REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

SYLLABUS

The Board of Engineers for Rivers and Harbors presents a general plan for the ultimate improvement of the Columbia River for navigation in connection with power development, flood control and irrigation, but reports that the Federal Government would not be justified at the present time in adopting any further plan for improvement than that covered by the existing navigation project or in participating in the cost of any of the portions of such plan other than to bear the cost of the construction of the navigation features of the plan for the development of the river below the mouth of the Snake. It recommends—(*a*) that the existing projects for the improvement of the Columbia River between Vancouver and the mouth of Snake River be modified to provide that if dams be built in this section of the river under authority of the Federal Water Power Act and substantially in accordance with Plan A of the division engineer's report, the United States shall construct the necessary locks thereat, and enlarge the channel section above the Warrendale Dam, at an estimated cost of $16,100,000, with $300,000 annually for maintenance and operation; (*b*) that additional studies of certain engineering features of the general plan be made, and (*c*) that the reports be published.

[Second endorsement]

BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
Washington, D.C., February 23, 1932.

To the Chief of Engineers, United States Army.

1. The following is in review of the report on Columbia River, Washington and Oregon, submitted under the provisions of House Document No. 308, 69th Congress, 1st Session, which was enacted into law, with modifications, in section 1 of the River and Harbor Act of January 21, 1927.

2. The reports herewith contain information concerning existing and prospective developments for navigation, power development, flood control and irrigation, and for certain important combinations thereof. A comprehensive plan for the ultimate utilization of the water resources of the river is presented by the division engineer. The principal considerations upon which this plan is based and its more essential features are summarized in paragraphs 3 to 15 below.

3. In the tidal section of the river the present and immediately prospective needs of navigation are sufficiently provided for by the existing project.

4. In the nontidal section below the mouth of the Snake River, prospective commerce is not assured to a sufficient extent to justify the cost of an adequate improvement for navigation alone. The benefits to navigation afforded by the construction of power dams providing slack water throughout this section, are sufficient to justify the United States in constructing or paying for the construction of the necessary locks. In addition, the United States might be justified in contributing a sum not in excess of $5,000,000 toward the cost of constructing the dams.

5. Above the Snake River conditions are not favorable to the development of any considerable amount of commerce, but the in-

terests of navigation should be safeguarded by reserving to the United States the right to construct or to require the construction of locks in power dams built in this section.

6. In the nontidal section there are no serious flood problems, and works for flood control either alone or in combination with other developments are not necessary.

7. In the tidal section considerable areas are subject to flooding. The most important areas have been protected by levees constructed by local interests, but many of these levees do not afford complete protection against the highest floods. It is considered that the parties interested would be justified in increasing the extent of existing protection and extending it somewhat to unprotected lands, but that this is an independent problem which cannot profitably be combined with navigation, power development, or irrigation. In case power development in the upper river with extensive development of storage should be carried on in the future along the lines discussed in this report, some minor degree of flood protection for these lands will be an incidental result.

8. Power development is not feasible in the tidal section.

9. In the nontidal section the development of power is of paramount importance. It will have no adverse effect on navigation in the tidal section; it can and should be made to aid navigation in the nontidal section. Irrigation development will need the economic support of power developed for the general power market.

10. A large amount of water power could be developed at low cost, but only by the construction of very large projects. The comprehensive plan of the division engineer includes 8 dams, utilizing a little more than 92 percent of the available head and providing for an ultimate installation of more than 8,500,000 kilowatts or 11,330,000 horsepower. Of these dams, 2 are located below the Snake River and 6 above. One of the latter is now under construction at Rock Island Rapids as a private development.

11. Of the seven undeveloped sites, the three of special interest in connection with combined development, and in the order of their location going upstream are:

a. At or near Warrendale, at the foot of the Cascade Rapids.

b. At the Dalles, about 3 miles above the city of The Dalles.

c. At the head of Grand Coulee in the State of Washington.

12. Dams at the first and second sites will develop a large amount of power and will afford canalization of the river from tidewater to the mouth of the Snake, but will not provide slack water during freshets; some of the power can probably be used for irrigation by pumping. The dam at the Grand Coulee will be primarily for power development and irrigation. Full power development at any one of the three sites should properly defer power development at the others until the growth of the power market justifies further development. Prime power from either The Dalles or the Grand Coulee sites can be delivered in large quantities at the load centers in the Pacific Northwest at relatively low cost.

13. Irrigation has already been provided for most of the land which can be irrigated at low cost and its extension to the remaining lands of this type will be substantially independent of other uses of the waters of the river. One large area of upland, known as the "Columbia Basin", could be irrigated by gravity diversion from the Clark Fork and Spokane River or by pumping from the Columbia River by means of secondary power developed at the plant on the Columbia River near Grand Coulee. The feasibility of the pumping plan is dependent on the possibility of selling practically the entire output of primary power from this plant at a remunerative rate. Various smaller but still important areas might also be irrigated by pumping, chiefly by secondary power. None of those projects is considered economically feasible if it be required that the payments for irrigation water be sufficient to repay the construction cost of the pumping and distributing systems within 40 years with interest at 4 percent. If a combined power and irrigation development at Grand Coulee were built by the United States, the receipts from power and from reasonable charges for irrigation water might, under certain specified conditions, be sufficient to repay the construction cost within a period of from 60 to 90 years with interest at 4 percent. The district engineer states that the plan proposed amounts to some extent to assessing the adjacent region to pay for the indirect benefits which might accrue to it from the irrigation development, the payments being made in the form of increased rates for power rather than by direct assessment.

14. The division engineer concludes that the most feasible plan for ultimate utilization of the resources of the Columbia River is as follows:

a. A system of 8 dams along the main stream located at:
Head of Grand Coulee, Wash.
Foster Creek, Wash.
Chelan, Wash.
Rocky Reach, Wash.
Rock Island Rapids, Wash. (under construction).
Priest Rapids, Wash.
The Dalles, Oreg.-Wash.
The foot of Cascade Rapids (Warrendale), Oreg.-Wash.

b. Additional dams, with locks, for navigation only, at points 14 and 40 miles above the mouth of the Snake, to be constructed when justified by the needs of navigation.

15. He states that the power dams in *a* above would develop 92.3 percent of the total head between the international boundary and tidewater. This system would receive full benefit from such storage and regulation in the tributaries as may be created in the future. It would furnish slack-water conditions, except at high water and thus benefit navigation. It would permit irrigation of large tracts of land in Oregon and Washington and would reduce flood heights in the tidal section of the river. He states that provision should be made for locks through the dams below the mouth of the Snake River to be installed simultaneously with the construction of the dams, and through the dams above the Snake when river traffic justifies the cost of locks. He recommends that this plan be adopted by the United States as its guide in controlling and supervising development of the Columbia River above tidewater, navigation being considered chargeable with the cost of locks through dams below the mouth

of Snake River and subject to contribution of not over $5,000,000 toward the cost of these dams; and that the plan for the tidal section of the river remain as at present.

VIEWS AND RECOMMENDATIONS OF THE BOARD

16. As stated in the act of March 3, 1925, the primary purpose of this survey was: "The formulation of general plans for the most effective improvement of the river for the purposes of navigation and the prosecution of such improvement, in combination with the most efficient development of the potential water power, the control of floods and the needs of irrigation."

17. Based upon the information now available, the Board concurs in general in the views of the division engineer as to the best general plan for a comprehensive development of this river except as to the number of dams which should be constructed between the mouth of Snake River and tidewater. In this section the plan of the division engineer provides for an extremely high dam and large reservoir at The Dalles and a relatively low dam at Warrendale. An alternative plan, designated in the report as "Plan A", develops the head in this section of the river by four dams of moderate height located at Umatilla Rapids, John Day Rapids, The Dalles, and Warrendale. Although this plan would not develop as much total power as the one recommended by the division engineer, the Board prefers it as being better suited to progressive development to meet the growth of the power market.

18. The Board desires, however, to point out the fact that considering the limited time and money available, the length and character of the river, the multiplicity of available dam sites and the various combinations possible of consideration, the reports, voluminous as they are, must still be considered as general in character only, and not sufficiently complete to permit of definite recommendations for construction even were the Board otherwise prepared to make such recommendation.

19. For the proper development of the Cascade Rapids section, a dam at Warrendale with a head of about 50 feet, appears to offer the most satisfactory solution. Yet this involves a structure that must provide safely for a possible flood discharge of 1,400,000 cubic feet per second, and must be built upon a foundation of sand and gravel. The Board has found no precedent for such a structure, and could not endorse the plan proposed as sound from an engineering standpoint without further field investigation and extended and detailed studies. Likewise the dam proposed at The Dalles, which requires the closure of a channel 500 feet wide and 150 feet deep with very high velocities, involves methods of construction without precedent, and would require further investigation and detailed studies. At other places, notably Rocky Reach and Chelan, further investigation of foundation conditions would be required to determine beyond question the feasibility of the constructions proposed.

20. The Department of the Interior, through the Bureau of Reclamation is charged with the development of irrigation projects and copies of the portions of the reports covering the proposed Columbia Basin project, including the dam at Grand Coulee, were furnished that Bureau for its information. In a report dated January 7, 1932, to the

Commissioner of the Bureau, the chief engineer thereof, while suggesting certain modifications in the project works and submitting certain different estimates of cost and concurring generally in the views of the reporting officers as to the economic feasibility of the project, makes the following statement in which the Board concurs:

> In order to perfect final construction plans it will be necessary that further information be secured by diamond drilling of the foundation of the Columbia River Dam; that additional field exploration and laboratory tests be made to determine the amount and source of supply of the concrete aggregates for the Columbia River Dam; that a topographic survey and land classification be made of the irrigable area of the project; that test pits and borings be made to determine the classification of material to be excavated in the main canals of the project distribution system for use in final designs and estimates; and that a survey be made to determine the cost of irrigating land by pumping water from the Spokane River and using Columbia River Dam power.

21. Also, the question of the necessary provision for the passage of fish over the dams or other provision therefor will require more definite determination. The salmon fishing industry is of great importance to the States of Oregon and Washington, and should not be endangered. For moderate heights of dams, fish ladders may provide for the passage of fish upstream for spawning, but for dams of 100 feet or more in height no feasible plans have as yet been fully developed.

22. Irrespective of the points above referred to, the Board's views are substantially as follows.

23. In the tidal section of the river the existing project is sufficient for the present and immediately prospective needs of navigation, and future needs can be met independently of any other use of the stream. Further flood control measures are primarily of local importance and can be taken independently of other developments. No power and no important irrigation developments are possible in this section.

24. Above the tidal section the river is naturally divided into two sections, one below and one above the mouth of the Snake. There are no important flood problems in either of these sections.

25. In the section below the Snake River improvements for navigation have included open channel work and the construction of lateral canals at the Cascades and the Dalles-Celilo section, at a total cost of approximately $8,975,000. The chief difficulties of navigation in this section are due to the swift currents. These could not be eliminated by further work of open river improvement, and the most satisfactory plan for providing for barge navigation as desired by local interests, appears to be the construction of the series of dams above indicated, together with enlargement of the channel section above the Warrendale dam to reduce the velocity at high stages. Logically, if this work were undertaken, it should start with the lower dam and proceed progressively upstream. The estimated cost of the navigation features only of this system is $16,100,000 ($14,600,000 for locks and $1,500,000 for channel enlargement), and the carrying charges would be approximately $900,000 per annum. The figures submitted by the district and division engineers indicate a maximum gross saving of transportation costs by water over existing rail charges as a little over a million dollars per annum, based on the movement of 600,000 tons an average distance of 200 miles, with a saving of 0.9 cent per ton-mile. The Board notes that with an estimated saving of 20 percent of the cost of rail haul, which is the rate generally fixed

for barge navigation on the Mississippi and Warrior systems, this gross saving would be reduced to about $600,000, which is less than the annual carrying charges. The Board is therefor of the opinion that the United States would not be justified in expending for navigation more than the amount above indicated ($16,100,000) as the cost of the features required solely for navigation.

26. The estimated cost of the dams and power installations in this section, exclusive of the navigation features, is $317,320,000. While there is also a possibility of the ultimate irrigation of approximately 375,000 acres by pumping, such development is not urged at this time, and it is therefore clear that the primary feature of the proposed plans for this section of the river is the development of a large amount of potential water power. Local interests urge that this development be undertaken along the general lines adopted for the Colorado River at Boulder Canyon, involving as the chief feature a provision that no work shall be done until contracts for all of the power to be developed have been made. Suggestions have also been made to the effect that in order to secure for the people the maximum possibilities of cheap power, it might be desirable for the United States to construct transmission lines to the chief centers of population or industry. The Board is not prepared to recommend development on such basis. It does not understand that the action of Congress in the Boulder Canyon case was intended to be considered as a precedent in the establishment of a policy for the development of water power by the Federal Government on its navigable rivers. On the contrary, it believes that the policy set forth in the Federal Water Power Act is the adopted policy for such development. This view is supported by the action taken in the case of the Tennessee River where there is also a large amount of potential power. The report thereon (H.Doc. No. 328, 71st Cong., 2d sess.) was under the same provision of law as in this case. It submitted a comprehensive project for the development of the river and recommended in substance that the power be developed under the provisions of the Federal Water Power Act by private interests, States, or municipalities. This project was adopted by Congress in the River and Harbor Act of 1930. There does not appear to be any insuperable difficulty in the development of the Columbia River power on the same basis at any time when it can be demonstrated beyond question that the value of the power is such as to justify its development on a purely business basis.

27. In the Columbia River above the mouth of the Snake, expenditures for navigation have been limited and navigation has in recent years been negligible in amount. As indicated in the reports of the district and division engineers, there is little prospect that any considerable amount of navigation would be developed even were a complete system of dams and locks constructed. The Board concurs in the views of the division engineer that were such dams constructed, the United States would not be justified at the present time in bearing the cost of constructing locks therein, but should reserve under the terms of the Federal Water Power Act the right to install such locks or to require them to be installed when needed in the interests of navigation.

28. Local interest in this section of the river is centered in the Columbia Basin project, which involves the construction of a dam for the development of a large amount of power at the Grand Coulee

site, and the irrigation of a very large tract of land by pumping from the river. The economic feasibility of the plan is largely based on subsidizing irrigation by profits from the sale of power. The Board expresses no opinion as to the wisdom of this policy, which is presumably based on the theory that the consumers of the power would be justified by the indirect benefits which they might receive from the settlement of the areas proposed to be irrigated in paying higher rates therefor then would otherwise be required to carry the power project only. The economic feasibility is also dependent upon the future growth of power demand over a period of years. This is a question involving many uncertain factors and obviously impossible of exact determination. The Board does not undertake to make a definite prediction, but is of the opinion that the estimates of the reporting officers that the growth in power demand will be such that the entire prime output would be absorbed in a period of 15 years after 1940 and that this output would amount to only about 37 percent of the total increase in demand is unduly optimistic. Should the period required to build up a load for this plant be as much as 25 years or more, as has been estimated by the present division engineer, the capital charges would probably be so increased that the profits from the sale of power at the proposed rates would be insufficient to finance the irrigation project by the method set forth by the district engineer or by that proposed by the Bureau of Reclamation in the report referred to in paragraph 20. Furthermore, in view of the existing world-wide overproduction of agricultural products and of the extensive and long-continued depression in the farming industry, it does not seem that at this time expenditures of this magnitude can be justified for the purpose of bringing new land under cultivation. The Board is in receipt of a letter from the Secretary of Agriculture, dated January 30, 1932, with appendices, supporting this view and stating in very positive terms his opinion that the Federal Government should not now undertake to further enlarge the areas devoted to agriculture in this country. While local interests have submitted a brief in opposition to this statement, the Board accepts the views of the Secretary and is unable to recommend the adoption of this project at the present time.

29. In view of the above, the Board reports that, based on present information, the best general plan for the comprehensive utilization of the natural water resources of the Columbia River and for its ultimate improvement for the purpose of navigation in combination with the efficient development of the potential water power, the control of floods and the needs of irrigation is substantially as follows: (For general estimates of cost see table, pp. 14 and 15.)

a. A system of 10 dams for the development of water power, located along the main stream at the following sites:

Warrendale.
The Dalles.
John Day Rapids.
Umatilla Rapids.
Priest Rapids.
Rock Island Rapids (under construction).
Rocky Reach.
Chelan.
Foster Creek.
Head of Grand Coulee.

Locks and other facilities needed solely for navigation to be provided at all dams below the mouth of the Snake at the same time the dams are constructed. The provision of locks and dams above the mouth of the Snake to be deferred until it is apparent that prospective traffic will justify their construction.

b. Two low navigation dams with locks between the mouth of Snake River and the Priest Rapids site, to be built when justified by the prospective traffic.

c. Channel enlargement above the Warrendale Dam to reduce velocities at high stages.

d. Irrigation on a large scale by pumping from the river at the Grand Coulee Dam and similar irrigation on a smaller scale at some or all of the other sites.

e. Maintenance, strengthening, and possible extension by local interests of the flood control works which they have built in the tidal section of the river, the only one having serious flood problems.

f. Improvement of the tidal section below Vancouver as provided by existing Federal projects, or as may be authorized by future modification thereof.

30. The Board further reports that in its opinion the Federal Government would not be justified at the present time in making any improvement of the river other than as authorized by existing projects, nor would it be justified in participating in the cost of any portion of the comprehensive plan above outlined other than to bear the cost of the construction of the navigation features of the plan for the development of the river below the mouth of the Snake.

31. The Board therefore recommends:

a. That the existing projects for the improvement of the Columbia River between Vancouver and the mouth of Snake River be modified to provide that, if dams be built in this section of the river under authority of the Federal Water Power Act and substantially in accordance with "plan A" of the division engineer's report, the United States shall construct the necessary locks thereat, each 60 feet wide, 360 feet long, and having 9 feet of water on the sills at low water, or of such other dimensions as may be approved by the chief of engineers, and shall enlarge the channel section above the Warrendale Dam, all at an estimated cost of $16,100,000, with $300,000 annually for maintenance and operation.

b. That, with the object of more definitely determining the engineering features (pars. 19 and 20) of the general plan presented above, further investigations and studies be specifically authorized. The Board suggests that the investigations of the irrigation features of the Columbia Basin development might appropriately be made by the Bureau of Reclamation of the Department of the Interior.

c. That the reports of the district and division engineers, forwarded herewith, with plans and appendixes, be printed, since they contain information of value to State, municipal, and private interests, and to agencies of the United States in connection with future development on this river.

For the Board:

WM. J. BARDEN,
Colonel, Corps of Engineers,
Senior Member.

Estimates of cost of the comprehensive plan for the ultimate development of the Columbia River for the improvement of navigation in connection with the development of water power, the control of floods, and the needs of irrigation.

Power and navigation costs

Site and item	Interest rate on power projects	
	4 percent	6 percent
Warrendale (elevation 54):		
Dam and reservoir	$24,100,000	$24,800,000
Power house and machinery (660,000 kilowatts)	32,450,000	33,350,000
Total construction cost for power	56,550,000	58,150,000
Carrying charges	2,320,000	3,480,000
Total investment for power	58,870,000	61,630,000
Navigation facilities (see note A):		
Locks	3,100,000	3,100,000
Channel improvement	1,500,000	1,500,000
Total investment for power and navigation	63,470,000	66,230,000
The Dalles (elevation 150):		
Dam and reservoir	22,050,000	22,700,000
Power house and machinery (1,370,000 kilowatts)	61,990,000	63,700,000
Total construction cost for power	84,040,000	86,400,000
Carrying charges	4,490,000	6,740,000
Total investment for power	88,530,000	93,140,000
Navigation facilities	2,100,000	2,100,000
Total investment for power and navigation	90,630,000	95,240,000
John Day Rapids (elevation 258):		
Dam and reservoir	45,600,000	46,000,000
Power house and machinery (1,080,000 kilowatts)	57,200,000	59,700,000
Total construction cost for power	102,800,000	105,700,000
Carrying charges	7,060,000	10,600,000
Total investment for power	109,860,000	116,300,000
Navigation facilities	5,400,000	5,400,000
Total investment for power and navigation	115,260,000	121,700,000
Umatilla Rapids (elevation 330):		
Dam and reservoir	26,300,000	26,900,000
Power house and machinery (910,000 kilowatts)	30,790,000	31,550,000
Total construction cost for power	57,090,000	58,450,000
Carrying charges	2,970,000	4,470,000
Total investment for power	60,060,000	62,920,000
Navigation facilities	4,000,000	4,000,000
Total investment for power and navigation	64,060,000	66,920,000
Lock and marginal canal at Richland	800,000	800,000
Lock and marginal canal at 40 miles above Snake	950,000	950,000
Priest Rapids (elevation 540):		
Dam and reservoir	41,301,632	43,178,978
Power house and machinery (648,000 kilowatts)	16,590,710	17,344,833
Total construction cost for power	57,892,342	60,523,811
Carrying charges	4,956,196	7,772,216
Total investment for power	62,848,538	68,296,027
Navigation facilities	5,400,000	5,400,000
Total investment for power and navigation	68,248,538	73,696,027
Rock Island (elevation 599): Navigation facilities	1,800,000	1,800,000
Rocky Reach (elevation 665):		
Dam and reservoir	23,682,057	24,559,171
Power house and machinery (336,000 kilowatts)	12,931,840	13,410,797
Total construction cost for power	36,613,897	37,969,968
Carrying charges	1,420,923	2,210,325
Total investment for power	38,034,820	40,180,293
Navigation facilities	2,300,000	2,300,000
Total investment for power and navigation	40,334,820	42,480,293

Power and navigation costs—Continued

Site and item	Interest rate on power projects	
	4 percent	6 percent
Chelan (elevation 762):		
Dam and reservoir	22,676,864	23,516,747
Power house and machinery (450,000 kilowatts)	14,968,465	15,522,853
Total construction cost for power	37,645,329	39,039,600
Carrying charges	1,814,149	2,822,010
Total investment for power	39,459,478	41,861,610
Navigation facilities	3,000,000	3,000,000
Total investment for power and navigation	42,459,478	44,861,610
Foster Creek (elevation 928.6):		
Dam and reservoir	24,524,372	25,639,116
Power house and machinery (691,000 kilowatts)	21,696,684	22,682,897
Total construction cost for power	46,221,056	48,322,013
Carrying charges	2,942,924	4,615,041
Total investment for power	49,163,980	52,937,054
Navigation facilities	5,400,000	5,400,000
Total investment for power and navigation	54,563,980	58,337,054
Grand Coulee (elevation 1,287.6):		
Dam and reservoir	138,736,160	147,180,969
Power house and machinery (1,575,000 kilowatts)	32,450,617	34,425,872
Total construction cost for power	171,186,777	181,606,841
Carrying charges	33,296,676	52,985,149
Total investment for power	204,483,453	234,591,990
Navigation facilities	11,000,000	11,000,000
Total investment for power and navigation	215,483,453	245,591,990
Grand total:		
Power development (7,720,000 kilowatts)	711,310,269	771,856,974
Navigation facilities (see note B)	46,750,000	46,750,000
Power and navigation	758,060,269	818,606,974

NOTE A.—The interest on navigation facilities during construction not included.
NOTE B.—The cost of the navigation facilities below the Snake River is $16,100,000.

Irrigation costs

Based on 4 percent money, settlement at a rate of 50,000 acres per year

Columbia Basin project (plan 4), 1,199,430 acres:	
Pumping plant at Grand Coulee	$15,631,300
Distributing works	165,194,030
Total	180,825,030
Carrying charges	40,896,850
	221,721,880
Smaller projects below mouth of Snake River, 378,060 acres:	
Capital cost	38,789,965
Carrying charges	6,956,304
Total	45,746,269
Total for irrigation	267,468,149

Flood control costs

Raising 216 miles of levees 2 feet above crest of 1894 flood	1,665,000
Alternate project, raising 216 miles of levees 4 feet above crest of 1924 flood	6,705,000
New levees to protect 23 square miles	1,179,000