SEATTLE DISTRICT - FILE COPY

CORPS OF ENGINEERS, U. S. ARMY
Office of the District Engineer
Seattle District
4735 E. Marginal Way
Seattle 4, Washington

Report on Survey
for
Flood Control
of
SKAGIT RIVER AND TRIBUTARIES,
WASHINGTON

February 21, 1952

Copy No. 26

NOT FOR PUBLIC RELEASE

P 000179

SYLLABUS

The District Engineer finds that flooding in Skagit River Basin occasionally causes substantial damage. Local interests have constructed extensive levee systems to protect large areas from the more frequent high-water stages, and subsequently development of agricultural lands has reached a high level. To increase the existing degree of flood protection, additional protective works have been investigated including floodwater storage in multiple purpose hydroelectric dam and reservoir projects, raising the existing levee system, and flood diversion channels. These investigations indicate that Federal construction of none of these works is justified at this time.

The District Engineer recommends that the existing flood control river diversion project on which no work has been done, and for which no local cooperation has been offered, be abandoned, and that no other project for control of floods be adopted at this time.

REPORT ON SURVEY
FOR
FLOOD CONTROL OF SKAGIT RIVER
AND
TRIBUTARIES, WASHINGTON

TABLE OF CONTENTS

Subject	Paragraph No.	Page No.
Syllabus		
Table of contents		
Authority	1	1
Scope of review	3	2
Prior reports	4	2
General description	5	3
Geography	5	3
Stream valley and tributaries	6	3
Topography	9	4
Geology	11	4
Soils	14	5
Stream slopes	17	5
Cross-sectional dimensions	18	6
Channel capacity	20	6
Economic development	23	7
Population	23	7
Resources and local industries	24	8
Agriculture	25	8
Forest resources	27	9
Fisheries	30	10
Oyster industry	31	10
Mineral resources	32	10
Hydroelectric power development	33	10
Navigation	36	13
Bridges	37	13

Subject	Paragraph No.	Page No.
Railways	38	14
Highways	40	14
Airfields	41	15
National and departmental reservations	42	15
Climatology	43	15
Run-off and stream flow data	46	16
Floods	48	17
Standard project flood	51	19
Extent and character of flooded area	52	19
Area west of Sedro Woolley	53	20
Area east of Sedro Woolley	59	22
Type and extent of improvements	60	23
Value and productivity	65	24
Flood damages	66	24
Existing Corps of Engineers flood control projects	68	25
Authorized project	68	25
Emergency flood control work	69	26
Improvements by other Federal and non-Federal agencies	70	26
Dikes and diking districts	71	26
Drainage districts	73	27
Upstream area	74	28
Ross Reservoir	75	28
Improvement desired	76	29
Flood problems and solutions considered	78	29
Problems	78	29
Solutions considered	81	30
Storage	81	30
Diversion	87	35
Levee improvement	89	36
Nookachamps Creek area	93	38

Subject	Paragraph No.	Page No.
Changing mouth of North Fork	94	38
Dredging main river channels	95	39
Discussion	96	40
Conclusions	107	44
Recommendations	108	44

TABLES

Table No.	Subject	Page No.
1	Seattle hydroelectric power development on Skagit River	12
2	Bridges over Skagit River	14
3	Discharge in Skagit Basin for major floods of record	18
4	Areas in flood plain	20
5	Flood damage summary	25
6	Dam and reservoir investigations summary	34

Maps at end of report:

Drainage Basin	File No. E-6-6-84
Flood plain west of Sedro Woolley	File No. E-6-6-85

CORPS OF ENGINEERS, U. S. ARMY
Office of the District Engineer
Seattle District
4735 E. Marginal Way
Seattle 4, Washington

21 February 1952

SUBJECT: Report on Survey for Flood Control of Skagit River and Tributaries, Washington

TO: Division Engineer
North Pacific Division
Corps of Engineers
500 Pittock Block
Portland 5, Oregon

1. Authority. - The following report, with map, on survey for flood control of Skagit River and its tributaries, Washington, is submitted in compliance with the following Acts of Congress:

a. The Act of Congress approved June 13, 1934, reads, in part, as follows:

> "Be it enacted * * * , that the Secretary of War be, * * * 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 * * * ."

b. Section 6 of the Act of Congress approved June 22, 1936, 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: * * * Skagit River and tributaries, Washington. * * * ."

c. Section 5 of the Act of Congress approved August 28, 1937, provides:

> "That section 6 of the Act * * * approved June 22, 1936, is hereby amended by adding to the list of localities at which preliminary examinations and surveys are authorized to be made the following names: * * * North and South Forks of the Skagit River from Mount Vernon to Skagit Bay, Washington. * * * ."

2. The report on preliminary examination directed by the Acts of June 13, 1934, and June 22, 1936, was submitted by the District Engineer March 29, 1937, and after a favorable review by the Board of Engineers for Rivers and Harbors, a survey report was ordered by the Chief of Engineers July 29, 1937.

3. Scope of survey. - Field topographic surveys, field flood damage estimates, and foundation explorations have been undertaken as needed to provide data for the report studies. Throughout the course of the survey, meetings and consultations were had with Skagit County officials, local farm organizations, other governmental agencies, including the Department of Agriculture and the Federal Power Commission, Washington State Department of Conservation and Development, and interested private citizens.

4. Prior reports. - In addition to the preliminary examination report mentioned in paragraph 2, two prior reports giving consideration to flood control measures have been made. These reports are described as follows:

a. 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 (1925). The Chief of Engineers recommended a survey to study flood control plans for the Skagit River.

b. 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 (1934). This report considers the water resources of the entire basin and discusses several possibilities of flood control storage in conjunction with power production as well as flood control by means of river improvements and diversion. The Chief of Engineers concluded that flood control measures were needed but that Federal participation in their cost was not warranted at that time.

P 000185

5. General description. - Geography. - The Skagit River Basin lies on the western slope of the Cascade Range in the northern part of the State of Washington. The drainage basin covers 3,140 square miles, extending south from Canadian territory to the watersheds of Stillaguamish and Snohomish Rivers, and west from the summit of the Cascades to Puget Sound. The basin is roughly T-shaped, with the top extending 100 miles north and south along the Cascade Range. A small portion of the northern mountainous part of the basin lies in Canada. Bordering river basins include those of the Nooksack, Fraser, and Samish on the north; Columbia River tributaries on the east; and Stillaguamish and Snohomish on the south.

6. Stream valley and tributaries. - Skagit River has its source in Canada, 28 miles north of the international boundary, from where it flows south and west for 135 miles to Puget Sound. About 7 miles above its mouth, the river divides into two main branches, North Fork and South Fork. Freight-carrying river boats use the North Fork and ascend the river to the city of Mount Vernon at river mile 11. Log towboats use both forks of the river and may travel upstream as far as Marblemount at mile 78. Largest tributaries are Sauk and Baker Rivers. Other important tributaries are Cascade River, Thunder Creek, and Ruby Creek.

7. 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, elevation 10,436 feet, taking all the run-off from its extensive glacial fields.

8. Baker River has its source on the eastern slope of Mount Shuksan, elevation 9,038 feet, flows south 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 Mt. Baker and Mt. Shuksan.

P 000186

9. Topography. - A major portion of the Skagit Drainage Basin is in the Cascade Mountains. The upper reaches of the tributaries are in precipitous mountain valleys, and as the valleys progress downstream they broaden but maintain their steep mountain walls. The main river flows in a valley 1 to 3 miles wide from Rockport to Sedro Woolley. In this section, the valley walls are steeply-rising, timbered hills. Below Sedro Woolley, the valley falls to nearly sea level and widens to a flat, fertile, outwash plain which joins with the Samish Valley to the north and extends west through Mount Vernon to LaConner and south to the delta of Stillaguamish River.

10. Elevations in the mountainous portion of the drainage basin range up to 10,750 feet at the summit of Mt. Baker. Other peaks include Glacier Peak, 10,436 feet; Jack Mountain, 9,070 feet; Mt. Shuksan, 9,038 feet; Mt. Logan, 9,080 feet; and numerous other mountains having elevations between 5,000 and 9,000 feet. In these mountains are many glaciers and permanent snow fields which are maintained by the abundant precipitation and cold temperatures at the high levels.

11. Geology. - The Skagit River Basin drains the most rugged area of the Cascade Mountains. The basin reaches the crest of the range for 130 miles, measured along the divide. Altitudes along this portion of the divide are generally about 7,000 feet. The basin has been severely glaciated by continental and valley glaciers, and valley glaciers still exist above elevation 5,000 feet. The ultimate effect of the glaciation was the carving of hundreds of cirques, broadening valleys to U-shaped cross profiles, general active erosion of the higher areas, subduing of the lowland hills, and deposition of sediments in the lower areas. The courses of the Suiattle and Sauk Rivers were changed during the glacial epoch and the courses of the Skagit and Baker Rivers have probably been modified locally.

12. The Skagit River drains into Puget Sound through channels now concentrated southwest of Mount Vernon. The distributary system

P 000187

formerly included the area west and north of Mount Vernon as well. The entire flat area west of Sedro Woolley, except for scattered low hills, is a delta plain overlying bedrock at an unknown depth.

13. Most of the drainage basin is underlain by ancient greenstone, phyllite, schist, marble, and other metamorphosed sediments, intruded locally by igneous bodies. Mount Baker and Glacier Peak are made up of andesite lava. Terraces and flood plains are composed of sand, gravel, silt, and some glacial till.

14. 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 1911, 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 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.

15. The extensive delta 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 a very poor and artificial drainage is necessary. Each of these types is extremely productive. Oats, wheat, potatoes, vegetables, and small fruits are extensively grown.

16. The soil in the upland areas, lying between the valley and the surrounding hills, consists 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.

17. Stream slopes. - From its source in Canada to Rockport,

P 000188

Washington, a distance of 70 miles, Skagit River has an average slope of 15 feet per mile. Within this section a 10-mile portion having a slope of 70 feet per mile is under development by the city of Seattle for hydroelectric power production. Between Rockport and Sedro Woolley the river has an average slope of 4 feet per mile. In the delta below Sedro Woolley to the mouth, the normal water surface slope averages about 1 foot per mile. The major tributaries generally have steep river slopes ranging from 30 to 80 feet per mile.

18. Cross-sectional dimensions. - Below Sedro Woolley, Skagit River has irregular widths varying from 1,000 to 1,500 feet between levees. Each of the forks has channel widths varying from 300 to 500 feet. Average channel depths in the main river and forks are 15 to 20 feet below the natural top of bank. Water depths vary with river discharge. For navigation, a controlling depth of about 3 feet or less exists over the North Fork bar in Skagit Bay. Noticeable tidal effects from Puget Sound extend upstream for 15 miles, but are most significant near the mouths where navigation interests utilize high tide for crossing the bars. During floods, the tidal effect is not important for more than 3 or 4 miles above the mouth of each fork.

19. Above Sedro Woolley the river slope is steeper--4 feet per mile to the mouth of Sauk River--and the river does not always occupy a stable channel as in the reach below Sedro Woolley. Between Sedro Woolley and Concrete channel widths vary from 500 to 1,000 feet and the height of the riverbanks varies from 5 to 10 feet above normal low flows. In this reach the river meanders and bank caving and erosion is common.

20. Channel capacity. - Because of the varying river channel conditions and the several degrees of channel improvement throughout the valley the maximum safe discharge capacity ranges from 90,000 to 120,000 second-feet, depending upon the location. Between the mouth of Sauk River and Sedro Woolley it is estimated that appreciable flood damage will commence

P 000189

above flows of 100,000 second-feet. There is no direct observational data to confirm this figure.

21. Below Sedro Woolley safe channel capacity estimates based on flood observation have been made. Skagit River channel is diked from Burlington to its mouth. The capacity of the diked channel is not uniform. During the November 1949 flood, a maximum flow of 114,000 second-feet was recorded at the U. S. Highway 99 bridge gage. At Sedro Woolley, 7 miles upstream, the flow is estimated to have been 135,000 second-feet, the difference being due to natural storage in the Nookachamps Creek area. In the 1949 flood, the river between Burlington and Mount Vernon carried the discharge, 114,000 second-feet, with a sufficient freeboard, and it is estimated that this section of the river could safely carry 120,000 second-feet. In the February 1951 flood the channel between Burlington, Mt. Vernon, and the forks carried 145,000 second-feet, but the dikes had practically no freeboard and were in great danger of failure.

22. Based on recent flood experience, reasonably safe channel capacities are summarized as follows:

River Section	Discharge
Sauk River to Sedro Woolley	100,000 second-feet (Concrete gage)
Sedro Woolley to Mount Vernon	120,000 " " (Highway 99 gage)
Mount Vernon to mouth	90,000 " " " " "

In spite of the relatively low carrying capacity, the river levees below Mount Vernon have never experienced general failure during the maximum floods of record (up to 220,000 second-feet at Sedro Woolley). The reason is that relief has come from levee failures in various districts and natural overflow into the Samish Basin on the north.

23. Economic development. - Population. - The Skagit River Basin occupies a major portion of Skagit County. The 1950 population of Skagit County is 43,066, of which 34,800 is estimated to be within Skagit Basin. Population statistics are summarized as follows:

P 000190

Place	Population 1950	Population 1940
Skagit County	43,066	37,650
Skagit Basin	34,800	30,300
Skagit Basin west of Sedro Woolley	28,000	24,400
Skagit Basin east of Sedro Woolley	6,800	5,900
Mount Vernon	5,198	4,278
Sedro Woolley	3,288	2,954

These statistics show a considerable population growth in the past 10 years for Skagit Basin.

24. Resources and local industries. - Farming and logging are the principal activities in the Skagit Basin. These industries are directly concerned with the Skagit River because the best farm lands are on the river's flood plain and the river is used for transporting logs to tidewater. In addition, an important amount of hydroelectric power is produced in the basin which is transmitted primarily to the city of Seattle. Cement manufacturing and fisheries also add to the basin's economic status. A further description of these industries is given in the following paragraphs.

25. Agriculture. - In the extensive valley bottom lands of Skagit River Basin farming is the predominant occupation. Dairying and allied products comprise the largest single type of farming, but many farms grow a variety of crops including vegetables, seed, grain, and field crops. The 1948 United States Census of Agriculture gives a detailed breakdown of farm crop values for that year. The data are summarized as follows:

Dairy products	$4,800,000
Hay and forage	1,500,000
Seeds, bulbs, flowers, specialties	1,900,000
Vegetables	1,800,000
Poultry and poultry products	1,300,000
Livestock and livestock products	800,000
Grain	500,000
Fruits and nuts	200,000
Total	$12,800,000

These values are for all of Skagit County, but it is estimated that farm lands within the Skagit River and Samish River lowlands produced

P 000191

at least 95 percent of the total. For 1949 a total crop value in excess of $14,000,000 for the county has been reported by the county agricultural agent.

26. Skagit Valley farms produce 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 fresh to the Puget Sound consuming centers, the remainder being condensed and canned in local plants for later shipment out of the basin.

27. Forest resources. - Based on data furnished in 1945 by the Pacific Northwest Forest and Range Experiment Station, United States Forest Service, it is estimated that the Skagit Basin contains 16,274,000,000 board feet of merchantable timber available for cutting, of which about 10 billion feet are within Mount Baker National Forest, the remainder being held in State, county, municipal, or private ownership. Distribution of the available saw timber of the Skagit Basin by species is as follows:

Species	Volume in million board feet
Douglas fir	3,686
Western hemlock	5,667
Cedars	2,487
Balsam firs	3,774
Others	660
Total	16,274

28. In recent years capacity of logging companies operating within the Skagit Basin amounted to more than one million board-feet per day. The logs are used mainly by mills in Bellingham and Everett. The following tabulation shows the annual volume of timber cut by years, 1942-46, in the basin:

P 000192

Year	Volume in million board feet
1942	364
1943	319
1944	308
1945	249
1946	213

29. With the exception of lumber cut at Rockport and Sedro Woolley by mills having a combined daily capacity of about 25,000 board feet, practically all lumber is cut at tidewater mills outside of Skagit Basin.

30. Fisheries. - Skagit River is the largest stream entering Puget Sound and is an important contributor to the salmon fishing industry of Washington. Greatest value of the river for salmon is its spawning grounds on the numerous tributaries. Salmon reared in the Skagit River Basin constitute a considerable part of the commercial and sports fishery in Puget Sound and the coastal waters of Washington. In the mouths of Skagit River a large number of salmon are caught by gill-net fishermen.

31. The oyster industry. - For a number of years, Japanese (Pacific) oysters have been raised successfully on Washington tidelands, notably in Willapa Harbor in southwestern Washington, and in Samish Bay. In 1932 the first planting of oysters was made in Padilla Bay, and from data now available it appears that the industry in that locality is financially successful.

32. Mineral resources. - The only mineral resources that have been developed are sand, gravel, limestone, talc, and silica. A cement mill at Concrete has a daily capacity of 6,000 barrels, and produces over one million barrels annually. Talc and silica are produced at Marblemount, but in small quantities only.

33. Hydroelectric power development. - The most extensive power development is that being done by the city of Seattle under Federal

P 000193

Power Commission license on Skagit River above the mouth of Cascade River. The system, when completed, will consist of three dams with powerhouses as follows: Gorge, farthest downstream; Diablo; and Ross, farthest upstream. Ross Dam and Reservoir provides a large amount of storage for its own power plant as well as for the downstream plants whose dams are primarily for head development. The first generators in the Gorge plant were completed in 1924 and the entire development is still under construction and modification. Table 1 shows pertinent data on the Seattle hydroelectric power project on the upper Skagit. During the winter, flood control storage space will also be available in Ross Reservoir. This subject is covered in more detail in following portions of this report.

34. In addition to the city of Seattle power plants, one other major plant, owned by the Puget Sound Power and Light Company, is located on Baker River near its mouth. This development consists of a concrete, gravity-arch dam, 286 feet high, creating a reservoir having a usable storage capacity of 132,500 acre-feet. The concrete powerhouse is located 900 feet downstream from the dam and is served by a 22-foot diameter tunnel. The power plant has two units of 20,000-kilowatt capacity each. This project was completed in 1927. With normal power operation no significant storage space is available during the flood season.

35. Two other small plants are located on a tributary to Baker River. These plants have a combined capacity of about 1,000 kilowatts and are owned by the Superior Portland Cement Company, which operates them for the cement mill at Concrete.

Table 1. - Seattle hydroelectric power development on Skagit River

Plant	Description	Installed capacity, kw. Present	Under construction	Additional planned	Total	Remarks
Newhalem powerhouse ------	500' head from tributary creek diversion	2,000	0	0	2,000	Originally built for power during construction of other works.
Gorge Dam and powerhouse -	Diversion dam, 20.5' diameter tunnel 11,000' long to powerhouse with 270' head	60,000	40,000	50,000	150,000	Concrete diversion dam 40' high completed 1950; replaced timber crib structure. Future installation dependent upon raising diversion dam. Storage for pondage only.
Diablo Dam and powerhouse-	Concrete arch, 389' high, 7-1/2 miles above Gorge Dam. 19.5' diameter tunnel 2,000' long to powerhouse with 307' head.	120,000	0	0	120,000	Installation completed in 1930. Storage nominally for power only.
Ross Dam and powerhouse --	Concrete arch 545' high, completed in 1948. Two 24' diameter tunnels 800' long to powerhouse with 395' head.	0	270,000	90,000	360,000	270,000 kw. scheduled for 1953, 360,000 kw. by 1956. Dam may be ultimately raised to height of 675'; construction indefinite. Present storage 1,400,000 ac.-ft., ultimate storage 2,950,000 ac.-ft.
Total, power installation		182,000	310,000	140,000	632,000	

P 000195

36. Navigation. - Skagit River is navigable to Marblemount, 78 miles above the mouth. None of the tributaries is navigable. Present navigation upstream from Mount Vernon is limited to the towing of logs by small boats, but freight service is maintained between Mount Vernon and Seattle. Logs dumped in South Fork or adjacent sloughs are towed to salt water via that branch. The existing navigation project, adopted by the River and Harbor Act of June 25, 1910, and described in House Document No. 1188, Sixtieth Congress, second session, 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. 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 1-1/2 feet at mean lower low water. A shift in flow distribution between the forks has occurred so that at present the North Fork carries a somewhat greater amount than the South Fork, and the mattress sill has now been removed to facilitate navigation in the North Fork. A controlling depth of about 3 feet exists over the bar at the mouth of North Fork.

37. Bridges. - The eight bridges crossing Skagit River are listed in table 2.

P 000196

Table 2. - Bridges over Skagit River

Location: Miles above mouth	Location: Nearest town	Owner	Kind	Purpose
4.0	Mount Vernon	Skagit County	Swing	Highway
5.5 1/	Fir	Skagit County	Swing	Highway
10.8	Mount Vernon	Skagit County	Swing	Highway
15.0	Mount Vernon	State of Washington	Swing	Highway
15.5	Mount Vernon	Great Northern Railway Company	Swing	Railway
21.8	Sedro Woolley	Northern Pacific Railway Company	Swing	Railway
22.0	Sedro Woolley	Skagit County	Swing	Highway
78.0	Marblemount	State of Washington	Fixed	Highway

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

38. Railways. - The coastal route of the Great Northern Railway between Seattle, Washington, and Vancouver, British Columbia, 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.

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

40. Highways. - The Pacific Highway (U. S. 99) crosses the western end of 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 100 miles in length, and

P 000197

numerous gravel and improved dirt roads adequately serve the basin.

41. Airfields. - Within the Skagit Basin are five airfields, three of which are small private fields near Sedro Woolley and Mount Vernon. A municipally-owned and operated airfield is at Concrete. An inactive Naval field near Mount Vernon is used only as an emergency landing field. No other air traffic facilities are available in the Skagit Basin.

42. National and departmental reservations. - About 2,100 square miles of the Skagit River Basin are included within the Mount Baker National Forest. Other reservations included within the forest area are two recreation areas, two game preserves, and the North Cascade Primitive Area.

43. Climatology. - The Skagit Basin ranges in elevation from sea level to more than 10,000 feet, which causes marked differences in temperature and precipitation throughout the area. The United States Weather Bureau has maintained 16 climatological stations in or near the basin, of which 10 are currently operated. Another climatological station is also operated by the Department of Agriculture, Province of British Columbia. These stations vary in elevation from 30 feet at Anacortes to 4,150 feet at Mount Baker Lodge. The extremes in temperature recorded in or near the basin have reached a maximum of 109° F. at Skagit power plant and a minimum of -11° F. at Darrington Ranger Station and Mount Baker Lodge. Average length of growing season varies from 105 days at Mount Baker Lodge to 236 days at Anacortes, just outside the western edge of the basin.

44. Approximately 75 percent of the precipitation in the Skagit Basin falls during the period October through March. Heavy winter snows occur in the higher elevations and remain until late spring or early summer. The average snowfall at Mount Baker Lodge is 504 inches and at Anacortes is 5 inches. The total annual precipitation varies from 109 inches at Mount Baker Lodge to 27 inches at Anacortes.

Detailed climatological data for representative stations are summarized in the appendix.

45. The principal agricultural portion of the basin lies west of Sedro Woolley and has a mild climate without extremes of heat or cold. Precipitation is likewise moderate, averaging 45 inches annually at Sedro Woolley, with lesser amounts on the farm lands to the west. In most seasons, spring and summer rainfall is adequate for optimum crop production, yet in common with the rest of the Puget Sound area, the summer season is the driest period in the year. Some farmers irrigate with sprinklers, obtaining water from wells or river channels, but the practice is not widespread. The climatic and soil conditions result in Skagit Valley farms being outstanding for the high quality and quantity of their products.

46. Run-off and stream flow data. - Stream gaging in the Skagit Basin was inaugurated in 1908 when stations were established on Skagit River near Newhalem and Sedro Woolley. Since that time the United States Geological Survey has maintained partial or complete records for 53 stream gaging stations and 4 lake and reservoir stations. The Geological Survey currently obtains data for 25 stations in the Skagit Basin. The locations of these gaging stations are shown on a map in the accompanying appendix.

47. Skagit River and most of its tributaries have a relatively low discharge from July through September or October. However, some tributaries which are fed by glaciers and snow fields have a relatively high discharge during these months, normally the warmest of the year. The flow from October or November through March is characterized by frequent sharp rises resulting from concentrated 2- to 5-day storms or series of storms. These storms, with their intense rains, are frequently accompanied by warm winds which cause appreciable snow melt. The combined rain and snow melt produce a high rate of run-off, which results in high water or floods in the lower valley. April through

P 000199

June flows are relatively high and sustained as a result of the melting of the snow pack accumulated at the higher elevations during the winter months but remain below bank-full capacity. Normal annual run-off varies from more than 130 inches on the headwaters of Baker River to 35 inches on the upper Skagit River, principally that portion of the basin in British Columbia. Detailed stream flow data are summarized in the appendix.

48. Floods. - All major floods of record on Skagit River have occurred in winter and have been caused by high rates of precipitation and warm winds with accompanying snow melt. This type of flood has a high crest which is of shorter duration than the annual spring snow melt high water. Several winter rises may be expected each year, and the most severe floods of this type have been experienced in November and December and two of lesser magnitude in February. Occasionally, two or more floods follow in close succession as in the floods from November 23 to November 30, 1909, and from December 19, 1917, to January 1, 1918.

49. Table 3 summarizes available data for three gaging stations for seven major floods of record and five historical floods. A discussion of methods used in determining discharges for these early floods and probable accuracy is contained in the appendix to this report. Data for the floods of February 1932, January 1935, November 1949, and February 1951, are not comparable with the earlier floods shown as discharges of the later floods were modified by storage in the three power reservoirs. Shannon Lake and power plant on Baker River was completed in June 1927. Diablo Reservoir and power plant on the upper Skagit River was completed in 1930, and Ross Reservoir, approximately 5 miles upstream from Diablo Reservoir, was completed in 1948, giving 1,400,000 acre-feet of storage. Since 1940 increasing amounts of power storage in Ross Reservoir have been available as dam construction progressed.

Table 3. - Discharge in Skagit Basin for major floods of record

Date	Maximum instantaneous discharge in cubic feet per second					
	Skagit River at Reflector Bar or at Newhalem		Skagit River at the Dalles or near Concrete		Skagit River near Sedro Woolley	
1815	a/	115,000	a/	500,000	a/	400,000
1856	a/	95,000	a/	350,000	a/	300,000
November 16, 1896	d/		d/		a/	185,000
November 19, 1897	a/	48,000	a/	275,000	a/	190,000
November 16, 1906	d/		d/		a/	180,000
November 30, 1909	a/	70,000	a/	260,000		220,000
December 30, 1917	a/	43,000	a/	220,000		195,000
December 12-13, 1921	a/	63,000	a/	240,000		210,000
February 27, 1932	b/	45,000		147,000	d/	
January 25, 1935	b/	30,300		131,000	d/	
November 27, 1949	b/ c/	14,000	c/	158,000	c/	135,000
February 10, 1951	b/ c/	12,000	c/	139,000	c/	150,000

a/ Estimated by Mr. J. E. Stewart in 1923 for U. S. Geological Survey and Skagit County.

b/ Discharge below Gorge power plant.

c/ Preliminary estimate.

d/ Not available.

50. The existing reservoirs are not effective in preventing major flooding in the Skagit Valley. Diablo Reservoir is ordinarily maintained at a high level by Ross storage and has no flood storage. Shannon Lake is likewise held at a high level if stream flow permits, but an incidental degree of minor flood protection might be available if the reservoir should be drawn down because of deficient run-off before a flood. Ross Reservoir above Diablo has a large amount of storage, primarily for power, but the Federal Power Commission has required a reservation of winter flood control storage space. Studies are under way to determine the amount of such storage, and it is believed that it will not exceed 200,000 acre-feet. Because of

P 000201

its far upstream location Ross Reservoir storage cannot greatly reduce major floods on the lower Skagit River. The effectiveness of Ross storage in reducing peak discharges depends upon location of the storm center and other variable storm characteristics. Estimates based on average conditions indicate that crest reductions varying between 15,000 and 25,000 second-feet may be expected at Sedro Woolley.

51. Standard project flood. - The standard project flood was derived for Skagit River at Sedro Woolley by application of the unit hydrograph procedure to rainfall and snow melt resulting from heavy precipitation over the basin combined with other hydrological factors favorable to a rapid run-off. The standard project flood so derived at Sedro Woolley is 440,000 second-feet without upstream storage. Flood control storage in Ross Reservoir would reduce that discharge to 415,000 second-feet. The standard project flood has twice the discharge of the maximum flood of record since establishment of the gaging station in 1908 and is 110 percent of the estimated maximum historical flood occurring about 1815.

52. Extent and character of flooded area. - The Skagit Basin is divided by topography and economic development into two main areas, i.e. the valley lands east and those west of Sedro Woolley. The bottom land area west of Sedro Woolley is much larger and very much more highly developed than is the bottom land in the eastern or upstream area. Table 4 lists the areas in the flood plain.

P 000202

Table 4. - Areas in flood plain

Area	Acreage: Total	Acreage: Protected by levees
West of Sedro Woolley	68,000	46,000
Skagit Section	43,000	36,000
Samish Section	25,000	10,000
East of Sedro Woolley	22,000	0
Agricultural and urban	8,000	0
Uncleared and river bottom	14,000	0
Total, entire	90,000	46,000

53. Area west of Sedro Woolley. - The western area contains two main subdivisions, the Skagit section and the Samish section. The Skagit section lies west and south of Burlington adjacent to the main channel and forks of Skagit River. Samish section lies northwest of Sedro Woolley and is normally separated from Skagit River by a low divide roughly defined by a line between Sedro Woolley and Burlington. Flood flows at Sedro Woolley in excess of 150,000 second-feet would rise above the low divide and a portion of the floodwaters would flow into the Samish River Basin. Major right bank levee breaks in the vicinity of Burlington could reduce the flood flow passing into the Samish Basin.

54. The right bank levee begins in the vicinity of Burlington at high ground on the divide separating Skagit and Samish drainage basins. The upstream portion of the levee protects Burlington from medium floods, but floods which would overtop the Skagit-Samish divide would also outflank the end of the levee and permit floodwaters to pass through Burlington. It is likely that such floods would also breach the levee at Burlington and further add to the flooding of the area.

55. The left bank levee begins about 1-1/2 miles downstream from Burlington at the Great Northern Railway bridge. From this point downstream both banks of Skagit River and its forks are continuously

leveed. The efficacy of this levee system is partially dependent upon conditions between Sedro Woolley and Burlington. At the present time the leveed portion is benefited by overflow into the Nookachamps Creek area and occasionally into the Samish section. These natural overflow areas, combined with breaks in the right bank levee below Burlington, prevented major failure of the remaining down-river levees in the two largest floods of record (1909 and 1921). The weak right bank levee sections just below Burlington have since been strengthened by local interests so that future floods may be expected to send more water to the downstream levees than in 1921 or 1909. This situation was demonstrated in the November 1949 and February 1951 floods when no breaks occurred between Burlington and Mount Vernon, but levee sections on each of the forks failed.

56. Below Mount Vernon two levee failures occurred in the November 1949 flood. One was on the left bank of the North Fork in Diking District No. 15 which caused flooding to depths of 8 feet or more as the floodwaters were confined by the sea dikes. An adjacent diking district (No. 21) was flooded to shallow depths by floodwaters from District No. 15 overtopping but not destroying dikes along a salt-water slough forming the boundary between the two districts. The second break occurred about 1-1/2 miles south of Conway on the left bank of the South Fork. This break flooded about one quarter of Diking District No. 3 to generally shallow depths varying from a few inches to 4 or 5 feet. The floodwaters in District No. 3 were prevented from extending south to the Stanwood area at the mouth of Stillaguamish River by flood fighting efforts on a cross dike located near the Skagit County and Snohomish County line.

57. In the flood of February 1951, with a peak discharge of 145,000 second-feet at Mount Vernon, even more serious breaks than in 1949 took place in the lower river areas. Diking District No. 13 was badly flooded by a dike failure on Deer Slough near its head where it

P 000204

leaves the left bank of the North Fork. A second break occurred in District No. 13 a short distance downstream from the North Fork bridge. In addition to the damage from water standing at depths up to 8 feet, several hundred acres of land were seriously scoured and one group of farm buildings was completely destroyed. On the South Fork, District No. 3 was again flooded by dike breaks in the vicinity of Conway. Repairs to the 1949 dike failure were not complete and the repaired section was overtopped; in addition another large break occurred about one-quarter of a mile south of Conway. The town had to be quickly evacuated and about one-half of District No. 3 was flooded. The Pacific Highway (U. S. No. 99) was flooded to depths of several feet and the highway was closed for more than a week, necessitating back road detours. Stillaguamish River also caused major flooding in the Stanwood area at this time and the lowlands between Conway and Stanwood were completely inundated. The degree to which Skagit River contributed to flooding in the Stanwood area is unknown. Farther up the river near Burlington dike breaks on the right bank of Skagit River were averted only by extensive flood fighting.

58. Immediately southwest of Sedro Woolley is the Nookachamps Creek area, which is subject to frequent overflow. The area has no flood protective works, but farms are operated with the expectancy of frequent flooding and consequently severe flood damages do not occur. As previously mentioned, the Nookachamps Creek area provides a valuable storage space for reducing flood stages in the downstream leveed river sections.

59. Area east of Sedro Woolley. - The valley upstream from Sedro Woolley is narrow and relatively undeveloped, the agricultural area extending in general only to Concrete. Even in the stretch from Sedro Woolley to Concrete about two-thirds of the bottom land is uncleared or is occupied by river channels and sloughs. These upstream lands are subject to inundation by the river, but riparian owners are more

P 000205

concerned with riverbank erosion which takes place during both medium and high river stages.

60. Type and extent of improvements. - Most of the farm lands under cultivation in the areas west of Sedro Woolley have a high state of development. As shown in table 4, a total of 46,000 acres are protected against flooding by levees. Where needed, these lands also have adequate drainage systems. The levees and drainage systems have been constructed by organized districts concerning which further information is given later in this report.

61. Practically all leveed areas in the Skagit section are subject to river overflow and, in addition, some of them also require protection against high tides. Tidal flooding is prevented by the sea dikes bordering Skagit Bay and Padilla Bay. These sea levees sometimes aggravate river flood conditions as described in the following paragraph.

62. The levees in the Samish River section of the valley are designed solely to reclaim tidelands and they afford no protection from overflow of the Skagit River. During major floods of the Skagit River floodwaters are trapped behind the sea levees and so prolong the period of inundation of the Samish Valley lands, or build up sufficient head to rupture the levees and so permit intrusion of salt water upon the land. When levees along Skagit River break, the floodwater is also frequently impounded by the sea levees thus causing additional damage.

63. River improvements in the upstream area above Sedro Woolley consist only of bank protective works at scattered points. This work has been done from time to time by county, State, and Federal agencies. Further information about the work in the upstream area is given in a later section of this report.

64. The flood plain also contains all or portions of the towns of Hamilton, Lyman, Sedro Woolley, Burlington, Mount Vernon, and LaConner, as well as several smaller residential communities. Total

P 000206

population of the flood plain is estimated to be more than 34,000 persons. About 44 miles of railroad and about 200 miles of highway serve the farms and towns in the flood plain. More than half of the highways have some type of improved hard surface.

65. Value and productivity. - The total value of property and improvements in the flood plain is estimated from Skagit County assessor's records to be about $50,000,000. This figure does not include such nonassessed property and improvements as schools, churches, public roads, and diking and drainage works. The gross value of agricultural production from the Skagit flood plain was about $14,000,000 in 1949. A true evaluation of the productivity of the valley should also include the annual income of local business and industries dependent upon this agricultural production. No means are readily available for making such a determination of total productivity, but it is believed that the amount would be at least twice the value of the gross agricultural production.

66. Flood damages. - High flood flows west of Sedro Woolley divide into three parts in the vicinity of Burlington as follows:

a. The leveed river channel which would carry nearly bankfull flows with scattered levee breaks.

b. Overland flow into the right bank Skagit section north and west of the main river channel and North Fork channel which would occur both from levee failures and from outflanking of the upper end of the right bank levee at Burlington.

c. Overland flow in the Samish section from water crossing the low Skagit-Samish divide between Burlington and Sedro Woolley. Quantitative distribution of flood flows into the three parts have been computed for the purpose of establishing flood profiles used in evaluating future flood damages.

67. Field appraisals were made of the flood plain west of Sedro Woolley. All of the area subject to flooding was included and estimates

P 000207

were made of the damage caused by a flood of record and possible future higher floods. Estimates are based on the 1951 state of development in the valley. West of Sedro Woolley the valley agricultural lands are highly developed and it is expected that future flood damages will be much the same as under existing conditions, unless some major economic change now unforeseen should occur. The total average annual flood damages in the Skagit Valley are estimated at $188,000 on the basis of November 1951 prices and with 120,000 acre-feet of flood control storage at Ross Reservoir. Results of the flood damage determinations are summarized in table 5. Further information on this subject is given in the appendix.

Table 5. - Flood damage summary
November 1951 prices

Area	Damages: 210,000 cfs.	Damages: 1949 flood 135,000 cfs.
West of Sedro Woolley:		
Skagit diked section, right bank	$3,100,000	$ 24,400
Skagit diked section, left bank	1,160,000	173,000
Skagit, Nookachamps area	215,000	50,000
Skagit, other areas	148,000	59,300
Samish section	700,000	0
Total west of Sedro Woolley	$5,323,000	$306,700
East of Sedro Woolley	1,280,000	280,000
Total	$6,603,000	$586,700

68. Existing Corps of Engineers flood control projects. - Authorized project. - The Flood Control Act of 1936 authorized a project for the partial control of floods in the lower valley by diversion of part of the floodwaters through a bypass to be constructed between the river at Avon and Padilla Bay. Other project works include channel widening and bank revetting between Burlington and Avon, concrete control works at the head of the bypass, and a concrete weir near the outlet. The latest approved estimated cost is $3,150,000 for construction and $1,832,000 for lands and damages (1938 annual report of the Chief of Engineers). Local interests are required to 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

P 000208

damages due to the construction works, and maintain and operate all the works after completion in accordance with regulations prescribed by the Department of the Army. The terms of local cooperation have not yet been met and no Federal funds have been appropriated for this project.

69. Emergency flood control work. - Since 1947 the Corps of Engineers has spent more than $158,000 on reconstruction of damaged or destroyed flood control structures under appropriate emergency flood control laws. This work is summarized in the following tabulation:

Nature of work	Date completed	Federal cost
Bank revetment near Utopia----------	February 1947	$13,419.07
Bank revetment at Burlington Bend---	September 1948	49,963.43
Levee repair, District No. 15-------	December 1949	6,662.75
Levee repair near Milltown----------	April 1951	64,939.73
Levee repair near Conway------------	May 1951	23,275.55
Total-------------------		$158,260.53

70. Improvements by other Federal and non-Federal agencies. - Existing works for control of floods on Skagit River consist of dikes built by local interests and a flood control storage reservation in Ross Reservoir, owned by the city of Seattle. Together, these works are adequate to protect the areas west of Burlington against all spring floods and also to give a fair degree of protection against all but the more severe winter floods. Except as noted in the previous paragraph, local interests have performed maintenance and major repairs to the works described herein.

71. Dikes and diking districts. - Downstream from Sedro Woolley are 16 diking districts, organized and operating under the laws of the State of Washington, and embracing a total area of approximately 45,000 acres. To 1947 the districts have expended a total of about $2,355,000, or $52 an acre on the construction and maintenance of levees. In addition to the area inclosed by district levees about 1,000 acres have been leveed by individual landowners. Of the total area inclosed by levees, the Skagit River section has 36,000 acres protected against high river and sea

P 000209

stages, and the Samish River section has 10,000 acres protected against high tides. The Samish levees give no protection from overflow waters of Skagit River which occasionally cover the area. In Skagit and Samish Basins the total length of levees is 120 miles, of which 40 miles are main Skagit River levees. No accurate separation of costs between salt and fresh water levees is possible but, in general, the river levees are of heavier section and more costly construction than the sea levees, so that the total cost of river levees, both district and private, has probably been more than $1,000,000.

72. The levees were built at various times starting in 1897 without the benefit of an over-all plan or design. These levees have been constructed of materials most readily available, usually fine river sand and silt. Heights vary from 5 to 10 feet, side slopes average about 1 on 2.5 or steeper, and top widths are narrow, usually only 2 or 3 feet. The floods of November 1949 and February 1951 afforded a good opportunity to observe the effectiveness of the levee system. Major levee breaks occurred during both floods below the forks and during the larger flood (February 1951) severe breaks between Burlington and the forks were averted by extensive flood fighting and the fact that the dangerously high river stages were of short duration. The failure of certain levee sections reduced river stages so that other breaks did not occur. In all major past floods of record similar levee breaks have taken place in one or two scattered areas with the result that only part of the flood plain has been inundated at any one time. The pattern of levee failures has not been consistent, and no means exists for predicting the location of future breaks. Since 1932 the levees upstream from Mount Vernon have been raised and strengthened more than downstream levees so that more breaks would be expected in the downstream areas for medium floods. Higher floods of the magnitude of those in 1909, 1921, and 1951, would endanger the entire levee systems from Burlington downstream.

73. Drainage districts. - In addition to the levee improvements,

Skagit and Samish lowlands are organized into 11 drainage districts under the laws of the State of Washington. These districts include an area of nearly 40,000 acres and up to 1947, $1,356,000 was spent for construction and maintenance. The total cost per acre is therefore $34. Drainage improvements are generally satisfactory and no major change or extension is needed.

74. Upstream area. - The only flood control works in the upstream area above Sedro Woolley are limited amounts of bank revetments. In 1938 a Works Progress Administration bank protection project, under the engineering supervision of the district engineer, was completed. About 22,000 linear feet of weighted willow mat revetment was laid. Skagit County, as the sponsoring agency, contributed 12 percent of the total cost of $269,000. Because of insufficient maintenance and the tearing action of log rafts, much of the revetment is no longer useful. During the past 5 years, Skagit County and the State of Washington have placed rock riprap revetment at the most severe points of erosion. At Burlington Bend and Utopia the Corps of Engineers, under appropriate emergency flood control authorizations, has aided local interests in flood control bank protection projects of limited scope.

75. Ross Reservoir. - The city of Seattle owns and operates a series of hydroelectric power plants on the upper Skagit River. The uppermost site, Ross Dam and Reservoir, provides the necessary seasonal storage for the downstream plants, which are primarily head development projects with storage being limited to pondage. The system lies within the Mount Baker National Forest and all development has been done under Federal Power Commission license. The Federal Power Commission has required a storage reservation for flood control in Ross Reservoir. At the Commission's request, the Corps of Engineers is studying the flood storage requirements and recommendations will soon be made regarding the storage needed and the operating procedure. It is expected that the storage requirement will not exceed 200,000 acre-feet. By coincidence,

P 000211

winter flood storage required to realize a high degree of control on the upper Skagit does not seriously interfere with power production. Flood storage in Ross Reservoir cannot prevent major floods on the lower river, but it is estimated that peak discharges at Sedro Woolley will be reduced from 15,000 to 25,000 second-feet.

76. Improvement desired. - At a public hearing held jointly by the Departments of War and Agriculture on March 2, 1937, in connection with the preliminary examination, Skagit County officials stated that the county's financial position was such that it would be impossible at that time for the county to furnish the local cooperation required for the construction of the Avon bypass as authorized under the existing project. The consensus was that the bypass 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 bypass.

77. Further public hearings have not been held but many meetings and discussions have taken place from time to time with interested local citizens and Skagit County officials. The general desires of the community are similar to what they were in 1937. Further requests have been received to study the possibility of upstream flood control storage and also to investigate the desirability of dredging the river mouths in the interest of flood control.

78. Flood problems and solutions considered. - Problems. - The principal flood problem in the Skagit Basin is in the Skagit and Samish section of the flood plain west of Sedro Woolley. The Skagit section, with the exception of the Nookachamps Creek area, is protected from medium flood flows by an extensive levee system. The Samish section is also protected from medium floods by a natural low divide between Skagit and Samish River Basins. Flood stages capable of doing major damage occur only in the winter months, and have a low frequency of occurrence.

The existing levees and natural topographic features give the Skagit and Samish sections a considerable degree of protection against winter floods. Against spring high-water stages which occur from melting snow nearly every year, these areas enjoy practically complete protection. The problem of providing flood control works for most of the area west of Sedro Woolley is therefore mainly one of giving added protection to an area already having a good degree of protection against the more frequent floods.

79. No serious flood damage takes place in the Nookachamps Creek area southwest of Sedro Woolley. Inundation of farm and pasture land is fairly frequent, but the farm economy has been geared to these conditions. If the area were protected from floods, the land could be put to higher type agricultural use than at present, but local prevention of flooding in Nookachamps area would add to the flood problem of the large remaining Skagit and Samish sections of the flood plain by eliminating a natural overflow storage area.

80. East of Sedro Woolley where much of the flood plain is uncleared or otherwise unsuitable for farming, the principal problem is that of riverbank erosion. Because of unpredictable changes of the river in this area, and the consequent difficulty of defining and locating necessary work far in advance, a regularly authorized flood control project is not considered feasible. Local interests are providing bank protection where required to the extent of available funds.

81. Solutions considered. - Storage. - Flood control by storage has long been advocated as a possible solution to the Skagit Basin flood problems. Several sites for dams and reservoirs exist but none have been found at which a Federal project could be justified at this time. Justification of plans for storage in the Skagit Basin must depend principally on the benefits that could be obtained from hydroelectric power production at the storage sites. At only four sites can storage in significant amounts be obtained. They are the following:

P 000213

Faber site on Skagit River near Concrete

Cascade site on the Cascade River

Upper Sauk site on Sauk River above Darrington

Upper Baker site on Baker River above Shannon Lake

Investigation of small, run-of-the-river power projects without flood control value was not undertaken in this study.

82. Subsurface drillings and explorations were made at the Faber site during the course of the investigation. At the Cascade site some subsurface data from previous drillings were available. Geological information on the upper Sauk and Baker sites was obtained by field reconnaissance only. Table 6 contains a summary of pertinent information about the dam sites investigated. Power benefits for the Faber and upper Baker sites were estimated on the basis that flood control reservations of 300,000 and 140,000 acre-feet, respectively, would be made during the flood season. These reservations would result in some loss of power at upper Baker, but with no loss at the Faber site, during the critical period. In the case of the Cascade and upper Sauk sites, no flood control reservations were considered, and only the power benefits were estimated. The benefit-cost ratios of the latter two sites are so low that even if the entire amount of flood damages in the basin were added to their power benefits, the total annual benefits in each case would still be less than the annual costs.

83. With regard to the fish requirements, existing water supply and flow conditions are normally quite satisfactory for maintenance of salmon runs, and no improvements for that purpose are needed. The U.S. Fish and Wildlife Service and the Washington State Departments of Fisheries and Game were advised in 1949 of the studies being made on Skagit River and their comments were invited. In their replies they were unanimous in opposing the construction of a high dam at the Faber or lower Sauk sites because of the extensive loss to anadromous fishes that would result. They advised that the Skagit River is the

P 000214

nest salmon stream in the State of Washington, with the exception of the Columbia River, and that construction of a dam at the Faber site would be a severe blow to all salmonoid migratory species now utilizing the Skagit. The reasons they gave were that the dam would be too high for the salmon to pass successfully, and the reservoir would flood large spawning grounds. The Sauk River and tributaries are highly regarded for the spawning areas they contain, and for the large steelhead and salmon population they support. The State Department of Fisheries submitted the opinion that a dam at the lower Sauk site would destroy the Skagit River as an important producer of anadromous fishes.

84. In subsequent conversations State Fisheries officials have stated that construction of a dam of any height at the Faber or Sauk sites would be opposed until biological factors affecting the passage of fish over dams are better understood. The Fish and Wildlife Service declined to make a definite statement regarding the upper Baker or Cascade sites pending a detailed study of their probable effects. However, both the State Departments of Fisheries and Game stated that the upper Baker project would flood out a large part of the available spawning rounds, as well as destroy the natural beauty of Baker Lake, at the head of Baker River. In the case of the Cascade site, the State agencies advised that the fish losses that would result from a project couldn't be determined exactly until further biological studies had been completed. It was their opinion, however, that the losses would be substantial. As shown in table 6, none of the proposed projects except upper Baker could be justified at this time, even if the fisheries losses could be ignored.

85. The possibility of storage in the existing reservoir of Baker Dam was investigated. Winter flood control storage could be provided either by reducing the normal operating pool level or by raising the dam. It was found that neither method was economically feasible and that an equivalent amount of protection could be obtained at less cost by other means.

P 000215

86. The city of Seattle has applied to the State Department of Conservation and Development for a permit for a hydroelectric plant on Skagit River about 9 miles downstream from Newhalem. Tail-water at this point is about elevation 350 feet, and the proposed reservoir would extend to tail-water at the existing Gorge power plant. The permit has not been granted as yet, pending completion of studies to be made by the State Departments of Fisheries and Game. If this plant were to be constructed, the maximum gross head available at the Faber site would be reduced from 306 feet to 166 feet, and the storage at maximum operating pool level would be reduced from 4,650,000 acre-feet to 1,230,000 acre-feet. The effect of these reductions would be a substantial decrease in benefits for the Faber project.

P 000216

Table 6. - Dam and reservoir investigations summary

Site	Type of dam	Average continuous power kw.	Load factor	Installed capacity kw.	First cost (1951)	Annual cost	Annual power benefit 3/	Total annual benefit incl. F/C	Benefit-cost ratio
Faber, Skagit River	Earthfill, 300 feet high	188,000 1/	0.40	728,000	$218,800,000	$10,960,000	$8,620,000	$8,790,000	0.80
Dalles Reregulating Dam	Concrete, 65 feet high	31,700 1/	0.80	53,000	21,400,000	1,070,000	997,000	997,000	0.93
Combined Faber and Dalles Dams		219,700 1/	--	781,000	240,200,000	12,030,000	9,617,000	9,787,000	0.81
Cascade River	Concrete gravity, 300 feet high	32,900 2/	0.50	66,000	54,000,000	2,700,000	1,320,000	5/	0.49
Upper Baker River 4/ combined with existing dam	Concrete gravity, 300 feet high	32,550 1/	--	97,000	28,960,000	1,485,000	1,675,000	1,766,000	1.19
Upper Sauk River	Earthfill, 220 feet high	37,000 2/	0.50	74,000	47,600,000	2,380,000	1,485,000	5/	0.62
Lower Sauk River	An alternate site to Faber. Would have less power and flood control potentiality. Fisheries objection same as Faber site. No detailed estimates made.								

1/ Based on Phase C-2 Columbia River critical period from September 1928 to February 1932 inclusive.
2/ Based on Phase C-2 Columbia River critical period from September 1929 to February 1932 inclusive.
3/ Power values for 100% L.F.= 2 mills per kw.hr. for energy; $16.16 per kw.yr. for capacity; 3% transmission loss; $4.12 per kw. yr. for transmission cost.
4/ Includes costs and benefits for 35,000 kw. added installation at existing downstream plant (46% load factor operation).
5/ Flood control benefits not computed, but would be very small.

87. **Diversion.** - The existing flood control project for Skagit River would create a floodway bypass channel to protect the area west of Sedro Woolley. This project was discussed in a previous report (House Document No. 187, 73d Cong., 2d Sess.) but was shown to have costs exceeding expected benefits and was not recommended by the Chief of Engineers. No work has been done on the project because local interests have not met the terms of local cooperation and a large group of local farmers are opposed to the project. This report reconsiders the project particularly for any possible modification or combination with a levee improvement plan that might reduce the total project costs.

88. The layout of diversion plans estimated for this report differs somewhat from that of the adopted project. Estimates indicate that some saving in cost would result if the intake were moved upstream to the area between Burlington and the Great Northern Railway bridge. From this point a wide bypass channel would extend westerly to Padilla Bay, passing just north of the town of Avon, then crossing the Anacortes branch of the Great Northern Railway, and continuing to Padilla Bay closely parallel to the railroad. In arriving at the combined levee and diversion plan costs discussed later in this report, several diversion channel cost estimates were prepared. To illustrate the type of works considered, there are listed below the important features of a flood diversion channel having a design capacity of 100,000 second-feet with the river channel carrying its present safe discharge of 90,000 second-feet:

Length ------------------	48,000 feet
Bottom width ------------	1,100 "
(Total cost varies only slightly for bottom widths between 1,100 feet and 1,500 feet.)	
Depth of water ----------	16 feet
Freeboard ---------------	3 "

P 000218

Levee side slopes ----- 1 on 3 water side
1 on 4 land side

Excavation ------------ 7,738,000 cubic yards

Inlet---fixed weir with crest at elevation 25, diversion channel flow would commence with river flow of 40,000 second-feet.

89. Levee improvement. - Existing levees vary in height usually from 5 to 8 feet, with a few sections about 10 feet high. The levees generally have a very narrow top width, frequently less than 2 feet, which results in an inadequate cross section subject to leakage and wash-outs. For cost estimates of improvements to the existing levees, a standard cross section having a top width of 12 feet and side slopes of 1 on 2.5 was used. A 12-foot top width is required for proper stability and access for maintenance. Estimates were made for modifying and raising all main river levees from Burlington downstream. Water surface profiles for assumed design floods were computed and a 3-foot freeboard allowed. The existing levee alinement was followed in most cases.

90. With the cost data for various capacities of diversion channels and for various increased capacities of the leveed river channel curves have been drawn showing the cost of several combinations of diversion channel and improved river channel for any given design flow. These curves show that the most economical type of improvement is principally by raising the existing river levees. If the design flow were 200,000 second-feet, the least costly project would be by levee improvement alone, and for a design flow of 300,000 second-feet the river channel should carry 205,000 second-feet and bypass channel 95,000 second-feet. These results are illustrated in the following tabulation:

P 000219

To protect against a peak flood flow of:	Project first costs (1951 prices)		
	Bypass with no levee improvement	Levee improvement only	Combination
200,000 cfs.	$9,600,000 (bypass, 110,000 cfs. existing levees 90,000 cfs.)	$ 5,900,000	None, levees least cost
300,000 cfs.	$16,000,000 (bypass, 210,000 cfs. existing levees 90,000 cfs.)	17,000,000 +	$10,800,000 (bypass, 95,000 cfs., levees, 205,000 cfs.)
415,000 cfs. standard project flood	No data	No data	$17,000,000 (approx.) (bypass, 215,000 cfs., levees, 200,000 cfs.)

91. The studies of diversion plans and improvement to the existing levee system indicate that for any plan, levee improvement would be a major component. If allowable design capacities are near 200,000 second-feet, consideration of a diversion channel is not warranted. If design capacities are appreciably greater than 200,000 second-feet, then a combined levee and diversion project would be most economical. This situation suggests a progressive flood control improvement program with improvement to the existing levee system being the first that should be undertaken.

92. The maximum flood of record (1909) had an estimated discharge of 220,000 second-feet at Sedro Woolley. Taking into consideration the existence of Ross Reservoir, a recurrence of the 1909 flood under existing conditions would result in a discharge of about 185,000 second-feet at Sedro Woolley, requiring a channel capacity below Burlington of about 170,000 second-feet. These reductions in peak flow would be caused first by storage in Ross Reservoir, which would give a lower peak at Sedro Woolley, and second, by natural storage in the Nookachamps Creek area. The least degree of protection believed advisable for a Federal flood control project is one which would give protection against a

P 000220

flood somewhat greater than the maximum of record. For the discussion herein, a flow of 250,000 second-feet at Sedro Woolley may be considered as the minimum design flood. The flow of 250,000 second-feet at Sedro Woolley would be reduced by natural storage in the Nookachamps Creek area so that 220,000 second-feet would be the resulting discharge to be taken care of below Burlington. The first cost of improving the levees to this capacity would be $7,500,000 (1951 prices) and the annual cost, $375,000. Average annual flood control benefits determined from the damage-frequency curves would amount to $150,000. The benefit-cost ratio is therefore 0.40. Similar computations for higher and lower degrees of protection indicates that no higher benefit-cost ratio can be attained. From approximate cost studies for a project to give complete protection against the standard project flood, the benefit-cost ratio was found to be very low. Further details of the economic analysis are given in the appendix to this report.

93. Nookachamps Creek area. - If levees were extended upstream to protect this area, the natural storage effect of reducing downstream peaks would be lost and the entire levee system would have to be raised. If Nookachamps area were included in the example in the previous paragraph, downstream project costs would be about $8,100,000, (excluding the cost of Nookachamps levees) or an increase of $600,000. The annual cost of this increase would be $30,000 whereas Nookachamps area annual benefits would be only about $15,000; and furthermore, this comparison does not include the cost of levees required in the Nookachamps area.

94. Changing mouth of North Fork. - Some local interests have advocated modifying the course of North Fork near its mouth to achieve lowered flood stages in that branch and in the main river. The suggested change in the North Fork would affect its lower mile and one-half where the river leaves the diked channel and flows through the tide flats to Skagit Bay. Local interests desire that the North Fork continue a straight course into Skagit Bay instead of making the

P 000221

existing right angle bend to the north. Because of the extensive mud flats along the entire Skagit delta, a straightened North Fork channel would have to extend nearly as far as the present channel to reach deep water. Furthermore, because the lower course of the North Fork is affected daily by tidal action, it is the high tides rather than length of channel that control maximum water surface elevations in the lower course of the river during floods. Backwater computations show that during floods a straightened channel would lower water stages about 1 foot at the extreme downstream end of the diking system, and that the effect of this change would disappear about 2 miles farther upstream. Benefits are therefore small and affect only a minor portion of the Skagit diked lands. To modify the outlet of North Fork as suggested by local interests would require the initial excavation of an estimated 1,100,000 cubic yards of material. Maintenance of the channel would present further problems not fully evaluated. Because of the minor benefit which would be realized as compared to the large annual cost, no further consideration has been given to this proposal.

95. Dredging main river channels. - Local interests have also stated that the bed of Skagit River and its forks is rising to the extent that flood stages are higher now than they were in the past. To check this statement, two river-sounding surveys have been compared. A detailed survey of the river was made by the Corps of Engineers about 1930. Using similar data and control points, a check survey of both forks and the main river up to Mount Vernon was made in 1950. Average river-bottom profiles were drawn and it was found that no significant over-all change had taken place in the river channels in the past 20 years. However, below the diked areas where the river enters Skagit Bay the tide flats are increasing because Skagit River carries quite a large suspended load, whereas in the river channels to which flood stages are related, a condition of stability or equilibrium has been reached. Because of this natural state of equilibrium between the

P 000222

erosive and filling power of the river, it is believed that any lowering of the river bottom by dredging would merely be temporary. If major levee improvements were ever undertaken, a likely source of material would be from the river bottom, but for the reasons just cited, no appreciable increase in carrying capacity should be attributed to the channel excavation. No further study of flood relief by dredging main river channels is believed warranted at this time.

96. Discussion. - Skagit River Basin has important resources in agriculture, timber, hydroelectric power, and fisheries. Of these major resources and their related activities, agriculture is the one most directly dependent upon having a reasonable degree of flood protection. The most important agricultural lands, amounting to 46,000 acres, are located on the Skagit River flood plain west of the town of Sedro Woolley. Also located in the flood plain are Mount Vernon, the county seat, the town of Burlington, and several smaller residential communities as well as the principal highways and railroads serving the basin.

97. Before development of the valley lands flooding was probably an annual event with two high-water periods, one in the winter months, having no regularity of occurrence, and the second in May or June each year from the spring snow melt in the extensive mountainous portions of the basin. To obtain relief from these flood conditions, local interests--commencing before 1900--have constructed an extensive levee system starting at Burlington and extending to the mouths of the river. In addition, many miles of levees along the shores of Skagit Bay, Padilla Bay, and Samish Bay have been constructed by local interests to reclaim large areas of tidelands for agricultural purposes. The river and sea levees jointly protect nearly all of the flood plain west of Sedro Woolley from the more frequent high-water stages in either the river or the sea. In addition to the diking system, limited flood regulation of the upper Skagit River is now possible in Ross Reservoir,

a hydroelectric power development owned by the city of Seattle. These measures give a reasonable degree of protection from floods having frequencies of 15 to 20 years.

98. When the less frequent but more serious winter floods occur, valley bottom improvements and facilities are damaged. In major floods of record, complete failure of the levee system has always been prevented by breaks at several points which lowered water surface elevations on the remaining portions. The location of particular breaks in the levees has not been the same but it is believed that the general pattern of flooding from isolated failures in the past will be repeated in future floods.

99. To evaluate the extent of flood damage under existing conditions, field appraisals of past and potential floods have been made. The information has been translated into monetary average annual flood damage to be expected over a long period of time, and for the entire basin this damage is estimated to be $188,000 annually (Nov 1951 prices).

100. The river bottom lands upstream from Sedro Woolley are not very extensive and their development has not matched those west of Sedro Woolley. This upper portion of the flood plain is subject to flooding, but a more pressing problem is active riverbank erosion. Skagit County has provided bank protection at the most critical places and on several occasions has received assistance from the Federal Government. No apparent justification exists for a Federal flood control project in the upper area.

101. Considerable study has been given to improving and increasing the capacity of the existing levee system in the flood plain west of Sedro Woolley. The possibility of floodwater diversion both alone and in conjunction with levee improvement has been investigated. No plan has been found which has a favorable benefit-cost ratio. A project having the minimum degree of protection considered advisable would be one to rebuild the existing levee system to safely carry 250,000 second-feet which is somewhat greater than the peak of the largest flood of

record at Sedro Woolley. The first cost of such a project would be $7,500,000 (Nov 1953 prices) and the benefit cost ratio would be only 0.40. Studies show that no higher ratios can be obtained by using higher or lower design floods. The standard project flood has about twice the discharge of the largest flood of record and works giving protection against it would cost approximately $17,000,000 (Nov 1953 prices). Average annual flood damage which could be prevented by such works would justify only about one-fifth of the cost, and therefore standard project flood protection is clearly not economically justified at this time.

102. Nookachamps Creek area west of Sedro Woolley has no existing flood control works. The area is frequently inundated, and farming is planned with the expectation of floods, so that excessive annual damages do not occur. During floods, overflow in the Nookachamps Creek area gives valuable river stage reduction in the downstream leveed channels. Control of floods in the areas west of Sedro Woolley will be best served by leaving unimpaired the natural channel storage space now available in the Nookachamps Creek area.

103. At the request of local interests, an investigation was made of the effects of modifying the outlet of North Fork. It was found that a new outlet channel would require expensive initial construction and possible future heavy maintenance, whereas the flood control benefits would be negligible. Investigations of the river bottom show it to be fairly stable and not building up so as to increase water stages during floods.

104. Flood regulation by means of additional storage reservoirs would benefit practically the entire basin. However, the construction of any storage reservoir is dependent upon the feasibility of constructing a combined hydroelectric and flood control project, as the flood control benefits by themselves are not adequate to justify a storage project. Of the four reservoir sites in the basin, only those at Faber

P 000225

and upper Baker are indicated by the report studies to be worthy of serious consideration. A project at the Faber site could eliminate most of the flood damages in the basin and produce a very large amount of prime power. The total benefits, however, based on the present values would not justify the annual costs. The opposition by the fisheries interests to this project, moreover, is of such magnitude as to eliminate the possibility of its construction in the near future. This project may become feasible at some future date when the fisheries problems may be resolved and the value of power has been increased.

105. The upper Baker River offers a favorable reservoir site, and an apparently favorable dam site, for combined flood control and power. The cost estimate for development of this site, as presented herein, is based on no subsurface investigation and is therefore subject to revision when subsurface data become available. Development of the site is opposed by fisheries interests because of destruction of spawning grounds and would probably meet with additional opposition because of the inundation of Baker Lake. Storage at the site could, however, produce a substantial amount of at-site power and increase the potential of the privately-owned downstream plant, and at the same time prevent nearly one-half of the annual damage in the Skagit River Valley. The flood control benefits are sufficient to justify less than 10 percent of the annual costs of the project, so that primary justification must rest upon other benefits. The only other tangible benefit--from power available at the site--is not sufficient in itself to provide, at present values, enough additional benefit to justify the cost. Only by coordinated operation of the project with the existing privately-owned downstream plant, and with additional installation at the latter, could sufficient benefits to justify the estimated cost be realized. The relatively low indicated benefit-cost ratio of the combined development (1.19), and the uncertainties as to full realization of the indicated benefits and necessary revenue to repay the project power costs if constructed as a Federal project, combine to indicate that development of the site by the Federal Government is not warranted at this time.

The flood control value of the reservoir, if it be developed by a non-Federal agency, can be preserved to the public through existing legislation.

106. Local interests have taken no action toward providing the required local cooperation for the existing flood diversion project adopted by the 1936 Flood Control Act. Studies made for this report indicate that the degree of protection contemplated by this adopted project can be obtained at less cost by improving the existing levee system, but even this work cannot be economically justified at this time.

107. Conclusions. - In view of the foregoing, it is concluded that local protection works have been constructed by local interests to the full extent justified by existing development in the valley; and that further construction of such works by the Federal Government is not justified at this time. It is further concluded that flood control by storage, either alone or in combination with power development, is not now feasible. Potential power sites exist at Faber and Upper Baker, where future development is dependent upon increase in power value and the solution of problems associated with the maintenance of fisheries resources. Neither of the sites appears favorable for Federal development at this time, but each has large flood control value which should be preserved at such time as development is undertaken by any agency. In view of the present economic infeasibility of the existing project for flood control of Skagit River, it is further concluded that the project authorization should be terminated.

108. Recommendation. - I therefore recommend that the existing project for flood control of Skagit River, Washington, be abandoned, and that no other project for control of floods be adopted at this time.

JOHN P. BUEHLER
Colonel, Corps of Engineers
District Engineer