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AVON BYPASS

SKAGIT RIVER, WASHINGTON

With Supplement to NPS Reactivation Rept Nov 1963

REACTIVATION REPORT

U.S. ARMY ENGINEER DISTRICT, SEATTLE

CORPS OF ENGINEERS

SEATTLE, WASHINGTON

November 1963

36

1517-08 Survey Rept Files
SKAGIT RIVER (AVON BYPASS) - REACTIVATION REPT - with SUPPL to NPS Reactivation Rept
Nov 1963
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NPSEN-BP
25 September 1964

SUPPLEMENT TO NPS
REACTIVATION REPORT OF NOVEMBER 1963
AVON BYPASS PROJECT
SKAGIT RIVER, WASHINGTON

1. References.

a. OCE 2d Indorsement dated 20 April 1964, subject, "Reactivation Report, Avon Bypass, Skagit River, Washington."

b. Discussions NPS-NPD-OCE Conference 5 and 6 August 1964.

c. NPD comments in letter dated 7 August 1964, subject: "Reactivation Report, Avon Bypass, Skagit River, Washington."

2. Purpose. This report presents supplemental information on the Reactivation Report for the Avon Bypass, and updates the November 1963 report to 1964 conditions. Specifically, the following matters are considered:

a. Revision of project costs, interest rates and benefit-to-cost ratio to FY '65 base. Modified frequency curves and resulting effects on project benefits are presented.

b. Discussion of design comments.

c. Discussion of the degree of protection afforded by the Avon Bypass.

d. Additional information on a flood control plan for the Skagit River basin to show that the Avon Bypass is a justified and necessary part of the long-range plan for basin development.

e. Review of the optimization of a project channel design for 60,000 c.f.s. capacity with a 100-year life.

f. Discussion of alternate plans considered.

g. Summary of status and extent of local support.

3. Review of costs and benefits. Updating of construction costs from November '63 to July '64 has increased total Federal costs for the project from $19,100,000 to $19,700,000, and total non-Federal construction costs from $4,150,000 to $4,240,000. The increases in costs, with the exception of a portion of the Federal engineering and design costs, are attributable to the increase in the construction cost index from FY '64 to FY '65. Engineering and design for the Federal portion of the project was increased by $95,000 to allow for more detailed foundation investigations and channel alinement studies in the preconstruction planning stage. A copy of the latest PB-3 (Project Cost Estimate) showing the basis for the increases is furnished as Exhibit 1 of this report.

4. Revised annual costs, reflecting the updated construction costs and the recently adopted 3-1/8% interest rate, are presented in the following tabulations:

	50-Years	100-Years
Federal: Interest and amortization	$819,000	$674,000
Non-Federal: Interest and amortization	$176,000	$145,000
Operation and maintenance	31,000	31,000
Major replacements	24,000	25,000
Total non-Federal	$231,000	$201,000
Total annual charges	$1,050,000	$875,000

Additional hydrologic information gained during continuing studies of the Skagit River basin have resulted in modification of the flood frequency curves. The modified curves for the Skagit River near Mount Vernon are shown in Exhibit 2. The frequency curves have been revised primarily in the upper ranges above 90,000 c.f.s. The revision is illustrated by changes in the basic unregulated frequency curve from 250,000 c.f.s. to 215,000 c.f.s. for a 50-year flood, 300,000 to 250,000 c.f.s. for a 100-year flood and 350,000 to 285,000 c.f.s. for a 200-year flood.

5. The changed frequency and adjustment in the discount rate applied to future growth, because of the advancement of Federal interest rate from 3 to 3-1/8%, have resultedin revised project benefit estimates. The revised flood control benefits for the Avon Bypass based on operation in conjunction with proposed future downstream channel and levee improvements, have changed from $2,102,000 to $1,959,000 annually for a 100-year economic life and from $1,758,000 to $1,660,000 annually for a 50-year economic life. The resulting benefit-to-cost ratios are 2.2 for a 100-year life and 1.6 for a 50-year life.

6. Design modifications. With regard to comments in OCE 2d Indorsement to the Reactivation Report, detailed stability investigations of channel slopes have not been made because the study was limited to a survey scope investigation

of project feasibility. These investigations will be carried out as part of later design studies when the final channel alinement has been determined. The effect of providing a berm, if required, would be principally an increase in non-Federal costs for lands. This increase is within the total project contingency allowance.

7. Degree of protection afforded by the Bypass. In paragraphs 19 to 21, the optimum Bypass diversion capacity is shown to be 60,000 c.f.s. Overall protection afforded by the Bypass downstream from Sedro Woolley, with 60,000 c.f.s. diversion capacity, first added, would range from 14-year protection along the lower North and South Forks to more than 35-year protection upstream of the confluence of the Forks. A survey report recommending a plan to establish increased channel capacity by improvement of the levee system and by widening constricted reaches of the existing channel downstream from the Bypass is now being revised for resubmission to the Division Engineer, North Pacific Division. Construction of the Bypass, together with levee and channel improvements, would increase flood protection to a minimum 35-year level downstream from Sedro Woolley. The 35-year level was cited as 30 years in the previous report, but has been changed because of the frequency curve modifications. The 35-year level of flood protection provided by the Avon Bypass with levee and channel improvements would protect against 79 percent of average annual flood damages under present conditions. These flood damages are 75 percent agricultural and only 25 percent urban. Therefore, the project is now required essentially for the protection of agricultural lands, and the 35-year level of protection is well suited to present development.

8. The Bypass would substantially improve the degree of protection for urban areas by lowering water surface elevations during flood periods, and thereby provide a greater degree of protection. There would be no physical basis for a false sense of security as only minor levee improvements are planned in the immediate vicinity of urban areas. Flood peaks in the Skagit River valley are sharp and of short duration. Encroachment on the 2-foot freeboard proposed for the Bypass project and the levee improvements could provide flood protection of up to 75-year frequency for the delta. Local interests would be required, as a part of local cooperation, to notify the public annually of the limited protection being provided so that all concerned would be knowledgeable.

9. Basin objectives for flood control. Studies to date have confirmed that improved flood protection in the delta downstream from Sedro Woolley is the highest priority need in the basin. Immediate flood control measures are needed to prevent large losses in areas that have developed markedly since the last major floods in 1951 and 1921, and are now only partially protected by levees. Long-range flood control measures to provide flood protection in the range of 75- and 100-year frequency will be required to permit future urban, residential and industrial developments. This type of high level flood protection is required to realize enhancement benefits. However, the immediate need is for measures to relieve the hazard of flood damages from more frequent floods. The estimated average annual flood damage of

$2,216,000 in the Skagit flood plain downstream from Sedro Woolley under present conditions is an excellent indication of the economic importance of immediate flood control measures. Basin planning to date has been directed toward developing first-priority flood control and related measures that can be constructed with sound economic feasibility under present conditions, and to assure that these projects will retain their feasibility when considered with potential future projects. Possible means of providing flood control in the delta area include upstream storage, levee and channel improvements, and diversion. Current studies have indicated that single-purpose flood control storage is not economically feasible at the present time. Because added power in Cascade projects in the Pacific Northwest will not be marketable until at least 1975, consideration of a multipurpose upstream storage development to provide immediate flood protection for the delta area is not practical. Thus, the first-priority projects to provide immediate flood relief for the delta area are the authorized Avon Bypass and the levee and channel improvements downstream from the Bypass.

10. Levees. The Skagit River flood plain downstream from Sedro Woolley is protected by 43 miles of riverbank levees. These levees have capacities varying from 91,000 to 143,000 cubic feet per second. Overtopping of low areas in the levee system begins at flows of 84,000 c.f.s. Through sandbagging of low areas and minor flood fighting, the levees can provide capacity for a 91,000 c.f.s. flow with an average minimum freeboard of one foot. The levee system now affords protection from probable floods of once in 3 to once in 10 years. Levee and channel improvements proposed in the forthcoming survey report would give the entire levee system a minimum capacity of 120,000 cubic feet per second to protect against floods with an expected occurrence of once in seven years.

11. Protection for flows exceeding 120,000 c.f.s. would require major raising of the existing levee system. The existing levee system rests on sand and silt foundations prevalent in the delta. Differential heads of water in flood flow periods result in seepage through levee foundations, causing boils and blowouts that flood adjacent croplands. The semi-pervious foundation conditions preclude any general raising of levees without extensive broadening of the levee sections, construction of cutoffs to reduce seepage, and relocation of the road systems adjacent to the levee system. A project to provide flood protection by major levee and channel improvements would cost six to seven million dollars more than a project to provide equivalent flood protection with the Bypass and downstream levee and channel improvements, and was therefore found infeasible.

12. Upstream storage. Few potential sites for upstream storage development are available in the Skagit River basin. A favorable site on the Sauk River six miles upstream from its confluence with the Skagit River appears to be the only location in the Skagit River basin at which major upstream storage is possible. Single-purpose flood control storage on the Sauk is not feasible; however, a dam at this site could develop approximately 700,000 acre-feet of multiple-purpose storage. About 250,000 acre-feet of storage would be usable for flood control. This amount of storage would increase the 35-year flood protection in the delta afforded by the Avon Bypass and downstream levee and channel improvements to more than a 100-year level of protection. Effective storage in the Sauk River reservoir, with the present

level of flood protection, could control a 10-year flood at Mount Vernon to 91,000 c.f.s. corresponding to minimum capacities of downstream levees with minor sandbagging. The Sauk River storage, together with the levee and channel improvements, would yield 30-year frequency flood protection in the delta. Multi-purpose storage in the Sauk project could also provide hydroelectric power, irrigation, recreation, and low flow augmentation in addition to flood storage. The largest multiple-purpose benefit for the project would be hydroelectric power. Because the hydroelectric power would not be marketable before 1975, the project could not be scheduled for in-service operation prior to 1975. As the project could not be justified until the power is marketable, the Sauk project should be considered a potential element in a future plan of water resource development. The Sauk River has large migratory runs of salmon and steelhead which constitute a significant part of both the sports and commercial fishery of the region. Opposition can be expected from fish and wildlife interests on any major storage project in the Skagit River basin. Such opposition is another reason that storage on the Sauk River should be considered only as a possible element of a future basin plan. Therefore the Avon Bypass and the channel and levee improvements in the delta would provide an immediate and very much needed first increment in a basin flood control plan.

13. The Bypass last added to upstream storage, plus levee and channel improvements, would increase the level of flood protection to more than 100-year frequency. Annual benefits of $1,178,900 would accrue to the Avon Bypass, last added to Sauk River storage, plus levee and channel improvements. These benefits consist of flood damage benefits of $445,900, plus enhancement benefits of $733,000. These benefits would yield a benefit-to-cost ratio of 1.3 for the Bypass last added to upstream storage, thus confirming feasibility.

14. Summary of planning. Flood control has the highest priority of the immediate water-control needs in the Skagit River basin. The present flood damage expectancy is once in 3 to once in 10 years, varying with individual diking districts. An intermediate level of flood protection, corresponding to protection from flooding of once in 35 years, can be achieved in the delta by constructing the authorized Avon Bypass in combination with the proposed levee and channel improvements downstream from the Bypass. These improvements are well justified when considered as first elements of a basin plan. They also retain their justification when considered as last added; or, in a plan for upstream storage, which would yield a much higher level of flood protection as well as other water resource benefits. Because of strong concern by fisheries interests about the effect of the Sauk River storage project on fish and because hydroelectric power from the project would not be marketable until 1975, construction of the Sauk project at this time can only be considered as a potential element of future plan of water resource development. Thus, the Bypass and downstream levee and channel improvements are the only flood control proposals now attainable.

15. Other alternative plans. Alternative plans of flood control in the delta have been considered. These plans are (1) channel deepening, (2) channel widening and (3) channel dredging at the mouth of the river.

16. Deepening the Skagit River to carry flood flows is not feasible. Substantial deepening of the river to carry flood flows would undermine existing levees along the river banks. The Skagit River carries large quantities of bed sediment estimated at more than 500,000 cubic yards annually. An excavated channel of sufficient depth to carry flood flows would require annual dredging to remove deposited sediment and would be economically impracticable.

17. Flood protection by widening the Skagit River channel and setting back levees was also considered. To achieve the same results as the Bypass and levee improvements, the channel would have to be widened from 300 to 600 feet from the downstream limits of Sedro Woolley to the mouth of the river, a distance of over 20 miles. This work would be infeasible as the cost would be about six to seven million dollars more than the cost of equivalent flood protection with the Bypass and downstream levee and channel improvements. One of the principal reasons for the higher cost of this plan is that much of the land on both banks of the river is well developed, and widening would require costly relocations and acquisition of land.

18. Widening of the river at its mouth, proposed as a flood control measure by local residents in the basin would provide only very localized flood protection. Such widening would lower flood stages slightly for a short distance upstream from the mouth of the river, but would not provide flood protection for the upper delta in the vicinity of Mount Vernon and Burlington.

19. Optimization of design. As the Avon Bypass is an integral part of a long-range basin plan for flood control, a 100-year economic life has been utilized in optimizing the design. The high degree of flood protection for enhancement benefits could be obtained either by greatly increasing the Bypass capacity or by upstream storage. Justification for adding enhancement to the Bypass evaluation can not be made until some future indeterminate time, when upstream storage feasibility is finally ascertained. Enhancement has not been included in the present analysis because:

a. The added Bypass capacity for enhancement benefits could be constructed at any time in the future without adversely affecting the feasibility of a lesser capacity channel first constructed.

b. A channel to develop enhancement benefits is completely beyond the present capability of local interests.

20. The Avon Bypass was first considered without the levee and channel improvements. In this plan, the Bypass would begin operation at 84,000 c.f.s. flow downstream from Sedro Woolley. Operation of the Bypass in this manner would retain freeboard in the existing levee system with a minimum of flood fighting. Based on this plan of operation, curves showing average annual costs and average annual benefits were plotted against a scale of varying Bypass channel capacities. As illustrated in Exhibit 3, these curves show that the maximum net benefit value is realized for a Bypass capacity of about 60,000 c.f.s., corresponding to a B/C ratio of 2.9. A channel of this capacity would provide full flood protection from flows of 144,000 c.f.s. downstream from Sedro Woolley. Overall protection afforded by the Bypass in the delta area would range from 14-year protection along the lower North and South Forks to more than 35-year protection upstream.

21. <u>Optimization of Bypass design with proposed levee and channel improvements.</u> The Avon Bypass, when considered jointly with levee and channel improvements, would begin operation at about 100,000 c.f.s. Operation on this basis would permit the addition of a sport fishery and recreation to the Bypass channel. Curves of total average annual costs and average annual flood control benefits for the combined Bypass and levee and channel improvement projects were plotted against a scale of added channel capacity downstream of Sedro Woolley. As illustrated in Exhibit 3, these curves show that the maximum net benefit value for the combined projects is realized from an added channel capacity of 96,000 c.f.s. corresponding to a Bypass capacity of 60,000 c.f.s., and a 36,000 c.f.s. increase in the main river minimum capacity from 84,000 to 120,000 c.f.s. The combined B/C ratio of the flood control features for the added channel capacity of 96,000 c.f.s. is 2.5.

22. The foregoing studies indicate that 60,000 c.f.s. flow is about the optimum channel capacity. However, because of possible changes which may result from future alinement studies, some modification of this capacity may develop in final design studies.

23. <u>Status of local support.</u> The Skagit County Commissioners, by letter of 1 August 1962, indicated their willingness to furnish local cooperation. A copy of their letter is shown as Exhibit 1 of the Reactivation Report. The project is well supported by nearly all elements of state and local governments. A public hearing was held in Mount Vernon, Washington, on 10 January 1964 to present the Corps' plan for levee and channel improvements, and for the inclusion of recreation in the Bypass project. A portion of this meeting was devoted to the Avon Bypass. A record of the public hearing is attached as Exhibit 4. The Bypass project was indorsed by representatives of the State of Washington, the Board of County Commissioners of Skagit County, the City of Mount Vernon, the Skagit County Flood Control Council representing a majority of Diking Districts in the valley, granges, and various individuals and diking and drainage districts. A petition signed by 219 persons supported the Bypass. A list of proponents for the project is shown on Page 2 of the Public Hearing Record.

24. Opposition to the Bypass project was expressed by representatives of Fire District No. 6 and Diking District No. 12, on the grounds that the Bypass cost would be excessive, would sever the Districts, and make access difficult. Several landowners along the path of the Bypass channel objected to the loss of farmland that would result from construction of the project. A petition signed by 740 persons was presented by a citizen's group that opposed the use of the Bypass on the following grounds:

a. The Bypass will not provide protection for major floods.

b. The Bypass will endanger a new area to flood hazard.

c. The Bypass will cause eventual silting-up of shallow Padilla Bay.

Letters to Congressmen from leading sponsors of this petition followed the public hearing. To clarify some of the misunderstanding, a meeting was held on 13 March 1964 in the District office with leaders of the citizens opposing the project, most of whom are from the Bayview and Burlington areas. The group included Mrs. Edna Breazeale, Mr. John Swisher, Mr. Norman Dahlstedt, and others. Each of the foregoing arguments was considered in detail. The importance of the Bypass as a major element of a flood control plan was explained. The broad width of levee berms in the Bypass, amounting to 50 feet or more, dispensed arguments that the Bypass would open up a new area to flood hazards. Regarding the statement that the Bypass would cause silting of shallow Padilla Bay, the group was advised that the Bypass would include provisions for a continuous diversion flow of about 100 c.f.s. to prevent stagnation. The diversion flow is less than one percent of the mean annual flow of the Skagit River, and much of it would occur during periods when the Skagit River is carrying little, if any, sediment load. Bed load in the river would be prevented from entering the channel by the ogee weir crest of the headwater which is about 20 feet above the river bottom. In addition, with the downstream levee and channel improvements, the Bypass would only be used once every four years for flood flows. The amount of flood discharge in the Bypass would vary from perhaps 10,000 c.f.s. once every 4 years to a maximum of 60,000 c.f.s. at 35-year intervals. The duration of this flood discharge would be from 24 to 48 hours. None of the foregoing operations would result in any sedimentation that would affect or even be noticeable in Padilla Bay.

25. On the basis of the arguments cited above, District representatives believe they were able to dispose of the objections cited in the petition on engineering grounds. Opposition was also expressed on grounds other than those cited above. The group felt that the Bypass was being forced upon them without adequate opportunity for a full public hearing; and that the potential recreation aspects of the project might bring a horde of hunters, fishermen and others into the area who would invade the privacy now enjoyed by residents.

26. In cooperation with the local sponsor, the District now plans a public hearing on the Bypass after the alinement is fixed. If modification of the alinement is feasible, many objections to the project may be eliminated. With respect to recreation development, local residents have been advised that this feature is permissive and is entirely a local interest responsibility. The project is feasible for flood control without recreation

EXHIBITS

1. PB-3, Avon Bypass Cost Estimate, attached.
2. Flood frequency curves, Skagit River near Mount Vernon, attached.
3. Cost-benefit-capacity curves, attached.
4. Record of Public Hearing at Mount Vernon, Washington - 10 January 1964, inclosed with report.

SYNOPSIS

The Avon Bypass project, to divert a portion of floodwaters from Skagit River to Padilla Bay, was authorized by the Flood Control Act of 1936. Assurances of local cooperation were not forthcoming and the project has been inactive since 1952.

Review report studies initiated in 1961 have shown that with present-day development, construction of the Avon Bypass is the most urgently needed project for flood control in the delta area of the Skagit River Basin. The Avon Bypass project is well justified, and is well supported by local interests. Assurances of local cooperation have been received and the project is recommended in this report for reactivation. The report shows that the Avon Bypass, as proposed, is an integral part of a long-range basin plan for flood control.

The project consists of a diversion channel eight miles long that would have a design capacity of 60,000 c.f.s. Structures include a gated intake control, a downstream overflow weir, an intermediate weir and eight new highway and two new railroad bridge crossings. The project includes extension and improvement of four miles of levees on the right bank of Skagit River immediately above the intake control structure.

Construction of the Avon Bypass will increase flood protection in the Skagit River delta from an average 5-year frequency at present to about 30-year protection when operated concurrently with the proposed downstream levee and channel improvements. Improvements of the Skagit River system downstream of the Bypass by providing uniform top widths and heights of levees and by minor channel widening will be recommended in a survey report scheduled for submission in December 1963.

The Avon Bypass project would cost \$23,250,000, of which \$4,150,000 are local interests costs. Average annual benefits of \$2,102,000 for the project and average annual costs of \$823,000 yield a benefit-cost ratio of 2.5 for the project.

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AVON BYPASS

REACTIVATION REPORT

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GENERAL

AVON BYPASS PROJECT

REACTIVATION REPORT

1. GENERAL

1.01 Project authorization. The Avon Bypass was authorized by the Flood Control Act of 1936. The project provides for a channel to divert a portion of the flood water from the Skagit River to Padilla Bay, and for improvement and construction of four miles of levee on the right bank of the Skagit River between the towns of Burlington and Sedro-Woolley. Following authorization, local interests were unable to meet the requirements of local cooperation which included furnishing necessary highway and railway bridge crossings, rights-of-way lands and utility relocations. Because local cooperation requirements could not be satisfied, the project became inactive.

1.02 Report purpose. A restudy of the flood control needs in the Skagit River Basin was authorized following major flooding in the valley in 1959. In ensuing studies, the Avon Bypass was found to be one of the most effective means of providing flood control in the lower valley. This report sets forth the basis for proposed reactivation of the Avon Bypass project.

1.03 Scope. The report furnishes information about general planning, costing and justification of the Avon Bypass project in sufficient detail to permit a recommendation for early construction. The report includes consideration of the Avon Bypass in the immediate and long range plans for water resource development of the Skagit River Basin. The plans described herein are in full consonance with the survey report plans to be

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submitted in the latter part of calendar year 1963 for the next phase of development of the Skagit River Basin.

1.04 Historical background. The project was authorized by the Flood Control Act of 1936. At a Public Hearing on 2 March 1937, responsible County officials stated that county finances were such that it was then impossible for local interests to furnish the required local cooperation. No assurances of local cooperation were furnished and the project was subsequently classified inactive in 1952. The District Engineer in a survey report (submitted in February 1952) recommended that the Avon Bypass project be abandoned. Subsequently, the Chief of Engineers in a report dated 16 June 1956 to the Secretary of the Army concurred in the findings of the District Engineer's 1952 report. No action was taken by Congress on the recommendation.

1.05 A restudy of the Skagit River Basin was authorized by resolutions of the Senate Committee on Public Works adopted 4 January 1960 and House Committee on Public Works adopted 9 June 1960 which stated in part " . . . that the Board of Engineers for Rivers and Harbors, be, and is hereby, requested to review the reports on Skagit River, Washington published as House Document No. 187, 73rd Congress, 2d Session, and other reports, with a view to determining whether any modification of the recommendations contained therein is desirable at the present time with particular reference to provision of flood control and allied improvements in the basin."

1.06 Studies initiated in 1961 showed that with present day development, improvement of the existing levee system downstream of the Avon Bypass and construction of the Avon Bypass are the two most urgently needed projects for flood control in the Skagit River Basin and are well justified.

Local interests were found to be very interested and necessary assurance of local cooperation has been received. A letter report to NPD, dated 2 October 1962, subject: "Avon Bypass, Skagit River, Washington" recommended reactivation of the project. A 2d indorsement from OCE, dated 16 November 1962, requested additional information to determine that the Bypass would be an integral and justified part of any long range plan for basin development.

Skagit River Basin, producing a mild but wet climate. Approximately 75 percent of the precipitation falls during the period October through March. The normal annual basin precipitation above Sedro Woolley is 93.5 inches. Recorded total annual precipitation amounts vary from 109 inches at Mt. Baker Lodge to 27 inches at Anacortes. Heavy snows occur in the higher elevations during the winter and remain until late spring or early summer. Average recorded snowfall ranges from 530 inches at Mount Baker Lodge to 5.9 inches at Anacortes. Mean annual temperatures for climatological stations vary from 40.1°F. at Mount Baker Lodge to 50.9°F. at Concrete, and recorded temperature extremes range from 116°F. to -11°F.

2.05 Stream characteristics. Mean annual flows in the Skagit River range from 12,000 to 20,000 c.f.s. at Sedro Woolley. The maximum recorded discharge at Sedro Woolley was 220,000 c.f.s in November 1909, and the minimum recorded was 2830 c.f.s. in 1915. Base flow is normally low from August through March. During April or May, the flow increases because of melting snowpack and normally crests in early June. Winter flows are characterized by frequent sharp rises resulting from concentrated 2- to 5-day storms or series of storms. All major floods of record on the Skagit River have occurred between November and February, and have been caused by high rates of precipitation with accompanying snowmelt. This type of flood has a crest which is normally higher and of shorter duration than the annual spring snowmelt high water. Occasionally, 2 or more floods follow in close succession. The flood of November 1949 is a good example of the flattening of a flood crest as it moves downstream. Channel storage had a marked effect on the sharpness of the peak by the time the crest reached Mt. Vernon, and the peak discharge of 153,000 c.f.s. near Concrete was reduced to 114,000 near Mount Vernon. Precipitation records in the basin at the time of this flood partly explain the reduction in crest in the lower reaches of the channel. The Sedro Woolley gage indicates that very little rainfall occurred in the lower part of the basin. The flood of February 1951 is a good example of a flood crest of long duration. The peak near Concrete lasted many hours longer than the peak of November 1949, although it did not reach as great a discharge. The peak of the November 1949 flood remained above 120,000 c.f.s. for only about 14 hours, whereas the February 1951 flood remained above the same point for over 22 hours. The duration of the peak reduced the effect of channel storage and the peak downstream was increased by a large contribution of runoff from the lower elevations. The peak discharge near Concrete was 139,000 c.f.s. and near Mount Vernon it was 144,000 c.f.s.

2.06 Economics. The Skagit River basin comprises most of the Skagit County, as well as parts of Snohomish and Whatcom Counties and a very small portion of British Columbia. Most of the land area and developments are within the boundaries of Skagit County. The 1,110,400 acres of land in Skagit County is utilized within the limits imposed by topography. Timberland covers more than 848,000 acres, representing about three-fourths of the land of the county. Most of this is classified as commercial timber. Of the remaining land, approximately 13 percent or 141,770 acres are farms. Another 9,000 acres are urban and industrial, and about 10 percent is in wasteland. Most of the farms are in the Skagit flats, which is composed of rich river silt. About 17,000 acres of this bottom land is U.S.D.A.,Class I, rated at more than average productivity with high farm income. Another 20,000 acres is U.S.D.A.,Class II, which has average productivity and

BASIN FLOOD PROBLEM

3. BASIN FLOOD PROBLEM

3.01 Flood Plain. The entire valley floor of the Skagit River and its delta comprise the flood plain. The flood plain covers 90,000 acres, 68,000 acres of which are fertile delta land downstream and west of the town of Sedro Woolley, and 22,000 acres of river bottom land east and upstream of this town. The major portion of the bottom land east of Sedro Woolley is in developed farmsteads, and the remainder is mostly uncleared and swampy area. Delta area farms are highly developed with well maintained buildings, residences, and other improvements. Encroaching on the agricultural land are the urban communities of Burlington, LaConnor, and part of Mt. Vernon. The flood plain contains thousands of structures and includes a full range of farm, residential, commercial, and industrial buildings with connecting roads and utilities. The total valuation of lands in the 68,000 acre delta area through and below Sedro Woolley is estimated at $113,300,000 under 1962 conditions. Because the bottom land areas east of Sedro Woolley would not be affected by the Avon Bypass or the downstream levee system improvements, they are not considered in this report.

3.02 The valuation of lands in the flood plain downstream from the town of Sedro Woolley are summarized below:

Real Estate Valuation of Land Downstream of Sedro Woolley (1962 prices)

Urban Land (1270 acres)		$82,000,000
Agricultural Land (66,730 Acres)		31,300,000
	Total	$113,300,000

The above acreages include lands in Samish River valley and northwesterly of the drainage basin in the delta area, which are subject to flooding by Skagit River (Plate 1).

3.03 Existing flood protective works. Farmland and towns in the flood plain west of Sedro Woolley are protected by levees that prevent flooding from the river and from tidal salt water. Plate 2 illustrates the location and general extent of the existing diking districts in the Skagit and Samish River valleys and plate 3 shows the existing levee system downstream of Burlington, Washington. River levees prevent flooding of land by spring floods and by minor winter floods. Levees built along salt water bays and channels prevent inundation of land by the highest tides. River levees were built by local landowners and provide varying degrees of protection. Federal, State and local governments have given aid in rebuilding sections of levees damaged by floods. There are 16 Diking Districts inclosing a total of 45,000 acres of land within levees. Individual owners have inclosed an additional 1,000 acres of land. The present levee system provides protection for flows ranging from about 90,000 c.f.s. to about 140,000 c.f.s. Table 1 gives the area inclosed by each levee, length of levee, date of organization of levee district, and maximum practical river discharge that the levees can withstand without failure. The levees are usually constructed from fine river sand and native silts. Sod is grown on levee slopes to minimize erosion. Heights vary from 5 to 10 feet and top widths from 3 to 12 feet. Levees are generally riprapped in the vicinity of river bends.

3.04 The city of Seattle owns and operates a series of hydroelectric power plants on the upper Skagit River. The uppermost site, Ross Dam and Reservoir, is the only existing development with a significant

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amount of flood storage. The Federal Power Commission license for Ross Dam requires a storage reservation of 120,000 acre feet for flood control during the winter months.

TABLE 1

SKAGIT RIVER DIKING DISTRICTS

Diking Dist. No.	Date organized	Area Protected (acres)	Miles of Levee: Bordering Saltwater bays & channels	Miles of Levee: Bordering river channels	Maximum 1/ flow river levees will withstand (c.f.s.)	Probable recurrence interval of flooding in District (years) 2/
1	1897	8,264	0	7.9	108,000	5
2	1897	2,669	0	6.4	91,000	3
3	1897	6,365	0	11.5	101,000	4
4	1897	1,577	4.1	2.5	123,000	8
5	1897	2,847	6.6	2.0	123,000	8
8	1897	632	2.1	0.9	108,000	5
9	1897	1,419	3.5	1.7	108,000	5
12	1897	13,379	12.6	6.5	108,000	5
13	1897	1,869	2.6	2.6	91,000	3
15	1903	885	1.8	1.9	91,000	3
16	1904	407	0	2.9	101,000	4
17	1910	1,263	0	4.5	143,000	13
18	1918	576	1.4	0.6	91,000	3
19	1919	1,961	2.7	1.8	123,000	8
20	1919	537	0	3.0	143,000	13
21	1922	391	2.1	0	91,000	3
Private dikes	-	1,000	5.7	9.5	91,000	3
Totals		46,041	45.2	66.2		

1/ Discharge of river at stage 1 foot below the average top of levees (Mount Vernon gage).

2/ For failure of levee protecting District. This does not take in account flooding from failure of cross levees.

The effectiveness of this storage in reducing peak discharges downstream, depends upon the location of the storm center and other storm characteristics. Based on average conditions, Ross Dam flood storage produces crest reductions varying between 20,000 and 35,000 c.f.s. in the delta area.

3.05 Puget Sound Power and Light operates two dams in the Baker River basin primarily for power. The Federal Power Commission license stipulates a reservation of 16,000 acre-feet of storage in Upper Baker reservoir to replace lost valley storage.

3.06 Flood damage appraisals. Basic data for estimates of flood damages were obtained by field appraisals made in 1940, 1950, and 1961. The appraisal in 1961 made a field review of all previous appraisals and surveyed damages from the 1959 flood. Data available to the 1961 field team consisted of high-water marks and damage appraisals of various floods; aerial photographs of the flood plain flown in 1956; a 1961 profile of the top of all existing levees; computed river profiles for several river discharges measured at the Mount Vernon gage. Detailed maps containing elevations throughout the flood plain and the topography of the uplands provided further information.

3.07 Each levee system in the flood plain was examined and weak areas located. A pattern of levee failures was established on the basis of past experiences. In general levees were assumed to fail when flow profiles were within one foot of the average top height of the levees. Each river discharge provided an individual pattern of flooding. An appraisal was made for three flood flows representing the full range of probable flows. Existing land use was determined by an examination of the flood plain. The effect of flooding on agriculture was estimated from interviews with owners, operators, and agricultural organizations. Field survey was made of damages to buildings and other improvements. A real estate evaluation was made of the flood plain to determine existing land values and estimated changes in values with flood protection.

3.08 Table 2 summarizes damages under 1963 prices and developments that would result from floods of the magnitude of February 1932, December 1921, and once in 100 years. At Mt. Vernon the 1932 flood of 140,000 c.f.s. has a 12-year frequency; the 1921 flood of 182,000 c.f.s. has a 30-year frequency; and a flood of 245,000 c.f.s. would have a 100-year frequency. A discharge damage-relationship was established for each flooded area and a composite discharge-damage curve prepared for the flood plain, also a flow frequency curve for river discharges. The above relationships were used to estimate average annual damages. The average annual damage in the Skagit flood plain downstream from Sedro Wooley was found to be $2,170,000 for 1963 prices and conditions. Frequency and damage estimate curves are contained in the Appendix.

3.09 Without flood protection, growth in the flood plain is expected to average 1.4 percent annually. This growth rate approximates the historical population increase of Skagit River flood plain during the period 1950 to 1960 as discussed in paragraph 2.16. Future growth of Skagit County is keyed to the rate of conversion of farmland to specialty crops and to further industrialization either on the reclaimed tidelands or on agriculture lands. Higher land use in the flood plain for agriculture or industrial and urban expansion requires control of floods. Accordingly, growth in the basin without flood control will be retarded. The average

TABLE 2

FLOOD DAMAGES IN SKAGIT RIVER BASIN
(Downstream from Sedro Woolley - 1963 prices and conditions)

No.	Item	Feb. 1932 flood (157,000 cfs) 1/ $	Dec. 1921 flood (210,000 cfs) 2/ $	100-Year flood (278,000 cfs) 3/ $
1.	Flood fighting & restoration of levees, dikes, tide gates, & drainage facilities	175,000	234,000	360,000
2.	Building and contents, yards, autos & refuges	1,692,000	3,477,000	6,024,000
3.	Land and crops, and dairy losses	8,414,000	9,099,000	13,694,000
4.	Power and telephone facilities	15,000	20,000	28,000
5.	Railroads	20,000	54,000	128,000
6.	Highways, roads, streets & sewers	293,000	389,000	679,000
		$10,609,000	$13,273,000	$20,913,000

1/ 140,000 c.f.s. at Mount Vernon gage and 157,000 c.f.s. at Sedro Woolley gage

2/ 182,000 c.f.s. at Mount Vernon gage and 210,000 c.f.s. at Sedro Woolley gage

3/ 245,000 c.f.s. at Mount Vernon gage and 278,000 c.f.s. at Sedro Woolley gage annual damage in the flood plain downstream of Sedro Woolley at 1963 prices and with forecast future growth over the 100-year project life is estimated to be $3,450,000.

3.10 Historical flood damages. The delta lands west of Sedro Woolley have been inundated many times by the Skagit River since the area was first settled in about 1869. River levees in the diking districts are not capable of preventing damages from high winter floods. Protection against flooding varies in the several districts. Capability of levees to withstand flood flows ranges from 90,000 c.f.s. in some districts to about 140,000 c.f.s. in others, provided sufficient time is available to place sandbags and strengthen weak points in levees. Estimates of damages from historical floods under present prices and conditions are tabulated in Table 3.

TABLE 3

ESTIMATED DAMAGES FROM HISTORICAL FLOODS

(1963 Prices and Conditions)

Dates of flood	Discharge near Concrete (c.f.s.)	Discharge at Sedro Woolley (c.f.s.)	Damages in flood plain west of Sedro Woolley ($)
16 Nov. 1896	-	185,000	11,900,000
19 Nov. 1897	-	190,000	11,980,000
16 Nov. 1906	-	180,000	11,810,000
30 Nov. 1909	-	220,000	14,060,000
30 Dec. 1917	-	195,000	12,067,000
12-13 Dec. 1921	-	210,000	13,273,000
27 Feb. 1932	-	157,000	10,500,000
13 Nov. 1932	-	125,000	6,600,000
22 Dec. 1933	-	110,000	2,350,000
25 Jan. 1935	131,000	-	9,050,000
27 Nov. 1949	-	140,000	6,870,000
10 Feb. 1951	-	150,000	11,360,000
30 Apr. 1959	-	99,000	500,000
24 Nov. 1959	-	93,000	390,000

BASIN PLANS FOR FLOOD CONTROL

AND

OTHER WATER RESOURCE DEVELOPMENT

4. BASIN PLANS FOR FLOOD CONTROL AND OTHER WATER RESOURCE DEVELOPMENT

4.01 General. Studies in progress since 1961 have shown that improved flood protection in the delta area downstream from Burlington is the most pressing water resource development need in the basin. On a long range basis, the development of additional water supply, low flow augmentation for fisheries, consideration of primitive areas, hydro-electric development and an ultimately higher degree of flood protection are all important objectives.

4.02 There are three major phases of development in providing flood protection. These are: (1) improvement of existing levee system; (2) construction of bypass channel and; (3) developing an upstream storage project. Each of the three phases has limitations as to the amount of development that is practically feasible, and each one has its position with respect to optimum fulfillment of a basin plan.

4.03 Improvement of existing levee and channel widening. The entire Skagit River system downstream of Mount Vernon, Washington, including both the North and South Fork distributaries at the mouth, has been leveed piecemeal over a long period of time. There are 40 miles of levees along the river banks (Plate 3), that vary greatly in top width and height. At some locations, these levees are only capable of withstanding flows of 90,000 c.f.s., and at other locations they are high enough to protect against 140,000 c.f.s. flows with at least 2 feet of freeboard. The levee system upstream of Mount Vernon, to a point on the right bank about three miles downstream of Sedro Woolley, and to the Great Northern

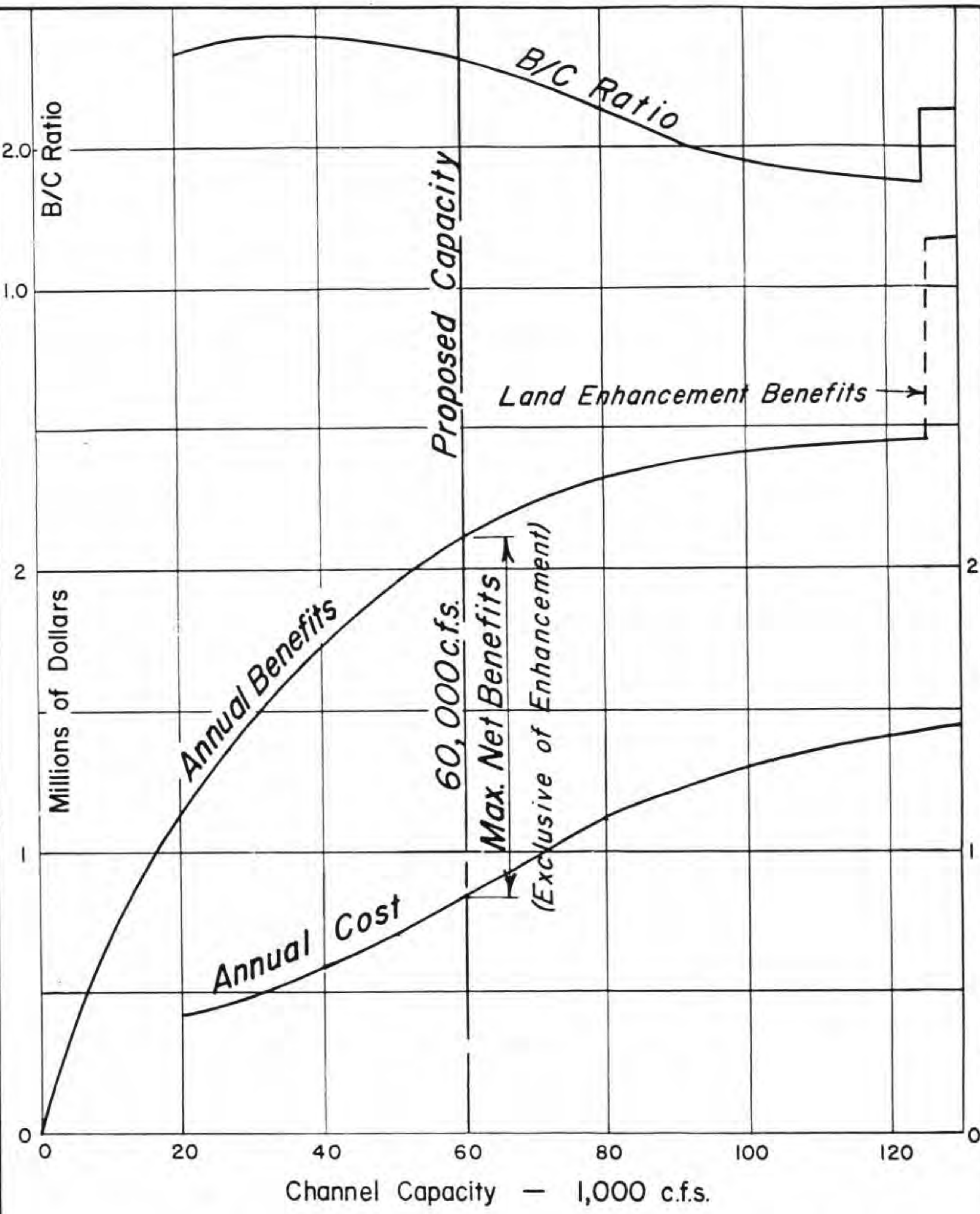
Railway main line bridge on the left bank has been improved during the past few years by state and local officials. This levee system now insures reliable protection in the Mount Vernon and Burlington urban areas for about 7-year frequency floods. There are three critical reaches of channel constriction in the river system downstream from the Bypass. Two of these reaches are on the North Fork at miles 3.8 to 4.7 and 7.0 to 8.1, respectively. The third constricted reach is located between miles 3.7 and 4.5 on Freshwater Slough channel of the South Fork. These constrictions were caused primarily by uncoordinated levee construction taking place over a long period of time and resulting in encroachments on the channel from both river banks. During flood periods, these reaches cause serious obstruction to the river flows, resulting in higher channel velocities through the narrow sections and damaging backwater effects upstream.

4.04 Consultation with local interests and field studies have established that the existing levee system rests on sand and silt formations which are prevalent in the delta area. The differential heads of water created by floods result in seepage through levee foundations and in boils and blowouts that flood adjacent croplands. Because of this condition, any appreciable increase in existing channel capacities should not be obtained by increasing the height of the levee system. The existing channel capacities can be increased to a uniform capacity with minor raising of low points in the levee system, by providing a minimum standard top width and by removal of constricted channel reaches. Accomplishment of these improvements would provide a levee system capable of withstanding flows of 120,000 c.f.s. with at least two feet of freeboard.

4.05 At an estimated total cost of about $6,500,000, downstream levee and channel improvement are the lowest cost increment of initial flood protection. Improvement of the downstream levee system (exclusive of Bypass) would modify the varying pattern of flood protection in the delta from the present 3-to-10 year frequency to a minimum 7-year frequency. As discussed in paragraphs 4.10 and 4.11, the downstream levee improvement and channel widening flood control benefits must be considered concurrently with the Bypass flood control benefits in order to realize the full multiple-purpose benefits of the Bypass. Unless otherwise noted, all Bypass benefits hereinafter described are on this basis. Authorization of levee and channel improvement will be sought in a forthcoming interim survey report.

4.06 Avon Bypass. The provision of a Bypass channel to divert flood waters from the Skagit River in the vicinity of Mount Vernon-Burlington area and discharge them into Padilla Bay, has long been contemplated as a positive means of affording flood protection to the delta area, without adversely affecting the levee system. Accordingly, the Bypass channel proposal has been restudied in detail as part of the present Skagit River basin flood control studies.

4.07 The cost and benefits of varying bypass capacities were analyzed. Results of the study are shown in Figure 1. Bypass capacities of up to 120,000 c.f.s. result in less than 100-year frequency flood protection and therefore benefits can be considered only with respect to flood damages prevented. A greater bypass capacity resulting in a higher degree of flood protection permits addition of enhancement benefits as indicated in Figure 1. The comparison of costs and benefits made in Figure 1 shows that without consideration of enhancement benefits, a 60,000 c.f.s. capacity bypass will yield maximum net benefits. A 60,000 c.f.s. bypass capacity, together with



AVON BYPASS AND LEVEE EXTENSION CAPACITY
COMPARISION OF COST AND BENEFITS

Figure 1

P 003596

levee and channel improvements downstream of the Bypass, results in 30-year flood protection from Burlington to the mouth.

4.08 The possibilities of a larger capacity Bypass have been considered. From the analysis indicated by Fig. 1, a capacity of at least 130,000 c.f.s. is required to develop a project with greater net benefits. The 130,000 c.f.s. channel would provide 100-year frequency flood protection and permit realization of enhancement benefits. From a practical standpoint, such a channel is now completely beyond the capability of local interests. Additional channel capacity to make 130,000 c.f.s. total capacity could be constructed in the future. However, comparable flood protection could also be developed by upstream storage as discussed in paragraph 4.12. Upstream storage has the advantage of providing flood protection for the entire basin, rather than the delta area alone. Feasibility of upstream storage will be considered in forthcoming basin studies.

4.09 Other Bypass purposes. In addition to flood control, the Avon Bypass can provide benefits for recreation, for a resident sports fishery, and possibly for rearing of migratory steelhead and salmon. Studies of this latter possibility are now being made by the State Department of Fisheries. The addition of a resident sport fishery and recreation would add annual benefits of about $277,000 at an added annual cost of approximately $28,000. A survey report recommending authorization of these added purposes is being readied for submission in the latter part of 1963.

4.10 Operation of Bypass. In order to realize the full multiple-purpose benefits of the Bypass, the project will have to be operated to minimize occurrence of flood flow discharges through the Bypass to avoid frequent flushing out of the fishery. Because the fishery will be stocked annually, occasional loss from flood control operation will be tolerable. At the same time, usage of the Bypass must be planned to avoid taxing downstream levees to full capacity, more often than is necessary, in order to avoid high maintenance costs. The plan of operation illustrated in Figure 2 satisfies the above criteria. In this plan, the Bypass will begin operation when river flows are 100,000 c.f.s. and flows in the Bypass will gradually be increased so when the total river flow is 180,000 c.f.s., the Bypass will carry 60,000 c.f.s., with the remaining 120,000 c.f.s. carried in the river between levees. This operation will provide approximately 30-year flood protection from Burlington downstream.

FIGURE 2

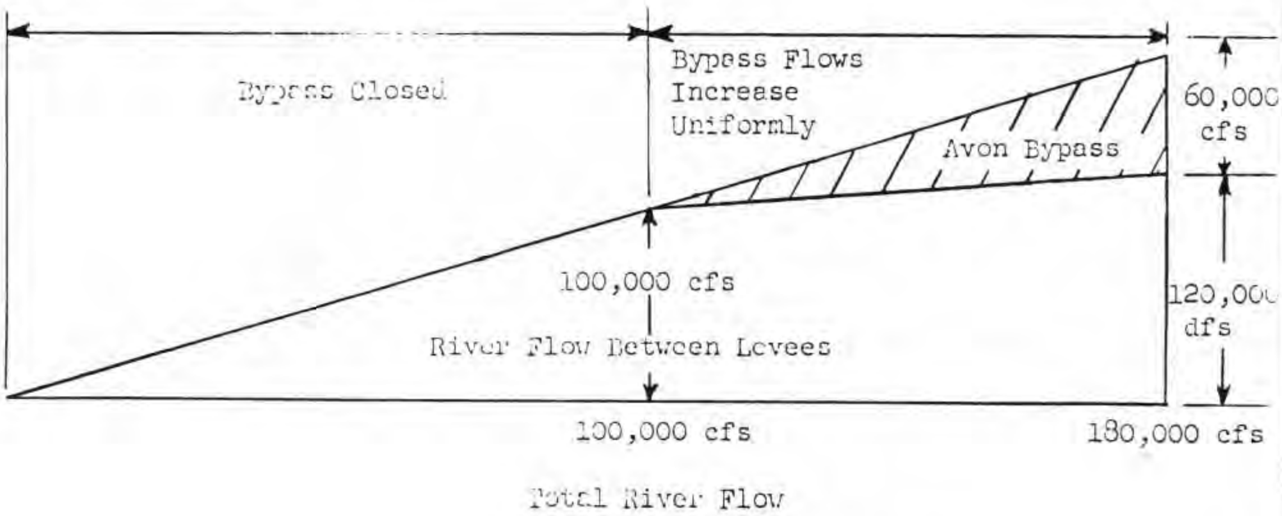


Figure 2 - PLAN OF OPERATION

4.11 The foregoing plan of operation presumes authorization and funding of added purposes for the Avon Bypass and uniforming of levee capacities about concurrently with planning and design of the Bypass for flood control under reactivation procedures. This appears to be a reasonable schedule and therefore benefit evaluation in this reactivation report and in the interim survey report now under preparation are based upon the foregoing plan of operation.

4.12 Storage. Ross Dam, on the upper main stem of the Skagit River, has 120,000 acre-feet of storage available for flood control. This storage permits control of the Skagit River watershed upstream of Ross Dam. The proposed Avon Bypass and uniforming of the downstream levee system, together with the existing upstream storage, will provide about 30-year flood protection in the lower Skagit River area. To provide long-term urban protection for this area and to enable full development of the Skagit River valley below Burlington, Washington, protection against flood flows of at least 100-year frequency is needed. Preliminary hydrologic and hydraulic studies have indicated that added flood storage of approximately 250,000 acre-feet will be required in the upper river systems for this degree of protection.

4.13 A private power company has developed potential sites on the Baker River for single-purpose power interests. There are only a few remaining potential sites for upstream storage development in the Skagit River basin. Of these, the Cascade site located on the Cascade River about eight miles from its confluence with the Skagit River, and the Copper Creek site located on the main stem of the river, about mile 87, are being considered for development by the City of Seattle for run of river power projects. Only minor flood control storage could be provided at these sites. Storage at the Faber site located about eight miles above Concrete has been investigated in previous studies. Damsite foundation and abutment conditions at this site are not favorable. Also, a structure at this site would be a major barrier for passage of migratory fish. Storage has been considered on the lower Sauk River as an alternate to the Faber site. The lower Sauk River is the only location in the Skagit River basin at which major upstream storage is possible.

4.14 Approximately 200,000 acre-feet of flood storage would be required in the Sauk project in addition to an undetermined amount of storage on the main stem of the Skagit River to provide the same degree of initial protection that can be provided by the Avon Bypass and by improvements of the levee systems in the delta area. The cost of 200,000 acre-feet of flood storage in a project on the Sauk River on a single-purpose basis would exceed $60,000,000. This cost would be increased by storage required on the main stem of the Skagit River and the total cost would be considerably more than the $30,000,000 (approximate) cost of providing equivalent flood protection of the delta area by the proposed Avon Bypass project and downstream levee improvements.

4.15 The Sauk site could provide 700,000 acre-feet of storage, of which 250,000 acre-feet are needed to increase the 30-year protection afforded by the Avon Bypass and by the improved levee system in the lower basin, to more than 100-year protection. The Sauk site has limitations on storage because of the overflow that would occur into the Stillaguamish River basin for a height of dam exceeding about 200 feet. Multiple-purpose storage in the

Sauk project would provide hydroelectric power, recreation and low flow augmentation in addition to flood storage. Flood control and hydroelectric power operation are somewhat competing purposes because flood storage must be provided during the winter critical period for power. At such time as other multiple-purpose uses for upstream storage become necessary, flood control storage could be incorporated in the Sauk River to give additional flood protection.

4.16 Avon Bypass without levee and channel improvements. Although the Avon Bypass will be an integral part of the basin flood control plan, together with proposed improvements of levees and channel downstream from the Bypass, there is a possibility that the downstream levee and channel improvements will not be authorized. Therefore the Avon Bypass must be considered without the downstream levee and channel improvements. Construction of the Avon Bypass with a capacity of 60,000 c.f.s., together with the existing levee system, would provide an average of about 25-year protection for the delta area downstream of the Bypass. The flood protection would vary from a minimum of 15-year frequency for several Diking Districts to 35-year protection for others. Without downstream channel and levee improvements the Avon Bypass would be operated more frequently for diversion of flood flows. However, such a plan would greatly restrict development of the Bypass for recreation and sports fishery purposes because of more frequent flood usage. Such a loss of recreation and fishery benefits would reduce the overall project B/C ratio and would result in a lesser resource development. Without downstream improvements, the flood control benefits of the Bypass would be greater and the B/C ratio would exceed the 2.5 value, heretofore cited. The increase in benefits is because flood damage benefits are greater in the lower range of flood protection.

AVON BYPASS PLAN

5. AVON BYPASS PLAN

5.01 Description. The proposed Avon Bypass project is a diversion channel and upstream right bank levee to divert excess flood flows from the Skagit River between Mt. Vernon and Burlington into Padilla Bay. The name "Avon Bypass" was applied to the project in the original authorization and stems from the proximity of the town of Avon to the channel boundaries. The upstream end of the channel is on the Skagit River near Burlington, Washington. The channel lies along the southern fringes of Bayview Ridge and discharges into Padilla Bay at the mouth of Indian Slough (See Plates 1 and 4).

5.02 The Avon Bypass project plan, shown on Plates 4 through 7, is comprised of the following elements:

a. A diversion channel approximately 8 miles long, of 360 feet bottom width with a gated intake control structure, a downstream control structure and an intermediate control structure. The channel requires 8 new highway bridge crossings and 2 new railroad bridge crossings.

b. Extension and improvement of 4 miles of levee on the right bank of Skagit River immediately upstream of the Bypass intake.

5.03 Alinement. The proposed route of the bypass channel is shown on Plate 4. The channel passes through Gages Slough, follows the toe of Bayview Ridge, west of Burlington, and discharges into Padilla Bay. Other alinements for the bypass were investigated during early discussions with local interests. The most favorable alternate route was a channel with an intake at mile 15 near Avon, flowing westward to Padilla Bay and joining the proposed channel at about Sta. 500+00. This alinement results in a shorter channel and appears to be an obvious route. However, the alternate alinement would require expensive enlargement for more than three miles of the existing river channel and was found to cost $3,900,000 more than the proposed alinement. The alinement would have fewer benefits for the following reasons:

a. The alternate alinement would require the taking of expensive agricultural lands that are now being intensively farmed and would also require relocation of many residences in the path of the channel. The land required along the proposed route is largely slough, brush and marginal farm land. Only a small part of the land is intensively cultivated and the private residences and buildings that need to be acquired are few.

b. The Washington State Highway Department is planning a new highway to Anacortes that would begin at Highway 99 on the right bank of the Skagit River above Avon at mile 17 and go westward to Anacortes. Rights-of-way for this route have been obtained. This highway does not cross the proposed route, but requires an expensive bridge crossing on the alternate alinement.

c. A head loss of over 3 feet occurs during floods in the reach of the Skagit River from the town of Avon to the Great Northern Railway bridge crossing at mile 17.5. The proposed alinement results in a 3- to 5-foot reduction in natural river stages at the intake during flood periods. The drawdown has beneficial effects extending upstream to about 1 mile above the town of Sedro Woolley and thereby provides additional flood protection to the Burlington and Sedro Woolley areas. In order to obtain the same benefits from the alternate alinement with the intake at Avon, costly widening of the Skagit River channel is required to remove restricted areas in approximately a 2-1/2 mile reach between Avon and the upstream end of the Great Northern Railway bridge crossing; or as a further alternate, extensive levee construction on both banks of the Skagit River through the Burlington and Sedro Woolley areas.

5.04 Channel. The channel would have a 360-foot bottom width, with 1 on 2 gravel blanketed side slopes from the channel bottom to 2-feet above low water, and 1 on 3 slopes for the remainder. The purpose of the gravel blanket is to prevent erosion of fine grained bank soils by wave wash. Design channel velocity is 5-feet per second. Spoil materials from channel excavation would be placed in disposal levees along both sides of the Bypass channel. Profile and sections are shown on Plate 5. Borings were made in 1962 by power auger at four locations shown on Plate 4. Logs of these borings are shown on Plate 7.

5.05 Control structures. Control structures are shown on Plate 6. The intake control structure at the upstream end of the channel is 328-feet long and controls inflow with six 48-foot wide by 19.5-foot high tainter gates. The downstream control structure is near the outlet, approximately seven miles below the intake structure. The downstream structure is an uncontrolled concrete weir with a sill elevation at +11.0 (MSL) to prevent tidal flows from entering the channel further than they do at present at Indian Slough, and to limit maximum velocities in the channel. Sluices will be installed in both structures for passing interior drainage, for flushing of the channel and for freshwater fishery flows when required. Fish barriers will be provided for sluices in the intake and downstream control structures to prevent entrance of migratory fish into the Bypass channel. These barriers may be either rotating chain link screens or rock and gravel filled crib filter structures to prevent fish entry. Designs and cost estimates for these facilities have not been prepared in detail for this report. An allowance of $209,000 has been made in the cost estimate for fish barriers in the intake control structure and $296,000 for fish barriers in the downstream control structure. An intermediate control structure, Plate 6, will be installed near the midpoint of the Bypass channel to control drawdown of the groundwater table during non-flood periods. The control is planned as a water inflated rubber-fabric dam fastened to a concrete sill. This dam would have a maximum height of 13 feet and can be deflated to avoid

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LOCAL COOPERATION

7. LOCAL COOPERATION

7.01 Project requirements. Local participation in the project requires acquition of right-of-way of about 800 acres of land; construction of 8 highway bridges and approaches; relocation of the Transmountain Oil Pipeline, the Cascade Natural Gas Line, and miscellaneous local power and telephone distribution systems; and operation and maintenance of the project after completion. The local sponsor will also be required to hold and save the United States free from damages and claims that may result from construction of the project. The estimated cost of right-of-way and local interest relocations is $4,150,000.

7.02 Status of local cooperation. Skagit County, Washington officials are fully aware of the local cooperation requirements of the project and by letter dated August 1962, Exhibit I, have expressed willingness to sponsor the project. The County is actively promoting the proposed project as the most effective and economical means of providing needed flood protection for the delta area. General public acceptance of the project is enthusiastic because of the flood protection afforded and the lack of conflict with the Skagit River fishery. There has been minimal opposition, stemming primarily from landowners along the channel right-of-way. Throughout the studies, meetings and conferences have been held with County officials and local interests to keep them informed and to obtain their views on the overall objectives and physical features of the project. In order to insure that all concerned will have a good knowledge of the recommended plan, Skagit County has contracted to have a detailed styrofoam model of the project and surrounding area constructed for general public display in the Mount Vernon area.

7.03 Urgency of project. The Skagit River delta area downstream from Mount Vernon, Washington, has only limited protection from flooding by the Skagit River, and the existing developments in this area are generally restricted to agriculture. Much of the agricultural use is changing from dairy farming to row cropping. This more productive use of the rich delta lands would undoubtedly be accelerated and stabilized by increased flood protection. The cities of Mount Vernon and Burlington, Washington, which have limited flood protection are limited in development at the present time. During the last major flood in 1951, the water surface of the river adjacent to these cities was nearly two feet higher than the existing protective works and was held back only by extensive flood fighting. Had the water surface been only slightly higher, disastrous flooding would have occurred in both cities.

7.04 The Area Redevelopment Administration of the U. S. Department of Commerce has designated Skagit County as a depressed area because of a continuing high rate of unemployment. The A.R.A. recently awarded a grant to a private consulting firm for the purpose of investigating possible siting of an industrial park in the area. The provision of major flood protection for the lower Skagit River area would help stabilize the economy of Skagit County and present a more attractive environment to potential new industry.

FREQUENCY CURVES

1 Frequency Curves. Cumulative frequency curves shown on Figures A-1 and A-2 were derived by the method shown in the draft of the Engineering Manual entitled "Hydrologic Frequencies and Correlations." Basic discharge data were obtained from the Water Supply papers of the U. S. Geological Survey. In the case of Concrete, 38 years of record were used (1898, 1910, 1918, 1922, 1925, 1928-60). Where listed discharges had been affected by existing storage projects, an adjustment was made to approximate unregulated conditions in order to define the unregulated frequency curve.

2 The unregulated frequency curve at Mount Vernon was based on a correlation between recorded flows at Concrete, Sedro Woolley and Mount Vernon. This curve assumes that all flow is contained within the existing levee system with the exception of the overbank storage which occurs in the Nookachamps Creek area.

3 The frequency curves for regulated flow by both existing and proposed storage projects are based on estimated discharges obtained from the flood routing method contained in U. S. Geological Survey paper 1543-B, "Storage and Flood Routing."

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