UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY Water Resources Division Portland, Oregon

April 15, 1969

To: Mr. Forrest Cooper, State Highway Engineer
Oregon State Highway Department
Salem, Oregon

Subject: WILLAMETTE RIVER AT LAMBERT BEND, OREGON

Floodflow Characteristics of the

Proposed Greenacres Road Crossing

OPEN-FILE REPORT
by D.D. Harris

This is a report on the floodflow characteristics of the proposed Greenacres Road crossing of the Willamette River at Lambert Bend. This study was made at the request of the Oregon State Highway Department through a cooperative agreement with the Geological Survey.

We gratefully acknowledge the valuable assistance given by the staff of your Preliminary Studies Section and by Mr. Lowell M. Stratton, Resident Engineer, Woodburn, Oregon.

We appreciate the opportunity to provide this service to your agency and we hope the report meets with your approval.

GEOLOGICAL SURVEY - PORTLAND, OREGON

Stanley F. Kapustka

Stanley F. Kapustka, District Chief

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SUMMARY

Requirements of the Study

The proposed crossing of the Willamette River at Lambert Bend involves a 2.3-mile-wide flood plain. Two of the three principal tangents of the crossing will include bridges that will span the main channel and an overflow channel of the river, as shown in figure 1, page 3. The Oregon State Highway Department wants to know what flow will result when the water-surface elevation upstream from the bridges is 100.0 feet (mean-sea-level datum). This design elevation will be referred to as Condition 1 in this report. Also required in Condition 1 is how much backwater is represented in the 100-foot elevation and how often did this flow occur before the river became regulated in 1941.

The Highway Department also wants to know what flow could be expected from a flood event equal to that of December 1964, but regulated by three additional reservoirs that have been completed since 1964. This design discharge will be referred to as Condition 2 in this report. Also required in Condition 2 is the amount of backwater caused by the two constrictions and how often the design flood occurred before regulation began in 1941.

Summary--Continued

Conclusions

Condition 1

A design headwater elevation of 100.0 feet (upstream from the proposed constriction) will result in a discharge of 195,000 cfs (cubic feet per second). The 100.0-foot elevation is related to a point 1,300 feet upstream from the overflow bridge (sec. 1) and includes 0.4 foot of backwater. The main channel bridge does not contribute any backwater at this elevation. A discharge of 195,000 cfs occurred on the average of once every 3 years prior to 1941.

Condition 2

The flood of December 1964 resulted in a discharge of 320,000 cfs at the proposed bridge site. With an optimum 470,600 acre-feet of additional storage now available from three new reservoirs, an equivalent flood event could now be reduced to 261,000 cfs. With this flow, the constricted headwater elevation (at sec. 1) would reach 105.1 feet which includes 0.5 foot of backwater from the overflow bridge. The main channel bridge does not add any significant amount of backwater to this elevation. Before regulation, 261,000 cfs occurred on the average of once every 5 years.

LAMBERT BEND

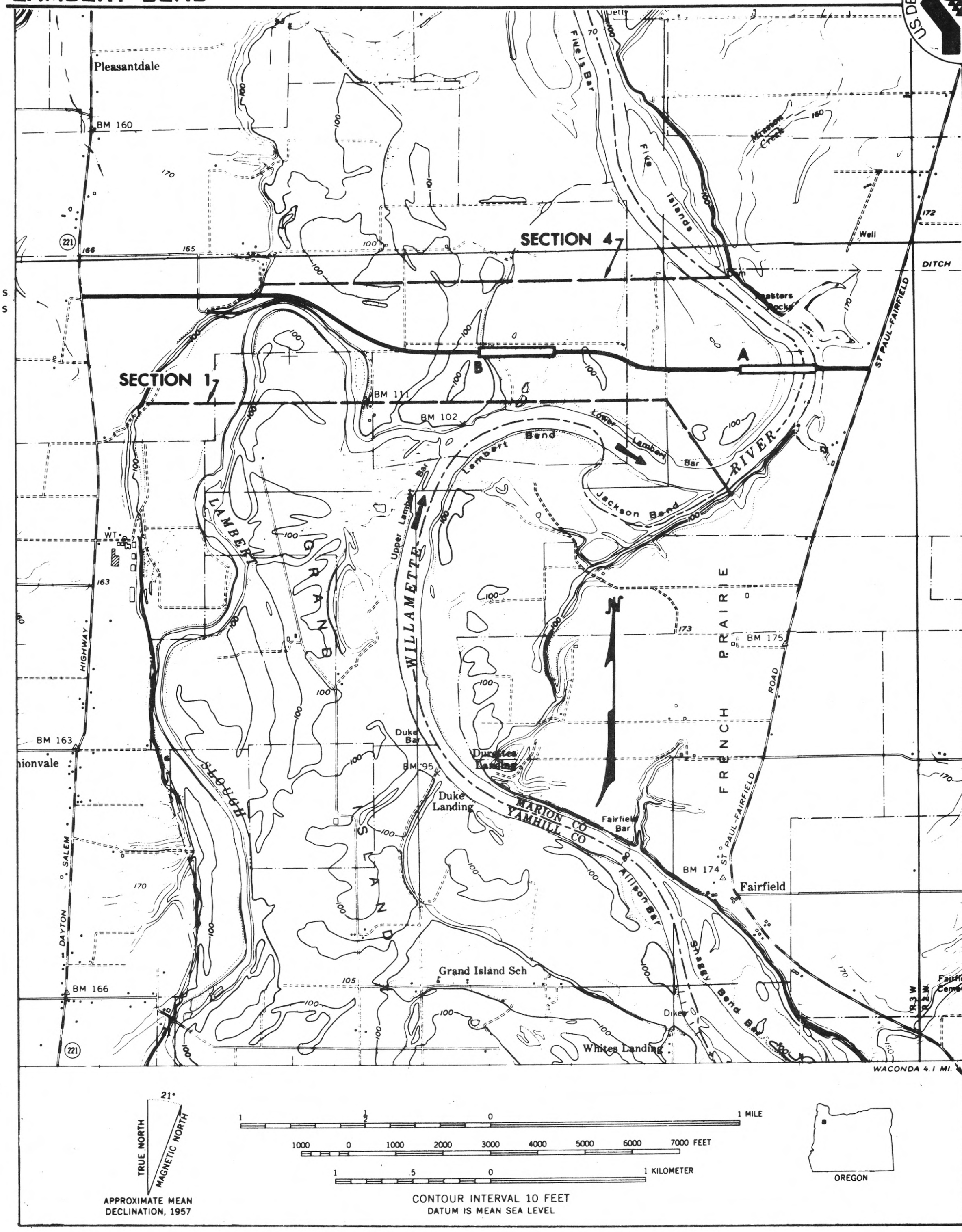

Figure 1.--Map of Lambert Bend area showing proposed bridge site.

INTRODUCTION

The Oregon State Highway Department has asked the Geological Survey to define the floodflow characteristics of a proposed multiple-bridge system on the Willamette River at Lambert Bend. The proposed site is located at the northern end of Grand Island, 7 miles west of Woodburn and 20 miles downstream from Salem, Oreg. The drainage area at the site is 7,490 square miles, of which runoff from only 96 square miles is ungaged.

The proposed crossing will consist of three principal tangents across a 2.3-mile-wide flood plain. The bridges will span the main channel of the river (Bridge A) and an overflow channel (Bridge B) as shown in figure 1, page 3. The flood plain consists primarily of cultivated farmlands with small areas of moderate to dense vegetation. There are areas showing severe undulations caused by past floods.

Figure 1 shows the extreme meanders of the main channel and an anabranch (Lambert Slough) immediately upstream from the crossing. The north bank of the slough is considerably higher in elevation than Grand Island and this creates a natural backwater condition on Grand Island.

The Highway Department is interested in the floodflow characteristics associated with (1) a design headwater elevation of 100.0 feet and (2) a flood equivalent to that of December 1964 but further regulated by the recently completed Fall Creek, Blue River, and Green Peter Reservoirs. These requirements are referred to as Conditions 1 and 2 in this report.

The Highway Department provided copies of the bridge-design detail (drawing 24436), a site-plan drawing, and three valley cross sections representing ground elevations upstream from the crossing (sec. 1), at the crossing (sec. 3), and downstream from the crossing (sec. 4). These data and the computations supporting the results of this study are in the files of the Geological Survey, Portland, Oreg. All elevations given in this report are referred to mean sea level datum, 1947 adjustment.

This study was made under the general supervision of S. F. Kapustka, district chief in charge of Water Resources Division investigations in Oregon, and under the immediate supervision of R. B. Sanderson, P. E., associate district chief.

HYDROLOGY

Stage-Discharge Relation

To relate water-surface elevations to streamflow, a stage-discharge relation was developed at section 4. (See fig. 2, p. 6.) Section 4 represents a valley cross section where the stage-discharge relation will not change due to the addition of the road crossing on the flood plain. In developing this relation, high water marks from the floods of December 23, 1964, and January 14, 1969, and the water-surface elevation of February 3, 1969, were related to discharge in the following manner. For the given flood events, the streamflow at the proposed site is nearly equivalent to the combined flows of gaging stations 14-1910.00 Willamette River at Salem and 14-1920.00 Mill Creek at Salem. Although only a small part of the total, the additional flow from the 96 square miles of ungaged drainage area was estimated on the basis of runoff records for gaging stations 14-2015.00 Butte Creek at Monitor and 14-1930.00 Willamina Creek at Willamina.

Effects of Present Flood-Control Regulation

Almost 40 percent of the drainage basin is currently affected by flood-control regulation. The peak discharge for December 23, 1964, at the Salem gaging station was 308,000 cfs. While this is 164,000 cfs less than what the unregulated flow would have been, this discharge could have been further reduced to 249,000 cfs if the additional 470,600 acre-feet of storage from Green Peter, Blue River, and Fall Creek Reservoirs had been available (Corps of Engineers, 1966). A flood discharge of 249,000 cfs at Salem would be increased by the flow from Mill Creek and by the flow from the intervening area below Mill Creek to 261,000 cfs at section 4. This design flood results in an elevation of 103.2 feet at section 4, which is 4.3 feet lower than the 1964 peak elevation.

Flood Frequency

The frequency of discharges for Conditions 1 and 2 of this study cannot be determined for current conditions because of the flood-control activities in the basin. The runoff from a flood is lessened by the amount of available reservoir storage at the time of the event. For example, the second of two similar and successive storms may result in a much greater runoff because of less available storage. However, the discharges can be related to a flood-frequency analysis reflecting unregulated conditions, as published for the gaging station at Salem (Hulsing and Kallio, 1964). Before flood-control regulations began in 1941, the flow determined for Condition 1 (195,000 cfs) occurred on the average of once every 3 years. A discharge of 261,000 cfs (Condition 2) occurred on the average of once every 5 years.

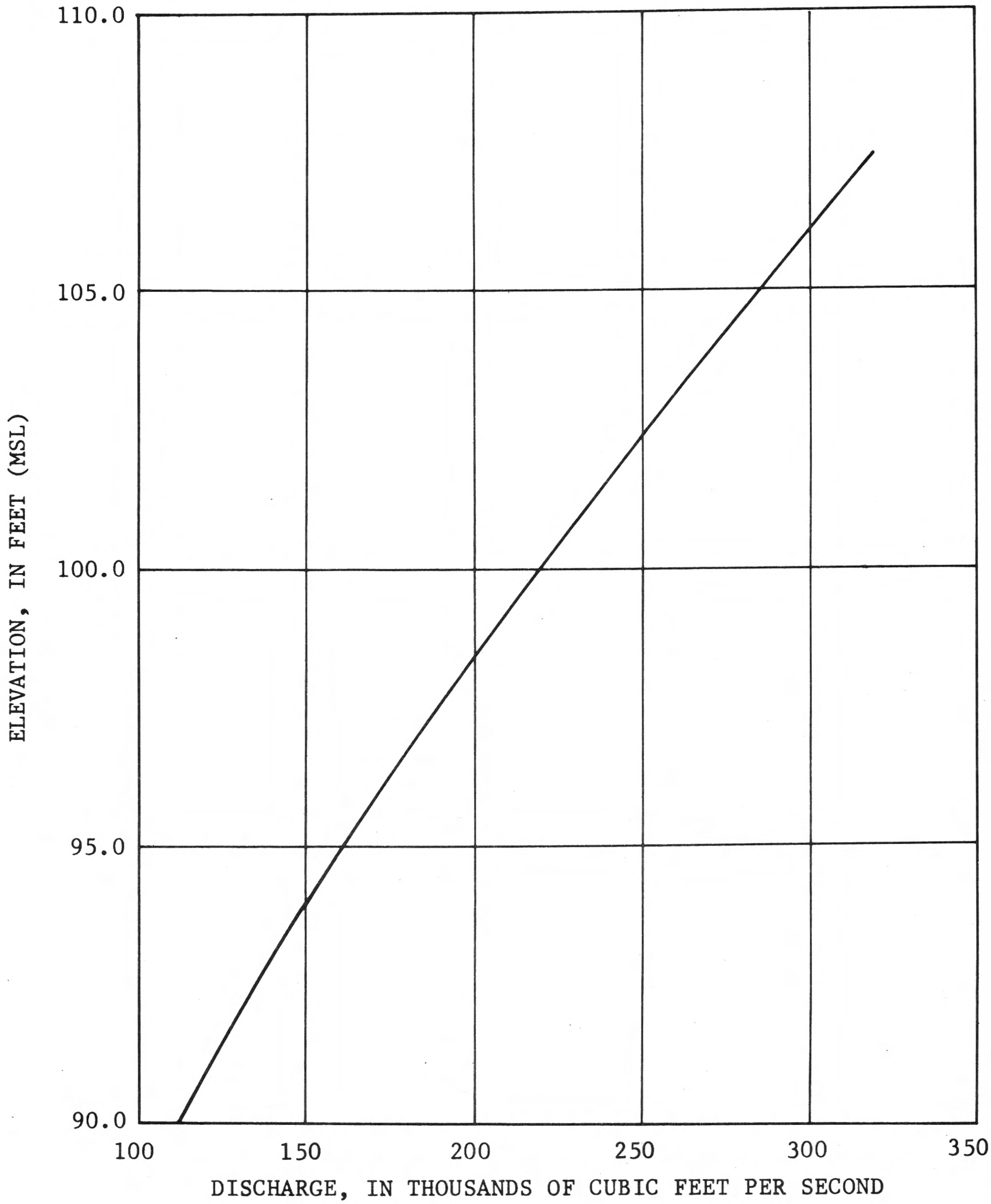

Figure 2.--Stage-discharge relation curve at section 4.

FLOW CHARACTERISTICS

Proposed Constrictions

Both proposed bridges are in the east half of the flood plain. Except for the road fill at the overflow bridge (B), the grade elevation west of the bridge generally follows the natural ground level of the flood plain at an average elevation of about 108 feet.

The embankment and abutment slopes for the 1,600-foot-long bridge are given as 2:1. The bridge will be supported by 25 pile bents spaced 50 feet apart, and each bent will have seven 16-inch concrete piles placed normal to the bridge alignment. The elevation of the low concrete of the bridge stringer is given as 107 feet.

The grade elevation for the 4,060-foot-long embankment between bridges is given as 100 feet and 108 feet for Conditions 1 and 2 of this report.

The 1,783-foot-long main-channel bridge also spans 770 feet of the left bank flood plain. The embankment and abutment slopes at the left end bent will be 2:1, and the bridge will tie into the natural right bank of the main channel with no constriction of flow. The bridge will be supported by nine 4-foot-wide concrete piers spaced 110 feet apart, and by three 8-foot to 5-foot-wide piers spaced 200 and 250 feet apart with the longest span at midchannel. The low concrete of the bridge stringer at the left end bent will be at a 106-foot elevation.

Distribution of Flows

Section 1 represents a valley cross section 1,300 feet upstream from the proposed overflow crossing. This section is used in determining the distribution of flow across the flood plain and as a reference point for relating changes in elevation (backwater) caused by the constrictions.

Usually, a flow distribution can be determined through application of the Manning flow equation assuming a uniform energy slope across the section in which case incremental flows would be directly proportional to the conveyance of the channel. At Lambert Bend, the energy slope is not uniform primarily because of the influence of the flood-plain configuration upstream from the section.

Flow characteristics--Continued

The water-surface profile from the flood of December 23, 1964, provided a fair indication of this variation in slope. The distribution of flows for Conditions 1 and 2 was therefore made through application of the Manning equation with the slope factor varied within the limits indicated by the 1964 flood and the average energy slope known to exist for the entire section.

The apportionment of flows through the bridges is influenced by the reverse curve between the bridges and the location and density of vegetation upstream from the reverse curve. A theoretical division of flow, based only on the relative sizes of the bridge openings, would occur 1,620 feet east of the right abutment of the overflow bridge (B). The upstream part of the reverse curve and the west edge of a very dense strip of vegetation is 70 feet west of the theoretical division of flow. The apportionment of flows for Conditions 1 and 2 is therefore related to the edge of the vegetation 1,550 feet east of the overflow-bridge abutment.

Hydraulics

The methods used in computing the backwater resulting from the proposed constrictions are described in Geological Survey publications (Cragwall, 1958; Matthai, 1967; and Davidian and others, 1962).

Condition 1

With a design headwater elevation of 100.0 feet, all the flow through section 1 is east of the high west bank of the overflow channel. The flow on the north end of Grand Island at section 1 is ineffective because of the containment caused by the high left bank (looking downstream) of Lambert Slough.

In computing the flow that would result in a constricted headwater elevation of 100.0 feet, an assumed discharge of 195,000 cfs was related to an elevation of 98.0 feet at section 4. (See fig. 2.) The water-surface profiles for the floods of December 23, 1964, and January 14, 1969, were then used to compute normal non-constricted elevations at the proposed crossing (sec. 3) and at section 1.

Flow characteristics--Continued

The discharge of 195,000 cfs was distributed across section 1 using a variable slope factor as described earlier. This, and the apportionment of flow through the bridge openings, resulted in a discharge of 45,000 cfs through the overflow bridge (B) and 150,000 cfs through the main channel bridge (A). These flows would cause an average velocity of 3.79 fps (feet per second) through the overflow bridge and 3.00 fps through the main channel bridge.

The discharge of 45,000 cfs through bridge B resulted in an elevation of 100.0 feet (at sec. 1) and includes 0.4 foot of backwater. This elevation is 0.8 foot higher than the 99.2 feet computed upstream from the main channel bridge, which indicates a lateral slope to the constricted headwater elevations. There is very little constriction of flow in the main channel, and the 99.2-foot elevation represents no backwater effect.

Before flood-control regulations began in 1941, a discharge of 195,000 cfs occurred on the average of once every 3 years.

Condition 2

A flow of 261,000 cfs will extend to the west of Lambert Slough, but the high ground about a quarter of a mile west of the overflow bridge blocks the direct access to the overflow bridge of water crossing Grand Island. (See fig. 1.)

As stated earlier, this flow corresponds to an elevation of 103.2 feet at section 4, and a normal flood profile was developed to section 1 from this elevation using the same techniques explained for Condition 1. The distribution of flow through section 1 and the apportionment through the bridge openings resulted in 91,000 cfs through the overflow bridge (B), and 170,000 cfs through the main channel bridge (A). The resultant average velocity at the overflow bridge is 4.20 fps; the main channel, 4.13 fps.

A discharge of 91,000 cfs through the overflow bridge resulted in a constricted headwater elevation of 105.1 feet, of which 0.5 foot is backwater. A discharge of 170,000 cfs through bridge A resulted in an insignificant amount of backwater because of the very small contraction of flow. The constricted headwater elevation is therefore equal to the normal elevation of 104.6 feet at section 1. Again, a lateral slope of the constricted headwater elevation is indicated by a 0.5-foot difference in elevation. A discharge of 170,000 cfs occurred on the average of once every 5 years prior to regulation in 1941.

DISCUSSION

Without detailed documentation of water-surface profiles, it is impossible to evaluate "natural" backwater effects in some areas of the flood plain. For example, the water-surface profile of the flood of December 23, 1964, indicated a significant loss of energy in the main channel caused by the very sharp channel curvature immediately downstream from the main channel bridge. Also, the containment of flow at the north end of Grand Island probably contributes significantly to the inundation of the island. At this time, there is no known way to isolate the various sources of backwater at this site. This investigation does indicate that the proposed constriction will not contribute more backwater than the increment computed above the overflow bridge.

The floodflow characteristics presented in this report are based on the present physical properties of the flood plain. Future changes in the channel or in the location and density of the vegetation near the proposed crossing could result in completely different flow patterns at the site.

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