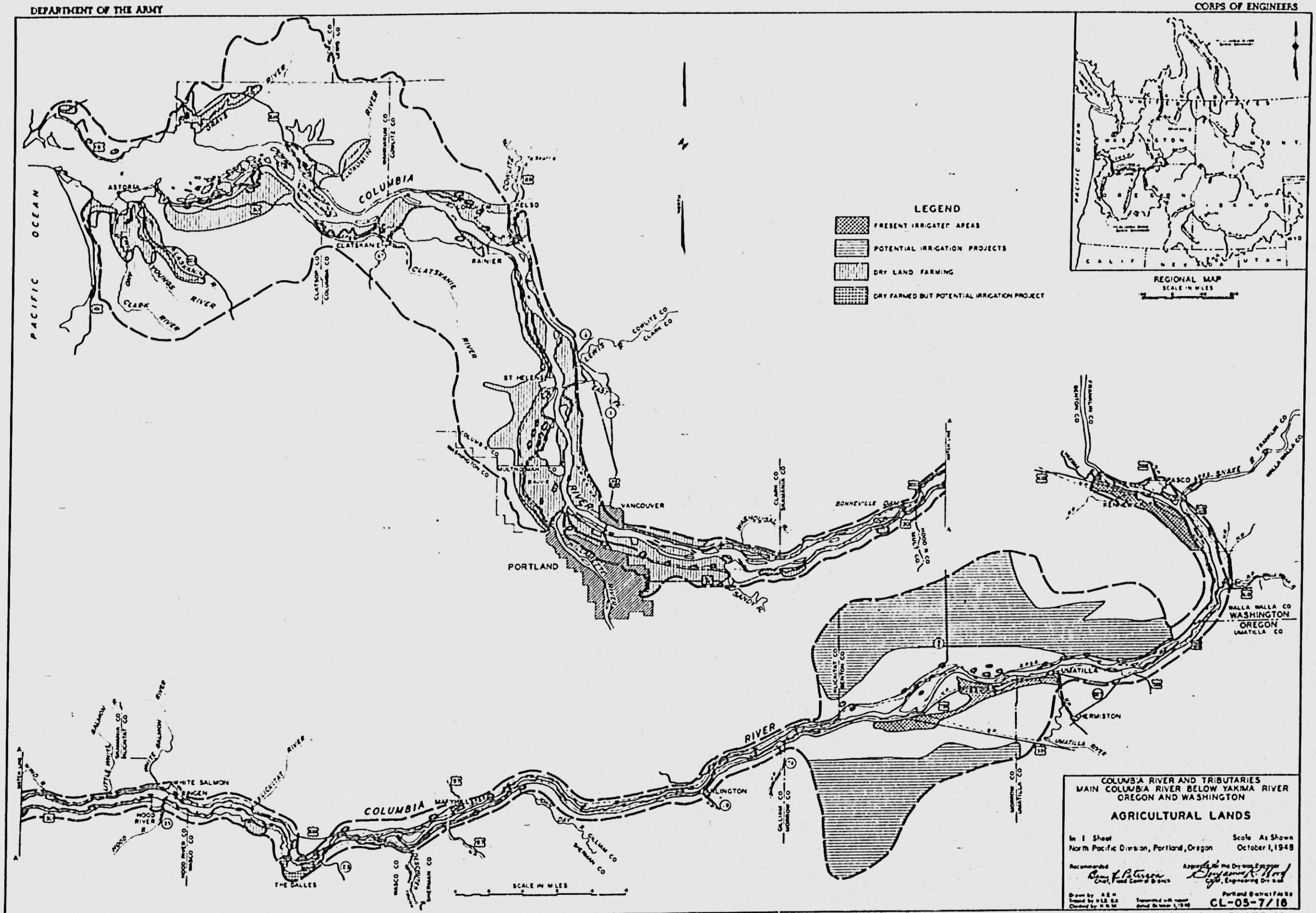
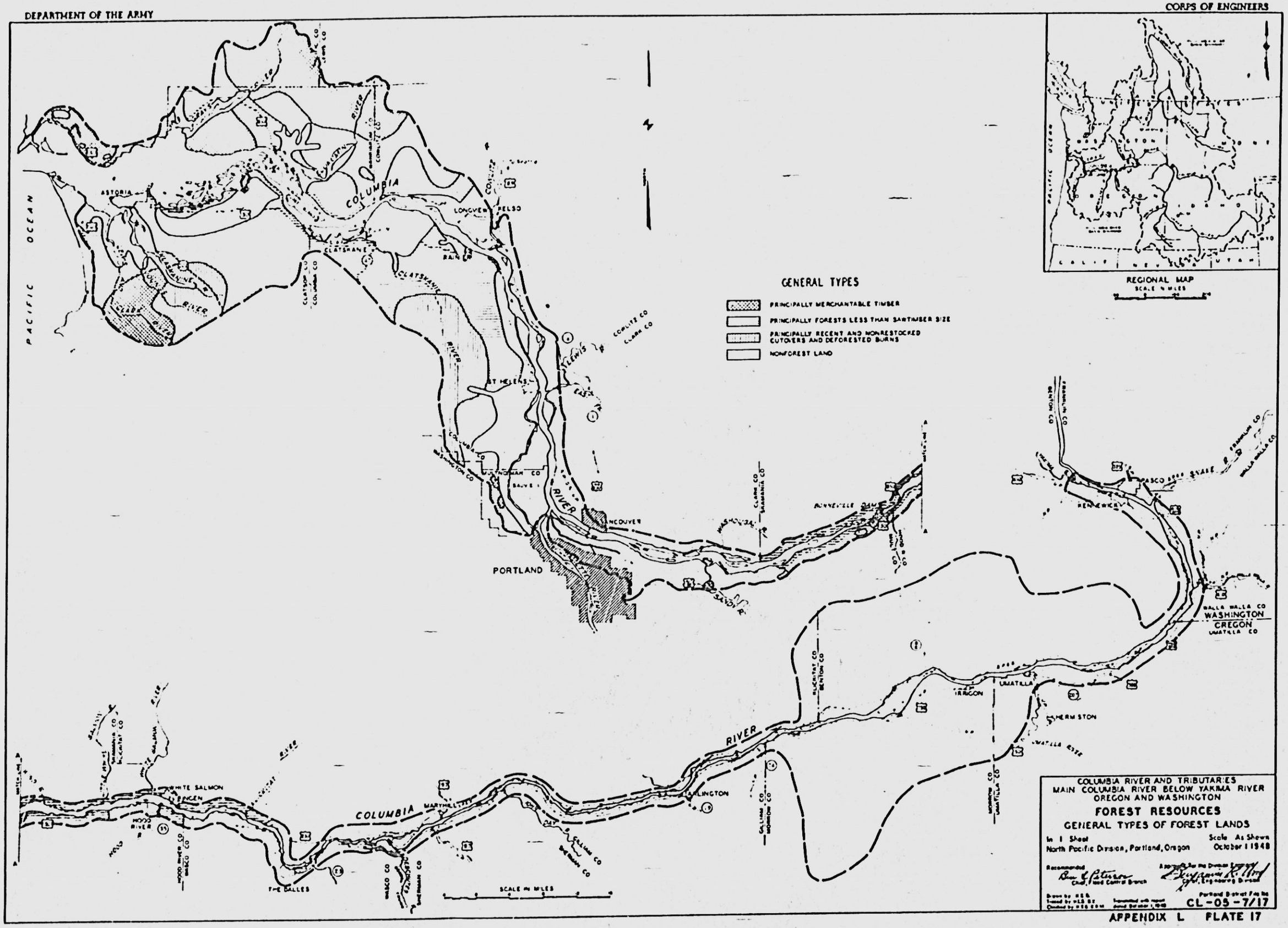

CANADA
WASHINGTON
MONTANA
OREGON
IDAHO
NEVADA
UTAH
CALIFORNIA
PACIFIC OCEAN
SEATTLE
SPOKANE
YAKIMA
PORTLAND
EUGENE
BONNEVILLE DAM
GRAND COULEE DAM
COLUMBIA RIVER
MISSOULA
BUTTE
GREAT FALLS
MISSOURI RIVER
BOISE
POCATELLO
WYOMING
400,000
350,000
300,000
250,000
200,000
150,000
80,000
40,000
20,000
10,000
5,000
3,000
1,000
500
100
SCALE OF POPULATION
— NOTE —
BASIC MAP WITH DISTRIBUTION OF POPULATION PREPARED BY PACIFIC NORTHWEST REGIONAL PLANNING COMMISSION AND NATIONAL RESOURCES PLANNING BOARD, REGION 8. DATA ON ADDITIONAL COUNTIES IN MONTANA AND WYOMING, STREAM COURSES AND OTHER INFORMATION WERE ADDED BY PORTLAND DISTRICT, U.S.E.D.
LEGEND
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
COUNTY BOUNDARIES
OUTLINE OF TRIBUTARY TRADE AREA
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
POPULATION DISTRIBUTION
1940 CENSUS
Sheet
North Pacific Division, Portland, Oregon
Scale As Shown
October 1, 1948
CL-05-7/14



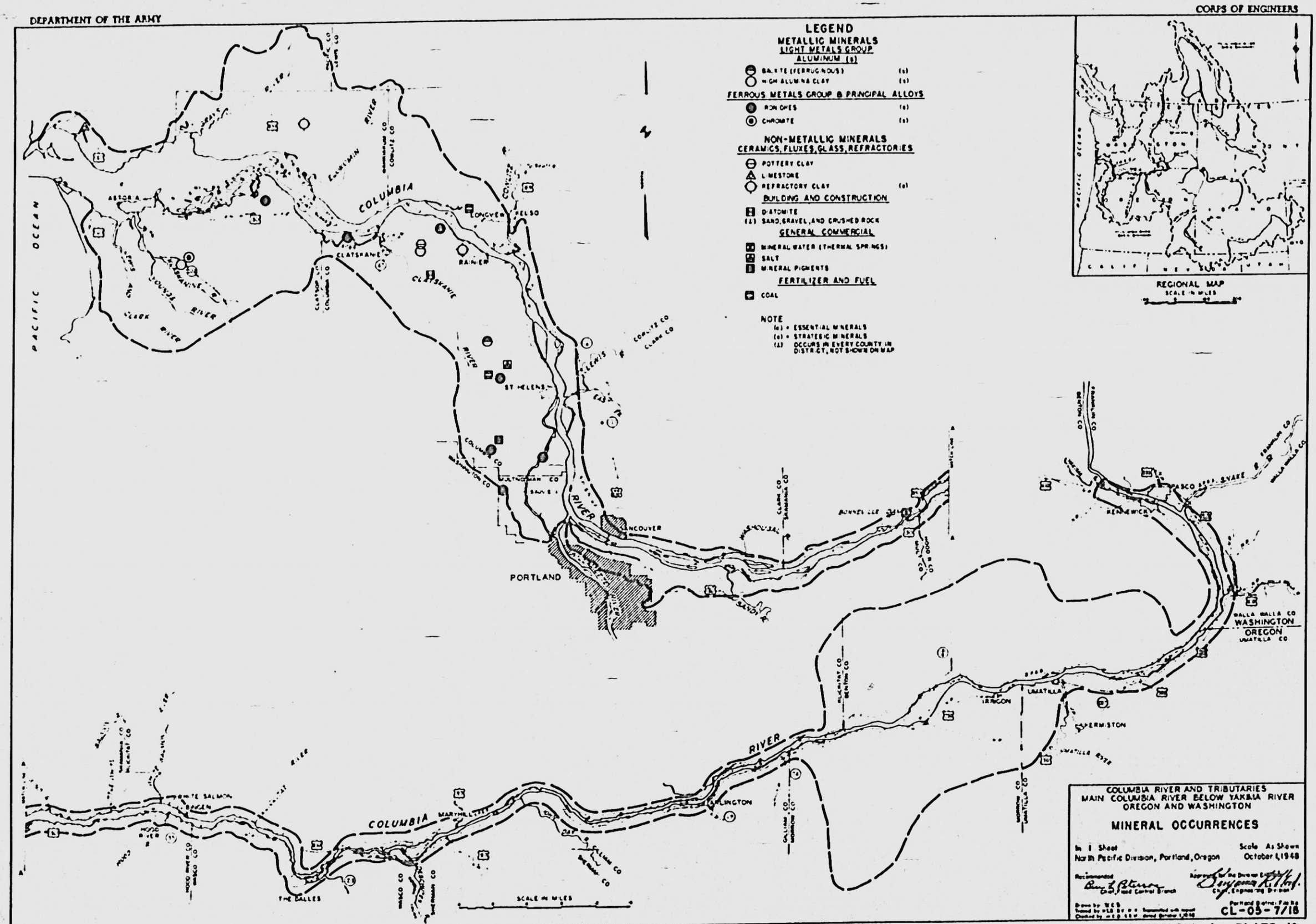
APPENDIX L PLATE 15

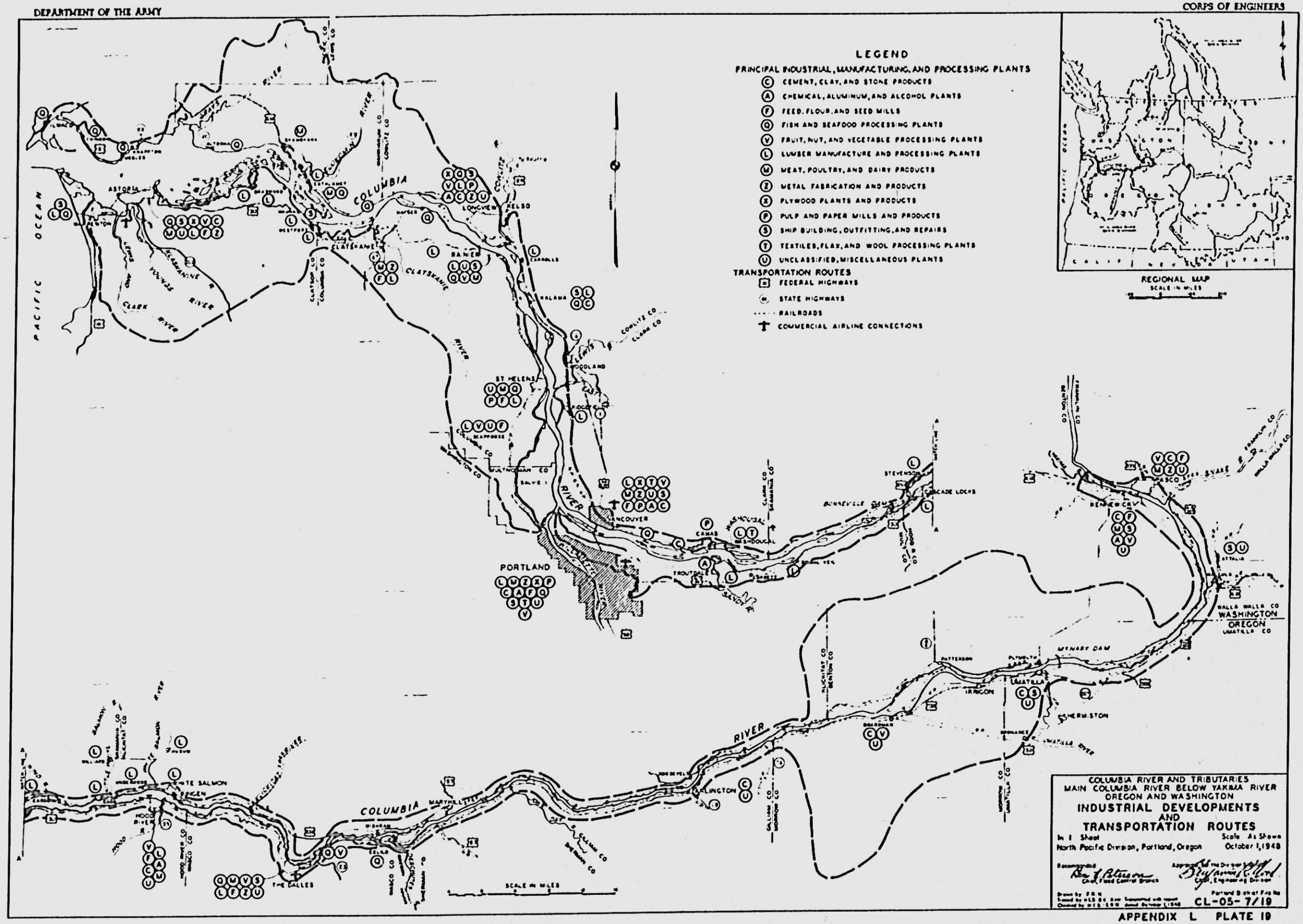


01275 O—51—vol. VI

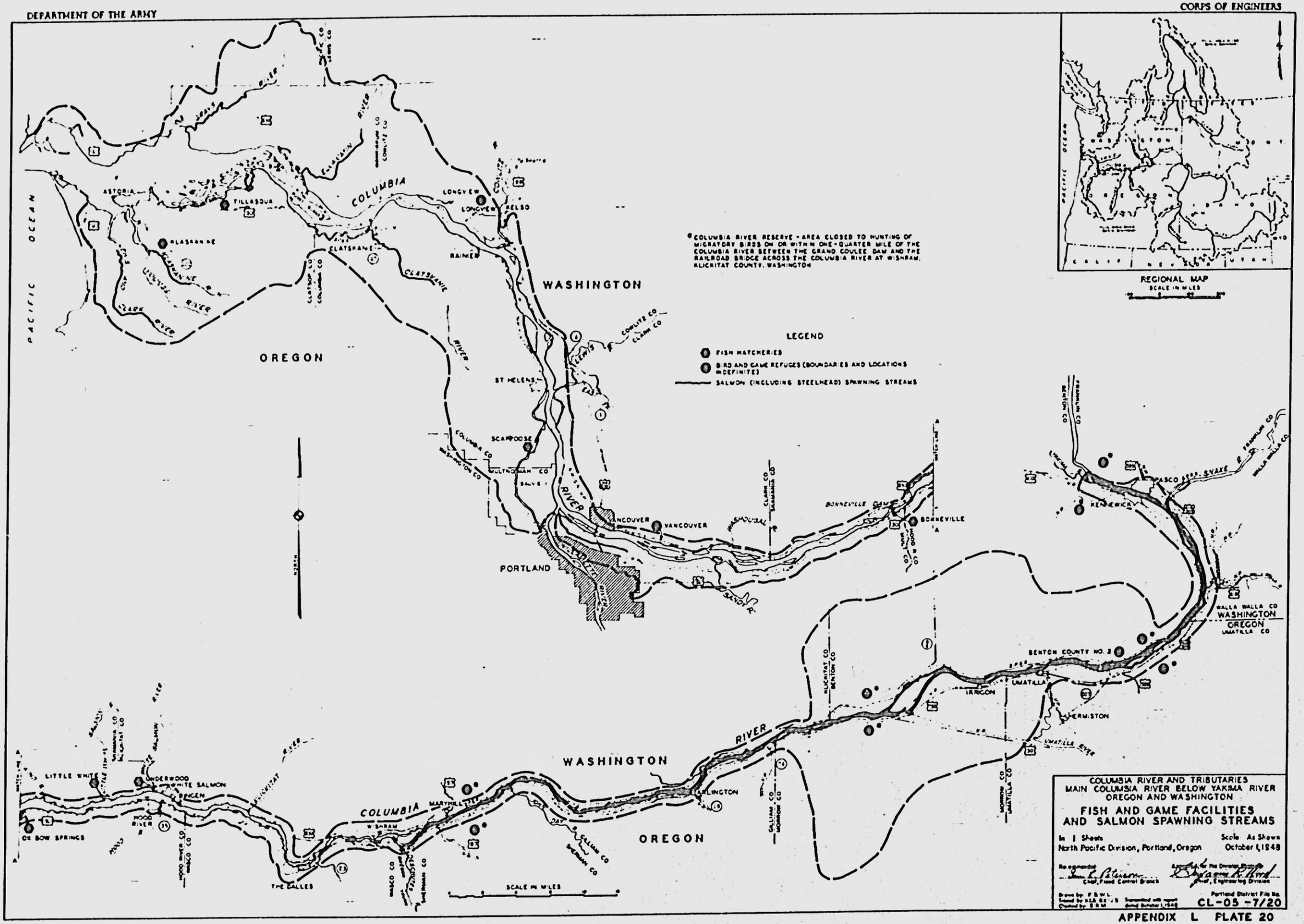


APPENDIX L PLATE 17


LEGEND
METALLIC MINERALS
LIGHT METALS GROUP
ALUMINUM (e)
BAUXITE (FERRUGINOUS) (s)
HIGH ALUMINA CLAY (s)
FERROUS METALS GROUP & PRINCIPAL ALLOYS
IRON ORES (e)
CHROMITE (s)
NON-METALLIC MINERALS
CERAMICS, FLUXES, GLASS, REFRACTORIES
POTTERY CLAY
LIMESTONE
REFRACTORY CLAY (e)
BUILDING AND CONSTRUCTION
DIATOMITE
(z) SAND, GRAVEL, AND CRUSHED ROCK
GENERAL COMMERCIAL
MINERAL WATER (THERMAL SPRINGS)
SALT
MINERAL PIGMENTS
FERTILIZER AND FUEL
COAL
NOTE
(e) = ESSENTIAL MINERALS
(s) = STRATEGIC MINERALS
(z) OCCURS IN EVERY COUNTY IN DISTRICT, NOT SHOWN ON MAP
REGIONAL MAP
SCALE IN MILES
PACIFIC OCEAN
COLUMBIA RIVER
ASTORIA
CLATSKANIE
RAINIER
LONGVIEW
KELSO
ST HELENS
VANCOUVER
PORTLAND
WASHOUGAL
BONNEVILLE
HOOD RIVER
BENGEN
WHITE SALMON
THE DALLES
MARYHILL
BIGGS
ARLINGTON
UMATILLA
IRRIGON
PENDLETON
PASCO
KENNEWICK
WALLA WALLA CO
WASHINGTON
OREGON
UMATILLA CO
SCALE IN MILES
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
MINERAL OCCURRENCES
In 1 Sheet
Scale As Shown
North Pacific Division, Portland, Oregon
October 1, 1948
Chief, Flood Control Branch
Chief, Engineering Division
Portland District File No
CL-05-7/18



91275 O—51—vol. VI



* COLUMBIA RIVER RESERVE - AREA CLOSED TO HUNTING OF MIGRATORY BIRDS ON OR WITHIN ONE-QUARTER MILE OF THE COLUMBIA RIVER BETWEEN THE GRAND COULEE DAM AND THE RAILROAD BRIDGE ACROSS THE COLUMBIA RIVER AT WISHRAM, KLICKITAT COUNTY, WASHINGTON

LEGEND

- FISH HATCHERIES
- BIRD AND GAME REFUGES (BOUNDARIES AND LOCATIONS INDEFINITE)
- SALMON (INCLUDING STEELHEAD) SPAWNING STREAMS

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EXISTING ELECTRIC GENERATING PLANTS[1]

INDEX NO	NAME	OWNER	LOCATION	NAME PLATE RATING KW HYDRO	NAME PLATE RATING KW STEAM
1	POWERDALE	PACIFIC POWER & LIGHT CO	HOOD RIVER	(8,000)	
2	CONDIT	" " " "	WHITE SALMON RIV	(19,600)	
3	BONNEVILLE	CORPS OF ENGINEERS	COLUMBIA RIVER	518,400	
4	—	CROWN-ZELLERBACH CO	CAMAS, WASH		8,750
5	—	COLUMBIA RIVER PAPER CO	VANCOUVER, WASH		2,500
6	—	VANCOUVER PLYWOOD CO	" "		2,250
7	LONGVIEW	PUD NO 1, COWLITZ CO	LONGVIEW WASH		27,000
8	—	LONGVIEW FIBRE CO	" "		8,000
9	—	WEYERHAEUSER TIMBER CO	" "		15,000
10	WESTPORT	WESTPORT LUMBER CO	WESTPORT, OREGON		2,750
11	ASTORIA	PACIFIC POWER & LIGHT CO	ASTORIA, OREGON		10,000
12	—	PROUTY LUMBER & BOX CO	" "		1,250
			SUB-TOTAL	518,400	75,500
			TOTAL	593,900	

NOTES NUMBERS IN PARENTHESES NOT INCLUDED IN TOTALS - SEE APPENDIX "A".
1 AS OF JANUARY 1, 1948

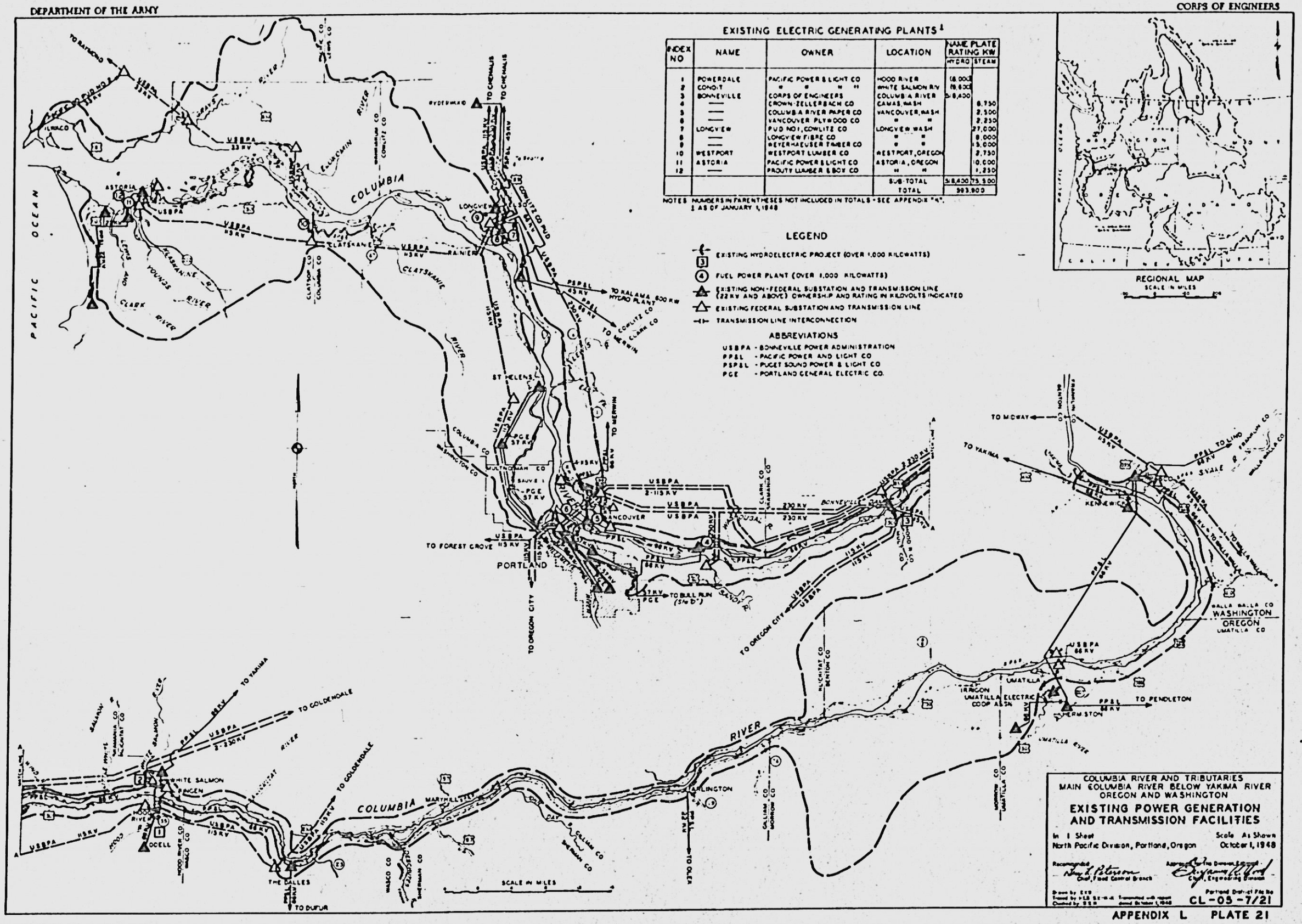
LEGEND

- EXISTING HYDROELECTRIC PROJECT (OVER 1,000 KILOWATTS)
- FUEL POWER PLANT (OVER 1,000 KILOWATTS)
- EXISTING NON-FEDERAL SUBSTATION AND TRANSMISSION LINE (22 KV AND ABOVE) OWNERSHIP AND RATING IN KILOVOLTS INDICATED
- EXISTING FEDERAL SUBSTATION AND TRANSMISSION LINE
- TRANSMISSION LINE INTERCONNECTION

ABBREVIATIONS

USBPA - BONNEVILLE POWER ADMINISTRATION
PPSL - PACIFIC POWER AND LIGHT CO
PSPSL - PUGET SOUND POWER & LIGHT CO
PGE - PORTLAND GENERAL ELECTRIC CO.

REGIONAL MAP
SCALE IN MILES



COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

EXISTING POWER GENERATION AND TRANSMISSION FACILITIES

In 1 Sheet — Scale As Shown
North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch
Approved: Chief, Engineering Division

Drawn by EVD
Traced by H.E.B. Sr. Draftsman
Checked by E.S.B.
Portland District File No CL-05-7/21

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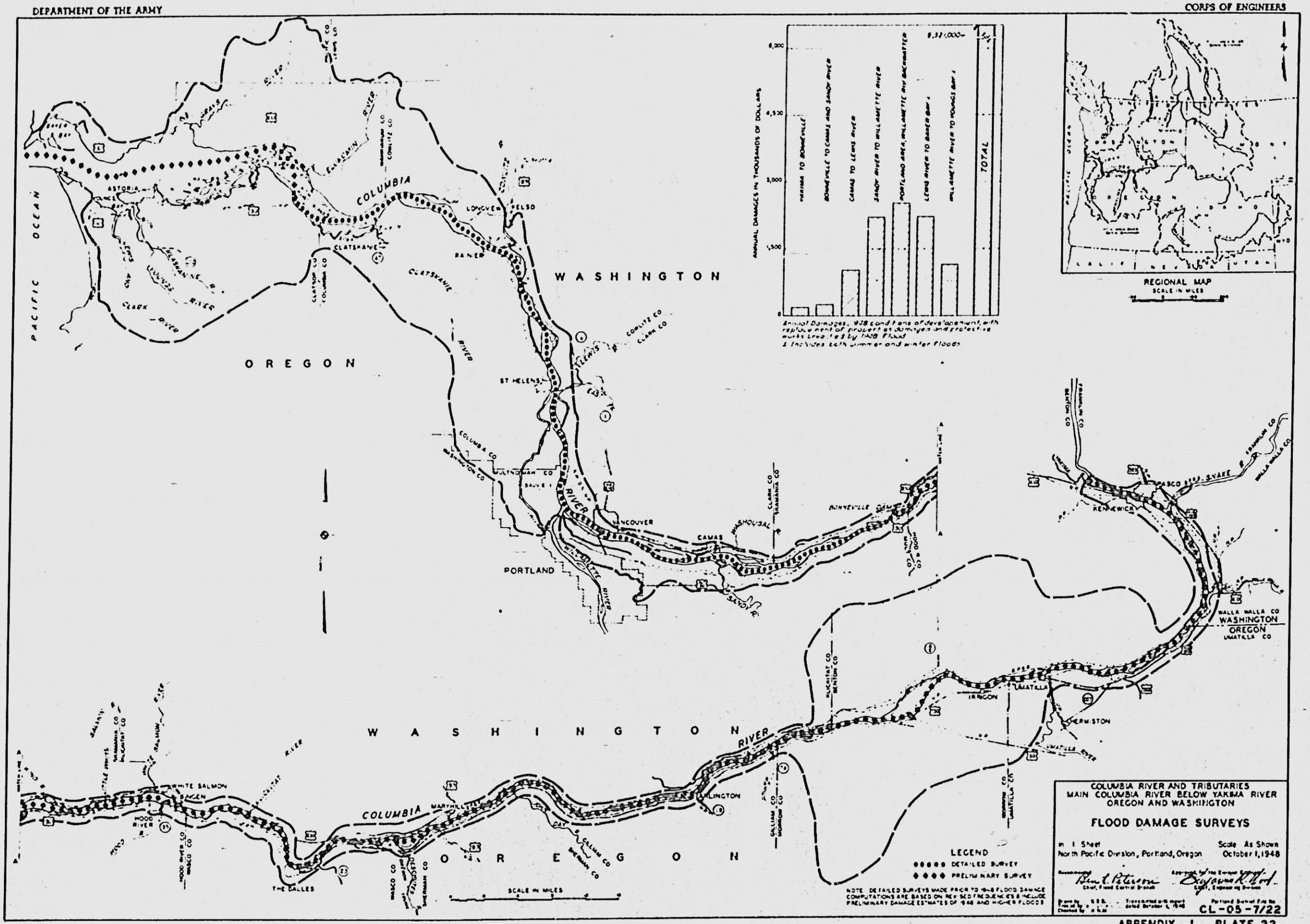
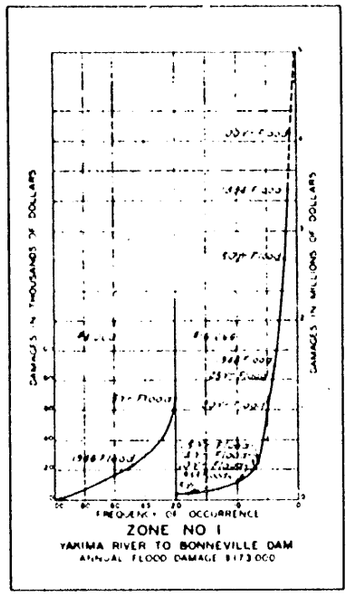
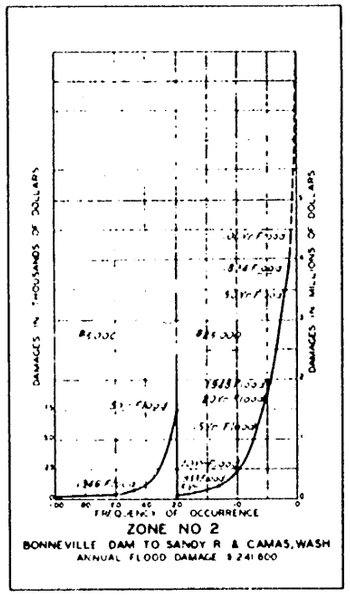
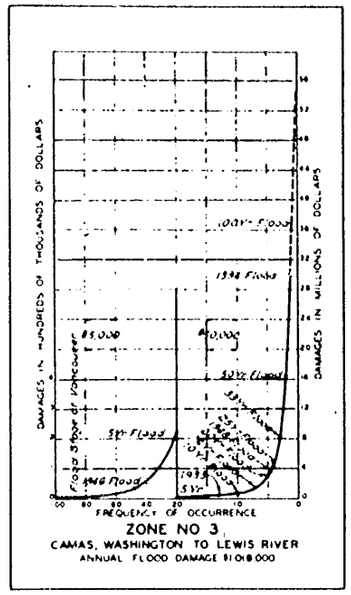

PACIFIC OCEAN
OREGON
WASHINGTON
COLUMBIA
ASTORIA
CLATSKANIE
RAINIER
ST HELENS
PORTLAND
VANCOUVER
CAMAS
BONNEVILLE DAM
KENNEWICK
PASCO
WALLA WALLA CO
WASHINGTON
OREGON
UMATILLA CO
PENDLETON
UMATILLA
HERMISTON
ARLINGTON
MAYHILL
THE DALLES
WHITE SALMON
BIGGEN
HOOD RIVER
ANNUAL DAMAGES IN THOUSANDS OF DOLLARS
6,000
4,500
3,000
1,500
0
VARIOUS TO BONNEVILLE
BONNEVILLE TO CAMAS AND SANDY RIVER
CAMAS TO LEWIS RIVER
SANDY RIVER TO WILLAMETTE RIVER
PORTLAND AREA, WILLAMETTE RIV BACKWATER
LEWIS RIVER TO BAKER BAY 1
WILLAMETTE RIVER TO HOUGH BAY 1
TOTAL
8,521,000
Annual Damages, 1938 conditions of development with replacement of property damages and protective works levees by 1948 Flood
1 Includes both summer and winter floods
REGIONAL MAP
SCALE IN MILES
SCALE IN MILES
LEGEND
DETAILED SURVEY
PRELIMINARY SURVEY
NOTE DETAILED SURVEYS MADE PRIOR TO 1948 FLOOD DAMAGE COMPUTATIONS ARE BASED ON REV SED FREQUENCIES & INCLUDE PRELIMINARY DAMAGE ESTIMATES OF 1948 AND HIGHER FLOODS
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
FLOOD DAMAGE SURVEYS
in 1 Sheet
Scale As Shown
North Pacific Division, Portland, Oregon
October 1, 1948
CL-05-7/22



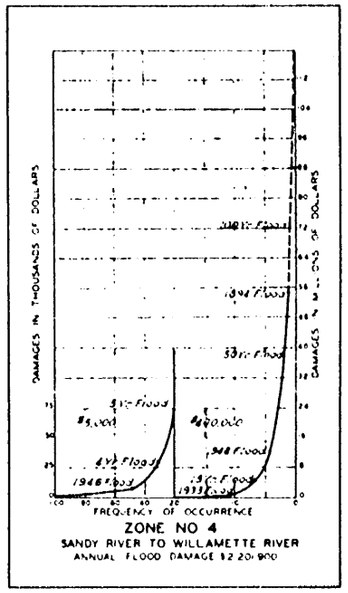
ZONE NO 1
YAKIMA RIVER TO BONNEVILLE DAM
ANNUAL FLOOD DAMAGE $173,000



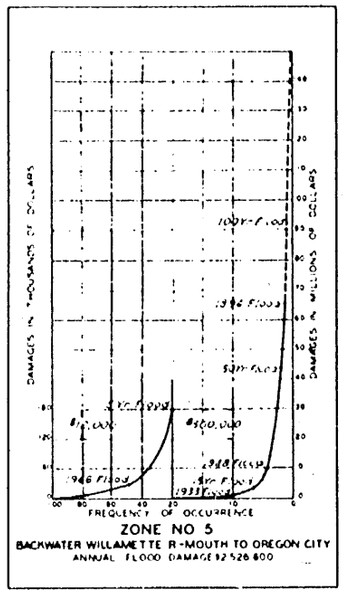
ZONE NO 2
BONNEVILLE DAM TO SANDY R & CAMAS, WASH
ANNUAL FLOOD DAMAGE $241,800



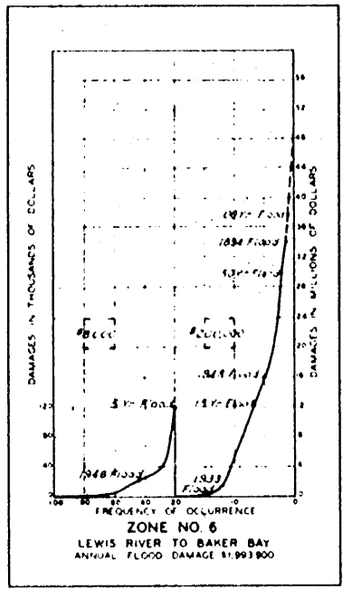
ZONE NO 3
CAMAS, WASHINGTON TO LEWIS RIVER
ANNUAL FLOOD DAMAGE $1,018,000



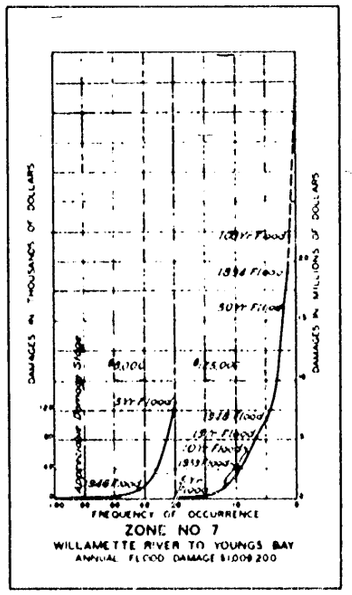
ZONE NO 4
SANDY RIVER TO WILLAMETTE RIVER
ANNUAL FLOOD DAMAGE $2,201,900



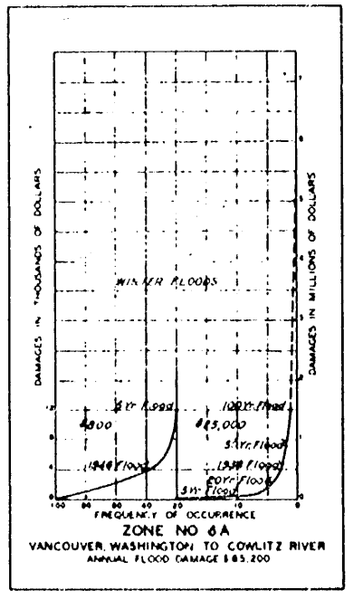
ZONE NO 5
BACKWATER WILLAMETTE R-MOUTH TO OREGON CITY
ANNUAL FLOOD DAMAGE $2,526,800



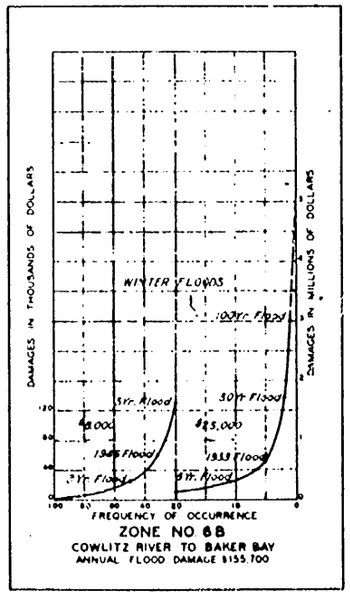
ZONE NO. 6
LEWIS RIVER TO BAKER BAY
ANNUAL FLOOD DAMAGE $1,993,900



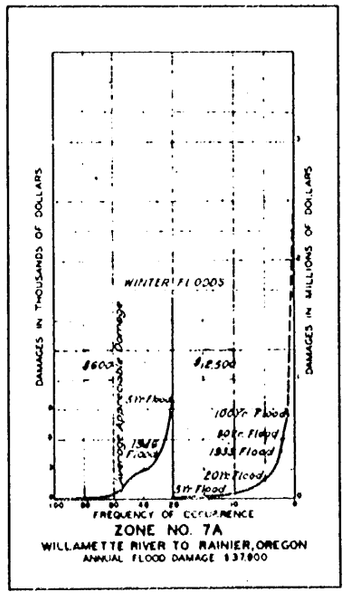
ZONE NO 7
WILLAMETTE RIVER TO YOUNGS BAY
ANNUAL FLOOD DAMAGE $1,009,200



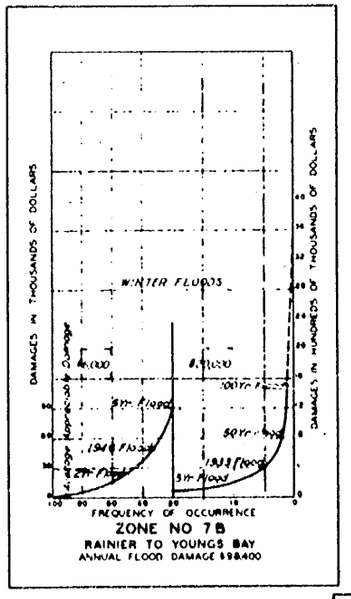
ZONE NO 6A
VANCOUVER, WASHINGTON TO COWLITZ RIVER
ANNUAL FLOOD DAMAGE $85,200



ZONE NO 6B
COWLITZ RIVER TO BAKER BAY
ANNUAL FLOOD DAMAGE $155,700



ZONE NO. 7A
WILLAMETTE RIVER TO RAINIER, OREGON
ANNUAL FLOOD DAMAGE $37,900



ZONE NO 7B
RAINIER TO YOUNGS BAY
ANNUAL FLOOD DAMAGE $98,400

ZONE	ANNUAL FLOOD DAMAGES
1	$ 173,000
2	241,800
3	1,018,000
4	2,201,900
5	2,526,800
6	1,993,900
7	1,009,200
6A	85,200
6B	155,700
7A	37,900
7B	98,400
TOTALS	$9,521,400

Note
Annual damages are derived from areas enclosed by damage frequency curves with the scales of damages in dollars and frequency of occurrence in any one year.
Damage estimates are based on preliminary incomplete appraisals of 1948 flood damages and the damages to be expected with recurrence of higher flood stages. Complete appraisals of 1948 flood damages and those for higher stages may increase materially present estimates of annual damages.
Damages are based on 1948 conditions of economic development.

Note
Flood damage data for zones 1 to 7 inclusive are for spring and summer floods. Winter floods cause damages only in zones 6A to 7B inclusive, the areas of which overlap the lower portion of zones 3 and all of zones 6 and 7.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

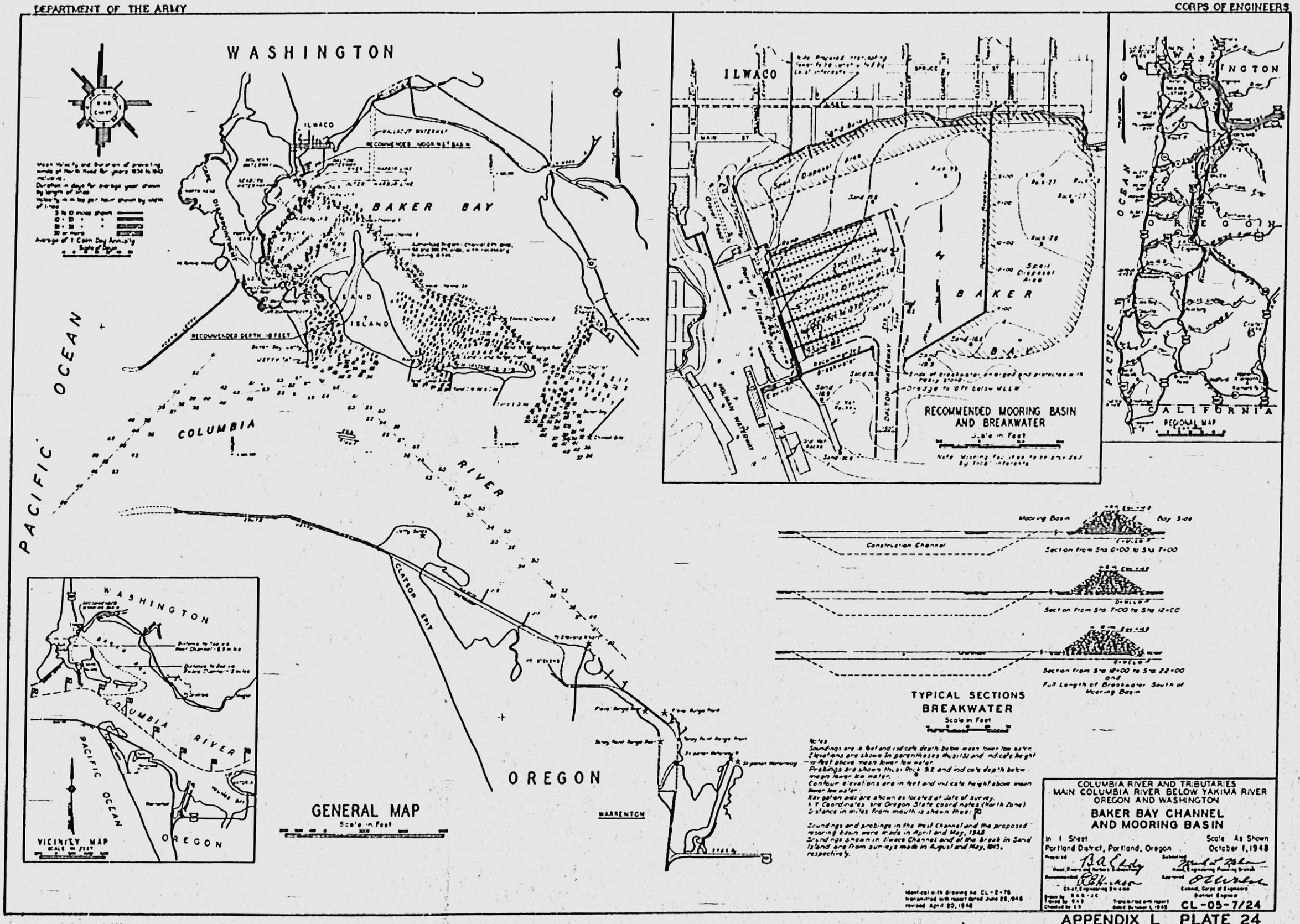
DAMAGE FREQUENCY CURVES

In 1 Sheet — Scale As Shown
North Pacific Division, Portland, Oregon — October 1, 1948

Recommended: Chief, Flood Control Branch
Approved, for the Division Engineer: Chief, Engineering Division

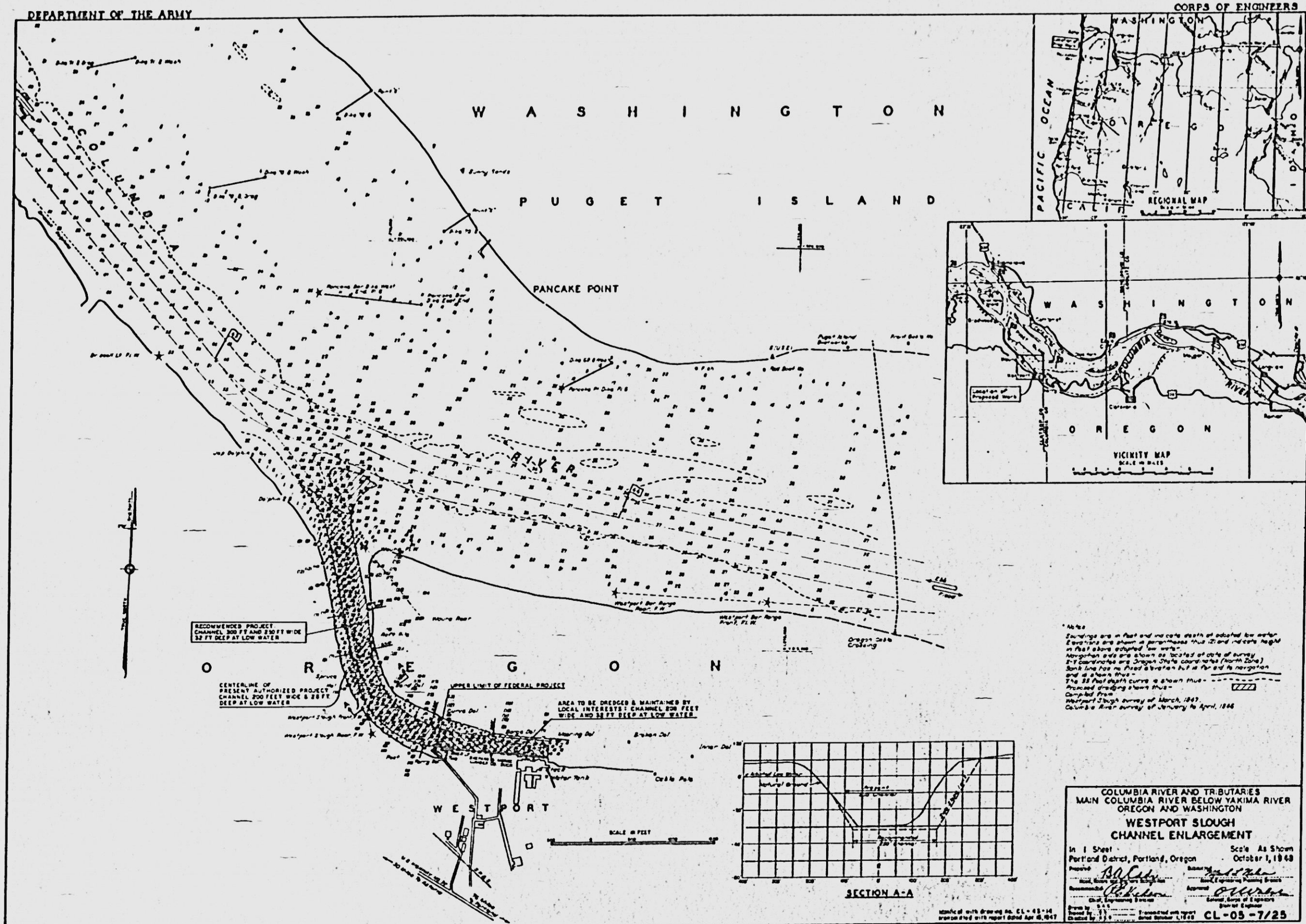
Drawn by: W.S.T.J.
Traced by: B.V.
Checked by: E.R.M.
Transmitted with report dated October 1, 1948
Portland District File No. CL-05-7/23

01275 O—51—vol. VI

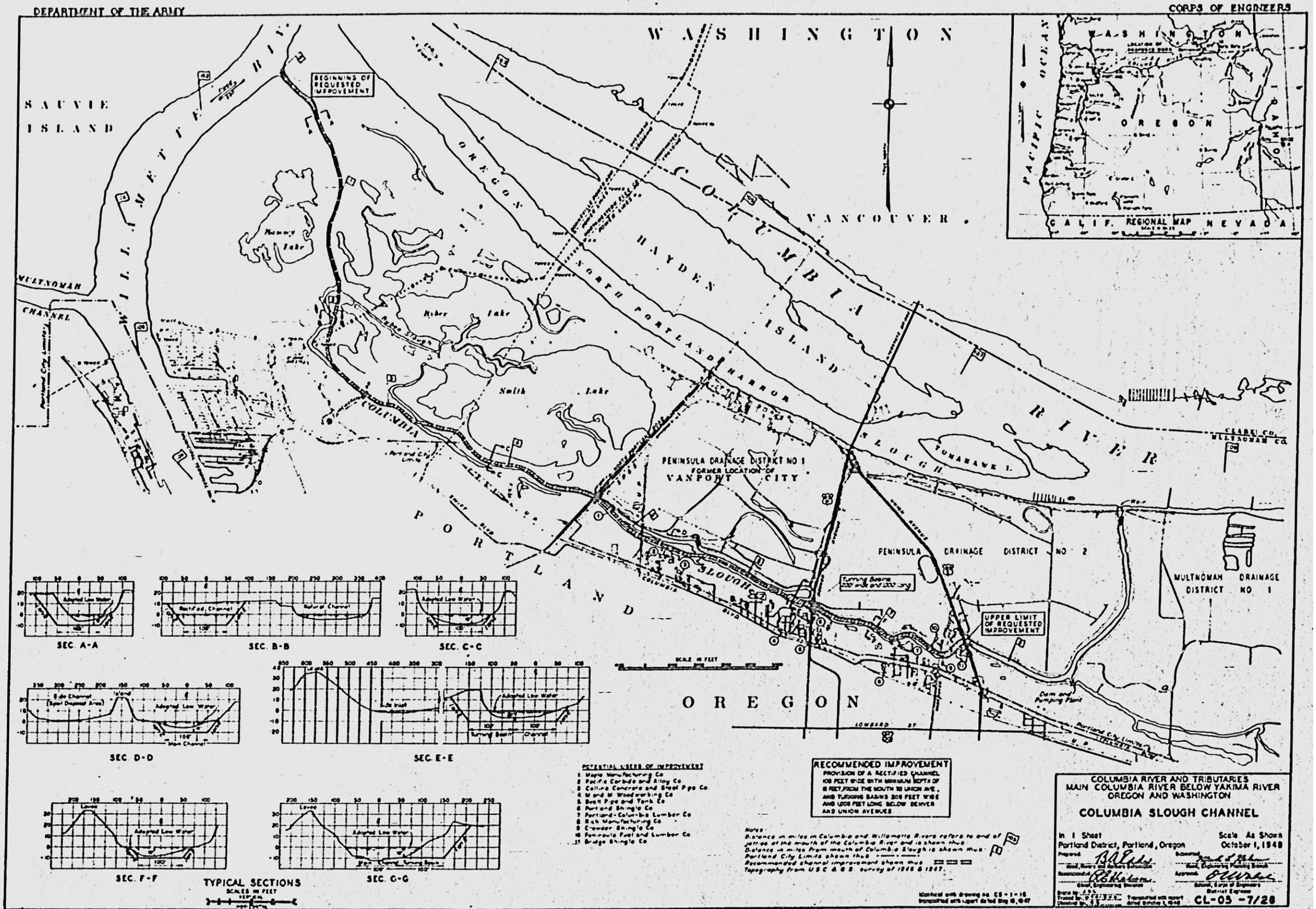

WASHINGTON
ILWACO
BAKER BAY
SAND ISLAND
RECOMMENDED DEPTH 18 FEET
PACIFIC OCEAN
COLUMBIA RIVER
CLATSOP SPIT
OREGON
WARRENTON
GENERAL MAP
Scale in Feet
VICINITY MAP
RECOMMENDED MOORING BASIN AND BREAKWATER
Scale in Feet
DALTON WATERWAY
HOLMAN WATERWAY
REGIONAL MAP
CALIFORNIA
Mooring Basin
Bay Side
Construction Channel
Section from Sta 0+00 to Sta 7+00
Section from Sta 7+00 to Sta 12+00
Section from Sta 12+00 to Sta 22+00 and Full Length of Breakwater South of Mooring Basin
TYPICAL SECTIONS BREAKWATER
Scale in Feet
Notes
Soundings are in feet and indicate depth below mean lower low water.
Elevations are shown in parentheses thus (3) and indicate height in feet above mean lower low water.
Probings are shown thus: Rock 3.2 and indicate depth below mean lower low water.
Contour elevations are in feet and indicate height above mean lower low water.
Key gateways are shown as located at date of survey.
X Y Coordinates are Oregon State coordinates (North Zone)
Distance in miles from mouth is shown thus: 10
Soundings and probings in the West Channel and the proposed mooring basin were made in April and May, 1948.
Soundings shown in Illwaco Channel and of the Break in Sand Island are from surveys made in August and May, 1943, respectively.
Identical with drawing no CL-8-76 transmitted with report dated June 28, 1948 revised April 20, 1948
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
BAKER BAY CHANNEL AND MOORING BASIN
In 1 Sheet
Scale As Shown
Portland District, Portland, Oregon
October 1, 1948
Submitted
Head, Engineering Planning Branch
Approved
Colonel, Corps of Engineers
District Engineer
Head, Rivers and Harbors Branch
Chief, Engineering Division
Transmitted with report dated October 1, 1948
CL-05-7/24

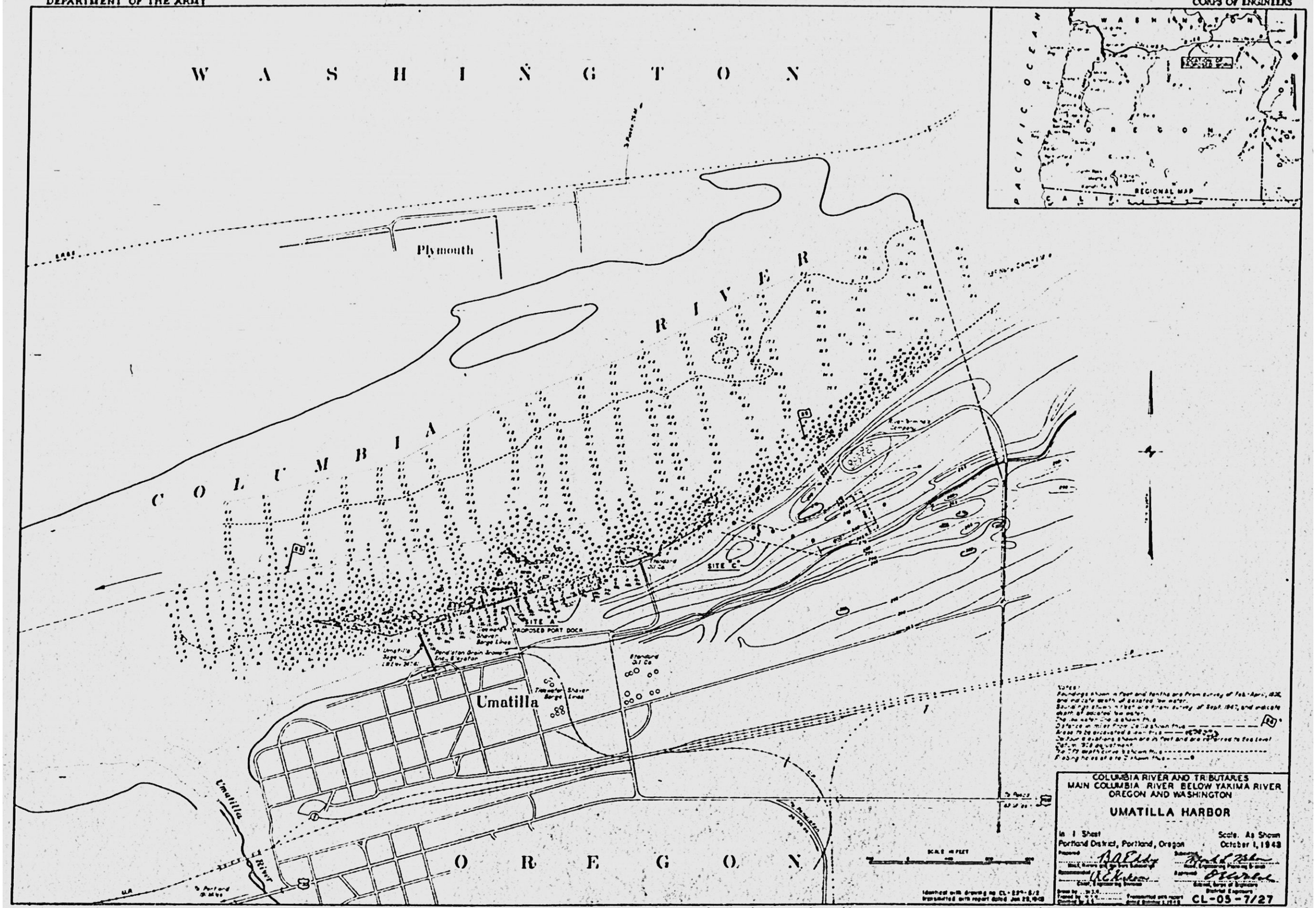
DEPARTMENT OF THE ARMY

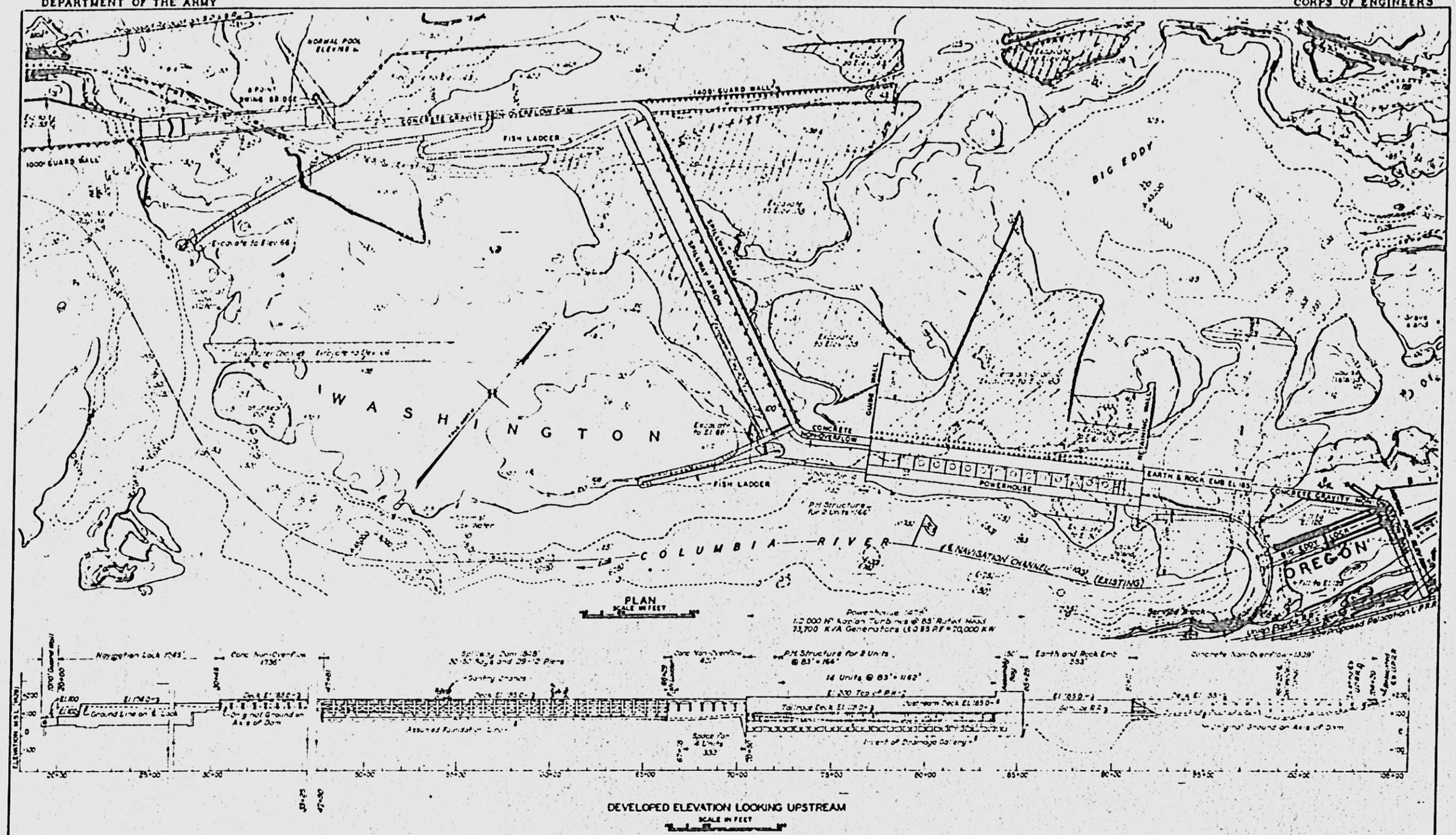
CORPS OF ENGINEERS



APPENDIX L PLATE 25


WASHINGTON
SAUVIE ISLAND
WILLAMETTE RIVER
BEGINNING OF REQUESTED IMPROVEMENT
MULTNOMAH CHANNEL
OREGON
COLUMBIA
VANCOUVER
HAYDEN ISLAND
NORTH PORTLAND HARBOR
Heron Lake
Kiber Lake
Smith Lake
COLUMBIA SLOUGH
PORTLAND
PENINSULA DRAINAGE DISTRICT NO 1
FORMER LOCATION OF VANPORT CITY
SLOUGH
TOMAHAWK I.
RIVER
CLARK CO.
MULTNOMAH CO.
PENINSULA DRAINAGE DISTRICT NO 2
MULTNOMAH DRAINAGE DISTRICT NO 1
UPPER LIMIT OF REQUESTED IMPROVEMENT
Dam and Pumping Plant
LOMBARD ST
OREGON
PACIFIC OCEAN
WASHINGTON
OREGON
CALIF.
NEVADA
REGIONAL MAP
SEC. A-A
SEC. B-B
SEC. C-C
SEC. D-D
SEC. E-E
SEC. F-F
SEC. G-G
TYPICAL SECTIONS
SCALES IN FEET
POTENTIAL USERS OF IMPROVEMENT
1 Maple Manufacturing Co
2 Pacific Carbide and Alloy Co
3 Collins Concrete and Steel Pipe Co
4 Wand W Woodworking Co
5 Best Pipe and Tank Co
6 Portland Shingle Co
7 Portland-Columbia Lumber Co
8 Rich Manufacturing Co
9 Crowder Shingle Co
10 Peninsula Fuel and Lumber Co
11 Bridge Shingle Co
RECOMMENDED IMPROVEMENT
PROVISION OF A RECTIFIED CHANNEL 100 FEET WIDE WITH MINIMUM DEPTH OF 8 FEET, FROM THE MOUTH TO UNION AVE., AND TURNING BASINS 300 FEET WIDE AND 1200 FEET LONG BELOW DENVER AND UNION AVENUES
Notes:
Distance in miles in Columbia and Willamette Rivers refers to end of jetties at the mouth of the Columbia River and is shown thus
Distance in miles from mouth of Columbia Slough is shown thus
Portland City Limits shown thus
Recommended channel improvement shown thus
Topography from U S C & G S survey of 1946 & 1947.
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
COLUMBIA SLOUGH CHANNEL
In 1 Sheet
Scale As Shown
Portland District, Portland, Oregon
October 1, 1948
CL-05 -7/28


WASHINGTON
Plymouth
COLUMBIA RIVER
SITE C
SITE A
PROPOSED PORT DOCK
Umatilla
Umatilla River
OREGON
PACIFIC OCEAN
REGIONAL MAP
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
UMATILLA HARBOR
Scale: As Shown
October 1, 1948
Portland District, Portland, Oregon
CL-05-7/27



COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

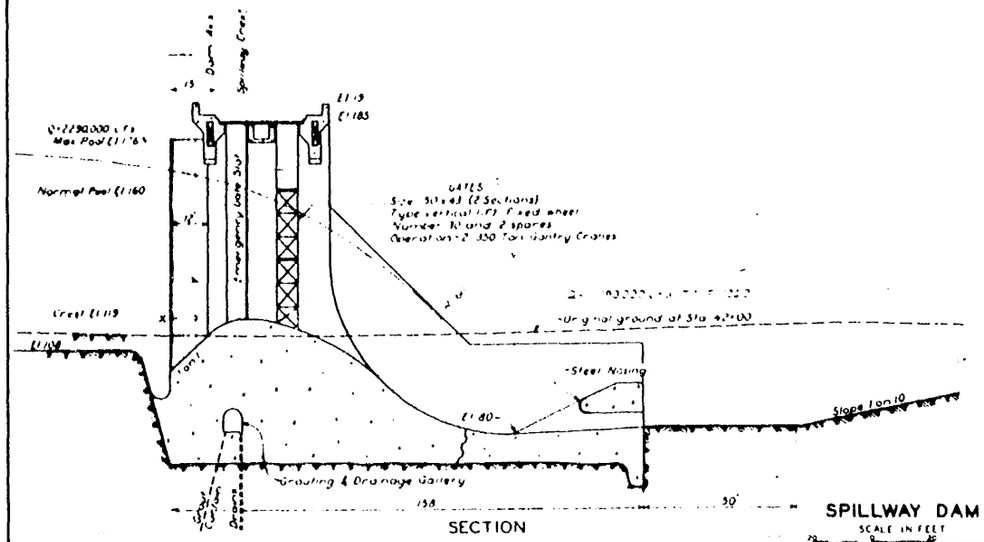
THE DALLES DAM
LAYOUT AND PROFILE

In 1 Sheet — Scale As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared: Head, Soil Report Section
Submitted: Head, Engineering Planning Branch
Recommended: Chief, Engineering Division
Approved: Colonel, Corps of Engineers, District Engineer

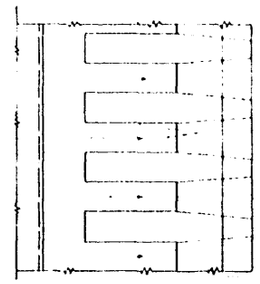
Drawn by: G.A.A.
Traced by: [illegible]
Checked by: [illegible]
Transmitted with report dated October 1, 1948

CL-05-7/28

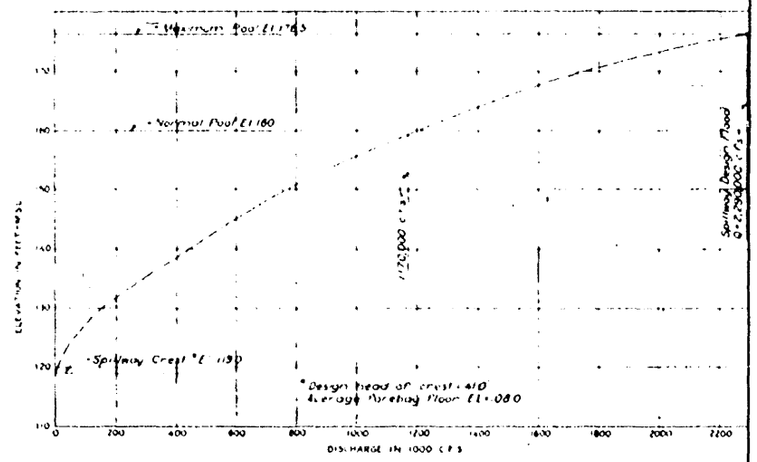


SECTION

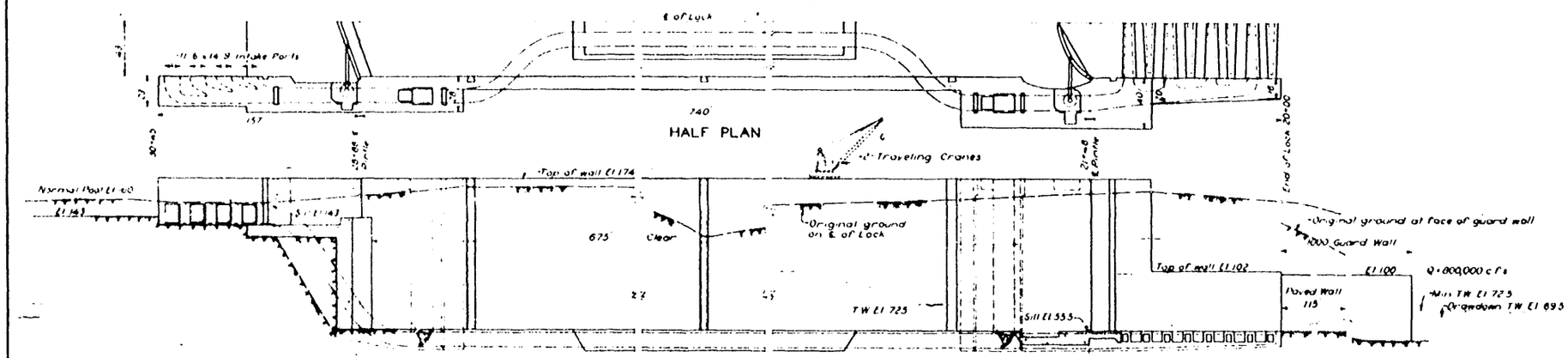
SPILLWAY DAM
SCALE IN FEET



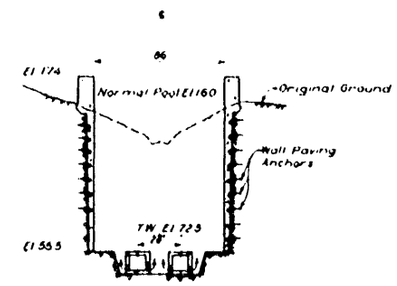
PLAN OF APRON



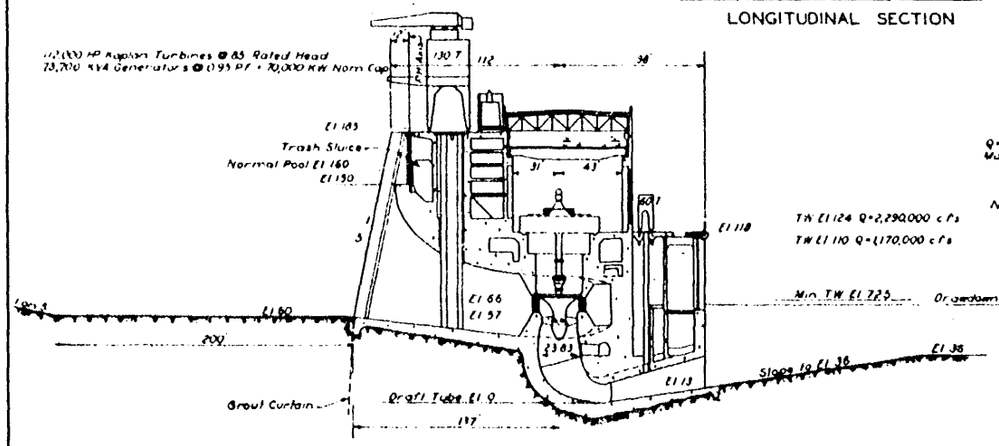
SPILLWAY RATING CURVE (FREE DISCHARGE)



LONGITUDINAL SECTION



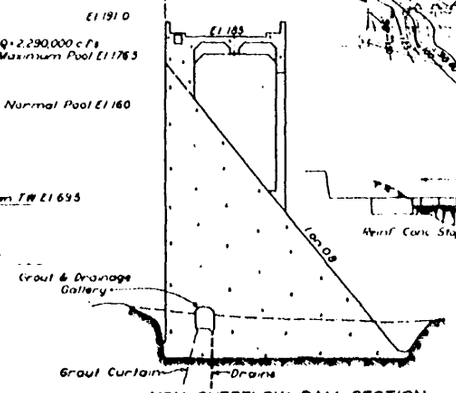
CROSS SECTION
STA 25+30



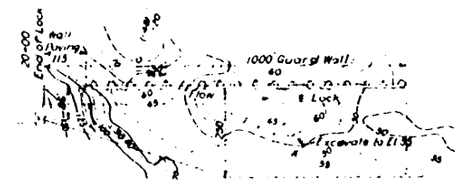
INTAKE & POWERHOUSE SECTION

SCALE IN FEET

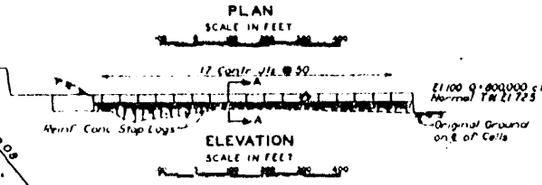
LOCK
SCALE IN FEET



NON OVERFLOW DAM SECTION
SCALE IN FEET

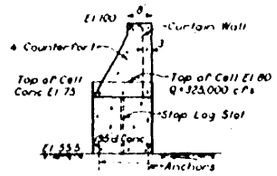


PLAN
SCALE IN FEET



ELEVATION
SCALE IN FEET

DOWNSTREAM GUARD WALL



SECTION A-A
SCALE IN FEET

Note:
The studies shown on this plate were completed prior to the 1948 Flood in Columbia River, therefore the published value of maximum discharge, 1,170,000 second-feet has been used. Data obtained during 1948 flood indicate that this discharge should be revised to 1,240,000 second-feet

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

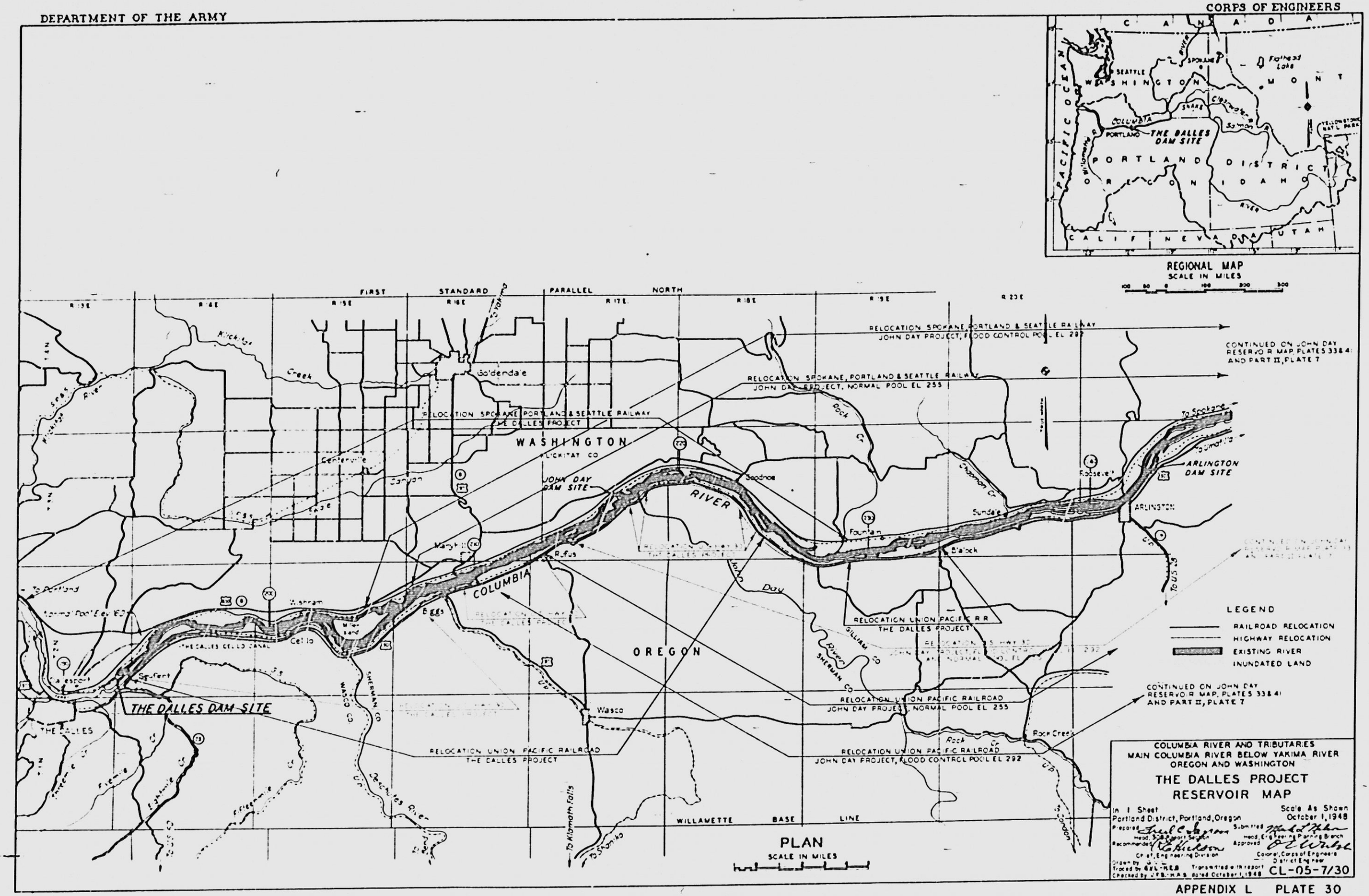
THE DALLES DAM
SECTIONS AND DETAILS

In 1 Sheet — Scale As Shown
Portland District, Portland, Oregon — October 1, 1948

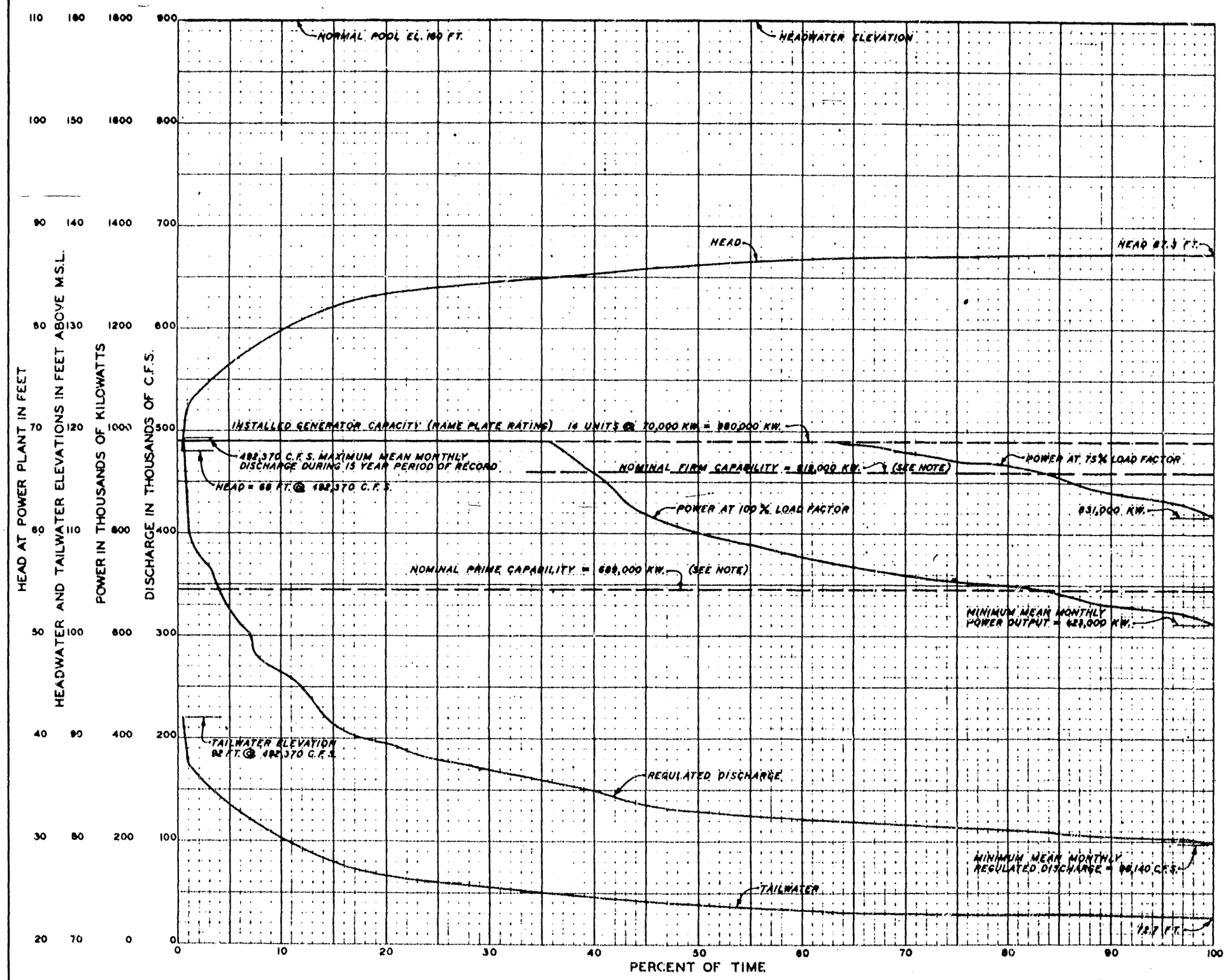
Prepared: Head, SOS Report Section
Submitted: Head, Engineering Planning Branch
Recommended: Chief, Engineering Division
Approved: Colonel, Corps of Engineers, District Engineer

Drawn by L.L.A.
Traced by A.J.S.
Checked by L.T.T.
Transmitted with report dated October 1, 1948

CL-05-7/29



91275 O—51—vol. VI



1. The "power at 100 percent load factor" curve and the "regulated discharge" curve are based on the Phase C system power study for the period October 1927 through September 1942, under the following conditions:
   a. Discharges are modified by future irrigation for initial development in the Snake River Basin and for ultimate development elsewhere.
   b. Flathead Lake is regulated for a minimum discharge of 4,300 cubic feet per second.
   c. 817,000 Acre-feet of existing storage in Kootenay Lake (Canada) are used in the interest of Corra Linn Power Plant.
   d. The following storages are used in the interest of the system:

Hungry Horse	2,980,000 acre-feet
Glacier View	3,160,000 " "
Paradise	4,080,000 " "
Albeni Falls	1,140,000 " "
Grand Coulee	5,118,000 " "
Hells Canyon	3,280,000 " "

   e. A deduction of 2,500 cubic feet per second at the site for leakage, fish migration, miscellaneous uses, and losses has been made. Over-all plant efficiency is assumed at 88 percent.
2. The tailwater curve is shown as affected by Bonneville headwater fluctuations. See Reference No. 1.
3. Nominal prime capability is the average output for the critical months of the system critical power period: September 1, 1929 to March 1, 1932. See Reference No. 2.
4. Average annual energy production equals 7,274,000,000 kw. hrs.

REFERENCES

1. Appendix O Chart 32, "The Dalles Storage, Headwater, Tailwater, Power Output, and Plant Capability"
2. Appendix O Chart 50, "The Dalles Discharge and Power Graphs 1927 - 1942."

Note:
Nominal prime and nominal firm capabilities of The Dalles power plant in the phase C-2 system are 701,000 kilowatts and 825,000 kilowatts respectively.
See Appendix O text for explanation.

COLUMBIA RIVER AND TRIBUTARIES

THE DALLES

POWER PLANT CHARACTERISTICS

PHASE C DEVELOPMENT

In 1 Sheet — Scale: As Shown

Portland District, Portland, Oregon — October 1, 1948

Prepared: A. L. [illegible] — Submitted: [illegible]

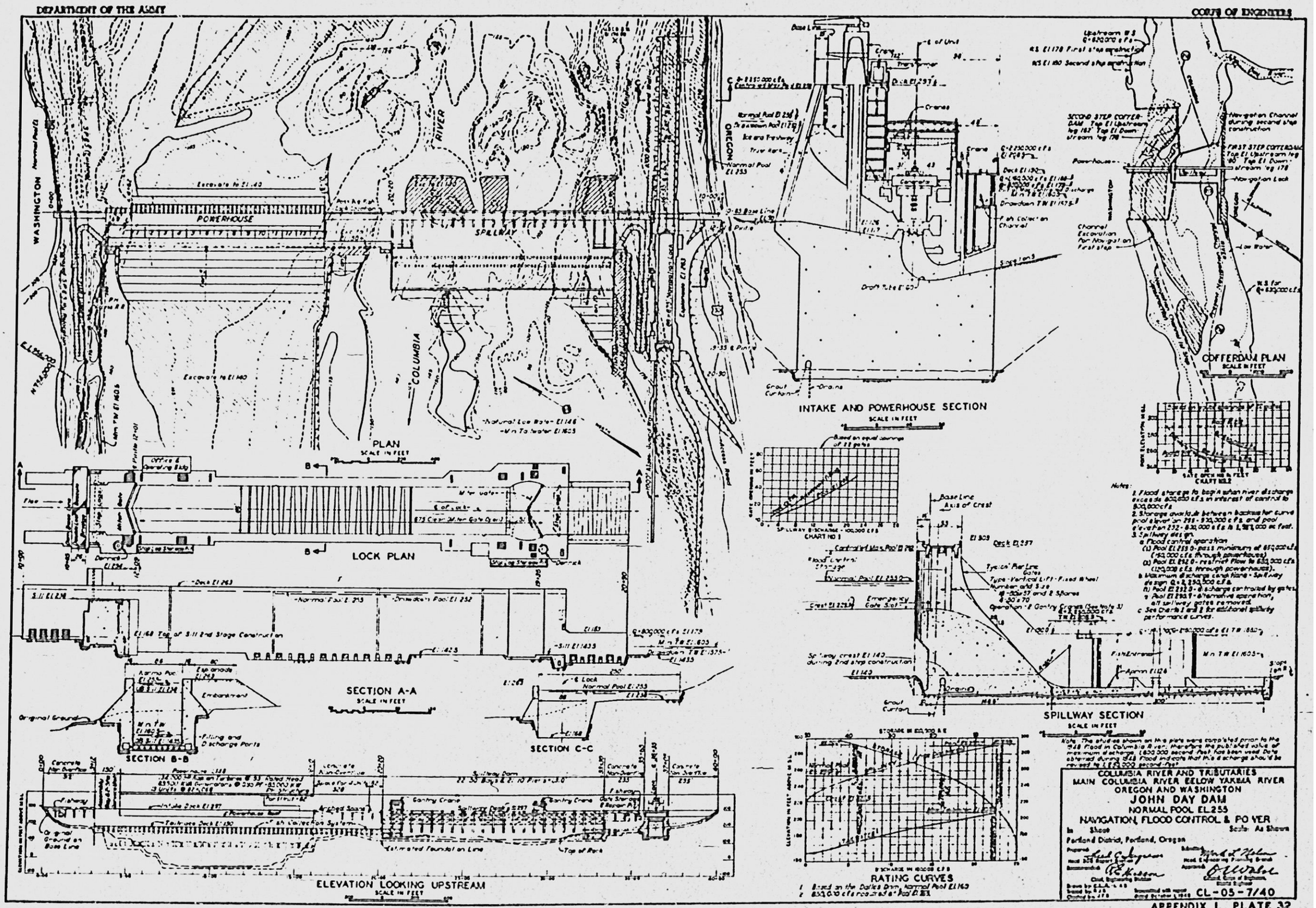
Head, Technical Services Section — Head, Chief, Planning Branch

Recommended: [illegible] — Approved: [illegible]

Chief, Engineering Division — Colonel, Corps of Engineers, District Engineer

Drawn By: W.F. — Traced By: [illegible] — Transmitted with report dated October 1, 1948

Checked By: K.P.T. — CL-05-9/12



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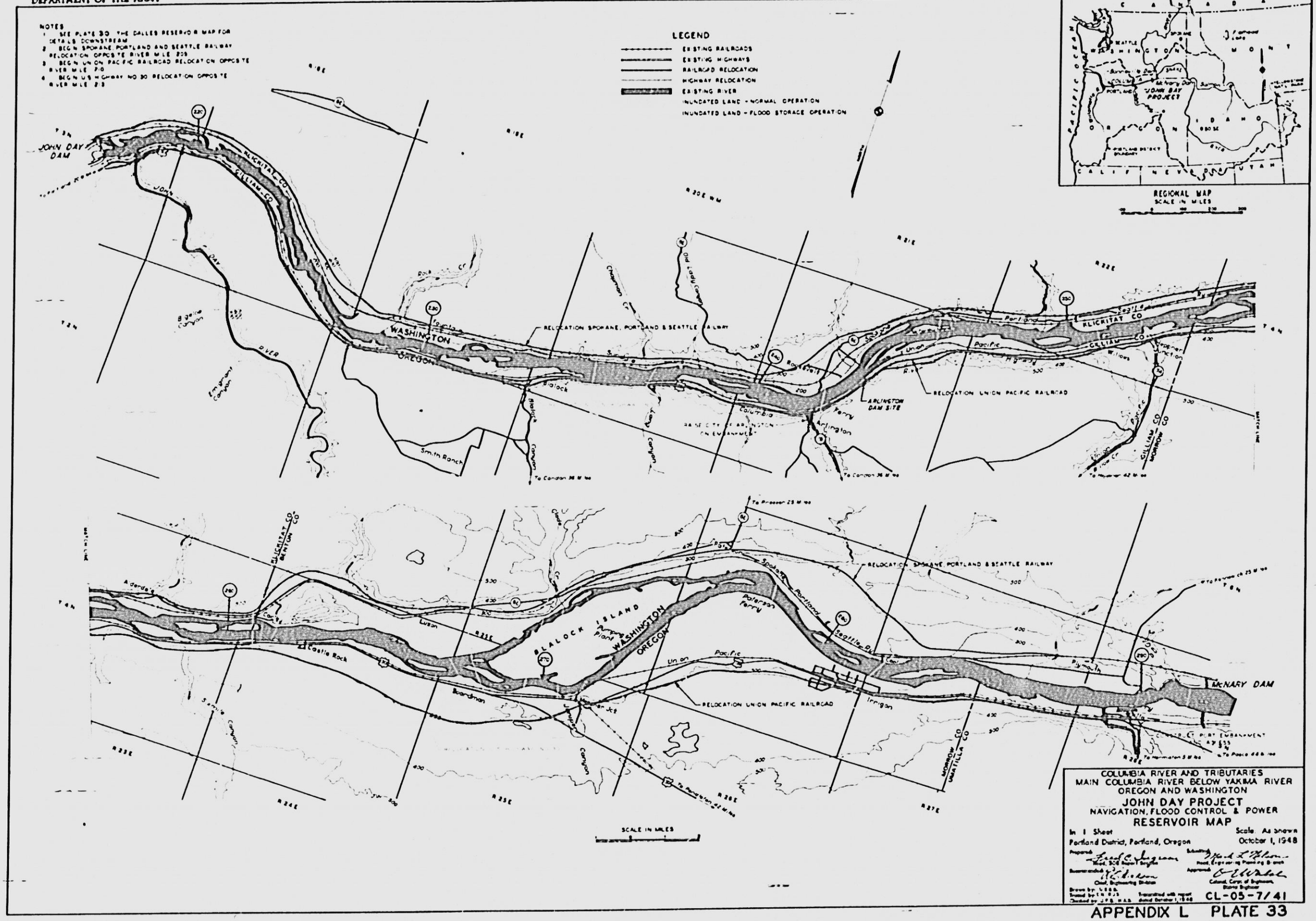
NOTES
1. SEE PLATE 30 THE DALLES RESERVOIR MAP FOR DETAILS DOWNSTREAM
2. BEGIN SPOKANE, PORTLAND AND SEATTLE RAILWAY RELOCATION OPPOSITE RIVER MILE 209
3. BEGIN UNION PACIFIC RAILROAD RELOCATION OPPOSITE RIVER MILE 210
4. BEGIN U.S. HIGHWAY NO. 30 RELOCATION OPPOSITE RIVER MILE 213

LEGEND
- EXISTING RAILROADS
- EXISTING HIGHWAYS
- RAILROAD RELOCATION
- HIGHWAY RELOCATION
- EXISTING RIVER
- INUNDATED LAND - NORMAL OPERATION
- INUNDATED LAND - FLOOD STORAGE OPERATION

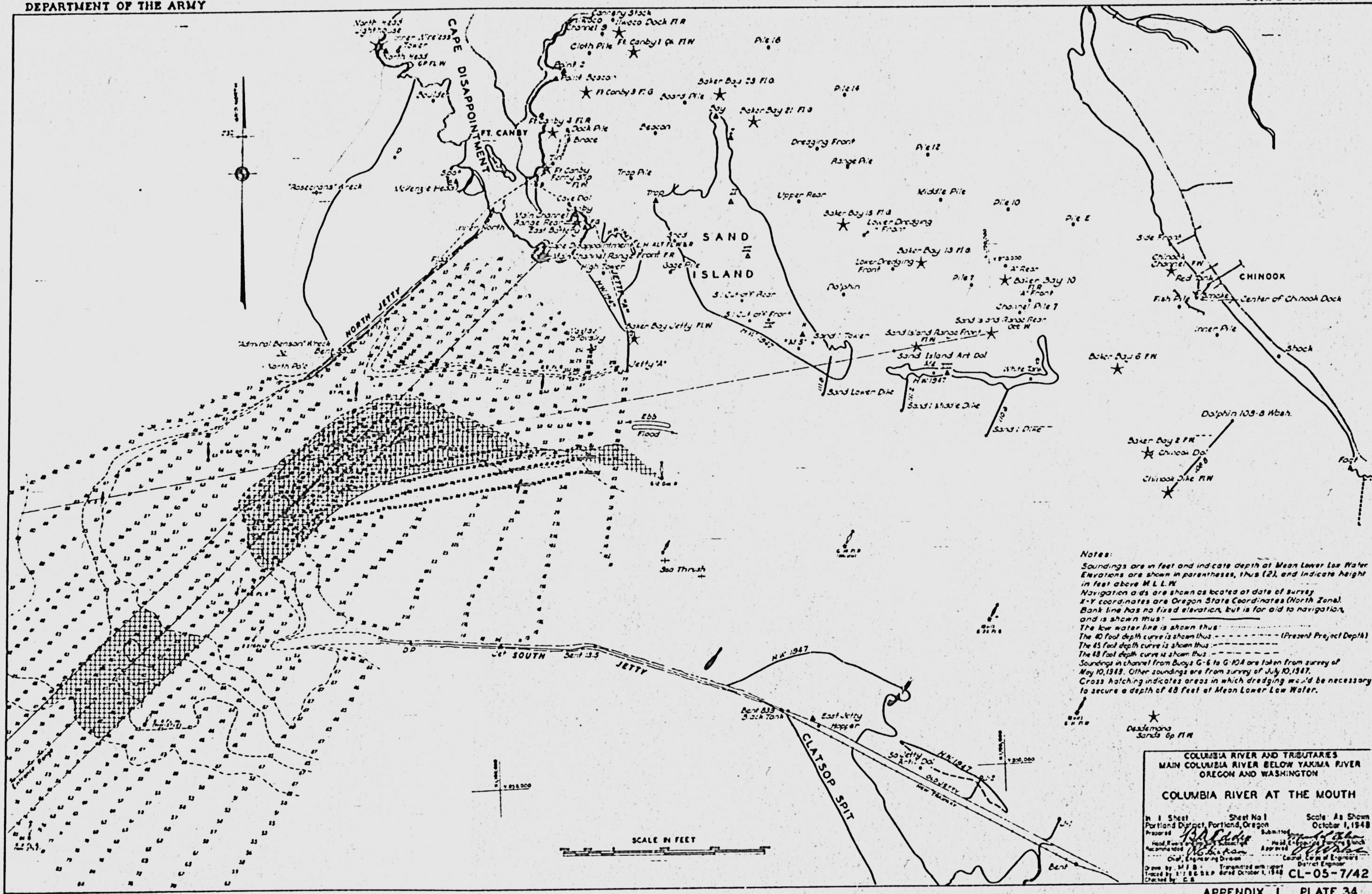


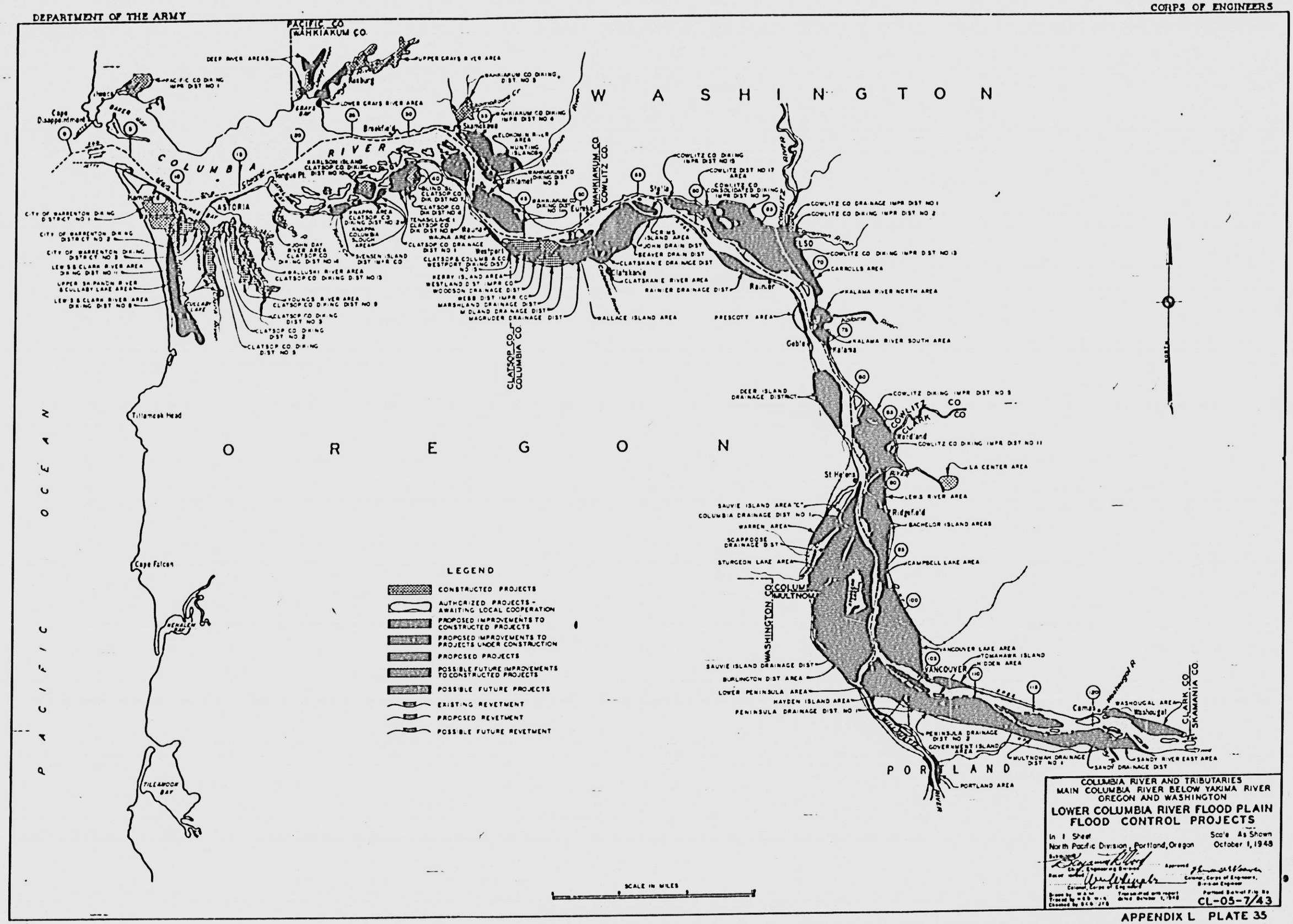
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
JOHN DAY PROJECT
NAVIGATION, FLOOD CONTROL & POWER
RESERVOIR MAP

In 1 Sheet — Scale: As shown
Portland District, Portland, Oregon — October 1, 1948

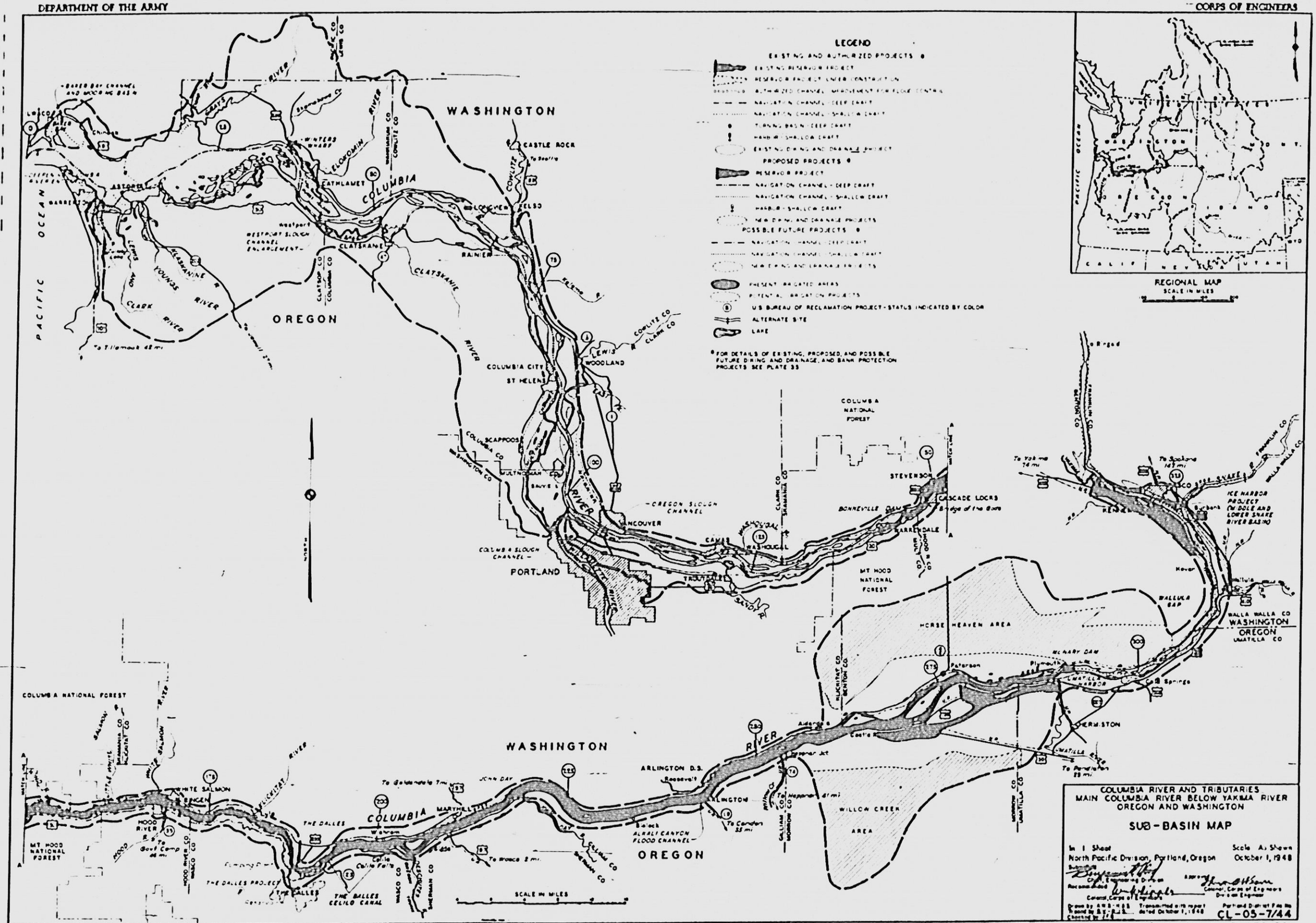
CL-05-7/41

91275 O—51—vol. VI


CAPE DISAPPOINTMENT
FT. CANBY
North Head Lighthouse
Inner Wireless Tower
North Head GP FL W
Cannery Stack
Ilwaco Channel 9
Ilwaco Dock Fl R
Ft. Canby 1 Qk Fl W
Cloth Pile
Point 2
Point Beacon
Ft Canby 3 Fl G
Board Pile
Baker Bay 23 Fl G
Baker Bay 21 Fl G
Pile 16
Pile 14
Pile 12
Pile 10
Pile E
Pile 7
Ft Canby 4 Fl R
Dock Pile
Brace
Beacon
Dredging Front
Range Pile
Middle Pile
Ft Canby Ferry Slip Fl W
Trap Pile
Trap
"Rosecrans" Wreck
McKenzie Head
Cove Dol
Main Channel Range Rear
East Battery
Inner North
Cape Disappointment L.H. ALT FL W & R
Main Channel Range Front FR
High Tower
Sage Pile
SAND ISLAND
Upper Rear
Baker Bay 15 Fl G
Lower Dredging Front
Baker Bay 13 Fl G
Baker Bay 10 Fl R
"A" Rear
"A" Front
Channel Pile 7
Dolphin
Sand Island Range Rear Occ W
Sand Island Range Front Fl W
Sand Island Art Dol
White Tank
Sand I Tower
Sand Lower Dike
Sand I Middle Dike
Sand I Dike
H.W. 1947
Baker Bay Jetty Fl W
Jetty "A"
NORTH JETTY
"Admiral Benson" Wreck
North Pole
Ebb
Flood
Side Front
Chinook Channel Fl W
Red Tank
CHINOOK
Fish Pile
Stack
Center of Chinook Dock
Inner Pile
Shack
Baker Bay 6 Fl W
Dolphin 103-8 Wash.
Baker Bay 2 Fl R
Chinook Dol
Chinook Dike Fl W
Sea Thrush
SOUTH JETTY
Bent 13.5
CLATSOP SPIT
Bent 833 Black Tank
East Jetty Hopper
So. Jetty Arti. Dol
OLD JETTY
Entrance Range
Desdemona Sands Gp Fl W
Bent
SCALE IN FEET
Notes:
Soundings are in feet and indicate depth at Mean Lower Low Water. Elevations are shown in parentheses, thus (2), and indicate height in feet above M.L.L.W.
Navigation aids are shown as located at date of survey.
X-Y coordinates are Oregon State Coordinates (North Zone).
Bank line has no fixed elevation, but is for aid to navigation, and is shown thus:
The low water line is shown thus:
The 40 foot depth curve is shown thus (Present Project Depth)
The 45 foot depth curve is shown thus
The 48 foot depth curve is shown thus
Soundings in channel from Buoys G-6 to G-10A are taken from survey of May 10, 1948. Other soundings are from survey of July 10, 1947.
Cross hatching indicates areas in which dredging would be necessary to secure a depth of 48 feet at Mean Lower Low Water.
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
COLUMBIA RIVER AT THE MOUTH
In 1 Sheet
Sheet No 1
Scale: As Shown
Portland District, Portland, Oregon
October 1, 1948
Prepared
Submitted
Recommended
Approved
Chief, Engineering Division
Colonel, Corps of Engineers District Engineer
Drawn by: M.F.B.
Checked by: C.S.
Transmitted with report dated October 1, 1948
CL-05-7/42



91275 O—51—vol. VI


LEGEND
EXISTING AND AUTHORIZED PROJECTS *
EXISTING RESERVOIR PROJECT
RESERVOIR PROJECT UNDER CONSTRUCTION
AUTHORIZED CHANNEL IMPROVEMENT FOR FLOOD CONTROL
NAVIGATION CHANNEL - DEEP DRAFT
NAVIGATION CHANNEL - SHALLOW DRAFT
TURNING BASIN - DEEP DRAFT
HARBOR - SHALLOW DRAFT
EXISTING DIKING AND DRAINAGE PROJECT
PROPOSED PROJECTS *
RESERVOIR PROJECT
NAVIGATION CHANNEL - DEEP DRAFT
NAVIGATION CHANNEL - SHALLOW DRAFT
HARBOR - SHALLOW DRAFT
NEW DIKING AND DRAINAGE PROJECTS
POSSIBLE FUTURE PROJECTS *
NAVIGATION CHANNEL - DEEP DRAFT
NAVIGATION CHANNEL - SHALLOW DRAFT
NEW DIKING AND DRAINAGE PROJECTS
PRESENT IRRIGATED AREAS
POTENTIAL IRRIGATION PROJECTS
U.S. BUREAU OF RECLAMATION PROJECT - STATUS INDICATED BY COLOR
ALTERNATE SITE
LAKE
* FOR DETAILS OF EXISTING, PROPOSED, AND POSSIBLE FUTURE DIKING AND DRAINAGE, AND BANK PROTECTION PROJECTS SEE PLATE 35
REGIONAL MAP
SCALE IN MILES
PACIFIC OCEAN
WASHINGTON
OREGON
COLUMBIA
CASTLE ROCK
KELSO
CATHLAMET
ASTORIA
CLATSKANIE
RAINIER
LEWIS
WOODLAND
COLUMBIA CITY
ST HELENS
SCAPPOOSE
PORTLAND
VANCOUVER
CAMAS
WASHOUGAL
TROUTDALE
STEVENSON
CASCADE LOCKS
BONNEVILLE DAM
BIGGS
MT HOOD NATIONAL FOREST
COLUMBIA NATIONAL FOREST
HORSE HEAVEN AREA
WILLOW CREEK AREA
ICE HARBOR PROJECT (IN DOLE AND LOWER SNAKE RIVER BASINS)
WALLULA GAP
WALLA WALLA CO
WASHINGTON
OREGON
UMATILLA CO
PENDLETON
PASCO
WHITE SALMON
HOOD RIVER
THE DALLES
THE DALLES PROJECT
THE DALLES CELILO CANAL
ARLINGTON D.S.
ARLINGTON
ALKALI CANYON FLOOD CHANNEL
SCALE IN MILES
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
SUB-BASIN MAP
In 1 Sheet
Scale As Shown
North Pacific Division, Portland, Oregon
October 1, 1948
CL-05-7/44

PART II—SPECIAL STUDIES

SECTION I—PRECIPITATION CHARACTERISTICS

GENERAL

1. Effective utilization and control of the water resources of a region are contingent upon knowledge of precipitation characteristics. In recognition of the fundamental importance of those climatological and meteorological factors that determine the distribution of precipitation, with regard both to time and area, a study was made of all available precipitation data for stations along Columbia River. A detailed isohyetal map of normal annual precipitation was developed, geographical variations in the seasonal distribution were investigated, storm studies were made, and the longer precipitation records were analyzed statistically to detect, if possible, evidence of secular variations or long-time trends. Plates 4, 5, and 6 of part I of this appendix show certain pertinent results of these studies.

NORMAL ANNUAL PRECIPITATION

2. The isohyetal map of normal annual precipitation, plate 4, illustrates the wide range in precipitation along Columbia River. Data from precipitation stations as well as other such factors as vegetative cover, topographic details, geological studies, and atmospheric flow patterns were given detailed consideration in the development of the final pattern. In order that the influence of periods of precipitation that deviate from the normal should not be overemphasized, precipitation records were adjusted to long-period normals by means of the double-mass-curve method. To accomplish this adjustment, the basin was assumed to be divided into two major climatic zones, one east and the other west of the Cascade Range. A primary base station was carefully selected for each. The two zones were further divided into areas of approximate meteorological homogeneity, within each of which a secondary base station was chosen and adjusted to the proper primary base station. Other stations within each area were in turn adjusted to the proper controlling secondary station. Although the most reliable normals were developed from records in excess of 10 years in length, reasonable normals were derived from shorter records. In a few instances, records for periods as short as 1 or 2 years were utilized, recognizing, however, the lower reliability of the computed normal.

3. Vegetative cover, when considered in relation to such modifying influences as elevation, slope, exposure, and soil mantle, supplies a clue to the amount of precipitation, and was used as a guide in the absence of other information. In addition, the density of the vegetation provided an indication of transpiration losses, thus permitting fuller use of run-off data.

4. The effects on the normal annual precipitation of such geographic and topographic features as elevation, distance from the ocean, previous atmospheric lift, steepness, and concavity, were investigated. Atmospheric flow diagrams were prepared to show the most common

trajectories of moist maritime air over the basin during the various seasons. Attempts were made to weigh the influence of forced convergence occurring as a result of topographic features.

5. Users of the isohyetal map, plate 4, should be aware of the fact that it is a simplified representation of what actually occurs in nature. Although the isohyetal pattern as drawn may appear complicated, the true pattern is undoubtedly much more intricate. Modifications and refinements will of course be indicated as data accumulate. As the map purposely was somewhat generalized, it does not necessarily indicate precisely correct point values. Average areal values, however, are reasonably accurate.

SEASONAL DISTRIBUTION

6. The bar charts on plate 5 and the profiles on plate 6 show how the distribution of precipitation through the year varies with location. Solid lines of the precipitation profiles indicate the actual amount, in inches, which normally occurs during the seasons, October through December, October through March, October through June, and October through September, the latter being the mean annual precipitation. Similarly, the dashed lines indicate the percentage of mean annual preciptiation occurring during the various seasons. Normal percentage during the remaining portion of the year may be obtained in each case by subtracting the indicated percentage from 100. Likewise, subtracting the actual amount for any given season from the mean annual precipitation gives the amount occurring during the remainder of the year at any given point.

7. Indications of both maritime and continental type precipitation regimes are evident on the charts. The former, with a pronounced winter maximum, is dominant over the western portion of the sub-basin. Over the Cascade Range and in the area to the west, more than one-half of the annual precipitation occurs during the period November through February. In the eastern portion, the winter maximum, though present, is much less pronounced. The proportion of precipitation occurring as snow within the sub-basin is insignificant, although snowfall and antecedent snow-melt in Columbia River Basin, particularly at high levels, largely determine the run-off and flood-producing potential of the stream.

PRECIPITATION TRENDS

8. Plate 6 shows certain results of a statistical study of precipitation records in and adjacent to the basin. Four stations, Astoria, Portland, and The Dalles, Oreg., and Walla Walla, Wash., were selected on the basis of length and continuity of record, and the precipitation records analyzed in detail for the purpose of detecting, if possible, secular variations in the recorded amounts of precipitation.

9. Such variations can be shown either by means of residual mass curves or by moving averages. Ordinates of the former are summations of the precipitation from the beginning of the period to the year in question minus the product of the mean for the entire period times the number of years in the record up to the one in question. A general upward trend of such a curve indicates a period of super-

normal precipitation, and conversely. Because the smoothing device known as moving averages is preferred by many, curves of these quantities also are shown on plate 6, below the corresponding curves of cumulative residuals. As is the general practice, a 10-year period was selected for computation of the averages. To reduce the effects of possible nonrepresentative irregularities of an individual station, the data were averaged for the two stations west of the Cascade divide, Astoria and Portland, and for the two stations to the east, The Dalles and Walla Walla.

10. In addition to graphic protrayal of past fluctuations of annual precipitation, curves are shown illustrating variations of precipitation during the months of January and July. Both the accumulated departures from mean and the departures of moving averages are expressed in percentage of mean. Because January is normally a wetter month than July, the January variations, expressed percentually, generally are less than the July variations. For the same reason, the annual curves are more conservative than either of the two monthly curves. Although the periods of record are much too short to justify the drawing of definite generalizing conclusions, the curves do reveal a number of apparently real trends and relationships.

11. When the 10-year moving averages of all four stations were averaged, the resulting data defined the curve shown on plate 6. The most striking feature of that curve is the definite downward trend. Secondary cycles with a wave length of approximately 20 years appear to be superposed on the primary downward trending line, but the conclusion that precipitation generally has been decreasing appears to be inescapable.

12. The curves shown on plate 6 are not intended for use as forecasting tools. Because of the complexity of climatic fluctuation phenomena, reliable extrapolation of apparent trends or cycles is not yet practicable. Continued studies and accumulating data are, however, gradually building a foundation for the understanding of the cause and nature of climatic variations, so that long-range forecasting may eventually become possible.

Section II—Cost Estimates

INTRODUCTION

13. Cost estimates for all of the units which would enter into an immediate comprehensive development program for the sub-basin, except for bank protection and diking and drainage projects, and auxiliary harbors, are contained herein. The estimates have been prepared in detail in those instances in which adequate data were available. Approximation has been necessary in the cases of the proposed diking and drainage projects, bank protection work, and auxiliary harbors in connection with the proposed reservoirs. For these projects, estimates are based on prior reports modified as nearly as possible to reflect present conditions, or on past experience in accomplishing comparable work. Cost of local protective works and auxiliary harbors are summarized in part I. Detailed estimates for local protective works will be presented in a separate report. Detailed estimates for auxiliary harbors can be prepared at a later

date in connection with detailed planning for construction of proposed dams and reservoirs on Columbia River.

14. The projects for which detailed estimates are shown would be constructed by the Corps of Engineers, and can be divided into two groups; local navigation projects, and locks and dams. The former are relatively small projects involving short channels or harbor improvements. Previously submitted individual survey reports present pertinent data in regard thereto. No further discussion of these estimates is contained herein except to note that, where necessary, estimates prepared prior to January 1, 1948, were adjusted to that cost base.

15. Estimates for the lock and dam projects, aggregating about $600,000,000, are the principal subjects of the following discussion. A detailed estimate for the previously reported The Dalles project, as proposed herein, is included as table 1. A detailed estimate of the proposed John Day project with surcharge flood-control storage capacity, is presented as table 2. Detailed estimates for improvements at Baker Bay, Westport slough channel, Columbia slough channel, and Umatilla Harbor are contained in tables 5 through 8.

PREPARATION OF ESTIMATES

16. All estimates are based on price levels prevailing as of January 1, 1948. All of the dams considered herein, including those proposed and the alternatives studied, would consist essentially of navigation locks, spillways, and power plants which would be similar, except for variation in height, to those at Bonneville and McNary Dams. Personnel with the advantage of experience and data gained in connection with those projects reviewed and checked unit prices used in the detailed estimates in order to insure coordination of design, construction, and operation viewpoints. Data as to required extent of fishery facilities were obtained from responsible State and Federal agencies. Costs of electrical equipment and hydraulic turbines have been derived from manufacturers quotations.

SEQUENCE OF CONSTRUCTION

17. In preparing the present estimates, it was assumed that construction of the previously reported The Dalles project would precede that of the John Day project. Should the John Day project precede The Dalles project, some modification in the diversion feature of both projects would be possible with a slight reduction in both cost estimates. The above sequence has been assumed for the purpose of the report, however, in the interest of conservation.

TEMPORARY HOUSING DURING CONSTRUCTION

18. Unit prices employed in estimating the cost of the various projects are adequate to include the cost of temporary housing for construction workers. These costs would be borne by the contractors involved, without separate payment therefor.

PERMANENT BUILDINGS AND GROUNDS

19. The estimates for permanent buildings and grounds provide for housing, stores, schools, recreation facilities, utilities, and miscellaneous facilities for personnel employed in normal operation and maintenance of the dams and power plants after construction. The estimates of personnel, of the number and size of housing units, and of other facilities required are based on requirements at Bonneville Dam and on estimated requirements for McNary Dam. Consideration was given to housing and facilities available in nearby areas. In the cases of The Dalles Dam, which would be relatively close to The Dalles, no stores, schools, or similar community facilities would be required and it is estimated that 50 percent of the personnel would be housed outside the project reservations. John Day project, because of its relative isolation, would be provided with complete community facilities and housing facilities for 60 percent of the required personnel.

LANDS AND IMPROVEMENTS

20. The flowage estimates included in project costs are based on payment of fair market value for lands and improvements which would be affected by backwater from the projects considered. Severance has been included where applicable. The appraisals are based upon reconnaissance field inspections and information obtained from county records and various other reliable sources.

UTILITY RELOCATIONS

21. Relocation projections serving as the basis for cost estimates were made on photogrammetric maps with 10-foot contour interval and scale of 1 inch equals 600 feet. Designs were prepared with a view to maintenance of existing standards and to the replacement, in kind, of existing facilities. Information was obtained by field reconnaissance to supplement survey data and to afford a basis for classification of required excavation.

CONTINGENCIES

22. Percentages used for contingencies were variable in accord with the amount of basic information available and the completeness of design. In general, 15 percent was added to all construction items. Exceptions are the utility relocation estimates to which 25 percent was added to cover details impossible of evaluation prior to final design.

INDIRECT COSTS

23. Indirect costs in the amount of 13½ percent have been added to the direct construction costs, which include allowances for contingencies. This percentage allows 2½ percent for preparation of a detailed engineering report and plans and specifications, 7 percent for engineering supervision during construction, and 4 percent for overhead. Supervision is based on the type of work involved and is independent of volume of work. Overhead percentage varies with the amount of work under construction in the district and the value

selected is representative of the low percentage costs applicable under a large construction program.

PAYMENT IN LIEU OF TAXES

24. Estimates of annual charges, shown in part I, contain a non-Federal item for loss of taxes to include all loss of tax revenue to non-Federal interests as a result of changed conditions following construction of proposed projects. If the Congress deems such action advisable, these amounts may be considered to be a Federal annual charge, payable to non-Federal agencies in lieu of taxes lost. For purposes of this report, however, these amounts are shown, where appropriate, as non-Federal annual costs resulting from construction. No change in total annual charges would result if these amounts were considered as Federal payments in lieu of taxes.

SECTION III—SPILLWAY DESIGN FLOODS

BASIS FOR DERIVATION OF SPILLWAY DESIGN FLOODS

25. The conventional method of deriving a spillway design flood from a maximum-possible storm is not applicable in the case of Columbia River, since the maximum annual floods are the result of the melting of a 5-month accumulation of snow. Rainstorms have not resulted in any exceptionally high stages on lower Columbia River. In view of these facts, an analysis of the snow-melt potentialities of the basin is the logical approach to the determination of a spillway design flood for lower Columbia River. The spillway design flood for McNary Dam was derived by the procedure outlined below and was utilized in determining the design flood for the downstream The Dalles and John Day projects.

EVALUATION OF SNOW-MELT CONDITIONS

26. The evaluation of the worst possible snow-melt conditions used in the derivation of the spillway design flood for McNary Dam involved the determination of—

(*a*) Maximum-possible annual precipitation.
(*b*) Maximum-possible flood season run-off that could occur in the year of maximum-possible annual precipitation.
(*c*) Snow-melt run-off rates during a maximum-possible flood.
(*d*) A realistic temperature sequence that would produce the greatest concentration of snow-melt.

The required hydrograph was obtained by integrating simultaneously the worst-possible conditions noted above and routing the accumulated snow-melt through channel storage above McNary dam site.

MAXIMUM-POSSIBLE FLOOD-PRODUCING METEOROLOGICAL CONDITIONS

27. At the request of the Chief of Engineers, the Hydrometeorological Section of the United States Weather Bureau prepared a report entitled, "Tentative Estimates of Maximum-Possible Flood-Producing Meteorological Conditions in the Columbia River Basin," dated January 25, 1945, in which meteorological conditions causing floods of recent record were evaluated and limiting meteorological factors were

presented. The report includes estimates of maximum-possible precipitation, in terms of mean annual precipitation in the basin, for areas of 2,000 to 50,000 square miles, and prescribes limits of maximum and minimum temperatures of 7- and 30-days duration for like areas. Extrapolations of these data were made to establish the maximum-possible flood-producing meteorological conditions for the basin above McNary dam site. Details of these extrapolations are discussed in subsequent paragraphs.

MEAN ANNUAL PRECIPITATION

28. The mean annual precipitation for Columbia River Basin above McNary dam site is 24.1 inches, as determined from the mean annual isohyetal map of the basin. Development of the isohyetal pattern was on the basis of adjusted long-term station normals, using topographic features and run-off records as guides.

MAXIMUM-POSSIBLE ANNUAL PRECIPITATION

29. The Hydrometeorological Section of the United States Weather Bureau states in its Columbia River Basin report that certain broad relationships are apparent between the maximum-possible and the mean annual precipitation for a wide range in areas and mean annual precipitation. These relationships are graphically illustrated on plate 1 of part II. By extrapolating the curve of mean annual basin precipitation to a drainage area equivalent to that above McNary dam site, the maximum-possible annual precipitation for Columbia River Basin above McNary dam site was determined to be 1.92 times the mean annual precipitation of 24.1 inches, or 46.2 inches. The maximum-possible 12-month precipitation so derived for the basin is 158 percent of the greatest observed precipitation, 29.2 inches in 1927, and 135 percent of the estimated precipitation of 34.2 inches in 1894. Annual precipitations are based on the 12-month period, October through the following September, in order to correspond with the water-year data in published reports of the United States Geological Survey.

SURFACE LOSSES AND RUN-OFF

30. The sum of surface losses and natural basin run-off for any year, October through the following September, is assumed to be equivalent to the annual precipitation for the corresponding period. In the development of a maximum-possible flood, basin losses resulting from evaporation, transpiration, and deep percolation are considered a minimum. Relationships of annual surface losses and natural run-offs, for Columbia River at McNary dam site, to annual precipitation are shown in figures 2 and 3, plate 1. The basin precipitation for each year was determined from precipitation records at 14 representative stations, shown on plate 1, by the following equation:

$$\text{Basin annual precipitation} = \frac{\text{Sum of annual precipitation at 14 stations} \times \text{Basin mean annual precipitation}}{\text{Average annual sums for 14 stations}}$$

Natural annual runoffs at McNary dam site were derived from flows observed near The Dalles, which were adjusted to reflect the effects of

Snake River irrigation depletions and of minor tributary inflows between McNary dam site and The Dalles. Irrigation depletions in other tributaries are insignificant and were not considered. In figure 2, plate 1, losses for each year were plotted against corresponding annual precipitation and a curve drawn to envelope the minimum losses. The observed annual run-off and precipitation relationship is illustrated in figure 3, plate 1, in which a curve was drawn to envelope the maximum run-offs. Extrapolation of the curves shown in figures 2 and 3 to a maximum annual precipitation of 46.2 inches indicates a basin loss of 20.7 inches and a run-off of 25.5 inches, or 290,000,000 acre-feet, for the maximum-possible flood year.

BASE FLOW

31. Base flows of Columbia River are fairly constant throughout the year. By the end of the summer, surface run-off is terminated and the river recedes to base flow, which continues until the spring freshets in March. Occasional winter rainstorms or early spring thaws may result in surface run-off for short periods. Inspection of daily discharge hydrographs for The Dalles indicates an average base flow of 90,000 second-feet. In all computations involving the 7-month flood run-off volume, base flows were segregated from the significant flood run-off volumes.

32. A review of daily discharge hydrographs for The Dalles for the larger floods of record indicates that base flows varied from 80,000 to 120,000 second-feet. No consistent correlation existed between the magnitude of base flows and flood discharges. In determining the spillway design flood hydrograph, however, an effort was made to select a base flow that would be in excess of any that may have prevailed during any previous flood. The base flow adopted for the spillway design flood, therefore, was 140,000 second-feet. This represents the difference between annual run-off and 7-month flood season run-off, distributed throughout the year. Since this base flow is small in comparison to the peak discharge of the spillway design flood, a greater or smaller base flow would not affect materially the peak of the design flood.

FLOOD-SEASON RUN-OFF

33. The significant flood portion of the annual run-off for Columbia River Basin occurs from March through September. A fairly definite relationship exists between the 7-month flood season run-off, less base flow, and the annual run-off which is illustrated by figure 4, plate 1. To determine the maximum 7-month flood run-off, less base flow, that might occur, run-offs occurring in a period of 40 years were analyzed and a curve was drawn to envelop the maximum 7-month flood season run-off. This curve, when extrapolated to a maximum annual run-off of 290,000,000 acre-feet, indicated a maximum 7-month flood season run-off, less base flow, of 190,000,000 acre-feet, 143 percent of the largest observed 7-month run-off. The largest observed annual run-off, 214,650,000 acre-feet in 1894, had a corresponding 7-month flood season run-off of 132,700,000 acre-feet.

SNOW-MELT RUN-OFF RATES

34. The apparent snow-melt rates during the maximum-possible flood season were based upon an extrapolation of rates from floods of record. These observed melt rates were determined by plotting mass curves of natural run-off at McNary dam site, for the period March 7 through October 6, against the accumulated heat supply for the basin during years in which stages varied from law water to extreme high water. The accumulated heat supply for the basin is represented by the sum of the average day-degrees above 32°, commencing March 1, for seven representative stations in the basin. The mass curves of heat supply versus run-off are shown in figure 1, plate 2.

35. The slope at any point on the mass curves defines the rate of runoff per unit of heat supply and represents the apparent melt rate routed through valley storage. The melt rate is termed "apparent," as it does not represent the actual rate of melt at any particular point, but it is the composite rate at which the entire basin contributes water from snow. The apparent rates of melt are not constant but vary during the season with the changing snow-cover area. This area varies from a minimum in the early flood season to a maximum in midseason and again approaches a minimum as the snow cover disappears. The steepest slope of the mass curve of runoff versus heat supply represents the greatest apparent melt rate for the season. A relationship between maximum annual apparent melt rate and annual flood season run-off is evident from figure 2, plate 2. From an extrapolation of the surve of observed maximum seasonal melt rates to the maximum 7-month flood season run-off of 190,000,000 acre-feet, the maximum seasonal run-off rate was determined to be 94,300 acre-feet per day-degree above 32° F., approximately 160 percent of that during the maximum flood year of 1894.

36. A curve representing the apparent rates of melt, after March 1, for the maximum-possible flood is shown in figure 3, plate 2. This curve was derived from a graph of apparent melt rates for the 10 largest flood years, figure 1, plate 2, by increasing the observed melt rates on the basis of the ratio of the volume of the maximum 7-month flood season run-off of 190,000,000 acre-feet to the average flood season volume of the 10 largest floods. The only exception was the maximum rate for the year, which was obtained from figure 2, plate 2. This maximum rate was assumed to occur at the time of the highest average basin temperature in order to provide an additional increase in the maximum-possible run-off.

WORST-POSSIBLE SEQUENCE OF SNOW-MELT TEMPERATURES

37. The temperature sequence used in the derivation of the spillway design flood for McNary dam site was determined in accordance with criteria presented in the Weather Bureau report previously cited. The Weather Bureau studies indicate that, for maximum-possible flood-producing meteorological conditions, the temperature would remain at or near freezing during the winter and spring months so that the snow pack would remain a maximum over the basin. When the season had advanced to a point where the temperature could no longer remain below freezing for a major portion of the basin, a rapid transition would be made from the lowest-possible to

the highest-possible temperature in a period of 2 weeks. A continuous temperature curve for the flood season, used in deriving the maximum-possible flood, is shown in figure 4, plate 2. The curve of maximum snow-melt runoff rates was adjusted so that the peak run-off rate would occur at the time of highest temperatures. This arrangement would produce the greatest possible flood discharge. The enveloping maximum and minimum 7- and 30-day temperature duration curves shown in figure 4, plate 2, were derived from an extrapolation of United States Weather Bureau estimates of highest and lowest possible average air temperatures for Columbia River Basin.

EFFECT OF RAINFALL ON MAXIMUM-POSSIBLE FLOOD

38. Occurrence of a maximum-possible flood in Columbia River Basin would depend entirely upon the basin snow cover and melting temperatures. Late spring and early summer rains in Columbia River Basin above McNary dam site generally are of low intensity and short duration. At that time of year the infiltration and evaporation losses are high, a condition which results in a moderate run-off from late season storms. The occasional thunderstorm or cloudburst type of storm is localized and not of sufficient areal extent or duration to produce any noticeable increase in Columbia River discharge. Furthermore, climatological records indicate that a large general rainstorm at that time of year could not be accompanied by maximum-possible temperatures. Therefore, the resultant reduction in snow-melt run-off from a decrease in temperature in the maximum-possible run-off year, as a result of a maximum-possible late spring storm, would be greater than the increment of flow resulting from the storm. The net effect of rainfall would be to decrease the maximum discharge of Columbia River at McNary dam site and prevent the occurrence of a maximum-possible flood.

SPILLWAY DESIGN FLOOD

39. The spillway design flood for McNary Dam was derived by applying maximum seasonal run-off rates determined from figure 3, plate 2, to the increments of heat supply of figure 4, plate 2, and increasing the discharge increments thus obtained by a base flow of 140,000 second-feet. The flood thus derived has a maximum discharge of 2,200,000 second-feet and a 7-month flood season volume of 249,000,000 acre-feet, or 21.9 inches of run-off from the 213,500-square-mile basin above McNary dam site. The hydrograph is shown in figure 5, plate 2. The spillway design flood would have a peak discharge approximately twice as large and a volume one and one-half times as great as for the 1894 flood, the largest of record.

SPILLWAY FLOOD ROUTINGS

40. Because of the negligible storage capacity of McNary Reservoir in comparison with the run-off volume, and because of the flat-crested hydrograph, the maximum discharge of the spillway design flood would be unchanged in passing through the reservoir. Flows in excess of 1,400,000 second-feet, however, would be retarded slightly

by surcharge storage. McNary spillway will discharge 2,600,000 second-feet, or 118 percent of the spillway design flood peak, with the reservoir pool at the top of the dam, elevation 365.0 feet. Plate 3 illustrates the relation between pool elevation and discharges in excess of 1,400,000 second-feet.

BASIS FOR DERIVING SPILLWAY DESIGN FLOOD FOR THE DALLES AND JOHN DAY DAM SITES

41. The spillway design flood for Columbia River at The Dalles dam site was determined by a rational extrapolation of the spillway design flood derived for McNary Dam. That for John Day dam site was determined by interpolation between the spillway design floods for McNary Dam and The Dalles dam site.

42. The spillway design flood derived for The Dalles dam site is 2,290,000 second-feet with a 7-month flood volume run-off of 258,000,000 acre-feet, which is equivalent to 20.4 inches of run-off. The volume and peak discharge relationship curves used to extrapolate the McNary spillway design flood to one for The Dalles dam site are shown in figures 5 and 7 on plate 4. The hydrograph of The Dalles dam site spillway design flood, together with the five maximum floods of record, is shown in figure 2 on plate 4.

43. The spillway design flood for John Day dam site is 2,250,000 second-feet, with a 7-month flood volume of 253,800,000 acre-feet, which is equivalent to 21.1 inches of run-off. The volume and peak discharge relationship curves used to interpolate between McNary Dam and The Dalles dam site spillway design floods are shown in figures 1 and 2 on plate 5. The hydrograph of John Day dam site spillway design flood, together with the five maximum floods of record on Columbia River at The Dalles, is shown in figure 3, plate 5.

44. The spillway design floods at John Day and The Dalles dam sites have a peak discharge approximately twice as large and a volume 1½ times as great as the flood of 1894, the largest of record.

SPILLWAY FLOOD ROUTINGS FOR THE DALLES AND JOHN DAY DAM SITES

45. Since the volume of flood-control storage at John Day Reservoir and surcharge storage at The Dalles Reservoir would be very small in comparison with the volume of the spillway design flood, and since the hydrograph is broad crested, the reservoirs would have a negligible effect in reducing the peak discharge of the spillway design flood. Figure 1, plate 4, illustrates the results of routing of flood through the reservoir at The Dalles Dam. Figure 4, plate 4, shows the relation between pool elevation and discharges in excess of 1,200,000 second-feet at The Dalles Dam. The proposed spillway at The Dalles Dam would discharge 150 percent of the spillway design flood peak with the reservoir pool at the top of the dam, elevation 185 feet. John Day Dam, with top elevation of 297 to provide about 2,000,000 acre-feet of flood-control storage, would have sufficient spillway capacity to pass the spillway-design flood at elevation 290.7. With the pool at the top of dam, the spillway would pass 114 percent of the spillway-design flood peak.

SECTION IV—GEOLOGY

JOHN DAY DAM SITE

46. *General.*—Areal geology of John Day dam site is shown on plate 14 of part II. Columbia River at the site flows in a channel about 3,000 feet wide at the bottom of a steep-walled canyon several hundred feet deep. Practically no flood plain exists. Adopted low-water elevation is 146 feet. The channel contains numerous islands, most of which are composed of bedrock. Many of the islands are very small, but others are several hundred feet across. The channel is divided into two parts by a large rock and gravel island about a mile long, the upper end of which lies across the axis of the proposed dam. The abutments rise more or less gradually from the edge of the river to an elevation of about 200 feet or more, then rise almost vertically to an elevation greater than 300 feet, well above the maximum pool elevation.

47. *Subsurface exploration.*—Subsurface exploration in the site area consisted of 28 seismic lines and 11 core drill holes, totaling 2,112 linear feet of drilling. DH-1 and DH-2 were drilled in 1930, and the cores have been lost or destroyed. Holes DH-3 through DH-11 were drilled in 1948. DH-6 was lost at 48 feet depth without encountering bedrock; however, DH-11 was drilled at a later date in the same general area. Logs of drill holes and tabulation of the seismic data are shown on plate 7.

48. *Regional geology and physiography.*—The site is in the Columbia Basin subprovince of the Columbia Intermontane Physiographic province. The region is a rolling plateau into which Columbia River and a tributary, John Day River, have cut relatively narrow valleys several hundred feet deep. Columbia River basalt, of Miocene age, underlies the entire area, and occurs in widespread flows, which are either horizontal or show very broad, gentle folding. The Dalles formation, consisting of silt, sand, and gravel, overlies the Columbia River basalt at the higher elevations but is not found in the major stream valleys. Faults are not numerous; a major east-west trending fault, however, forms the north side of the Columbia River Valley and extends for a number of miles both upstream and downstream from John Day dam site. The fault probably is normal, with the upthrown side to the north. At the site the fault lies about a mile north of the river channel and does not affect foundation conditions.

49. *Site geology.*—Bedrock at the site is Columbia River basalt, which underlies the stream and forms both abutments. Nine different basalt flows, ranging in thickness from 15 feet to 70 feet, were encountered in core drilling. Individual flows in some instances vary in thickness by as much as 30 feet. The three uppermost flows, those above approximate elevation 60 feet, are relatively massive, being from 40 to 70 feet thick, and are composed of jointed, but nevertheless sound, rock. The flows below elevation 60 generally are thinner and more closely fractured, but, to the depth explored, all exceed 15 feet in thickness. Thin sandy and muddy interbeds occur between the flows below elevation 60, but the interbeds were not encountered in all drill holes at the same contact horizons and are not continuous.

50. A thin bed or beds of sandstone totaling 15 feet in thickness was encountered at the lowermost depths reached in drilling. This stratum rises 20 feet in elevation toward the right abutment but, everywhere in the site area is beneath the assumed foundation grade. The sandstone is fine-grained, friable, and micaceous, with thin contorted bedding and many shaly seams. Contained within the sandstone are thin flows of basalt. The sandstone is less competent than the other strata forming the foundation at the site but is believed to be of sufficient competence and depth beneath the foundation grade lines to have no definite bearing on any of the engineering features of the proposed structure.

51. The geologic structure of the site area appears to be that of a very broad, very gentle, arch. Several miles downstream from the site, component dips of about 2° downstream were observed in the basalt flows. Component dips in the same amount, but in the upstream direction, are found several miles above the site. No dip can be observed on the north side of the river at the site. On the south side, at the axis, a downstream component dip of 2° or less was found, but east of John Day River the basalt flows are horizontal. The site axis appears to be very close to the crest of the arch, where where the river has cut the John Day Rapids and associated bedrock islands in relatively massive flows.

52. Bedrock underlies the site at very shallow depths except under the north channel. Beneath the north shore and the rock outcrops on the main island is a deposit of river gravel, sand, and cobbles approximately 1,200 feet wide and, as shown by DH–11, at least 203 feet in thickness. DH–6 and seismic soundings are inconclusive and do not give the lateral limits of this pot hole but the structural and areal geology of the site area indicate that foundation conditions as good or better than those at the presently proposed axis would be found by moving the axis either slightly upstream or downstream.

53. A sand and gravel deposit occurs about one-half mile above the proposed axis. This deposit, through which the present channel of John Day River is cut, is about 2,000 feet in diameter. The upper surface is at an elevation of about 280 feet, or about 130 feet above both river channels. Seismic soundings indicate that the underlying bedrock surface is at or below the river elevation. The deposit, therefore, may be as much as 150 feet thick at the maximum. A rough stratification is exposed in a gravel pit along the highway about 2,000 feet upstream from the proposed axis. This bedding shows a strike of about N. 85° W. and a dip of 15° to 20° south. The dip is due to original deposition in fore-set beds and does not represent geologic deformation of the material. Elsewhere on the deposit, the bedding is obscured by a covering of blow sand.

54. Recent talus is confined to narrow, minor deposits along both abutment walls. All talus deposits are believed to be stable. Numerous deposits of blow sand, covering the bedrock to a depth of a few feet, are found on the lower portions of the abutments. Other than in the north channel, very little alluvium was found in the site area, although relatively minor deposits exist around the mouth of John Day River. Reconnaissance indicates that the south channel is essentially bare of overburden.

55. *Leakage conditions at the site.*—Pressure tests made in connection with the core drilling at the site indicate that the relatively thick

flows between elevation 160 and elevation 60 are fairly tight. In some instances, tests made in this interval show that, at pressures up to 100 pounds per square inch, no water could be forced into the rock. In the thinner basalt flows below elevation 60, all tests showed much leakage of water through the rock fractures. Tests made in the abutments above elevation 160 also indicated considerable leakage.

THE DALLES DAM SITE

56. *General.*—The Dalles dam site is located in the gorge of Columbia River near the junction of the extensive Columbia River basalt plateau on the east and the folded and uplifted basalts and related lavas of the Cascade Range on the west. The topography is youthful with box-like canyons separated by broad stretches of generally flat to rolling plateau surface. The topography is intimately related to the character of the basalts which erode by undermining and sapping and break off on vertical faces which are controlled by the vertical columnar jointing of the basalt. This erosion characteristic produces a cliff and bench topography within the canyons. Water level of Columbia River varies through the rapids of the dam site area but is at an average elevation of 60 feet. The river bed is characterized by large and deep potholes and scour channels, some of which extend more than 100 feet below river level. Plates 19 through 22 show areal geology, foundation exploration, geologic sections, and logs of drill holes.

57. The principal rock unit of the region is the Columbia River basalt of Miocene age, the combined flows of which have an estimated thickness of 3,000 feet. Of this total, less than 1,000 feet are exposed in the canyon walls adjacent to the dam site. The basalt flows are in series, 11 of which occur within the area examined. These are usually separated by thin soil layers or minor unconformities. Each series consists of from 1 to 5 flows and individual flows range from 5 to more than 50 feet in thickness. Agglomeratic interphases are rare, and surface examination reveals no thick or extensive tuff beds within the series. The flows exhibit columnar structure, horizontal jointing, vesicular to scoriaceous phases, and some lateral thinning, but primarily are composed of good hard sound rock of excellent quality. In general, the majority of the flow contacts are well sealed and closed.

58. The Columbia River basalt is overlain unconformably by the younger, moderately consolidated, terrestrial sediments of the Pliocene, The Dalles and Shutler formations. Neither of these rock units are known to occur at the dam site, so are not discussed in detail here.

59. Late Pleistocene gravel and finer alluvium is present in terrace remnants between 50 and 250 feet above river level. Recent deposits consist of sand, gravel, silt, and sand dunes on the valley floor and talus and sand dunes on the slopes. Coarse detritus partially fills the deeper potholes and scour channels.

60. The chief structural feature of the general area is The Dalles syncline, an open asymmetrical fold trending approximately north 30° east and appearing to terminate against the Columbia fault a mile or more north of the river. The axis of the synclines ies 2 miles west of the site and the basalt flows dip from Threemile Rapids southwesterly into The Dalles syncline at a very low angle. Although, in general, the river flows through a gorge, the warp of the syncline has tipped

the basalt flows downward from the northeast to southwest, so that on the north abutment of the site and for several miles downstream on the north side of the river, the rim of the basalt rises only 100 to 200 feet above the general river level. Just above Threemile Rapids, which is located at the western limits of the site, the dips of the basalt flows reverse to the northeast forming a shallow asymmetrical intermediate syncline with a steeper western limb. This syncline plunges to the south and has an axial trend slightly west of north. This secondary fold is intimately associated with the faults present, and is probably due to cumulative compressive stresses ending in the faulting.

61. The major Columbia River fault, as nearly as it can be traced, lies to the north, well outside the dam site area. Three secondary northwest-southeast tranverse faults occur in the area mapped. The westernmost, at the foot of Threemile Rapids, and the easternmost, at the head of Fivemile Rapids, bound a horst block, while an intermediate fault occurs at Big Eddy. The faults appear to be of the rotational, or hinge, type with the greater throw on the north side of the river. The Dalles formation appears to have been displaced on at least two of the faults. Hence, the faulting is post-Pliocene in age, but a masking by undisturbed Quaternary deposits indicates no activity in late geologic times. Shear zones of the faults in the basalt form lines of weakness resulting in rapid headward erosion with abundant production of talus and the development of chutes.

62. The Threemile Rapids fault is downthrown on the west side, with displacement approaching 130 feet on the north side of the river and decreasing to 30 feet on the south side.

63. The Big Eddy fault is upthrown on the west side with displacement approaching 50 feet on the north side of the river, and decreasing to 15 or 20 feet on the south side. A pseudo-anticline in the basalt, due to drag, is noticeable in the gulch on the north side of the river at Big Eddy. This fault crosses under the proposed earth- and rock-fill section, at which point the indicated throw is 30 feet.

64. The Fivemile Rapids fault, crossing the river just above the head of that rapids, also apparently has a greater throw progressively northward with a possible displacement in excess of 150 feet on the north side of the river.

65. The possibility of additional faulting normal to the above-discussed transverse faults is suggested by the sharp rectilinear edge of the low-rock platform on the north side of the river from Threemile Rapids to Big Eddy and by the linear west-east continuation of the chutes paralleling Fivemile Rapids. However, examination of the area showed no displacement in the flows.

66. A separate joint system parallel to the strike of the flows is noticeable in the area adjacent to the axis of the intermediate syncline on the south side of the river, but is poorly defined on the north side.

67. The stratigraphic and structural features of the site area indicate that:

(*a*) The basaltic bedrock of the area is, in general, of excellent quality for foundations.

(*b*) Permeable zones will be present along some flow contacts but can be fully outlined and adequately treated.

(*c*) The fault zones can be fully delineated and potential leakage treated.

(*d*) The typical columnar structure of the basalt lends itself to plucking, scouring, and in some cases undersapping, particularly by back surge of large streams of water dropping over sharp declivities.

(*e*) A considerable portion of the large rock sizes required for the proposed earth- and rock-fill section can be secured from the necessary excavations and from interadjacent areas.

ARLINGTON DAM SITE

68. *General.*—Areal geology of the Arlington site is shown on plate 16 of part II. In the present site area, the river is approximately 3,000 feet wide and has a low-water elevation of about 184 feet. Present in the left portion of the river are two low gravel islands, each approximately 1 mile long and 800 feet in width. The south valley wall rises somewhat over 300 feet in 1,500 feet. The slope of the north valley wall is broken at elevation 300, approximately 1,000 feet from the river. Beyond this point the terrain is essentially level for an additional 1,500 feet northward, where it abuts the nearly vertical rock face of the canyon wall, which rises 1,000 feet or more above the river.

69. *Subsurface investigation.*—Preliminary exploration of the site was initiated in 1930 and has been continued intermittently to date. The exploration consists of 49 seismic lines, 4 core-drill holes having a total footage of 410.9 feet, and 1 churn-drill hole 102.5 feet deep. Cross sections and logs of drill holes are shown on plate 17, part II.

70. *Physiography and regional geology.*—The site is located in the Columbia Basin subprovince of the Columbia Intermontane Physiographic Province, between the North Central Plateau and the Yakima Folds section. The topography and present course of Columbia River in this region are largely resultant of the generally east-west trending Columbia River Fault and auxiliary faults. The topography is characterized by a gently rolling upland, the surface of which ranges from 500 to 1,000 feet above the level of the river on the south and north sides, respectively. Into this upland, Columbia River and tributaries have cut relatively narrow, steep-walled canyons.

71. The bedrock of this region consists of two or more series of Columbia River basalt flows and occasional interbeds of ash and sedimentary deposits of variable thickness. The thickness of individual basalt flows varies greatly. Ash interbeds tend to be thin and of a lenticular nature, but those composed of sedimentary material, clay, soft shale, and poorly consolidated sandstone vary from thin rather limited zones to continuous and extensive beds of considerable thickness. The latter beds may belong to or be associated with the Latah or Ellensburg formations.

72. *Site geology.*—Bedrock, Columbia River basalt flows, is present in both abutments. On the right, it is exposed over a considerable area; on the left it generally is obscured by overburden and is completely covered above elevation 275. At low water, bedrock is exposed along both edges of the river at approximate elevation 185.

73. In the nearly flat-lying basalt, a northeasterly or upstream dip of about one-half of 1° is measurable on the right abutment. The rock, which has poorly developed columnar jointing, generally is hard, dense, and sound. The joints appear tight and should not leak

to any appreciable amount. No interbeds were observed in the site area, nor were any encountered in any of the drill holes.

74. Seismic lines indicate that bedrock is present beneath the island portion of the channel section at approximate elevation 135 feet, beneath some 60 or more feet of Recent alluvium. Data from subsequent core drill holes tend to corroborate that indication. Hole DH-4, located on the axis between the island on the south shore, encountered bedrock at elevation 179.3; no alluvium was present at this point. Hole DH-5, located some 500 feet downstream from the axis and below the island, however, was lost after penetrating river gravels to elevation 68; no rock was encountered. Two other holes DH-1 and DH-2 drilled some 2,000 feet downstream from the axis, encountered bedrock at elevation 175.7 and 134.0, respectively.

75. The Columbia River fault, which cuts through the site area in a northeast-southwest direction nearly parallel to the river and about 2,400 feet north of it, is just beyond the northwest extension of the contemplated dam site. The fault appears to be normal with the upthrown side lying to the north. Vertical displacement along the fault may amount to as much as several hundred feet in some places.

76. Overburden deposits are present in quantity only on the left abutment. At the axis, the overburden consists of talus and slopewash admixed with some gravel and overlain in places by a thin layer of blow sand. Many of the talus blocks are of enormous size. These blocks, together with smaller fragments, have broken away from a basalt rimrock which outcrops at approximate elevation 750 feet, a considerable distance south of the river. As gravel is exposed in a borrow pit, about one-half mile below the site, some gravel may underlie at least a portion of the talus and slopewash on the left abutment. This could explain the presence of gravel in this material near the lower portion of the abutment face. Overburden is thin on the right abutment and consists of only a few feet of sandy soil covering the more level portions of the abutment.

77. Recent alluvium, river sand, and gravel deposits are present in the site area as islands in the river and in some places constitute the river bottom. The extent and depth of these deposits generally is not known, but in some locations depths in excess of 98 feet occur.

78. *Alternate site geology.*—An alternate axis, located about one-half mile upstream from the adopted location was investigated, but was rejected because a suitable abutment south of the river was not available.

SECTION V—ALTERNATE PLANS

INTRODUCTION

79. In addition to studies for the proposed John Day project discussed in part I of this appendix, alternate storage plans and plans for improvement of the reach of Columbia River between the head of the proposed The Dalles Reservoir and McNary Dam were studied and comparisons of cost estimates were made to determine the relative merits of the schemes investigated.

80. Alternative plans of development investigated are listed below.

(*a*) Storage plans (John Day Reservoir for navigation, power, and flood control).

(*b*) Single-dam plan (John Day Dam without flood storage).

(*c*) Open-channel improvement (channel enlargement to provide 12-foot minimum depth over a width of 250 feet).

(*d*) Two-dam-plan (John Day and Arlington Dams for navigation and power).

These plans are discussed in the following text.

STORAGE PLANS

81. *General.*—Four storage plans, designated case I through IV in table 3, were studied prior to selection of the proposed plan to provide about 2,000,000 acre-feet of flood-control storage space at John Day Dam. Data in table 3 indicate that surcharge storage space in the amount of 1,927,000 acre-feet, measured between the backwater curves at normal and maximum pool elevations for a discharge of 800,000 second-feet, can be obtained at a cost of about $31 per acre-foot, with smaller amounts at lesser cost, and that to obtain storage capacity by drawdown would cost about $100 per acre-foot. Inasmuch as it is not deemed practicable to exceed the maximum water surface elevations which would result at McNary Dam and at Umatilla, from adoption of maximum flood control pool elevation 292, that elevation was adopted as providing the maximum feasible surcharge flood-control storage capacity for John Day Reservoir. With higher pool level the town of Umatilla would require complete relocation and interchange of cargo between permanent shore installations clearing the maximum storage level and barges operating at normal pool level would become increasingly difficult. See part I for description of the proposed project, which is comparable to case III of table 3. Following are brief descriptions of cases I, II, and IV, the rejected alternatives shown in table 3.

82. *Case I.*—Case I differs from the alternative single-dam plan for John Day without flood-control storage in operation of the spillway and in the size of spillway gates. This plan would utilize the 764,000 acre-feet of surcharge storage space between normal and maximum pool to regulate the discharge during floods. The additional cost at the dam would result from higher spillway gates to restrict discharges and stronger turbines to withstand the higher head imposed during storage periods. Flowage design would be based on the backwater profile of the 1894 flood superimposed on maximum pool elevation 271.5 at John Day Dam, in lieu of the normal pool 255 without flood-control storage. Costs due to this rise in elevation would account for 60 percent of the incremental storage cost. Unit cost of the storage space made available would be about $21 per acre-foot. No provisions for operation of the navigation lock at levels above normal pool were considered.

83. *Case II.*—With maximum flood control pool at elevation 282 and normal pool 255, this plan would make available 1,380,000 acre-feet of usable storage between backwater profiles for 800,000 second-feet. The essential differences from the single-dam plan for John Day project without flood storage would be due to increase in pool elevation and the necessity for restricting flows at maximum pool. The top of dam, allowing 5-foot freeboard, would be at elevation 287, and the spillway crest elevation, established to allow passing the design discharge at maximum pool through the twenty-two 50-foot spillway bays, would be 215.5. The height of the gates would be

55 feet, including 2-foot freeboard. The stilling basin would be provided with baffles and end sill, designed for 2,250,000 second-feet discharge at pool elevation 282. The navigation lock would not be designed for operation at levels above normal pool 255, except that the upstream emergency dam would be designed to retain the 282 pool. Under this storage plan the adverse effect of backwater at McNary Dam power plant during flood-control operations would be nearly compensated for by the increased head at John Day and by utilization of the 15-percent overload capacity of the generators. Generator thrust bearings and turbines at John Day would be designed for the additional head imposed during flood storage operations.

84. Utility relocation costs would constitute the greater portion of the incremental cost chargeable to flood control. The taking line elevation would be increased 27 feet at the dam and, because of decreasing backwater effect, somewhat less upstream. The usable storage of 1,380,000 acre-feet available under this plan would cost $33,050,000, or about $24 per acre-foot.

85. *Case IV.*—This plan utilizes surcharge storage between pool elevations 255 and 292, and draw-down storage to pool elevation 241. The usable flood-control storage capacity available between pool elevations 241 and 292 for 800,000 second-feet backwater amounts to 2,381,000 acre-feet. Releases of normal storage to pool elevation 241 would be based on forecasts of floods expected to exceed 800,000 second-feet. Releases would be calculated as nearly as possible so that the pool would be at elevation 241 when the flood discharge reached 800,000 second-feet.

86. The spillway would be designed to pass 650,000 second-feet at minimum pool elevation 241 and to restrict the flow to 650,000 second-feet at maximum pool elevation 292. The required spillway gate height would be 72 feet, including 2 feet of freeboard. The navigation lock would be designed to handle traffic at normal pool and during draw-down to minimum pool prior to a flood. This operation would require that the upper lock sill be set at elevation 227 and that the upper gate be 36 feet in height. The emergency dam upstream from the upper lock gate would extend from the upper sill to maximum pool elevation 292, with a 2-foot freeboard.

87. The installation of four additional turbines and generating units to compensate for power lost because of the 14-foot draw-down would constitute the greater portion of incremental costs chargeable to flood control under this plan. With the required 17-unit powerhouse, space would remain for future installation of only one additional unit. The turbines and generator-thrust bearings would be designed for the maximum head at 600,000 second-feet discharge. Flowage for this plan would be identical to that for the proposed plan with maximum pool elevation 292. The usable flood-control storage would be 2,381,000 acre-feet and would cost $105,619,000 or about $44 per acre-foot. The incremental draw-down storage, however, would cost more than $100 per acre-foot.

SINGLE-DAM PLAN WITHOUT FLOOD STORAGE

88. *General.*—This plan would develop the head between The Dalles pool and McNary Dam for power production, and provide slack water for navigation. The normal pool level considered for John Day Dam,

elevation 255, was selected to utilize most economically the intervening head and to provide satisfactory navigation conditions as regards depths and velocities at the upper end of the pool. In connection with head utilization, economic factors control. Backwater effect at McNary Dam could be reduced by raising John Day pool and overlapping McNary tailwater to a greater degree. To accomplish this, however, it would be necessary to raise John Day Dam and further to elevate reservoir relocations, thus incurring additional dam and reservoir costs. Further, the incremental head developed would be variable, depending upon the stage of upstream storage development and the minimum regulated flow available. A preliminary evaluation indicates that elevation 255 feet is the highest normal pool elevation economically justifiable. This elevation is 3 feet lower than the pool level recommended for Arlington Dam in House Document No. 704, Seventy-fifth Congress, third session, but, because of differences in reservoir lengths, backwater effects of either would be practically identical.

89. *Description.*—Lay-out and details of the single-dam John Day project with normal pool elevation 255, without flood-control storage, are shown on plate 6. The structure would be about 95 feet high from headwater to tailwater and would consist essentially of a spillway, a navigation lock, a hydroelectric generating plant, and facilities for passing anadromous fish. The proposed lay-out is similar to that for the proposed John Day Dam with flood-control storage. Instead of maximum flood-control pool at elevation 292 the maximum water surface would be at elevation 271.5 and the crest of the dam would be at elevation 282.

90. Several features of the plan would be identical to those for the proposed John Day Dam. Cofferdam design and construction schedules, navigation locks, and fish facilities would be identical while recreation facilities and the nonoverflow construction section would be quite similar.

91. *Flowage and relocation.*—John Day Reservoir with pool elevation 255 is shown on plate 7. Railroads, highways, and other utilities located near the river would require relocation above the backwater profile of the 1894 flood passing the dam at normal pool elevation 255. Backwater profiles are shown on plate 8. Estimates of costs for relocation are based upon the construction of the project following completion of McNary and The Dalles projects.

92. The principal difference, insofar as flowage and relocations are concerned, between this plan and the proposed plan, is the difference in maximum pool elevation. The town of Arlington would be raised similarly to the proposed plan, the variation being in the height of fill required. North Umatilla would be protected by a levee which would eliminate present flood damage in that portion of the town. Irrigation would be only slightly affected, but Boardman would require relocation. Studies showed protection of these two towns by levees to be infeasible.

93. *Costs.*—Initial costs of the single-dam John Day power and navigation project with 13 generating units installed are summarized below. These costs are on the basis of January 1948 price levels and are based on the prior construction of The Dalles and McNary Dams. A summary capital-cost estimate of the single dam without flood storage is contained in table 4, which compares costs of accomplish-

ment of alternative plans. The total estimated construction and capital costs for the single-dam plan without flood storage are $320,547,000 and $354,805,000, respectively. The estimated annual charges are $15,711,000 to the Federal Government and $13,000 to non-Federal interests.

OPEN-RIVER IMPROVEMENT

94. A preliminary study was made of the feasibility of providing open-river navigation improvement for the 75-mile reach between the head of The Dalles pool and McNary Dam. Channel widths of 250 feet and 12-foot minimum depth were considered adequate for such improvement. As the minimum release of water through the McNary power plant would determine future low-flow conditions, no increase in stream flow due to future upstream storage was assumed during the low-water season. For the plan considered herein, however, McNary power plant was assumed to be operated in such a manner that the present minimum flow would not be further reduced. Typical backwater computations made through selected sections of the reach indicate that provision for draw-down of the water surface, which would occur where enlargement of the channel is necessary, could be approximated by allowing for 1-foot overdepth in excavation. This allowance was made in preparation of the estimate of cost. The present river profile and navigation depths are controlled to a large extent by rock outcrops through the rapids. As most of the excavation would be removal of rock in swiftly flowing water at these rapids, the cost would be high. Based on surface examinations, the material requiring excavation has been classified and an estimate of cost is shown in the following tabulation:

Item	Unit	Quantity	Unit price	Amount
Excavation, rock	Cubic yard	1,765,000	$14.25	$25,151,000
Excavation, boulders	do	353,000	4.00	1,412,000
Excavation, sand and gravel	do	633,000	2.50	1,583,000
Total cost				28,146,000

95. Interest at 3 percent on the above investment and amortization over a 50-year period would amount to $844,000 and to $249,000 annually, respectively. In addition, maintenance is estimated to require the expenditure of about $320,000 each year. Total annual cost of the improvement would thus be $1,413,000.

96. The benefits from this plan of open-river improvement would consist of savings to barge operators, resulting from decreased operating costs. This saving is estimated at 1¼ mills on the January 1948 estimated operating cost of 9 mills per ton-mile and would result principally from increased load factor and number of barges per tow. Decreasing the cost of barge operation also would increase the tonnage shipped by water. Total tonnage used in determining annual benefits is liberally estimated as that which would develop under ultimate slack-water improvement as shown in table 28 of appendix M, or 4,600,400 tons annually. Total annual benefits creditable to open-river improvement through the 75-mile reach would, on this basis, amount to $431,000.

97. A comparison of annual benefits and annual costs for open-river improvements indicates that it would not be economically feasible, the benefit-to-cost ratio being 0.30 to 1. Aside from the unfavorable economic aspect, open-river improvement would nullify potential flood control, power, and irrigation benefits of great value which are subject to realization under multiple-purpose slack-water development. The only advantage would lie in the provision of natural river conditions for migrating and spawning fish.

TWO-DAM PLAN

98. *General.*—The two-dam plan given consideration in this appendix is that recommended in 1937 in House Document No. 704, Seventy-fifth Congress, third session, as a part of a comprehensive plan for development of Columbia and Snake Rivers in Oregon, Washington, and Idaho. It consists of a low dam with normal pool elevation 210 at the John Day site and a low dam, normal pool elevation 255, at the Arlington site, 26 miles upstream. Location of the Arlington site is shown on plates 1 and 36 of part I. The 1937 recommendation was a modification of an original proposal for a single high dam at the John Day site. The 1937 studies recognized an initial cost differential favoring the single-dam plan but fixed charges aplicable to the single-dam development during a long period of power load development were anticipated to exceed this saving and the two-dam plan was thought basically the more economical. Studies in connection with the present report, however, indicate that no appreciable power load development period would be necessary for the single-dam development and that the initial cost of the two-dam plan is greatly in excess of that of the single-dam plan.

99. The structures considered for the two-dam plan generally are similar to the single John Day Dam previously discussed, except for height. Each would include a navigation lock, spillway, powerhouse, and facilities for passing fish over the dam. Arlington Dam site was selected for the additional dam of this plan as it is upstream from the town of Arlington, which would undergo major dislocation under the single-dam plan, and as the geologic and topographic characteristics of this reach of the river are favorable. Pool elevation 255 was established for Arlington Dam in conformance with the level proposed for the single dam at John Day site. Pool level for the low John Day Dam was set at elevation 210, which is in accordance with the previous proposal of House Document No. 704. John Day Reservoir at pool elevation 210 would overlap Arlington Dam, which is located at natural low-water elevation 183, by 27 feet. The head at the low John Day Dam at a discharge of 800,000 second-feet, which is the upper flow criterion for firm capability, would be 31 feet or 63 percent of maximum. While reduction in the level of John Day pool below elevation 210 would result in some savings in flowage costs and in concrete in the spillway and lock, the percent head reduction at a discharge of 800,000 second-feet would be increased, with consequent increase in cost of power facilities. In addition, navigation conditions at the upstream end of the pool would be somewhat less favorable.

100. *John Day Dam, pool elevation 210.*—Geologic and lay-out considerations which governed the arrangement of John Day Dam to pool

elevation 255 also would be applicable to the lower structure. The general lay-out and details of the dam are shown on plate 10.

101. At normal pool elevation, the spillway would be capable of passing 1,420,000 second-feet, a flow larger than the maximum of historical record. The design discharge of 2,250,000 second-feet would be passed at pool elevation 228, 18 feet above normal level. The crest profile would be based on the head at spillway design discharge.

102. The navigation lock, fish facilities, and power facilities would be similar to those for the dam with normal pool elevation 255. The lift of the navigation lock would vary from a maximum of 49.5 feet at low flows to 31 feet at a discharge of 800,000 second-feet. Fish facilities would be comparable to those for the dam with normal pool at elevation 255, with the exception that fish locks would not be necessary and the cost of fish hatchery facilities would be reduced about 50 percent. The powerhouse would house 14 generating units each rated 42,000 kilowatts. Space would be available for four additional units. The total ultimate installed capacity of the 18 units would be 756,000 kilowatts. The power plant would be designed for constant headwater level, but the head available at the power plant would be reduced during floods because of the tailwater rise at high discharges.

103. Plate 11 illustrates head and output characteristics of John Day power plant (normal pool 210) under phase C development as related to river discharge conditions. The tabulation following summarizes data pertinent to the generating equipment:

Item	Description
Nominal prime capability	376,000 kilowatts.[1]
Nominal firm capability	501,000 kilowatts.[1] [2]
Installed generator capacity	588,000 kilowatts.
Type of turbine	Automatic, adjustable 5-blade propeller.
Design head	40 feet.
Rated head	48 feet.
Maximum head	53 feet.
Minimum head[3]	31 feet.
Turbine rated output	65,500 horsepower.
Revolutions per minute	66.7.
Diameter of turbine runner	320 inches.
Elevation centerline of runner	122 feet, mean sea level.
Unit spacing	94 feet.
Generator rating at 0.95 power factor	44,200 kilovolt-amperes.

[1] See appendix O.
[2] Computed on basis of 75-percent load factor.
[3] For river discharge of 800,000 second-feet.

104. *Arlington Dam, normal pool elevation 255.*—Arlington Dam, the second unit of the two-dam plan, would be located at river mile 243.5, approximately 2 miles upstream from Arlington, and would create a reservoir at elevation 255, 45 feet higher than the low John Day pool. The project would consist of a navigation lock, spillway, powerhouse, and related facilities. A complete geologic description of Arlington dam site is contained in section IV of part II and on plate 16.

105. *Lay-out.*—Plate 12 illustrates the lay-out considered for Arlington Dam. The project would consist of a navigation lock, spillway, powerplant, fish facilities, and connecting nonoverflow sections. All facilities would be comparable to those at the proposed John Day project except for the variations due to the decreased head. The

powerhouse would provide space for the installation of 12 generating units with a capacity of 450,000 kilowatts, as discussed under phase C development in appendix O. Space would be available for four additional units.

106. Plate 13 illustrates head and output characteristics of Arlington power plant under phase C development as related to river discharge conditions. See appendix O. The following tabulation summarizes data pertinent to the generating equipment:

Item	Description
Nominal prime capability	339,000 kilowatts.[1]
Nominal firm capability	452,000 kilowatts.[1, 2]
Installed generator capacity	540,000 kilowatts.
Type of turbine	Automatic, adjustable 5-blade propeller.
Design head	42 feet.
Rated head	45 feet.
Maximum head	48 feet.
Minimum head [3]	36 feet.
Turbine rated output	67,000 horsepower.
Revolutions per minute	69.2.
Diameter of turbine runner	315 inches.
Elevation centerline of runner	171 feet, mean sea level.
Unit spacing, feet	92 feet.
Generator rating at 0.95 power factor	47,400 kilovolt-amperes.

[1] See appendix O.
[2] Computed on basis of 75-percent load factor.
[3] For river discharge of 800,000 second-feet.

107. *Flowage and relocations.*—Plate 36 of part I shows Arlington dam site and its relationship to the communities of Arlington, Oreg., Roosevelt, Wash.; and other settlements along Columbia River. Plate 8 shows backwater profiles for various flows up to 1,150,000 second-feet, based on the published discharge of the 1894 flood, which were used in determining land acquisition and utility relocation limits for the two-dam plan as well as for the single-dam John Day project discussed earlier in this appendix. The 1894 backwater profile for Arlington Reservoir and for the pool for John Day Dam for navigation and power above Arlington dam site are nearly coincident, the variation not exceeding 1 foot. Flowage problems and costs along this upper reach of the river, therefore, would be practically identical for the two-dam plan and the single-dam plan previously described.

108. Under the two-dam plan, the railroads downstream from Arlington Dam would require relocation as under the single-dam plan, but to a lesser degree. The principal areas held free from the inundation which would occur under the single-dam plan would be steep side-hill slopes. Arlington, however, would remain essentially unaffected by the two-dam plan, although the railroad and accessory facilities along the water front would have to be raised about 10 feet.

109. Estimates of relocation cost were made on the assumption that, for reasons of economy, construction of Arlington Dam would precede that of John Day Dam.

110. A comparison of the single-dam and two-dam plans is summarized in table 4 of part II. The total difference in reservoir costs between the two-dam and single-dam plans amounts to $5,602,000, of which $3,295,000 would be chargeable to relocations, and $2,307,000

would be chargeable to cost of lands and improvement occurring largely in the town of Arlington.

111. Cofferdam designs for the two-dam plan are predicated on construction of Arlington Dam prior to John Day Dam. This sequence is favorable in that Arlington cofferdams would not be increased in height because of backwater from John Day pool. Cofferdams for the low John Day Dam would be influenced by the backwater effect of The Dalles Reservoir and would be identical with the cofferdams required for the John Day Dam for navigation and power. The sequence of construction operations also would be similar.

112. Railroad relocation is estimated to require 1 year for each dam of the two-dam plan. Two years work within each first-step cofferdam would be required and 3 years within each second-step cofferdam, after which four generating units could be placed in operation. Additional generators would be installed thereafter at the rate of four per year. Total construction time for John Day Dam with 14 units would be 8½ years. For Arlington Dam, with 12 units, the construction time would be 8 years.

113. *Costs.*—Summary estimates of initial costs for the two-dam plan are included in table 4. Estimates of annual charges were prepared upon the basis previously described for the proposed project. The total estimated capital cost of the two-dam plan is $523,227,000. This total includes a preliminary estimate for Arlington Dam, based on the rock line shown on plate 12. Later drilling showed rock to be at a greater depth than indicated on plate 12. Inasmuch as, on the basis of the preliminary estimate, the two-dam plan would be extremely unfavorable, new estimates were not made, and the preliminary estimate for Arlington Dam was used in the comparisons following. An additional amount of 5 percent for contingencies was included to allow for construction items which would be dependent upon foundation elevation. If no more favorable site could be developed, actual costs at the adopted Arlington location probably would be increased about $10,000,000 over the preliminary estimate shown.

114. Total estimated capital cost of the two-dam plan, as shown in table 4, is $168,422,000 in excess of that for the single-dam plan. Whereas estimated reservoir costs for the two-dam plan are $5,602,000 less than for the single-dam plan, estimated structure costs are $157,725,000 more. About $34,769,000 of the structure cost differential would be attributable to duplication of cofferdams and spillway and lock facilities. The greater portion, $118,524,000, however, would be attributable to increased cost of power facilities. The estimated cost of each generating unit at the low dams is approximately equal to the estimated cost of each generating unit at the single-dam John Day project, even though those at the latter structure would develop about twice as much power. This is accounted for by slower rotational speeds of the turbine runners and by the larger physical dimensions of the lower head units, which would require larger hydraulic passages with consequent increase in dimensions of the structure for each unit. The following comparison illustrates these data for each dam of the single-dam and two-dam plans.

Item	Two-dam plan,		Single-dam plan, John Day
	John Day	Arlington	
Normal pool elevation	210	255	255
Power plant data:			
Maximum head, feet	53	48	98
Rated head, feet	48	45	93
Turbine diameter, inches	320	315	280
Unit spacing, feet	94	92	82
Revolutions per minute	66.7	69.2	85.7
Generator capability per unit	42,000	45,000	85,000

115. Table 4 illustrates also the annual costs chargeable to both the single-dam and two-dam plans. As a result of the larger capital expenditure, annual interest and amortization charges for the two-dam plan would be $6,545,000 in excess of those chargeable to the single-dam plan and, because of duplication of facilities susceptible to replacement and requiring operating personnel, annual charges of that nature against the two-dam plan would exceed those against the single-dam plan by $1,441,000. Considering all items, annual charges in connection with the two-dam plan would exceed those of the single-dam plan by $7,982,000.

116. *Accomplishments.*—As an alternate plan to the single John Day Dam, two lower dams, one at John Day site and the other at Arlington site, would utilize the full fall of the river between The Dalles pool and McNary Dam for power and would provide slack water for navigation. Navigation and power development would be the principal accomplishments, with irrigation and recreation as secondary benefit features.

117. Development of John Day and Arlington dam sites would logically follow that of The Dalles Dam. Power developed from the projects would be used locally, and surplus power would be transmitted to the Northwest power pool. Power output of the two plants would be roughly equal to that which could be produced at the alternative single-dam John Day project for navigation and power.

118. No irrigation benefits would be creditable to John Day low dam with a pool elevation of 210 feet, as pumping from this lower level would not be practical as compared to pumping from pools at elevation 255 feet. Inasmuch as the Arlington, Willow Creek, and Roosevelt irrigable areas may be served equally well from either the John Day or Arlington pool at elevation 255, irrigation benefits for the alternative single-dam or two-dam plans would be equal.

119. Recreation benefits also would be creditable to both the single-dam and two-dam plans in about the same amount, and the intangible values previously mentioned also would accrue to the two-dam plan.

COORDINATION WITH OTHER AGENCIES

120. All agencies known to be concerned with the John Day project or alternatives thereto were kept informed regarding the studies that were made. Prior to final selection of the proposed project for flood control, navigation, and power, a public hearing was held at Arlington on May 25, 1948, to acquaint all interests with features of the alternative single-dam project. The United States Fish and Wildlife Service was consulted as to fish ladder and hatchery requirements for the

single-reservoir project. The views obtained were influenced to some extent by the opinions of Oregon and Washington agencies responsible for fish and game in those States. Power production and transmission problems were analyzed with assistance from representatives of the Federal Power Commission and the Bonneville Power Administration. The highway departments of Oregon and Washington, and the United States Public Roads Administration were consulted as to the desirability of incorporating a highway bridge in John Day Dam and all three agencies expressed unfavorable opinion. The United States Coast Guard, which is responsible for the establishment and maintenance of navigation aids through the reservoir area, furnished estimates of cost for the necessary revision of those facilities in connection with reservoir development.

SUMMARY

121. *Discussion.*—The proposed project and three alternative methods of improvement for the reach of Columbia River between the head of the proposed The Dalles Reservoir and McNary Dam were considered. Alternatives included the single-dam plan (John Day Dam with normal pool 255), open-river improvement (channel enlargement to provide 12-foot minimum depth over a width of 250 feet), and the two-dam plan (John Day Dam with normal pool 210 and Arlington Dam with normal pool 255).

122. The alternative single- or two-dam plans would provide for multiple-purpose development of the river, yielding slack-water navigation benefits, revenue from sale of power, and irrigation and recreation advantages. The open-river improvement would afford navigation benefits only and such benefits, because no reduction in the present swift river velocities would be effected, would not be equal to those for slack-water improvement. Open-river improvement in this reach would restrict efficient utilization of the adjacent constructed and authorized slack-water pools. Furthermore, this type of improvement would not provide needed flood control or develop a valuable potential power resource. In view of these unfavorable features, and inasmuch as the ratio of benefit to costs for open-river improvement would be only 0.30 to 1, based on the most favorable assumption, this type of improvement would be vastly inferior to slack-water development.

123. The benefits accruing to the single-dam or the two-dam plan of development would be nearly equal. The single-dam plan would have a slight margin in navigation benefits because of one eliminated lockage and also a small margin in power benefits because of the elimination of a 0.5-foot head loss due to backwater, but the total differential would be insignificant. Table 4 lists initial costs and annual charges for the two-dam and single-dam plans. Under the two-dam plan, the initial capital expenditure would be greater by $168,422,000, and annual expenditure would be $7,982,000 greater than under the single-dam plan. Further, slightly smaller returns would be attributable to the increased investment required under the two-dam plan. The single-dam plan, on the basis of the costs and benefits set forth above, would be overwhelmingly more favorable than the two-dam plan.

124. Annual charges previously mentioned are predicated upon conditions at each dam following complete installation of generating equipment. That absorption of power output which would actually occur at a rate justifying immediate installation of all generating facilities is shown in appendix N, Report on Power Markets and Developments in the Pacific Northwest, prepared by the Bonneville Power Administration. As shown therein, the average energy demand, in a period 10 years hence, probably would be increasing at the rate of 5,000,000,000 kilowatt-hours, or about 570,000 kilowatts per year. The 1,105,000-kilowatt installation at John Day Dam thus would be absorbed as rapidly as developed, and no carrying charges over a period of load development would be assessable against the project.

125. Only relatively intangible considerations favor the two-dam plan. One of these, the temporary dislocation of the city of Arlington, would be compensated for by the development of a superior town site on the embankment proposed for construction at the present town site. Local residents have made no issue of the single-dam proposal, and no protests were presented at the hearing on John Day project. Another factor, passage of fish over a single high dam in contrast to passage over two lower dams, is not susceptible to evaluation at this time. Apparently, any advantage creditable to the two-dam plan in this respect would not be significant.

CONCLUSION

126. The foregoing data demonstrate the advantages of development, for navigation and power, of Columbia River between the head of the proposed The Dalles Reservoir and McNary Dam by a single dam at the John Day site as compared to development by two lower dams. The need for flood-control storage at John Day site is discussed in part I of this appendix and in appendix M. Accordingly, on the basis of alternative studies previously described, about 2,000,000 acre-feet of flood-control storage should be provided at the proposed John Day Dam.

SECTION VI—LOWER COLUMBIA RIVER BACKWATER STUDIES

GENERAL

127. Occurence of the 1948 flood, the largest flood in the last 54 years on Columbia River, provided an opportunity to obtain detailed high-water data for lower-river areas where levees are required to protect land from floods as small as 400,000 second-feet. The maximum discharge of the 1948 flood was slightly in excess of 1,000,000 second-feet and the water surface was about 15 feet above flood stage at Vancouver, Wash.

PROFILES

128. Water-surface profiles from the mouth of Columbia River to Bonneville Dam, a distance of 145 miles, were obtained for the maximum flow during the flood and also for an 800,000 second-foot discharge. These profiles, as shown on plate 18, were the basis for a backwater study made to determine the effect of future levees below Vancouver.

BACKWATER STUDIES

129. All backwater computations were made, using Manning's formula, and velocity head was taken into consideration. The first part of the backwater study was the determination of the channel roughness, as expressed in terms of n value. These values were found to vary from 0.035 to 0.015, with an average value of 0.025 for the lower Columbia River, between mile 30 and 120. These coefficients are for the main channel. The overbank area, which carried only a small part of the total discharge, was assumed to have a roughness coefficient of 0.15.

130. Cross-sections of the river at approximately 2-mile intervals were taken from topographic maps and river surveys. These sections varied in width from 3,500 feet to 35,000 feet. In several instances, topographic data for the overbank section were not complete.

131. The actual variation in channel roughness probably is not as great as the computed values would indicate, because all such losses as those resulting from eddies, bends, and inaccuracies in river cross section are compensated for in the computed roughness coefficient.

132. The effects of future levees were computed for an 800,000-second-foot discharge, the 1948 flood, and the 1894 flood, using the computed channel-roughness factors and the reduced cross sections. Plate 18 illustrates graphically the increase in water-surface elevation that would result from the construction of certain new levees shown thereon. Below mile 100, the effect of these future levees would be minor for floods smaller than that of 1948. The maximum effect of future levees, however, would be to increase peak stages for floods such as those of 1948 and 1894 by about 1 foot. Present levees would raise the 1894 water surface at Vancouver about 1 foot. Should an 1894 flood occur after the completion of all proposed levees, the maximum stage at Vancouver would be 2.2 feet higher than that observed in 1894.

SECTION VII—FLOOD-DAMAGE ESTIMATES

FLOOD-DAMAGE SURVEYS

133. Two separate floods occurred on Columbia River in 1933. The June flood reached a stage of 25.5 feet at Vancouver and had a frequency of about once in 12 years. The December flood, caused by heavy precipitation over the lower tributary areas and high tides in the lower river, was the highest winter flood of record below the mouth of Willamette River and equaled or exceeded the stage of the 1894 flood below Cathlamet, Wash.

134. Following these floods, the Weather Bureau, the Bureau of Agricultural Economics, and the Corps of Engineers made surveys of the damages resulting from each flood. For the summer flood, losses on agricultural land were estimated to average $11 per acre. Damages in Kelso, Wash., were estimated to be at least $500,000. Damages to other urban areas were partially appraised. The estimated total damage due to the June flood was approximately $4,000,000 and the damages in the December flood were somewhat higher.

135. A survey was made in 1947 to determine damages from floods of 1894 and 1933 proportions and an intermediate flood that might be

expected below Bonneville Dam with existing protective works and under present conditions of economic development. The survey was extended early in 1948 to include Hood River, The Dalles, Arlington, and intermediate points above Bonneville. Extensive flood-protective works had been constructed since the 1933 floods. Very few of the levee systems had adequate freeboard to provide protection against the 1894 flood, but in this survey it was anticipated that the levees would withstand stages in excess of the 1876 flood.

THE 1948 FLOOD

136. This flood, occurring a few months after the extensive survey made to determine probable damages from the 1894 and lesser floods, made possible a check on the accuracy of the prior survey and allowed for general revision of the estimates on the basis of what actually occurred. Corps of Engineers' employees previously engaged on the 1947 flood-damage survey made constant observations of conditions in the flood plain.

137. The 1948 flood caused the greatest damage and economic loss of any flood that has ever occurred on the main stem of Columbia River. The sequence of disasters attributable to this flood resulted in at least 25 deaths, required evacuation from their homes of about 100,000 persons, destroyed 5,100 homes, inundated 137,500 acres of high-class agricultural land, disrupted all traffic facilities, and caused heavy damage to industrial, commercial, and all other enterprises in the flood zone.

138. The first notice that a major flood was in prospect was published Friday, May 28, 1948, with the forecast of 30-foot stages at Portland and Vancouver. It was realized that this stage would inundate all unprotected areas in the lowlands and top a few of the dikes. No great anxiety, however, was felt concerning other areas which were believed to be adequately protected. Various public agencies were alerted, sandbag reserves were established, and the area generally prepared to wait out the flood.

139. On Sunday, May 30, the first major disaster occurred with the breaking of the railroad fill which was part of the levee system protecting Vanport City, Oreg. This fill, approximately 35 feet high and 40 feet wide on top and carrying three lines of track, was constructed in 1918 and widened at intervals over a period of several years, and was considered well compacted and stable. Without previous warning, the break occurred at 4:20 p. m. and inundated, within a very short time, the entire Vanport area, containing a Government housing project serving 18,500 persons. At least 14 persons were drowned, and 8 still are listed as missing. Property damage was estimated at $21,500,000, including $15,000,000 to buildings and improvements of the Federal Housing Authority and $6,500,000 to personal property owned by residents. Within about 30 hours after the inundation of Vanport, the cross fills supporting Denver Avenue and Union Avenue likewise collapsed, allowing the flooding of areas which contained numerous auto courts, Portland Meadows race track, the residential communities of Faloma and Bridgeton, Columbia Edgewater golf course, and similar properties. Losses in these areas were estimated at $5,000,000.

140. Almost simultaneously with the breaking of these fills, the levees protecting the town of Woodland, Wash., gave way, inundating much of that town of 1,200 people, and flooding 8,370 acres of diked agricultural land, including 260 acres of tulips and large areas of truck land.

141. Continuing high stages brought worsening conditions to other dikes in the areas as the soil became saturated and seepage increased. On June 8 the dikes protecting Puget Island and Marshland drainage districts gave way, inundating an additional 4,400 acres of agricultural land. The final major break occurred on June 11 when a secondary levee along Columbia slough protecting Multnomah district No. 1 collapsed, allowing floodwaters to inundate an area of 8,417 acres containing the Portland Municipal Airport, Army Air Base, four golf courses, and about 1,000 residences. A total of 17 dikes, excluding a previously damaged levee at La Center, were breached or overtopped, inundating 29,971 acres during the course of the flood.

142. In addition to the more spectacular levee failures, great damage was done by natural inundation of lands below the level of the flood crest. In Portland, about 650 blocks devoted mainly to storage and industrial uses were flooded. These areas contained all the mainline railroad tracks, the industrial area in Guilds Lake, the housing project on Mocks Bottom, and other waterfront properties. Extensive areas in Vancouver likewise were under water, including 12 blocks in the city, the Vancouver Airport, Fruit Valley housing project, industrial areas along Vancouver Lake, and other properties. Smaller areas were flooded in Camas, Washougal, and Kalama, Wash., and St. Helens and Rainier, Oreg. Also numerous sawmills, packing plants, and other industrial establishments not connected with any urban area were flooded and damaged.

143. Below Rainier, Oreg., and Longview, Wash., the effects of the flood were combined with the effects of ocean tidal conditions. The topping of the Puget Island dike was due to high tidal inflow further raising the flood stage. The effect of the flood was felt not only to the mouth of the river but far out to sea. Great damage was done to marine life and fishing due to dilution of sea water and the outflow of silt and debris brought down by the river.

144. In the reaches of Columbia River above Sandy River, serious damage resulted to navigation facilities and to urban and suburban properties in and near The Dalles and Umatilla, Oreg., and Pasco and Kennewick, Wash. A portion of the city of The Dalles was inundated and rail traffic interrupted for several days when low levees protecting industrial areas and the railroad yard were broken. Emergency repairs of the levee, however, prevented more extensive damages. The canal and locks around Celilo Falls sustained considerable damage, as did docks and storage facilities at various points along the river. Several trailer camps and suburban properties near Pasco and Kennewick were inundated. The cofferdam protecting the north abutment of McNary Dam (under construction) was damaged, but not severely. Extensive tracts of orchard, small fruits, and garden land along the river were inundated. Reduction of head at Bonneville Dam due to high tailwater reduced the power output to approximately 30 percent of normal capacity.

145. Navigation on the entire river was disrupted because of loss of navigation markers, excess currents, and shifting channels, and

because of the added hazards to saturated levees resulting from wash during passage of ships.

146. Many areas not actually flooded suffered damages and losses because of seepage and evacuation of properties. The Reynolds Aluminum Co. plant in Sandy drainage district was closed down due to flood hazard, and incurred emergency costs in excess of $600,000, without considering loss of production. Emergency levees were built around the Aluminum Corp. of America plant, and by continuous flood fighting it was kept in operation with emergency costs exceeding $1,000,000. A part of the Crown-Zellerbach Corp. properties was operated under adverse conditions, but the costs incurred in clean-up and reconditioning plants amounted to $1,128,000. Other concerns experienced, to some extent, similar tieups.

147. All people and livestock were evacuated from nearly all of the diked districts during the last of May or first part of June and remained out at least 3 weeks. During this time crops were left untended, large acreages usually planted to truck crops could not be worked, and dairying operations were disrupted. Crop production on several thousand acres in various low areas was drastically reduced due to seepage which raised the water table sufficiently to drown out or seriously retard growing crops. The Corps of Engineers spent about $3,000,000 in combating the flood, saved 33 dikes that protected property worth an estimated $500,000,000, and expected to spend $2,000,000 rebuilding and repairing dikes and levees. Multnomah County estimated costs of flood fighting at $280,000, the city of Portland estimated expenses at nearly $1,000,000, and Oregon State Highway Department spent nearly $500,000 on temporary repairs to Denver Avenue and Union Avenue fills, and will spend at least $1,000,000 on permanent repairs to various State highways affected. The Red Cross spent approximately $3,000,000 on immediate relief, food, and housing, in addition to large amounts of food and clothing donated by individuals, organizations, and communities.

148. The total losses and damages caused by the 1948 flood will never be known. Commercial interests and industries at near and far-distant points were disrupted because of traffic interruption and other difficulties. Power production at Bonneville and Grand Coulee Dams was much reduced, and a severe power shortage was prevented only by the fact that numerous industries were forced to close down because of flood conditions. Fish hatcheries at Bonneville and White Salmon were flooded, and at least 10,000,000 salmon fry were liberated into floodwaters at an age when survival was at best problematical. Similarly, many thousands of game-bird nests were inundated and fledglings were drowned.

149. Flood-damage surveys of the 1948 flood in this sub-basin are being made in cooperation with agencies of the Department of Agriculture. The Soil Conservation Service, Bureau of Agricultural Economics, and the Bureau of Production and Marketing are obtaining detailed data on agricultural properties in the five counties of the lower basin. The Corps of Engineers is obtaining data on small part-time agricultural suburban tracts and data on all other classifications of properties for all types of damages. The present known and estimated losses amount to nearly $80,000,000 as shown on sheet 2 of table 33, part I of this appendix and, with other unknown costs,

the total damage due to this flood could very easily amount to $100,000,000 in this sub-basin.

RESURVEY OF DAMAGES FOR FLOODS OF 1894 AND 1933 MAGNITUDES

150. In connection with field appraisals of the 1948 flood damages, consideration was given to what would occur with repetition of the 1894 and 1933 floods. Recomputations of rating curves and flood profiles indicate that levees, bridges, and other obstructions would increase the 1894 natural stage about 1.6 feet at Vancouver and Portland and 1.0 foot at Longview. Present levees, except possibly those surrounding Longview and Kelso, would not withstand a flood of 1894 magnitude and duration. In those areas, seepage would exceed the capacity of pumping plants to such an extent that extensive ponding would occur. All of the levees protecting agricultural areas above mile 30 would be overtopped by the calculated stages. Bank erosion and secondary channel changes occurring during such a flood would be great. A number of industrial establishments are located adjacent to the river, with warehouses, docks, and other facilities located, for advantageous handling of materials at low and intermediate stages, at levels below a maximum flood stage. Preliminary estimates indicate that the damages for a flood of 1894 magnitude would total over $210,000,000 as shown on sheet 1 of table 33, part I, of this appendix.

151. The June 1933 flood, if repeated at this time, would do but little more damage than occurred in 1933. While property values in the flood plain have risen greatly, much of the low area now is protected adequately against floods of this stage. Review of the damage estimates made in 1947 indicates a total damage of $4,497,000, based on present developments and conditions of protection. Details of these damages are shown on sheet 3 of table 33, part I, of this appendix.

WINTER FLOODS

152. In addition to the described spring and summer floods, winter floods occur principally because of heavy local inflow from floods on streams west of the Cascade Range superimposed on normal or slightly higher than normal natural flow and tidal conditions in the main Columbia River. These floods cause appreciable damage in the lower river area. As mentioned heretofore, the highest such flood occurred in December 1933. Much of the area inundated by that flood now has adequate levee protection, and damages due to a recurrence at this time are estimated at $2,050,000. A similar flood with lesser stages occurred on the lower river in December 1946, for which damage data were obtained, indicating damages amounting to about $140,000.

FLOOD-DAMAGE APPRAISALS

153. In all surveys of flood damges, both the direct damages and either the known or estimated indirect losses were obtained directly from property owners and by appraisals. The direct damages consist only of the actual physical damage caused by contact of floodwaters with properties, and include cost of repair and rehabilitation of buildings, furnishings, and equipment; replacing stocks of goods;

the loss of crops inundated; erosion of banks and topsoil where such can be determined; and damages to railroads, highways, streets, utilities, and industrial properties. The indirect costs include flood fighting to hold levees; emergency policing, and other emergency expenditures for evacuation of people, livestock, and materials; loss of production and wages due to closing of industries, disruption of transportation, or other factors; increased cost or losses from detouring traffic or interruption of traffic; and such other items of loss that are not included as physical damages. A complete and accurate evaluation of all indirect items is impossible. To facilitate segregation and compilation of damages, the main river and backwater areas below the mouth of Yakima River were divided into seven zones, and three of the lower river zones were further divided into four subzones for segregation of damages due to winter floods.

STAGE-DAMAGE CURVES

154. In order to determine the damages at various stages, flood-damage curves were prepared for each zone along the river. These curves were plotted, using as key points the probable damages to be expected with recurrence of the 1933, 1948, and 1894 summer floods, and the 1933 and 1946 winter floods. The curves were adjusted to take into account the probability that some of the areas where residential properties suffered very severe damages in 1948, especially the Vanport area, would be utilized for other purposes with properties less likely to sustain heavy flood damages.

DETERMINATION OF ANNUAL DAMAGES

155. The average annual damages in each zone were estimated by use of damage-frequency curves and the mass diagrams thereunder. By plotting the probable damages at various stages against the expected frequency of occurrence of these stages in any one year and drawing a damage-frequency curve, a mass diagram of annual damages was obtained for each zone. The area encompassed by the curve was measured to obtain average annual damages. These curves and diagrams are shown on plate 23 of part I of this appendix.

156. In order to check this computation, and to establish damages which would be readily comparable with damages remaining with various headwater flood control reservoirs in operation, annual damages were computed mathematically as shown in table 9, part II, of this appendix.

COMPARISON OF RESULTS OF METHODS OF COMPUTATION

157. The two methods of determining the average annual damage give generally comparable results. The variation in results between the two methods for the various zones ranges from less than 1 percent to 10 percent. The over-all totals show a variation of only 1 percent as indicated in the following tabulation:

Zone and description	Annual damages from mass diagrams of damage-frequency curves	Annual damages by mathematical computation
SPRING AND SUMMER FLOODS		
1. Yakima River to Bonneville	$173,000	$193,400
2. Bonneville Dam to Sandy River and Camas, Wash	241,600	241,800
3. Camas, Wash., to Lewis River	1,018,000	1,106,400
4. Sandy River to Willamette River	2,201,900	2,138,200
5. Portland vicinity, Willamette backwater	2,526,600	2,415,600
6. Lewis River to Baker Bay	1,993,900	2,088,400
7. Willamette River to Youngs Bay	1,009,200	1,051,000
WINTER FLOODS		
6A. Vancouver, Wash., to Cowlitz River	65,200	78,500
6B. Cowlitz River to Baker Bay	155,700	182,300
7A. Willamette River to Rainier, Oreg	37,900	42,100
7B. Rainier, Oreg., to Youngs Bay	98,400	112,400
Total	9,521,400	9,650,100

DETERMINATION OF FUTURE DAMAGES

158. In order to evaluate probable future damages and the benefits that would be derived from flood control works to be installed at a future date, an estimate was prepared of increased economic development that might be anticipated by 1975. The year 1975 was taken as the most logical future date when construction of the proposed projects would reach a stage at which effectiveness would be realized. The forecast of future trends considers only the development that would take place without additional flood control improvements. The estimate is based on normal growth and development in each zone during the past 40 years as shown by population growth and increased valuation of taxable property, the increase in industrial growth and population forecast by Bonneville Power Administration and the Pacific Northwest power pool in establishing future power demands, the area available for such expansion in each zone, the forecasts of requirements for navigation facilities, and other pertinent factors. In estimating ratios of increase for each zone, individual ratios were determined for various general classifications of properties, such as agricultural, industrial, suburban, and urban, both for residential and commercial development. These individual ratios were weighted in each zone to determine the over-all ratio for the zone. Based on these factors, the average increase during the next 27 years and the estimated average annual future damages would be as shown in the following tabulation:

Zone and description	Percent increase, 1948 to 1975	Annual damage, 1975 developments
1. Yakima River to Bonneville	25	$216,000
2. Bonneville Dam to Sandy River and Camas, Wash	25	302,000
3. Camas, Wash., to Lewis River	100	2,036,000
4. Sandy River to Willamette River	60	3,523,000
5. Portland vicinity, Willamette backwater	45	3,664,000
6. Lewis River to Baker Bay	40	2,791,000
7. Willamette River to Youngs Bay	25	1,262,000
6A. Vancouver, Wash., to Cowlitz River	50	98,000
6B. Cowlitz River to Baker Bay	40	218,000
7A. Willamette River to Rainier, Oreg	25	47,000
7B. Rainier, Oreg., to Youngs Bay	25	123,000
Estimated total evaluated average future annual damages		14,280,000

TABLE 1.—*Detailed cost estimate, The Dalles project*

[Phase C-2 development, 980,000-kilowatt installation]

Feature or item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Utilities						$33,148,000
Relocations					$23,364,000	
Union Pacific RR	Mile	36.1	$258,700.00	$9,339,000		
Spokane, Portland & Seattle Ry.	do	45.3	180,000.00	8,154,000		
Wishram yards	Job		Lump sum	2,483,000		
Columbia River bridge	do		Lump sum	956,000		
United States Highway No. 30.	Mile	18.7	126,000.00	2,356,000		
Maryhill Ferry slips	Job		Lump sum	17,000		
Power lines	do		Lump sum	17,000		
Telephone lines	do		Lump sum	42,000		
Contingencies, 25 percent.					5,841,000	
Indirect costs, 13½ percent.					3,943,000	
Lands and acquisition						728,000
Lands					165,000	
Privately owned:						
Cultivated, irrigated.	Acre	222	125.00-375.00	46,000		
Orchard, irrigated	do	107	430.00-625.00	62,000		
Nontillable	do	5,039	1.90-38.00	38,000		
Industrial	do	9	125.00	1,000		
Plotted town	Job		Lump sum	15,000		
Indian lands	Acre	234	12.50-625.00	3,000		
Public domain	do	326				
Improvements					325,000	
Farm units	Each	34		93,000		
Town units	do	29		89,000		
Industrial	do	10		143,000		
Severance	Job		Lump sum		26,000	
Land and reservoir surveys	do		Lump sum		43,000	
Contingencies, 5 percent	do		Lump sum		28,000	
Acquisition	do		Lump sum		54,000	
Indirect costs, 13½ percent					87,000	
Reservoir clearing						269,000
Clearing					187,000	
Medium	Acre	73	400.00	29,000		
Light	do	1,053	150.00	158,000		
Fishwheel removal	Each	10	1,900.00		19,000	
Contingencies, 15 percent.					31,000	
Indirect costs, 13½ percent.					32,000	
Cofferdams and diversion						9,719,000
Diversion channel excavation.	Cubic yard	445,000	2.80		1,246,000	
Cofferdams	Job		Lump sum		5,700,000	
Pumping	do		Lump sum		500,000	
Contingencies, 15 percent					1,117,000	
Indirect costs, 13½ percent					1,156,000	
Gate controlled spillway section.						26,067,000
Excavation					4,278,000	
Forebay approach channel.	Cubic yard	546,000	2.80	1,529,000		
Tailrace:						
Common	do	86,000	.95	81,000		
Rock	do	240,000	2.80	672,000		
Foundation	do	430,220	4.25	1,829,000		
Trench	do	7,000	9.40	66,000		
Foundation preparation	Square yard	36,000	2.80	101,000		
Concrete and imbedded steel.					10,660,000	
Mass in dam, apron, and cut-off.	Cubic yard	293,000	18.50	5,420,000		
Piers	do	49,330	30.00	1,480,000		
Deck girders and railing	do	13,700	65.00	890,000		
Sills	do	21,800	30.00	654,000		
Reinforcing steel	Pound	12,200,000	.11	1,342,000		
Structural steel	do	3,120,000	.28	874,000		
Gates and appurtenances					4,634,000	
Gates and guides	Pound	10,333,330	.35	3,616,000		
Cranes 2—350-ton	Ton	700	1,400	980,000		
Control house	Each	2	18,800.00	38,000		

TABLE 1.—*Detailed cost estimate, The Dalles project*—Continued

Feature or item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Gate controlled spillway section—Continued						
Miscellaneous					$399,000	
Lighting and wiring	Linear foot	1,800	$56.50	$102,000		
Drilling, for grouting	do	38,900	3.75	146,000		
Grouting	Cubic foot	38,900	2.80	109,000		
Drilling, for drainage	Linear foot	11,160	3.75	42,000		
Contingencies, 15 percent					2,995,000	
Indirect costs, 13½ percent					3,101,000	
Nonoverflow concrete dam						$8,975,000
Excavation					539,000	
Rock	Cubic yard	102,220	4.25	434,000		
Foundation preparation.	Square yard	37,330	2.80	105,000		
Concrete and imbedded steel.					5,639,000	
Mass	Cubic yard	236,500	18.50	4,375,000		
Reinforced roadway	do	14,400	65.00	936,000		
Reinforcing steel	Pound	2,983,330	.11	328,000		
Miscellaneous					698,000	
Drilling, for grouting	Linear foot	52,500	3.75	197,000		
Grouting	Cubic foot	105,000	2.80	294,000		
Lighting and wiring	Linear foot	3,450	37.60	130,000		
Drilling, for drainage	do	20,580	3.75	77,000		
Contingencies, 15 percent					1,031,000	
Indirect costs, 13½ percent					1,068,000	
Power facilities (14 units)						145,541,000
Substructure					28,762,000	
Rock excavation, forebay and tailrace.	Cubic yard	432,670	2.80	1,211,000		
Foundation excavation	do	424,670	4.25	1,805,000		
Trench	do	11,500	9.40	108,000		
Excavation (wet), outside cofferdam.	do	10,000	9.40	94,000		
Drilling, for grouting	Linear foot	46,900	3.75	176,000		
Foundation grouting	Cubic foot	93,800	2.80	263,000		
Foundation preparation	Square yard	40,000	2.80	112,000		
Mass concrete	Cubic yard	342,000	21.00	7,182,000		
Reinforced concrete, heavy.	do	228,000	35.00	7,980,000		
Reinforced concrete, medium.	do	79,000	45.00	3,555,000		
Reinforcing steel	Pound	40,400,000	.11	4,444,000		
Structural steel	do	3,364,000	.28	942,000		
Station service bay	Job		Lump sum	436,000		
Assembly bay	do		Lump sum	425,000		
Drilling, for drainage	Linear foot	7,800	3.75	29,000		
Superstructure	Cubic foot	11,468,750	.60		6,881,000	
Power generating equipment.					69,361,000	
Turbines	Each	14	2,379,000.00	33,306,000		
Generators	do	14	1,830,000.00	25,620,000		
House units	do	2	184,000.00	368,000		
Switching and auxiliary equipment.	Kilovolt-ampere.	1,033,000	8.95	9,247,000		
Miscellaneous power plant equipment.	Job		Lump sum	820,000		
Gates and equipment					6,500,000	
Intake gates, frames, and imbedded parts.	Pound	14,480,000	.35	5,068,000		
Trash racks, frames, and imbedded parts.	Square foot	80,000	5.15	412,000		
Draft tube steel stop logs and imbedded parts.	Pound	2,280,000	.28	638,000		
Gantry crane:						
Intake deck	Job		Lump sum	229,000		
Tailrace deck	do		Lump sum	153,000		
Contingencies, 15 percent					16,726,000	
Indirect costs, 13½ percent					17,311,000	

TABLE 1.—*Detailed cost estimate, The Dalles project*—Continued

Feature or item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Powerhouse structure for 2 future units:						$8,257,000
Substructure					$4,551,000	
Rock excavation, forebay, and tailrace.	Cubic yard	118,010	$2.80	$331,000		
Foundation	do	84,000	4.25	357,000		
Trench	do	1,700	9.40	16,000		
Drilling, for grouting	Linear foot	14,100	3.75	53,000		
Foundation grouting	Cubic foot	28,200	2.80	79,000		
Foundation preparation	Square yard	5,000	2.80	14,000		
Mass concrete	Cubic yard	38,710	21.00	813,000		
Reinforced concrete:						
Heavy	do	42,670	35.00	1,493,000		
Medium	do	15,190	45.00	684,000		
Reinforcing steel	Pound	5,200,000	.11	572,000		
Structural steel	do	481,820	.28	135,000		
Drilling, for drainage	Linear foot	1,020	3.75	4,000		
Superstructure	Cubic foot	1,638,390	.60	983,000	983,000	
Gates and equipment					792,000	
Intake gates, frames and imbedded parts.	Pound	2,068,570	.35	724,000		
Frames and imbedded parts (draft tube stop logs).	do	150,000	.28	42,000		
Trash racks (imbedded parts only).	Job		Lump sum	26,000		
Contingencies, 15 percent					949,000	
Indirect costs, 13½ percent					982,000	
Rock and earth-fill dam						11,181,000
Embankment section:						
Rock (quarry run) to 5-ton.	Cubic yard	1,408,000	2.80	3,942,000		
Rock, 8- to 10-ton	do	95,700	10.00	957,000		
Pervious:						
Below elevation 110	do	721,000	2.00	1,442,000		
Above elevation 110	do	137,500	.75	103,000		
Impervious:						
Below elevation 110	do	489,000	2.00	978,000		
Above elevation 110	do	180,000	1.00	180,000		
Riprap		192,330	2.80	539,000		
Retaining wall	Job		Lump sum	425,000		
Contingencies, 15 percent					1,285,000	
Indirect costs, 13½ percent					1,330,000	
Navigation lock						13,190,000
Lower approach channel					1,613,000	
Excavation	Cubic yard	75,000	9.95	746,000		
Concrete guard wall	do	11,400	65.00	741,000		
Reinforcing steel	Pound	1,140,000	.11	126,000		
Upper approach channel					925,000	
Excavation:						
Rock	Cubic yard	133,000	2.80	372,000		
Common	do	15,000	.95	15,000		
Guard wall	do	4,000	4.25	17,000		
Foundation preparation	Square yard	5,300	2.80	15,000		
Concrete	Cubic yard	11,000	35.00	385,000		
Reinforcing steel	Pound	1,100,000	.11	121,000		
Main lock excavation					1,961,000	
Channel:						
Common	Cubic yard	46,000	.95	43,000		
Rock	do	406,220	4.25	1,727,000		
Trench	do	16,400	9.40	154,000		
Foundation preparation	Square yard	13,330	2.80	37,000		
Concrete and imbeded steel					3,317,000	
Mass in walls and sills	Cubic yard	107,250	18.50	1,984,000		
Reinforced	do	8,500	35.00	297,000		
Conduit lining	do	4,720	45.00	212,000		
Paved walls	do	13,660	35.00	478,000		
Reinforcing steel	Pound	2,800,000	.11	308,000		
Anchors	Each	4,000	9.40	38,000		
Gates and appurtenances					1,893,000	
Miter gates	Pound	2,170,000	.35	759,000		
Miter gate operating machinery.	Each	4	42,000	168,000		
Tainter gates	Pound	314,000	.45	141,000		
Tainter gate operating machinery.	Each	4	40,000	160,000		
Emergency dams	Pound	1,635,000	.28	458,000		
Emergency dam derricks.	Each	2	65,800	132,000		
Operating house	Job		Lump sum	75,000		

TABLE 1.—*Detailed cost estimate, The Dalles project*—Continued

Feature or item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Navigation lock—Continued						
Miscellaneous					$396,000	
Mooring bits	Each	6	$3,800	$23,000		
Movable bridge	Job		Lump sum	188,000		
Electrical system	do		Lump sum	132,000		
Pipe handrail, floor grating, etc.	do		Lump sum	34,000		
Drilling and grouting	Job		Lump sum	19,000		
Contingencies, 15 percent					1,516,000	
Indirect costs, 13½ percent					1,569,000	
Mooring facilities						$245,000
Mooring facilities	Job		Lump sum		188,000	
Contingencies, 15 percent					28,000	
Indirect costs, 13½ percent					29,000	
Fish facilities						23,305,000
Fish ladders	Job		Lump sum		17,055,000	
Hatchery facilities	do		Lump sum		800,000	
Contingencies, 15 percent					2,678,000	
Indirect costs, 13½ percent					2,772,000	
Buildings and grounds						3,189,000
Buildings and grounds	Job		Lump sum		2,443,000	
Contingencies, 15 percent					366,000	
Indirect costs, 13½ percent					380,000	
Construction of Indian village and fishing facilities:						613,000
Construction of Indian village and fishing facilities.	Job		Lump sum		470,000	
Contingencies, 15 percent					70,000	
Indirect costs, 13½ percent					73,000	
Recreation facilities						255,000
Recreation facilities	Job		Lump sum		195,000	
Contingencies, 15 percent					29,000	
Indirect costs, 13½ percent					31,000	
Oregon-Washington Highway Bridge.	Job		Lump sum			791,000
Navigation aids						72,000
Navigation aids	Job		Lump sum		51,000	
Contingencies, 25 percent					13,000	
Indirect costs, 13½ percent					8,000	
Miscellaneous						741,000
Access road, earth dike, etc.	Job		Lump sum		568,000	
Contingencies, 15 percent					85,000	
Indirect costs, 13½ percent					88,000	
Total estimated construction cost.						286,286,000

TABLE 2.—*Detailed cost estimate, John Day project*

[Flood-control pool elevation 292, phase C-2 development, 1,105,000-kilowatt installation]

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Utilities						$75,524,000
Relocations					$52,174,000	
Union Pacific R. R.	Mile	82.8	$285,570.00	$23,645,000		
Spokane, Portland & Seattle Ry.	do	81.8	255,550.00	20,904,000		
United States Highway No. 30.	do	62.6	102,280.00	6,403,000		
County road	do	46	17,560.00	808,000		
Power lines	Job		Lump sum	105,000		
Telephone lines	do		Lump sum	309,000		
Umatilla port facilities					1,059,000	
Embankment	Cubic yard	1,807,000	.50	903,000		
Riprap	do	52,000	2.80	146,000		
Roadway	Job		Lump sum	10,000		
Contingencies, 25 percent					13,308,000	
Indirect costs, 13½ percent					8,983,000	
Lands and acquisition						11,305,000
Lands					1,035,000	
Privately owned:						
Irrigated	Acre	3,979	50.00-500.00	410,000		
Irrigable	do	182	40.00- 75.00	8,000		
Dry	do	2,938	20.00- 50.00	65,000		
Grazing	do	37,661	4.00- 7.00	169,000		
Towns:						
Boardman, Oreg	Lot	206	Lump sum	30,000		
Castle Rock, Oreg	do	288	Lump sum	5,000		
Irrigon, Oreg	Block	53	Lump sum	24,000		
Umatilla, Oreg	Lot	602	Lump sum	299,000		
Alderdale, Wash	Acre	45	Lump sum	2,000		
Roosevelt, Wash	Lot	172	Lump sum	2,000		
Luzon, Wash	do	192	Lump sum	3,000		
Plymouth, Wash	do	607	Lump sum	8,000		
Patterson, Wash	Block	38	Lump sum	10,000		
Government land	Acre	3,072				
Improvements					3,473,000	
Farm units	Set	110	Lump sum	345,000		
Commercial units	do	12	Lump sum	161,000		
Schools	do	1	Lump sum	10,000		
Towns:						
Arlington, Oreg	do	121	Lump sum	1,905,000		
Boardman, Oreg	do	79	Lump sum	163,000		
Umatilla, Oreg	do	131	Lump sum	797,000		
Alderdale, Wash	do	15	Lump sum	12,000		
Roosevelt, Wash	do	23	Lump sum	52,000		
Plymouth, Wash	do	5	Lump sum	13,000		
Patterson, Wash	do	6	Lump sum	15,000		
Relocate cemeteries—grave removal.	Job		Lump sum		33,000	
Severance	do		Lump sum		280,000	
Land and reservoir survey	do		Lump sum		86,000	
Contingencies, 10 percent					491,000	
Acquisition					710,000	
Indirect costs, 13½ percent					825,000	
Raising town of Arlington					2,963,000	
Embankment	Cubic yard	3,400,000	0.65	2,210,000		
Revise flood channel	Job		Lump sum	553,000		
Sewerage and disposal plant.	do		Lump sum	60,000		
Water system and plant	do		Lump sum	35,000		
Streets and sidewalks	do		Lump sum	80,000		
Electrical and telephone revision.	do		Lump sum	25,000		
Contingencies, 30 percent					889,000	
Indirect costs, 13½ percent					520,000	
Reservoir clearing						219,000
Unclassified	Job		Lump sum		168,000	
Contingencies, 15 percent					25,000	
Indirect cost, 13½ percent					26,000	
Cofferdam and diversions						13,927,000
First step cofferdam					4,942,000	
Steel sheet piling, furnish and place.	Ton	7,410	[1] 270.00	2,001,000		
Gravel fill	Cubic yard	204,500	1.50	307,000		
Remove steel sheet piling.	Ton	7,410	50.00	371,000		
Remove gravel fill	Cubic yard	204,500	1.50	307,000		

TABLE 2.—*Detailed cost estimate, John Day project*—Continued

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Cofferdam and diversions—Con.						
First step cofferdam—Con.						
Embankment:						
Pervious	Cubic yard	437,000	$.80	$350,000		
Impervious	do	80,000	1.00	80,000		
Removal	do	517,000	.60	310,000		
Pumping	Job		Lump sum	200,000		
Excavation common, navigation channel.	Cubic yard	2,540,000	.40	1,016,000		
Second-step cofferdam					$4,968,000	
Steel sheet piling:						
Furnish and place	Ton	2,040	[1] 270.00	551,000		
Place [2]	do	[2] 5,930	180.00	1,067,000		
Gravel fill	Cubic yard	216,000	1.50	324,000		
Remove steel sheet piling.	Ton	7,970	50.00	399,000		
Remove gravel fill	Cubic yard	216,000	1.50	324,000		
Embankment:						
Pervious	do	250,000	.80	200,000		
Impervious	do	33,000	1.00	33,000		
Impervious blanket	do	50,000	2.00	100,000		
Removal	do	283,000	.60	170,000		
Pumping	Job		Lump sum	400,000		
Excavation, upstream lock approach.	Cubic yard	270,000	2.80	756,000		
Temporary gate slots, spillway piers, 22 sets.	Job		Lump sum	44,000		
Temporary fish ladders	do		Lump sum	600,000		
Third step spillway bay cofferdams.					760,000	
Steel bulkheads:						
Upstream	Each	7	48,000.00	336,00		
Downstream	do	7	36,000.00	252,000		
Temporary bulkheads abutments downstream.	do	19	8,000 00	152,0000		
Pumping	Job		Lump sum	29,000		
Contingencies, 15 percent					1,601,000	
Indirect costs, 13½ percent					1,656,000	
Navigation lock						$17,605,000
Lower approach channel					2,101,000	
Excavation:						
Common	Cubic yard	35,000	.95	33,000		
Rock	do	347,000	4.25	1,475,000		
Foundation preparation.	Square yard	4,000	2.80	11,000		
Concrete:						
Mass	Cubic yard	29,000	18.50	537,000		
Paved wall	do	700	35.00	25,000		
Reinforcing-steel	Pound	180,000	.11	20,000		
Upper approach channel					691,000	
Excavation:						
Common	Cubic yard	20,000	.95	19,000		
Rock	do	5,500	2.80	15,000		
Foundation preparation.	Square yard	3,300	2.80	9,000		
Concrete:						
Mass	Cubic yard	22,000	25.00	550,000		
Paved wall	do	1,500	35.00	53,000		
Reinforcing steel	Pound	405,000	.11	45,000		
Main lock					8,161,000	
Excavation:						
Common	Cubic yard	31,000	.95	29,000		
Rock	do	329,000	4.25	1,398,000		
Trench	do	4,600	9.40	43,000		
Foundation preparation.	Square yard	15,000	2.80	42,000		
Backfill	Cubic yard	165,000	1.00	165,000		
Concrete:						
Mass	do	290,250	18.50	5,370,000		
Reinforced	do	14,000	35.00	490,000		
Conduit lining	do	4,700	45.00	212,000		
Reinforcing steel	Pound	3,748,000	.11	412,000		
Gates and appurtenances					2,114,000	
Miter gates	Pound	2,326,000	.35	814,000		
Miter gates operating machinery.	Each	4	42,000	168,000		
Tainter gates	Pound	294,200	.45	132,000		

[1] Includes allowance of $20 per ton for salvage.
[2] 80 percent of first-step piling.

TABLE 2.—*Detailed cost estimate, John Day project*—Continued

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Navigation lock—Continued						
Gates and appurtenances—Continued						
Tainter gates operating machinery.	Each	4	$40,000	$160,000		
Emergency dams	Pound	2,260,000	.28	633,000		
Emergency dam derricks.	Each	2	66,000	132,000		
Operating house	Job		Lump sum	75,000		
Miscellaneous					$121,000	
Mooring bits	Each	8	3,875	31,000		
Movable bridge	Job		Lump sum	188,000		
Electrical system	do		Lump sum	132,000		
Pipe handrail, etc.	do		Lump sum	34,000		
Drilling and grouting	do		Lump sum	36,000		
Contingencies, 15 percent					2,023,000	
Indirect costs, 13½ percent					2,094,000	
Spillway (gate controlled)						$37,830,000
Excavation					2,914,000	
Forebay, rock	Cubic yard	61,000	2.80	171,000		
Tailrace, rock	do	31,000	2.80	87,000		
Foundation, rock	do	574,000	4.25	2,440,000		
Trench, rock	do	3,150	9.40	30,000		
Foundation preparation.	Square yard	66,400	2.80	186,000		
Concrete and steel	Cubic yard				18,656,000	
Mass, dam, apron, cutoff.	do	603,000	18.50	11,156,000		
Piers	do	107,000	30.00	3,210,000		
Deck, girders, railings	do	9,800	65.00	637,000		
Sills and apron blocks	do	9,400	30.00	282,000		
Training walls	do	6,640	50.00	332,000		
Reinforcing steel	Pound	19,090,000	.11	2,199,000		
Structural steel	do	3,000,000	.28	840,000		
Gates and appurtenances					6,793,000	
Gates and guides	Pound	14,500,000	.35	5,075,000		
Cranes, two 600-ton	Ton	1,200	1,400	1,680,000		
Control house	Each	2	19,000	38,000		
Miscellaneous					620,000	
Lighting and wiring	Linear foot	1,330	56.50	75,000		
Drilling grout holes	do	42,000	3.75	158,000		
Grouting	Cubic foot	110,000	2.80	308,000		
Drilling drain holes	Linear foot	21,000	3.75	79,000		
Contingencies, 15 percent					4,347,000	
Indirect cost, 13½ percent					4,500,000	
Power facilities						192,087,000
Substructure					55,033,000	
Excavation:						
Forebay and tailrace:						
Common	Cubic yard	1,171,400	.95	1,113,000		
Rock	do	107,900	2.80	302,000		
Foundation:						
Common	do	1,411,600	.95	1,341,000		
Rock	do	240,000	4.25	1,054,000		
Trench, rock	do	8,000	9.40	75,000		
Drilling grout holes.	Linear foot	94,000	3.75	352,000		
Foundation grouting.	Cubic foot	175,000	2.80	490,000		
Drilling drain holes.	Linear foot	47,000	3.75	176,000		
Foundation preparation.	Square yard	38,000	2.80	106,000		
Concrete:						
Mass, scroll, case and draft tube.	Cubic yard	381,000	21.00	8,001,000		
Mass	do	1,016,000	18.50	18,796,000		
Reinforced, heavy	do	310,000	35.00	10,850,000		
Reinforced, medium	do	114,000	45.00	5,130,000		
Reinforcing steel	Pound	49,400,000	.11	5,434,000		
Structural steel	do	3,400,000	.28	952,000		
Station service bay	Job		Lump sum	436,000		
Assembly bay	do		Lump sum	425,000		
Superstructure	Cubic foot	12,569,000	.60		7,541,000	
Power generating equipment.					77,585,000	
Turbines	Each	13	2,951,000	38,363,000		
Generators	do	13	2,060,000	26,780,000		
House units	do	2	184,000	368,000		
Switching and auxiliary equipment.	Kilovolts	1,253,000	8.95	11,214,000		
Miscellaneous power plant equipment.	Job		Lump sum	860,000		

TABLE 2.—*Detailed cost estimate, John Day project*—Continued

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Power facilities—Continued						
Gates and equipment					$7,006,000	
Intake gates, frames and imbedded parts.	Pound	15,600,000	$0.35	$5,460,000		
Trashracks, frames, and imbedded parts.	Square foot	80,000	5.15	412,000		
Draft tube steel stop logs and imbedded parts.	Pound	2,690,000	.28	753,000		
Gantry crane, intake deck.	Job		Lump sum	229,000		
Gantry crane, tailrace deck.	do		Lump sum	152,000		
Contingencies, 15 percent					22,075,000	
Indirect costs, 13½ percent					22,847,000	
Nonoverflow concrete dam						$8,220,000
Excavation					288,000	
Common	Cubic yard	44,000	.95	42,000		
Rock	do	50.800	4.25	216,000		
Foundation preparation	Square yard	10.800	2.80	30,000		
Concrete and steel					5,551,000	
Mass	Cubic yard	262.300	18.50	4,853,000		
Reinforced roadway	do	4,960	65.00	322,000		
Reinforcing steel	Pound	2,072,000	.11	228,000		
Fillets and pillars	Cubic yard	3,280	45.00	148,000		
Miscellaneous					458,000	
Drilling grout holes	Linear foot	40,000	3.75	150,000		
Grouting	Cubic foot	82,000	2.80	230,000		
Lighting and wiring	Job		Lump sum	44,000		
Drilling drain holes	Linear foot	9,000	3.75	34,000		
Contingencies, 15 percent					945,000	
Indirect costs, 13½ percent					978,000	
Mooring facilities						245,000
Mooring facilities	Job		Lump sum		188,000	
Contingencies, 15 percent					28,000	
Indirect costs, 13½ percent					29,000	
Fish facilities						17,980,000
Fish ladders	Job		Lump sum		10,025,000	
Fish locks	do		Lump sum		2,950,000	
Hatchery facilities	do		Lump sum		800,000	
Contingencies, 15 percent					2,066,000	
Indirect costs, 13½ percent					2,139,000	
Permanent buildings and grounds.						3,947,000
Buildings and grounds	Job		Lump sum		3,024,000	
Contingencies, 15 percent					454,000	
Indirect costs, 13½ percent					469,000	
Recreation facilities						367,000
Recreation facilities	Job		Lump sum		281,000	
Contingencies, 15 percent					42,000	
Indirect costs, 13½ percent					44,000	
Provisions at McNary Dam						400,000
Miscellaneous provisions	Job		Lump sum		306,000	
Contingencies, 15 percent					46,000	
Indirect costs, 13½ percent					48,000	
Navigation aids						170,000
Navigation aids	Job		Lump sum	120,000	120,000	
Contingencies, 25 percent					30,000	
Indirect costs, 13½ percent					20,000	
Total estimated construction cost.						379,826,000

TABLE 3.—*Comparative estimates, John Day flood-control storage*

Item	Data for assumed storage conditions				
	Without flood-control storage	With various amounts of flood-control storage			
		Case I 764,000 acre-feet usable [1]	Case II 1,380,000 acre-feet usable [1]	Case III 1,927,000 acre-feet usable [1]	Case IV 2,381,000 acre-feet usable [1]
Normal pool elevation, feet, mean sea level	255	255	255	255	255
Maximum controlled pool elevation, feet, mean sea level [2]	255	271.5	282	292	292
Minimum controlled pool elevation, feet, mean sea level [2]	255	255	255	255	241
River discharge at start of storage, second-feet	1,400,000	800,000	800,000	800,000	800,000
Spillway (22 50-foot-width gates):					
Crest elevation, feet, mean sea level	205	205	215.5	223.5	209.5
Height of spillway gates, feet [3]	52	55	55	57	72
Power facilities:					
Rated head, feet	93	93	93	93	93
Maximum head, 800,000 second-feet (feet)	76	92.5	103	113	113
Maximum head, 600,000 second-feet (feet)	81	97.5	108	118	118
Installed generator capacity, kilowatts	1,105,000	1,105,000	1,105,000	1,105,000	1,445,000
Number of units	13	13	13	13	[4] 17
Incremental costs:					
Utility relocations	----------	$10,500,000	$17,200,000	$23,673,000	$23,673,000
Lands and improvements	----------	500,000	825,000	1,137,000	1,137,000
Arlington, Oreg	----------	2,100,000	3,425,000	4,715,000	4,715,000
Umatilla, Oreg	----------	1,175,000	1,920,000	2,619,000	2,619,000
Miscellaneous provisions at McNary Dam	----------	200,000	300,000	400,000	500,000
John Day Dam:					
Spillway	----------	413,000	2,778,000	6,496,000	8,776,000
Nonoverflow	----------	----------	978,000	1,748,000	−470,000
Navigation lock	----------	----------	160,000	342,000	368,000
Power plant	----------	1,090,000	5,464,000	18,149,000	64,301,000
Total, incremental costs	Base	15,978,000	33,050,000	59,279,000	105,619,000
Cost per acre-foot total flood-control storage	0	$20.90	$23.95	$30.76	$44.36
Incremental flood-control storage, acre-feet	0	764,000	616,000	547,000	454,000
Incremental cost	0	$15,978,000	$17,072,000	$26,229,000	$46,340,000
Cost per acre-foot incremental storage	0	$20.89	$27.71	$47.95	$102.10

[1] Between backwater curves, discharge=800,000 second-feet.
[2] For flood regulation only.
[3] Determined by discharge of 650,000 second-feet at maximum pool elevation.
[4] Four additional units to maintain power capability during draw-down.

TABLE 4.—*Comparative estimates—John Day project single dam (without flood storage) and two dam plans (1948 base)*

Item	Single dam John Day	2-dam plan		
		John Day	Arlington	Total
River mile	217.3	217.3	243.5	----------
Natural low-water elevation, feet, mean sea level	146.0	146.0	182.6	----------
Normal pool elevation, feet, mean sea level	255.0	210.0	255.0	----------
Maximum pool elevation, feet, mean sea level	271.5	228.0	272.4	----------
Minimum pool elevation, feet, mean sea level	252.0	207.0	252.0	----------
Tailwater elevation, Q=800,000 cubic feet per second	179.0	179.0	219.0	----------
Tailwater elevation, maximum flood of record	188.0	188.0	225.8	----------
Tailwater elevation, spillway design flood	208.5	208.5	246.6	----------
Rated head, feet	93	48	45	----------
Head, Q=800,000 cubic feet per second, feet	76	31	36	----------
Length of pool, miles	74.7	26.2	48.5	----------
Power installation, kilowatts	1,105,000	588,000	540,000	----------
Average construction period, years	7½	7¼	7	----------
Initial costs, 1948 base:				
Utilities	$50,639,000	$17,567,000	$29,777,000	$47,344,000
Navigation aids	134,000	47,000	86,000	133,000
Lands and acquisition	4,153,000	191,000	1,658,000	1,849,000
Reservoir clearing	148,000	50,000	95,000	145,000
Cofferdams and diversion	13,927,000	13,927,000	10,990,000	24,917,000
Gate-controlled spillway section	31,334,000	22,861,000	26,211,000	49,072,000
Nonoverflow concrete dam	6,472,000	1,829,000	5,271,000	7,100,000
Rock- and earth-fill dam	----------	----------	731,000	731,000
Power facilities	173,938,000	165,306,000	127,156,000	292,462,000
Navigation lock	17,263,000	11,931,000	11,128,000	23,059,000
Mooring facilities	245,000	245,000	245,000	490,000
Fish facilities	17,980,000	9,124,000	8,621,000	17,745,000
Permanent buildings and grounds	3,947,000	3,947,000	3,136,000	7,083,000
Recreation facilities	367,000	255,000	284,000	539,000
Subtotal	320,547,000	247,280,000	225,389,000	472,669,000
Interest during construction	34,258,000	26,892,000	23,666,000	50,558,000
Total capital cost	354,805,000	274,172,000	249,055,000	523,227,000
Annual costs (3 percent financing):				
Interest	10,644,000	8,225,000	7,472,000	15,697,000
Amortization	3,144,000	2,429,000	2,207,000	4,636,000
Interim replacements	626,000	549,000	497,000	1,046,000
Operation and maintenance	1,297,000	1,216,000	1,102,000	2,318,000
Loss of taxes	13,000	1,000	8,000	9,000
Total	15,724,000	12,420,000	11,286,000	23,706,000

TABLE 5.—*Detailed cost estimate, Baker Bay channel and mooring basin*

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Federal cost						$442,000
Breakwater					$252,000	
Stone	Cubic yard	36,000	$7.00	$252,000		
"Dalton" waterway and mooring basin:					130,000	
Dredging	do	650,000	.20	130,000		
West channel					60,000	
Additional dredging	do	300,000	.20	60,000		
Non-Federal cost						112,000
Lands and easements	Job		Lump sum	5,000	5,000	
Construction costs					107,000	
Piling	Linear foot	18,000	1.25	22,500		
Logs	Thousand feet, board measure.	420	40.00	16,800		
Lumber	do	115	115.00	23,000		
Hardware	Pound	10,000	.20	2,000		
Ramps and approaches	Job		Lump sum	2,700		
Utilities, lights, water, etc.	do		Lump sum	10,000		
Intercepting sewer	do		Lump sum	30,000		
Total estimated cost of improvement.						554,000

NOTE.—Allowances for contingencies and indirect costs have been made in the unit prices shown above.

TABLE 6.—*Detailed cost estimate, Westport slough channel enlargement*

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Federal cost						$111,750
Dredging	Cubic yard	745,000	$0.15	$111,750	$111,750	
Non-Federal cost						31,500
Dredging	do	210,000	.15	31,500	31,500	
Total estimated cost of improvement.						143,250

NOTE.—Allowances for contingencies and indirect costs have been made in the unit prices shown above.

TABLE 7.—*Detailed cost estimate, Columbia slough channel*

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Federal cost						$905,100
Clearing	Acre	20	$450.00	$9,000	$9,000	
Snagging	Job		Lump sum	5,000	5,000	
Dredging					830,700	
Channel, mouth to Union Ave.	Cubic yard	1,980,000	$0.39	772,200		
Turning basins:						
Denver Ave.	do	82,000	.39	32,000		
Union Ave.	do	68,000	.39	26,500		
Building new tower foundations and moving present towers of Bonneville Power Administration.	Job		Lump sum	55,000	55,000	
Navigation aids and markers	do		Lump sum	5,400	5,400	
Non-Federal cost						236,200
Lands and rights-of-way	Job		Lump sum	5,600	5,600	
Bridge alterations					240,600	
Alter Union Pacific railway bridge and construct fenders as required at other bridges.	Job		Lump sum	240,600		
Accrued amortization, to be deducted.	do		Lump sum	9,000	9,000	
Salvage value, to be deducted	do		Lump sum	1,000	1,000	
Total estimated cost of improvement.						1,141,300

NOTE.—Allowances for contingencies and indirect costs have been made in the unit prices shown above.

TABLE 8.—*Detailed cost estimate, Umatilla Harbor*

Item	Unit	Quantity	Unit price	Item cost	Feature cost	Total cost
Federal cost						$416,250
Drilling and blasting	Cubic yard	25,000	$10.65	$266,250	$266,250	
Excavation and disposal	do	25,000	6.00	150,000	150,000	
Non-Federal cost						204,700
Dock and terminal facilities	Job		Lump sum	196,700	196,700	
Extension, pile trestle	do		Lump sum	3,000	3,000	
Extension, conveyor belt to grain elevator.	do		Lump sum	5,000	5,000	
Total estimated cost of improvement.						620,950

NOTE.—Allowances for contingencies and indirect costs have been made in the unit prices shown above.

TABLE 9.—*Computation of average annual flood damages on Columbia River and tributaries affected by backwater*

[Based on 1948 economic developments]

ZONE 1—YAKIMA RIVER TO BONNEVILLE DAM (STAGES REFERRED TO AT CELILO CANAL)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	135	1.00	0	0.04	$500	$20
Average appreciable damage stage	137	.96	$1,000	.48	11,500	5,520
1946 flood	144	.48	2,000	.28	43,500	12,180
5-year flood	147.5	.20	65,000	.02	67,000	1,340
1933 flood	147.6	.18	69,000	.113	324,500	36,670
15-year flood	151.6	.067	580,000	.03	1,026,500	30,800
1948 flood	154.6	.037	1,473,000	.017	2,086,500	35,470
50-year flood	158	.02	2,700,000	.006	3,080,000	18,480
1894 flood	160.1	.014	3,460,000	.014	3,780,000	52,920
Maximum flood considered in economic analysis	162	.00	4,100,000			
Average annual damages						193,400

ZONE 2—BONNEVILLE DAM TO SANDY RIVER AND CAMAS, WASH. (STAGES REFERRED TO AT VANCOUVER, WASH.)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	12	1.00	$1,500	0.10	$2,250	$225
Average appreciable damage stage	14	.90	3,000	.42	5,000	2,100
1946 flood	21.4	.48	7,000	.28	40,500	11,340
5-year flood	25	.20	74,000	.07	151,250	10,590
1933 flood	26.3	.13	228,500	.063	624,250	39,330
15-year flood	28.5	.067	1,020,000	.023	1,481,300	34,070
1948 flood	30.2	.044	1,942,600	.024	2,711,300	65,070
50-year flood	33.5	.020	3,480,000	.007	3,673,000	25,710
1894 flood	35	.013	3,866,000	.013	4,133,000	53,730
Maximum flood considered in economic analysis	36.5	.00	4,400,000			
Average annual damages						242,100

ZONE 3—CAMAS, WASH., TO LEWIS RIVER (STAGES REFERRED TO AT VANCOUVER, WASH.)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	12	1.00	$2,000	0.10	$3,500	$350
Average appreciable damage stage	14	.90	5,000	.42	18,500	7,770
1946 flood	21.4	.48	32,000	.28	126,000	35,280
5-year flood	25	.20	220,000	.07	321,000	22,470
1933 flood	26.3	.13	422,000	.063	951,000	59,910
15-year flood	28.5	.067	1,480,000	.023	2,505,000	57,620
1948 flood	30.2	.044	3,530,000	.024	10,265,000	246,360
50-year flood	33.5	.020	17,000,000	.007	23,475,000	164,320
1894 flood	35	.013	29,950,000	.013	39,475,000	513,180
Maximum flood considered in economic analysis	36.5	.00	49,000,000			
Average annual damages						1,107,300

TABLE 9.—*Computation of average annual flood damages in Columbia River and tributaries affected by backwater*—Continued

ZONE 4—SANDY RIVER TO WILLAMETTE RIVER (STAGES REFERRED TO AT VANCOUVER, WASH.)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	12	1.00	$1,000	0.10	$1,500	$150
Average appreciable damage stage	14	.90	2,000	.42	4,500	1,890
1946 flood	21.4	.48	7,000	.28	40,500	11,340
5-year flood	25	.20	74,000	.07	202,000	14,140
1933 flood	26.3	.13	330,000	.063	2,465,000	155,300
15-year flood	28.5	.167	4,600,000	.023	8,450,000	194,350
1948 flood	30.2	.044	12,300,000	.024	25,150,000	603,600
50-year flood	33.5	.020	38,000,000	.007	46,500,000	325,500
1894 flood	35	.013	55,000,000	.013	64,000,000	832,000
Maximum flood considered in economic analysis	36.5	.00	73,000,000			
Average annual damages						2,138,300

ZONE 5.—BACKWATER WILLAMETTE RIVER, MOUTH TO OREGON CITY (STAGES REFERRED TO AT U. S. E. D. MOORINGS)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	11.5	1.00	0	0.15	$1,000	$150
Average appreciable damage stage	15	.85	$2,000	.37	16,000	5.920
1946 flood	20.9	.48	30,000	.28	104,000	29,120
5-year flood	24.5	.20	178,000	.07	341,500	23,900
1933 flood	26	.13	505,000	.063	2,102,500	132,460
15-year flood	28.2	.067	3,700,000	.023	6,987,500	160,710
1948 flood	29.7	.044	10,275,000	.024	27,137,500	651,300
50-year flood	33.2	.02	44,000,000	.007	54,630,000	382,410
1894 flood	34.7	.013	65,200,000	.013	79,130,000	1,028,690
Maximum flood considered in economic analysis	36.2	.00	93,000,000			
Average annual damages						2,415,600

ZONE 6.—LEWIS RIVER TO BAKER BAY (STAGES REFERRED TO AT LONGVIEW, WASH.)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	9	1.00	0	0.18	$1,000	$180
Average appreciable damage stage	10	.82	$2,000	.38	7,000	2,660
1946 flood	14.7	.44	12,000	.24	66,000	15,840
5-year flood	16.8	.20	120,000	.08	860,000	68,000
1933 flood	18.2	.22	1,600,000	.053	7,050,000	373,650
15-year flood	19.8	.067	12,500,000	.017	14,250,000	242,250
1948 flood	20.3	.05	16,000,000	.03	23,000,000	690,000
50-year flood	23.5	.02	30,000,000	.007	32,150,000	225,050
1894 flood	24.8	.013	34,300,000	.013	36,150,000	469,950
Maximum flood considered in economic analysis	25.8	.00	38,000,000			
Average annual damages						2,088,400

SUBZONE 6A.—LOWER COLUMBIA RIVER, VANCOUVER, WASH., TO COWLITZ RIVER[1] (STAGES REFERRED TO AT LONGVIEW, WASH.)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	7	1.00	0	0.45	$500	$225
Damage stage	10	.55	$1,000	.05	2,000	100
2-year flood	10.2	.50	3,000	.12	3,500	420
1946 flood	10.6	.38	4,000	.18	8,000	1,440
5-year flood	11.9	.20	12,000	.15	106,000	15,900
20-year flood	14.8	.05	200,000	.026	400,000	10,400
December 1933 flood	16.6	.024	600,000	.004	750,000	3,000
50-year flood	17.2	.02	900,000	.01	1,200,000	12,000
100-year flood	18	.01	1,500,000	.01	3,500,000	35,000
Design flood	20	.00	5,500,000			
Average annual damages						78,500

TABLE 9.—*Computation of average annual flood damages in Columbia River and tributaries affected by backwater*—Continued

SUBZONE 6B.—BELOW COWLITZ RIVER, COWLITZ RIVER TO BAKER BAY (STAGES REFERRED TO AT CATHLAMET, WASH.)

Item	Stage (mean sea level)	Expected frequency	Flood damages per flood	Number of floods of interval stage	Average damage at interval stage	Summation
Annual flood	9	1.00	0	0.09	$1,750	$160
Damage stage	9.5	.91	$3,500	.41	14,250	5,840
2-year flood	10.1	.50	25,000	.18	42,500	7,650
1946 flood	10.5	.32	60,000	.12	95,000	11,400
5-year flood	10.9	.20	130,000	.15	390,000	58,500
December 1933 flood	11.7	.05	650,000	.03	1,175,000	35,250
50-year flood	12.2	.02	1,700,000	.01	2,350,000	23,500
100-year flood	12.5	.01	3,000,000	.01	4,000,000	40,000
Maximum	13	.00	5,000,000			
Average annual damages						182,300

[1] Stages of secondary winter floods.

ZONE 7—WILLAMETTE RIVER TO YOUNGS BAY (STAGES REFERRED TO AT LONGVIEW, WASH.)

Annual flood	9	1.00	0	0.18	$1,000	$180
Average appreciable damage stage	10	.82	$2,000	.38	7,000	2,660
1946 flood	14.7	.44	12,000	.24	71,000	17,040
5-year flood	16.8	.20	130,000	.08	515,000	41,200
1933 flood	18.2	.22	900,000	.053	3,050,000	161,650
15-year flood	19.8	.067	5,200,000	.017	5,900,000	100,300
1948 flood	20.3	.05	6,600,000	.03	11,300,000	339,000
50-year flood	23.5	.02	16,000,000	.007	17,500,000	122,500
1894 flood	24.8	.013	19,000,000	.013	20,500,000	266,500
Maximum flood considered in economic analysis	25.8	.00	22,000,000			
Average annual damages						1,051,000

SUB-ZONE 7A—WILLAMETTE RIVER TO RAINIER, OREG.[1] (STAGES REFERRED TO AT LONGVIEW, WASH.)

Annual flood	7	1.00	0	0.45	$500	$225
Damage stage	10	.55	$1,000	.05	1,500	75
2-year flood	10.2	.50	2,000	.12	2,500	300
1946 flood	10.6	.38	3,000	.18	6,500	1,170
5-year flood	11.9	.20	10,000	.15	65,000	9,750
20-year flood	14.8	.05	120,000	.026	260,000	6,760
December 1933 flood	16.6	.024	400,000	.004	450,000	1,800
50-year flood	17.2	.02	500,000	.01	600,000	6,000
100-year flood	18	.01	700,000	.01	1,600,000	16,000
Design flood	20	0	2,500,000			
Average annual damages						42,100

[1] Stages of secondary winter floods.

SUB-ZONE 7B—RAINIER TO YOUNGS BAY (STAGES REFERRED TO AT CATHLAMET, WASH.)

Annual flood	9	1.00	0	0.09	$1,750	$160
Damage stage	9.5	.91	$3,500	.41	14,250	5,840
2-year flood	10.1	.50	25,000	.18	37,500	6,750
1946 flood	10.5	.32	50,000	.12	70,000	8,400
5-year flood	10.9	.20	90,000	.15	245,000	36,750
December 1933 flood	11.7	.05	400,000	.03	600,000	18,000
50-year flood	12.2	.02	800,000	.01	1,150,000	11,500
100-year flood	12.5	.01	1,500,000	.01	2,500,000	25,000
Maximum	13	0	3,500,000			
Average annual damages						112,400

SUMMARY

Subtotal, damage in subbasin due to primary spring and summer floods	$9,236,100
Subtotal, annual damage due to secondary winter floods	415,300
Total, average annual damage	9,651,400

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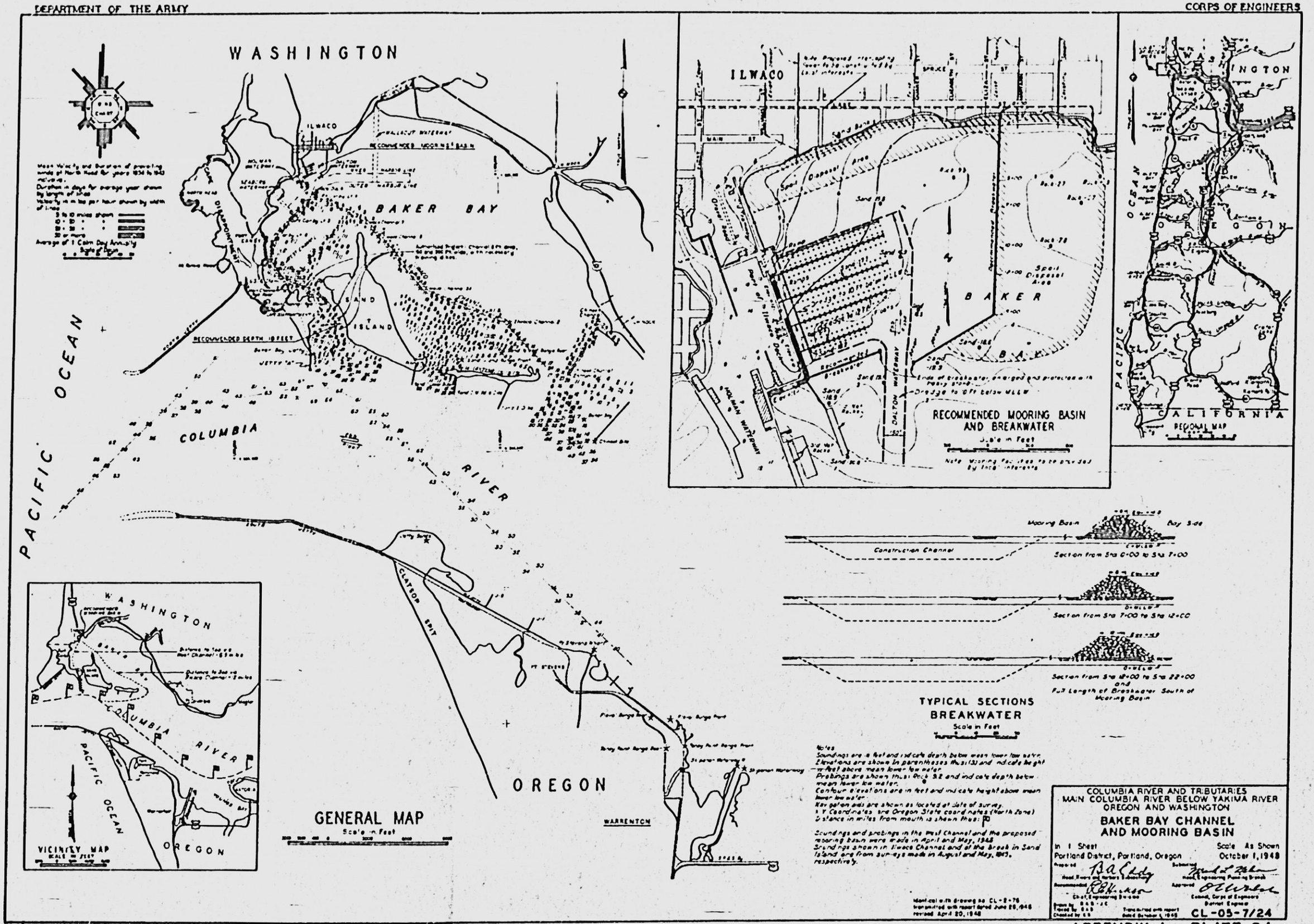

WASHINGTON
ILWACO
BAKER BAY
SAND ISLAND
PACIFIC OCEAN
COLUMBIA RIVER
CLATSOP SPIT
OREGON
WARRENTON
GENERAL MAP
Scale in Feet
VICINITY MAP
RECOMMENDED MOORING BASIN AND BREAKWATER
Scale in Feet
REGIONAL MAP
CALIFORNIA
TYPICAL SECTIONS BREAKWATER
Scale in Feet
Mooring Basin
Construction Channel
Section from Sta 0+00 to Sta 7+00
Section from Sta 7+00 to Sta 12+00
Section from Sta 18+00 to Sta 22+00 and Full Length of Breakwater South of Mooring Basin
Notes
Soundings are in feet and indicate depth below mean lower low water.
Elevations are shown in parentheses thus: (3) and indicate height in feet above mean lower low water.
Probings are shown thus: Prob. 32 and indicate depth below mean lower low water.
Contour elevations are in feet and indicate height above mean lower low water.
Navigation aids are shown as located at date of survey.
X Y Coordinates are Oregon State coordinates (North Zone)
Distance in miles from mouth is shown thus: 10
Soundings and probings in the West Channel and the proposed mooring basin were made in April and May, 1948.
Soundings shown in Ilwaco Channel and at the break in Sand Island are from surveys made in August and May, 1945, respectively.
Identical with drawing no. CL-8-76 transmitted with report dated June 28, 1948
revised April 20, 1948
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
BAKER BAY CHANNEL AND MOORING BASIN
In 1 Sheet
Scale As Shown
Portland District, Portland, Oregon
October 1, 1948
Prepared
Head, Rivers and Harbors Branch
Recommended
Chief, Engineering Division
Submitted
Head, Engineering Planning Branch
Approved
Colonel, Corps of Engineers
District Engineer
Traced by
Checked by
Transmitted with report dated October 1, 1948
CL-05-7/24

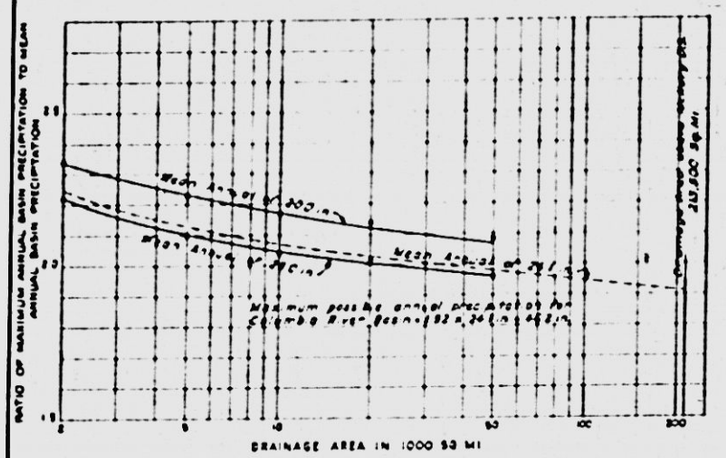


FIG. 1 - MAXIMUM POSSIBLE ANNUAL PRECIPITATION
COLUMBIA RIVER BASIN

Notes
1. Data for this chart were taken from the report titled "Tentative Estimates of Maximum Flood Producing Meteorological Conditions in the Columbia River Basin" by the Hydrometeorological Section of the Weather Bureau, U.S. Dept of Commerce
2. From the above chart the maximum possible precipitation over the Columbia River Basin above McNary D.S. is 193 per cent of the mean annual precipitation. The mean annual precipitation for the basin as computed from the mean annual isohyetal map (Plate 6) is 24.1 in

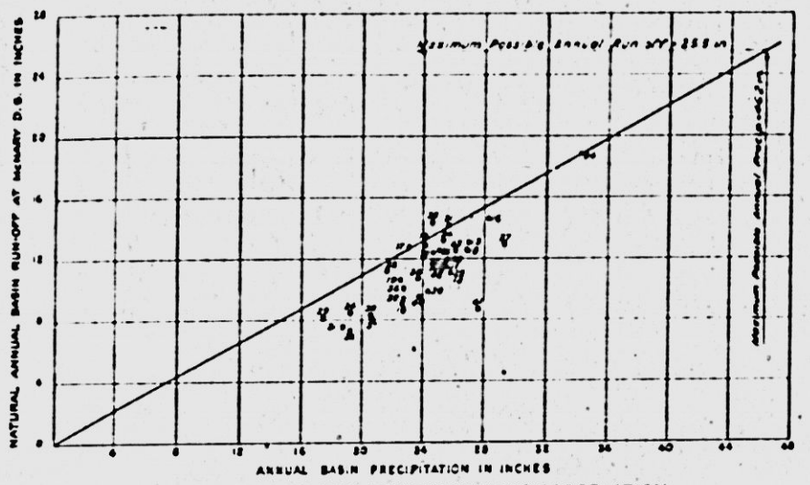
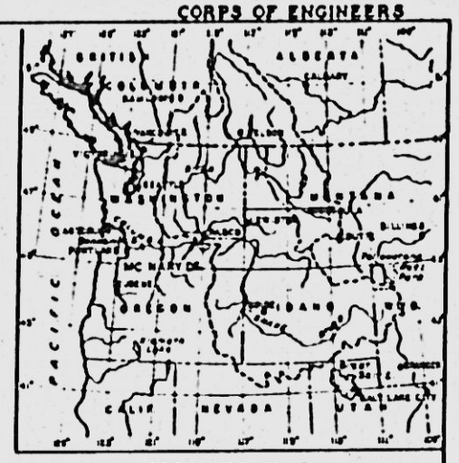
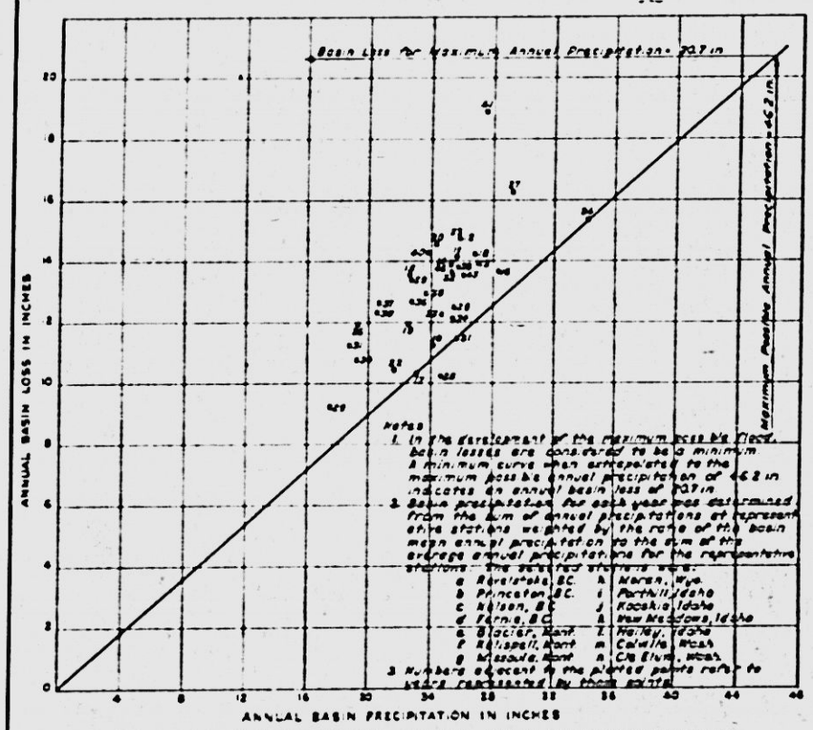


FIG. 3 - ANNUAL PRECIPITATION-RUN-OFF CORRELATION

Notes
1. The above Precipitation-Run off curve was drawn to envelop all years of major floods. This curve when extrapolated to the maximum possible annual precipitation of 46.2 in indicated a basin run off of 25.9 in.
2. Natural run offs at McNary Dam Site are based on observed flows near The Dalles, adjusted for Snake River depletions and tributary inflows between McNary Dam Site and The Dalles.
3. Annual basin precipitation was determined as explained in Fig 2.
4. Numbers adjacent to the plotted points refer to years represented by those points



REGIONAL MAP
SCALE IN MILES

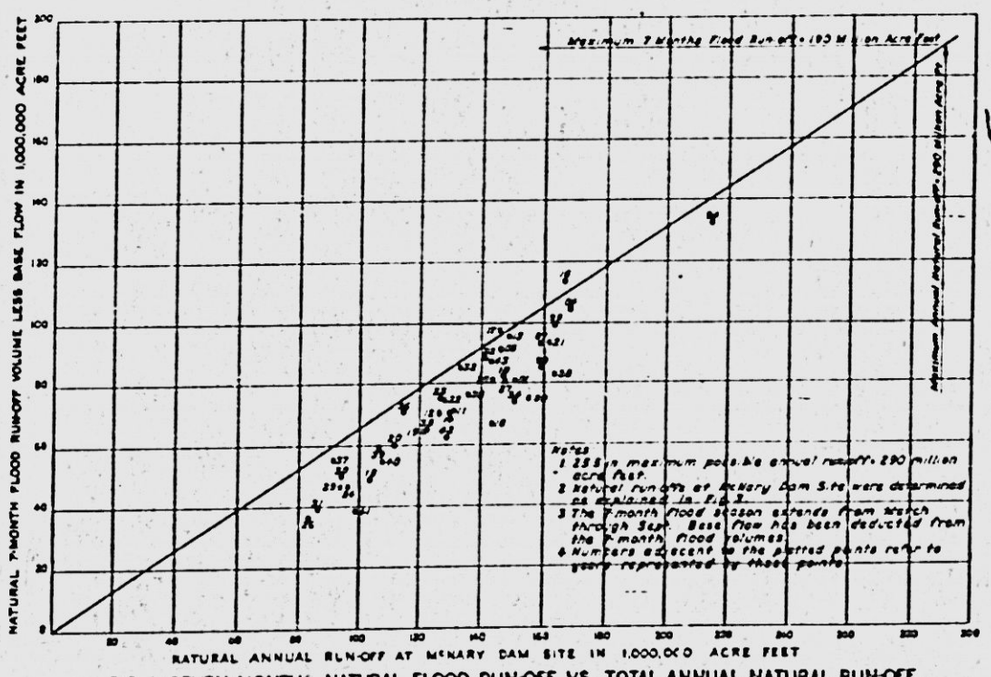


Notes
1. In the development of the maximum possible flood, basin losses are considered to be a minimum. A minimum curve when extrapolated to the maximum possible annual precipitation of 46.2 in indicates an annual basin loss of 10.7 in
2. Basin precipitation for each year was determined from the sum of annual precipitations at representative stations weighted by the ratio of the basin mean annual precipitation to the sum of the average annual precipitations for the representative stations. The selected stations were:

a	Revelstoke, B.C.	h	Moran, Wyo.
b	Princeton, B.C.	i	Porthill, Idaho
c	Nelson, B.C.	j	Kooskia, Idaho
d	Fernie, B.C.	k	Van Meadows, Idaho
e	Blaxter, Mont.	l	Hailey, Idaho
f	Kalispell, Mont.	m	Colville, Wash.
g	Missoula, Mont.	n	Cle Elum, Wash.

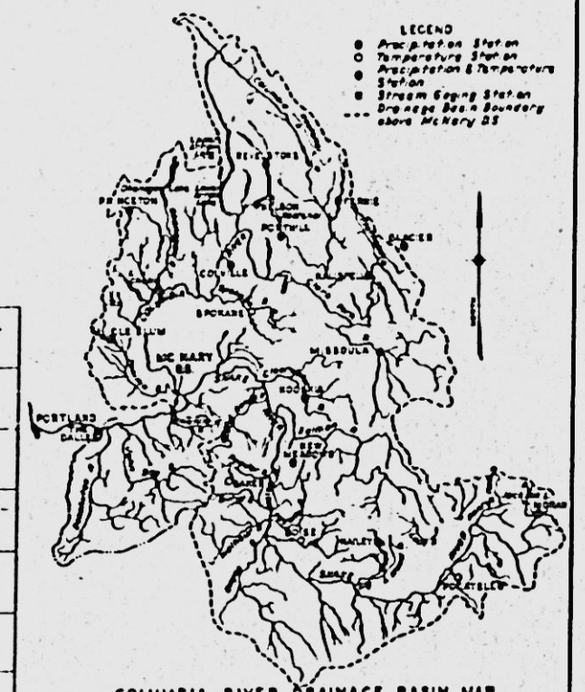
3. Numbers adjacent to the plotted points refer to years represented by those points

FIG. 2 - ANNUAL PRECIPITATION-ANNUAL BASIN LOSS CORRELATION



Notes
1. 25.9 in maximum possible annual runoff = 29.0 million acre feet
2. Natural run offs at McNary Dam Site were determined as explained in Fig 3
3. The 7-month flood season extends from March through Sept. Base flow has been deducted from the 7-month flood volumes
4. Numbers adjacent to the plotted points refer to years represented by those points

FIG. 4 - SEVEN-MONTHS NATURAL FLOOD RUN-OFF VS. TOTAL ANNUAL NATURAL RUN-OFF



COLUMBIA RIVER DRAINAGE BASIN MAP
SCALE IN MILES

Drainage area above McNary D.S. = 213,500 sq mi.
Drainage area above The Dalles = 237,000 sq mi.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
McNARY DAM
PRECIPITATION AND RUN-OFF
RELATIONSHIPS

In 1 Sheet — Scale As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared — Submitted — Recommended — Approved
Chief, Engineering Division — Colonel, Corps of Engineers, District Engineer

Drawn by — Traced by — Checked by — Transmitted with report dated October 1, 1948

CL-05-7/55

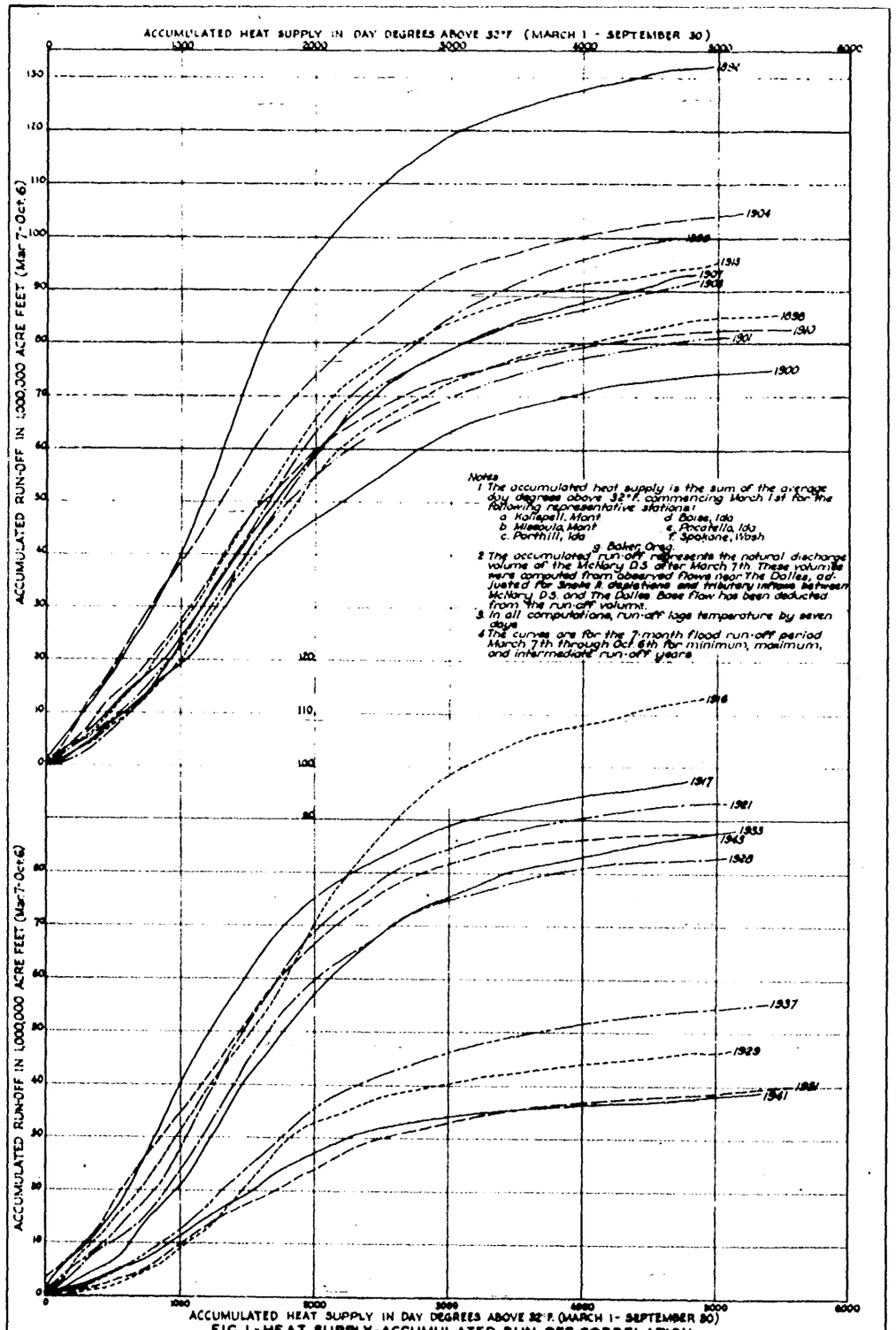
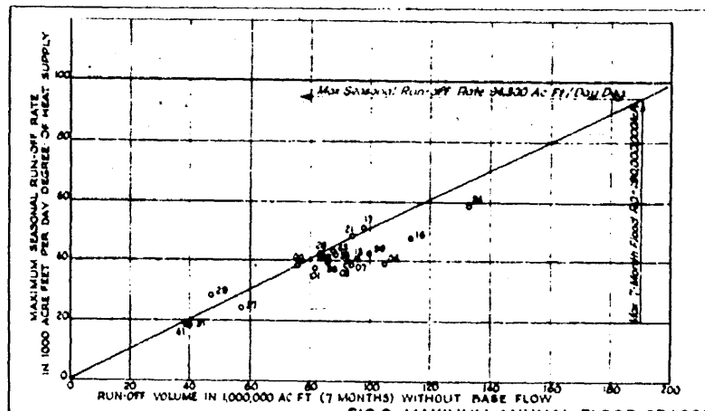
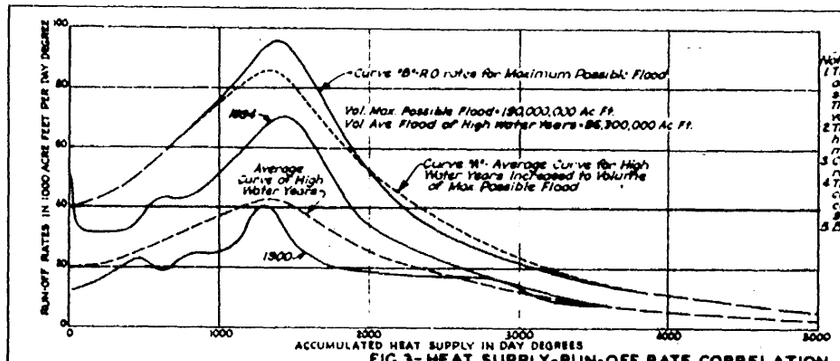


FIG. 1 - HEAT SUPPLY-ACCUMULATED RUN-OFF CORRELATION



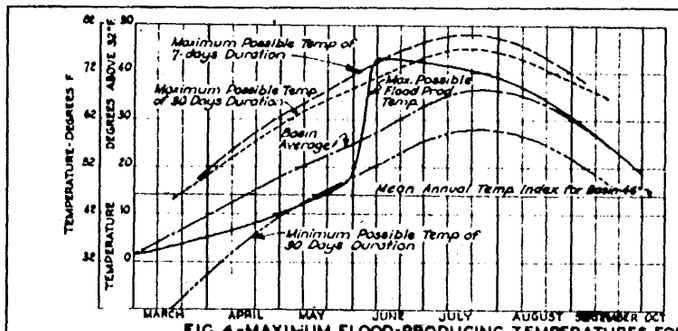
Notes:
1 The run-off rate per day-degree is the slope of the Heat Supply - Accumulated Run-Off curve (Fig 1) The plotted maximum annual run-off rates represent the steepest slope of the annual curves
2 In general, the maximum annual run-off rates shown either preceded or occurred at the time of peak discharge. In the years 1894, 1901, 1934, and 1937 the maximum run-off rate occurred sometime after the peak discharge. In these instances the run-off rate plotted is that occurring at the time of peak discharge.
3 The 7-month flood run-offs are based on observed flows near The Dalles, adjusted for Snake River depletions and tributary inflows between McNary D.S. and The Dalles The 7-month flood season is the Period from Mar 7 to Oct 6 Base Flow has been deducted from these volumes
4 The above curve was drawn to envelop all years of major floods This curve when extrapolated to the maximum possible flood season (7-month) run-off volume of 190,000,000 Ac Ft, indicated a maximum run-off rate of 34,300 Ac Ft per day degree of heat supply
5 Numbers adjacent to the plotted points refer to the years represented by those points.

FIG 2 - MAXIMUM ANNUAL FLOOD SEASON RUN-OFF RATE



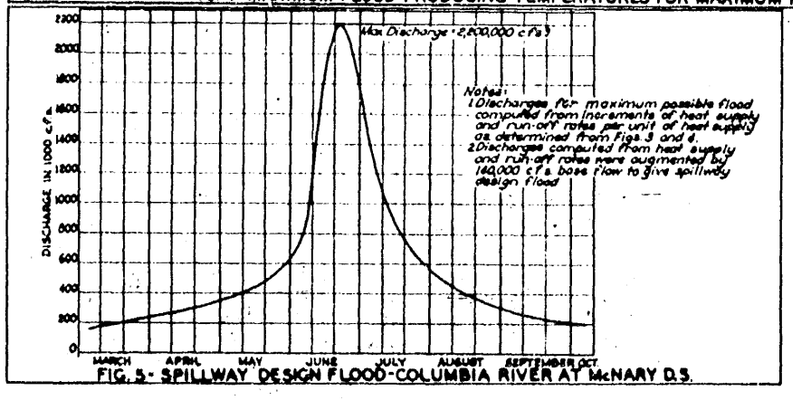
Notes:
1 This graph shows the run-off rate at any value of accumulated heat supply The run-off rate is the slope of the Heat Supply Run-Off Mass Curve (Fig 1) The total area under each curve is equal to the volume of flood run-off in Ac Ft
2 The curves for 1894 and 1900 are representative of high water years The average curve represents the mean run-off rate for high water years studied
3 Curve "A" is the average curve increased by volumetric ratio of maximum flood to average flood.
4 The maximum flood run-off rates indicated by curve "B" were obtained by increasing the peak of curve "A" to the maximum seasonal run-off rate of 34,300 Ac Ft per day degree of heat supply.
5 Base flow has been deducted from all volumes

FIG. 3 - HEAT SUPPLY-RUN-OFF RATE CORRELATION



Notes:
1 Highest and lowest possible average basin surface air temperatures are derived from extrapolation of data presented in a report titled "Tentative Estimates of Maximum Flood-Producing Meteorological Conditions in the Columbia River Basin" by the Hydrometeorological section of the U.S Weather Bureau
2 To produce the maximum flood season run-off for the Columbia River Basin the following temperature sequences were observed
a Temperatures from the beginning of the water year until the latter week in May were held near a minimum, thereby resulting in very little loss of run-off during the pre-flood period
b In the period between the last week of May and second week of June temperatures were raised to reach the highest possible temperatures. This sequence of temperatures resulted in the 7-day duration maximum flood discharge.
3 Curve of Maximum Possible Flood-Producing temperatures was developed from methods advocated by U.S Weather Bureau
4 Mean annual and mean monthly temperature indexes for the basin were computed from published records of the representative U.S Weather Bureau stations noted in Fig 1

FIG. 4 - MAXIMUM FLOOD-PRODUCING TEMPERATURES FOR MAXIMUM POSSIBLE FLOOD SEASON



Notes:
1 Discharges for maximum possible flood computed from increments of heat supply and run-off rates per unit of heat supply as determined from Figs 3 and 4.
2 Discharges computed from heat supply and run-off rates were augmented by 140,000 c.f.s. base flow to give spillway design flood

FIG. 5 - SPILLWAY DESIGN FLOOD-COLUMBIA RIVER AT McNARY D.S.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

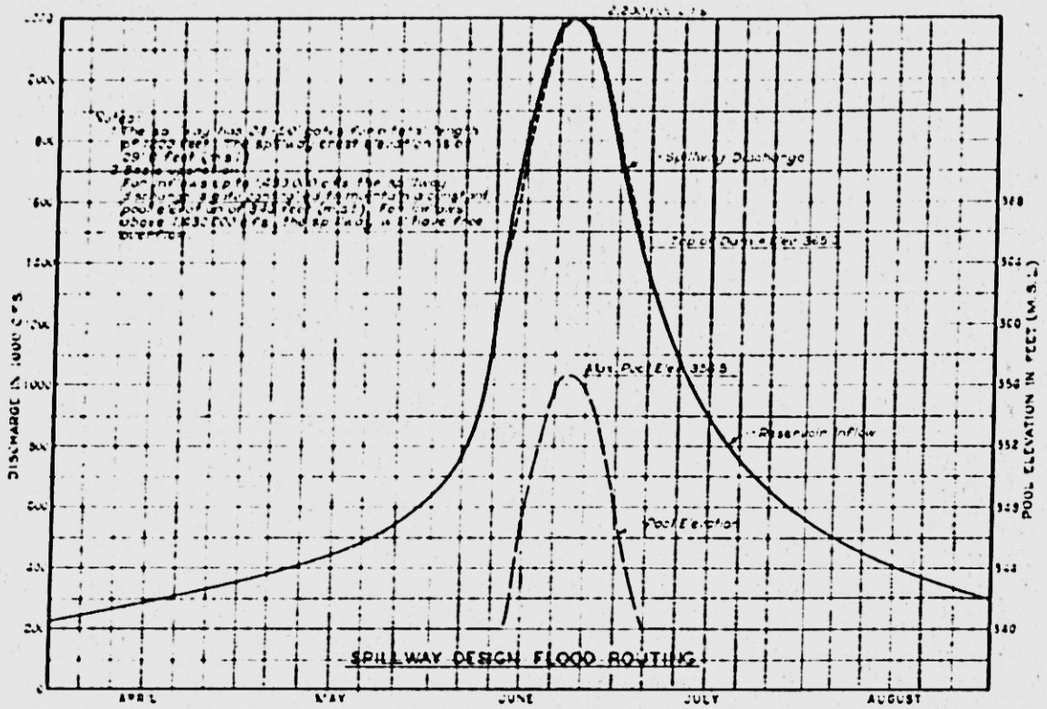
McNARY DAM
DERIVATION DATA
SPILLWAY DESIGN FLOOD

In 1 Sheet — Scale As Shown
Portland District, Portland, Oregon — October 1, 1948

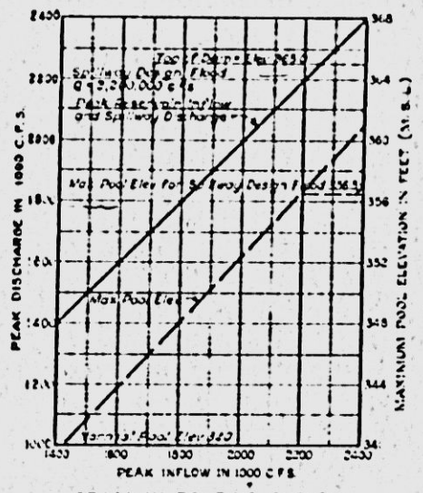
Proposed: Head, Planning and Reports Section — Submitted: Head, Engineering Planning Branch
Recommended: Chief, Engineering Division — Approved: Colonel, Corps of Engineers, District Engineer

Drawn by: M.H.C. - D.M.A. Traced by: M.H.C. Checked by: C.F. Transmitted with report dated October 1, 1948

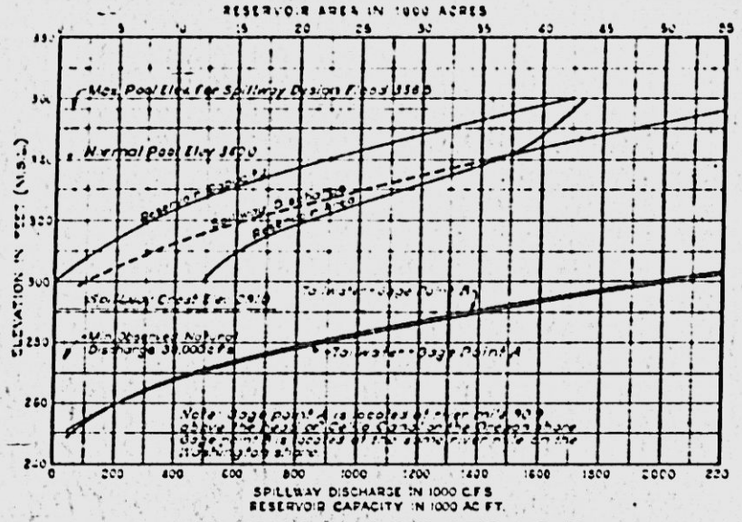
CL-05-7/56



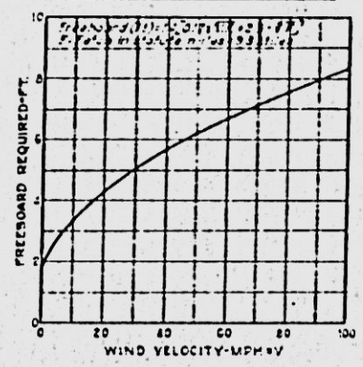
SPILLWAY DESIGN FLOOD ROUTING



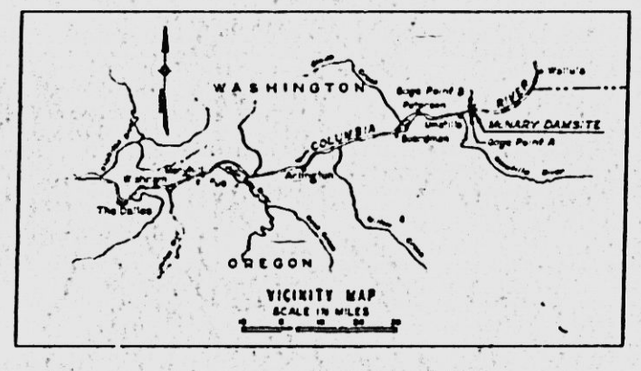
SPILLWAY ROUTING CURVES

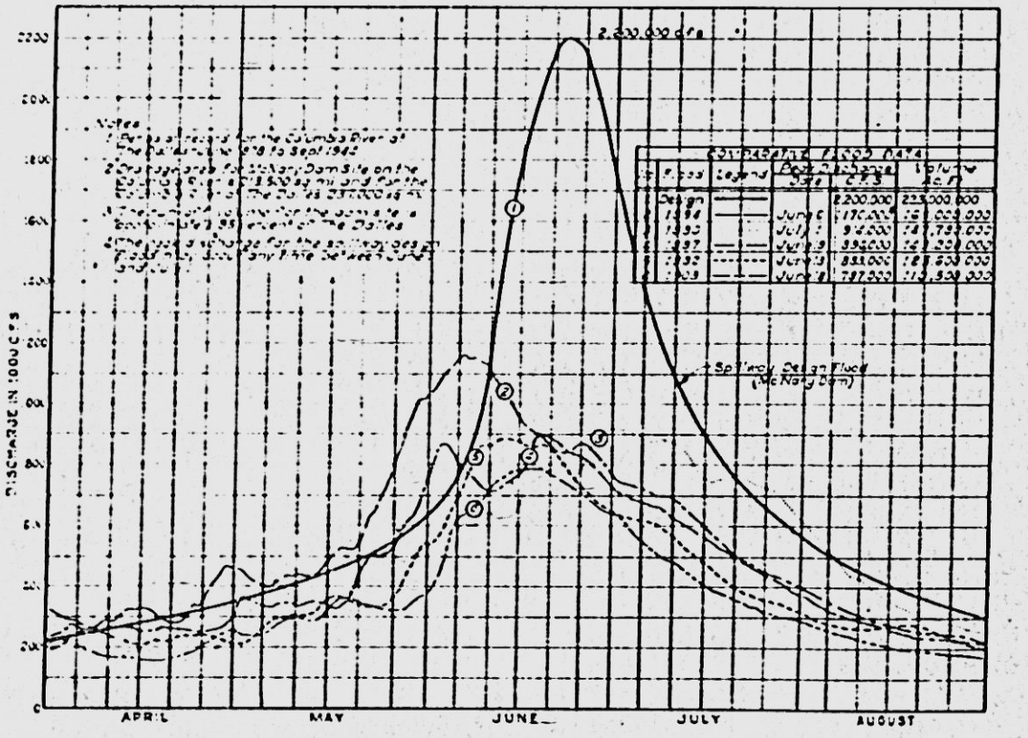


AREA, CAPACITY AND DISCHARGE CURVES

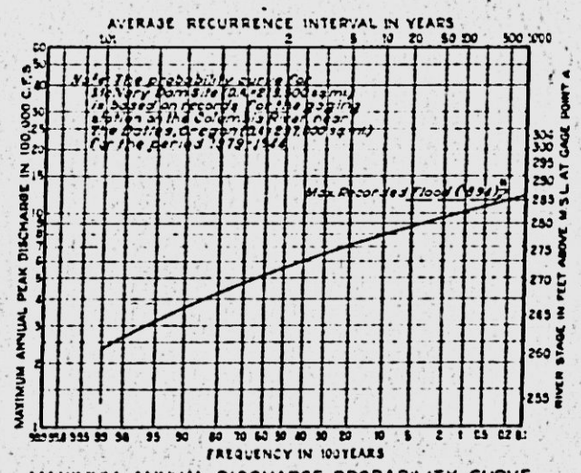


RESERVOIR WIND SET-UP





McNARY DAM SPILLWAY DESIGN FLOOD
COMPARED WITH THE FIVE LARGEST FLOODS ON THE COLUMBIA RIVER AT THE DALLES



MAXIMUM ANNUAL DISCHARGE PROBABILITY CURVE

*Note:
The studies shown on this plate were completed prior to the 1948 Flood in Columbia River, therefore the published value of maximum discharge, 1,170,000 second feet, has been used. Data obtained during 1948 flood indicate that this discharge should be revised to 1,240,000 second-feet.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

McNARY DAM
SPILLWAY DESIGN FLOOD
AND RELATED HYDRAULIC DATA

In 1 Sheet — Scale As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared — Submitted
Head, Technical Review Section — Head, Engineering Planning Branch
Recommended — Approved
Chief, Engineering Division — Colonel, Corps of Engineers, District Engineer
Drawn by R.S.C. - S.H.B.
Traced by K.B.R. — Transmitted with report dated October 1, 1948
Checked by C.P.

CL-05-7/57

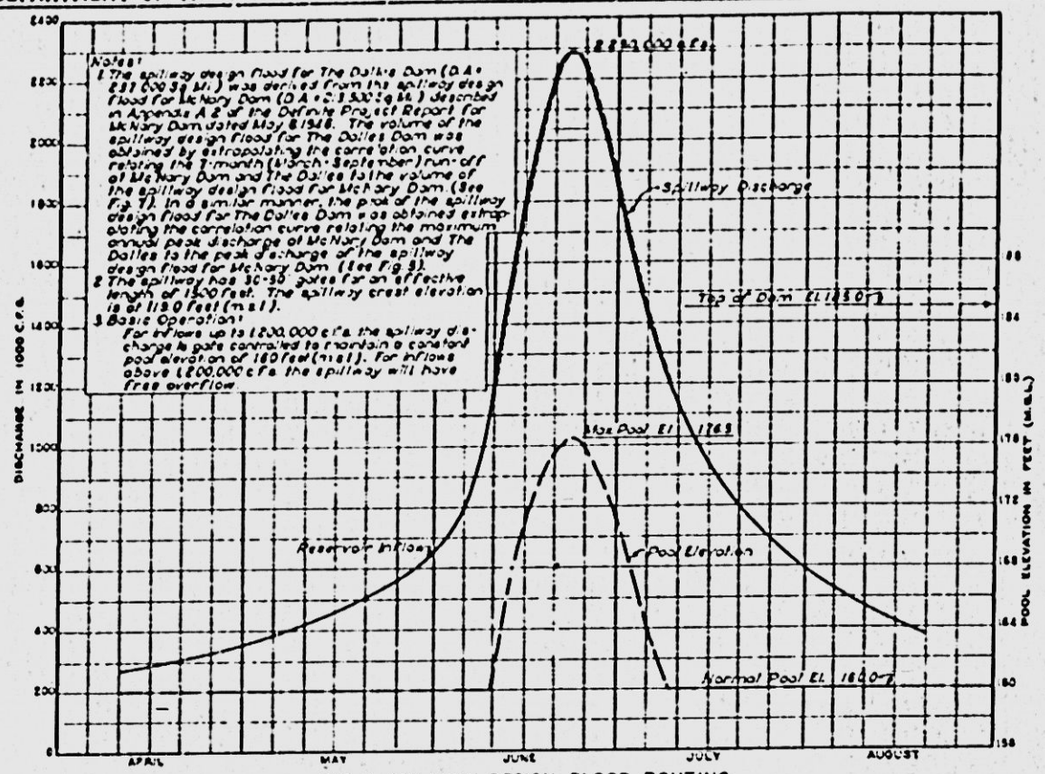


FIG 1 - SPILLWAY DESIGN FLOOD ROUTING

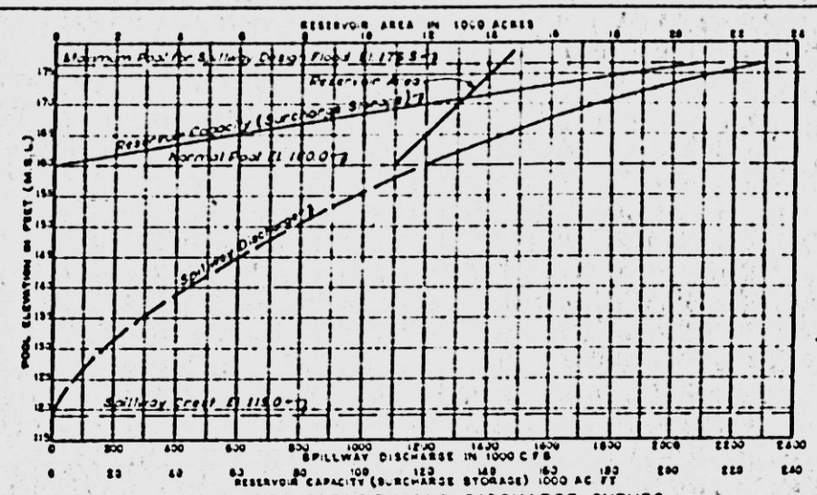
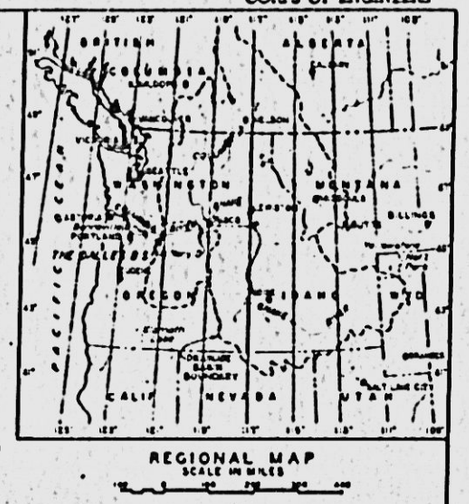


FIG 3 - AREA, CAPACITY, AND DISCHARGE CURVES



REGIONAL MAP
SCALE IN MILES

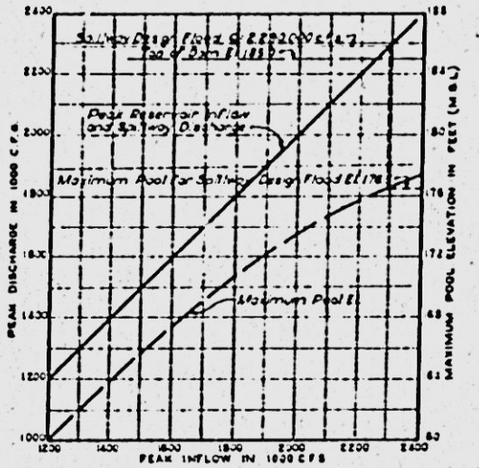


FIG 4 - SPILLWAY ROUTING CURVES

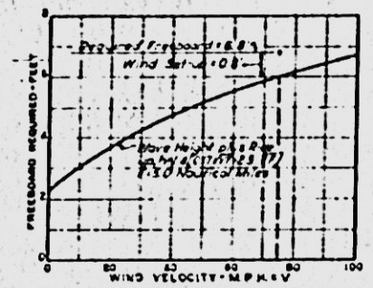


FIG 6 - FREEBOARD REQUIREMENT

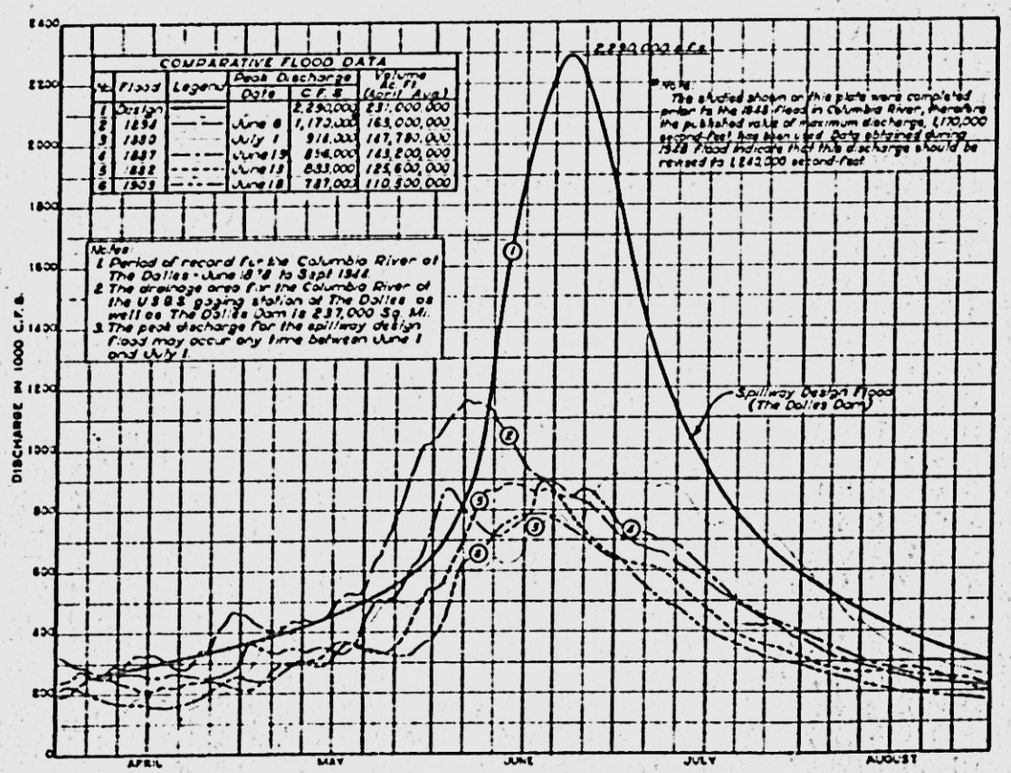


FIG. 2 - THE DALLES DAM SPILLWAY DESIGN FLOOD
COMPARED WITH THE FIVE LARGEST FLOODS ON THE COLUMBIA RIVER AT THE DALLES

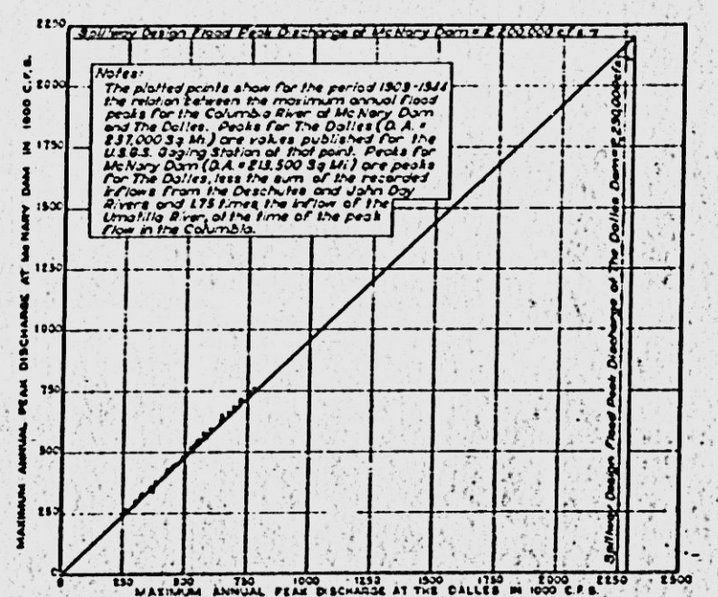


FIG 5 - MAXIMUM ANNUAL FLOOD PEAK CORRELATION
McNARY DAM VS THE DALLES

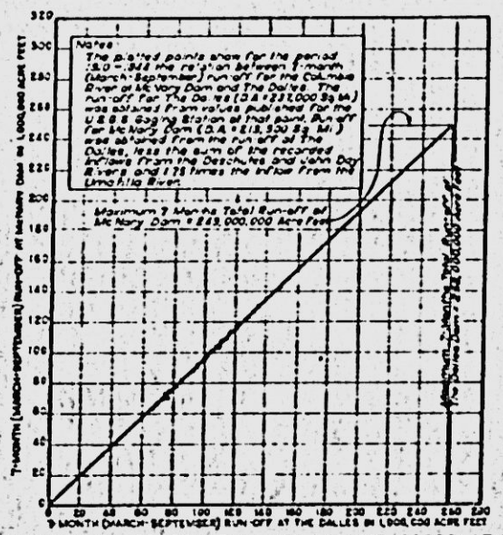


FIG. 7 - FLOOD SEASON RUN-OFF VOLUME CORRELATION
McNARY DAM VS THE DALLES

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

THE DALLES DAM
SPILLWAY DESIGN FLOOD
AND RELATED HYDRAULIC DATA

In 1 Sheet — Scale As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared — Submitted
Head, Planning Section — Head, Engineering Planning Branch
Recommended — Approved
Chief, Engineering Division — Colonel, Corps of Engineers, District Engineer
Drawn by D.M.B. — Traced with ring-in
Checked by E.E. — Dated October 1, 1949

CL-03-7/89

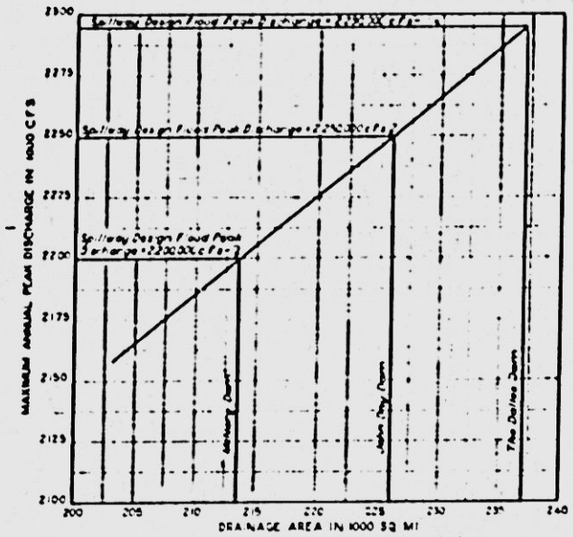


FIG 1-PEAK DISCHARGE CORRELATION
SPILLWAY DESIGN FLOOD

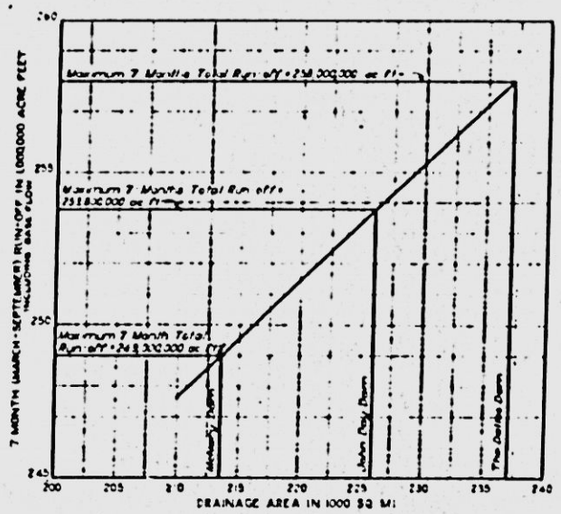
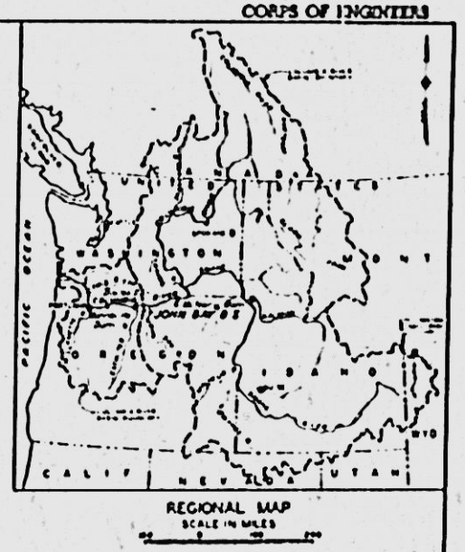


FIG 2-FLOOD SEASON RUN-OFF CORRELATION
SPILLWAY DESIGN FLOOD



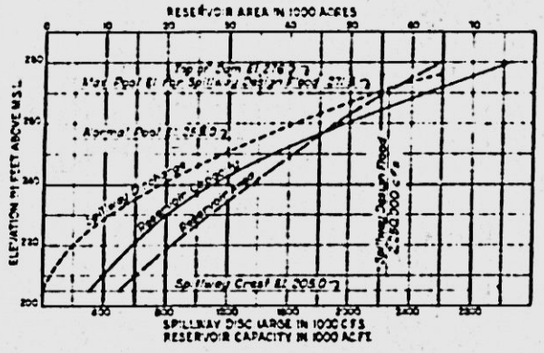


FIG 5-AREA, CAPACITY, AND DISCHARGE CURVES

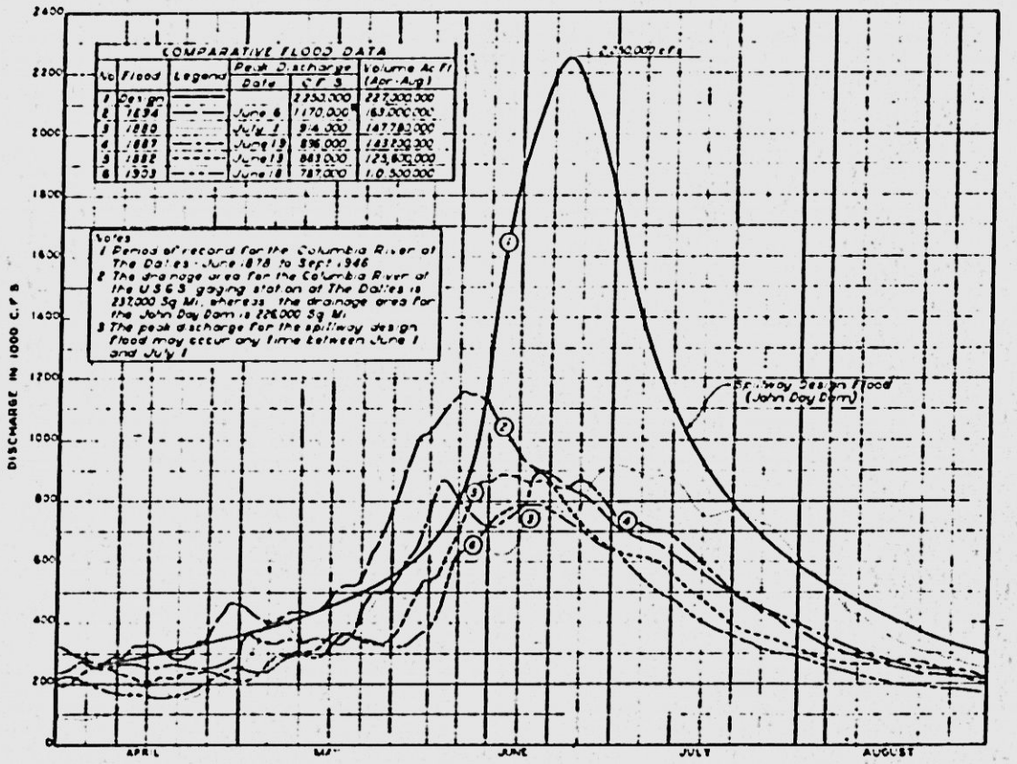


FIG 3-THE JOHN DAY DAM SPILLWAY DESIGN FLOOD
COMPARED WITH THE FIVE LARGEST FLOODS ON THE COLUMBIA RIVER AT THE DALLES

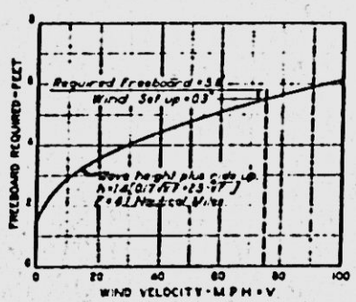


FIG. 4-FREEBOARD REQUIREMENT

Notes

1 The spillway design flood for John Day Dam Site was derived from the spillway design floods at McNary Dam (D.A. = 213,500 sq mi) and The Dalles Dam Site (D.A. = 237,000 sq mi), described in Appendix A 2 of the Definite Project Report for McNary Dam, dated May 6, 1946, and Interim Report No 1 for The Dalles Dam, dated March 21, 1946

2 Figure 1 indicates the drainage area relation of peak discharges and Figure 2 shows the relation of flood season run-off volumes in acre-feet for the spillway design floods at McNary Dam and The Dalles Dam Site. The peak discharge and flood season run-off for the spillway design flood at John Day Dam Site were obtained by interpolation on these curves

3 No reduction of the peak discharge considered for reservoir storage.

4 Area, Capacity and Discharge curves based on John Day high dam

*Note:
The studies shown on this plate were completed prior to the 1948 flood in Columbia River, therefore the published value of maximum discharge, 1,170,000 second-feet has been used. Data obtained during 1948 flood indicate that this discharge should be revised to 1,240,000 second-feet

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

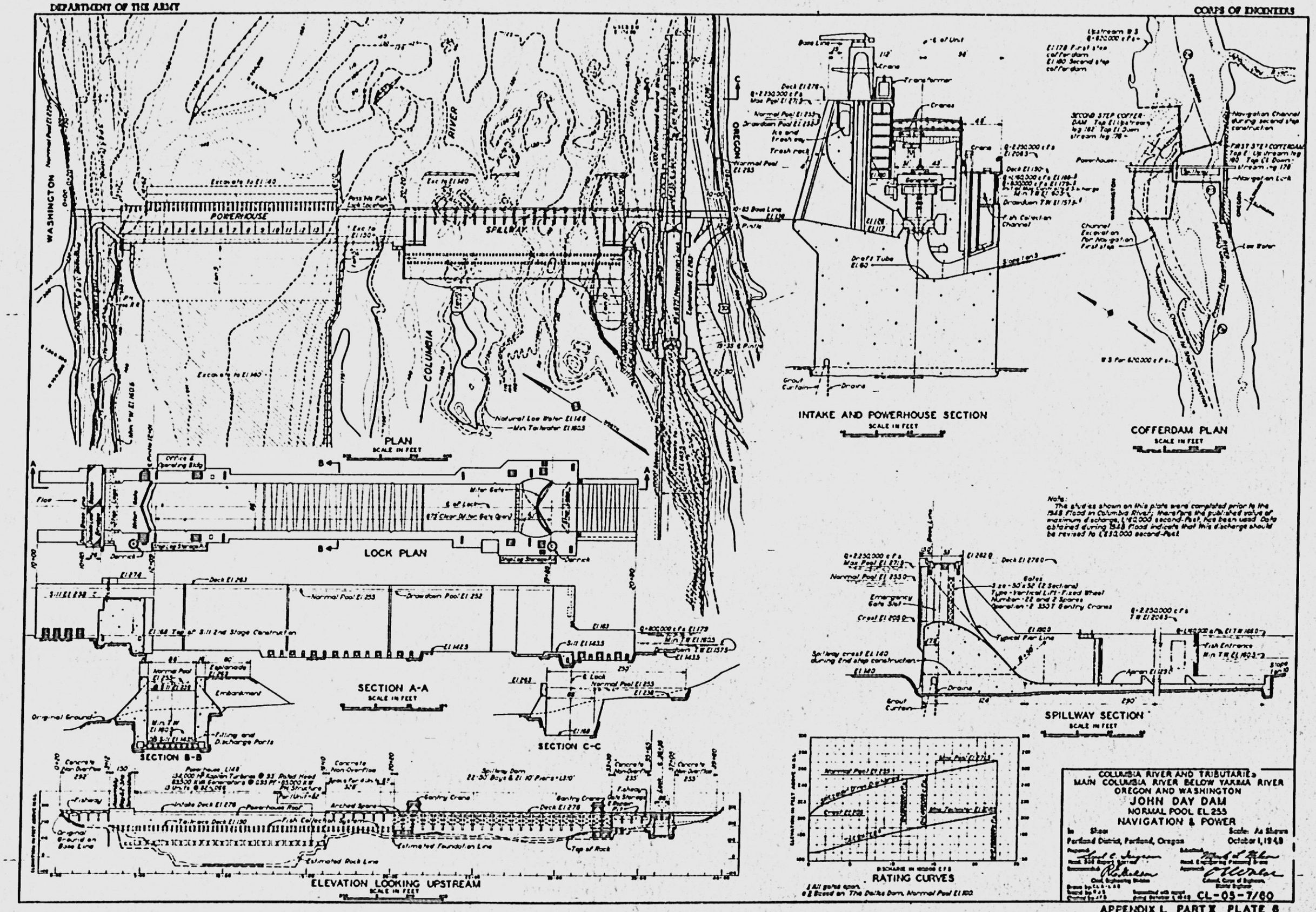
JOHN DAY DAM
SPILLWAY DESIGN FLOOD

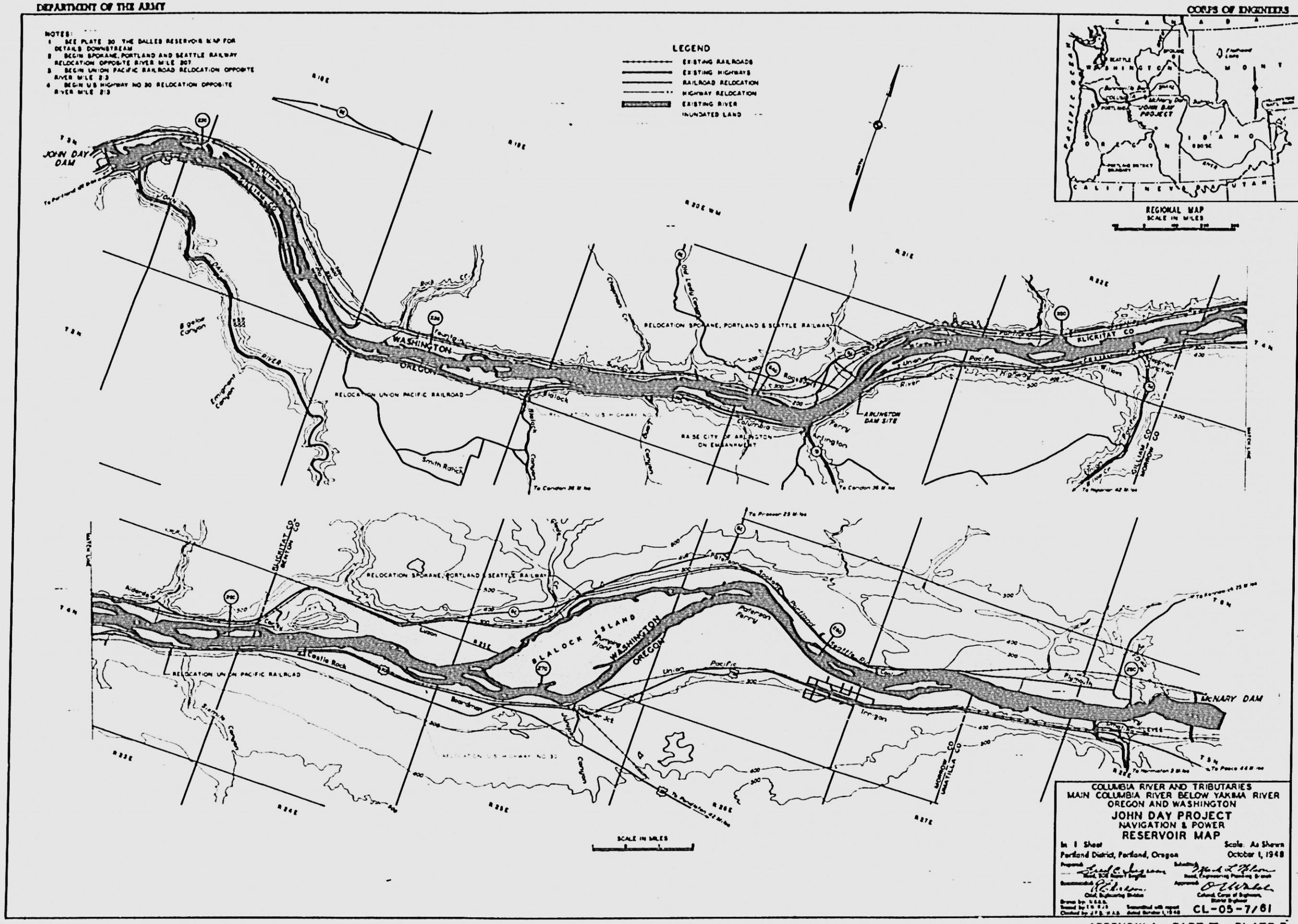
In 1 Sheet — Scale As Shown
Portland District, Portland, Oregon — October 1, 1948

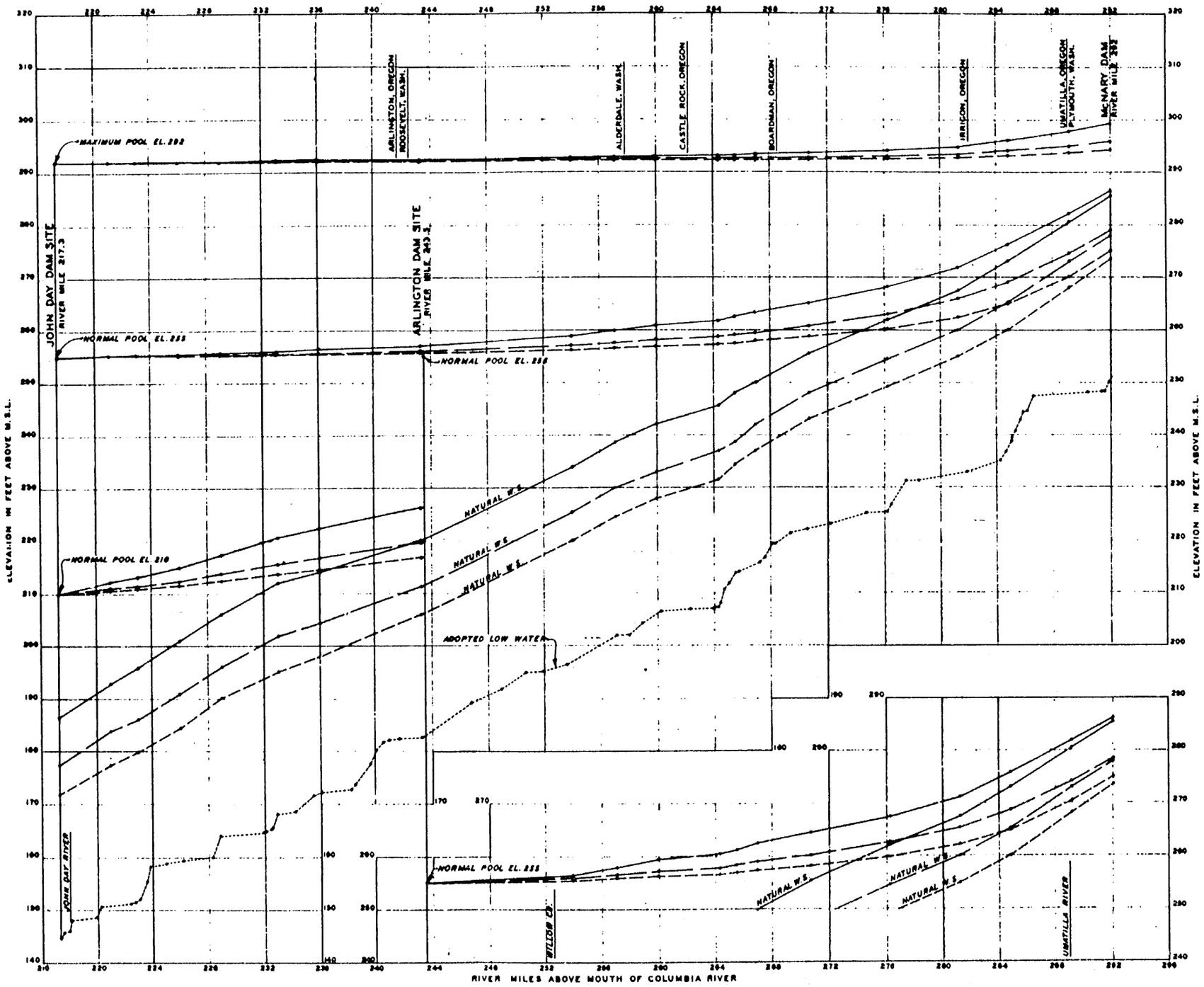
Prepared: Head, Technical Services Section — Submitted: Head, Engineering Planning Branch
Recommended: Chief, Engineering Division — Approved: Colonel, Corps of Engineers, District Engineer

Drawn by D.H.B. Traced by D.H.B. Checked by C.P. — Transmitted with report dated October 1, 1948

CL-05-7/59


WASHINGTON
OREGON
COLUMBIA
RIVER
POWERHOUSE
SPILLWAY
PLAN
SCALE IN FEET
LOCK PLAN
SECTION A-A
SCALE IN FEET
SECTION B-B
SECTION C-C
ELEVATION LOOKING UPSTREAM
SCALE IN FEET
INTAKE AND POWERHOUSE SECTION
SCALE IN FEET
COFFERDAM PLAN
SCALE IN FEET
SPILLWAY SECTION
SCALE IN FEET
RATING CURVES
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
JOHN DAY DAM
NORMAL POOL EL 255
NAVIGATION & POWER
Scale: As Shown
Portland District, Portland, Oregon
October 1, 1948
CL-05-7/60


NOTES:
1 SEE PLATE 30 THE DALLES RESERVOIR MAP FOR DETAILS DOWNSTREAM
2 BEGIN SPOKANE, PORTLAND AND SEATTLE RAILWAY RELOCATION OPPOSITE RIVER MILE 207
3 BEGIN UNION PACIFIC RAILROAD RELOCATION OPPOSITE RIVER MILE 213
4 BEGIN U.S. HIGHWAY NO 30 RELOCATION OPPOSITE RIVER MILE 213
LEGEND
EXISTING RAILROADS
EXISTING HIGHWAYS
RAILROAD RELOCATION
HIGHWAY RELOCATION
EXISTING RIVER
INUNDATED LAND
REGIONAL MAP
SCALE IN MILES
JOHN DAY DAM
WASHINGTON
OREGON
KLICKITAT CO
RELOCATION SPOKANE, PORTLAND & SEATTLE RAILWAY
RELOCATION UNION PACIFIC RAILROAD
ARLINGTON DAM SITE
RAISE CITY OF ARLINGTON ON EMBANKMENT
BLALOCK ISLAND
McNARY DAM
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
JOHN DAY PROJECT
NAVIGATION & POWER
RESERVOIR MAP
In 1 Sheet
Scale: As Shown
Portland District, Portland, Oregon
October 1, 1948
CL-05-7/61
SCALE IN MILES



LEGEND

- 1,150,000 C.F.S.
- 800,000 C.F.S.
- 600,000 C.F.S.
- LOW WATER

NOTE:
THE STUDIES SHOWN ON THIS PLATE WERE MADE PRIOR TO THE 1948 FLOOD IN COLUMBIA RIVER. THE DISCHARGE VALUE OF 1,150,000 SECOND-FEET IS BASED ON THE PUBLISHED VALUE FOR MAXIMUM DISCHARGE FOR THE 1894 FLOOD. BASED ON DATA OBTAINED DURING THE 1948 FLOOD THE MAXIMUM DISCHARGE WOULD BE 1,210,000 SECOND-FEET WITH NO CHANGE IN WATER SURFACE ELEVATION.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

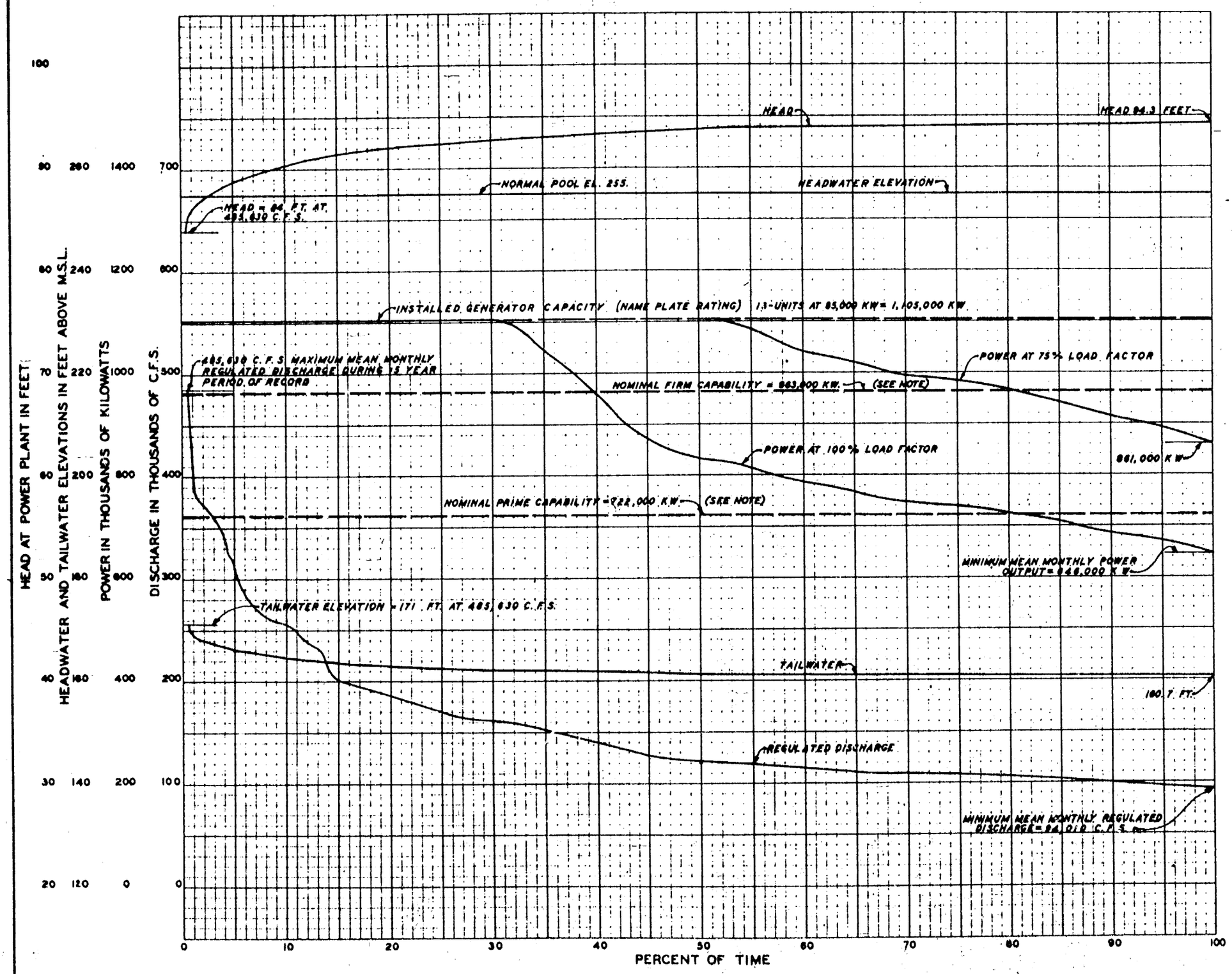
JOHN DAY PROJECT
BACKWATER PROFILES

In 1 Sheet — Scale: As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared: Head, Res. Report Section
Submitted: Head, Engineering Planning Branch
Recommended: Chief, Engineering Division
Approved: Colonel, Corps of Engineers, District Engineer

Drawn by: E.L.A.-B.D.B.
Traced by: H.L.B.
Checked by: A.S.A.
Transmitted with report dated October 1, 1948

CL-05-7/62



1. The "power at 100 percent load factor" curve and the "regulated discharge" curve are based on the Phase C system power study for the period October 1927 through September 1942, under the following conditions:
   a. Discharges are modified by future irrigation for initial development in the Snake River Basin and for ultimate development elsewhere.
   b. Flathead Lake is regulated for a minimum discharge of 4,300 cubic feet per second.
   c. 817,000 Acre-feet of existing storage in Kootenay Lake (Canada) are used in the interest of Corra Linn Power Plant.
   d. The following storages are used in the interest of the system:

Hungry Horse	2,980,000 acre-feet
Glacier View	3,160,000 " "
Paradise	4,080,000 " "
Albeni Falls	1,140,000 " "
Grand Coulee	5,118,000 " "
Hells Canyon	3,280,000 " "

   e. A deduction of 2,000 cubic feet per second at the site for leakage, fish migration, miscellaneous uses, and losses has been made. Over-all plant efficiency is assumed at 88 percent.
2. The tailwater curve is shown as affected by The Dalles headwater. See Reference No. 1.
3. Nominal prime capability is the average output for the critical months of the system critical power period: September 1, 1929 to March 1, 1932. See Reference No. 2.
4. Average annual energy production equals 7,829,000,000 kw.hrs.

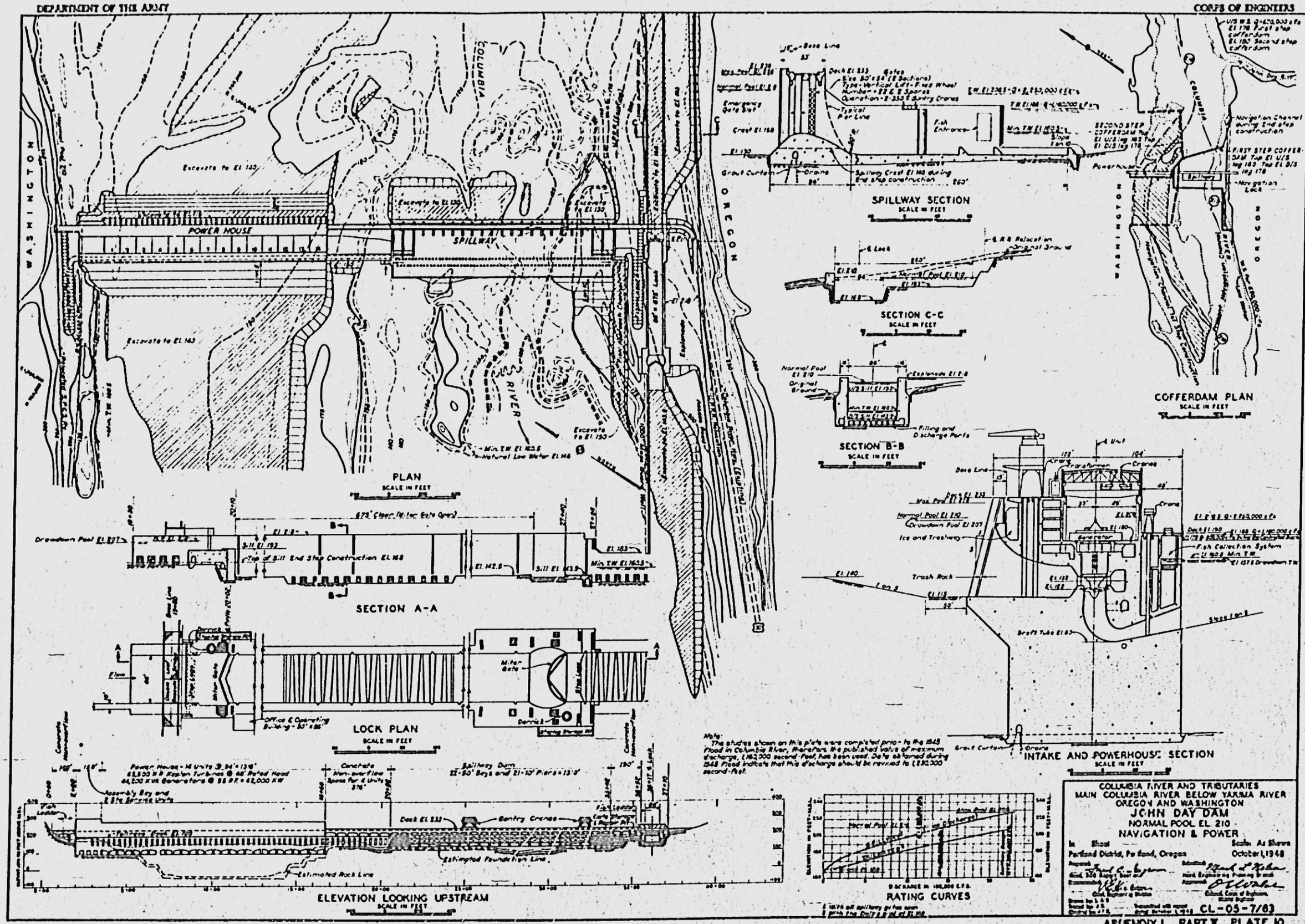
REFERENCES

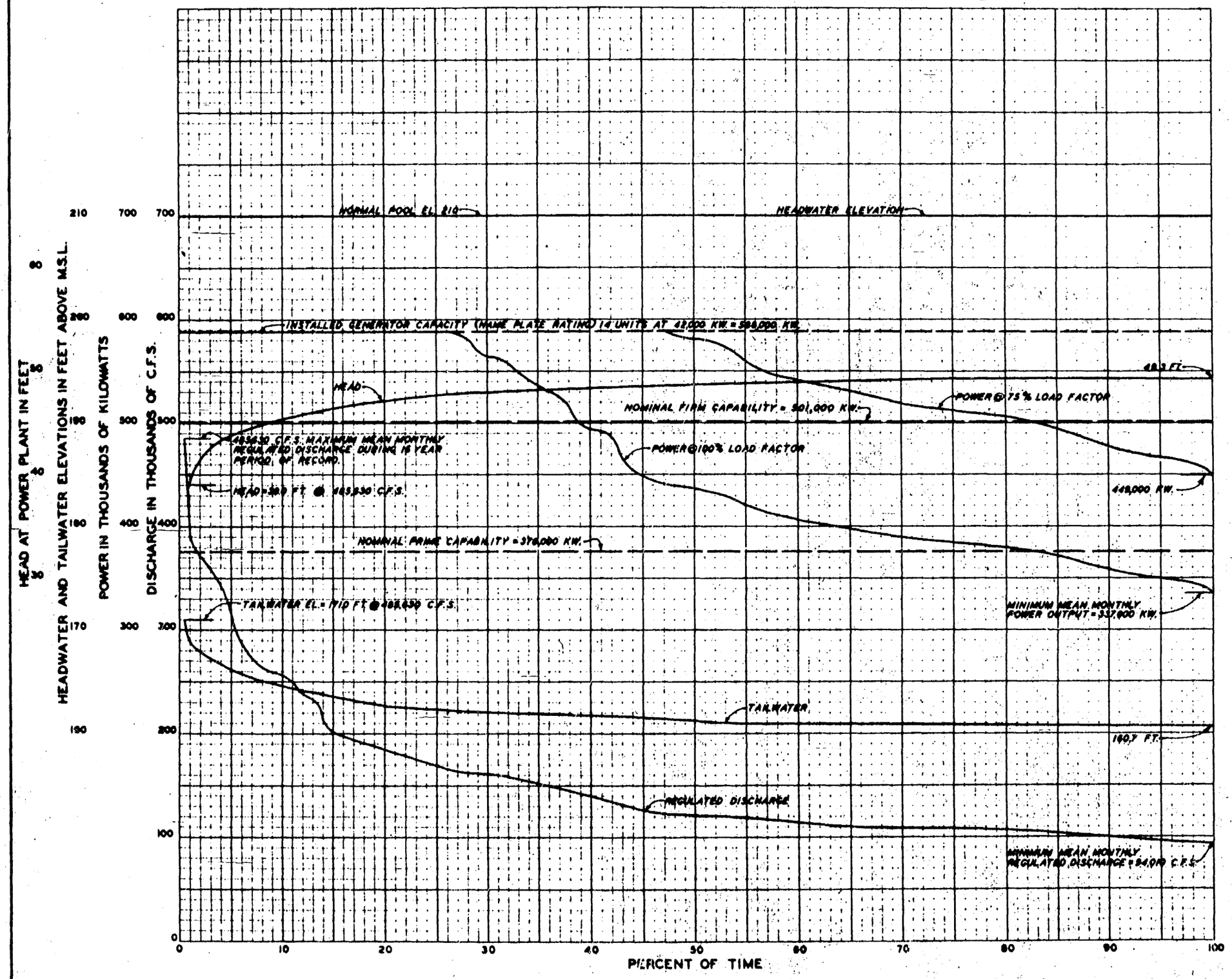
1. Appendix O Chart 31 "John Day (Pool Elev. 255) Storage, Headwater, Tailwater, Power Output, and Plant Capability."
2. Appendix O Chart 49 "John Day (Pool Elev. 255) Discharge and Power Graphs 1927 - 1942."

Note:
Nominal prime and nominal firm capabilities of John Day power plant in the phase C-2 system are 735,000 kilowatts and 580,000 kilowatts respectively.
See Appendix O text for explanation.

COLUMBIA RIVER AND TRIBUTARIES
JOHN DAY
(POOL ELEVATION 255)
POWER PLANT CHARACTERISTICS
PHASE C DEVELOPMENT.

In 1 Sheet — Scale: As Shown
Portland District, Portland, Oregon — October 1, 1948
Prepared ..... Submitted .....
Head, Technical Services Section — Head, Engineering Planning Branch
Recommended ..... Approved .....
Chief, Engineering Division — Colonel, Corps of Engineers, District Engineer
Drawn By: W.F. ..... Traced By: L.M.A. ..... Checked By: H.K.T. ..... Transmitted with report dated October 1, 1948 CL-05-9/11


PLAN
SCALE IN FEET
SECTION A-A
LOCK PLAN
SCALE IN FEET
ELEVATION LOOKING UPSTREAM
SCALE IN FEET
SPILLWAY SECTION
SCALE IN FEET
SECTION C-C
SCALE IN FEET
SECTION B-B
SCALE IN FEET
COFFERDAM PLAN
SCALE IN FEET
INTAKE AND POWERHOUSE SECTION
SCALE IN FEET
RATING CURVES
WASHINGTON
OREGON
COLUMBIA
RIVER
POWER HOUSE
SPILLWAY
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
JOHN DAY DAM
NORMAL POOL EL. 210
NAVIGATION & POWER
Scale: As Shown
October 1, 1948
CL-05-7/63



1. The "power at 100 percent load factor" curve and the "regulated discharge" curve are based on the Phase C system power study for the period October 1927 through September 1942, under the following conditions:
   a. Discharges are modified by future irrigation for initial development in the Snake River Basin and for ultimate development elsewhere.
   b. Flathead Lake is regulated for a minimum discharge of 4,300 cubic feet per second.
   c. 817,000 Acre-feet of existing storage in Kootenay Lake (Canada) are used in the interest of Corra Linn Power Plant.
   d. The following storages are used in the interest of the system:

Hungry Horse	2,980,000	acre-feet
Glacier View	3,160,000	" "
Paradise	4,080,000	" "
Albeni Falls	1,140,000	" "
Grand Coulee	5,118,000	" "
Hells Canyon	3,280,000	" "

   e. A deduction of 2,000 cubic feet per second at the site for leakage, fish migration, miscellaneous uses, and losses has been made. Over-all plant efficiency is assumed at 88 percent.
2. The tailwater curve is shown as affected by The Dalles headwater. See Reference No. 1.
3. Nominal prime capability is the average output for the critical months of the system critical power period: September 1, 1929 to March 1, 1932. See Reference No. 2.
4. Average annual energy production equals 4,100,000,000 kw hrs.

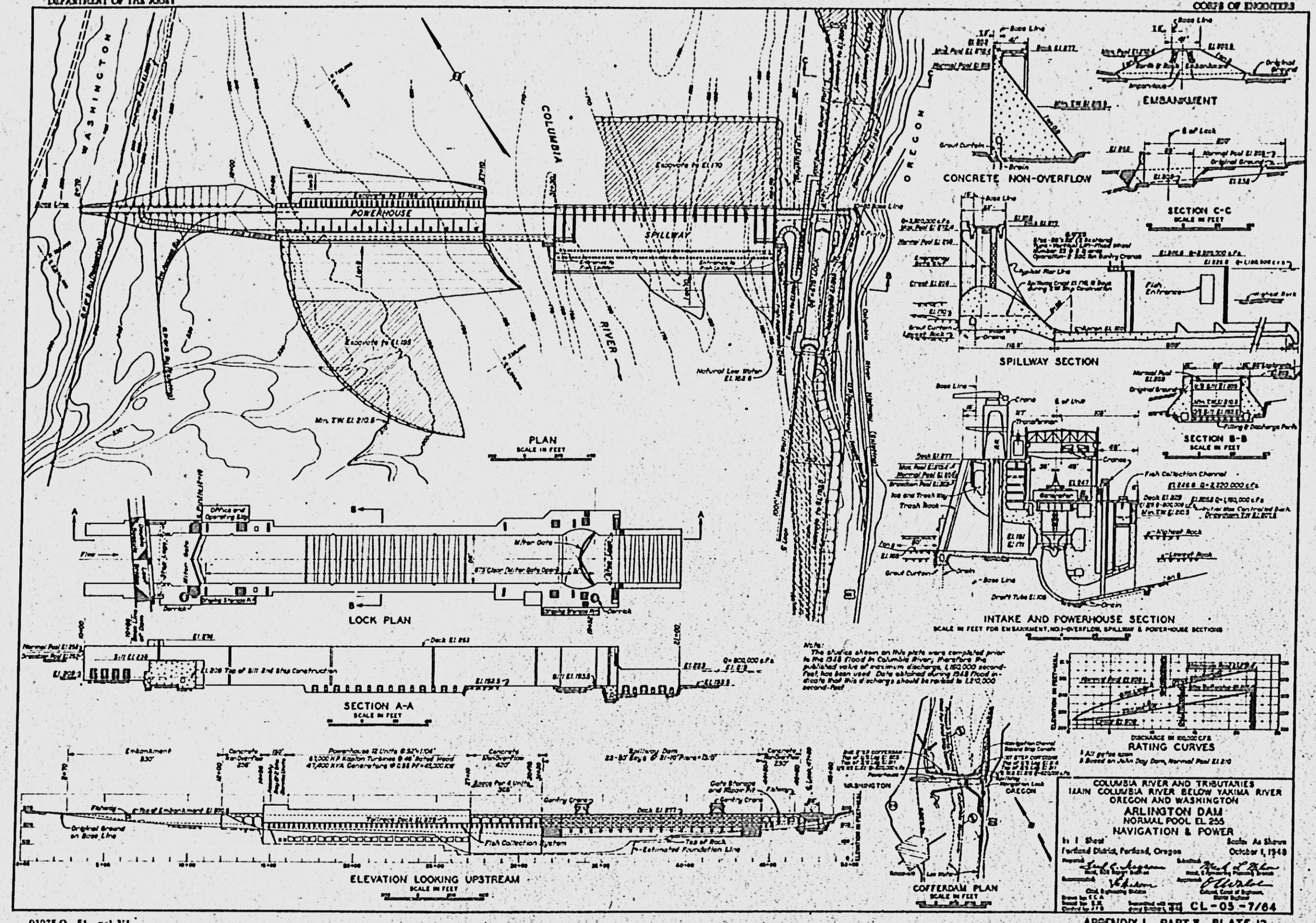
REFERENCES

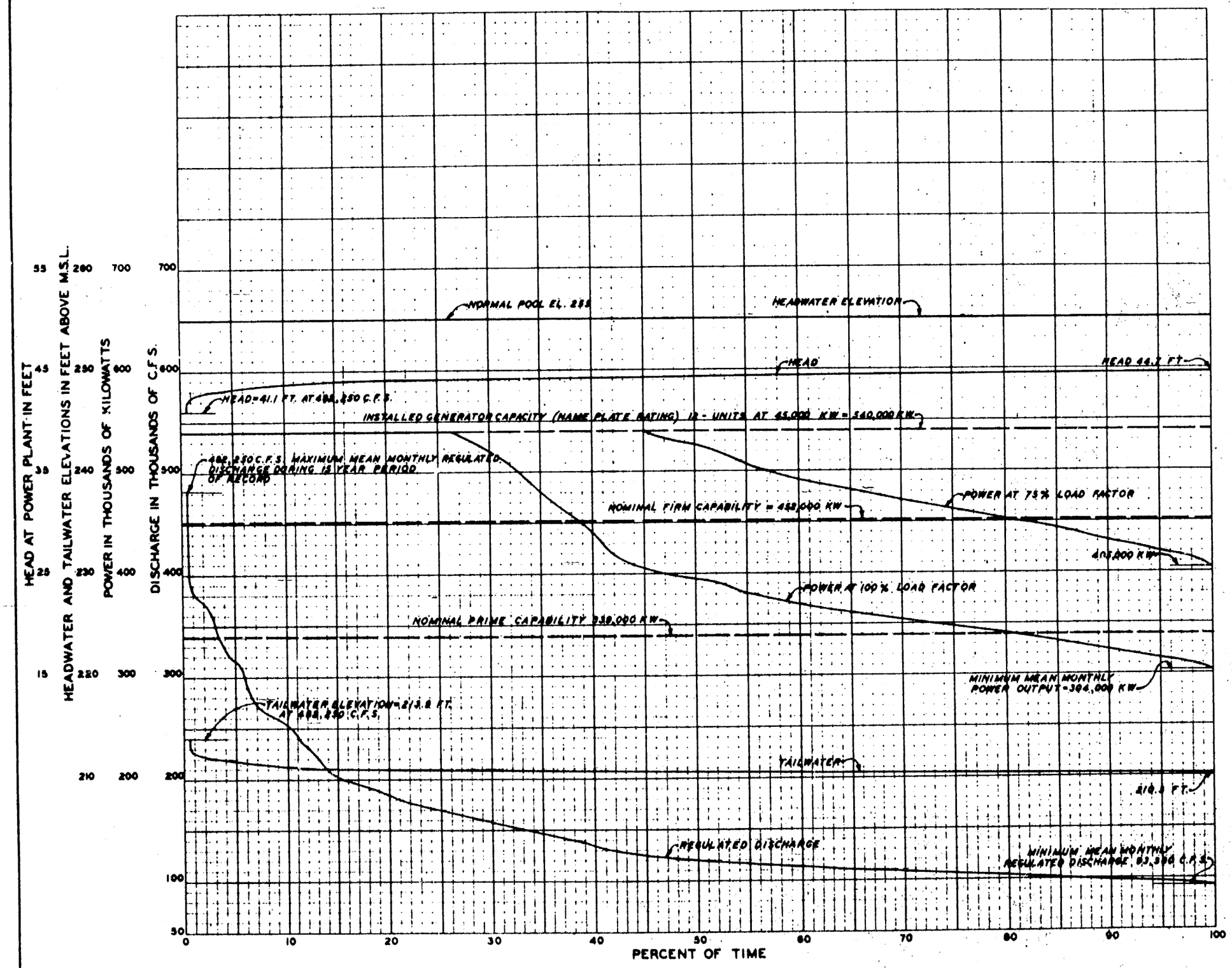
1. Appendix O Chart 31 "John Day (Pool Elev. 210) Storage, Headwater, Tailwater, Power Output, and Plant Capability."
2. Appendix O Chart 48 "John Day (Pool Elev. 210) Discharge and Power Graphs 1927 - 1942."

COLUMBIA RIVER AND TRIBUTARIES
JOHN DAY
(POOL ELEVATION 210)
POWER PLANT CHARACTERISTICS
PHASE C DEVELOPMENT

In 1 Sheet — Scale: As Shown
Portland District, Portland, Oregon — October 1, 1948
Prepared: Head, Water Control Section I — Submitted: Head, Engr. Planning Branch
Recommended: Chief, Engineering Division — Approved: Colonel, Corps of Engineers, District Engineer
Drawn By: E.V.W.
Traced By: V.J.R. — Transmitted with report dated October 1, 1948
Checked By: W.H.K.

CL-05-9/10


WASHINGTON
COLUMBIA
RIVER
OREGON
POWERHOUSE
SPILLWAY
PLAN
SCALE IN FEET
LOCK PLAN
SECTION A-A
SCALE IN FEET
EMBANKMENT
CONCRETE NON-OVERFLOW
SECTION C-C
SCALE IN FEET
SPILLWAY SECTION
SECTION B-B
SCALE IN FEET
INTAKE AND POWERHOUSE SECTION
SCALE IN FEET FOR EMBANKMENT, NON-OVERFLOW, SPILLWAY & POWERHOUSE SECTIONS
Note:
The studies shown on this plate were completed prior to the 1948 flood in Columbia River, Therefore the published value of maximum discharge, 1,160,000 second-feet has been used. Data obtained during 1948 flood indicate that this discharge should be revised to 1,210,000 second-feet
RATING CURVES
ELEVATION LOOKING UPSTREAM
SCALE IN FEET
COFFERDAM PLAN
SCALE IN FEET
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
ARLINGTON DAM
NORMAL POOL EL. 255
NAVIGATION & POWER
Sheet
Scale: As Shown
Portland District, Portland, Oregon
October 1, 1948
CL-05-7/64



1. The "power at 100 percent load factor" curve and the "regulated discharge" curve are based on the Phase C system power study for the period October 1927 through September 1942, under the following conditions:
   a. Discharges are modified by future irrigation for initial development in the Snake River Basin and for ultimate development elsewhere.
   b. Flathead Lake is regulated for a minimum discharge of 4,300 cubic feet per second.
   c. 817,000 Acre-feet of existing storage in Kootenay Lake (Canada) are used in the interest of Corra Linn Power Plant.
   d. The following storages are used in the interest of the system:

Hungry Horse	2,980,000	acre-feet
Glacier View	3,160,000	" "
Paradise	4,080,000	" "
Albeni Falls	1,140,000	" "
Grand Coulee	5,118,000	" "
Hells Canyon	3,280,000	" "

   e. A deduction of 2,000 cubic feet per second at the site for leakage, fish migration, miscellaneous uses, and losses has been made. Over-all plant efficiency is assumed at 88 percent.
2. The tailwater curve is shown as affected by The Dalles headwater. See Reference No. 1.
3. Nominal prime capability is the average output for the critical months of the system critical power period: September 1, 1929 to March 1, 1932. See Reference No. 2.
4. Average annual energy production equals 3,720,000,000 kw hrs.

REFERENCES

1. Appendix O Chart 30. "Arlington (Pool Elev. 255) Storage, Headwater, Tailwater, Power Output, and Plant Capability."
2. Appendix O Chart 47 "Arlington (Pool Elev. 255) Discharge, and Power Graphs 1927 - 1942."

COLUMBIA RIVER AND TRIBUTARIES

ARLINGTON
(POOL ELEVATION 255)

POWER PLANT CHARACTERISTICS

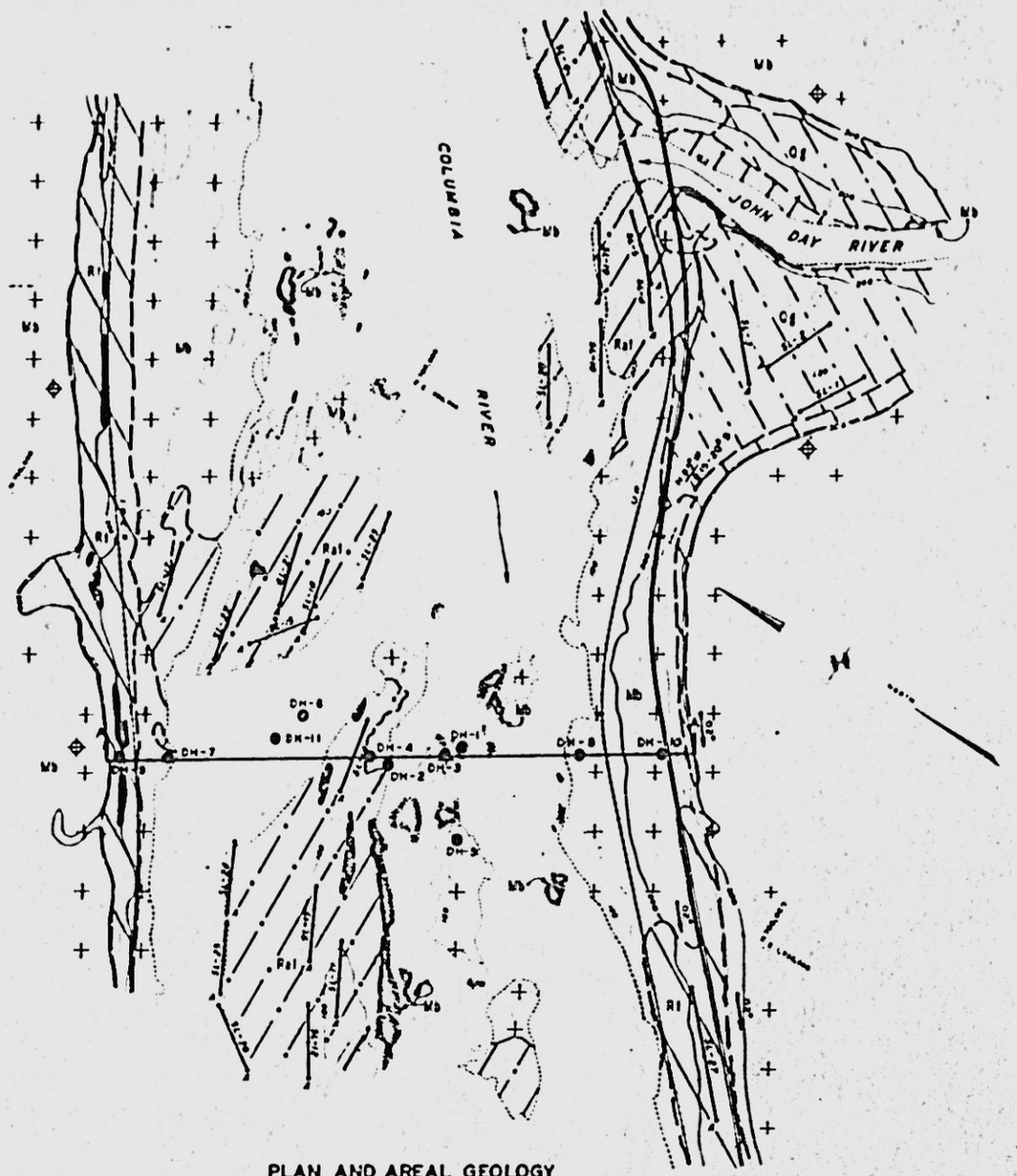
PHASE C DEVELOPMENT

In 1 Sheet — Scale: As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared: C.A.B. — Submitted: [illegible]
Head, Technical Services Section — Head, Engineering Division
Recommended: [illegible] — Approved: [illegible]
Chief, Engineering Division — Colonel, Corps of Engineers, District Engineer
Drawn By: C.A.B.
Traced By: L.M.B. — Transmitted with report dated October 1, 1948
Checked By: H.P.T.

CL-05-9/9

APPENDIX L PART II PLATE 13

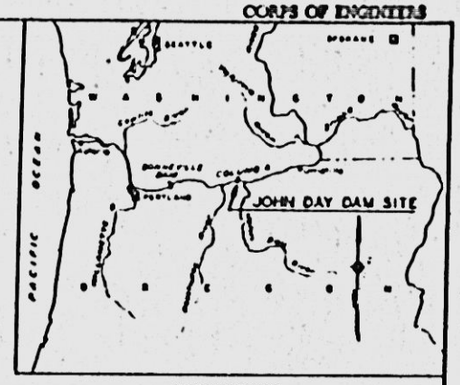


PLAN AND AREAL GEOLOGY

SCALE IN FEET

LEGEND FOR PLAN AND AREAL GEOLOGY

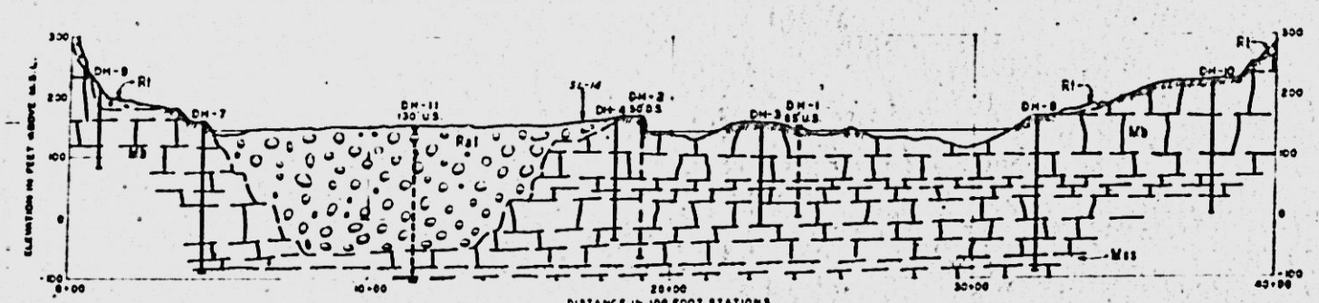
- Ral — RECENT ALLUVIUM - RIVER DEPOSITED SAND AND GRAVEL
- Ri — TALUS, SAND, AND SILT - GENERALLY OVERLYING BEDROCK AT SHALLOW DEPTH
- Os — PLEISTOCENE GRAVEL AND SAND - ROUGHLY STRATIFIED, OVERLAIN IN PART BY BLOW SAND
- Mb — MIOCENE COLUMBIA RIVER BASALT - FREQUENTLY OBSCURED BY THIN SAND AND TALUS DEPOSITS
- SMALL ROCK OUTCROP
- GEOLOGIC CONTACT
- STRIKE AND DIP
- COMPONENT DIP
- HORIZONTAL STRATA
- DH-1 — CORE DRILL HOLE
- DH-6 — CORE DRILL HOLE ABANDONED BEFORE REACHING BEDROCK
- SEISMIC LINE
- GEOLOGIC SECTION



REGIONAL MAP
SCALE IN MILES

LEGEND FOR SECTION

- Ral — RECENT ALLUVIUM
- Ri — RECENT TALUS
- Mb — MIOCENE COLUMBIA RIVER BASALT
- Mss — MIOCENE SANDSTONE INTERBED - SOFT, FINE-GRAINED, WITH SHALY SEAMS
- GEOLOGIC CONTACT
- ROCK OUTCROP
- DH-3 — CORE DRILL HOLE IN SECTION
- DH-1 85'U.S. — CORE DRILL HOLE PROJECTED INTO SECTION
- SL-14 — SEISMIC LINE



SECTION A-A

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

JOHN DAY DAM SITE

PLAN, AREAL GEOLOGY, AND SECTION

In 1 Sheet — Scale As Shown

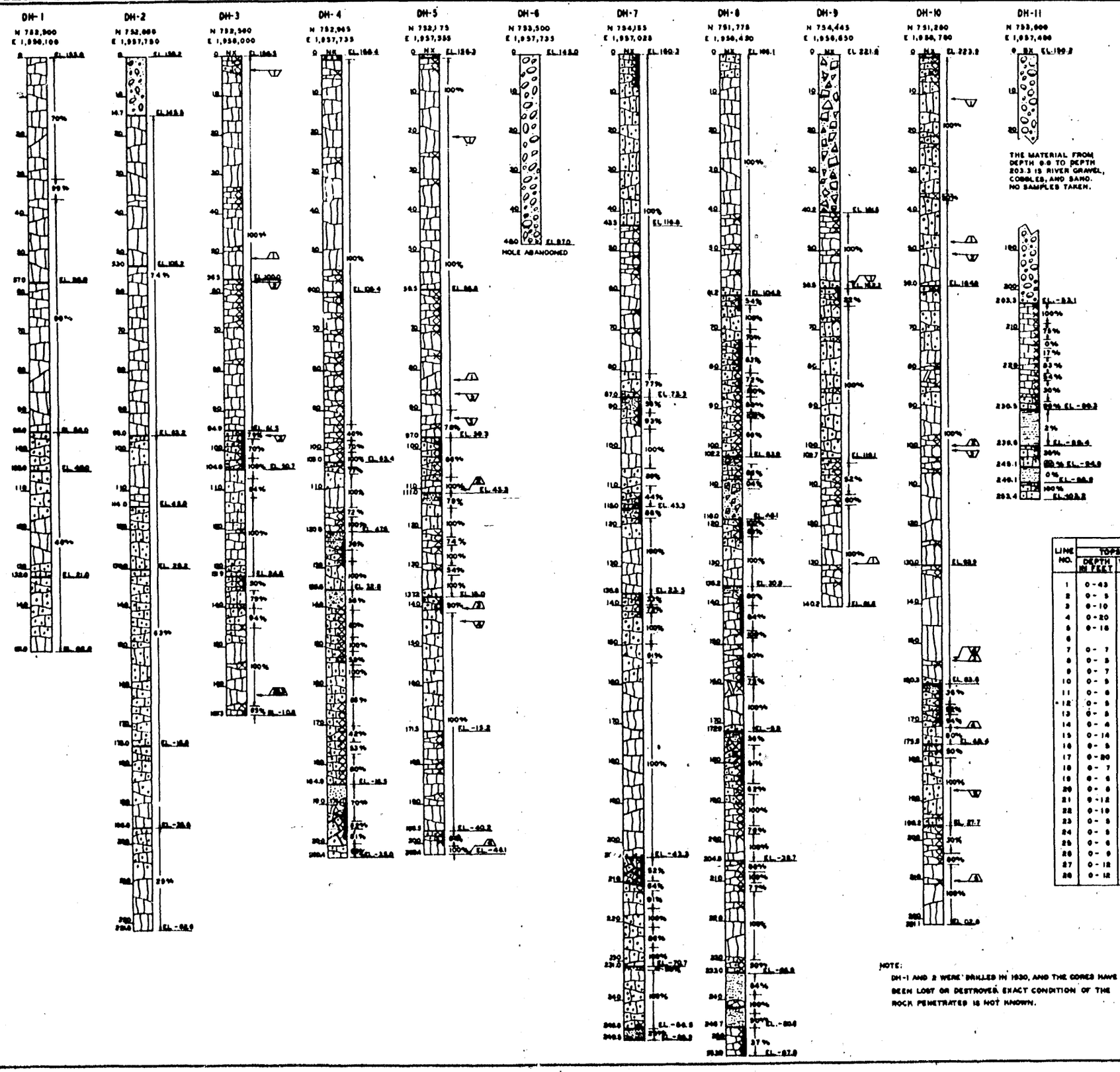
Portland District, Portland, Oregon — October 1, 1948

Chief, Engineering Division — Colonel, Corps of Engineers, District Engineer

Drawn by: F.W.T.
Traced by: E.V.M.
Checked by:

Submitted with report dated October 1, 1948

CL-05-7/65



LEGEND

OVERBURDEN

- BASALT TALUS, MIXED WITH SAND
- RIVER GRAVEL, COBBLES, AND SAND

BEDROCK

- BASALT - DENSE, HARD, FRACTURED
- BASALT, VESICULAR, MOD HARD TO HARD
- BRECCIATED BASALT - TOP OF FLOW MATERIAL
- SOIL ZONES OR INTERBEDS BETWEEN BASALT FLOWS COMPOSED PRIMARILY OF SAND AND ROCK FRAGMENTS
- SOIL ZONES OR INTERBEDS BETWEEN BASALT FLOWS COMPOSED PRIMARILY OF CLAY AND SILT WITH SOME SAND, FREQUENTLY GREENISH COLOR
- SANDSTONE - SOFT, FINE GRAINED, FRIABLE, MICACEOUS, THIN, CONTORTED BEDDING WITH FREQUENT SHALY SEAMS, BROWN TO GRAYISH COLOR

NX 2 1/8" CORE
BX 1 5/8" CORE

- ZONE OF CLOSE FRACTURES
- ZONE OF WEATHERING
- 100% PERCENT CORE RECOVERY
- LIMITS OF INDIVIDUAL WATER TEST

SEISMIC DATA

LINE NO.	OVERBURDEN: TOPSOIL DEPTH IN FEET	TOPSOIL VELOCITY FT/SEC.	INTERMEDIATE DEPTH IN FEET	INTERMEDIATE VELOCITY FT/SEC.	INTERMEDIATE DEPTH IN FEET	INTERMEDIATE VELOCITY FT/SEC.	ROCK: DEPTH TO ROCK IN FEET	ROCK VELOCITY FT/SEC.	DISTANCE CENTER TO END
1	0 - 43	1300	43->113	7500			>113		250
2	0 - 5	1000	5->105	1000			>105		250
3	0 - 10	1100	10 - 95	1600	95->105	6000	>105		250
4	0 - 20	900					20	9,300	250
5	0 - 15	900					15	8,600	250
6			0->76	3000			> 76		250
7	0 - 7	1000	7 - 35	2000			35	13,000	250
8	0 - 5	2000	5 - 44	3100			44	11,200	250
9	0 - 7	1500	7 - 30	2400			30	14,200	250
10	0 - 5	2000	5 - 39	3500			39	15,000	250
11	0 - 8	1600	8 - 37	2700			37	15,700	250
12	0 - 5	2000	5 - 25	3100			25	15,000	250
13	0 - 5	1000	5 - 31	3300			31	8,000	250
14	0 - 4	1500	4 - 27	2000			27	16,200	250
15	0 - 14	1000	14->84	7500			> 84		250
16	0 - 5	1000	5 - 33	4300	33->97	6100	> 97		250
17	0 - 20	1000					20	17,500	250
18	0 - 7	2400	7 - 51	7700			51	12,400	250
19	0 - 6	1200	6->90	7300			> 90		250
20	0 - 8	1500	8->97	7300			> 97		250
21	9 - 12	3000	12->98	7300			> 98		250
22	0 - 10	2400					10	16,500	250
23	0 - 5	2500	5 - 43	4700			43	15,000	250
24	0 - 5	2400	5->84	7600			> 84		250
25	0 - 6	2500	6->92	7003			> 92		250
26	0 - 9	2500	9 - 80	8500			80	14,700	250
27	0 - 12	1100					12	12,100	450
28	0 - 12	1000					12	8,000	450

NOTE:
DH-1 AND 2 WERE DRILLED IN 1930, AND THE CORES HAVE BEEN LOST OR DESTROYED. EXACT CONDITION OF THE ROCK PENETRATED IS NOT KNOWN.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
JOHN DAY DAM SITE
LOGS OF DRILL HOLES

In 1 Sheet — Scale: As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared: Chief, Geologic and Exploration Section
Submitted: Acting Chief, Soils and Geology Branch
Recommended: Chief, Engineering Division
Approved: Colonel, Corps of Engineers, District Engineer

Drawn by F.W.T.
Traced by R.E.M.
Checked by F.W.T.
Presented with report dated October 1, 1948

CL-05-7/66

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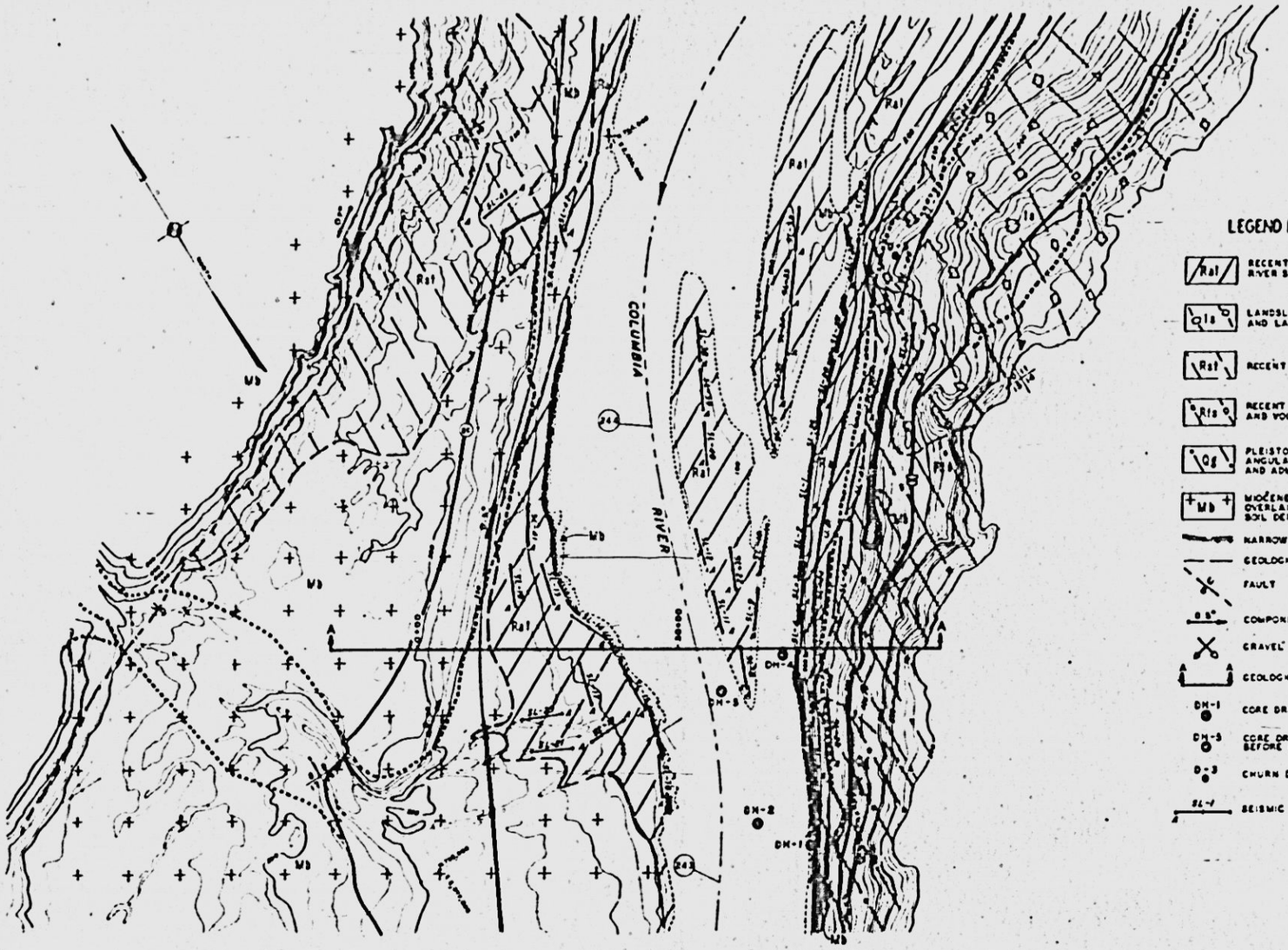
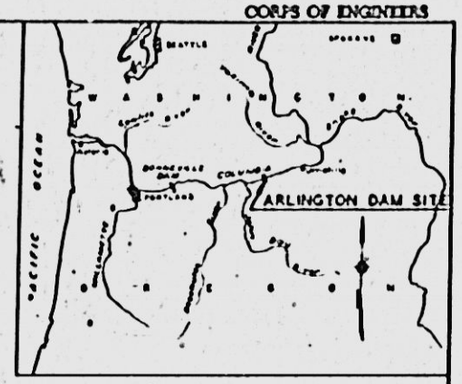


PLAN AND AREAL GEOLOGY

SCALE IN FEET



REGIONAL MAP

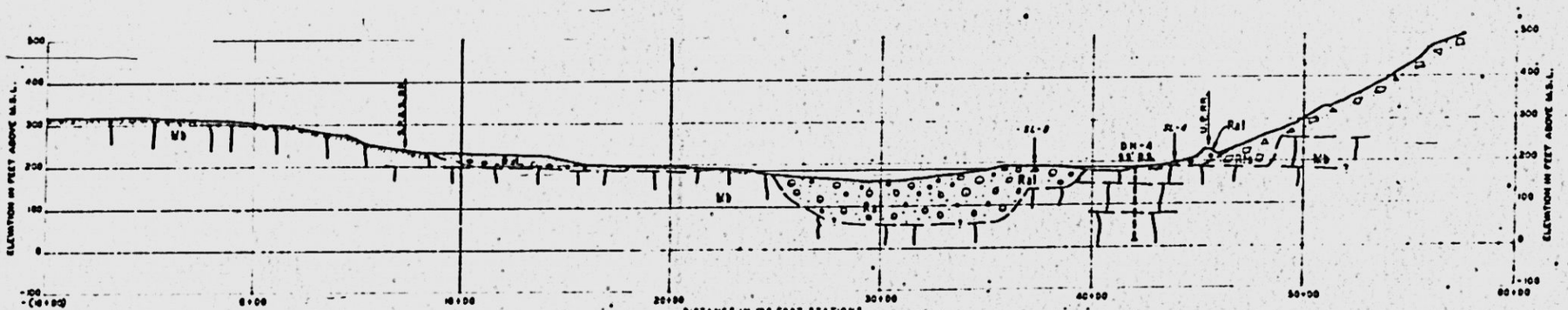
SCALE IN MILES

LEGEND FOR PLAN AND AREAL GEOLOGY

- Ral — RECENT ALLUVIUM - UNCONSOLIDATED RIVER SAND AND GRAVEL
- Qls — LANDSLIDE - SAND, SILT, ROCK FRAGMENTS, AND LARGE BASALT BLOCKS - MAY BE UNSTABLE
- Ral — RECENT SANDY SOIL AND TALUS
- Rts — RECENT BOULDER TALUS ADMIXED WITH SAND, SILT, AND VOLCANIC ASH, CONTAINING LARGE BASALT BLOCKS
- Qg — PLEISTOCENE GRAVEL, CONTAINING SAND AND ANGULAR ROCK FRAGMENTS - OVERLAIN BY AND ADMIXED WITH BOULDER TALUS
- Mb — MIOCENE COLUMBIA RIVER BASALT - MAY BE OVERLAIN IN PLACES BY BLOW SAND AND SOIL DEPOSITS A FEW FEET THICK
- NARROW ROCK OUTCROP
- GEOLOGIC CONTACT
- FAULT
- 0.5° — COMPONENT DIP
- GRAVEL PIT
- GEOLOGIC SECTION
- DH-1 — CORE DRILL HOLE
- DH-3 — CORE DRILL HOLE ABANDONED BEFORE REACHING BEDROCK
- D-3 — CHURN DRILL HOLE TO BEDROCK
- SL-1 — SEISMIC LINE

LEGEND FOR SECTION

- Ral — RECENT ALLUVIUM
- Rts — RECENT BOULDER TALUS
- Mb — MIOCENE COLUMBIA RIVER BASALT
- BEDROCK OUTCROP
- GEOLOGIC CONTACT
- SL-8 — SEISMIC LINE
- DH-4 — CORE DRILL HOLE PROJECTED INTO SECTION



SECTION A-A

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

ARLINGTON DAM SITE

PLAN, AREAL GEOLOGY, AND SECTION

In 1 Sheet — Scale: As Shown

Portland District, Portland, Oregon — October 1, 1948

Prepared: Head, Geologic and Exploration Section

Submitted: Army Head, Soils and Foundations Branch

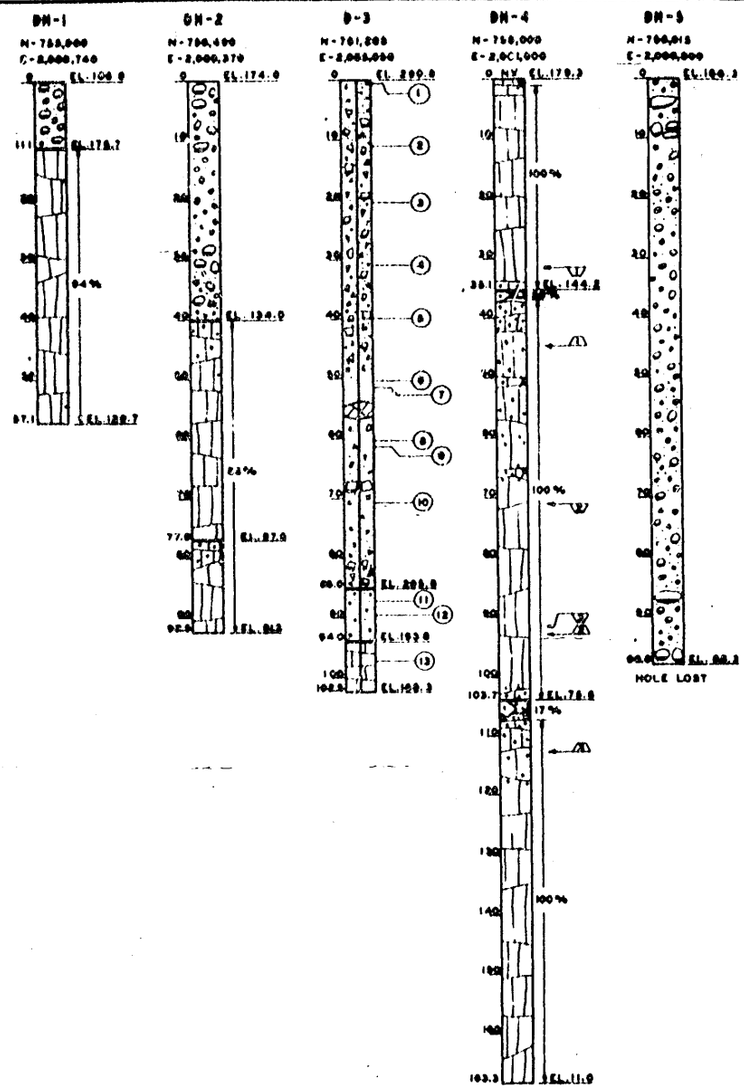
Recommended: Chief, Engineering Division

Approved: Colonel, Corps of Engineers, District Engineer

Drawn by: F.W.T.
Traced by: R.V.W.
Checked by:

Recommended with revisions dated October 1, 1948

CL-05-7/67



SEISMIC DATA

LINE NO	OVERBURDEN TOPSOIL DEPTH IN FEET	OVERBURDEN TOPSOIL VELOCITY FT/SEC.	OVERBURDEN INTERMEDIATE DEPTH IN FEET	OVERBURDEN INTERMEDIATE VELOCITY FT/SEC.	ROCK DEPTH TO ROCK IN FEET	ROCK VELOCITY FT/SEC	DISTANCE CENTER TO END
1	0 - 6	2600			8	20,000	250
2	0 - 10	9000			10	18,000	250
3	0 - 5	3200			5	18,500	250
4	0 - 4	5100			4	18,000	250
5	0 - 7	5000			7	18,000	250
6	0 - 6	2000			6	18,100	250
7	0 - 5	1700			5	15,800	250
8	0 - 6	1400	6 - 55	8300	55	17,500	250
9	0 - 10	2200			10	17,000	250
10	0 - 11	4000			11	18,000	250
11	0 - 10	2000			10	18,500	250
12	0 - 7	1200	7 - 31	7200	31	18,500	250
13	0 - 6	4200			6	17,500	250
14	0 - 6	3300			6	11,000	250
15	0 - 6	1500			6	15,000	250
16	0 - 8	1800			8	15,000	250
17	0 - 12	2300			12	16,000	250
18	0 - 7	1500			7	16,700	250
19	0 - 8	800	8 - 33	3300	33	17,000	250
20	0 - 6	1500			6	14,000	250
21	0 - 10	1500			10	20,000	250
22	0 - 7	1300	7 - >75	8300	>75		250
23	0 - 7	1000	7 - 40	2900	40	15,100	250
24	0 - 6	1000	6 - 41	4000	41	13,200	250
25	0 - 4	2200			4	16,200	250
26	0 - 6	2000			6	15,300	250
27	0 - 2	2000			2	14,100	250
28	0 - 3	3400			3	13,000	250
29	0 - 6	2500			6	13,700	250
30	0 - 6	1200	6 - 21	3400	21	9,163	250
31	0 - 13	2100			13	11,600	250
32	0 - 9	1600	9 - 40	6200	40	13,100	250
33	0 - 8	1500	8 - 30	5700	30	14,100	250
34	0 - 8	1400	8 - 50	6600	36	14,100	250
35	0 - 7	1360	7 - 26	5700	26	15,600	250
36	0 - 7	3900	7 - 32	7400	32	15,100	250
37	0 - 8	1800	8 - 46	7400	46	14,000	250
38	0 - 6	1800	6 - 42	7000	42	15,500	250
39	0 - 6	1300	6 - 34	7500	34	12,600	250
40	0 - 6	1400	6 - 16	5600	16	10,400	250
41	0 - 6	2000			6	13,500	250
42	0 - 5	2000			5	12,200	250
43	0 - 8	1200			8	9,000	250
44	0 - 8	800	8 - 44	3000	44	11,000	450
45	0 - 8	1300	8 - 30	2000	36	13,100	450
46	0 - 7	1000	7 - 57	2800	57	6,000	450
47	0 - 5	1000	5 - 55	3100	55	8,500	450
48	0 - 13	1100			13	6,000	450
49	0 - 15	2000			15	8,500	450

LEGEND

OVERBURDEN

SAND

GRAVEL

COBBLES AND ROUNDED BOULDERS

ANGULAR ROCK FRAGMENTS

SUPERPOSITION OF ABOVE SYMBOLS DENOTES MIXTURES OF MATERIALS

BEDROCK

BASALT - HARD, DENSE, JOINTED, DARK GRAY TO BLACK

BASALT - MODERATELY HARD TO HARD, VESICULAR, JOINTED, DARK GRAY TO BLACK

BRECCIATED BASALT, CHARACTERISTIC OF TOP OF FLOW - MODERATELY HARD, BRITTLE, CLINKERY, LOCALLY VESICULAR

NX 2 1/8" CORE

ZONE OF WEATHERING OR OXIDATION

ZONE OF CLOSE FRACTURES

100% PERCENT CORE RECOVERY

LIMITS OF INDIVIDUAL WATER PRESSURE TEST

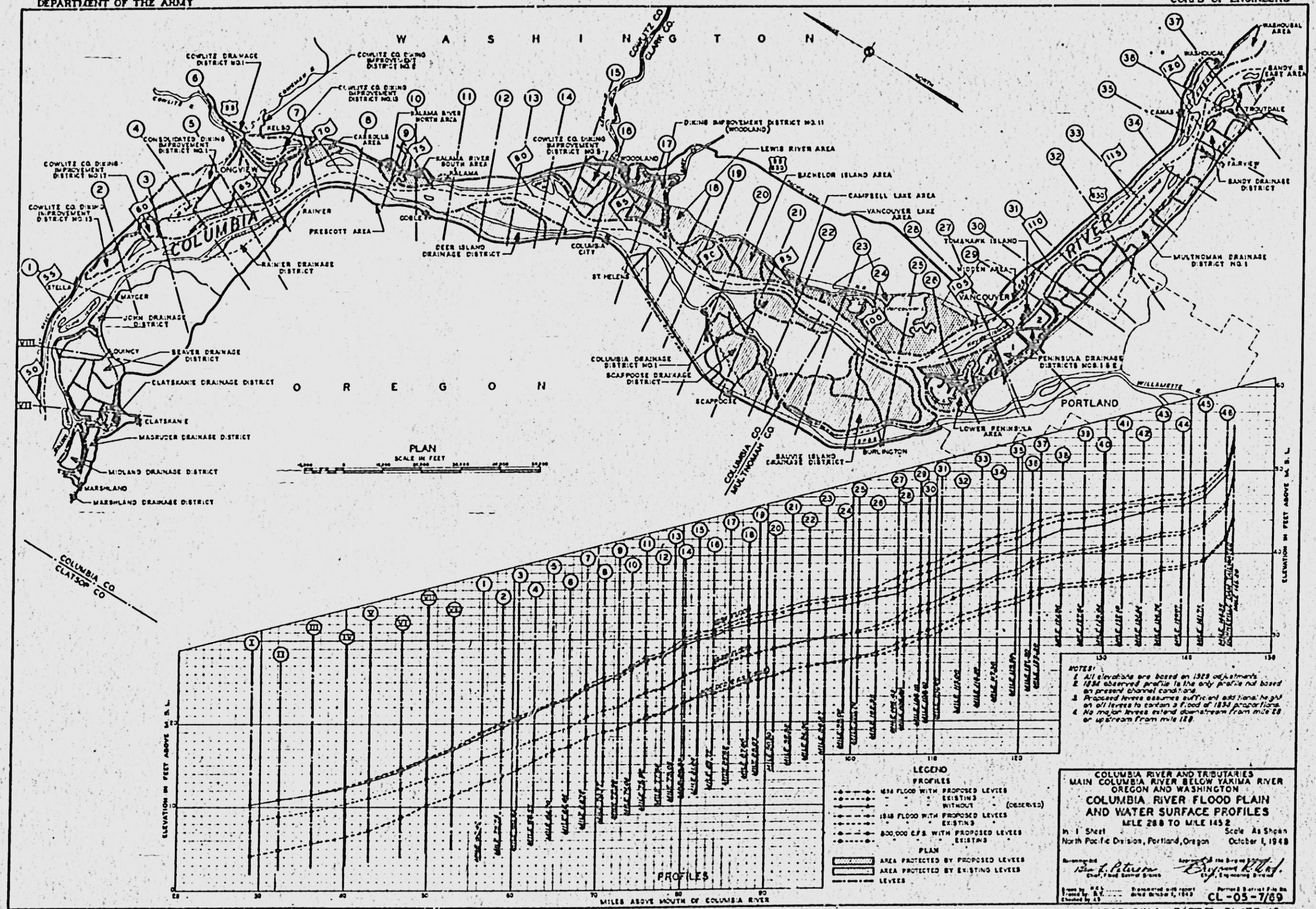
NOTE:
HOLES DH-1 & 2 WERE DRILLED IN 1930 AND THE CORES HAVE BEEN LOST OR DESTROYED. EXACT CONDITION OF THE ROCK IS NOT KNOWN.

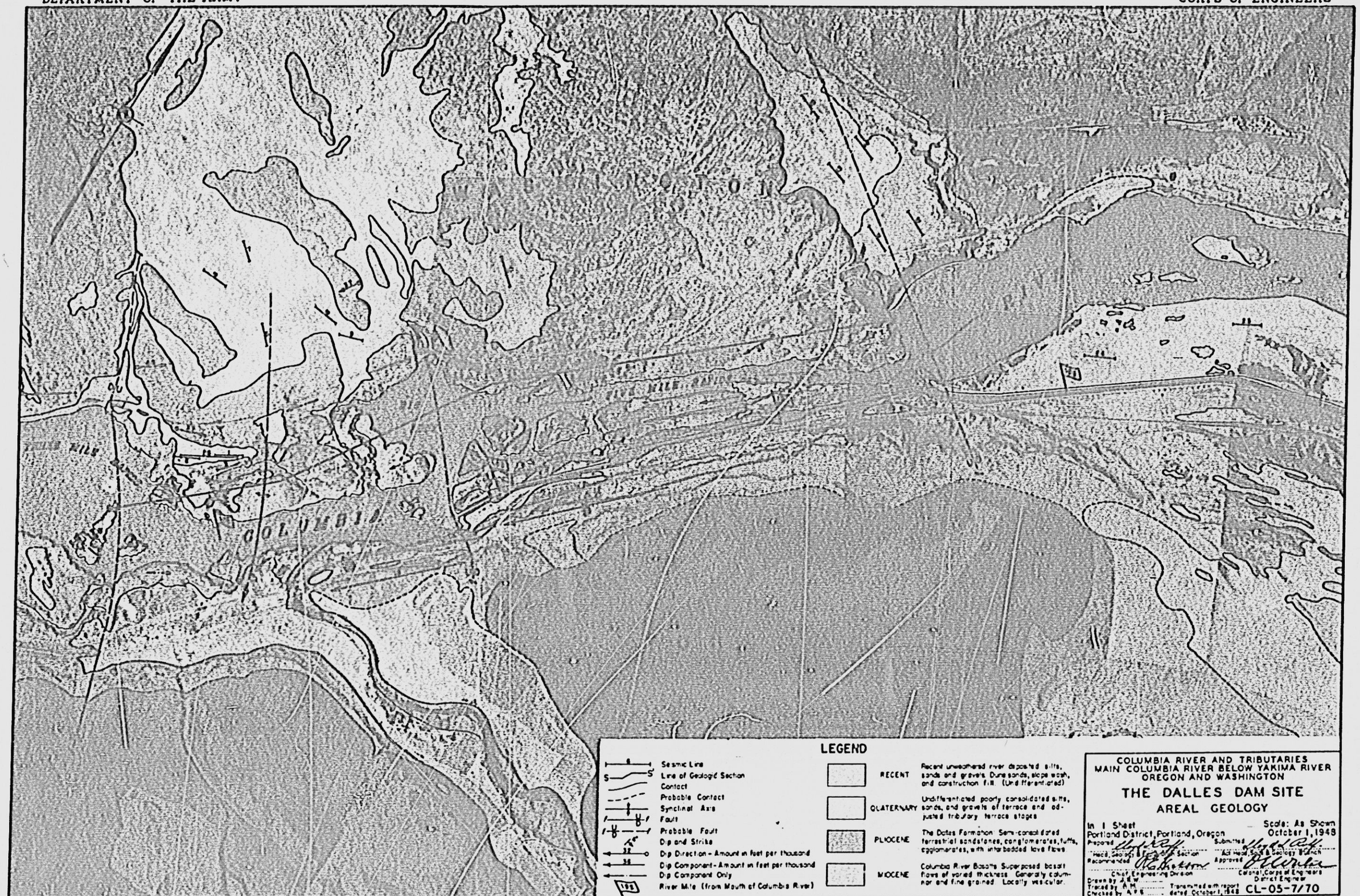
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

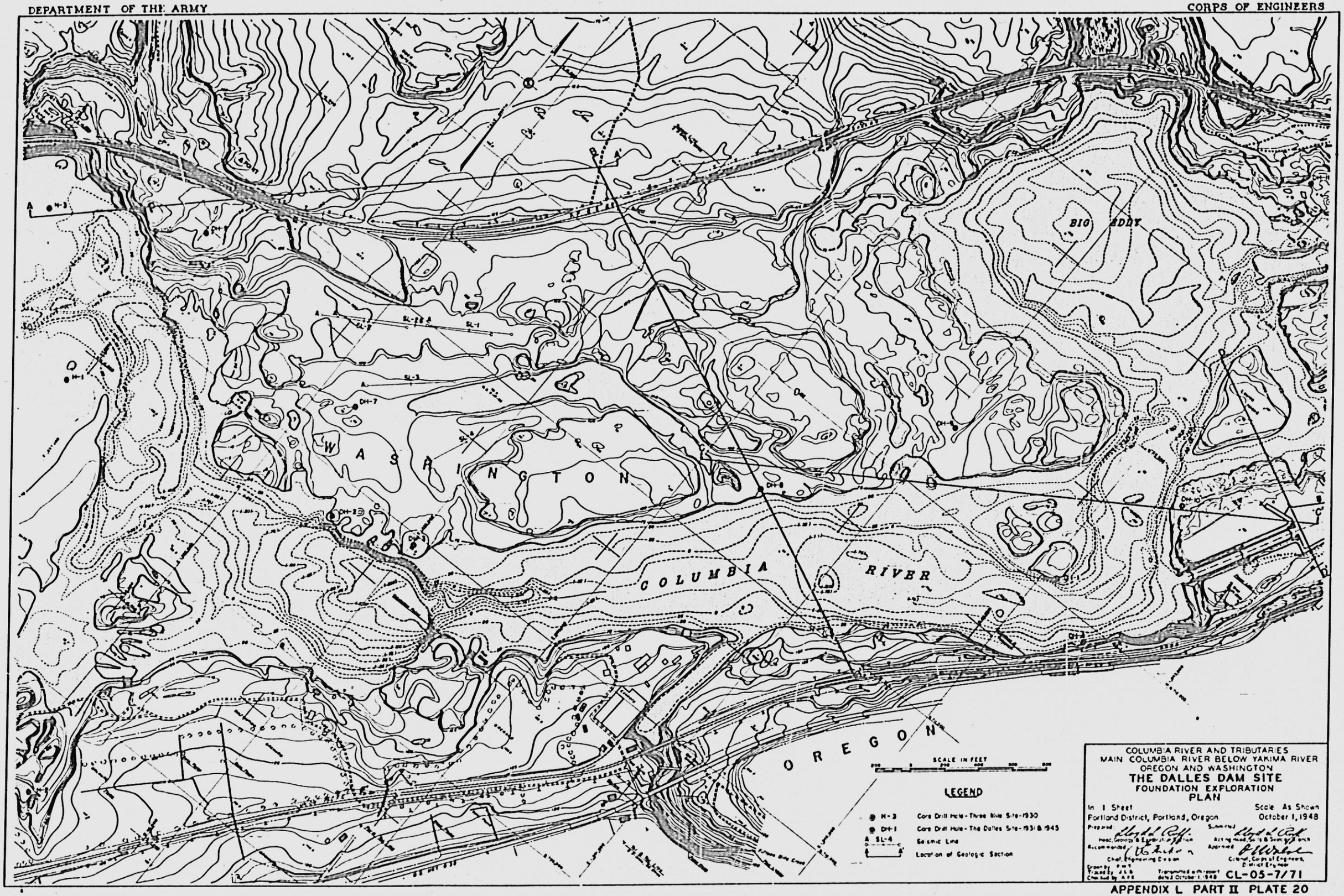
ARLINGTON DAM SITE
LOGS OF DRILL HOLES

In 1 Sheet — Scale: As Shown
Portland District, Portland, Oregon — October 1, 1949

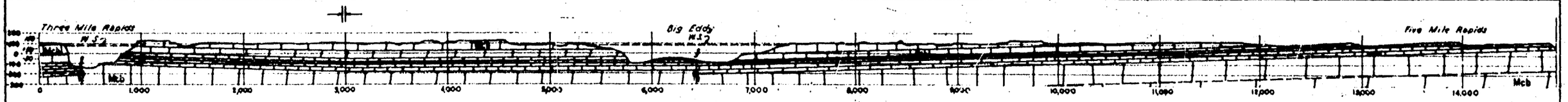
CL-05-7/68


WASHINGTON
OREGON
COLUMBIA RIVER
PLAN
SCALE IN FEET
PROFILES
MILES ABOVE MOUTH OF COLUMBIA RIVER
ELEVATION IN FEET ABOVE M.S.L.
COWLITZ DRAINAGE DISTRICT NO.1
COWLITZ CO. DIKING IMPROVEMENT DISTRICT NO.2
COWLITZ CO. DIKING IMPROVEMENT DISTRICT NO.3
CONSOLIDATED DIKING IMPROVEMENT DISTRICT NO.1
COWLITZ CO. DIKING IMPROVEMENT DISTRICT NO.11
COWLITZ CO. DIKING IMPROVEMENT DISTRICT NO.13
LONGVIEW
RELSO
CARROLLS AREA
KALAMA RIVER NORTH AREA
KALAMA RIVER SOUTH AREA
KALAMA
COWLITZ CO. DIKING IMPROVEMENT DISTRICT NO.8
WOODLAND
DIKING IMPROVEMENT DISTRICT NO.11 (WOODLAND)
LEWIS RIVER AREA
BACHELOR ISLAND AREA
CAMPBELL LAKE AREA
VANCOUVER LAKE AREA
RAINIER
PRESCOTT AREA
GOBLE
DEER ISLAND DRAINAGE DISTRICT
COLUMBIA CITY
ST. HELENS
RAINIER DRAINAGE DISTRICT
STELLA
MAYGER
JOHN DRAINAGE DISTRICT
QUINCY
BEAVER DRAINAGE DISTRICT
CLATSKANIE DRAINAGE DISTRICT
CLATSKANIE
MASRUDER DRAINAGE DISTRICT
MIDLAND DRAINAGE DISTRICT
MARSHLAND
MARSHLAND DRAINAGE DISTRICT
COLUMBIA DRAINAGE DISTRICT NO.1
SCAPPOOSE DRAINAGE DISTRICT
SCAPPOOSE
COLUMBIA CO.
MULTNOMAH CO.
COWLITZ CO.
CLARK CO.
COLUMBIA CO.
CLATSOP CO.
SAUVIE ISLAND DRAINAGE DISTRICT
BURLINGTON
TOMAHAWK ISLAND
HAYDEN AREA
VANCOUVER
LOWER PENINSULA AREA
PENINSULA DRAINAGE DISTRICTS NOS. 1 & 2
PORTLAND
WILLAMETTE
MULTNOMAH DRAINAGE DISTRICT NO.1
WASHOUGAL AREA
WASHOUGAL
SANDY R. EAST AREA
CAMAS
TROUTDALE
FAIRVIEW
SANDY DRAINAGE DISTRICT
NOTES:
1. All elevations are based on 1929 adjustments.
2. 1894 observed profile is the only profile not based on present channel conditions.
3. Proposed levees assumes sufficient additional height on all levees to contain a flood of 1894 proportions.
4. No major levees extend downstream from mile 28 or upstream from mile 188.
LEGEND
PROFILES
1894 FLOOD WITH PROPOSED LEVEES
EXISTING
WITHOUT (OBSERVED)
1948 FLOOD WITH PROPOSED LEVEES
EXISTING
800,000 C.F.S. WITH PROPOSED LEVEES
EXISTING
PLAN
AREA PROTECTED BY PROPOSED LEVEES
AREA PROTECTED BY EXISTING LEVEES
LEVEES
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
COLUMBIA RIVER FLOOD PLAIN AND WATER SURFACE PROFILES
MILE 288 TO MILE 145.2
In 1 Sheet
Scale As Shown
North Pacific Division, Portland, Oregon
October 1, 1948
CL-05-7/69

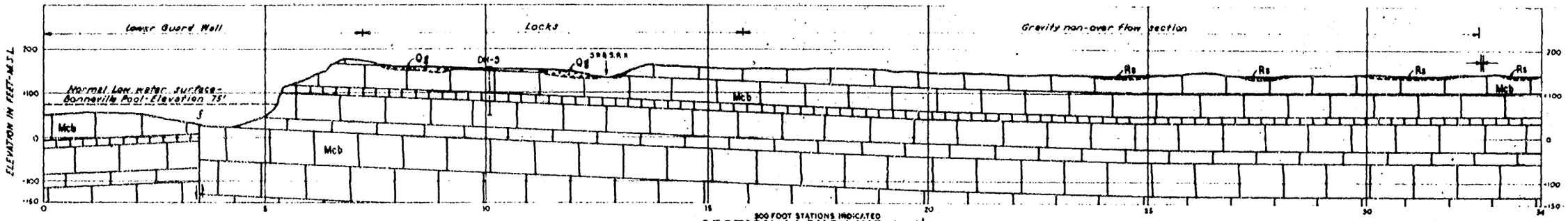

COLUMBIA
LEGEND
Seismic Line
Line of Geologic Section
Contact
Probable Contact
Synclinal Axis
Fault
Probable Fault
Dip and Strike
Dip Direction - Amount in feet per thousand
Dip Component - Amount in feet per thousand
Dip Component Only
River Mile (from Mouth of Columbia River)
RECENT
Recent unweathered river deposited silts, sands and gravels. Dune sands, slope wash, and construction fill. (Undifferentiated)
QUATERNARY
Undifferentiated poorly consolidated silts, sands, and gravels of terrace and adjusted tributary terrace stages
PLIOCENE
The Dalles Formation. Semi-consolidated terrestrial sandstones, conglomerates, tuffs, agglomerates, with interbedded lava flows
MIOCENE
Columbia River Basalts. Superposed basalt flows of varied thickness. Generally columnar and fine grained. Locally vesicular.
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
THE DALLES DAM SITE
AREAL GEOLOGY
In 1 Sheet
Scale: As Shown
Portland District, Portland, Oregon
October 1, 1948
Prepared
Submitted
Head, Geology & Engineering Section
Asst Head, Soil & Geology Branch
Recommended
Approved
Chief, Engineering Division
Colonel, Corps of Engineers
District Engineer
Drawn by J.R.W.
Traced by A.M.
Checked by A.P.S.
Transmitted with report dated October 1, 1948
CL-05-7/70



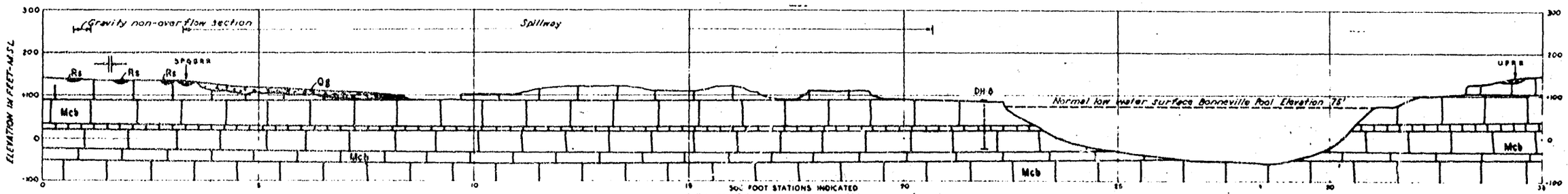
91275 O—51—vol. VI



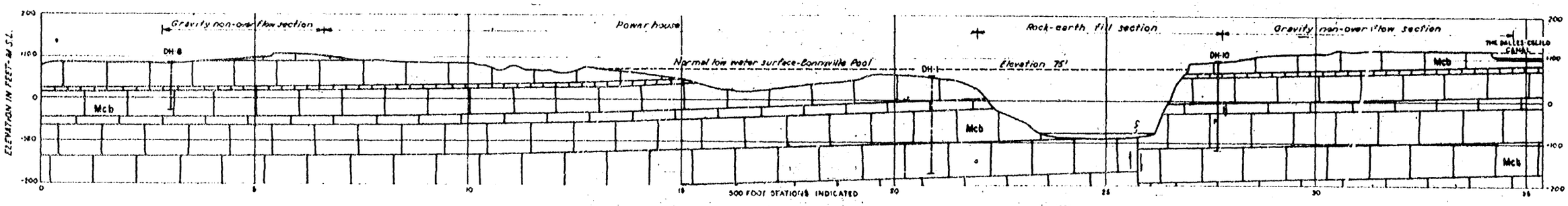
GEOLOGIC CROSS-SECTION S-S'



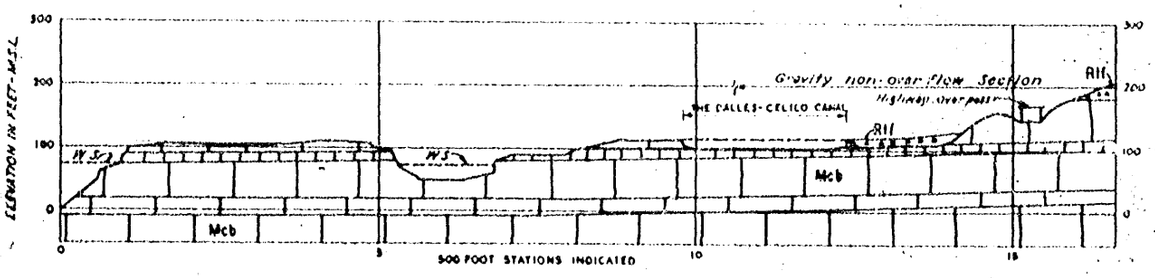
SECTION ALONG LINE A-A'



SECTION ALONG LINE B-B'



SECTION ALONG LINE C-C'



SECTION ALONG LINE D-D'

LEGEND

- Rs — Recent — Topsoil, sands, and dune sands
- Rff — Recent — Talus and fill
- Qg — Quaternary — Sands and gravels
- Mcb — Miocene — Columbia River Basalts
- DH-10 — Drill Hole on Line of Section
- DH-3 — Drill Hole Projected Into Line of Section
- Fault
- Syncline

GRAPHIC SCALES

SECTION S-S'

500 FOOT STATIONS SECTIONS A-A' TO D-D'

NOTE - LINE OF SECTION S-S' SHOWN ON PLATE 19. LINES OF SECTIONS A-A' TO D-D' SHOWN ON PLATE 20.

COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON

THE DALLES DAM SITE
FOUNDATION EXPLORATION
GEOLOGICAL CROSS-SECTIONS

In 1 Sheet — Scale: As Shown
Portland District, Portland, Oregon — October 1, 1948

Prepared: Lloyd L. Ruff, Head, Geology & Exploration Section
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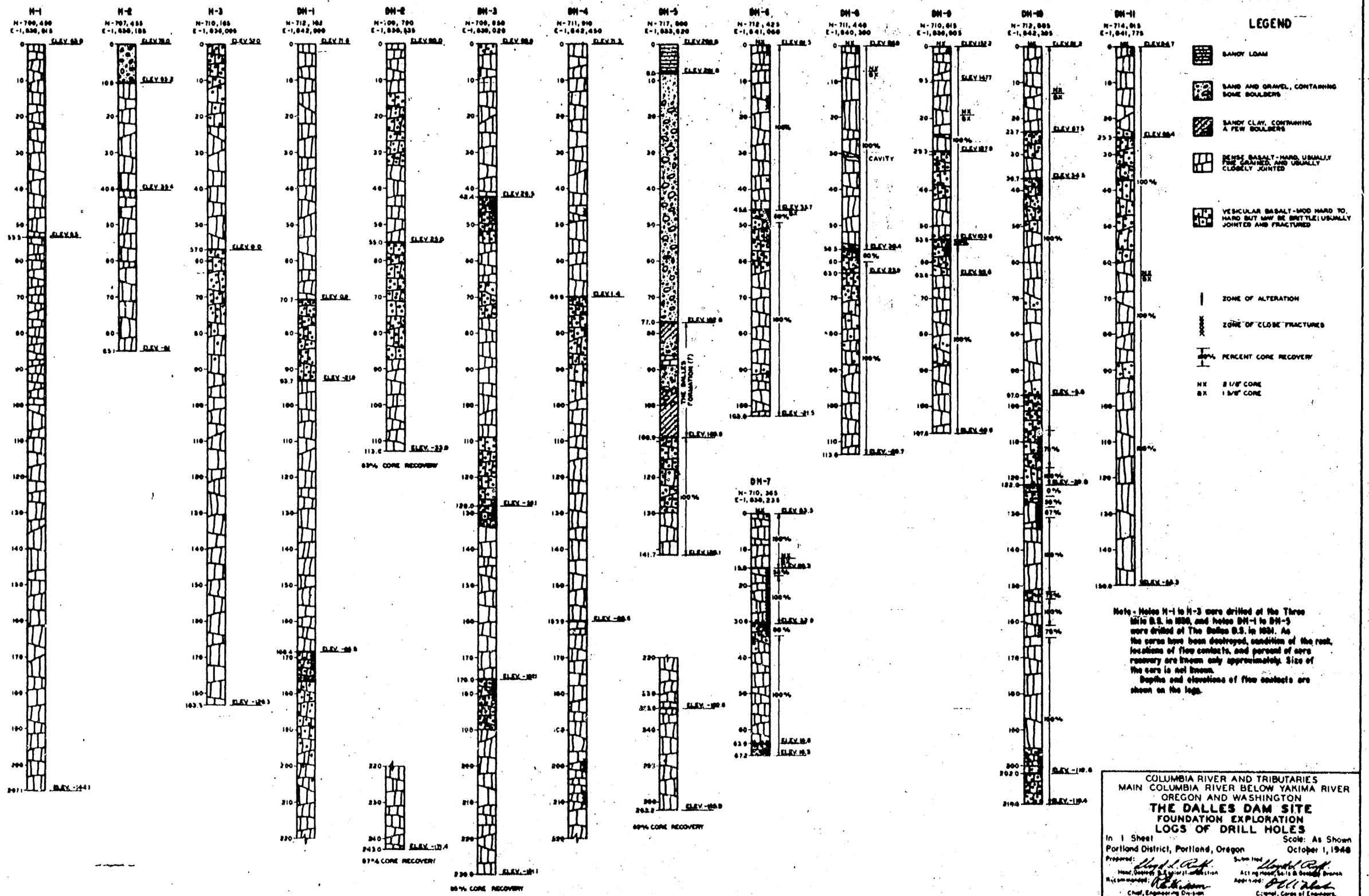
H-1
H-2
H-3
DH-1
DH-2
DH-3
DH-4
DH-5
DH-6
DH-7
DH-8
DH-9
DH-10
DH-11
THE DALLES FORMATION (?)
CAVITY
63% CORE RECOVERY
87% CORE RECOVERY
86% CORE RECOVERY
60% CORE RECOVERY
LEGEND
SANDY LOAM
SAND AND GRAVEL, CONTAINING SOME BOULDERS
SANDY CLAY, CONTAINING A FEW BOULDERS
DENSE BASALT - HARD, USUALLY FINE GRAINED, AND USUALLY CLOSELY JOINTED
VESICULAR BASALT - MOD HARD TO HARD BUT MAY BE BRITTLE; USUALLY JOINTED AND FRACTURED
ZONE OF ALTERATION
ZONE OF CLOSE FRACTURES
PERCENT CORE RECOVERY
NX 2 1/8" CORE
BX 1 5/8" CORE
Note - Holes H-1 to H-3 were drilled at the Three Mile B.S. in 1930, and holes DH-1 to DH-5 were drilled at The Dalles B.S. in 1931. As the cores have been destroyed, condition of the rock, locations of flow contacts, and percent of core recovery are known only approximately. Size of the core is not known.
Depths and elevations of flow contacts are shown on the logs.
COLUMBIA RIVER AND TRIBUTARIES
MAIN COLUMBIA RIVER BELOW YAKIMA RIVER
OREGON AND WASHINGTON
THE DALLES DAM SITE
FOUNDATION EXPLORATION
LOGS OF DRILL HOLES
In 1 Sheet
Scale: As Shown
Portland District, Portland, Oregon
October 1, 1948
Prepared:
Submitted:
Recommended:
Approved:
Chief, Engineering Division
Colonel, Corps of Engineers, District Engineer
Transmitted with report dated October 1, 1948
CL-05-7/73