Syllabus

Skagit River, the largest stream tributary to Puget Sound, is subject to floods that cause considerable damage, chiefly to the farm lands downstream from Burlington. Local interests, through the expenditure of over $3,000,000 for the construction and maintenance of dikes and drainage ditches, have provided partial protection to the farming areas and to Burlington and Mount Vernon.

The Avon By-pass, adopted by the Flood Control Act of 1936, would provide protection to the delta area for all floods up to the maximum of actual record. Local interests do not desire the construction of the by-pass at this time because of the large contribution required of them by the terms of the Flood Control Act.

The district engineer believes that a modification of the details of the existing flood control project can be developed that would reduce the cost of local cooperation, and that the project might be extended to provide for partial control of erosion.

He therefore recommends that a survey be authorized to determine the elements, cost and economic justification of such a modification.

WAR DEPARTMENT
United States Engineer Office
Seattle, Washington

March 29, 1937

Subject: Report on preliminary examination of Skagit River and tributaries, Washington.

To: The Division Engineer, North Pacific Division, Portland, Oregon.

I. INTRODUCTION

1. Authority. - The following report, with one map, on preliminary examination of Skagit River and its tributaries, Washington, with a view to the control of floods, is submitted in compliance with the following acts of Congress:

(a) The act of Congress approved June 13, 1934 (Public No. 331, 73rd Congress, H. R. 3383) reads as follows:

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that the Secretary of War be, and he is hereby, authorized and directed to cause a preliminary examination to be made of the Skagit River and its tributaries in the State of Washington, with a view to the control of its floods, in accordance with the provisions of section 3 of an Act entitled "An Act to provide for the control of the floods of the Mississippi River, and of the Sacramento River, California, and for other purposes", approved March 1, 1917, the cost thereof to be paid from appropriations heretofore and hereafter made for examinations, surveys, and contingencies of rivers and harbors."

(b) Section 6 of the Act of Congress approved June 22, 1936 (Public No. 738, 74th Congress, H. R. 8455) provides that:

> "The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following named localities, and the Secretary of Agriculture is authorized and directed to cause preliminary examinations and surveys for run-off and waterflow retardation and soil erosion prevention on the watersheds of such localities; the cost thereof to be paid from appropriations heretofore or hereafter made for such purposes:
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> Skagit River and tributaries, Washington.
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2. Scope of investigation. - No field surveys have been made in connection with the preparation of the present report. The data for this report h been taken largely from a report prepared under the provisions of House Docu No. 308, Sixty-ninth Congress, first session, and published as House Document No. 187, Seventy-third Congress, second session, modified where necessary, to conform with data made available since the publication of that document.

3. Data available and prior reports. - In the preparation of this report the following reports were available:

Various river and harbor preliminary examination and survey reports.

Report on preliminary examination of Skagit River, Washington, with a view to control of the floods, published as House Document No. 125, Sixty-ninth Congress, first session.

Report on Skagit River under the provisions of House Document No. 308, Sixty-ninth Congress, first session, and published as House Document No. 187, Seventy-third Congress, second session.

Discharge records, both published and unpublished, by the United States Geological Survey.

Reconnaissance soil survey of the eastern part of the Puget Sound Basin, Washington. United States Department of Agriculture, Bureau of Soils.

4. Existing project. - The Flood Control Act of 1936 (Public No. 738, 74th Congress, H. R. 8455) authorizes a project for the partial control of floods in the lower valley by diversion of part of the flood waters through a by-pass to be constructed between the river at Avon and Padilla Bay, together with channel widening and bank revetting between Burlington and Avon, with concrete control works at the head of the by-pass and a concrete weir near the outlet, all at an estimated cost of $3,130,100 for construction and $1,832,000 for lands and damages (House Document No. 187, 73rd Congress, 2nd session) subject to the provisions that local interests shall provide without cost to the United States all lands, easements and rights-of-way necessary for the construction of the project, hold and save the United States free from damages due to the construction works; and maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of War. The latest published maps are in the project document.

II. GENERAL DESCRIPTION OF DRAINAGE AREA

5. General description. - Skagit River, the largest stream tributary to Puget Sound, has its source in Canada, 28 miles by river north of the international boundary, and thence flows southerly and southwesterly for 135 miles to Skagit Bay, an arm of Puget Sound. Skagit basin touches, on the north, the basins of Nooksack, Fraser and Samish Rivers, on the east the basins of streams tributary to Columbia River, and on the south the basins of Stillaguamish and Snohomish Rivers.

6. About three miles downstream from Mount Vernon, which is ten miles above the mouth, the river divides and passes through two main and several lesser channels into Skagit Bay. The two main channels, North Fork and South Fork, are navigable for light-draft vessels. At the present time, the North Fork is the one principally used and, unless otherwise noted, its mouth will be considered as the mouth of the river. The tidal effect extends to the Great Northern Railway bridge, 15.5 miles above the mouth. The tidal range between mean low water and mean high water at La Conner, adjacent to the mouth of the river, is 7.7 feet; between mean lower low water and mean higher high water, is 11.1 feet; and the extreme range is about 19 feet.

7. The drainage basin of Skagit River and its tributaries, comprising an area of 3,140 square miles, of which 390 square miles are in Canada, lies on the western slope of the Cascade Mountains.

8. The two largest tributaries of the Skagit are the Sauk and Baker Rivers. Other important tributaries are the Cascade River, Thunder Creek and Ruby Creek, all of which head in the higher Cascades.

9. Sauk River enters the Skagit from the south, near the town of Rockport; it is 46 miles long and drains an area of 729 square miles. The Suiattle River is the most important tributary of the Sauk. The Sauk and the Suiattle completely surround Glacier Peak, in Snohomish County, taking all the run-off from its extensive glacial fields.

10. Baker River has its source on the eastern slope of Mount Shuksan, flows southward about 24 miles, passing through Baker and Shannon Lakes (the latter an artificial reservoir created by the power dam of the Puget Sound Power and Light Company) and joins the Skagit at the town of Concrete. The drainage basin of Baker River covers 270 square miles. The river derives a considerable portion of its flow from the glacial fields of Mounts Baker and Shuksan.

11. Altitudes within the Skagit Basin range from sea level to 8,000 feet at the crest of the Cascade Range, to 10,750 feet at the summit of Mount Baker, 10,436 feet at Glacier Peak (Snohomish County), 9,088 feet at Mount Shuksan, and to 8,894 feet at Glacier Peak (Whatcom County.) Part of the basin upstream

from Concrete lies above the timber line and within the zone of perpetual snow and ice.

12. Up to elevations of about 4,000 feet, the area was timbered with a growth of Douglas fir, hemlock and some cedar, but most of this stand adjacent to tidewater has been cut off. Above the timber line, which is at an elevation of approximately 6,000 feet, much of the surface is barren rock. Two-thirds of the entire Skagit Basin lies within the Mount Baker National Forest.

13. The delta area of Skagit Basin, which lies downstream from Sedro Woolley, is composed of rich alluvial soil. At higher elevations the prevailing soil is a coarse glacial gravel.

14. Geology. - Various publications of the Washington State Geological Survey have been freely drawn upon for the following. The eastern sections of the Skagit drainage area are very rugged and mountainous, much of the higher area being barren rock. All of the higher summits are glacier-clad and stand out in sharp contrast with the flat lowland of the delta section. The intervening lower lands and hills are more rolling and underneath the growth of vegetation are largely covered with a vast mantle of unconsolidated gravel, sand and clay left there by the advance and retreat of the great ice sheets of the past.

15. During some past age a profound deformation of the rocks took place in the form of a great upheaval in a more or less east-and-west direction through the center of Skagit County. Later on, erosion removed a vast quantity of the sediments, leaving remnants of the strata flanking the sides of this great upheaval. The upheaval was not without complications, and wrinkles were formed across the great raised area. Subsequent to this deformation period came the glacial epoch, as indicated by a number of channels of prehistoric streams as well as numerous fresh-water lakes.

16. At one time the Suiattle and Lower Sauk reached tidewater through the North Fork of the Stillaguamish River. Similarly, the upper six miles of South Fork of Sauk River was once the head of the South Fork of the Stillaguamish.

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The present divide between the Sauk and the North Fork of the Stillaguamish at Darrington is apparently a glacial moraine.

17. Soils. - The "Reconnaissance Soil Survey of the eastern part of the Puget Sound Basin, Washington", prepared by the Bureau of Soils, United States Department of Agriculture, in 1909, lists three principal types of valley soils in the Skagit Basin. In a comparatively narrow strip along the river and its tributaries lies a fine sandy loam soil, generally with good natural drainage. This soil, derived from the finer sand and silt deposited along their banks by the swifter currents of the rivers and their larger tributaries during times of overflow, is well adapted to the growing of nearly all truck, forage and orchard crops.

18. The extensive delta area of the Skagit Basin consists of silty clay or silt loam soils, laid down by overflow of the river. The natural drainage of the loam type is, in general, good, although that of the clay type is very poor and artificial drainage is necessary to permit cultivation. Each of these types is extremely productive. Oats, wheat, potatoes, vegetables, and small fruits are extensively grown.

19. The upland areas, lying between the valley and the surrounding hills consist of a gravelly sand loam, derived from the weathering of glacial drift. This soil, because of its excessive natural drainage, is not suited to general farming, but may be made to produce profitable yields by intensive cultivation. Little of the soil of this type in the Skagit Basin is under cultivation.

20. Cities and population. - The population within the Skagit Basin is about 22,800 (1930 census), 17,300 residing west of Sedro Woolley, in an area of 170 square miles. East of Sedro Woolley, area 2,970 square miles, the population is about 5,500, about two persons to the square mile. The six incorporated cities or towns in the basin - all of them below the mouth of the Sauk - have populations as follows:

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Burlington	1,407
Concrete	736
Hamilton	252
Lyman	441
Mount Vernon (County seat Skagit County)	5,690
Sedro Woolley	2,719

21. La Conner, with a population of 549, is located within the broadly defined delta area, although strictly speaking it is just outside of the drainage basin proper. Everett, with a population of 30,567, and Seattle, with a population of 365,583, 38 and 66 miles, respectively, to the southward of Mount Vernon; and Bellingham, with a population of 30,823, 28 miles to the northward, are the principal nearby cities.

22. Railways. - The coast line of the Great Northern Railway between Everett, Washington and Vancouver, B.C., crosses the western end of the Skagit Valley in a north-and-south direction, passing through Mount Vernon and Burlington; and a branch line runs westward from Burlington to Anacortes, and eastward to Rockport, paralleling the river. From Rockport, a railroad, owned and operated by the city of Seattle, continues on up the river to Diablo Dam, a distance of 30 miles.

23. The Northern Pacific Railway between Seattle, Washington, and Vancouver, B. C., also crosses the western end of the valley, passing through Sedro Woolley; a branch line from the Stillaguamish Valley extends into Darrington.

24. Highways. - The Pacific Highway crosses the western end of the Skagit Valley in a general north-and-south direction, paralleling the Great Northern Railway, passing through Mount Vernon and Burlington. Other paved highways aggregating about 70 miles in length and numerous gravel and improved dirt roads, lie within the basin and lead to outside points.

25. National and departmental reservations. - About 2,100 square miles of the Skagit River Basin is included within the Mount Baker National Forest. There are no other reservations involved. However, included within the forest area are two recreation areas, two game preserves and a primitive area.

26. Resources and local industries. - Farming, with its allied pursuits of dairying, poultry raising and seed production, is the principal industry of the Skagit Basin, followed in importance by lumbering and cement manufacturing. Since 1932 oysters have been grown on the tide lands of Padilla Bay. The delta of the river contains some of the richest and most productive farming land in the state. The uplands are more valuable for forestation than for agriculture.

27. Forest resources. - Based on data furnished by the Northwest Forest Experiment Station, United States Forest Service, it is estimated that there is in the Skagit Basin 19,180,843 thousand board feet of timber, of which 12,896,000 thousand board feet is within Mount Baker National Forest; the remainder being held in state, county, municipal, or private ownership. The approximate composition of this stand by species is shown in the following tabulation:

Species	Total Stand Thousand Board Feet
Douglas fir	4,159,481
Spruce	60,428
Hemlock	6,947,656
Cedar	2,965,184
Silver fir	4,518,246
Other conifers	456,504
Hardwoods	78,375
Total	19,180,843

28. In 1951 the daily capacity of logging companies operating within the Skagit Basin, amounted to 2,500 thousand board feet. The annual cut of logs is believed to be between 250,000 and 300,000 thousand board feet.

29. With the exception of lumber cut at Rockport, Lyman, Mount Vernon and Sedro Woolley by mills having a combined daily capacity of about 150 thousand board feet, practically all lumber is cut at tidewater. It is probable that only a small part of the remaining timber will be taken out by river.

30. Agriculture. - Mr. V. J. Valentine, County Agricultural agent for Skagit County, has estimated that the annual value of farm produce grown in the Skagit River Basin is about $8,420,000, itemized as follows:

Grain	$ 986,000
Vegetables and vegetable seeds	2,183,000
Hay and forage	1,033,000
Fruits and nuts	377,000
Dairy products	3,500,000
Poultry and poultry products	1,250,000
Meat products	100,000
Total	$9,429,000

31. It is stated that the Skagit delta produces 90 percent of the cabbage seed, 50 percent of the garden-beet seed, and 30 percent of the turnip and rutabaga seed used in the United States. Two canneries within the basin and three others at nearby points, furnish a market for the fruit and vegetable produce of the valley. Much of the milk produced is shipped as fresh milk to the Puget Sound consuming centers, the remainder being condensed and canned locally.

32. Mineral resources. - The only mineral resources that have been developed are at Concrete, where materials are quarried for the manufacture of Portland cement, and at various other points where sand and gravel is excavated. The cement factory at Concrete has a daily capacity of 6,000 barrels.

33. The oyster industry. - For a number of years Japanese (Pacific) oysters have been raised successfully on Washington tide lands, notably in Willapa Harbor in southwestern Washington, and in Samish Bay. In 1932 the first planting of oysters was made in Padilla Bay. Two companies are now operating in Padilla Bay: One with a holding of 3,200 acres and the other with 8,000 acres of potential oyster lands. An attempt is being made by one of these companies to use native-grown seed from the now full-grown imported stock.

34. The oyster "seed", as imported from Japan, is attached to cast-off oyster shells and sown on the beds. Marketing of the mature oysters is commenced, in Padilla Bay in from three to four years after planting, although in Willapa Harbor oysters reach comparable size in about eighteen months. Plantings of imported seed by one of the Padilla Bay companies have been as follows,

(Company data for 1932, 1933, 1934 and 1936; 1935 data from other sources):

Year	Imported cases planted	Value
1932	14,500	$ 80,000
1933	18,820	93,500
1934	47,716	262,500
1935	8,500	12,750
1936	0	0

35. Oyster lands are sold as tide lands by the State of Washington for $1.25 per acre. Some of the oyster companies own and operate their own lands, others have bought large areas and then sold small tracts therefrom to individuals, the operating management being retained in the parent company. Many tracts have changed hands for from $100 to $200 per acre, and it is reported, for as much as $1,000 per acre. One company owning 250 acres (not on Padilla Bay) valued its land, in 1932, at $35,000, or $140 per acre. The gross return in that year was $92 per acre. The average yield is reported to be from 30 to 40 gallons (average value $1.25 per gallon) per case of seed. The industry is not as yet stabilized and prices in excess of $200 per acre obviously are speculative and have nothing to do with any fundamental value nor with any established profits.

36. It has been reported that the Padilla Bay lands were selected for the growing of oysters because of the belief that no polluted or silt-bearing streams discharge into the bay. It is pointed out in paragraphs 60 and 117, however, that during flood periods Skagit River overflows its bank downstream from Sedro Woolley and inundates a large portion of the delta, the flood waters returning to Puget Sound through many sloughs and small channels discharging into Skagit, Padilla and Samish Bays. These flood waters, of course, carry not only the normal silt and pollution of Skagit River but additional pollution acquired from the farm yards of the inundated area.

37. Developed power. - Skagit River drains an area receiving a considerable part of its precipitation in the form of snow, and is fed by the glacial fields of the higher mountain peaks. This snow storage tends to regulate the stream flow by preserving for a time a portion of the heavy winter precipitation until released by warm summer temperatures, thus insuring a well maintained flow

during the summer season. Climatic conditions are such that ice never causes serious interruption in the operation of hydro electric plants in the western Cascade slope.

38. Six hydro electric plants have been constructed in the basin; one on Baker River, two on a small tributary of that stream, one on Newhalem Creek, and two on the upper Skagit River. The Baker River plant, half a mile upstream from the mouth, is owned and operated by the Puget Sound Power and Light Company. Two units of 10,000 kilowatts each are operated under a head varying from 255 feet to 180 feet. An ultimate installation of four 10,000 kilowatt units is contemplated.

39. The Superior Portland Cement Company operates two plants on a creek tributary to Baker River to furnish power for its cement mill at Concrete. The upper plant consists of one 350 kilovolt-ampere unit operating under a head of 74 feet, and the lower plant of three 650 kilovolt-ampere units operating under a head of 420 feet.

40. The city of Seattle has started a series of developments on the upper Skagit River. The first development, on Newhalem Creek, was constructed to furnish power for the building of the Gorge plant and now is connected with the Gorge plant. It consists of one 2,000 kilowatt unit under a head of 500 feet. The Gorge plant, at present, consists of three generators rated at 18,000 kilowatts each under a 270-foot head. The ultimate development calls for six such units, rated at 40,000 kilowatts under a head of 375 feet.

41. The Diablo development of the city of Seattle consists of a constant angle arch dam 389 feet high and a power tunnel 2,000 feet long and 19.5 feet in internal diameter leading to the power house. The present power installation is one 60,000 kilowatt generator under a head of 307 feet. Another unit of the same size will be ready for operation during the summer of 1937. Two more 60,000 kilowatt units will be installed when power demands warrant and when upstream storage will have been developed at the so-called Ruby site. (See paragraph 85.)

42. Bridges. — There are 8 bridges in the navigable stretch of the river, details of which are shown in Table I.

Table 1

Bridges over Skagit River.

Location				
Miles above mouth	Nearest town	Owner	Kind	Purpose for which bridge is used
4	Mount Vernon	Skagit County	Swing	Highway
5.5 1/	Fir	do	do	do
10.8	Mount Vernon	do	do	do
15.0	do	State of Washington	do	do
15.3 2/	do	Puget Sound Pulp and Timber Co.	do	Railway
15.5	do	Great Northern Ry. Co.	do	do
21.8	Sedro-Woolley	Northern Pacific Ry. Co.	do	do
22.0	do	Skagit County	do	Highway

1/ Above mouth of South Fork; all other mileages are above mouth of North Fork.

2/ This bridge is now partially dismantled.

43. Navigation. - Skagit River is navigable to Marblemount, 78 miles above the mouth. None of the tributaries are navigable. Present navigation upstream from Mount Vernon is limited to the towing of logs by small boats, but regular freight service is maintained between Mount Vernon and Seattle, via the North Fork. Logs dumped in or adjacent to South Fork are towed to salt water via that branch. The existing project, adopted by the River and Harbor Act of June 25, 1910, provides for a low-water channel in the South Fork between Skagit Bay and deep water in the river by the construction of a training dike at the mouth of the river, regulating dikes and a mattress sill at the head of the North Fork, and sills to close-subsidiary channels in the delta.

44. The mattress sill at the head of North Fork, the dikes closing off subsidiary sloughs, and the training dike at the mouth of South Fork, were completed in 1911. The expected results were not, however, secured, and the controlling depth over the bar at the mouth of South Fork does not exceed one and one-half feet at mean lower low water. Further work is held in abeyance awaiting the required local cooperation for work on a bar on the South Fork just below the head of the forks.

45. The larger part of the flow of Skagit River was formerly carried by the South Fork, but it now discharges through the North Fork, so that freight boats plying on the Skagit River have ceased to use the South Fork because of shallows therein and use the North Fork. The mattress sill across the North Fork was intended to throw more water down the South Fork, but apparently did not do so, or at least was not effective in improving depths in it; consequently, the sill was partially removed to facilitate navigation in the North Fork.

46. Temperatures. - The mean temperature of the Puget Sound country ranges from 38° in midwinter to 60° in summer. The average is from 35° to 45° in midwinter and from 50° to 74° in midsummer. From Table 2 it will be noted that the range of temperature in the Skagit Basin is from -1° to 99° in the lower portion, and from -11° to 109° in the foothills, with a mean annual temperature of about 48° to 50°.

Table 2. - Meteorological data for stations in or near Skagit River Basin. (Compiled from reports of United States Weather Bureau to December 31, 1936.)

		Temperature					Precipitation		
Station	Elevation above mean sea level	No. of yrs. obs.	Maximum	Mean Annual	Minimum	Length of growing season	No. of Yrs. Obs.	Mean Annual Precipitation	Average annual snowfall
	feet		F°	F°	F°	days		inches	inches
Mount Baker Lodge	4200	6	86	39.0	-11	92	10	113.10	505.6
Diablo Dam	892	5	105	46.6	-10	200	7	64.48	86.8
Baker Lake	670	-	-	-	-	-	8	102.88	58.1
Gorge Power Plant	502	22	109	49.1	-4	199	26	75.54	79.9
Darrington	500	16	105	48.2	-11	142	17	77.17	36.6
Concrete	243	22	106	50.5	-1	198	21	62.12	29.6
Anacortes	60	30	96	50.3	7	234	48	27.37	6.0
Sedro Woolley	48	40	99	50.2	-1	181	40	46.89	9.1

47. Precipitation. - The amount of precipitation is unequally distributed seasonally, there being a "wet" season beginning in October or November, and extending to March or April, or occasionally as late as May. On the average, about 80 percent of the annual precipitation occurs during the wet season, t[illegible] greater part usually falling during the night.

48. The mean annual precipitation in the mountainous portion of the Skagit Basin exceeds 100 inches, decreasing to about 30 inches or even less in the lowlands. November, December and January are the months with greatest precipitation; June, July and August are the driest. On the summits and higher slopes, the greater part of the winter precipitation is in the form of snow, which, at elevations between 5,000 and 10,000 feet, probably exceeds 500 inches annually, decreasing to less than 12 inches near the coast. (See Table 2.)

49. Gaging stations and stream-flow records. - The United States Geological Survey has gathered stream-flow data at 24 gaging stations on the Skagit River and tributaries for varying lengths of time from 1908 to the present. House Document No. 187, Seventy-third Congress, second session, presents a summary of all of these data to September 30, 1931. Table 3, following, summarizes the available discharge data to date for such of the gaging stations as are particularly pertinent to flood control problems.

Table 3 - Summary of Stream-flow data, Skagit [redacted] and Tributaries

Station	Drainage Area	Length of Record	Mean Discharge in Second-feet.												
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
	sq. mi.	years													
Skagit River below Ruby Creek	970	28[1]	1,700	2,1[illegible]	2,060	1,750	1,700	1,690	3,570	7,690	8,840	4,770	2,150	1,440	3,300
Skagit River near Concrete[2]	2,700	11	11,200	13,600	14,300	13,300	11,800	11,100	15,200	24,400	26,800	17,700	9,380	7,540	14,700
Skagit River near Sedro Woolley	2,970	16	10,700	16,400	16,300	13,500	12,0[illegible]	10,300	13,900	23,900	31,600	23,200	12,200	9,100	16,200
Cascade River at Marblemount	180	7	769	957	772	762	725	679	1,000	1,490	1,960	1,550	882	640	1,020
Sauk River near Sauk	714	9	2,750	4,480	4,160	4,290	3,890	3,420	4,010	6,150	7,970	5,400	2,590	2,000	4,260
Baker River below Anderson Cr.	164	18	1,830	1,750	1,810	1,520	1,400	1,110	1,710	2,850	3,590	2,990	1,800	1,490	1,990

1 11 years of record and 17 years of reliable estimate
2 Corrected for effect of storage regulation in Shannon & Diablo Reservoirs

50. Floods. - Skagit River, in common with other rivers similarly located on the western slope of the Cascade Range, is liable to severe floods which at times cause great damage. The whole of the Pacific Northwest is subject to a peculiar warm, moist wind blowing off the ocean, usually from the southwest, known as a "Chinook". The "Chinook" induces excessive precipitation over the entire area within its path, melts with great rapidity the accumulated snow lying on the generally rough and precipitous areas, augmenting the local down-stream run-off and producing short but high crest floods.

51. A flood is liable to occur at almost any season of the year. For example, in the year 1896 there was a flood in January, one in June, and one in November. A Chinook will usually cause a rise in the lower river about 36 hours after it begins to blow, the amount of the rise depending upon the velocity, temperature and duration of the wind, the intensity and amount of precipitation, and the amount and character of snow in the mountains. The highest floods usually occur in November and December when the winds carry a large amount of moisture, causing a heavy precipitation, and when the snow in the mountains is loose and porous.

52. The first white people settled in the valley about 1869. High-water marks since then have been recorded from time to time, with increasing accuracy. Prior to that time the record of floods depends upon testimony and tradition of the Indians, upon certain direct and indirect evidence of high-water marks and upon flood records elsewhere. Gaging stations have been established only since 1908 and the records therefrom are not, in general, continuous for any particular station.

53. In 1923, Mr. J. E. Stewart, of the United States Geological Survey, collected data for, and partially completed, a report on Skagit River, jointly for his department and for Skagit County. Mr. Stewart's report contained flood data and information on the climate and geology of the valley. He made a careful study and analysis of all data and evidence available and reached the conclusion that "a flood about 1815 was nearly a maximum, but there had been prior to that time several floods approximately as large." The 1815 flood had, he

believes, about twice the discharge of the floods of 1909, 1917 and 1921, and he also found evidence of a flood in 1856 about one and one-half times as great as those recent floods. The following data, with the exception of those for the 1932 and 1935 floods, are taken from Mr. Stewart's report.

List of Major Floods

About 1815: Maximum flood.

1856: Next highest and higher than any since settlement of the valley.

December 14, 1879; 1880; 1882; November 5, 1883; October 30, 1887; May 27, 1894: No specific record.

November 16, 1896: Highest, up to then, since settlement of the valley and probably since 1856.

November 19, 1897: Everywhere higher than that of 1896. Especially high from Cascade River to below Birdsview. In general in this section of the river the 1897 peak has not been exceeded since the settlement of the valley. This flood rose with remarkable suddenness due to a very warm Chinook and heavy rain. Both stopped suddenly after about 36 hours. The Cascade, Sauk, and Baker were very high and caused a high peak in the Skagit near the mouth of each stream, but due to sudden starting and stopping of flood conditions the peaks were rapidly reduced by storage in traveling down the Skagit.

November 16, 1906: Exceeded that of 1897 in the diked district, due to recent construction of dikes. Elsewhere lower.

November 30, 1909: Exceeded all previous since settlement, and exceeded all subsequent (up to 1923) floods above the Cascade River and below Birdsview to the sea, except where log jams affected the 1897 and 1921 floods.

December 30, 1917: Remarkable for length rather than peak height. Comparable in height to 1896 and 1906. Damage on the delta was due partly to the long period of overflow after the dikes had been broken.

December 13, 1921: Nearly as great as 1909.

February 27-28, 1932: Estimated natural discharge (corrected for effect of upstream storage) at The Dalles about the same as the discharge of the 1896 and 1906 floods. Measured discharge at The Dalles 35,000 second-feet less than estimated natural discharge. Occurred later in winter season than usual.

January 25, 1935: Somewhat lower than flood of February 1932.

34. Flood discharges as determined by Mr. Stewart, together with data on the floods of February 1932 and January 1935, are shown in Table 4.

Table 4. - Flood discharges of Skagit River.

Date	Skagit River at Reflector Bar (Drainage area 1,100 sq. miles.) Crest discharge		Skagit River at The Dalles (Drainage area 2,700 sq. miles.) Crest discharge		Skagit River at Sedro Woolley (Drainage area 2,970 sq. mi.) Crest discharge	
	Total	Per Sq.Mile	Total	Per sq. mile	Total	Per sq. mile
	Sec.ft.	Sec.ft.	Sec.ft.	Sec.ft.	Sec.ft.	Sec.ft.
1815	115,000	105	500,000	185	400,000	135
1856	95,000	86	350,000	130	300,000	101
Nov. 16, 1896	—	—	—	—	185,000	62
Nov. 19, 1897	48,000	44	275,000	102	190,000	64
Nov. 16, 1906	—	—	—	—	180,000	61
Nov. 30, 1909	70,000	64	260,000	96	220,000	74
Dec. 30, 1917	45,000	39	220,000	81	195,000	66
Dec. 12, 1921	65,000[1]	57	240,000	89	210,000	71
Feb. 27, 1932	45,000[2]	39	147,000[4]	54	—	—
do	47,400[3]	41	182,000[5]	67	—	—
Jan. 25, 1935	30,300[2]	26	131,000[4]	49	—	—

[1]United States Geological Survey Water Supply Paper No. 552 reports this as 58,000.

[2]Measured discharge below Gorge power plant (drainage area 1,160 square miles).

[3]Estimated discharge corrected for storage in Diablo reservoir.

[4]Measured.

[5]Estimated natural, corrected for affect of upstream storage.

55. The discharge of the 1921 flood at Mount Vernon (drainage area 3,093 square miles) was approximately determined by Mr. Stewart as 190,000 second-feet, of which 140,000 second-feet was carried by the river channel below a break in the dikes just above the Great Northern Railway bridge. It will be noted that for this flood the crest discharge is given as 240,000 second-feet at The Dalles; 210,000 second-feet at Sedro Woolley, and 190,000 second-feet at Mount Vernon. This decrease in peak discharge as the floods advance downstream is due to storage in the river channel and overflow areas.

56. Between 1921 and 1932 conditions of the Skagit River were materially modified by the construction of two power reservoirs: One in Baker River (Shannon Lake) with a usable capacity of about 132,000 acre-feet, and one on

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the upper Skagit River (Diablo reservoir) with a total capacity of 30,000 acre-feet. Although the reservoirs were constructed solely for power development, their normal operation was such that the beginning of the winter flood season found both reservoirs well drawn down and with a considerable amount of storage capacity available. Thus, although it occurred late in the winter season, the crest discharge of the February 1932 flood at The Dalles was measured as 147,000 second-feet, with a run-off, during the three days of highest discharge, of 602,000 acre-feet. It has been estimated that, if Shannon and Diablo reservoirs had not been in operation, the crest discharge at The Dalles would have been about 182,000 second-feet, with a corresponding three-day run-off of 706,000 acre-feet.

57. In general, floods in the Skagit Basin are of short duration. Occasionally two or more crests occur a few days apart. Tables 5 to 11, which show daily discharges through flood periods at the more important stations within the basin, illustrate these points.

Table 5 - Daily flood discharges of Skagit River below Ruby Creek
(Drainage area 978 square miles)

Date	Estimated discharge	Date	Estimated discharge	Date	Recorded discharge	Date	Estimated discharge	Date	Estimated discharge
	Sec.ft.		Sec.ft		Sec.ft		Sec.ft.		Sec.ft
1909		1917		1921		1932		1935	
Nov. 22	3,900	Dec. 27	2,120	Dec. 9	1,910	Feb. 24	890	Jan. 23	2,100
23	15,200	28	4,500	10	3,770	25	1,740	24	5,210
24	14,300	*29	21,200	11	12,400	26	11,400	25	14,000
25	8,820	30	19,000	*12	29,200	*27	27,500	26	18,200
26	6,160	31	18,300	13	24,200	28	23,600	27	14,700
27	4,720	1918		14	13,000	29	14,900	28	11,700
28	8,470	Jan. 1	24,300	15	8,600	Mar. 1	9,690	29	9,600
*29	22,400	2	19,400	16	6,580	2	7,270	30	8,250
30	25,700	3	14,600	17	5,470	3	5,710	31	7,560
Dec. 1	12,900	4	11,000	18	4,630	4	4,910	Feb. 1	7,690
2	8,610	5	8,900	19	3,800	5	4,380	2	10,200
3	6,150	6	8,110	20	3,180	6	3,970	3	10,600
4	4,670	7	7,800	21	3,070	7	3,500	4	9,840
Crest	54,000		33,500		45,700		32,000		—

Crest occurred on date indicated by *.

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Table 6 - Daily flood discharges of Skagit River [illegible]halem and Reflector Bar

Skagit River at Newhalem Drainage area 1160 square mi.		Skagit River at Reflector Bar Drainage area, 1100 square miles				Skagit River at Newhalem Drainage area, 1160 square miles					
Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge[1]	Date	Discharge[1]
1909	Sec. ft.	1917	Sec. ft.	1921	Sec. ft.	1921	Sec. ft.	1932	Sec. ft.	1935	Sec. ft.
Nov. 22	5,590	Dec. 27	2,720	Dec. 9	2,460	Dec. 9	2,060	Feb. 24	2,070	Jan. 23	3,220
23	21,700	28	5,730	10	5,420	10	8,350	25	2,950	24	9,280
24	20,400	*29	27,200	11	16,200	11	26,200	26	8,510	*25	24,200
25	12,600	30	24,400	*12	38,000	*12	42,400	*27	31,900	26	24,800
26	8,800	31	23,500	13	30,200	13	28,600	28	32,100	27	19,200
27	6,750	1918		14	16,700	14	18,700	29	19,500	28	14,300
28	12,100	Jan. 1	31,200	15	11,300	15	12,600	Mar. 1	13,000	29	11,600
*29	40,500	2	24,900	16	8,650	16	10,300	2	9,040	30	10,200
30	36,700	3	17,900	17	7,200	17	7,600	3	7,140	31	9,330
Dec. 1	18,400	4	14,100	18	6,300	18	6,190	4	6,320	Feb. 1	9,680
2	12,300	5	11,400	19	4,900	19	5,300	5	6,300	2	13,400
3	8,790	6	10,400	20	4,200	20	4,780	6	5,060	3	13,200
4	6,670	7	10,000	21	4,000	21	4,380	7	4,580	4	12,000
Crest	76,500		43,000		58,000		60,000		45,000		30,300

*Crest occurred on date indicated by *
[1] Affected by storage in Diablo Reservoir

Table 7 - Daily flood discharges of Skagit River at the Dalles and near Sedro Wooley

Skagit River near Sedro Woolley Drainage area, 2,970 square miles						Skagit River at The Dalles Drainage area 2,700 square miles			
Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge[1]	Date	Discharge[1]
1909	Sec. ft.	1917	Sec. ft.	1921	Sec. ft.	1932	Sec. ft.	1935	Sec. ft.
Nov. 22	20,600	Dec. 27	22,200	Dec. 9	14,100	Feb. 24	7,500	Jan. 23	34,000
23	68,500	28	60,400	10	21,500	25	[2]14,100	24	75,000
24	102,000	29	37,800	11	56,200	26	[2]69,400	*25	120,000
25	49,400	*30	155,000	12	111,000	*27	[2]129,000	26	95,000
26	28,800	31	87,000	*13	188,000	28	[2]105,000	27	65,300
27	21,700	1918		14	125,000	29	59,300	28	49,900
28	31,500	Jan. 1	119,000	15	95,000	Mar. 1	40,400	29	40,800
29	118,000	2	95,000	16	37,000	2	31,700	30	36,400
*30	198,000	3	65,800	17	29,300	3	24,100	31	32,700
Dec. 1	93,600	4	60,200	18	24,800	4	20,700	Feb. 1	33,600
2	53,100	5	52,000	19	19,700	5	23,700	2	43,900
3	37,000	6	42,500	20	19,700	6	21,900	3	42,200
4	30,400	7	53,500	21	17,300	7	18,400	4	36,100
Crest	220,000		195,000		210,000		147,000		131,000

Crest occurred on date indicated by *

1 Affected by storage in Shannon and Diablo Reservoirs

2 When corrected for effect of upstream storage regulation, these data would be:

Feb. 26 - 97,000
27 -160,000 (crest 182,000)
28 - 99,000

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Table 8 – Daily flood discharges of Cascade River at or near Marblemount

Cascade River near Marblemount Drainage area, 148 sq.mi		Cascade River at Marblemount Drainage area, 170 square miles			
Date	Discharge	Date	Discharge	Date	Discharge
1909	Sec. ft	1932	Sec. ft	1935	Sec. ft
Nov. 22	2,830	Feb. 24	390	Jan. 23	2,260
23					
24	7,870	25	1,030	24	5,820
	4,840	26	8,300	25	8,550
25	2,500	27	9,250	26	6,560
26	1,900	28	4,530	27	3,940
27	1,420	29	2,490	28	3,000
28	9,790	Mar. 1	1,880	29	2,470
29	31,700	2	1,500	30	2,240
30	8,590	3	1,250	31	2,030
Dec. 1	3,890	4	1,120	Feb. 1	2,290
2	2,360	5	1,150	2	3,210
3	1,740	6	1,020	3	2,720
4	1,380	7	875	4	2,240
		Crest	12,900		
			Feb. 26		

Table 9 - Daily flood discharges of Sauk River above Whitechuck River
(Drainage area, 152 square miles)

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
1917	Sec. ft	1921	Sec. ft.	1932	Sec. ft.	1935	Sec. ft.
Dec. 27	6,020	Dec. 9	1,200	Feb. 24	450	Jan. 23	3,750
28	8,000	10	3,900	25	2,370	24	9,820
*29	17,400	11	10,300	*26	14,600	25	12,700
30	7,810	*12	16,700	27	11,700	26	7,640
31	7,950	13	8,860	28	6,300	27	4,390
1918		14	4,420	29	3,560	28	3,340
Jan. 1	7,300	15	3,060	Mar. 1	2,440	29	2,750
2	4,420	16	2,390	2	1,600	30	2,400
3	3,770	17	1,970	3	1,560	31	2,200
4	4,110	18	1,650	4	1,440	Feb. 1	2,200
5	3,770	19	1,360	5	2,220	2	2,600
6	3,520	20	1,210	6	1,730	3	2,610
7	3,200	21	1,120	7	1,390	4	2,270
Crest	21,000		23,000		20,000		13,200

Crest occurred on date indicated by *

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Table 10 - Daily flood discharges of Sauk River at Darrington and near Sauk

Sauk River at Darrington Drainage area, 293 square miles				Sauk River near Sauk Drainage area, 714 square miles			
Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
1921	Sec. ft.	1932	Sec. ft.	1932	Sec. ft.	1935	Sec. ft.
Dec. 9	4,000	Feb. 24	1,150	Feb. 24	(1)	Jan. 23	14,500
10	11,700	25	4,830	25	(1)	24	36,300
11	19,400	*26	25,000	*26	51,400	25	46,300
*12	27,000	27	17,500	27	44,500	26	31,200
13	14,000	28	10,600	28	23,600	27	18,000
14	5,530	29	5,970	29	12,700	28	13,000
15	3,960	Mar. 1	3,970	Mar. 1	8,900	29	10,700
16	3,270	2	3,030	2	7,240	30	9,640
17	2,800	3	2,550	3	5,900	31	8,600
18	2,340	4	2,230	4	5,400	Feb. 1	8,630
19	1,950	5	5,050	5	7,900	2	10,700
20	1,700	6	3,200	6	6,900	3	10,300
21	1,590	7	2,280	7	5,530	4	8,960
Crest	36,000		36,000		68,500		(1)

Crest occurred on date indicated by *
1 Data not available

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Table 11 - Daily Flood Discharges of Baker River below Anderson Creek

(Drainage Area - 184 Square Miles)

Date	Discharge	Date	Discharge
1917	Second-ft.	1921	Second-ft.
Dec. 12	1,010	Nov. 25	1,770
13	1,940	26	1,380
14	5,410	27	4,440
15	5,240	28	3,060
16	11,400	29	2,380
17	6,660	30	2,910
18	11,400	Dec. 1	3,140
19	8,760	2	2,500
20	3,980	3	1,970
21	2,710	4	1,620
22	2,340	5	1,440
23	1,840	6	1,490
24	1,540	7	1,400
25	1,410	8	1,360
26	1,840	9	1,820
27	6,360	10	6,030
28	12,900	11	14,600
* 29	27,400	* 12	19,600
30	16,800	13	13,000
31	19,200	14	4,240
1918		15	(1)
Jan. 1	20,200	16	(1)
2	15,200	17	(1)
3	12,200	18	(1)
4	13,100	19	(1)
5	13,500	20	(1)
6	9,050	21	1,160
7	9,240	22	1,070
8	7,260	23	1,000
9	4,160	24	935
10	2,850	25	879
Crest	36,800		23,600

(1) Data not available

Crest occurred on date indicated by (*)

58. Table 12 condenses flood-flow data of the Skagit River system. In each case the discharge of the tributaries is given for the day preceding the maximum discharge at Sedro Woolley or at The Dalles. It will be seen that the tributaries of the Skagit River show markedly different rates of discharge. Thus Skagit River below Ruby Creek, which drains 33 percent of the area tributary to the river at Sedro Woolley, contributes less than 16 percent of the flood discharge at Sedro Woolley; whereas Cascade River near Marblemount, draining only 5 percent of the area, contributed in 1909, 18 percent of the discharge. It is most unusual for the upper reaches of a stream to show a lesser discharge per square mile than does the stream as a whole. The probable explanation of this lesser discharge of the upper Skagit Basin is that the area is shielded from the humid southwesterly winds by the high range of mountains of which Mount Baker, Mount Shuksan and Glacier Peak (Whatcom County) are a part.

Table 12 - Contribution of Tributaries to Flood Discharge of Skagit River

Item	Skagit River near Sedro-Woolley	Skagit River at The Dalles	Skagit River below Ruby Creek	Cascade River at Marblemount	Cascade River near Marblemount	Sauk River near Sauk	Sauk River at Darrington	Sauk River above Whitechuck River	Baker River below Anderson Creek
Drainage Area:									
Square Miles	2,970	2,700	978	180	148	714	293	152	184
% of area at Sedro-Wooley	100.0	90.9	32.9	6.1	5.0	24.0	9.9	5.1	6.2
% of area at The Dalles	110.0	100.0	36.2	6.7	5.5	26.4	10.9	5.6	6.8
Mean Discharge Apr. 1914-Mar. 1931:									
Second-feet	15,600	14,400	3,150	-	870	4,200	2,020	1,100	1,970
% of discharge at Sedro-Woolley	100.0	92.3	20.2	-	5.6	26.9	12.9	7.1	12.6
% of discharge at The Dalles	108.3	100.0	21.9	-	6.0	29.2	14.0	7.6	13.7
Second-feet per square mile	5.3	5.3	3.2	-	5.9	5.9	6.9	7.2	10.7
Crest Discharge in Second-feet:									
November, 1909	220,000	260,000	54,000[1]	-	-	-	-	-	-
December, 1917	195,000	220,000	33,500[1]	-	-	-	36,000	21,000	36,800
December, 1921	210,000	240,000	45,700	-	-	-	36,000	23,000	23,600
February, 1932 (measured)	135,000[1]	147,000	32,000[1]	12,900	-	68,300	36,000	20,000	-
-Do- (Corrected for storage)	160,000[1]	182,000[1]	(2)	(2)	-	(2)	(2)	(2)	-
Maximum 24-hour Discharge in Second-feet:									
November, 1909	198,000	-	28,400[1]	-	31,700	-	-	-	-
December, 1917	155,000	-	21,200[1]	-	-	-	-	17,400	27,400
December, 1921	188,000	-	29,200	-	-	-	27,000	16,700	19,600
February, 1932 (measured)	-	129,000	27,500	8,300	-	51,400	25,000	14,600	-
-Do- (Corrected for storage)	-	160,000[1]	(2)	(2)	-	(2)	(2)	(2)	-
Percent of discharge at Sedro-Woolley:									
November, 1909	100.0	-	14.3	-	16.0	-	-	-	-
December, 1917	100.0	-	13.7	-	-	-	-	11.2	17.7
December, 1921	100.0	-	15.5	-	-	-	14.4	8.9	10.4
Percent of discharge at The Dalles:									
February, 1932 (measured)	-	100.0	21.3	6.4	-	39.8	19.4	11.3	-
-Do- (Corrected for storage)	-	100.0	17.2	5.2	-	32.1	15.6	9.1	-
Highest 3 day Run-off in Acre-feet:									
November, 1909	812,200	-	132,900[1]	-	99,300	-	-	-	-
December, 1917	715,900	-	~~126,600~~[1]	-	-	-	-	65,900	125,700
December, 1921	840,800	-	131,700	-	-	-	119,800	71,100	93,600
February, 1932 (measured)	-	601,600	130,900	43,800	-	237,000	105,300	64,800	-
-Do- (Corrected for storage)	-	705,900[1]	(2)	(2)	-	(2)	(2)	(2)	-

123,000

[1] Estimated
(2) No upstream storage.

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59. Probable future floods. - Natural evidence at Reflector Bar indicated that the flood of 1815 was nearly a maximum, but that there had been, prior to that time, several floods approximately as large. The discharge of that flood at The Dalles (500,000 second-feet) is equivalent to a discharge of 185 second-feet per square mile from the entire tributary area. No flood of actual record in the Puget Sound region has approached such a rate of discharge for so large a drainage area; and it is probable that such floods will occur only at extremely long intervals. Table 4 shows that floods in excess of 180,000 second-feet, at Sedro Woolley, have occurred six times since 1896, or on an average of once in seven years. Such floods may be expected to occur in the future with about the same frequency, with materially larger floods, such as that of 1856, occurring at much longer intervals.

III. EXTENT AND CHARACTER OF FLOODED AREA

60. Flooded area.- The area subject to inundation by major floods of the Skagit River comprises about 75,000 acres, most of which is improved and cultivated land. Of this amount, 70,000 acres lie west of Sedro Woolley, including practically all of the area lying west of the Great Northern Railway between Milltown and Blanchard, about 36,000 acres of which are, at ordinary river stages, tributary to Samish River, Joe Leary Slough and other sloughs of Padilla Bay. About 45,000 acres of the flooded area have been inclosed by dikes (see paragraph 73), which offer some protection against inundation, so that the entire 75,000 acres would probably not be flooded during any ordinary flood. Included in the flood plain are portions of the towns of Hamilton, Lyman, Sedro Woolley, Burlington and Mount Vernon, as well as about 35 miles of railroad grade and 80 or more miles of state and county roads.

61. Land values. - Using data abstracted from the fifteenth census of the United States, it is estimated that there are, in the overflow area, about 1,000 farms, embracing an area of 53,000 acres and valued, with buildings and equipment, at $16,000,000. Buildings and farm machinery represent $5,000,000 of the value,

thus leaving $11,000,000 as the value of 53,000 acres, or an average of $208 per acre. About 22,000 acres of the farm land is uncleared or in pasture, and is subject to little damage by inundation. Assuming an average value for this non-crop land of $100 per acre, there would remain a valuation for crop land of $8,800,000, or $284 per acre, and a total valuation of $13,800,000 for crop land, buildings and equipment, all of which are liable to more or less damage at times of flood. The values given are as determined in 1930 and are materially higher than present-day prices. It is reported that the best valley land as of January 1936, was being quoted and was valued by the Federal Land Board at $150 per acre, and that partially cleared bottom land in the upper valley was quoted at $25 per acre.

62. No data are available as to the valuation or costs of town property, road and railroad grades, etc., or other non-farm areas subject to flood damage.

63. Flood damages. - Although the damage caused by floods in the Skagit Basin has been large, it is difficult to evaluate because of the lack of data. Lack of proper flood control will have a retarding effect on a higher development in the basin in future years, or if it be more highly developed without the flood control protection, an increase in the annual flood damage losses will result. The estimates of damages given in the succeeding paragraphs were prepared by various local agencies, no check being made by this office.

64. The spring flood of 1894, which destroyed crops valued at $1,500,000, prompted the settlers to extend their system of dikes. The flood of 1897 washed out the roadbed of the Great Northern Railway between Burlington and Sedro Woolley, flooded part of Mount Vernon, and caused a heavy loss of livestock and property above Concrete. The flood of 1906 caused a loss of $250,000. The discharge at Sedro Woolley during the 1897 flood was slightly greater than for the flood of 1906, so the damages resulting from the 1897 flood were probably on the order of $500,000. The flood of 1909 caused damages conservatively estimated at $1,500,000. It ruined many farms, destroyed several hundred head of livestock and washed out many miles of dikes and drainage ditches. The Great Northern

Railway embankment between Burlington and Mount Vernon was washed away and serious damage done to the state highway. That part of Mount Vernon west of the river was entirely flooded.

65. The flood of 1917 caused a loss estimated at $500,000. It destroyed the roadbeds of the Great Northern Railway and of the Pacific Northwest Traction Company (tracks now removed) between Mount Vernon and Burlington, seriously interrupting the communication of the region for two weeks. Extensive damage was also done to the dikes.

66. The 1921 flood caused a tangible loss of over $600,000, the greatest damage being inflicted upon the land and crops, roads and bridges, ditches and dikes and the logging industry.

67. The tangible damages due to the February 1932 flood of the Skagit River are estimated to have been about $600,000. This amount does not include such intangible damages as the loss of trade on account of the disruption of business and the crippling of transportation and communication. The chief damages suffered were, in round numbers: To farm lands, improvements and crops, $500,000; to railways, $46,000; to public roads and bridges, $36,000; and to dikes, $14,000.

68. A minor flood in December 1933 did damage to land and improvements in the upper valley to the extent of about $50,000. At the same time abnormally high tides breached sea dikes and flooded parts of the delta area with salt water. It is estimated that the damage from this source (which is not considered flood damage) was approximately $200,000. (See paragraph 74 for cost of repairs and betterments made by the Civil Works Administration and the Washington Emergency Relief Administration).

69. No data are available as to the damage resulting from the flood of January 1935, but by comparison of flood heights with the 1932 and 1933 floods, it is believed that the damage from the 1935 flood was about $100,000, chiefly in erosion of land.

70. Summary. - A summary of the reported flood losses is given in Table 13. This record is incomplete and based on very meager data for the earlier floods, but serves as a guide in deriving an estimate of annual flood losses.

Table 13 - Summary of known flood losses.

Year	Estimated Loss	Crest discharge at Sedro Woolley
		Second-feet
1894	$1,500,000	No record
1896 (Jan.)	No record	(1)
1896 (June)	No record	(1)
1896 (Nov.)	No record	185,000
1897	200,000	190,000
1906	250,000	180,000
1908	No record	92,600 (2)
1909	1,500,000	220,000
1914	No record	104,000 (2)
1917	500,000	195,000
1921	500,000	210,000
1932 (Feb.)	600,000	147,000 (3)
1932 (Nov.)	No record	116,000 (3)
1933	50,000	101,000 (3)
1935	100,000	131,000 (3)
Total	$5,300,000	
Average, 1894-1935 (42 years)	126,000	
Say	130,000	

(1) Probably over 100,000 second-feet.

(2) 24-hour discharge.

(3) At The Dalles

71. The incomplete estimate of $130,000 gives no consideration to losses resulting from lesser, unlisted, floods that occurred during the period, to the unrecorded damages for some of the floods listed in Table 13, to the probable increase in damages that would occur now or in the future for floods of the same magnitude, nor to the damages that would result from a flood like that of 1856. With these facts in mind and considering, further, that no allowance has been

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made for intangible damages, it is assumed that the average annual flood losses amount to $220,000. This estimate contains an allowance for the losses that be caused by floods equal to or less than that of 1856.

IV. WORK DONE BY LOCAL INTERESTS.

72. Existing flood-control works. - The only existing works for control of Skagit River floods consist of dikes and drainage ditches. Two reservoirs, constructed and operated in the interest of power development, furnish incidental storage for detention of flood waters. (See paragraph 80).

73. Dikes and diking districts. - Downstream from Sedro Woolley are 16 diking districts, organized and operating under the laws of the State of Washington, which embrace a total area of approximately 45,000 acres. They have expended on the construction and maintenance of dikes, to 1933, a total of about $1,900,000, or $42 per acre. In addition to the area inclosed by district dikes there are about 1,000 acres diked by individual land-holders, but the costs of these dikes are not available. Much of the diked land south of Samish River lies outside of the Skagit River Basin proper, but overflow waters of the Skagit occasionally cover the area. Over 30 percent of the existing dikes are designed to protect the area from inundation by salt water. No accurate separation of costs between salt and fresh-water dikes is possible; but in general the river dikes are of heavier section and more costly construction than the sea dikes, so that the total cost of river dikes, both district and private, has probably been between one and one-quarter and one and three-quarter million dollars.

74. Following the abnormally high tides of December, 1933, about 60 miles of dikes, chiefly along the sea front, were repaired and strengthened with Civil Works Administration and Washington Emergency Relief Administration funds at a cost of $161,203.14, the construction work being under supervision of this office.

75. Table 14 summarizes data pertaining to the 16 diking districts of the Skagit River delta.

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Table 14 - Diking Districts, Skagit County

District	Date Organ-ized	Acres in District (1934)	Estimated Value of Land: Total[3]	Estimated Value of Land: Per Acre	Recent Annual Assessments for Diking per Acre: 1928	1929	1930	1931	1932	1933	1934	Total Levies to 1934, Inclusive: Per Acre	Total
No. 1	1897	8,268	$1,571,000	$190	$0.51	$0.42	$0.42	—	$0.63	$0.42	$0.63	$ 37.26	308,027
No. 2	1897	2,632	564,000	210	1.52	1.52	0.95	$0.76	1.52	1.52	1.52	75.64	199,077
No. 3	1897	6,366	1,814,000	280	0.94	0.94	—	—	0.63	0.79	0.79	60.64	386,037
No. 4[1]	—	1,579	250,000	160	0.22	—	0.38	—	0.16	0.38	0.32	11.75	18,553
No. 5[1]	1897	2,825	638,000	230	0.50	1.50	1.50	1.00	1.00	1.50	2.00	59.19	167,206
No. 8[1]	1997	631	70,000	110	—	0.79	0.79	0.32	0.48	0.48	2.53	15.72	9,917
No. 9[1]	1897	1,419	320,000	230	0.35	—	—	—	—	0.21	—	14.01	19,883
No. 12[1]	1897	13,380	2,503,000	190	0.83	0.83	0.21	0.08	0.81	0.86	0.82	24.18	323,513
No. 13	[2] 1897	1,869	338,000	180	3.75	1.07	0.80	0.80	1.40	1.20	1.79	60.76	113,565
No. 15	1903	885	120,000	140	2.26	1.69	0.45	0.45	0.51	1.02	1.00	67.50	59,774
No. 16	1904	407	79,000	190	2.32	2.32	2.31	2.31	1.47	1.22	1.23	65.86	26,803
No. 17	1910	1,263	428,000	340	4.36	4.36	4.36	3.56	5.17	5.15	1.19	13.99	176,655
No. 18	1918	576	253,000	440	1.22	1.22	0.95	0.97	2.92	0.56	1.56	47.32	27,259
No. 19[1]	1919	1,960	442,000	230	—	0.51	0.15	0.03	0.26	0.61	1.08	11.06	21,685
No. 20	1919	537	24,000	50	1.86	0.93	0.42	—	0.93	—	3.50	38.78	20,825
No. 21	1922	391	176,000	450	2.05	2.84	1.18	0.58	0.90	1.23	1.79	21.91	8,567
Total or Average		44,988	9,590,000	[4] 213								41.95	1,887,306

1 Either wholly or partially outside of Skagit River drainage area, but area affected by overflow from the Skagit River.
2 Reorganized in 1929.
3 Based on 1934 assessment. County assessor says actual value is equal to assessed value X 4.515.
4 Local appraiser of Federal Land Bank estimates average value as $195 per acre.

76. The fact that Skagit River floods still inflict large damages in the delta area indicates that these dikes do not furnish adequate flood protection. Built without a comprehensive and coordinated plan, many of the dikes are poorly designed and improperly located. In an effort to enclose as much land as possible the dikes have been placed close to the river bank with little or no consideration given to alignment, river sections or other elements entering into the proper design of such a system. As a result frequent breaks, due to overtopping and to undermining of river banks and dikes, have occurred.

77. <u>Drainage and drainage districts.</u> - Supplementing the protection afforded by the diking districts are drainage ditches constructed by 12 drainage districts, also operating under state law. Data concerning these districts are summarized in Table 15.

Table 15 - Drainage Districts, Skagit County

District	Date Organ-ized	Acres in District (1934)	Estimated Value of Land: Total	Estimated Value of Land: per Acre	Recent Annual Assessments for Drainage per Acre: 1928	1929	1930	1931	1932	1933	1934	Total Levies to 1934, Inclusive: Per Acre	Total Levies to 1934, Inclusive: Total
No. 14	1900	9,453	$1,096,000	$120	$0.58	$0.54	$0.32	$0.42	$0.53	$0.53	$0.53	$23.17	$219,034
No. 15 [1]	1906	9,452	1,202,000	130	.85	.53	.38	.31	.31	.56	.99	17.93	169,484
No. 16	1906	2,874	649,000	230	.76	.54	.82	.82	.82	.82	1.00	16.21	46,581
No. 17	1909	4,987	648,000	130	1.30	1.20	.60	.60	1.20	1.29	1.40	35.91	179,088
No. 18	1910	1,575	220,000	140	.44	.51	.76	.51	.51	.51	.51	15.13	23,835
No. 19 [2]	1922	6,508	1,337,000	210	2.73	[5]6.82	[5]6.14	[5]5.51	3.19	—	.23	38.35	249,569
No. 20	1920	537	28,000	50	—	—	.05	—	.09	—	.75	7.01	3,763
No. 21	1922	547	104,000	190	3.74	4.75	3.64	3.39	3.53	1.28	—	39.30	21,495
No. 22	1928	1,134	197,000	170	—	2.65	1.76	1.97	1.45	.98	1.05	9.85	11,170
No. 23	1933	306	—	—	—	—	—	—	—	—	8.56	8.56	2,618
No. 13 [3]	1928	1,837	332,000	180	—	2.72	1.60	1.20	1.80	.80	.80	8.92	16,394
No. 16 [4]	1928	318	72,000	230	—	2.99	4.72	4.72	3.15	2.41	3.77	21.77	6,922
Total or Average		39,528	5,885,000	149								24.03	949,953

[1] Reorganized in 1934. [2] Drainage improvement district within diking district No. 20.
[3] Drainage improvement district within diking district No. 13.
[4] Drainage improvement district within diking district No. 16. [5] Mainly for retirement of bonds.

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78. Including all works done by the Civil Works Administration, by the Works Progress Administration, by diking and drainage districts and by individuals, the total expenditures for the reclamation and protection of the lands has been over $3,000,000. In addition there is provided by tax levy in Skagit County a fund known as the "River Improvement Fund" to be used for minor work of river protection and for collection of hydrographic and other data. This levy is limited by state law to one mill on the dollar per annum. Data are not at hand as to the total expenditures under this fund, but for the years 1932 to 1934, inclusive, the fund provided $1,678 for river protection and $575 for co-operation in maintenance of the gaging station at The Dalles. The work done by Mr. Stewart (paragraph 58) was also paid for from this fund.

79. Works Progress Administration project. - A Works Progress Administration project for the revetting of banks at points of erosion between Hamilton and Burlington, sponsored by Skagit County, is being prosecuted under the engineering supervision of this office. As set up, this project contemplates the placing of 21,400 linear feet of revetment, totaling 158,500 square yards, at an estimated cost of $228,000. To date, there has been completed 12,360 linear feet (95,450 square yards) at an expenditure of $132,760. More rapid progress would have been possible had sufficient relief labor been available. About 5 percent of the funds expended on this project has been furnished by the sponsoring agency.

80. Detention reservoirs. - Shannon and Diablo Dams, referred to in paragraph 56, were built, and are operated, for the development of power. The normal operation of these reservoirs, however, has found them well drawn down during the winter flood season, so that during the flood of February 1932 they absorbed a considerable part of the flood run-off from the upper Skagit and Baker Rivers. Lake Shannon will continue to be operated as a storage reservoir, but Diablo Dam will, in the future, serve only to create head and provide daily pondage, thereby reducing if not entirely eliminating the flood control value of that reservoir.

V. PROPOSED MEASURES OF RELIEF

81. Hearing. - A joint public hearing was held by the Departments of War and Agriculture in Mount Vernon, Washington, on March 2, 1937 at which about 70 persons were present. County officials stated that the county's financial position was such that it would be impossible at this time for the county to furnish the local cooperation required for the construction of the Avon By-pass as authorized under the existing project. The concensus of opinion was that the By-pass was not wanted but that dredging in the lower river channel and bank revetment to prevent erosion of land was necessary. One speaker suggested revetment to prevent erosion and the construction of a flood control reservoir on Sauk River in lieu of the construction of the Avon By-pass. A copy of the minutes of the hearing is inclosed.

82. Protective measures considered. - Four plans for reducing flood damage in the Skagit Basin have been considered: Storage of flood waters, diversion of flood waters, modification of the existing diking system, and channel improvement.

83. Storage. - Reference has already been made to the two existing reservoirs on the river system. Although these two reservoirs have in the past operated to reduce flood flow, no reliance can be placed upon their efficiency at future flood periods, inasmuch as both of these are now regulated solely to meet the exigencies of power demand.

84. Numerous undeveloped power sites exist in the Skagit Basin (see House Document No. 187, 73rd Congress, 2nd session, p. 76 et seq.), but of the investigated sites only four combine apparently favorable dam sites with sufficient storage capacity to make them effective as flood control reservoirs. These four are the Ruby site on the upper Skagit River, the Cascade site on the Cascade River, the lower Sauk site on the Sauk River, and the Baker Lake site on the upper Baker River.

85. Ruby site: - This site has been under investigation by the city of

Seattle for a number of years as a possible extension of its municipal power development. The dam site is on Skagit River, just below the mouth of Ruby Creek and approximately at the upstream limit of the backwater from Diablo D[illegible] The river at the site flows in a southwesterly direction through a rocky gorge, both banks of which are composed of granite bedrock. Test borings made by the city of Seattle indicate good foundation rock at depths varying from 25 to 55 feet below the stream bed. The physical condition at the site would permit a dam about 610 feet high creating a reservoir of 3,000,000 acre-feet total capacity. Such a capacity would be vastly in excess of the amount that would be needed for complete control of even a maximum flood at that site.

86. Table 12 shows that the run-off at the dam site for the three highest flood days of 1909, 1917, 1921 and 1932 was 133,000 acre-feet, 116,000 acre-feet, 132,000 acre-feet, and 151,000 acre-feet, respectively. It would appear, therefore, that a storage capacity of 150,000 acre-feet would be ample to detain the three-day run-off from an ordinary flood, and possibly a capacity of about 300,000 acre-feet would be sufficient to absorb the three-day run-off during such a flood as that of 1815. The smaller capacity could be provided by a dam 315 feet high and the larger by a dam 380 feet high.

87. By comparison of the crest discharges below Ruby Creek with those near Sedro-Woolley as given in Table 12 it will be seen that even though the entire flood flow of the river at the dam site were stored, the discharge through [illegible] delta area would still exceed the estimated capacity (140,000 second-feet - see paragraph 55) of the diked channel, and serious flooding of the lowlands would still result. The reason for this being, that although the drainage area at the Ruby site is 32.9 percent of the area at Sedro Woolley, the river, at the dam site, contributed but 15.5 percent or less of the maximum 24-hour discharge at Sedro Woolley and but 16.4 percent or less of the maximum three-day run-off. The city of Seattle was granted a preliminary permit for a power development at the site by the Federal Power Commission on March 3, 1927, and it is understood that application for license has been made by the city. It is believed, therefore, that further consideration of the site for purely flood control purposes is futile.

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88. Under the terms of the preliminary permit - ". . . the licensee shall, if so required by the Commission, provide for storage of flood waters in said Ruby reservoir in connection with any plans for flood relief that may be adopted by the state or by the United States on such terms of cooperation as may be deemed just and equitable by the Commission." A study of past stream flow at the site reveals that more than 200,000 acre-feet of storage might be reserved during the winter flood period (November to February, inclusive) with little or no sacrifice of power output. A reservation of 200,000 acre-feet would hold all of the three-day run-off at the Ruby site for a flood 50 percent greater in run-off than that of 1909; such a flood would approximate that of 1856. The city's present (although tentative) plans provide for a dam with crest at elevation 1,710 feet with control by gates to elevation 1,725 feet. The city states that, "The top layer of 15 feet depth is to be reserved for flood control, and will contain 300,000 acre-feet of storage".

89. In the absence of a detailed estimate of the cost of the Ruby power development, only an approximate estimate can be made of the cost of reserving storage for flood control. It would appear, however, that in view of the very small reduction in power output resulting from such reservation during the winter months, the city could afford to make such a reservation for a very small sum.

90. Cascade site: The dam site for this project is located on the Cascade River about eight miles above its mouth, where the drainage area is 148 square miles. The river at the dam site flows in a westerly direction through a rocky canyon, in which the bed of the stream, and the left bank for a height of about 125 feet, are composed of large boulders with sufficient clay and fines to fill the voids. Above this height solid rock, classified as diorite, is exposed on both sides. Three drill holes sunk at the site all encountered bedrock, the greatest depth being found about 90 feet below the water surface. The formation is apparently impervious and capable of supporting a dam of any reasonable height.

91. Records of flood flow at the dam site are limited to the major flood of November, 1909. The mean discharge for the day of greatest flow (November 29)

was 31,700 second-feet, or 16 percent of the discharge at Sedro Woolley, and the run-off for the three highest days was 99,500 acre-feet. As, elsewhere in the basin, the flood of 1909 was the highest since records have been kept, it may be assumed that the storage of 100,000 acre-feet would absorb the flood run-off of the Cascade River during ordinary floods, and that the storage of 200,000 acre-feet would effectively detain the flow of such a flood as the one of 1815. To provide storage of 100,000 acre-feet a concrete arch dam 360 feet high above the foundation would be required. A dam to provide 200,000 acre-feet is considered infeasible.

92. Investigations have revealed that a dam creating a total storage of 104,000 acre-feet might be justified for power development if there were a demand for the power. Under such a plan there could be reserved for flood storage, during the winter season, about 32,000 acre-feet without materially affecting the cost or quantity of the available power. In addition to the controlled storage there would be temporary storage of about 15,000 acre-feet above the spillway crest which would be effective in reducing the flood crest.

93. So far as known to this office, no agency has under consideration plans for development of this project. As the reservoir site lies almost entirely within the National Forest, any power development would be under the jurisdiction of the Federal Power Commission.

94. Sauk site: The dam site for this project is located on Sauk River about seven miles above its mouth, where the drainage area is 714 square miles. The natural low water surface elevation is 280 feet. On the left bank a natural abutment is formed by a ridge extending out into the valley. This ridge is composed of diorite that outcrops in many places. It is badly weathered at the surface, but probably sound and impervious at no great depth. The right bank is formed by a glacial bench that levels off at about elevation 525 feet and extends back about a quarter of a mile to the steep face of the foothill. Four test holes drilled at the site all encountered bedrock at elevations varying from 189 to 256 feet. The composition of the rock was variable, different strata being classified as basalt, greenstone schist, and slate;

but all seemed to be reasonably sound and impervious.

95. The possible forebay elevation is limited to approximately elevation 500 feet by the height of the ridge on the left bank at the dam site and also by the height of the divide between the Sauk and Stillaguamish River Basins at the upper end of the reservoir near Darrington. The elevation of the lowest point on this divide is about 505 feet, which suggests the possibility of diverting a portion of the flood flow into the North Fork of the Stillaguamish. (See paragraph 108).

96. From a study of flood flow records on the Sauk River it is estimated that a storage capacity of about 270,000 acre-feet would be required to detain the three-day run-off during floods of the size of those of 1909, 1917 and 1921. For a flood such as the one of 1815 probably about 500,000 acre-feet would be necessary. A reservoir of 270,000 acre-feet capacity could be provided by a dam to elevation 455 feet, and a reservoir of 500,000 acre-feet capacity by a dam to elevation 490 feet.

97. If the project were constructed in the combined interest of power and flood control about 200,000 acre-feet (between elevations 498 feet to 475 feet) could be reserved for flood storage. If such storage were reserved the year round the cost to flood control would be the entire additional expense of creating the top 200,000 acre-feet. If, however, the flood storage were reserved only during November, December, January and February of each year (the normal flood period), power production would be reduced only slightly below the production possible by using the entire storage for power development. On such a basis it would appear that flood control could properly be charged with only the value of the potential power thus lost.

98. So far as known, no power development at this site is planned by any agency. A small portion of the reservoir site lies within the Mt. Baker National Forest, and, since storage regulation would affect navigation on the main stream, it is believed that this project when developed should be under license from the Federal Power Commission.

99. Upper Baker site: The dam site for this project is located on Baker River about 12 miles above its mouth and eight miles downstream from Baker Lake at a point where the drainage area is 184 square miles. A number of core borings made at the site by the Puget Sound Power and Light Company disclose in general a slate or slate-and-quartz bedrock. Several outcrops of this material occur on the left bank, where apparently very little stripping would be required. A drill hole on the right bank disclosed approximately 150 feet of over-burden; however, bedrock outcrops at a point considerably higher up on this bank.

100. Flood discharge records at the site are available for the floods of 1917 and 1921. Of these two, the 1917 flood was much the more severe, reaching a crest discharge of 36,800 second-feet, and having a three-day run-off of 125,700 acre-feet. The crest flow represented a discharge of 200 second-feet per square mile, and the average discharge over the three-day period, a discharge of 115 second-feet per square mile. This rate of discharge is so large, as compared with other streams of the Puget Sound area, as to suggest that the 1917 flood must have been nearly as large as any of recent years. It is assumed, therefore, that a storage of 130,000 acre-feet would adequately control any but the most severe floods on the Baker River. A dam about 280 feet high (foundation to walkway) would be required to create 130,000 acre-feet of storage.

101. If the site were developed as a power project, it would be possible to reserve about 40,000 acre-feet of storage for flood control during the winter months at no material sacrifice of power output. Such a storage could absorb about one-half of the maximum day's run-off of the 1917 flood.

102. Preliminary investigations of the power project have been made by the Puget Sound Power and Light Company, but since the site is located within the National Forest, a license for its development must be secured from the Federal Power Commission.

103. Reservoir combination. - Mr. Stewart estimated that the diked channel below Sedro Woolley carried 140,000 second-feet during the 1921 flood. This estimate is subject to considerable uncertainty, however, and it is believed that the existing channel could not safely carry for long more than 100,000

second-feet. Studies have been made of the possibility of limiting the discharge to this figure by storage of flood waters in the proposed reservoirs. These studies, which are based on 24-hour average flows and which, therefore, give only approximate results, are summarised in Tables 16 and 17, and lead to the following conclusions:

(a) With storage for flood control only, no two of the proposed reservoirs could have been so operated as to reduce the discharge at Sedro Woolley during the 1921 flood, and probably during the 1909 flood, to 100,000 second-feet. Storage of the total input to Sauk, Ruby and Baker reservoirs during the maximum day of the 1921 flood could have reduced the discharge at Sedro Woolley to about 90,000 second-feet. In the absence of discharge data for the 1921 flood, the further reduction in discharge that could be effected by storage in Cascade reservoir cannot be determined.

(b) With storage for combined power and flood control, using the flood control reservations outlined in the preceding paragraphs, and allowing enough discharge through the turbines to satisfy the ordinary needs of power generation, regulation of Sauk, Ruby and Baker reservoirs could have reduced the discharge of the 1921 flood at Sedro Woolley to about 99,000 second-feet. It is believed that the use of top storage in Cascade reservoir could have reduced the 99,000 second-feet to about 88,000 second-feet, thus making an over-all reduction of 100,000 second-feet. Approximately the same reduction could have been made in the 1856 flood by similar use of top storage in the four proposed reservoirs. If it is assumed that the 1856 flood could be reduced by only 80,000 second-feet, the discharge of that flood at Sedro Woolley would be reduced from 300,000 second-feet to 220,000 second-feet, which is the measured crest discharge of the 1909 flood and the figure used in designing the Avon By-pass (see paragraph 110). Thus, a flood such as that of 1856 could be so controlled as to cause no overflow in the delta area by combining use of top storage in the four proposed reservoirs with the operation of the proposed Avon By-pass.

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104. These modified discharges, and those shown in Tables 16 and 17, disregard the effect of channel storage between the dam sites and Sedro Woo

105. Table 16 shows the effect of regulating the various proposed reservoirs in the interest of flood control alone. It is assumed that the entire run-off of the streams for the three highest days was retained in the reservoirs. The table shows the discharge at Sedro Woolley as modified by this storage, and the amount of storage necessary at each site to retain the three-day run-off.

106. Table 17 shows the effect of regulating the various proposed reservoirs in the combined interest of power and flood control. It is assumed in this study that sufficient water to satisfy the ordinary power demand is discharged through the turbines, and the remainder, within the limits of flood storage reservation outlined above, is stored. The contemplated flood storage reservations are as follows:

Reservoir	Flood storage reservation: Acre-feet	Flood storage reservation: Second-foot days
Ruby	200,000	101,000
Cascade	32,000	16,100
Sauk	200,000	101,000
Baker	40,000	20,200

107. The contemplated flood storage in Ruby reservoir is ample to absorb the maximum three-day run-off; and in Sauk reservoir is sufficient to absorb all but an insignificant part of the maximum three-day run-off. The contemplated storage in Cascade and Baker reservoirs, however, could control only a part of the three-day flood run-off, so that a large portion of the run-off would pass uncontrolled over the spillways.

Table 16 - Effect of upstream storage regulation, for flood-control alone, on flood discharge of lower Skagit River
(24-hour Discharges)

Date (1)	Natural Discharge Skagit River at Sedro-Woolley: Second-feet	Inflow to Reservoirs Second-feet: Ruby	Cascade	Sauk	Baker	Discharge at Sedro-Woolley as modified by storage in proposed reservoirs Second-feet: Storage in Ruby Reservoir only	Storage in Cascade Reservoir only	Storage in Sauk Reservoir only	Storage in Baker Reservoir only	Storage in Ruby and Cascade Reservoirs	Storage in Ruby and Sauk Reservoirs	Storage in Ruby and Baker Reservoirs	Storage in Sauk and Baker Reservoirs	Storage in Ruby Sauk and Baker Reservoirs
1909														
Nov. 29	118,000	[2]8,500	9,800	(3)	(3)	110,000	108,000	--	--	100,000	--	--	--	--
Nov. 30	198,000	[2]28,400	31,700	(3)	(3)	170,000	166,000	--	--	138,000	--	--	--	--
Dec. 1	93,600	[2]25,700	8,600	(3)	(3)	67,900	85,000	--	--	50,300	--	--	--	--
Total storage in Ac. - ft		[2]124,000	99,300											
1917														
Dec. 30	155,000	[2]21,200	(3)	[2]57,000	27,400	134,000	---	98,000	128,000	--	77,000	106,000	71,000	49,000
Dec. 31	87,000	[2]19,000	(3)	[2]26,000	16,800	68,000	---	61,000	70,200	--	42,000	51,200	44,200	25,200
1918														
Jan. 1	119,000	[2]18,300	(3)	[2]26,000	19,200	101,000	---	93,000	100,000	--	75,000	82,000	74,000	56,000
Total storage in Ac. -ft.		[2]116,000		[2]216,000	126,000									
1921														
Dec. 12	111,000	12,400	(3)	[2]36,000	14,600	99,000	---	75,000	96,000	--	63,000	84,000	60,000	48,000
Dec. 13	188,000	29,200	(3)	[2]49,000	19,600	159,000	---	139,000	168,000	--	110,000	139,000	119,000	90,000
Dec. 14	125,000	24,200	(3)	[2]26,000	13,000	101,000	---	99,000	112,000	--	75,000	88,000	86,000	62,000
Total storage in Ac.-ft.		130,000		[2]220,000	93,600									

(1) Date at Sedro-Woolley. Discharges at damsites are for preceding day to compensate for time of travel to Sedro-Woolley
(2) Estimated.
(3) Data not available.

Table 17 - Effect of upstream storage regulation, for combined power and flood-control, on flood discharge of lower Skagit River
(24-hour Discharges)

Date (1)	Natural Discharge Skagit River At Sedro-Woolley: Second-feet	Storage in Reservoirs Second-foot-days (2): Ruby	Cascade	Sauk (Estimated)	Baker	Discharge at Sedro-Woolley as modified by storage in proposed reservoirs Second-feet: Storage in Ruby Reservoir only	Storage in Cascade Reservoir only	Storage in Sauk Reservoir only	Storage in Baker Reservoir only	Storage in Ruby and Cascade Reservoirs	Storage in Ruby and Sauk Reservoirs	Storage in Ruby and Baker Reservoirs	Storage in Sauk and Baker Reservoirs	Storage in Ruby Sauk and Baker Reservoirs
1909														
Nov. 29	118,000	4,500	0	—	—	114,000	118,000	—	—	114,000	—	—	—	—
Nov. 30	198,000	24,400	16,100	—	—	174,000	182,000	—	—	158,000	—	—	—	—
Dec. 1	93,600	21,700	0	—	—	71,900	93,600	—	—	71,900	—	—	—	—
Total		50,600	16,100											
1917														
Dec. 30	155,000	17,200	—	54,000	20,200	138,000	—	101,000	135,000	—	84,000	118,000	81,000	64,000
Dec. 31	87,000	15,000	—	23,000	0	72,000	—	64,000	87,000	—	49,000	72,000	64,000	49,000
1918														
Jan. 1	119,000	14,300	—	23,000	0	105,000	—	96,000	119,000	—	82,000	105,000	96,000	82,000
Total		46,500		100,000	20,200									
1921														
Dec. 12	111,000	8,400	—	32,000	0	103,000	—	79,000	111,000	—	71,000	103,000	79,000	71,000
Dec. 13	188,000	25,200	—	46,000	17,600	163,000	—	142,000	170,000	—	117,000	145,000	124,000	99,000
Dec. 14	125,000	20,200	—	23,000	2,600	105,000	—	102,000	122,000	—	82,000	102,000	99,000	79,000
Total		53,800		101,000	20,200									
Contemplated flood storage		101,000	16,100	101,000	20,200									

(1) Date at Sedro-Woolley. Discharges at dam sites are for preceding day to compensate for time of travel to Sedro-Woolley.

(2) Allowance has been made for discharge through turbines as follows:

Ruby ---------- 4,000 Sec.-ft.
Cascade -------- 1,000 " "
Sauk ---------- 3,000 " "
Baker ---------- 2,000 " "

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108. Diversion. - As pointed out in paragraph 95, diversion of part of the flood flows of the Sauk River might be made to the North Fork of the Stillaguamish River near Darrington. Such a diversion would very materially reduce the flood heights through the Skagit River delta area, but would add to the already serious flood threat in the Stillaguamish Basin. No further consideration, therefore, should be given to such diversion.

109. Two possible routes exist by which a portion of the flood waters might be diverted from the lower Skagit Basin; one, 9.6 miles long, to divert just upstream from Burlington and discharge into Padilla Bay by way of Joe Leary Slouth; and the other to divert at Avon, downstream from Burlington, and also to discharge into Padilla Bay. The latter route, 5.6 miles long, is referred to herein as the Avon By-pass. The area protected by either by-pass is identical, about 65,000 acres, or 95 percent of the area flooded west of Sedro Woolley.

110. The maximum discharge of actual record, at Sedro Woolley, was 220,000 second-feet (November 30, 1909). It is estimated that the existing river channel and dikes are adequate to carry safely a flow of 100,000 second-feet, thus leaving 120,000 second-feet to be carried by the by-pass during a flood of the magnitude of the one of 1909.

111. The Avon By-pass, together with necessary channel improvement and revetment of the portion of the river between the high ground upstream from Burlington and the point of diversion, is the project adopted by the Flood Control Act of 1936. Some of the revetment, on the right bank of the river just above Burlington, has been completed as a Works Progress Administration project for work relief under the engineering direction of this office.

112. The alignment of the proposed Avon By-pass, as contemplated in the project document, was such as to deliver the diverted flood waters by the most direct route to Padilla Bay. Subsequent to the preparation of that report, oyster growing has been established as an industry on Padilla Bay, thereby creating a condition not anticipated in the project document. The Padilla Point Oyster Company has objected to the proposed discharge of flood waters from Skagit

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River into Padilla Bay, fearing that silt from the river would destroy the planted oysters and the value of the holdings as potential oyster lands.

113. Under the plan of diversion only the top strata of the river waters would be diverted, the lower and heavier silt-bearing strata continuing to flow in the existing river channel. No records of stream flow at the proposed point of diversion are available, but from records of the gaging stations at Sedro Woolley and Concrete it is estimated that the By-pass would have carried flood waters on only five, or possibly six, occasions in the last 28 years for a total of between nine and 18 days.

114. It is pointed out in paragraph 38 that pollution of oyster beds would, under present conditions, follow any major flood. The Department of Health of the State of Washington withholds certification of shellfish growing areas where pollution is a menace to the public health. After careful study of the proposed Avon By-pass the Department states that, "This department feels it would not be detrimental to the public health to allow the construction of the Avon By-pass."

See 147.82/30

115. Considering the infrequency with which the By-pass would carry flood waters, it is believed that satisfactory protection from silting of the oyster beds could be obtained by carrying the western end of the by-pass channel slightly to the south of the most direct route, thus passing to the south of the oyster beds, and by constructing a training dike at the outer end of the channel to prevent the flood waters from coursing laterally over the oyster beds. The channel as so modified would be about 1,000 feet longer than the route contemplated in the project document. This change in route is objectionable from the standpoint of navigation, as the waters from the re-routed by-pass would flow into the northern end of Swinomish Slough, which is under improvement by the United States. However, it is believed that whatever cross currents and deposition of silt might be occasioned thereby would not be serious and would have little effect on the cost of annual maintenance of Swinomish Slough channel, as the by-pass would take only top water from the river and will be used but seldom. The costs of the by-pass as set up in the Flood Control Act of 1936 include the additional cost of the re-routed channel to the south of the oyster beds.

116. The opposition of local interests (see paragraph 81) to the construction of the Avon By-pass is founded largely on the desire of these interests to avoid or reduce the heavy contribution required of them by the terms of the Flood Control Act. Further investigation and study may indicate that the amount of local cooperation could be reduced.

117. Modification of existing diking system. - In its natural condition Skagit River, during flood periods, overflowed its banks and inundated a large portion of the delta. The flood waters reached Puget Sound not alone through the river channels proper, but also through the many sloughs and small drainage channels, and by passing directly across the flats. The existing dikes hold the river partially in bounds, although during severe floods the dikes frequently fail by "boils" before being overtopped. A system of dikes proportioned to carry the entire flood flow at a surface elevation approximating that obtaining under natural conditions would include within the waterway so much valuable agricultural land as to be prohibitive in cost.

118. A system of dikes proportioned to carry the entire flood flow within the lateral limits of the natural river channel and at velocities below the point of scour would require high and expensive dikes, and, in addition, the raising of all bridges in the improved section and the construction of an expensive drop or series of drops at or near tidewater. The latter would probably also involve the construction of navigation locks.

119. Channel improvement. - Instead of creating the additional waterway required for passage of the flood waters by dikes alone it might be possible, and more economical, to combine dikes and channel improvement to provide the necessary cross-sectional area. This scheme would involve the construction of a protection dike on the right bank of the river from the high ground above Burlington to a point just upstream from the Great Northern Railway bridge. No dike is provided for the left bank along this stretch, as it is desirable to utilize this Nookachamps Creek area for storage at the higher river stages. This storage is valuable in that it reduces the flood crests past the Great Northern

bridge. The existing diked channel below the Great Northern bridge has an estimated maximum capacity of 140,000 second-feet, but the channel would not carry this discharge for long, as the dike material would soon become water-soaked and fail. To provide for a discharge of 220,000 second-feet (the greatest of actual record) below this point it would be necessary to enlarge the channel and to use the dredged material for the construction of adequate dikes.

120. It is estimated that a channel from Sedro Woolley to Skagit Bay via the North Fork of Skagit River, adequate to carry safely a discharge of 220,000 second-feet, would require the excavation of approximately 56,000,000 cubic yards of material, and the acquisition of about 5,000 acres of agricultural land for right of way. It might be desirable in the interest of flood control to swing the outlet of the North Fork to the south, thus giving a shorter route to tide-water. This would also aid navigation by reducing the amount of silting in the southern end of Swinomish Slough channel.

121. Erosion prevention. - It was suggested at the hearing that one large item of flood damage - the erosion of land - might be reduced or eliminated by the revetment of banks at points of erosion or by elimination of some of the bends at which erosion is most severe. A detailed examination of the channel would be required to determine the extent and cost of such works and the probable benefit to be obtained from them.

122. A Works Progress Administration project, under the engineering supervision of this office provides for an expenditure of $226,000 for revetment of a few critical points between Burlington and Hamilton as a work relief measure. This project is now about 40 percent completed. (See paragraph 79).

123. Irrigation. - Irrigation is not now practised in the Skagit Basin as rainfall is normally abundant for all crops now raised. Although irrigation on a limited scale may be undertaken in the future, the low-water discharge of the river is ample to satisfy the needs of such irrigation. Irrigation and flood control projects cannot be combined to reduce the cost of either or both.

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VI. DISCUSSION, CONCLUSION AND RECOMMENDATION

124. Discussion. - The project authorized by the Flood Control Act of 1936, i.e., the construction of Avon By-pass and the revetment of banks between Burlington and the point of diversion, appears to offer the greatest measure of relief from flood damage at the lowest aggregate cost. That project would afford protection to the area downstream from Sedro Woolley from a flood discharge of 220,000 second-feet, but would not reduce flood damage in the area upstream from Sedro Woolley nor protect against such a flood as the one of 1856. As pointed out in paragraph 81 the local cooperation required for the construction of the Avon By-pass is considered by the local interests to be too great to be met under present conditions.

125. The proposed Sauk reservoir, if operated solely for flood control, would offer a large measure of protection from lesser floods throughout the whole area downstream from the dam site, but would probably effect little diminution in damage caused by larger floods. The cost of providing such storage would be materially greater than the cost of the Avon By-pass and the resulting benefits downstream from Sedro Woolley very much less.

126. Reservation, for flood control during the winter months, of top storage in future power reservoirs could probably be made at a cost amply justified by the resulting benefits. Such storage along would not offer adequate protection to the delta area, but if it were made the second step in a program of which the Avon By-pass were the first step, even a flood such as that of 1856 would be carried safely through the delta lands. The Avon By-pass could be constructed whenever funds were made available, but provision of flood storage in the reservoirs cannot be economically secured until power development at those sites is undertaken at some indefinite future time.

127. Flood protection by means of dikes or channel improvement, or by a combination thereof, could be secured only at prohibitive initial and maintenance costs.

128. There appears to be reasonable possibility that protection against

erosion of valuable agricultural land, by means of revetment or channel rectification, could be secured at a cost commensurate with the benefits to be reali[illegible] but the extent of such works can be determined only by a detailed survey and investigation.

129. Interested parties. - The parties at interest and that might be expected to contribute in some degree to the cost of any measures for flood relief are: The owners of the land subject to erosion and/or inundation, the cities and towns adjacent to the river, Skagit County, the various railroad companies, the State of Washington, and the United States Government.

130. Conclusion. - It is concluded: That there is a reasonable probability of developing a modification of the details of the existing flood control project that would reduce the cost to local interests; and that a modification of the project so as to provide for at least partial control of erosion at a cost commensurate with the anticipated benefits may be possible. The details and cost of such a modified project cannot be determined without a survey.

131. Recommendation. - I therefore recommend that a survey be authorized to determine the elements, cost and economic justification of a modification of the existing flood control project for Skagit River.

H. J. Wild,
Lt. Col., Corps of Engineers,
District Engineer.

3 Incls.:
1 Map (tracing and 4 bps., E/8/4/33)
Papers presented at hearing. (Appendix A)
Minutes of hearing (Appendix B) } In quad.