SEDIMENT TRAPPING EFFICIENCIES OF MAINTENANCE DREDGE PLANS IN THE UPPER BASIN OF CAPITOL LAKE

by

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for

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and

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INTRODUCTION

Capitol Lake was formed in 1951 by a small dam constructed across the mouth of the Deschutes River near Olympia, Washington. There are two bridges crossing the lake which divide it into three basins--upper (south), middle, and lower (north). The middle basin is the largest of the three basins.

In recent years, sediment from the Deschutes River has rapidly filled the upper basin and caused considerable sediment accumulation in the middle basin. Dredging of accumulated sediments appears to be a feasible approach for lake restoration. To optimize dredging efficiency and environmental enhancement, the maintenance dredging operation should be concentrated in the upper basin in a deep sump which can trap incoming sediments. This would prevent frequent dredging in the middle basin which would interfere with recreation and important fish rearing activities. The upper basin sediment trap should be designed so dredging would not be necessary but once every two years.

DESCRIPTION OF DREDGE PLANS

Plan 1

A previous study* of the sediment problem recommended that the existing islands in the upper basin be combined into one and a sediment trap sump dredged behind it. It addition, the previous study suggested that a groin be built at the west bank to divert flood flow toward the sediment trap. The details of this plan, designated as Dredge Plan 1, are described on pages 284-286* and illustrated in Figure 1 in this report.

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*"Hydraulic and Water Quality Research Studies of Capitol Lake Sediment and Restoration Problems, Olympia, Washington," Dept. of Civil and Environmental Engineering, Washington State University, Project Report 7374/9, 12-1310, September, 1975, 315 pp.

During a public meeting for the restoration of Capitol Lake, August 25, 1976, in Olympia, several citizen groups expressed their concern of possible environmental damages to the wildlife habitat in the upper basin that would be caused by modifying and combining the existing islands in Plan 1. Even though the environmental impact of Plan 1 would be short term, it was decided that alternative dredge plans should be studied that would minimize the modification of existing islands.

Plan 2

After several field trips to the upper basin by Jerry Bachmann of the Department of General Administration, Dale King of CH_2M-Hill, and Walter Mih, an alternative plan, Dredge Plan 2 (Figure 2), was proposed. Although two small channels (C and D in Figure 2) in the south side of the upper basin will be deepened to 6 ft, Plan 2 does not change the existing islands. Compared with Plan 1, the surface area and the depth of the sump are the same, but the area has an oval shape. The groin on the west side in Plan 1 was removed and a new training wall was added in Channel B.

Plan 3

Because model tests showed that sediment trapping efficiency in Plan 2 was small, a groin as in Plan 1 was added to the west side to divert flow to the sump area. In addition, the Channel B training wall of Plan 2 was removed, resulting in Plan 3 as shown in Figure 3.

Plan 4

Plan 4 is the same as Plan 3 except that the fan-shaped area of Plan 1 was used to test the effect of different sump area. Figure 4 illustrates Plan 4.

OBJECTIVE

The objective of this study is to determine the relative sediment trapping efficiencies of the four plans mentioned above. The sediment trapping efficiency is defined as the sediment accumulation in the sump area divided by the total sediment accumulation in the entire lake.

MODEL DESCRIPTION AND SCALES

The original study* used a model built in accordance with the 1951 topography and on a horizontal scale of 1:200 and a vertical scale of 1:20. The same model was used for this study, except for the upper basin, which was modified in accordance with dredge plans and the 1975 topography. The middle and lower basins of the model were left in the deeper 1951 condition. The middle basin practically trapped all the sediment passing through the upper basin.

The Froude model law was used for dynamic similitude. The model-prototype scale ratios given in Table 1 are derived from the chosen length scales and Froude's criterion.

Table 1. Capitol Lake Model-Prototype Scale Ratios

Parameter	Equation	Numerical Ratio
Horizontal Length	$L_r = L_m/L_p$	1:200
Vertical Length	$H_r = H_m/H_p$	1:20
Volume	$\forall_r = L_r^2 H_r$	1:800,000
Velocity	$V_r = \sqrt{H_r}$	1:4.47
Discharge	$Q_r = V_r L_r H_r = L_r H_r^{3/2}$	1:17,888
Time	$T_r = L_r/V_r = L_r/\sqrt{H}$	1:44.7

Notes: m model; p prototype; r ratio

PROCEDURES

Based on hydrological data and analyses, the flood with one-year recurrence interval in the Deschutes River is 3,000 cfs, and the 5-year flood is 5,000 cfs. Most sediment deposition occurs during a flood period which usually lasts for about two days. During the low and moderate flow periods, the

*Ibid.

sediment load in the river can be considered negligible even though local sediment scouring and shifting occur, particularly during a lake drawdown. The average annual sediment accumulation is 41,000 cubic yards.* The significant flow rates and sediment volumes used in the model tests were computed from the model scale ratios and are given in Table 2.

Table 2. Model Testing Parameters

Parameters	Prototype	Ratio	Model
Water Flow	3,000 cfs	1:17,888	0.168 cfs
	5,000 cfs	1:17,888	0.280 cfs
Flood Period	About 45 hr	1:44.7	1.0 hr
Average Annual Sediment Accumulation	41,000 yd^3	1:800,000	1.38 ft^3

Fine Delmonte sand, crushed quartz having a mean diameter of 0.005 in, was used in both this and the previous studies. The dry sand was added to water flow uniformly by an adjustable automatic sand feeder at a location corresponding to the lower falls of the Deschutes River upstream from the upper basin.

As mentioned earlier, a two-year dredging program was proposed. Therefore, a test program was established which supplied the equivalent of an average annual sediment load (41,000 yd^3) for two consecutive annual flood flows. Each flow was to consist of two equal time periods. The first period (1 hr model time) was to have the equivalent annual sediment load (1.38 ft^3) added at a uniform rate to the flow. The second time period, also of 1 hr duration, had the same flow rate, but no sediment was added. Model flow rates corresponding to the three and five year floods (3,000 and 5,000 cfs) were used in this study.

The detailed test program, designed to simulate the natural heavy sediment input during floods followed by a period of low sediment-free flow that

*Ibid, p. 72.

produces some local scour and representing the proposed dredging cycle of two years, was conducted as follows:

1. The water flow in the model was set corresponding to the 3,000 cfs flood (0.168 cfs).
2. After the water in the lake reached the normal level, and flow was steady, Delmonte sand was added uniformly to the water flow for one hour. The total volume of sand added was 1.38 ft^3, which is equivalent to one year of prototype sediment accumulation.
3. After stopping the sand input, the water flow continued for one more hour to simulate the scouring action during low and moderate flow periods. Sand accumulation patterns in the model were stable after 45 minutes of clear water flow, indicating that one hour of clear flow was sufficient to simulate the scouring during a long period of low flow.
4. The cycle was then repeated with 1.38 ft^3 of sand added again over one hour, followed by one hour of clear water flow. This completed the two-year maintenance dredge cycle.
5. The flow was stopped at the end of the fourth hour. Total sand added for each test run was 2.76 ft^3, which has a dry weight of 194 lbs. The model was drained slowly to avoid any change in sand accumulation patterns. The sand was then collected from the following five separate areas in the model:*
   ① Deschutes River, downstream from the lower falls,
   ② Sediment trapping sump,
   ③ Outside the sump in the east side of the upper basin,
   ④ West channel including the boat ramp area, and
   ⑤ Entire middle basin.
6. The sand collected from the five areas was spread out separately on clean concrete floor in a thin layer to be dried. The dried sand was then weighed and expressed as a percentage of the total accumulation in the model.
7. The entire procedure was then repeated for a river flow of 5,000 cfs.

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*Figure 5 shows the five sediment accumulation areas for Plan 1, Figure 6 for Plan 2 or 3, and Figure 7 for Plan 4.

RESULTS AND DISCUSSION

The results of the sediment tests are tabulated in Table 3 where the most significant values are the sediment accumulation ratios of Areas 2 and 5. The sediment accumulation ratio of Area 2 is the sediment trapping efficiency of the sump. The higher the efficiency, the better the plan. Plan 4 has the highest efficiencies: 59.1% for 3,000 cfs and 54.2% for 5,000 cfs. The efficiency of Plan 2 is very small and therefore should not be used. The sediment accumulation ratio in the middle basin, Area 5, is the percentage of sediment that has bypassed the upper basin. The lower the figure, the better the plan. Comparing the four plans tested, again Plan 4 is the best with the lowest bypass ratio of 10.6% for 3,000 cfs and 22.3% for 5,000 cfs.

Table 3. Sediment Test Results

Sediment Accumulation Areas		Sediment Accumulation in Each Area as Percentage of Total Sediment				Remarks
		PLAN 1	PLAN 2	PLAN 3	PLAN 4	
FLOW 3,000 cfs						
1	Deschutes River	2.7	6.7	5.5	4.1	
2	Sump*	53.7	2.8	53.2	59.1	-Sediment Trapping Efficiency
3	East Side (outside sump)	15.8	19.2	15.1	17.8	
4	West Channel	13.4	20.5	10.5	8.4	
5	Middle Basin*	14.4	50.8	15.7	10.6	-Bypassed Upper Basin
	TOTAL	100.0	100.0	100.0	100.0	
FLOW 5,000 cfs						
1	Deschutes River	1.4	0.3	2.6	2.5	
2	Sump*	43.6	4.6	52.9	54.2	-Sediment Trapping Efficiency
3	East Side (outside sump)	16.1	23.9	6.3	14.9	
4	West Channel	7.2	2.9	10.1	6.1	
5	Middle Basin*	31.7	68.3	28.0	22.3	-Bypassed Upper Basin
	TOTAL	100.0	100.0	100.0	100.0	

*Significant values for comparison.

The tests indicated the two most important factors in providing high sump trapping efficiency were the ability to divert most of the flow into the east channel and the shape of the sump. The use of the groin to deflect the flow in Plans 1, 3, and 4 is particularly effective. Plan 2, which does not have the groin, caused most of the flow through the west channel, thus bypassing the sump area and dumping sediment directly into the middle basin. The trapping efficiencies of Plans 3 and 4 show that the fan-shaped area of Plan 4, having a greater cross-sectional area normal to the flow direction, is superior to the oval-shaped area of Plan 3.

In summary, Plan 4 demonstrated the best sediment trapping efficiency in the model tests, and thus is recommended for adoption for use in controlling sediment accumulation in Capitol Lake.

Another point observed in the model is that the boat ramp area has a large accumulation of very fine sediment. The river flow is not capable of flushing them out, hence, dredging is necessary for their removal.

RECOMMENDATION

1. Among the four plans tested, Plan 4 has the highest sediment trapping efficiency. The details of Plan 4 are shown in Figure 4.
2. The boat ramp area in the upper basin has large accumulation of very fine sediment which should be dredged once every two years to keep the ramp usable.

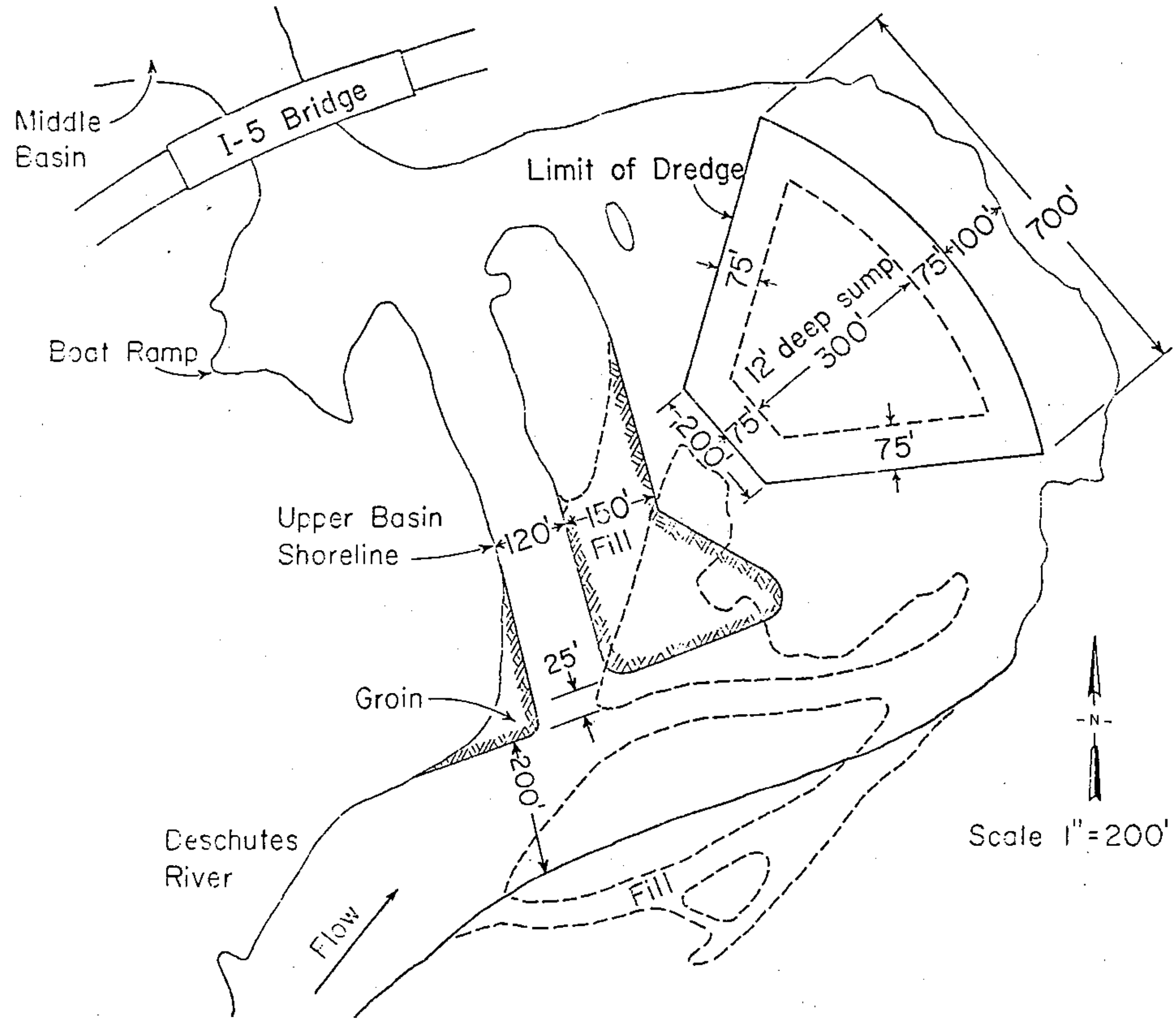

Fig. 1. Dredge Plan 1

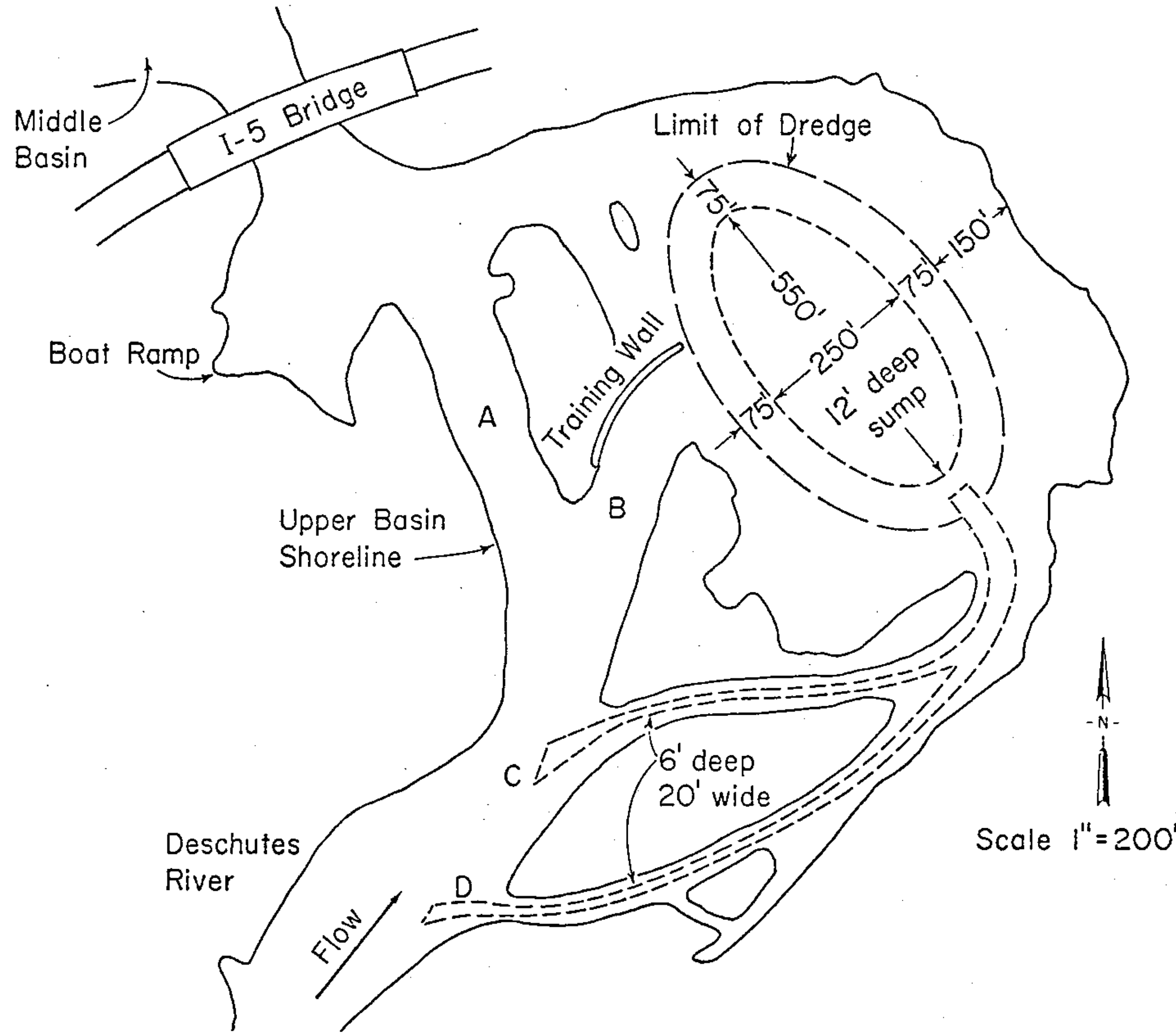

Fig. 2. Dredge Plan 2

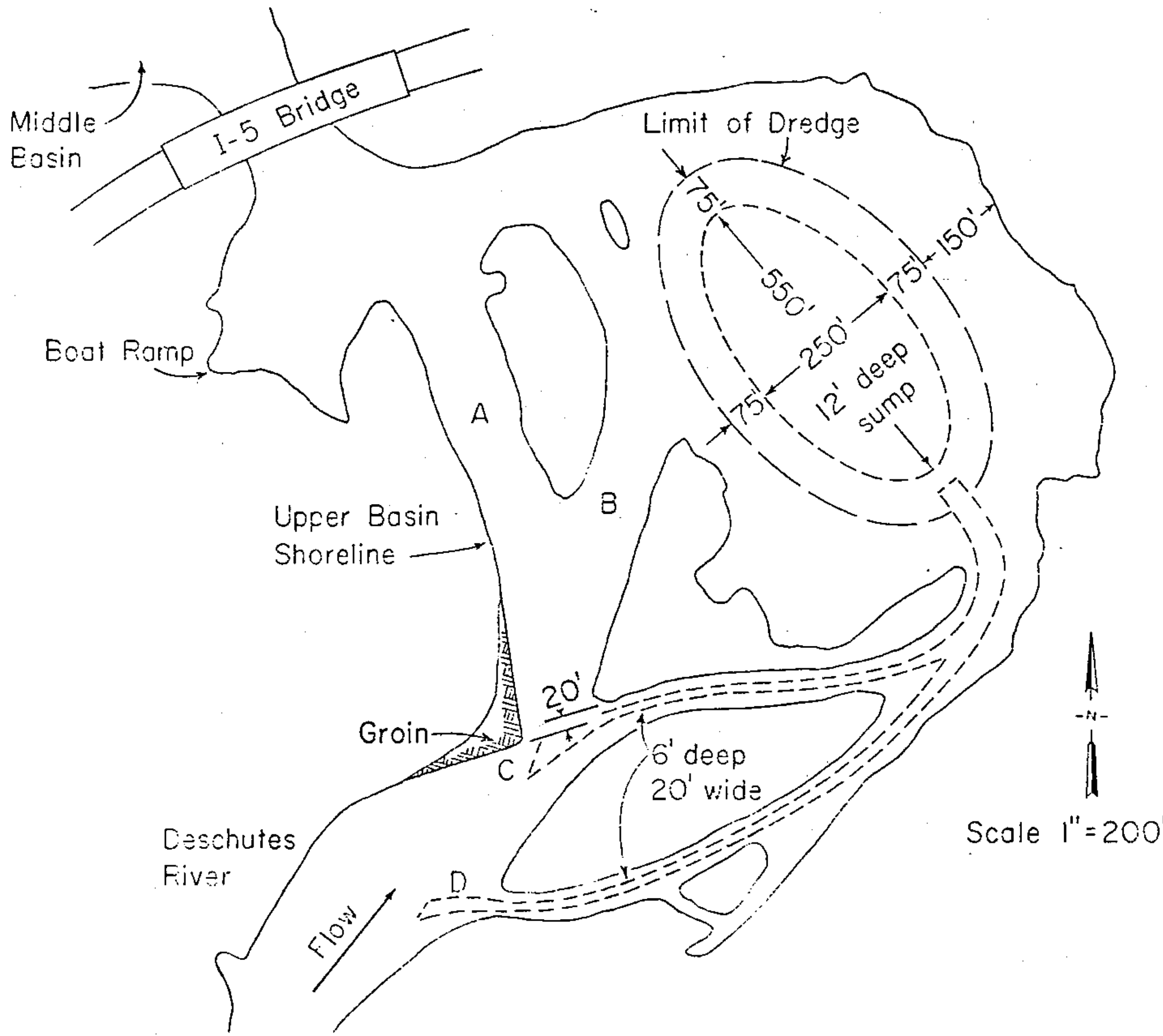

Fig. 3. Dredge Plan 3

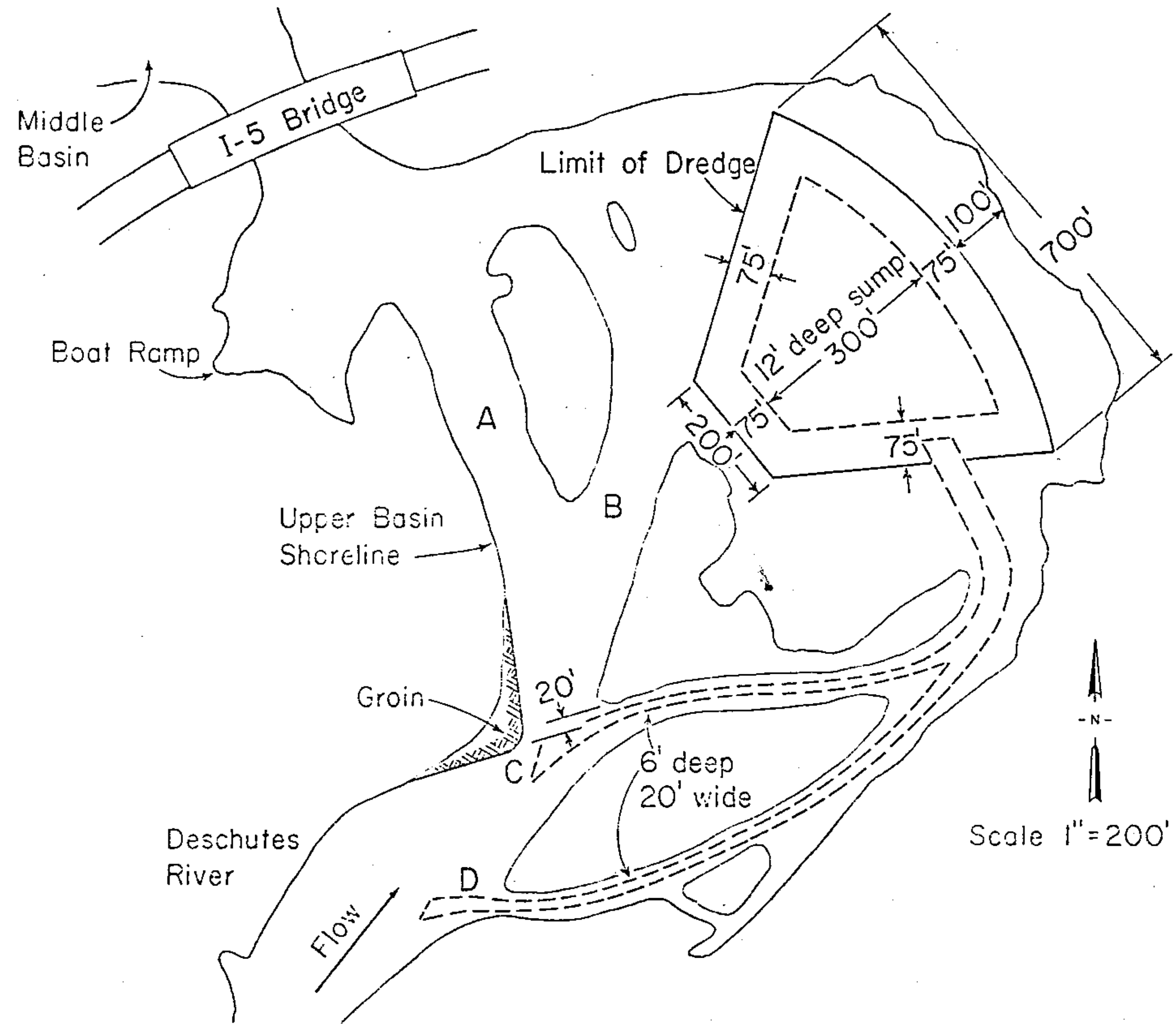

Fig. 4. Dredge Plan 4

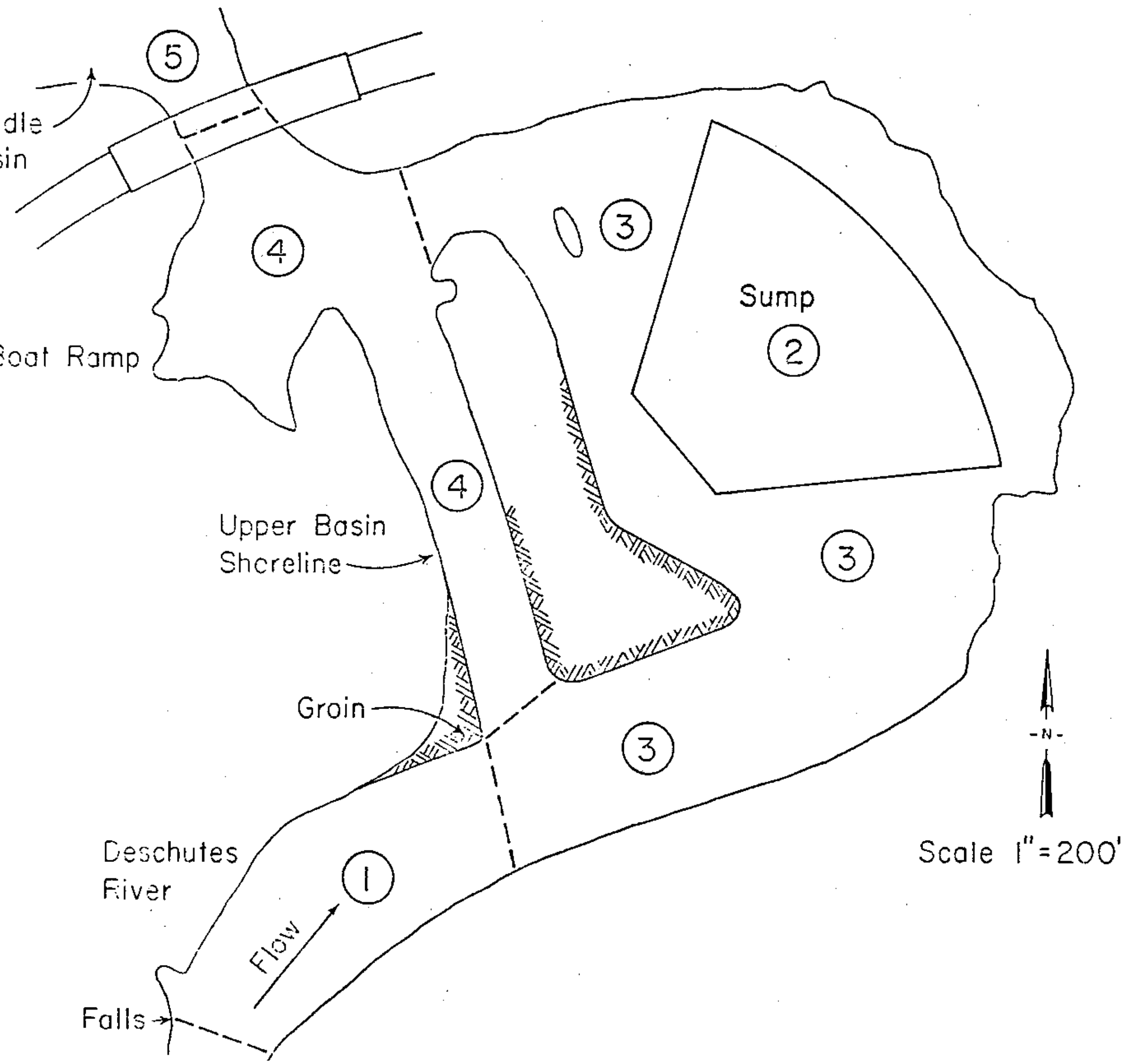

Fig. 5. Sediment Accumulation Areas--Dredge Plan 1

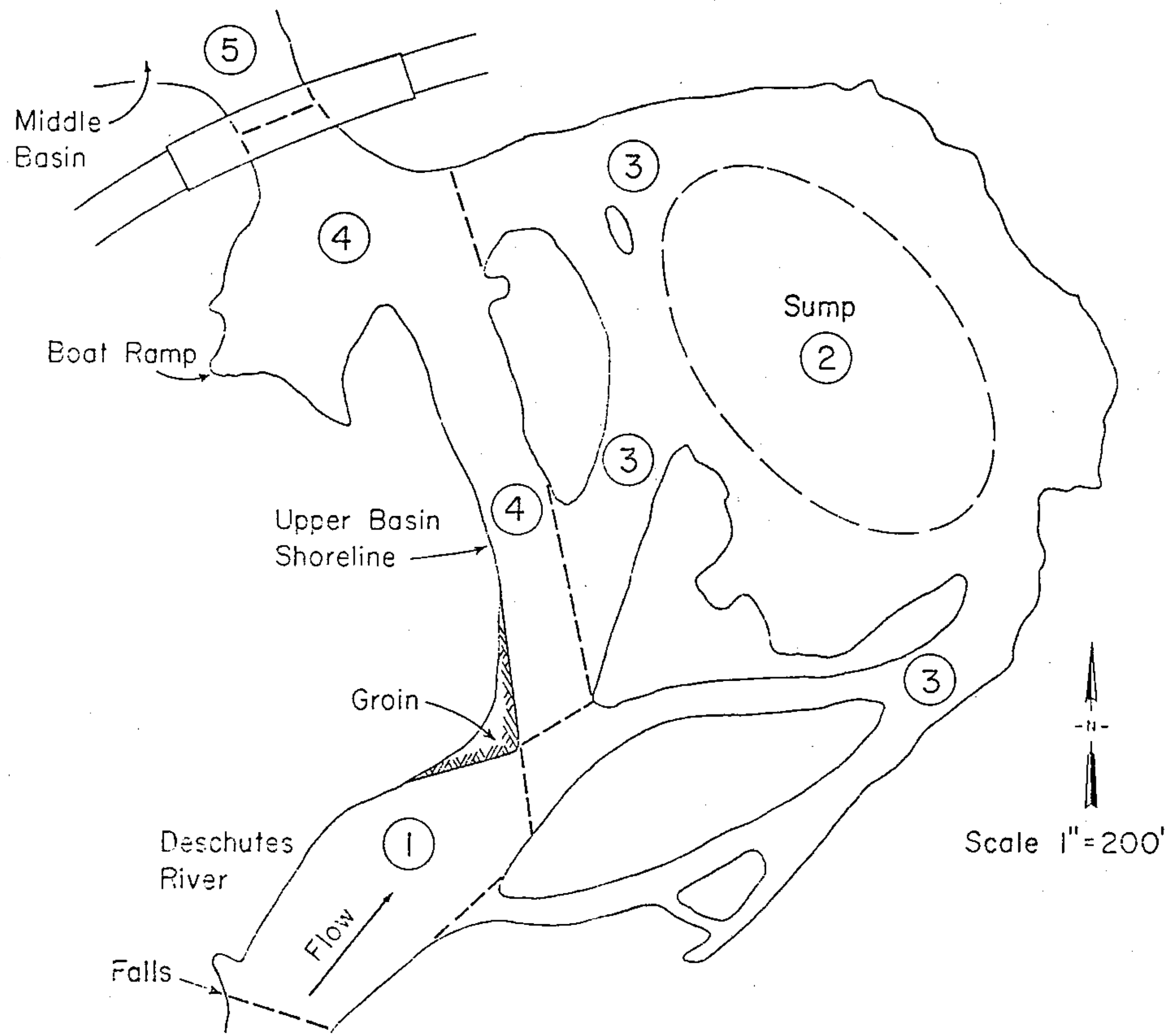

Fig. 6. Sediment Accumulation Areas--Dredge Plan 2 or 3

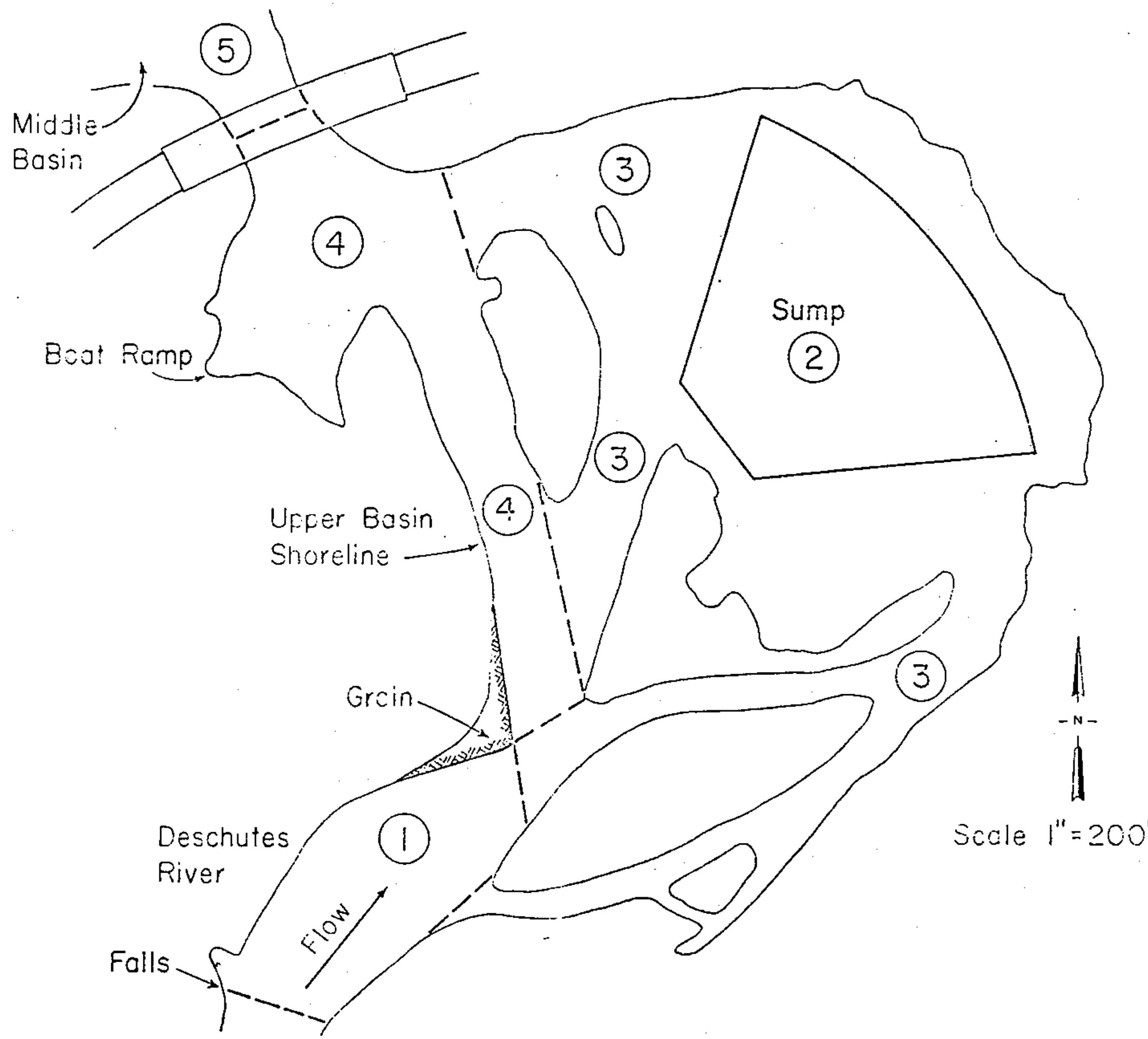

Fig. 7. Sediment Accumulation Areas--Dredge Plan 4

Albrook Hydraulics Laboratory (509) 335-4546

January 12, 1977

Mr. Dale L. King
CH_2M-Hill Engineers
1500-114th Avenue S.E.
Bellevue, Washington 98004

Dear Mr. King:

We have completed the additional tests on Capitol Lake to determine sediment trapping efficiencies of the maintenance dredge plans in the Upper Basin. Five copies of the final report are enclosed. I have also sent five copies to Jerry Bachmann, Department of General Administration.

If you or Mr. Bachmann have any questions regarding this report, I will be happy to discuss them with you. I can be reached at the above telephone number or (509) 335-2402.

Sincerely yours,

Walter C. Mih

Walter C. Mih, P.E.
Associate Professor

WCM:rab

cc: Alan Babb, Acting Director, Albrook Laboratory
Jerry Bachmann, Facilities Planning, Dept. of General Administration

Enclosures (5)