78TH CONGRESS } HOUSE OF REPRESENTATIVES { DOCUMENT
2d Session } { No. 494

CHEHALIS RIVER AND TRIBUTARIES, WASHINGTON

LETTER

FROM

THE SECRETARY OF WAR

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, UNITED STATES ARMY, DATED DECEMBER 16, 1943, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND AN ILLUSTRATION, ON A PRELIMINARY EXAMINATION AND SURVEY OF CHEHALIS RIVER AND TRIBUTARIES, WASHINGTON, AUTHORIZED BY THE FLOOD CONTROL ACT APPROVED JUNE 22, 1936, AND BY AN ACT OF CONGRESS APPROVED JUNE 13, 1934

MARCH 13, 1944.—Referred to the Committee on Flood Control and ordered to be printed with an illustration

WAR DEPARTMENT,
Washington, March 9, 1944.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

DEAR MR. SPEAKER: I am transmitting herewith a report dated December 16, 1943, from the Chief of Engineers, United States Army, together with accompanying papers and an illustration, on a preliminary examination and survey of Chehalis River and tributaries, Washington, authorized by the Flood Control Act approved June 22, 1936, and by an act of Congress approved June 13, 1934.

The project, if adopted, would require a substantial amount of critical materials, manpower, and construction equipment, without either essentiality to, or presently indicated value to the war effort, being established. The Department is of the opinion that the submission of any estimate or request for appropriation for construction, or the initiation of any construction on this project, should be deferred until after the war.

The Bureau of the Budget has been consulted and advises that while there would be no objection to the submission of this proposed

report to the Congress, in the absence of evidence showing that the proposed works are necessary to the prosecution of the war, the submission during the present emergency of any estimate of appropriation for the construction of the project would not be in accord with the program of the President.

Respectfully,

HENRY L. STIMSON,
Secretary of War.

LETTER OF THE CHIEF OF ENGINEERS, UNITED STATES ARMY

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., December 16, 1943.

Subject: Chehalis River, Wash.
To: The Secretary of War.

1. I submit for transmission to Congress my report with accompanying papers and an illustration on preliminary examination and survey of Chehalis River and tributaries, Washington, authorized by act of June 13, 1934, and by the Flood Control Act approved June 22, 1936.

2. Chehalis River rises in southwestern Washington, flows north and east 42 miles to the city of Chehalis, thence north 6 miles to Centralia and northwesterly 62 miles to Aberdeen where it empties into Grays Harbor, an arm of the Pacific Ocean. Important tributaries from the east are Newaukum River at Chehalis and Skookumchuck River which in its lower 3 miles flows through the outskirts of Centralia. The tidal reach of the stream extends for 31 miles above the mouth and has three important tributaries, all from the north. These are Satsop River at mile 23, Wynoochee River 6 miles below, and Wishkah River which joins Chehalis River within the city of Aberdeen. Chehalis River drains an area of 2,063 square miles. The divide to the northeast separating the basin from the drainage of Puget Sound has an elevation of about 130 feet. Much greater elevations are found in other parts of the basin with a maximum of 5,000 feet in the extreme north. The high portions of the watershed, drained by the headwaters and the easterly and northerly tributaries, are rugged and densely forested. From near Chehalis to Grays Harbor, the river meanders through a flat fertile plain with average width of about 2 miles. The Federal navigation project for improvement of Grays Harbor and Chehalis River, 88 percent completed, provides for a deep-draft entrance channel from the ocean to the Union Pacific Railroad bridge at Aberdeen, thence a channel 18 feet deep and 3 miles long to the adjoining city of Cosmopolis and 16 feet deep to Montesano, a further distance of about 11 miles.

3. Chehalis River Basin has a population of about 80,000. Its largest cities are Aberdeen with 18,600 in 1940, Hoquiam adjoining it on the west with 10,800, Centralia with 7,300, and Chehalis with 4,800. Cosmopolis and Bucoda, the latter on Skookumchuck River, have populations of 1,200 and 1,700, respectively. Lumbering, mining, agriculture, and fishing are the principal industries. Several mills for manufacture of timber products operate in the basin. The effluent from a pulp mill at Hoquiam discharges into Grays Harbor. Investigations by the State of Washington indicate that this discharge

produces conditions harmful to fish life when river flows are low. Agricultural activities in the basin are largely confined to the lowlands bordering the streams. Irrigation is not extensively practiced although prolonged droughts are not uncommon during the growing season. The mean annual precipitation in the basin varies from about 45 inches at Centralia to over 143 inches in the high northern part of the basin. However, about 85 percent occurs during the months from October to April. Large areas of land are susceptible to irrigation except that depletion of the natural stream flow by its use for that purpose would aggravate the polluted condition of Grays Harbor and be inimical to fish life, an important source of revenue in the area. The region is served by improved highways and by several railroads which in general are located in the stream valleys.

4. Hoquiam, Aberdeen, and Cosmopolis are subject to extensive damages resulting from high tidal stages in Grays Harbor caused by winds. The range between mean lower low water and mean higher high water is 9.9 feet. However, on six occasions since 1912, flood tides have reached elevations ranging from 14.9 to 15.8 feet above mean lower low water and have inundated extensive municipal areas. Hoquiam has recently been afforded considerable protection by dikes constructed by the United States under the Emergency Relief Appropriation Act of 1935 at a cost of $186,492 and only its eastern portion is now considered subject to tidal flooding. Based on the past frequency of extraordinary tides, the district engineer estimates the average annual damages to the unprotected areas from tidal inundations at $72,000.

5. Above these municipal areas the basin is subject to damaging headwater floods with an approximate frequency of once in 3 years. These result from heavy precipitation and have occurred only during the months from November to February, inclusive. Approximately 58,000 acres are subject to inundation by major headwater floods principally along the main stream. Centralia and Bucoda are the only municipal areas suffering important headwater flood damages. At Centralia, overflows of Skookumchuck River are an important factor in flood conditions. The district engineer estimates the average annual flood damages based upon headwater floods of record as follows:

Farm losses along Chehalis River and upper tributaries	$38,000
Farm losses along Satsop, Wynoochee, and Black Rivers	12,000
Highways and highway bridges	2,000
Railroads	4,000
City of Centralia except industries	12,000
Industries, largely in Bucoda	7,000
Total	75,000

6. Local interests have organized two diking and drainage districts within the basin, one on the north side of Chehalis River above Montesano and the other on the south side in South Aberdeen, which have expended $263,600 for improvements to December 31, 1939. Under a Civil Works Administration project a minor amount of channel rectification has been accomplished in Skookumchuck River at Centralia. Congress has not authorized any specific projects for flood control within the watershed. However, exclusive of the navigation project, various agencies of the United States have expended in excess of $590,000 for stream improvements under general

authorizations. These works have included removal of snags, channel excavation and bank protection works at various locations on the main stream and several tributaries. Local interests desire additional works for alleviating flood damages and suggest channel improvements, reservoir storage of floodwaters, and diking of the municipal areas subject to tidal floods. City officials of Aberdeen and Hoquiam have given reasonable assurance that they will suitably cooperate in the costs of works to protect municipal areas from tidewaters.

7. The district engineer has given consideration to reduction of headwater flood damages by means of levees, channel improvements, and reservoir storage of floodwaters, taking into account the possibilities of power development in connection with the reservoirs and the use of the reservoirs to provide water for irrigation and for pollution abatement, and finds that no such improvements would be economically justified at this time. For investigation purposes, he divides the municipal sections subject to tidal floods into four separate areas: Area A in South Aberdeen and Cosmopolis, south of Chehalis River; area B in East Hoquiam and Aberdeen, north of Chehalis River and west of Wishkah River; area C in East Aberdeen, north of Chehalis River and east of Wishkah River; and area D in East Aberdeen, upstream along Wishkah River. Area D is largely brush-covered swamp with few improvements and suffers an estimated average annual flood damage of only $700. Protection for this area is found unwarranted. For areas A, B, and C, the district engineer considers protection by a system of dikes with crest elevations of 18.5 feet above mean lower low water, consisting of earth levees, concrete and sheet piling walls, and railroad embankments increased in height, to be supplemented by four pumping plants, tide gates, and other incidentals. He considers that local interests should be required to furnish rights-of-way, to bear the costs of reconstructing streets, bridges, water mains, sewer outfalls, and miscellaneous railroad track changes, to hold the United States free from damages and to maintain and operate the works after completion. On that basis he presents estimates for the improvements as follows:

Area	Estimated first cost			Estimated annual costs			Estimated annual benefits	Ratio costs to benefits
	Federal	To local interests	Total	Federal	To local interests	Total		
A	$322,200	$27,800	$350,000	$12,540	$3,590	$16,130	$25,800	1 to 1.60.
B	274,500	65,500	340,000	10,670	5,350	16,020	58,800	1 to 3.67.
C	72,300	2,700	75,000	2,810	530	3,340	3,350	1 to 1.00.
Total	669,000	96,000	765,000	26,020	9,470	35,490	87,950	1 to 2.48.

He points out that in addition to the evaluated benefits as shown, intangible benefits would also result such as the elimination of business losses and traffic delays. The district and division engineers concur in recommending the protective works for areas A, B, and C, subject to fulfillment of the indicated conditions of local cooperation.

8. The Board of Engineers for Rivers and Harbors, having fully considered the reports of the district and division engineers and afforded local interests an opportunity to present additional information, concurs in the conclusion of the reporting officers that further improvement of streams in the Chehalis River watershed for the reduction of headwater flood damages is not economically justified at this time. It is of the opinion that works for the protection of municipal areas at Grays Harbor, from tidal floods, are warranted and that the district engineer has presented a suitable plan for this purpose. The Board recommends improvements in general accordance with the plan subject to local cooperation.

9. After due consideration, I concur in the views of the Board and recommend the improvement of Chehalis River, Wash., to protect municipal areas at Hoquiam, Aberdeen, and Cosmopolis from tidal floods by construction of a system of levees, embankment modifications, and flood walls with pumping plants and other related works, in general accordance with the plan of the district engineer as shown on the accompanying drawing, at an estimated cost to the United States of $669,000 for construction; subject to the condition that responsible local agencies give assurances satisfactory to the Secretary of War that they will (*a*) provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project; (*b*) bear the costs of reconstructing streets, bridges, sewers, and water mains, miscellaneous track changes and tide gates at sewer outlets; (*c*) hold and save the United States free from damages due to the construction works; and (*d*) maintain and operate all the works after completion in accordance wth regulations prescribed by the Secretary of War.

E. Reybold,
Major General,
Chief of Engineers.

REPORT OF BOARD OF ENGINEERS FOR RIVERS AND HARBORS

[Second endorsement]

The Board of Engineers for Rivers and Harbors,
Washington, D. C., November 8, 1943.

Subject: Chehalis River, Wash.
To: The Chief of Engineers, United States Army.

1. Local interests were advised of the nature of the report of the division engineer and invited to submit additional information to the Board. Careful consideration has been given to the communications received.

2. The Board concurs in the finding of the reporting officers that additional stream-improvement measures for the prevention of damages from floodwater run-off in the Chehalis River Basin are not economically justified at this time. In its opinion, the district engineer has presented a suitable plan for protection of the municipal areas at Grays Harbor from tidal floods and has proposed proper requirements of local cooperation. The prospective benefits of this work fully warrant the expenditures required. Accordingly the Board recommends the improvement of Chehalis River, Wash., to protect municipal areas at Hoquiam, Aberdeen, and Cosmopolis from tidal floods by a system of levees, embankment modifications, and flood walls with pumping plants and other related works, in general accordance with the plan of the district engineer as shown on the accompanying drawing, at an estimated cost to the United States of $669,000 for construction; subject to the conditions that responsible local agencies

give assurances satisfactory to the Secretary of War that they will (*a*) provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project; (*b*) bear the costs of reconstructing streets, bridges, sewers and water mains, miscellaneous track changes, and tide gates at sewer outlets; (*c*) hold and save the United States free from damages due to the construction works; and (*d*) maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of War.

For the Board:

JOHN J. KINGMAN,
Brigadier General, United States Army,
Senior Member.

SURVEY REPORT ON CHEHALIS RIVER AND TRIBUTARIES, WASHINGTON, FOR FLOOD CONTROL

SYLLABUS

The district engineer reports that floods of Chehalis River and its tributaries cause damages estimated at $75,000 annually to farms, utilities, and urban property, and that high tides in Grays Harbor do potential annual damage of $88,720 to the harbor cities. He considers various methods of reducing these flood damages and concludes that no method for controlling floods of Chehalis River is economically feasible at the present time. He presents a plan for levees and sea walls to protect East Hoquiam, Aberdeen, and Cosmopolis from high tides, and shows that the probable annual benefits from such a project are over twice the estimated annual costs. He, therefore, recommends the adoption of a project for protection of the harbor cities, at estimated first costs of $669,000 from Federal funds for construction, and of $96,000 from local funds, for rights-of-way, raising of streets and railroads, etc., subject to the provision that local interests hold the United States free from all claims for damages arising out of the construction, and maintain the structures, at an estimated annual cost of $5,000, after completion.

WAR DEPARTMENT,
UNITED STATES ENGINEER OFFICE,
Seattle, Wash., February 1, 1943.

Subject: Report on preliminary examination and survey for flood control of Chehalis River and tributaries, Washington.

To: The Division Engineer, Pacific Division (San Francisco Branch), San Francisco, Calif.

1. *Authority.*—The following report, with map, on preliminary examination and survey for flood control of Chehalis River and tributaries, Washington, is submitted in compliance with the following acts of Congress:

(*a*) The Act of June 13, 1934 (Public, No. 337, 73d Cong., H. R. 9431), provides that "* * * the Secretary of War be, and he is hereby, authorized and directed to cause a preliminary examination to be made of the Chehalis River and its tributaries in the State of Washington, with a view to the control of its floods, * * * the cost thereof to be paid from appropriations heretofore or 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 Cong., 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 water-flow 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:

* * * * * * *

Chehalis River and tributaries, Washington.

* * * * * * *

2. The report on preliminary examination called for by both acts was submitted by the district engineer on May 25, 1937; by the division engineer on July 19, 1937; and reviewed by the Board of Engineers for Rivers and Harbors on August 23, 1937. The Board recommended a survey to determine the advisability and cost of improvements and local cooperation required, and the Chief of Engineers on September 10, 1937, ordered the survey to be made.

3. *Prior reports.*—One prior report involving consideration of flood control has been made. A report on "Chehalis River, Wash., covering navigation, flood control, power development, and irrigation" was submitted by the Chief of Engineers, December 9, 1931, under authority of House Document No. 308, Sixty-ninth Congress, first session, and published as House Document No. 148, Seventy-second Congress, first session. That report concludes—

that the further improvement of Chehalis River, Wash., for navigation, in connection with power development, the control of floods or the needs of navigation, or any combination thereof, is not deemed advisable at the present time.

4. *Description.*—The basin of the Chehalis River and its tributaries, embracing portions of seven counties, occupies an area of approximately 2,174 square miles lying in the southwestern part of the State of Washington. It is bounded on the east and northeast by the Puget Sound Basin; on the south and southeast by the Columbia River Basin; and on the west and north by the basins of streams draining directly into the Pacific Ocean. The drainage area is triangular in shape with its apex to the north, on the southern slope of the Olympic Mountains; its eastern leg adjacent to the Puget Sound Basin; its western leg approximately parallel to, and about 20 miles east of, the Pacific coast; and its base along the northern watershed of the Columbia River. The basin extends 84 miles from north to south, and 65 miles from east to west.

5. The Chehalis Basin has no high mountain ranges within its borders. It is separated from the main range of the Olympic Mountains by valleys draining into the Pacific Ocean or Hood Canal; and from Mount Rainier and the Cascade Range by valleys draining into Puget Sound or the Columbia River. Consequently, the divides are comparatively low, except at the northern angle, where the watershed reaches an elevation of about 5,000 feet. The Willapa Hills on the west and southwest of the basin do not exceed an elevation of 1,500 feet, and the high points around the southeast angle of the basin reach a maximum elevation of about 3,800 feet. In the vicinity of Black Lake, on the northeast side of the basin, the divide is only 130 feet above sea level. Thus the basin lies generally below the line of heavy snows and extensive snow storage.

6. The higher portions of the basin are rugged and densely forested, but near the city of Chehalis the river debouches onto a fertile plain through which it meanders to Grays Harbor.

7. *Geology.*—The following summary of the geology of the Chehalis Basin is from a report by the late Henry Landes, formerly dean of the College of Science and professor of geology and mineralogy at the University of Washington:

The main stream of Chehalis River occupies a broad valley which extends from the head of Grays Harbor easterly and then southerly to the country about the city of Chehalis. The principal tributaries drain a large portion of the southern slopes of the Olympic Mountains and the northern and eastern parts of the Willapa Hills, or that area between the lower Columbia and Chehalis Rivers. All of the larger tributaries are situated in areas of heavy rainfall, and their valleys have been deeply eroded, giving rise to a very rough topography. All of the erosion has been done by running water, and none by glaciers.

Only a limited variety of rocks is found in the Chehalis drainage basin. The Willapa Hills are composed of sandstones, shales, and conglomerates, with many layers of basalt that essentially are conformable with the sedimentary beds. In a broad region around Chehalis and Centralia the strata are mostly sandstones and shales which contain several seams of workable coal. In this general area the basalts and other igneous rocks are almost wholly absent. Along the lower courses of the tributaries which come out of the Olympics the prevailing outcrops of rock are sandstones and shales, but toward the headwaters the formations are mainly quartzites and slates, with various igneous rocks occurring as dikes. The hills, immediately southwest of Olympia, are made up almost wholly of basalt.

The Puget Sound glacier did not extend far enough south to encroach to any degree upon the Chehalis Basin. When the glacier was at its maximum size the drainage from the melting ice all reached the sea by way of the lower Chehalis River. The streams flowing from the ice front were all overburdened with debris and deposited large quantities of stratified sand and gravel which filled the broad Chehalis Valley to a depth of many feet. These outwash plains or valley trains were continuous from certain parts of the ice front all the way to Grays Harbor.

As the great ice mass melted away, its terminus gradually retreated farther and farther to the northward. When the ice had laid bare some of the southern inlets of Puget Sound a series of small lakes and finally one large water body, came into existence. While this lake occupied the basin south of the ice front, the escape for the water was by way of Black River and thence into the Chehalis. This large volume of water was ample to erode a large part of the debris carried down by the glacial streams that flowed directly from the ice into the Chehalis Valley. That which remains today is found in the several low terraces which may be seen along the sides of lower Chehalis Valley, in the last 40 or 50 miles of its course.

At one time the outlet of Chehalis River was at the locality where Grays Harbor now enters the sea. The lower valley then consisted of a broad flood plain which extended for many miles up the river. Then came a sinking of the land with a consequent encroachment of the sea. The marine waters covered much of the river flood plain and formed the estuary of Grays Harbor. The debris since brought down by the Chehalis has filled up a part of the original estuary, chiefly that part between Montesano and Aberdeen, and has also shoaled the entire embayment.

8. *Soils.*[1]—There are two main physiographic divisions in the basin—(1) the rolling, to hilly, uplands; (2) the broad alluvial valley of the river. The hills are rounded, with small shallow valleys intervening, but in most cases the slopes are steep and erode very rapidly when cleared. The land occupying the valley is almost level and has an average width of about 2 miles. The most common soil in the valley lands is classified as "Chehalis silty clay loam." This (as is all of the bottom land) is of alluvial origin and represents continual depositing over a long period of years. More recent deposits, which represent the greater portion of this soil type, are the result of annual overflows. This loam was derived from washings of the unglaciated uplands laid down by comparatively quiet waters.

9. There are approximately 50,000 acres of alluvial bottom land, about 45,000 acres of which is "Chehalis silty clay loam." All of this

[1] Condensed from: Reconnaissance Soil Survey of the Western Part of the Puget Sound Basin, Wash., Bureau of Soils, U. S. Department of Agriculture, 1912.

material is alluvial matter laid down by river waters, and the entire bottom lands may be called the flood plain.

10. The Chehalis River rises in the extreme southwestern corner of the basin and flows north for 21 miles to its junction with Elk Creek at Doty, its average gradient being 38½ feet a mile; thence east for 21 miles, with a total fall of 40 feet, to its confluence with the Newaukum River at the city of Chehalis. From Chehalis the river flows north for 6 miles to the city of Centralia, where it receives the waters of the Skookumchuck River. At Centralia the river turns to the northwest and flows for 18 miles to its confluence with the Black River, thence continuing northwest for 21 miles to the mouth of the Satsop River. The average gradient of the stream from Chehalis to Satsop is 2.8 feet a mile. At Satsop the river turns to the west and flows for 23 miles to tidewater at Grays Harbor, receiving the flow of the Wynoochee River at mile 17, the Wishkah River at mile 4, and the Hoquiam River at mile 0 above the mouth. The tidal effect extends upstream for about 31 miles.

11. The Chehalis River lies in general close to its southwestern watershed, and enters Grays Harbor at about the middle of the western boundary of the basin. Consequently, the tributary streams rising along the western shed enter the main river before they accumulate much water. The streams draining the northern and eastern portions of the basin, however, attain relatively large size and contribute important additions to the flow of Chehalis River.

12. The Newaukum River rises in the southeast angle of the basin and flows about 30 miles in a westerly direction to its confluence with the Chehalis River at the city of Chehalis. Its only important contributories are the North and Middle Forks.

13. The Skookumchuck River rises in the extreme eastern portion of the basin at an elevation of 3,800 feet and flows northwesterly for 12 miles; then westerly for 12 miles; and then southwesterly for 10 miles to join the Chehalis River at the city of Centralia. In the lower 3 miles of its course, the river flows through the outskirts of the city of Centralia.

14. Black River has its source in Black Lake (elevation 125 feet), 4 miles southwest of Olympia. The river follows a southwesterly course for 20 miles to its confluence with the Chehalis River near the town of Oakville.

15. Satsop River rises on the southern slopes of the Olympic Mountains in two forks which flow south for about 35 miles to their junction, from which the combined stream flows southeasterly for 4 miles to its confluence with the Chehalis River at the town of Satsop.

16. Wynoochee River rises in the extreme northern angle of the basin and follows a southerly course for about 50 miles to its confluence with the Chehalis River at the town of Montesano.

17. Wishkah River rises in the hills which form the western boundary of Wynoochee River and flows southward for 16 miles to its confluence with Chehalis River at the city of Aberdeen. Its watershed is generally low in elevation being only about 1,300 feet at the source of the stream.

18. Hoquiam River, which is considered to be tributary to Grays Harbor rather than to Chehalis River, rises in the hills that form the western boundary of Wishkah River and flows southward for 19 miles receiving the waters of its Middle Fork at mile 2 above the mouth, reaching Chehalis River at the town of Hoquiam.

19. *Channel capacities.*—Observations made during a minor flood in April 1937 indicate that in-bank capacities of the river channels are about as follows:

	Second-feet
Chehalis River below Skookumchuck River	25, 000
Chehalis River below Black River	33, 000
Chehalis River below Wynoochee River	56, 000
Satsop River at mouth	13, 000
Wynoochee River at mouth	10, 000

20. Approximate drainage areas of the Chehalis River are as follows:

	Drainage area, square miles
Chehalis River above Newaukum River	469
Newaukum River at mouth	161
Chehalis River below Newaukum River	630
Chehalis River above Skookumchuck River	678
Skookumchuck River at mouth	183
Chehalis River below Skookumchuck River	861
Chehalis River above Black River	1, 028
Black River at mouth	140
Chehalis River below Black River	1, 168
Chehalis River above Satsop River	1, 356
Satsop River at mouth	318
Chehalis River below Satsop River	1, 674
Chehalis River above Wynoochee River	1, 698
Wynoochee River at mouth	197
Chehalis River below Wynoochee River	1, 895
Chehalis River above Wishkah River	1, 930
Wishkah River at mouth	103
Chehalis River below Wishkah River	2, 033
Chehalis River above Hoquiam River	2, 063
Hoquiam River at mouth	111
Chehalis River at mouth	2, 174

21. *Economic development.*—The population within the basin of Chehalis River is approximately 80,000 as determined by the 1940 census. The principal cities and towns within the basin are as follows:

City or town	County	Population (1940 census)	City or town	County	Population (1940 census)
Aberdeen	Grays Harbor	18, 624	Centralia	Lewis	7, 308
Cosmopolis	do	1, 198	Chehalis	do	4, 818
Elma	do	1, 323	Pe Ell	do	[1] 891
Montesano	do	2, 186	Bucoda	Thurston	[1] 703
Oakville	do	[1] 469	Tenino	do	944
Hoquiam	do	10, 810			

[1] 1930 census.

22. Immediately to the northeast of the Chehalis Basin are the Puget Sound ports of Olympia (population 13,178) and Shelton (population 3,650). On Willapa Bay, west of the basin, are Raymond (population 4,039) and South Bend (population 1,798). All are connected to the basin by good roads.

23. *Railways.*—The coast line of the Northern Pacific Railway, connecting Seattle and Portland, enters the eastern side of the basin and passes south through Centralia and Chehalis. The tracks of this line are used by the Great Northern Railway and Union Pacific Railroad systems. One branch line of the Northern Pacific Railway extends from Chehalis to Raymond and another from Olympia to the Grays Harbor cities, entering the basin at Black Lake and following the Black and Chehalis Rivers to Aberdeen. The Chicago, Milwaukee, St. Paul & Pacific Railroad enters the basin from the Puget Sound region about 4 miles northeast of Tenino and branches at Maytown. One branch passes through Centralia to Chehalis; the other branch, combining with a branch of the Union Pacific Railroad, extends down the Chehalis River to Aberdeen. Westward from Chehalis, the Chicago, Milwaukee, St. Paul & Pacific Railroad operates over Northern Pacific tracks as far as Dryad, thence over its own tracks to Raymond. The Chehalis Western Railroad, a logging road, extends from Chehalis westward up the Chehalis River and the South Fork. The Newaukum Valley Railroad extends from Napavine to Onalaska; and the Cowlitz, Chehalis & Cascade Railway connects Chehalis with towns in the Cowlitz River Basin. Many logging railroads extend from the main line tracks into timbered portions of the basin.

24. *Highways.*—The paved Pacific Highway, connecting British Columbia and Mexico, passes south from Olympia through the Chehalis Basin, touching Centralia and Chehalis. The Olympic Highway, serving the Olympic Peninsula, crosses the basin in connecting Aberdeen with Olympia. A branch of the Olympic Highway extending up the Chehalis River Valley from Elma joins the Pacific Highway at Grand Mound. A good road, mostly paved, connects Chehalis with points on Willapa Bay, and a good gravel road joins Cosmopolis and Montesano with Raymond. Numerous second-class gravel roads extend throughout the central part of the valley and up the tributary valleys of the basin.

25. *National or departmental reservations.*—Parts of two national forests lie within the Chehalis Basin. About 108 square miles of the Olympic National Forest is contained within the northern apex of the basin, and about 15 square miles of the Snoqualmie National Forest lies in the southeastern corner of the basin. The Chehalis Indian Reservation, in the central portion of the basin, covers 4,125 acres, of which 471 acres were set aside for school purposes and the remaining 3,754 acres homesteaded by 36 Indians.

26. *Resources and local industries.*—The principal industries of the basin are lumbering, mining, agriculture, and fishing.

27. *Lumbering.*—The Pacific Northwest Forest and Range Experiment Station, United States Forest Service, has supplied the following data on the timber volume in the Chehalis River Basin as of January 1, 1932.

Ownership	Volume, thousands of feet, board measure			
	Douglas fir	Pulp species [1]	Other species [2]	Total
Private	10, 111, 917	3, 484, 237	894, 599	14, 490, 753
State	863, 024	320, 192	48, 063	1, 231, 270
County	5, 592	274	393	6, 259
Municipal	419	7, 937	108	8, 464
National Forest	1, 507, 296	1, 809, 551	241, 494	3, 558, 341
Indian	66			66
Other Federal	3, 021	848	43	3, 912
Total	12, 491, 335	5, 623, 039	1, 184, 700	19, 299, 074

[1] Western and mountain hemlock, Sitka spruce, white fir, noble fir, and amabilis fir.
[2] Principally western red cedar.

This timber furnishes raw material for about 20 sawmills, 1 pulp and paper mill, 3 plywood plants, 1 paper mill, and numerous shingle mills in the Chehalis Basin and Grays Harbor region.

28. *Mining.*—Coal, sand and gravel, andesite, sandstone, gold, silver, copper, and other minerals are reported to exist in the basin, but commercial production is limited to coal, sand and gravel, andesite, and sandstone. About 20 coal mines have been operated at one time or another in the area lying east and north of Centralia and Chehalis. The coal is subbituminous in grade, and occurs in a field of relatively simple structure. The total production of coal in the basin during a recent 10-year period was as follows:

Year	Total production (tons)	Total value at mine	Year	Total production (tons)	Total value at mine
1929	330,320	$733,108.70	1934	71,334	$161,519.48
1930	281,917	649,864.49	1935	82,874	192,959.86
1931	173,236	401,359.58	1936	79,125	205,613.70
1932	135,066	332,795.12	1937	86,267	226,679.38
1933	85,776	182,760.62	1938	71,797	191,867.30

29. Sand and gravel of good quality for road and concrete work are taken from pits near Centralia, Little Rock, Tenino, Bucoda, and localities along the river in Grays Harbor County. Sandstone is quarried at Tenino, and brick is burned at Chehalis from local clay deposits. During recent years more than 2,000,000 tons of andesite have been taken from a quarry on the upper Skookumchuck River for use in reconstructing the south jetty at Grays Harbor.

30. *Agriculture.*—Agriculture is very largely confined to the lowlands bordering the river and tributary streams. The following data concerning agricultural resources of the basin were abstracted from the Fifteenth Census of the United States (1930):

Number of farms in basin		3,500
Cropland (total)	acres	69,000
Land cropped in 1929	acres 60,000	
Pasture land	acres	152,000
All other farm land	do	47,000
Total farm land	do	268,000
Value of farm land		$17,100,000
Value of all farm buildings		7,500,000
Value of farm dwellings	$4,200,000	
Value of farm implements and machinery		1,500,000
Total farm value		26,100,000
Average acres a farm		76.5
Average total value an acre		$97.50

31. *Fishing.*—Commercial fishing and fish canning has been an important industry of the Grays Harbor region since the turn of the century. The industry dealt almost wholly in salmon up to 1934, but in that year fish traps, the principal source of canning fish, were outlawed on State waters and the industry turned to tuna, pilchard, clams, and crabs. In recent years the Harbor fishermen have received about $800,000 annually for their catch.

32. *Power resources.*—There are no hydroelectric power plants operating in the basin. Good potential sites on the main stream are almost entirely lacking. Three power sites exist on the Wynoochee River, two of which have a possible combined usable storage capacity of 300,000 acre-feet. The potential power at the three sites, with regulation of the proposed storage would be about 17,000 kilowatts for 90 percent of the time. The estimated cost per kilowatt, however, is $470, which is greatly in excess of the cost now justifiable.

33. *Bridges.*—There are 18 bridges in the navigable stretch of the river, details of which are shown in table 1.

TABLE 1.—*Bridges over Chehalis River*

Location		Owner	Kind—fixed, swing, vertical lift, etc.	Purpose for which bridge is used
Miles above mouth of the river	Nearest town			
[1] 3.8	Aberdeen, Wash	Union Pacific R. R	Swing	Railway.
[1] 4.0	do	City of Aberdeen	do	Highway.
[1] 5.5	South Aberdeen, Wash.	Northern Pacific Ry	do	Railway.
[1] 17.5	Montesano, Wash	Union Pacific R. R	do	Do.
[1] 17.8	do	Grays Harbor County	do	Highway.
[1] 26.0	Satsop, Wash	do	Fixed	Do.
[1] 31.0	Elma, Wash	do	do	Do.
[1] 31.0	do	Schafer Bros. Logging Co	do	Logging railway.
[1] 39.0	Porter, Wash	Grays Harbor County	do	Highway.
[1] 49.0	Oakville, Wash	do	do	Do.
51.0	do	do	do	Do.
[1] 58.0	Rochester, Wash	Chicago, Milwaukee, St. Paul & Pacific R. R.	do	Railway.
58.0	do	Thurston County	do	Highway.
64.0	Grand Mound, Wash	do	do	Do.
[1] 68.0	Galvin, Wash	Union Pacific R. R	do	Railway.
69.0	do	Lewis County	do	Highway.
[1] 71.0	Centralia, Wash	do	do	Do.
76.0	Chehalis, Wash	State of Washington	do	Do.

[1] Plans approved by War Department.

34. *Navigation.*—The river is considered navigable to Chehalis, about 76 miles above the mouth of the Hoquiam. Of the tributaries, only the lower 15 miles of the Black River are considered navigable. In the early days, Chehalis River was navigated to 80 or 90 miles above the mouth. Present navigation is limited to the tidal stretch from the mouth to Elma, about 31 miles, although very little commerce is carried above Montesano. The existing project (act of August 30, 1935) for improvement of the river by the Federal Government in the interest of navigation, provides for suitable bar and entrance channels and for a channel 18 feet deep at mean lower low water and 200 feet wide from Aberdeen to Cosmopolis, and for a channel 16 feet deep at mean lower low water and 150 feet wide from Cosmopolis to Montesano. An 18-foot channel has been dug to Cosmopolis and a 12-foot channel has been dug from Cosmopolis to Montesano; the completion to a 16-foot depth is awaiting the required local cooperation. The extreme tidal range at the mouth is 18.1 feet. The range between mean lower low water and mean higher high water is 9.9 feet.

35. *Climate and precipitation.*—In common with other portions of western Washington the Chehalis Basin enjoys a mild and equable climate. Although the basin compares with New Brunswick and northern Maine in latitude, extreme cold is unknown. The lowest temperature recorded in 41 years at Centralia, in the interior basin,

is −16° F., and in 47 years at Aberdeen is 6° F. Maximum temperatures of 105° have been recorded at both of these stations. The mean annual temperature throughout the valley is about 50°. The growing season (period between killing frosts) is about 209 days.

36. Rainfall throughout the basin is abundant, but distributed unevenly throughout the year. About 85 percent of the annual precipitation occurs during the wet season, from October to April. November, December, and January are the months of greatest precipitation; July and August are the driest months. Snowfall is normally quite light except at the headwaters of the Wynoochee and Satsop Rivers. Table 2 gives a summary of meteorological data for stations in and near the basin.

TABLE 2.—*Meteorological data for stations in and near the Chehalis River Basin, compiled from records of the U. S. Weather Bureau to Dec. 31, 1938*

Station	Elevation above mean sea level	Length of record		Mean annual precipitation	Average annual snowfall	Length of growing season	Temperature, F.°		
		Temperature	Precipitation				Maximum	Mean	Minimum
	Feet	*Years*	*Years*	*Inches*	*Inches*	*Days*			
Cushman Dam	790	11 (1914–1936)	17 (1914–1938)	97.65	41.1	239	101	50.4	6
Wynoochee Oxbow	660		10 (1926–1938)	143.45					
Wishkah Headworks	435		12 (1927–1938)	122.16					
Quinault	300	28 (1906–1938)	28 (1906–1938)	137.25	9.9	209	104	50.7	11
Centralia	182	41 (1890–1938)	43 (1890–1938)	45.38	10.4	174	105	51.1	−16
Grand Mound	162		12 (1894–1906)	51.82	14.6				
South Bend (near)	150	41 (1898–1938)	41 (1895–1938)	83.48	5.8	203	103	50.9	4
Aberdeen	105	47 (1891–1938)	47 (1891–1938)	81.57	13.9	191	105	49.6	6
Oakville	85	21 (1916–1938)	21 (1916–1938)	51.94	8.6	164	103	50.5	−8
Olympia	69	58 (1878–1938)	59 (1877–1938)	46.21	11.4	191	104	50.6	−2
Canto	12		11 (1927–1938)	113.3	6.9				
Lone Tree	9	12 (1909–1920)	12 (1909–1920)	73.85	5.3	301	86	50.1	12

37. *Gaging stations and stream-flow records.*—Records of Chehalis River discharges are extremely meager. In October 1928, the United States Geological Survey in cooperation with, and using funds provided by this Department, established a staff gage on the Chehalis River near the town of Grand Mound. The gage was changed to a recording station in October 1934, and has been maintained to the present time. In March and April of 1929, staff gages were established with War Department funds on the Chehalis River near Chehalis, on the Skookumchuck River near Centralia, on the Newaukum River near Chehalis, and on the Satsop River near Satsop; the first three being maintained until September 1931, and the Satsop gage (changed to a recording gage in March 1938) maintained until the present time. In October 1939, a staff gage was installed on Chehalis River near Doty, and the Skookumchuck station reestablished with a recording gage, both with War Department funds.

38. The United States Geological Survey has collected stream-flow records at two stations on the Wynoochee River: One at Oxbow, near the headwaters of the river, from May 1925 to the present time; and one near Montesano, about 15 miles upstream from the mouth, from February 1923 to September 1930.

39. Of the seven gaging stations only three—one on Chehalis River, one on Satsop River, and one on Wynoochee River—have records of four major flood periods (February 1932, December 1933, January

1935, and December 1937). Tables 3 to 5, following, summarize available stream-flow data for those three stations.

TABLE 3.—*Mean monthly discharge, in second-feet, of Chehalis River near Grand Mound*

Year ending Sept. 30	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1929	543	1,100	2,740	2,800	2,300	3,940	4,390	1,240	900	405	193	197	1,729
1930	272	326	2,890	2,070	6,830	3,100	1,570	1,200	710	287	155	189	1,600
1931	350	1,200	1,230	5,650	3,860	4,710	5,180	709	885	409	235	314	2,050
1932	1,470	4,120	5,610	6,030	6,650	7,340	4,320	1,100	588	399	252	242	3,170
1933	532	7,540	9,150	8,260	4,370	6,930	2,380	1,760	1,120	436	295	650	3,620
1934	1,790	2,792	19,280	9,445	2,020	3,453	1,565	891	353	243	189	229	3,558
1935	2,457	9,192	7,475	9,647	3,946	5,127	2,038	745	414	262	171	283	3,482
1936	294	837	1,921	10,320	5,141	5,522	1,577	1,567	2,482	550	264	268	2,561
1937	224	221	3,777	2,160	7,859	4,251	6,787	1,570	1,902	604	312	357	2,460
1938	664	8,107	8,822	5,817	4,193	5,290	3,366	983	381	223	159	131	3,172
1939	374	2,098	3,581	6,401	8,174	3,664	1,086	549	650	330	189	172	2,238
Mean	816	3,412	6,045	6,234	5,031	4,848	3,114	1,121	944	377	219	276	2,692

TABLE 4.—*Mean monthly discharge, in second-feet, of Satsop River near Satsop*

Year ending Sept. 30	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1929						2,300	2,490	992	794	413	284	227	
1930	314	280	2,030	1,510	4,850	1,890	2,050	894	556	342	250	296	1,250
1931	678	1,340	1,410	4,740	2,820	3,650	3,170	674	1,390	587	321	590	1,770
1932	1,990	3,750	4,970	4,690	4,750	4,960	3,180	888	488	422	372	273	2,560
1933	523	3,700	4,030	4,510	2,800	4,130	1,820	1,640	870	445	293	809	2,130
1934	2,062	2,481	9,296	6,413	2,269	2,787	1,187	976	420	462	314	327	2,432
1935	1,808	4,200	3,913	9,002	2,986	3,166	1,508	830	501	329	242	451	2,415
1936	491	1,006	2,298	5,807	2,677	2,980	1,112	1,178	1,328	645	317	374	1,687
1937	315	268	3,318	1,276	3,558	2,977	4,038	1,671	1,382	578	355	266	1,653
1938	1,703	6,372	5,060	3,567	2,821	3,324	2,702	1,031	510	351	258	208	2,320
1939	654	1,913	2,768	5,035	3,341	2,199	928	711	600	367	253	281	1,580
Mean	1,054	2,531	3,910	4,658	3,288	3,207	2,199	1,044	804	449	296	373	1,979

TABLE 5.—*Mean monthly discharge, in second-feet, of Wynoochee River at Oxbow*

Year ending Sept. 30	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1925								481	425	191	119	105	
1926	103	747	2,040	1,140	1,390	560	384	551	254	136	130	145	628
1927	1,160	1,260	1,270	1,530	1,330	822	572	894	536	258	150	394	846
1928	791	1,620	771	1,910	688	1,270	954	710	334	187	132	151	794
1929	747	955	880	514	247	708	796	590	590	228	133	96.7	542
1930	187	137	1,010	469	1,720	667	969	408	271	153	97.1	155	512
1931	392	590	608	2,080	983	1,320	1,210	386	550	256	127	299	732
1932	719	1,320	1,670	1,260	1,550	1,520	1,240	612	475	372	235	140	923
1933	343	1,684	1,321	1,465	722	1,274	836	979	764	485	212	551	887
1934	946	960	3,472	2,529	878	1,132	537	529	183	263	188	146	987
1935	910	2,049	1,388	3,473	1,303	1,214	614	511	404	226	150	369	1,051
1936	308	475	1,102	1,769	740	938	522	772	758	411	171	176	680
1937	140	112	1,395	339	644	1,140	1,494	1,055	919	303	174	141	655
1938	809	2,219	1,841	1,082	763	1,021	972	527	292	149	102	950	822
1939	549	923	1,259	1,890	926	682	548	494	327	229	131	146	675
Mean	579	1,075	1,430	1,532	992	1,019	832	644	472	256	150	207	765

40. *Floods.*—Floods have occurred in December 1891, in 1892, 1897, 1903, March 1908, November 1909, January 1914, December 1915, December 1917, January 1923, February 1932, December 1933, January 1935, January 1936, and December 1937, or on an average of about one in 3 years. The relative severity of these floods cannot be

determined from the existing data, but above the mouth of Satsop River the floods of December 1917 and December 1933 were the most severe. On the Satsop and Wynoochee Rivers the flood of January 1935 was the greatest of record, and at the mouth of the Chehalis the flood of December 1933 was most severe.

41. High tidal stages caused by wind result in inundation of extensive portions of the cities of Aberdeen, Hoquiam, and Cosmopolis. The following table shows the record of flood tides:

Elevation above mean lower low water

1912	15.0	December 1923	15.2
November 1913	15.2	December 1933	15.8
December 1920	14.9	October 1934	15.5

42. Records of daily discharges of Chehalis River near Grand Mound, Satsop River near Satsop, and Wynoochee River at Oxbow, are available for the floods of February 1932, December 1933, January 1935, and December 1937.

43. Of the 2,174-square-mile area drained by the Chehalis River system, 1,308 square miles, or 60 percent, is tributary to the three river gages mentioned in the preceding paragraph. The sum of the 24-hour discharges recorded at these gages for the floods of February 26, 1932; December 21, 1933; January 22, 1935; and December 28, 1937, were, respectively, 53,400 second-feet, 76,400 second-feet, 79,700 second-feet, and 67,900 second-feet. The estimated corresponding 24-hour discharges of Chehalis River at its mouth were 72,000 second-feet, 104,000 second-feet, 106,000 second-feet, and 90,000 second-feet.

44. A study of the few high-water periods occurring during the 10 years of record indicates that the Satsop and Wynoochee Rivers ordinarily reach their flood crest a day or two before the crest occurs on the upper Chehalis River, thus maintaining high stages on the Chehalis River below Wynoochee River for a longer period than on any of the tributaries.

45. Table 6 shows daily mean discharges at the three gages for the floods of February 1932, December 1933, January 1935, and December 1937.

TABLE 6.—*Flood data*

Date	Chehalis River near Grand Mound (drainage area, 928 square miles)			Satsop River at Satsop (drainage area, 315 square miles)			Wynoochee River at Oxbow (drainage area, 65 square miles)		
	Discharge in second-feet	Discharge in second-feet per square mile	Run-off in inches	Discharge in second-feet	Discharge in second-feet per square mile	Run-off in inches	Discharge in second-feet	Discharge in second-feet per square mile	Run-off in inches
Feb. 25, 1932	7,150	7.7	0.29	11,800	37.5	1.39	5,820	89.5	3.33
Feb. 26, 1932	15,800	17.0	.63	27,000	85.7	3.19	10,600	163.1	6.07
Feb. 27, 1932	21,800	23.5	.87	17,800	56.5	2.10	7,370	113.4	4.22
Feb. 28, 1932	18,400	19.8	.74	9,440	30.0	1.12	3,520	54.2	2.02
Mar. 4, 1932	7,240	7.8	.29	4,720	15.0	.56	1,320	20.3	.75
Mar. 5, 1932	12,700	13.7	.51	14,400	45.7	1.70	3,640	56.0	2.08
Mar. 6, 1932	19,700	21.2	.79	7,250	23.0	.85	1,990	30.6	1.14
Mar. 7, 1932	16,700	18.0	.67	5,420	17.2	.64	1,430	22.0	.82
Dec. 9, 1933	19,600	21.1	.78	17,400	55.2	2.05	5,780	88.9	3.31
Dec. 10, 1933	23,500	25.3	.94	12,000	38.1	1.42	3,590	55.2	2.05
Dec. 11, 1933	38,800	41.8	1.55	12,500	39.7	1.48	6,430	98.9	3.68
Dec. 12, 1933	24,900	26.8	1.00	12,000	38.1	1.42	6,140	94.5	3.51
Dec. 17, 1933	9,660	10.4	.39	14,700	46.7	1.74	4,120	63.4	2.36
Dec. 18, 1933	26,800	28.9	1.07	16,200	51.4	1.91	4,020	61.8	2.30
Dec. 19, 1933	42,900	46.2	1.72	11,400	36.2	1.35	3,450	53.1	1.97
Dec. 20, 1933	36,100	38.9	1.45	17,100	54.3	2.02	7,940	122.2	4.54

TABLE 6.—*Flood data*—Continued

Date	Chehalis River near Grand Mound (drainage area, 928 square miles)			Satsop River at Satsop (drainage area, 315 square miles)			Wynoochee River at Oxbow (drainage area, 65 square miles)		
	Discharge in second-feet	Discharge in second-feet per square mile	Run-off in inches	Discharge in second-feet	Discharge in second-feet per square mile	Run-off in inches	Discharge in second-feet	Discharge in second-feet per square mile	Run-off in inches
Dec. 21, 1933	45,000	48.5	1.80	21,200	67.3	2.50	10,200	156.9	5.84
Dec. 22, 1933	44,300	47.7	1.77	18,000	57.1	2.12	6,350	97.7	3.63
Dec. 23, 1933	38,800	41.8	1.55	11,600	36.8	1.37	3,440	52.9	1.97
Dec. 24, 1933	23,900	25.8	.96	7,800	24.8	.92	2,290	35.2	1.31
Jan. 22, 1935	17,800	19.2	.71	45,900	145.7	5.42	16,000	246.2	9.16
Jan. 23, 1935	36,300	39.3	1.46	30,100	95.6	3.56	12,000	184.6	6.87
Jan. 24, 1935	29,300	31.6	1.18	32,800	104.1	3.87	13,000	200.0	7.44
Dec. 28, 1937	26,800	29.9	1.11	30,100	95.6	3.56	11,000	169.2	6.29
Dec. 29, 1937	46,300	49.9	1.86	14,200	45.1	1.68	7,000	107.7	4.01
Dec. 30, 1937	35,800	38.6	1.44	13,800	43.8	1.63	4,740	72.9	2.71
Dec. 31, 1937	25,300	27.3	1.02	9,470	30.1	1.12	2,610	40.2	1.50

46. *Extent and character of flooded area.*—Following the severe flood of December 1933, a survey of flood damages on western Washington streams was conducted by the State planning council with funds provided by the Washington Emergency Relief Administration. This survey shows approximately 20,000 acres of agricultural land in the Chehalis Basin were inundated by the 1933 flood as follows:

River	Area flooded, December 1933			
	Cultivated land	Pasture land	Raw land	Total
	Acres	*Acres*	*Acres*	*Acres*
Chehalis	9,940	3,850	1,600	15,390
Skookumchuck	710	290	30	1,030
Black	470	160	10	640
Satsop	360	220	210	790
Wynoochee	910	480	380	1,770
Total	12,390	5,000	2,230	19,620

47. In addition to the agricultural area shown in the preceding tabulation, 1,534 acres in Hoquiam, Aberdeen, and Cosmopolis, and an undetermined number of acres of residential and industrial lands, particularly in Centralia and Bucoda, were inundated by the 1933 flood, and a further amount of brush and wastelands not included in the Washington Emergency Relief Administration survey. From outlines of the area inundated by the 1933 flood as sketched by the county engineers of Grays Harbor, Thurston, and Lewis Counties, it is estimated that a gross area of about 58,000 acres was inundated, as follows:

	Acres
Grays Harbor County	40,000
Thurston County	6,000
Lewis County	12,000
Total	58,000

48. Considering the character of the maps available, this estimate of 58,000 acres is in close agreement with the estimate of 50,000 acres,

derived from the soil survey, referred to in paragraph 9. The 58,000-acre estimate includes an area of about 12,000 acres, lying downstream from Montesano, that is flooded by backwater from high tidal stages but which was not included in the Washington Emergency Relief Administration survey.

49. *Land values.*—The following data concerning the amount and value of agricultural lands in the Chehalis Basin are abstracted from the 1930 census of the United States, and from the Washington Emergency Relief Administration flood damage survey:

Item	Washington Emergency Relief Administration survey of flooded area	U. S. Bureau of the Census data for entire basin
Number of farms	394	3,500
Total area in farms (acres):		
Cultivated land	17,000	69,000
Pasture land	12,300	152,000
Raw land	9,300	47,000
Farm area flooded, December 1933 (acres):		
Cultivated land	12,390	
Pasture land	5,000	
Raw land	2,230	
Total value of lands and improvements	$3,560,000	$26,100,000
Average value a farm	$9,040	$7,460
Average value an acre	$92	$97

50. It is estimated from appraisals by this office that the value of the land in East Hoquiam, Aberdeen, and Cosmopolis that would be inundated by a tide stage of 16 feet is $3,500,000, exclusive of buildings, etc., and would increase $800,000 if protected from flooding.

51. *Productivity.*—On the basis of the 1930 census returns it is estimated that the total value of farm produce of the Chehalis Basin for the year 1929 was about $6,000,000, of which amount approximately $1,500,000 was realized from the sale of poultry products. As most of the poultry farms are situated on the higher, less-productive land, a comparatively small amount of the poultry production was on land subject to flooding. No definite data are available as to what portion of the remaining $4,500,000 worth of farm produce came from the flooded area, but it has been shown that there is a total of 268,000 acres of farm land within the basin and that a total of 58,000 acres of all classes of land may be subject to flooding. The areas subject to flooding constitute the most fertile portion of the basin, and therefore, it is estimated that the corresponding production from the flooded area was about $3,500,000.

52. *Flood damages.*—No accurate account of losses occasioned by floods other than that of December 1933 is available, nor is there, in general, any record of river stages by which the relative severity of the floods prior to that of February 1932 can be compared. Local residents in the vicinity of Elma state that the floods of 1917 and 1933 reached approximately the same stage. Of the floods prior to 1917 neither the damages nor comparative stages are known.

53. Table 7 shows the estimated damage to farm property in the Chehalis Basin from the flood of December 1933.

TABLE 7.—*Farm damage from flood of December 1933 on Chehalis River and tributaries*

River	Damage to farms				
	Damage to land	Damage to crops	Damage to improvements	Other farm damage	Total farm damage
Chehalis (main stream and minor tributaries)	$82,000	$72,000	$45,000	$4,000	$203,000
Skookumchuck	10,000	11,000	4,000		25,000
Black	4,000	3,000	2,000		9,000
Satsop	17,000	7,000	1,000		25,000
Wynoochee	16,000	14,000	6,000		36,000
Total	129,000	107,000	58,000	4,000	298,000

54. It has been reported that the stage of the flood of December 1917 was approximately equal to that of December 1933. If the river valley had had the same state of development in 1917 as it had in 1933, farm damages resulting from the 1917 flood would also have been about $300,000 (table 7). Individual floods between 1917 and 1932 probably caused only minor damage, although some erosion occurs with each high water. The flood of February 1932 occurred so late in the season that spring plowing and planting of the flooded lowlands was much delayed, with consequent shortening of the growing season and loss of crops. There was also some damage to land and improvements. It is doubtful that the total loss to farms occasioned by that flood exceeded $100,000.

55. Inspection of the areas damaged in the January 1935 flood indicated that losses to farms from that flood were less than half of the losses caused by the 1933 flood, except in the Wynoochee and Satsop valleys where the 1935 flood was much more severe. Based on a study of the farm losses in Grays Harbor County made by the county agricultural agent, it is estimated that the total farm losses were about $100,000.

56. Because the flood of December 1937 occurred at the same season, and carried about the same crest discharge as the 1933 flood, the resulting damages were probably about the same as those of the 1933 flood.

57. Estimated flood damages to farm property in the Chehalis Basin, as given in paragraphs 53 to 56, are summarized as follows:

Flood of December 1917	$300,000
Floods from 1918 to 1931, inclusive	50,000
Flood of February 1932	100,000
Flood of December 1933 (Washington Emergency Relief Administration survey)	300,000
Flood of January 1935	100,000
Flood of December 1937	300,000
Total, December 1917–November 1940	1,150,000
Average yearly loss (23 years)	50,000

Using the 1933 survey as a guide, this annual loss would be distributed about as follows: Chehalis River and upper tributaries, $38,000; Black, Satsop, and Wynoochee Rivers, $12,000.

58. From statements furnished by county and city officials, utility companies, railroads, industries, and the State highway department, annual flood damages to those interests are estimated to be as follows:

State highways and bridges	$700
County roads and bridges	1, 300
City of Centralia (except industries)	12, 000
Railroads	4, 000
Industries (largely in Bucoda)	7, 000
Total	25, 000

59. No losses occurring within the Grays Harbor cities of Aberdeen, Hoquiam, and Cosmopolis are included in the tabulations of paragraphs 57 and 58. Floods in those cities are caused by abnormally high tides, which may or may not occur in conjunction with floods in the rest of the basin. In 1935, a system of levees was built with Emergency Relief appropriation funds to protect most of Hoquiam, and it is therefore probable that future flood losses in that city will be small. In connection with the present survey, an appraisal was made in November 1939 of the damages to East Hoquiam, Aberdeen, and Cosmopolis that would result from a tidal stage of 15.8 feet above mean lower low water (see par. 41). From these data, and assuming stages of zero damage for the various areas, curves were prepared relating damage to stage, and damages from all abnormal tides of record were read from those curves. Table 8 shows flood damages from 1912 to date.

TABLE 8.—*Flood losses for areas A, B, C, and D in Aberdeen and vicinity* [1]

Date	Tidal stage	Damage				
		Area A	Area B	Area C	Area D	Total
1912	15. 0	$94, 000	$195, 000	$10, 900	$2, 940	$302, 840
November 1913	15. 2	106, 000	230, 000	13, 000	3, 240	352, 240
December 1920	14. 9	88, 000	170, 000	9, 800	2, 800	270, 600
December 1923	15. 2	106, 000	230, 000	13, 000	3, 240	352, 240
December 1933	15. 8	144, 350	349, 000	19, 500	4, 150	517, 000
December 1934	15. 5	126, 000	290, 000	16, 300	3, 680	435, 980
Total 31 years (1912–42)	--------	664, 350	1, 464, 000	82, 500	20, 050	2, 230, 900
Average annual, say	--------	21, 400	47, 200	2, 700	700	72, 000

[1] See map for location of areas.

60. There have undoubtedly been indirect flood losses, such as loss of business to merchants, delays in transportation, increased shoaling of navigation channels, etc., but quantitative data on these losses are not obtainable.

61. *Existing flood-control projects.*—There is no authorized Federal project for flood control in the Chehalis Basin.

62. *Improvement by other agencies.*—No large-scale or coordinated flood-control projects have been undertaken by local interests. A few private landholders have constructed a small amount of revetment to prevent erosion of banks, and the various counties involved have done some protective work to prevent scour of bridge piers and roads. Some construction of sheer walls has been done with Civil Works Administration funds at points of severe erosion, but the amount expended in such work could not be ascertained.

63. Two diking and drainage districts, organized under the laws of the State of Washington, have been formed in the Chehalis Basin—both in Grays Harbor County. District No. 2, organized in 1920, includes 995 acres on the north side of Chehalis River, between Satsop and Montesano. District No. 4, organized in 1922, embraces 730 acres in South Aberdeen. To December 31, 1939, expenditures by district No. 2 had been $40,600 and by district No. 4, $223,000.

64. *Work under Civil Works Administration.*—The city of Centralia proposed a project for rectification of the channel of Skookumchuck River adjacent to the city. During the summer of 1934, construction of the lower 850 feet of the channel was inaugurated with Civil Works Administration funds, but the work was suspended before excavation had proceeded to the proposed depth. The improved channel serves, therefore, only to aid in the draining of flooded land after the subsidence of high stages in the Chehalis River.

65. *Work under Emergency Relief Appropriation Act of 1935.*—Under the provisions of the Emergency Relief Appropriation Act of 1935 this office constructed an extensive system of dikes and interior drains to protect the city of Hoquiam (except for East Hoquiam) during flood stages of Hoquiam River and high tidal stages of Grays Harbor. Work was commenced on the project September 13, 1935, and was completed in May 1936, at an expenditure of $186,492.09.

66. *Work under Works Progress Administration.*—A Works Progress Administration construction program on the Chehalis and its tributaries, the larger part of which has been under the engineering direction of this office, was suspended in June 1938, for lack of funds. This program involved snagging of Cloquallum Creek, Satsop River, Wynoochee River, and Chehalis River in Grays Harbor County, and of Chehalis and Skookumchuck Rivers and numerous smaller tributaries in Thurston County; revetment of Chehalis River in both counties; and erection of sheer cables and channel excavation on Chehalis River, Satsop River, and Wynoochee River. The project is considered complete and no further work is anticipated. Work on the project consisted of 92 miles of snagging; 92,515 square yards of brush revetment; 4,950 feet of cabled drift; 10,050 feet of sheer cable; and 47,827 cubic yards of channel excavation. Encumbrances to June 1938, were approximately $300,000. In addition to the above, several small jobs were executed, apart from this office, directly under the Works Progress Administration and amounting to about $92,000.

67. A soil conservation service project for bank revetment of Wynoochee River is now under construction. Expenditures to June 25, 1940, were approximately $16,000, most of which was for Civilian Conservation Corps labor. The total Federal funds already expended in construction work on the Chehalis and tributaries is thus in excess of $590,000, including the emergency relief work in Hoquiam as reported in paragraph 65, but excluding the Civil Works Administration work mentioned in paragraph 64.

68. The revetment used in the Works Progress Administration work involves sloping the bank to be protected to about 1 vertical on 3 horizontal and placing brush wired together in a continuous mat thereon. Weighted fascines, held in position by cables and stakes, are used to hold the underwater part of the mat in place. Willow shoots, planted through the brush mat, are depended on to prevent scour after the brush mat has deteriorated too far to be of further

use. Once the willows get a good start, they serve to protect the bank from erosion, but they should not be allowed to grow so profusely as to unnecessarily obstruct the flow of the water.

69. *Improvement desired.*—A joint public hearing was held at Chehalis on April 20, 1937, in connection with the preliminary examination by the War and Agricultural Departments, and was attended by about 60 persons. A representative of the latter Department presided at the portion of the hearing devoted to "measures for run-off and water-flow retardation and soil-erosion prevention" as provided for in section 2 of the Flood Control Act approved June 22, 1936. Representatives of Grays Harbor and Thurston Counties presented a written communication suggesting channel rectification and enlargement, bank protection, and storage of floodwaters as the most feasible methods of control. This same communication concluded that the organization of a flood-control district under a recently enacted State law is the only means of providing the local cooperation required by the Flood Control Act of 1936 but that, since the organization of such a district can only be effected by a favorable vote of the affected parties, no guaranty can be made that a district will be formed. Representatives of Lewis County and of various cities and communities in the basin spoke of their particular problems. A unified plan for relief measures was not presented.

70. *Surveys.*—The following data were available and were used in the present investigation:

(*a*) Air photographs (scale 1 inch equals approximately 870 feet) of the valley from Grays Harbor upstream to Doty and for short distances up the tributary valleys. Photography by Air Corps, United States Army; mosaics by this office.

(*b*) United States Geological Survey river surveys:

(1) Satsop River from mouth to mile 25 of East Fork and to mile 20 of West Fork. Six sheets, scale 1:31,680. Published 1937.

(2) North Fork Newaukum River. Scale 1:24,000. Unpublished.

(3) Skookumchuck River to vicinity of Bloody Run dam site, scale 1:24,000. Unpublished.

(4) Meskill and Ruth Reservoir areas, Chehalis River, scale 1:24,000. Unpublished.

(*c*) United States Geological Survey topographic sheets:

(1) Hoquiam quadrangle; 1:62,500; 1915.

(2) Chehalis quadrangle; 1:125,000; 1916.

(3) Eatonville quadrangle; 1:125,000; 1937.

(*d*) Corps of Engineers, United States Army, tactical maps:

(1) Meskill quadrangle; 1:62,500; 1940.

(2) Montesano quadrangle; 1:62,500; 1940.

(3) Walville quadrangle; 1:40,000 (advance sheet).

(4) Ford quadrangle; 1:40,000 (advance sheet).

71. To supplement these data field surveys and investigations were made by this office as follows:

(*a*) Topographic surveys of Meskill, Ruth, Pe Ell, and Doty dam sites, and of the flood plain in Aberdeen, East Hoquiam, and Cosmopolis.

(*b*) Seismic exploration of Meskill, Ruth, Pe Ell, Doty, Bloody Run, and North Fork Newaukum dam sites.

(*c*) River surveys of the Chehalis River from Centralia to Galvin and in the vicinities of Oakville, Porter, and Malone (surveyed in 1935).

(*d*) Appraisal of 1933 flood damages in the Aberdeen-Cosmopolis area.

72. The map, submitted with this report, has been based on these surveys and on the maps listed in paragraph 70.

73. *Flood problems.*—The data presented in preceding paragraphs indicate that floods of Chehalis River cause little direct damage to urban property, except at Centralia and Bucoda; that high tides do extensive damage in the Grays Harbor cities; and that many acres of farm land are inundated during flood periods, but that the resulting damage is comparatively small.

74. Protection to the Grays Harbor cities can be supplied only by levees. An Emergency Relief Administration project for leveeing of most of Hoquiam has furnished protection to that city, but Aberdeen, East Hoquiam, and Cosmopolis are unprotected. Estimates of the cost of levees for the protection of those cities have been made and are presented herein.

75. Protection to the Centralia area might be provided by leveeing of the flood zone, by channel improvement of Chehalis and Skookumchuck Rivers, or by upstream storage. A system of levees to protect the city would extend along the entire river front and on both banks of Skookumchuck River. Such levees would involve extensive alterations to railroads, highways, and city streets, would require pumping plants to care for storm run-off, and would require the acquisition of expensive right-of-way. The limited damages to the city could not justify the expense of such a system.

76. Improvement of the channels of Chehalis River and Skookumchuck River might lower flood heights not only in Centralia but also in the adjacent farm areas. Estimates of the cost of improving Chehalis River have been made, and show that the cost is excessive when compared with the resulting benefits. Upstream storage, to completely protect Centralia, would have to be provided on both Chehalis River and Skookumchuck River, but control of Skookumchuck River alone would eliminate all but a small part of the damages in Centralia. Such storage would offer flood protection to all lands downstream from the dam site, and might, in addition, be operated to serve other purposes. Accordingly, detailed study of storage possibilities has been made.

77. Protection to the farm lands might be provided by channel improvement or by storage. Levees to protect the long, narrow valley are not feasible. Local works of channel improvement, to provide partial protection to the areas most seriously flooded, appeared to be possible and therefore surveys and detailed studies of such improvements were made. Those studies showed that channel improvement is unduly expensive and can, at best, protect but a small area.

78. Preliminary investigations showed four possible storage sites on the upper Chehalis River as well as sites on several of the tributaries, including Elk Creek, and Newaukum, Skookumchuck, Satsop, and Wynoochee Rivers. The Satsop and Wynoochee sites are too far downstream to be of material benefit for flood control, but each of the other sites could give some protection to a large part of the farm area and the Skookumchuck sites could, in addition, provide protection to the city fo Centralia. To limit the discharge through the farm area to the in-bank capacity of the channel during a flood like the one of 1933, storage on either the Newaukum or the Skookumchuck Rivers and on the upper Chehalis River would be necessary.

79. Flood damages to agricultural interests, despite the extensive area subject to inundation and the frequency of flooding, are not large enough to justify the cost of two such reservoirs. The small flood damages are explained by the fact that the agricultural economy of the basin is adjusted to present conditions—frequent winter and spring flooding, followed by droughts during the growing season— and is therefore based largely on the growing of low-value flood- and drought-resisting forage grasses. This present land use yields to the farmer an unsatisfactory return on his investment and his labor; in fact it has been reported by one informed State official that "A surprising percentage" (of Chehalis Basin farmers) "have had to accept public assistance during the past several years." The fertility of the Chehalis Valley soil, and the long growing season characteristic of the basin, would be favorable to a much higher land use were the hazards of floods removed and a dependable supply of irrigation water assured. However, no benefits have been ascribed to such higher land use, as there are no assurances that the affected lands would actually be put to a higher use if and when floods were controlled and a suitable water supply were provided.

80. The natural low-water flow of Chehalis River and certain of its tributaries, if devoted exclusively to irrigation, would no doubt serve the demand for many years to come. The minimum flow of Chehalis River at Grand Mound might be adequate for the irrigation of at least 15,000 acres. Unfortunately, however, there is some doubt that much, if any, irrigation water will be allowed to be diverted from the Chehalis River or its tributaries for the reason that resulting depletion of the low-water discharge would seriously and adversely affect the migration of important food and game fish, especially in the Chehalis River estuary where serious pollution is caused by the effluent from the pulp mill in Hoquiam. The irrigation supply for Chehalis Valley lands must therefore come from stored water.

81. From the foregoing it is clear that neither flood control alone nor irrigation alone can greatly improve agricultural conditions in the Chehalis Basin, and that irrigation will involve the storage of spring run-off for release during the growing season. Accordingly, studies have been made of the possibility of providing storage for the combined uses of flood control and irrigation, with incidental benefits in the form of partial abatement of pollution in the Grays Harbor area. No single one of the possible storage sites on the upper main stream receives sufficient run-off to control the 1933 flood—the highest of record—or to supply the needs of irrigation. The lack of run-off on the upper river could be made up on either the Newaukum or Skookumchuck Rivers. The reservoir sites on Newaukum River are composed of good, developed farm lands, whereas the Skookumchuck site is almost entirely undeveloped. The Skookumchuck Reservoir, moreover, would provide flood protection to the city of Centralia that would not be provided by the Newaukum reservoirs. The most effective combination of reservoirs, therefore, is one on Skookumchuck River and one or more on the upper main stream.

82. Of the four dam sites on the upper stream only two—the Ruth site, just downstream from the mouth of the South Fork, and the Meskill site, upstream from the mouth of the South Fork—control enough of the catchment area to be effective in flood control or to provide the required irrigation storage. Development of either site would entail extensive rebuilding of the Northern Pacific Railway, the Chicago, Milwaukee, St. Paul & Pacific Railroad, and of State Highway No. 12. Development of the Ruth site would entail, in addition, the rebuilding of several miles of the Chehalis Western Railroad and of county roads and the inundation of 6,200 acres of land, including some of the finest farm land in Lewis County. Because of the high right-of-way cost for the proposed Ruth Reservoir, it is apparent that the Meskill site is the cheaper of the two. The Meskill site can be developed to provide 110,000 acre-feet of storage at a spillway crest elevation of 325 feet. The cost of such storage, as of 1940, is estimated to be as follows:

Dam and control works	$2, 280, 000
Right-of-way	310, 000
Road and railroad changes	2, 010, 000
Total	4, 600, 000

83. There are three possible sites on Skookumchuck River and its tributaries: one on Hannaford Creek, near its mouth; one on Skookumchuck River downstream from Bucoda; and one on Skookumchuck River just upstream from the mouth of Bloody Run Creek. The Hannaford Creek and lower Skookumchuck sites each involve the flooding of valuable land and the relocation of many miles of highways and railroads, and neither of them would offer any protection to Bucoda. The Bloody Run site lies in an undeveloped area, where reservoir costs would be negligible, and is located upstream from both Bucoda and Centralia, so that it would protect both communities. The Bloody Run site can be developed to provide 41,000 acre-feet of storage at a spillway crest elevation of 480 feet. The cost of such storage, as of 1940, is estimated to be as follows:

Dam and control works	$2, 860, 000
Right-of-way	10, 000
Total	2, 870, 000

84. The annual cost of the Meskill project would be $206,800, and of Bloody Run project $121,600, a total of $328,400. The reservoirs would be of use for the purposes of flood control and irrigation, and, to a small extent, of pollution abatement. Floods in the basin occur only between November 1 and March 1. The spring months are characterized by fairly high discharges and the summer months by low discharges. Under these conditions the reservoirs could be kept empty during the winter months, to absorb flood flows, then filled during the spring run-off to provide water for irrigation during the summer months. Any stored water in excess of the demand for irrigation could be used to increase the low-water flow into Grays Harbor and thus aid in reducing the pulp-mill pollution in the harbor.

85. The two reservoirs—Meskill and Bloody Run—would limit the stream discharge to the in-bank capacity of the channel during lesser floods, but would not control enough run-off to eliminate all flooding during floods like those of 1917 and 1933. It is believed, however, that the reservoirs would prevent all but a small part of the flood damages to farms, except on Black, Satsop, and Wynoochee Rivers, and to utilities, urban areas, railroads, highways, etc., as listed in paragraphs 57 and 58, or $63,000 annually.

86. The benefits that would accrue to irrigation interests from the storage to be provided in the proposed reservoirs are not readily

determinable. It is probable that irrigation facilities would be extended rapidly if a water supply could be assured, but it is not anticipated that the entire irrigable area would be brought under irrigation in the near future. It is assumed herein that 40,000 acres may be irrigated within the effective lifetime of the proposed reservoirs, and that the land could bear a total irrigation charge of $8 an acre a year, the same charge as was assumed for medium-value land in the Willamette River Valley in the report on Willamette River and tributaries, Oregon, published as House Document No. 544, Seventy-fifth Congress, third session. The cost of preparing the land for irrigation, providing distribution facilities, etc., is estimated to be, on an average, $4.85 an acre a year, thus leaving $3.15 an acre annually that could be applied to the cost of storage. With 40,000 acres irrigated, therefore, irrigation could contribute $126,000 a year to the cost of storage.

87. The storage capacity not required for irrigation could be utilized to diminish the effects of pollution in Grays Harbor, but the available storage could, at best, result in only a small reduction in pollution damage. Estimates by this office show that all of the effluent from the present pulp mill could be pumped to the Pacific Ocean, thus completely solving the problem of pollution in Grays Harbor, at an annual cost of $50,000. If it be assumed that the proposed storage reservoirs could reduce the pollution damage by 50 percent—an assumption that is extremely liberal—the maximum benefits to be obtained from pollution abatement would be $25,000 a year.

88. The operating program for the Meskill and Bloody Run Reservoirs involves keeping the reservoirs empty for absorption of flood flows from November 1 to March 1, then storing most, or all, of the spring run-off for release during the irrigation season. It would be possible by increasing the proposed heights of Meskill and Bloody Run Dams by 18 and 10 feet, respectively, to keep heads of 50 and 60 feet, respectively, available at all times and still furnish the required amount of flood storage. It would then be possible to develop about 1,500 kilowatts of prime power at Meskill and about 500 kilowatts at Bloody Run. Since ample cheap power is now available in this region, benefits from such small amounts of power have not been considered in determining the justification for these dams.

89. The data presented in the preceding paragraphs show that the total benefits that might result from construction of the Meskill and Bloody Run Reservoirs—the cheapest and most efficient of the possible sites in the basin—are $214,000 annually and that the annual costs of the reservoirs are $328,400. It is obvious, therefore, that storage is not, at present, economically feasible.

90. *Run-off and water-flow retardation and soil-erosion prevention.*—The survey by the Department of Agriculture on Chehalis River is not yet complete. The measures herein proposed, however, would not in any way interfere with any works by the Department of Agriculture.

91. *Plan of improvement.*—The plan of improvement herein presented contemplates the construction of levees to protect Aberdeen, East Hoquiam, and Cosmopolis against high tidal stages, the only works for which economic justification now exists.

92. Levees and floodwalls have been planned to protect portions of Aberdeen, East Hoquiam, and Cosmopolis from inundation by high tidal stages. Sawmills and other industries lying between the railroad belt lines and the river have not been included in the areas to be protected. The protection of these industries would necessitate the construction of expensive floodwalls in deep water. The handling of materials over these walls would entail added expense for reconstruction of the plants involved, and, in general, owners prefer to bear occasional flood losses rather than to make plant changes. The elevation of the top of the levees has been fixed at 18.5 feet above the plane of mean lower low water, which would provide a freeboard of 1.5 feet above the probable highest tide.

93. Four levee sections have been adopted for different locations, as follows:

Type	Top width (feet)	Side slopes
I	8	1 on 2½
II	12	1 on 2½
III	18	1 on 1½
IV	24	1 on 1½

Type I would be used throughout except in those locations in which special conditions would require a greater top width. Types II and IV would be used for levees designed to carry roadway traffic, and type III would be used for railroad embankments raised to serve as levees.

94. The flooded area comprises four independent areas separated from each other by natural boundaries. These areas are indicated on the map accompanying this report and are designated as A, B, C, and D. Area D, comprising a small section of East Aberdeen, was found to have such small flood damage in comparison with the cost of protection that it was eliminated from further consideration.

95. The protective works for area A, comprising most of South Aberdeen and a small portion of Cosmopolis, would consist of 16,100 linear feet of raised railroad embankment and 7,750 linear feet of earth levees of other types. By making slight modifications in the bridges and streets crossed by the railroad embankment or levee, no openings would be required to care for traffic. Three pumping plants would care for possible run-off within the diked area.

96. The protective works for area B, which includes East Hoquiam and the principal business district as well as a large part of the residential section of Aberdeen, would consist of 9,970 linear feet of raised railroad embankment, 12,500 linear feet of earth levee of other types, and 4,620 linear feet of concrete and steel sheet pile flood wall. This system includes levees on each side of Frye Creek extending upstream to high ground, to prevent inundation of the adjacent areas. One pumping plant would be required.

97. The protective works for area C, which includes a large part of East Aberdeen, would consist of 3,180 linear feet of earth levee and 2,420 linear feet of concrete flood wall. The economic feasibility of protecting this area, considered as a unit, would be questionable. However, as Federal Highways 101 and 410 lie within the flooded area, protection of this section would be necessary to prevent interruptions of traffic entering the business district of Aberdeen from the south and east.

98. The estimated cost of the projects for areas A, B, and C is as follows:

	Area A	Area B	Area C
Definite project report	$7,000	$7,000	$2,000
Specifications and drawings	6,500	6,500	1,000
Clearing, grubbing, and stripping	3,200	2,500	300
Raising railroad embankment	165,000	77,000	
Levee embankment	28,500	38,500	8,000
Concrete flood wall		100,000	61,000
Sheet piling flood wall		12,000	
Culverts and tide gates	35,000	15,000	
Side ditches	4,000		
Pumping plants	73,000	16,000	
Subtotal	322,200	274,500	72,300
Reconstruction of streets and bridges	18,000	22,000	
Miscellaneous track changes	2,500	500	
Rights-of-way	6,200	41,300	2,500
Relaying of water mains and tide-gating of sewer outfalls	1,100	1,700	200
Subtotal	27,800	65,500	2,700
Total	350,000	340,000	75,000
Grand total			765,000

99. The annual charges of the proposed project for areas A, B, and C are derived as follows:

	Area		
	A	B	C
(*a*) Federal investment: Estimated expenditure for new work of construction	$322,200	$274,500	$72,300
(*b*) Federal annual carrying charges:			
(1) Interest at 3 percent on (*a*)	9,670	8,230	2,170
(2) Amortization of obsolescence and depreciation: 50-year life at 3 percent on (*a*) at 0.89 percent	2,870	2,440	640
(3) Total Federal carrying charges	12,540	10,670	2,810
(*c*) Non-Federal investment:			
(1) Reconstruction of streets and bridges	18,000	22,000	0
(2) Miscellaneous track changes	2,500	500	0
(3) Value of lands and rights-of-way to be furnished	6,200	41,300	2,500
(4) Water-main changes and tide gates at sewer outlets	1,100	1,700	200
(5) Total non-Federal investment	27,800	65,500	2,700
(*d*) Non-Federal annual carrying charges:			
(1) Interest at 4 percent on (*c*) (5)	1,110	2,620	110
(2) Amortization of obsolescence and depreciation: 50-year life at 4 percent on (*c*) (5) at 0.66 percent	180	430	20
(3) Cost of operation and maintenance of structures	2,300	2,300	400
(4) Total non-Federal carrying charges	3,590	5,350	530
(*e*) Total carrying charges, items (*b*) and (*d*)	16,130	16,020	3,340

100. The total annual charges for areas A, B, and C are therefore $35,490, including non-Federal charges of $9,470.

101. *Average annual benefits.*—It has been shown in table 8, that, with the state of development of the Grays Harbor cities at the time of the damage appraisal, and with flood frequencies as recorded during the last 31 years, potential direct flood damages are $72,000 annually, distributed among areas A, B, C, and D in the amounts of $21,400, $47,200, $2,700, and $700, respectively. The damages so indicated do not include intangible damages or damages that would result from

the highest tide (17 feet) that the levees have been designed to protect against. But, as protection is to be provided from such a tide, it is considered proper to include under preventable damages the annual damage caused by such a stage occurring once within the 50-year life of the project. Such an annual damage would amount to $16,720 for areas A, B, C, and D, distributed in the amounts of $4,400, $11,600, $650, and $70, respectively. Total preventable damages are, therefore, $88,720, but, as area D is not included in the proposed plan of improvement, the total benefits for the proposed plan are $87,950, distributed among areas A, B, and C in the amounts of $25,800, $58,800, and $3,350, respectively.

102. As pointed out in paragraph 50, there would result an increase in land value of the harbor cities, if flood control were provided, of $800,000. That figure is based on information furnished by informed local interests and does not include any increment in value of buildings or improvements. Accepting the figure of $800,000, and assuming an annual ground rental of 7 percent, there would be a yearly increase in rental value, by virtue of flood control, of $56,000. The realization of that benefit would, however, be contingent upon the future demand for land in the present flood plain and might not come for many years.

103. *Justification of project and allocation of costs.*—Assuming that the only realizable benefits from construction of the proposed levees would be the prevention of future flood damages as given in paragraph 101, the ratio of the cost of each project to resulting benefits would be as 1:1.60, 1:3.67, and 1:1.00, respectively, for areas A, B, and C. The economic feasibility of the projects for areas A and B is firmly established, and, as stated in paragraph 97, it is believed that the project for area C is justified because of the importance of maintaining access to Aberdeen from the south and east during flood periods.

104. In deriving the annual costs, as given in paragraphs 99 and 100, the allocation of costs has been made, using the policy established by the Flood Control Act of 1936 as a guide. That act provides for construction, at Federal expense, of those flood-control works for which annual benefits, to whomsoever they may accrue, are in excess of the annual costs; providing local interests furnish, without cost to the United States, all necessary lands, easements, and rights-of-way, agree to hold the United States free from all claims for damages arising out of the construction, and maintain and operate the works after completion. In view of the local nature of the benefits, however, it is believed that local interests should furnish additional cooperation, consisting of the reconstruction of streets, bridges, water mains, and sewer outfalls, and the making of miscellaneous track changes.

105. *Discussion.*—The data presented in this report indicate that floods of the Chehalis River are a source of damage to urban property in Bucoda and Centralia, and a contributing cause to the unsatisfactory agricultural economy of the basin; but that, despite the extent of the inundated area and the frequency of flooding, the annual damages from river floods are only $75,000. It has also been shown that high tidal stages in Grays Harbor inundate a portion of East Hoquiam and large sections of Aberdeen and Cosmopolis, including the commercial districts in the two latter cities, and result in potential damages estimated at $88,720 a year. (See par. 101.)

106. Consideration has been given herein to all possible methods of reducing flood damages, but none of the proposed methods, so far as the river flood plain is concerned, is economically feasible under

present conditions. The most nearly feasible method for providing the desired control is by storage in two reservoirs, one on the upper Chehalis River near Meskill, and one on the upper Skookumchuck River, but the annual costs of such a project are 153 percent of the estimated annual benefits, including liberal allowances for the value of such storage for irrigation development and the abatement of pollution.

107. Protection of the Grays Harbor cities can be provided only by levees or sea walls. Plans for such a project are presented herein. The proposed project would provide complete protection to the vicinity, except for certain water-front industries whose operations prevent the placing of a levee on the seaward side of their plants, and for a little-developed portion (area D) of Aberdeen in which the cost of providing protection is in excess of the anticipated benefits. Table 9 presents a summary of the economic justification for the various areas.

TABLE 9.—*Justification summary*

Area	Annual benefits			Annual costs			Ratio of costs to benefits
	Direct damages	17-foot flood damages	Total annual damages	Federal	Non-Federal	Total	
A	$21,400	$4,400	$25,800	$12,540	$3,590	$16,130	1:1.60
B	47,200	11,600	58,800	10,670	5,350	16,020	1:3.67
C	2,700	650	3,350	2,810	530	3,340	1:1.00
Total, A, B, and C (proposed project)	71,300	16,650	87,950	26,020	9,470	35,490	1:2.48
D	700	70	770	970	550	1,520	1:0.51
Total, A, B, C, and D	72,000	16,720	88,720	26,990	10,020	37,010	1:2.40

108. It is believed that, should the project be adopted, local beneficiaries should cooperate to the extent of supplying all rights-of-way, reconstructing streets, bridges, water mains, and sewer outfalls, making miscellaneous track changes, assuming responsibility for all claims for damages arising out of construction of the project, and maintaining and operating the project works after completion. Reasonable assurance has been obtained that local interests can meet the required annual charges of $9,470 (see table 9) and that they will meet the suggested terms of cooperation if the project is adopted.

109. *Conclusions.*—In view of the foregoing, it is concluded that the construction of levees and sea walls to protect East Hoquiam, Aberdeen, and Cosmopolis from inundation during periods of high tides in Grays Harbor is justified by the resulting benefits, and that no other work for flood control in the Chehalis Basin, either alone or in conjunction with the needs of irrigation, the abatement of pollution, or the development of power can be justified at this time.

110. *Recommendation.*—I therefore recommend the adoption by the Federal Government of a project for levees and sea walls for the protection of East Hoquiam, Aberdeen, and Cosmopolis, at estimated first costs of $669,000 for construction from Federal funds, and of $96,000 from local funds for rights-of-way, raising of streets and railroads, and miscellaneous track, water, and sewer line changes; subject to the provision that local interests also furnish, in addition to the

work estimated to cost $96,000, assurances satisfactory to the Secretary of War that they will hold and save the United States free from all claims for damages arising out of construction of the project, and will maintain and operate the project works after completion at an estimated annual cost of $5,000. The project, if authorized, could be completed in 1 year, and funds for its construction should be made in one allotment.

R. PARK,
Colonel, Corps of Engineers,
District Engineer.

[First endorsement]

OFFICE, DIVISION ENGINEER,
PACIFIC DIVISION,
San Francisco Branch, August 25, 1943.

To the CHIEF OF ENGINEERS, UNITED STATES ARMY,
Washington, D. C.:

The division engineer concurs in the conclusions and recommendations of the district engineer.

WARREN T. HANNUM,
Brigadier General, Corps of Engineers,
Division Engineer.

○