1974

Preliminary Report

SEDIMENT REMOVAL AND MAINTENANCE SYSTEM

FOR THE UPPER BASIN OF CAPITOL LAKE

OLYMPIA, WASHINGTON

UPPER (SOUTH) AND MIDDLE PORTIONS OF CAPITOL LAKE NEAR OLYMPIA, WASHINGTON

Preliminary Report

on a

SEDIMENT REMOVAL AND MAINTENANCE SYSTEM FOR THE UPPER BASIN OF CAPITOL LAKE OLYMPIA, WASHINGTON

BASED ON

HYDRAULIC MODEL AND

ANALYTICAL STUDIES

Conducted at

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EXPLANATORY NOTE

This preliminary sedimentation report has been prepared to assist the Department of General Administration in its determination of methods and costs for modifying and maintaining the upper basin of Capitol Lake to serve as a more effective trap for sediment entering the Lake by way of the Deschutes River. Refinements and additions to this report will be included in the final project report of June 30, 1975.

SEDIMENT REMOVAL AND MAINTENANCE SYSTEM FOR THE UPPER BASIN OF CAPITOL LAKE OLYMPIA, WASHINGTON

I. INTRODUCTION

In response to a request from Governor Daniel J. Evans dated February 8, 1974, a proposal for sedimentation, water quantity and water quality research studies of Capitol Lake was submitted to the Department of General Administration on March 3, 1974. A contract to conduct these laboratory and field investigations was approved by both the Department of General Administration and Washington State University in mid-April, 1974. Figure 1 shows the location of Capitol Lake near Olympia, Washington.

This preliminary report on the sedimentation phase of the studies was requested by August 15 to assist the Department in determining costs for removing sediment from the upper (south) portion of Capitol Lake, and for maintenance of a sediment removal system. The Department will use the cost estimates to make its budget request to the Capitol Committee for dredging Capitol Lake and maintaining it. Other information on the water quantity and quality aspects of the study will be presented in the project report in June, 1975.

As shown in Figure 1, Capitol Lake consists of three basins formed by transportation corridors. The upper basin of the lake, situated south of the highway I-5 bridge and fill, forms a partial trap for sediment transported by the Deschutes River. In addition, a lesser amount of sediment enters the middle basin of Capitol Lake from Percival Creek on the west side of the lake.

Historical details on the sediment accumulation problem in Capitol Lake are well documented in numerous reports, and will not be repeated here.[1,2,3] It

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[1] Wilson, John A., "Reconnaissance Geologic Investigation on the Siltation Problem of Capitol Lake, Olympia, Washington," for Wash. Dept. of Fisheries by the Soil Conservation Service, Oct., 1970.

[2] Walker and Byrne, "Hydrographic Survey of Capitol Lake, Olympia, Washington," for the General Services Administration of Wash., Nov. 5, 1970.

[3] Byrne, Patrick J., "Engineering Investigation for Rehabilitation of Capitol Lake, Olympia, Washington," Vols. I and II, April, 1973.

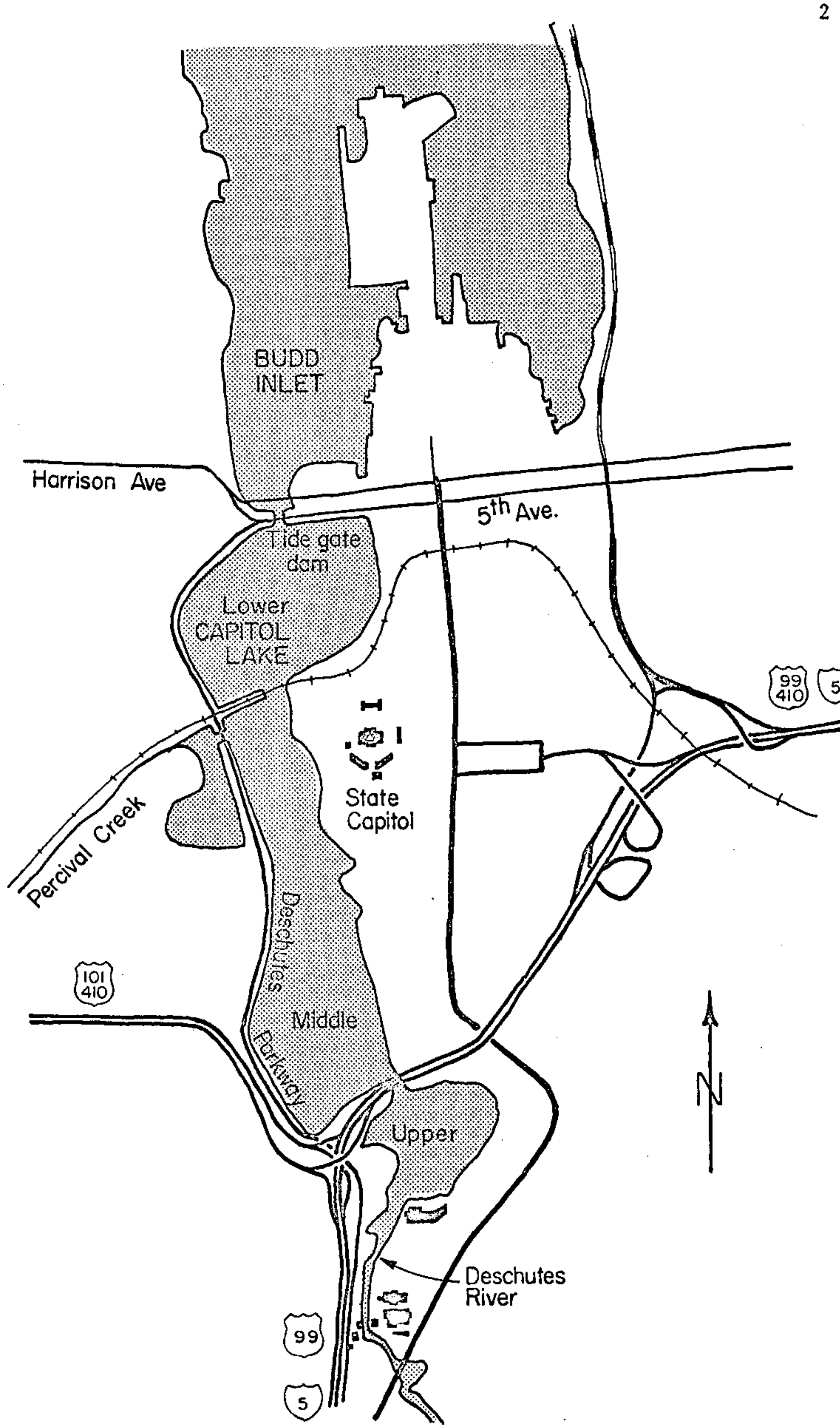

Figure 1. Location Map of Capitol Lake, Olympia, Washington

is sufficient to state that the construction of the dam across the Deschutes River tidal basin at 5th Avenue in 1951 formed a large sedimentation basin for the Deschutes River, Percival Creek and local runoff. The distribution of sediment accumulation was strongly modified by the construction of the highway I-5 fill which formed the upper basin, and has provided a primary sedimentation basin for the Deschutes River since 1956. Fine sediment sizes are transported into the middle and upper portions of Capitol Lake, and during flood periods in the Deschutes River some suspended sediment is transported out of the lake into Budd Inlet.

In recent years the accumulation of the sediment in the upper basin has come to an equilibrium condition with the Deschutes River flow regime. As a result, depending on the amount of discharge in the Deschutes River, varying amounts of sediment are being transported through the upper basin into the middle basin. This deposition downstream (north) of the highway I-5 bridge has begun to severely limit the utility of the middle basin of Capitol Lake. It is indicative also of the fact that the upper basin can no longer serve as an effective sedimentation basin for the rest of Capitol Lake unless portions of the upper basin are dredged.

A basin geometry similar to that of the upper Capitol Lake exists in a smaller scale at the mouth of Percival Creek. Here the bay was formed by the construction of the Deschutes Parkway, and this portion of the Lake has been used in recent years by the Department of Fisheries to rear fingerling salmon. The amount of natural sediment load transported by Percival Creek into Capitol Lake is almost insignificant compared to the amount deposited from the Deschutes River. But, urban development in the Percival Creek drainage basin is creating the potential for a man-generated increase in sediment. Due to the relatively smaller size of the problem and the short time allowed to complete the preliminary sedimentation report, the Percival Creek sedimentation problem will not be addressed in this report. Only miscellaneous streamflow records are maintained on Percival Creek by the U.S. Geological Survey, and there is no sediment information except the lake contour maps prepared in 1951 and 1970.[3] Further analysis will be completed on Percival Creek flows and sediment load between now and June, 1975, when the final project report will be submitted.

Streamflow records on the Deschutes River are quite adequate except that the gaging station at Olympia was discontinued in 1964. Correlations have been developed with other nearby stream gages to extend the average annual flow from 1964 to date, and numerous miscellaneous measurements have been made on various streams throughout the Deschutes River basin by the Geological Survey. Only those hydrologic records needed to estimate load entering Capitol Lake have been evaluated for this preliminary report, and they are presented in Section II.

Of particular and timely value to the Capitol Lake study is the sediment transport study of the Deschutes and Nisqually River basin conducted between November, 1971, and June, 1973, by the Geological Survey.[4] Suspended sediment data taken near LaGrande, Rainier, and Olympia have been compiled to provide good correlations of suspended sediment in the Deschutes River as a function of river flow. Figure 2 illustrates the location of Capitol Lake and the gaging stations in relation to the Deschutes and Nisqually River basins. It has been found also that the bed load transport of the Deschutes River (larger particles, i.e., gravel) is only about 10 percent or less of the suspended sediment transport. Most of the sediment is of small grain size and is generaged in the upper, steeper portions of the Deschutes River basin.

The results of the Geological Survey open-file report on sediment transport in the Deschutes and Nisqually River basins will be presented in more detail in Section III of this preliminary report on the Capitol Lake sedimentation problems and solutions. Extensions of the U.S. Geological Survey report have been developed between suspended sediment load, basin geomorphic parameters, annual precipitation, and streamflow so that a year-to-year estimate of Deschutes River sediment load entering Capitol Lake can be made in the future.

Another major emphasis in this preliminary report is on the dredging and maintenance of the upper basin so that it will serve as an efficient sedimentation basin for the rest of Capitol Lake. Very fine material will, of

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[4]Nelson, Leonard M., "Sediment Transport in Streams in the Deschutes and Nisqually River Basins, Washington, Nov., 1971 - June, 1973," U.S. Geological Survey. Prepared in cooperation with the State of Wash. Dept. of Ecology, Open File Report, Tacoma, Washington, 1973.

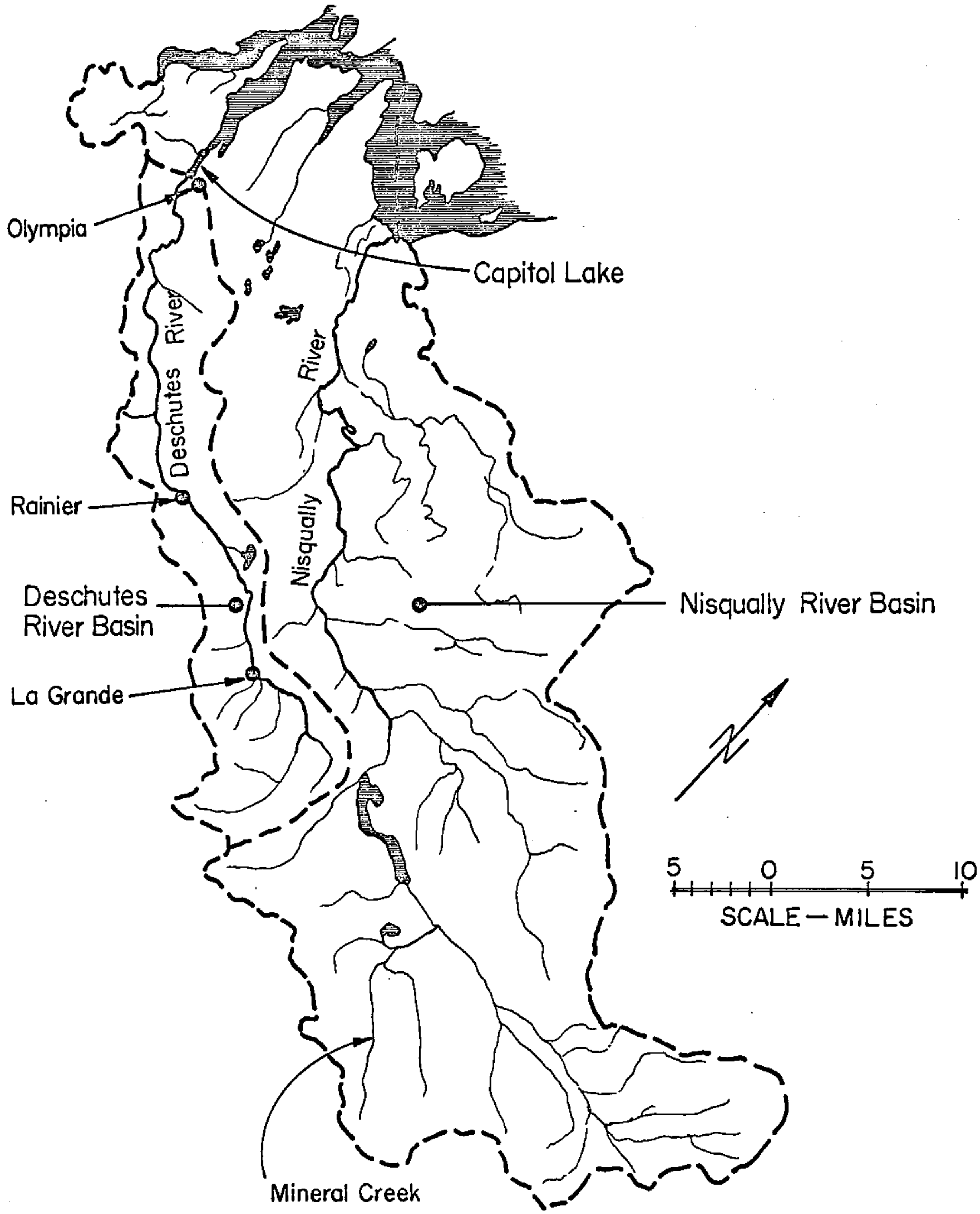


Figure 2. Deschutes River Basin and Nisqually River Basin

course, continue in suspension into the middle and lower basins, and into Budd Inlet, especially during periods of high discharge in the Deschutes River. These flood flows occur only for a very small percentage of the time. Also, with proper dredging of particular areas in the upper basin where sediment tends to accumulate, and with the installation of a maintenance system to remove accumulated sediment from year to year, Capitol Lake can be restored to approximately 1950 conditions and maintained to serve the purposes for which it is currently used without expensive redredging of the total lake. A maintenance system for removing the yearly sediment accumulation in certain portions of the upper basin, and in the vicinity of the I-5 bridge, has been analyzed and is discussed in detail in Section IV of this report. Following the concepts presented by the consultant for utilization of the upper basin as a sedimentation basin and maintained substantially in its current natural state, several systems including a permanent slurry pump and piping network system have been considered for removing sediment.[3] The network feeds into a holding and drainage tank on the southeast shore of the upper basin. Water drains from the stockpile into a clarification chamber and the clear water is returned to the Deschutes River. The accumulated dredgings can be removed according to plans developed by the consultant.[3] The slurry pump and piping system provides for complete maintenance dredging flexibility because it can be operated at any time, and at a wide variety of removal rates.

II. HYDROLOGY OF THE DESCHUTES RIVER BASIN

Precipitation and Streamflow Characteristics

In order to evaluate the historical and potential sediment loads which the Deschutes River has transported and will transport into Capitol Lake, the streamflow gaging station records, precipitation records, and geomorphic characteristics of the basin have been analyzed. These data provide the basis upon which the flow characteristics, and thus the sediment load, can be determined for the Deschutes River.

The hydrologic component of this preliminary sedimentation report has been analyzed only in enough detail to describe the sedimentation problem in Capitol Lake. The larger flows which carry a majority of the sediment load have received primary attention. A more complete hydrologic analysis of the Deschutes River- Capitol Lake basin will be made during the remainder of the project period, and the results will be presented in the final project report in June, 1975. Also, a more detailed description of the basin, including its vegetation, soils, and land use is presented in reference 3.

The average time distribution of flow in the Deschutes River depends on the seasonal distribution of precipitation. The average annual precipitation is strongly influenced by topographic relief as is demonstrated in Figure 3. The decrease in precipitation at 12 miles from the outlet of Capitol Lake is due to being in the lee of hills to the west. Most of the precipitation falls during the period of October through April in the form of rain and thus this is the period of highest flows and sediment transport.[5]

Although the Deschutes River stream gaging station at Olympia was discontinued in 1964, the gage near Rainier is still in operation. Typical hydrographs of average annual flow for these two gages and for Mineral Creek in the Nisqually River basin are shown in Figure 4 for the common period of record of 1951-54 and 1958-63. Mineral Creek is included because its flows correlate better with flows at Olympia than do the flows in the Deschutes

[5] Grant, Arvid and Assoc. Inc., "Water Pollution Control and Abatement Plan for Deschutes River Basin" - Water Resources Inventory Area No. 13, for the Thurston Regional Planning Council, June, 1974.

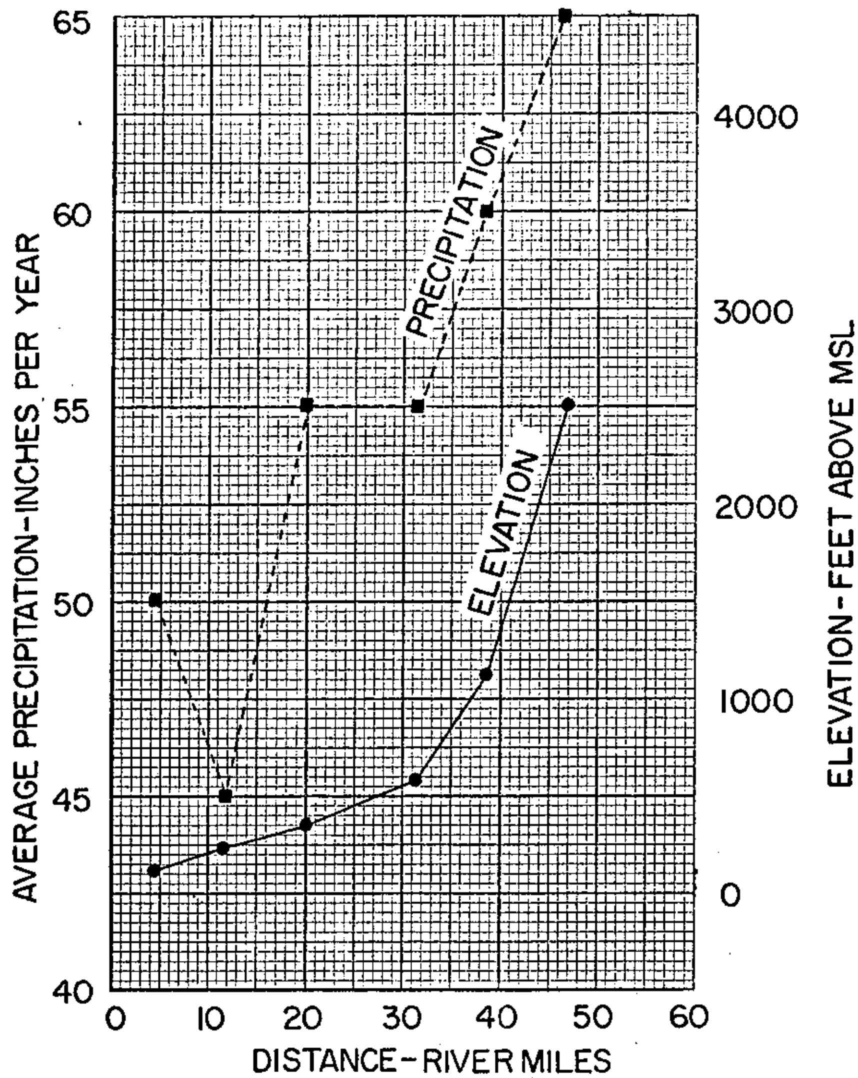


Figure 3. Effect of Elevation on Precipitation for the Deschutes River Basin Along a Line from Outlet of Capitol Lake to the Headwaters (Precipitation Profile Based on Figure 1 in Reference 4)

River at Rainier. The Mineral Creek correlation will be used to extend the Deschutes River flows at Olympia as needed later in the main hydrologic study. Miscellaneous measurements have been made recently on the Deschutes River near LaGrande in connection with the sediment studies. A regional relationship between average annual flow and the multiple of average annual precipitation and drainage area has been developed for gaging stations on the Deschutes River and on other nearby streams. The average annual flow for the period of record was used and the LaGrande and Olympia gaging periods were drier than the longer period for the gage at Rainier.

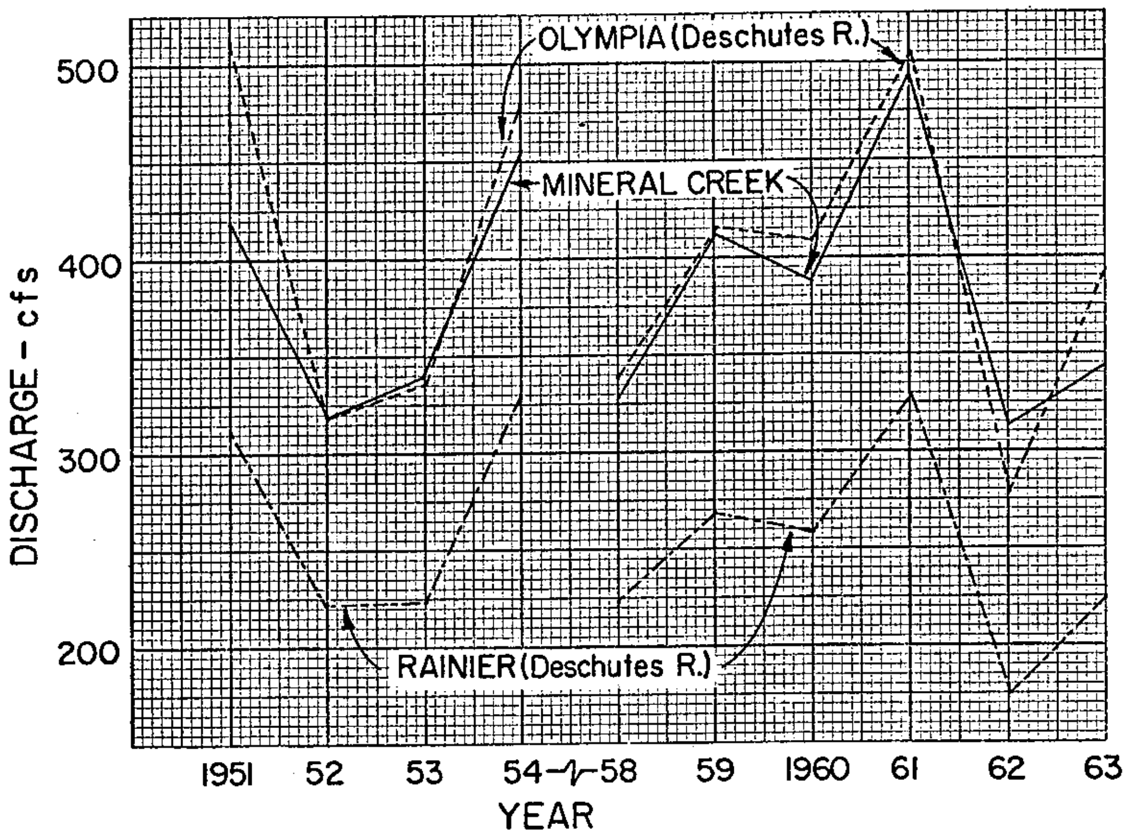


Figure 4. Average Annual Flow of Deschutes River at Rainier and Olympia, and for Mineral Creek in the Nisqually River Basin Between 1951 and 1963

The flow-duration curves for the Deschutes River at the Olympia and Rainier gages are presented in Figures 5 and 6. Of importance in these figures is the small percentage of time that the discharge exceeds a relatively large value of, say, 1000 cfs. For example, in Figure 5 at Olympia, 1000 cfs is

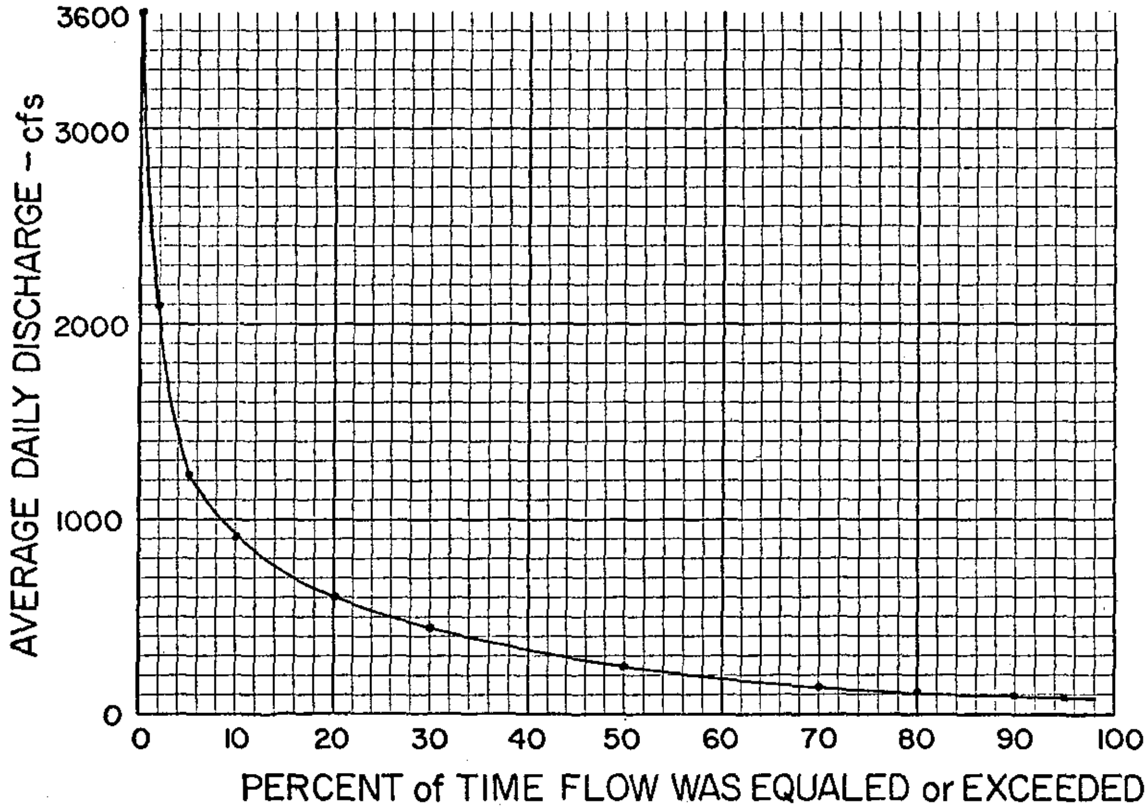


Figure 5. Flow Duration Curve for Gaging Station near Olympia on the Deschutes River (1946-54, 1958-63)

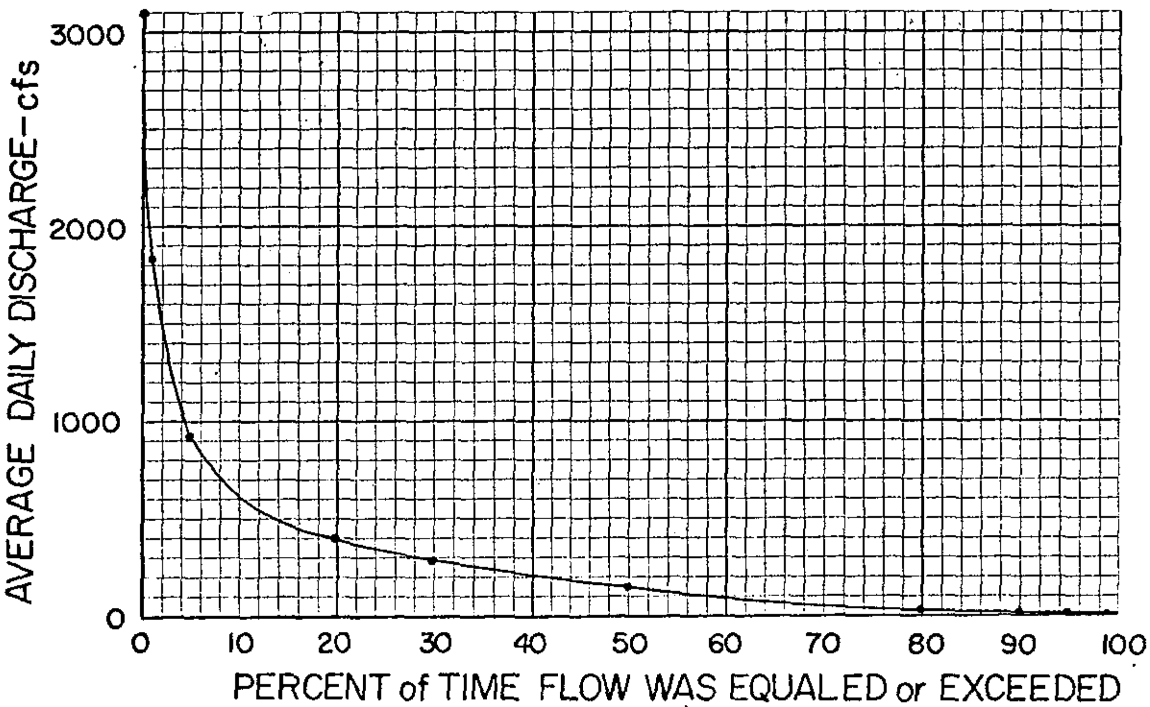


Figure 6. Flow Duration Curve for Gaging Station near Rainier on the Deschutes River (1950-64)

equaled or exceeded only about 8 percent of the time. As will be shown in the next section on sediment transport, these flows which occur only 8 percent of the time on the average, transport 80 to 85 percent of the sediment into Capitol Lake. In Figure 6 at Rainier, flows of 1000 cfs or greater occur only about 4 to 5 percent of the time but they transport about the same 80 to 85 percent of the average annual sediment load in the Deschutes River.

Geomorphic Features of the Deschutes River and Its Drainage Basin

The drainage patterns of streams are indicative of the geology and runoff characteristics. As a result, relationships can often be developed between geomorphic (landform) parameters and characteristic streamflows such as floods, average flows, and low flows. A typical set of geomorphic parameters have been developed for the three Deschutes River gaging stations near LaGrande, Rainier, and Olympia and they are presented in Table 1. The stream lengths and upper basin elevation were determined from 1:62500 scale U.S. Geological Survey topographic maps. The drainage areas and gage elevations are those published by the U.S. Geological Survey in its annual Water Supply Papers. Because the basin is merely increasing in drainage area in the same basin as one moves from the LaGrande gage to Rainier and to Olympia, the upper headwater elevation remains a constant.

A relationship between total stream length (LT) and the multiple of average annual precipitation and drainage area (P•A) is shown in Figure 7. The symbols for the gaging stations near LaGrande, Rainier, and Olympia are a triangle (▲), circle (●), and square (▣), respectively. This symbolism was developed for use in this report to signify and correspond to the increasing drainage (and symbol) area as one moves in a downstream direction from the uppermost gage near LaGrande to the downstream gage near Olympia. These symbols were initially used for these stations in Figure 8.

Referring to Figure 8, the average graphical relationship is defined by the equation

$$QAA = 0.052(P \cdot A) \qquad (1)$$

Table 1. River Basin Parameters of Deschutes River, Washington

Gage Station (No.)	L1 (mi)	LT (mi)	Upper Elev. (ft)	Gage Elev. (ft)	Relief H (mi)	Basin Area, A (sq mi)
LaGrande (12078902)	38.6 Σ=38.6	61.5 Σ=61.5	2550	549	0.38	56.2
Rainier (12079000)	11.2 Σ=49.8	24.1 Σ=85.6	2550	350	0.42	89.8
Olympia (12080000)	8.9 Σ=58.7	29.1 Σ=114.7	2550	95	0.47	160.0

Nomenclature: L1 = length of first-order (unbranched perennial streams;
LT = total length of perennial streams;
Upper Elevation = highest average contour around headwaters;
H = Relief--difference in elevation between headwaters and gage (or outlet, for ungaged basin); and
A = drainage area defined by topographic divide above gaging station or basin outlet.

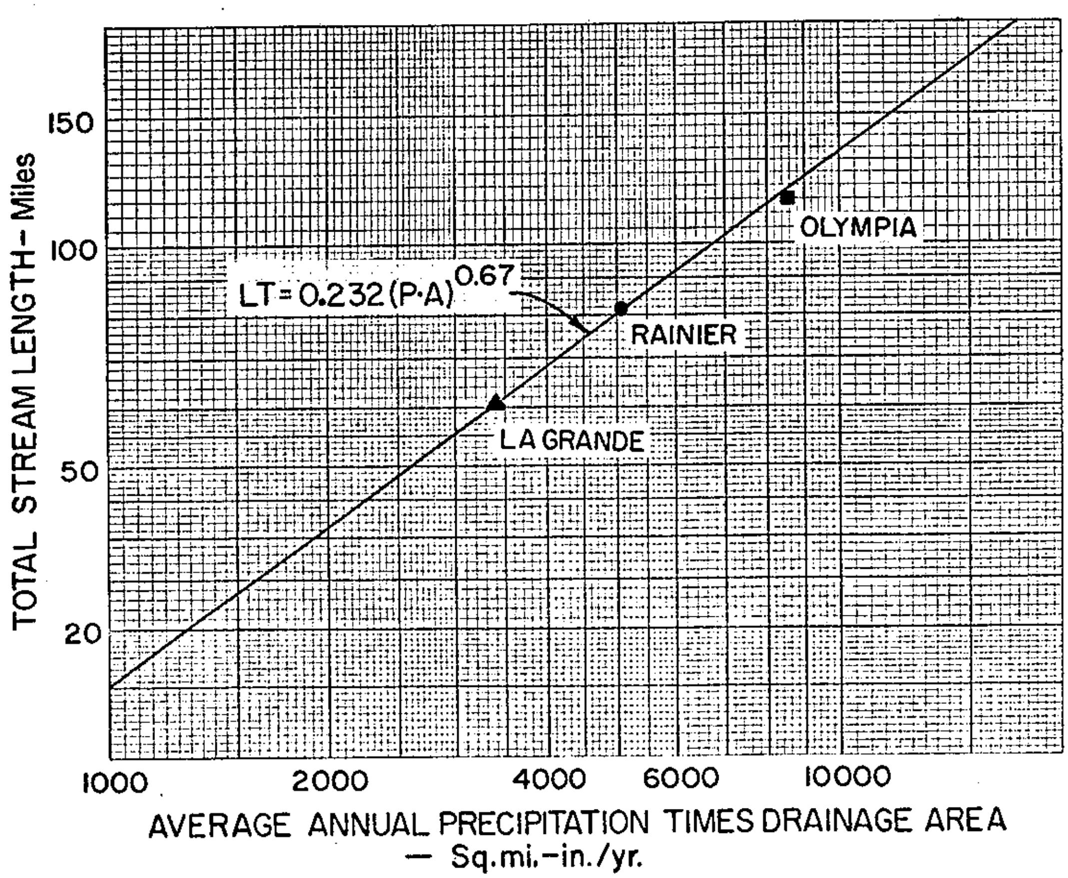
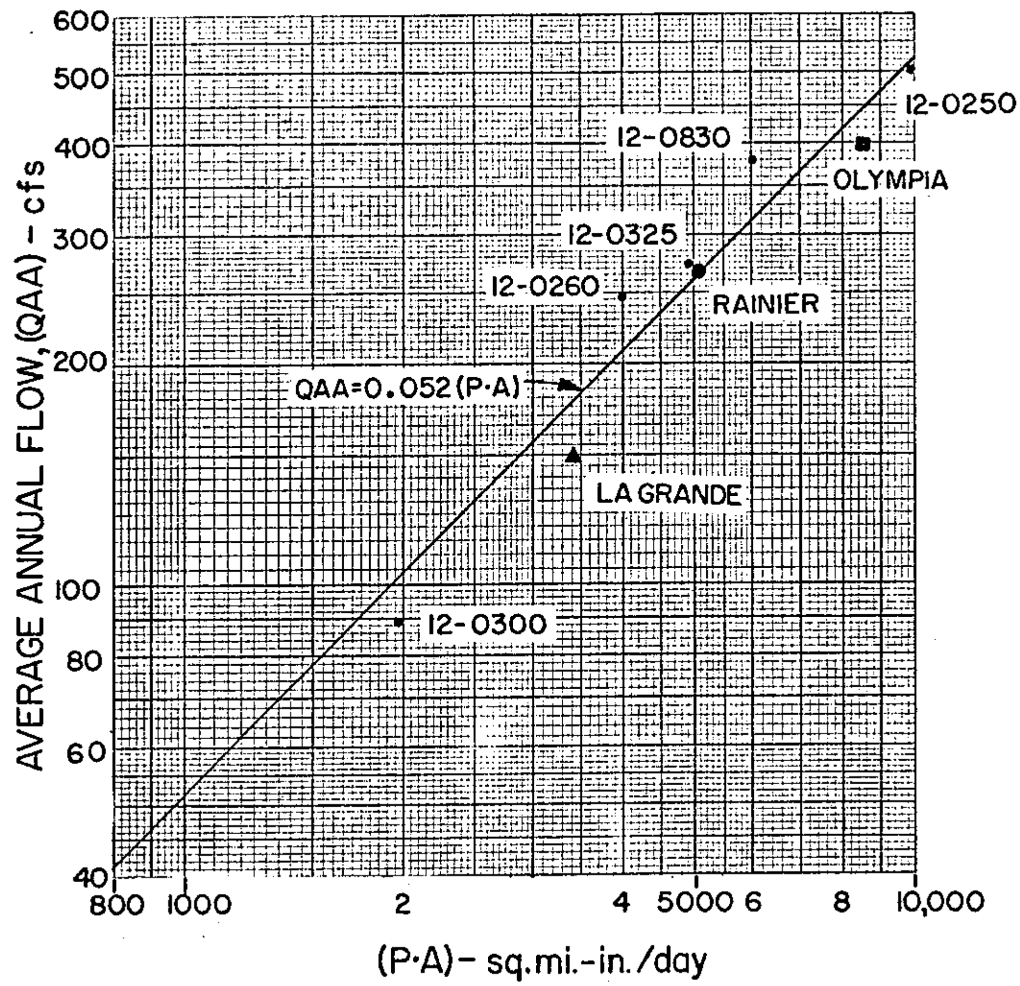


Figure 7. Total River Length Versus Annual Precipitation Times Drainage Area for Deschutes River Basin Study Area



Gage No.	River	Station Location	Area (sq mi)
120250	Newaukum	Near Chehalis	155.0
120260	Skookumchuck	Near Centralia	61.7
120300	Rock Creek	At Cedarville	24.8
120325	Cloquallum Cr.	At Elma	64.9
120830	Mineral Cr.	Near Mineral	75.2

Figure 8. Average Annual Flow Related to Average Annual Precipitation and Drainage Area for Deschutes River Stream Gages and Other Stream Gages in the Region

where (QAA) is the average annual streamflow in cfs (cubic feet per second), (P) is the average annual precipitation in inches per year, and (A) is the drainage area in square miles.

In Figure 7, the graphical relationship between total stream length (LT) in miles and the product of average annual precipitation and drainage area is

$$LT = 0.232(P \cdot A)^{0.67}. \qquad (2)$$

Rewriting Eq. (1) to define (P•A) yields

$$(P \cdot A) = QAA/0.052, \qquad (3)$$

and Eq. (2) yields

$$(P \cdot A) = (LT/0.232)^{1.50}. \qquad (4)$$

Combining Eqs. (3) and (4) allows for the determination of average annual streamflow (QAA) in terms of the total stream length (LT) by

$$QAA = 0.052(LT/0.232)^{1.50}. \qquad (5)$$

Reducing this further yields

$$QAA = 0.47(LT)^{1.5}. \qquad (6)$$

Other relationships have been developed between streamflows, geomorphic parameters, and the suspended sediment load in the Deschutes River. These relationships are used to verify and predict past and future sediment loads entering Capitol Lake.

III.

SEDIMENT CHARACTERISTICS OF THE DESCHUTES RIVER BASIN AND CAPITOL LAKE

Historical Data

The several studies which have been conducted recently on sediment accumulation in Capitol Lake provide comparative information for different periods of time. Average rates of sediment accumulation are summarized in Table 2. The first value for the years 1950-55 shows an average rate of accumulation of 1,420,000 cubic feet per year. The average river discharge of the Deschutes River at Olympia during this period was approximately 425 cfs. During the period of the second entry (1949-70), which included the 1950-55 period, the average rate of accumulation was approximately 1,100,000 cubic feet per year and the average river discharge was about 388 cfs. The third value of 810,000 cubic feet per year of accumulation shown in Table 2 was based on the Geological Survey study.[4] Assuming a submerged specific weight of 60 pounds per cubic foot, this volume converts to an annual

Table 2. Sediment Accumulation Rates in Capitol Lake, Washington

Period	Information Source	Computation Basis	Total Accumulation (cu ft)	Average Annual Rate (cu ft/year)
1950-55 (6 years)	SCS[1] (1970) for DOF[a]	Lake Volume Change	8,520,000 (195.6 acre-ft in 6 years)	1,420,000 (32.6 acre-ft per year)
1949-70 (18 years since dam built in 1952)	Walker and Byrne[2] for DGA[b] (1970)	Lake Volume Change	20,000,000 (739,000 cu yd in 18 years)	1,110,000 (41,000 cu yd per year)
	Nelson,[4] USGS for DOE[c] (197-)	Suspended Sediment Measurements		810,000 (30,000 cu yd per year) (25,000 tons at 60 lb/ft^3 assumed wet specific weight

1, 2 and 4 are reference numbers.

[a]Department of Fisheries (DOF)

[b]Department of General Administration (DGA)

[c]Department of Ecology (DOE)

weight rate of deposition equal to approximately 25,000 tons. This was the estimated value calculated by the U.S. Geological Survey based on its study between 1971 and 1973 of suspended sediment at the three stations (LaGrande, Rainier, and Olympia) on the Deschutes River. In Figure 10a of reference 4, the December 6, 1973, field survey shows a lake surface area of 289 acres and a lake volume of 2450 acre-feet. Comparing with 1970 conditions in Table 3, this would indicate an 11 percent increase in total lake volume in three years which is highly improbable. These values are being checked with the authors of references 2 and 4.

Table 3. Sediment Accumulation in Capitol Lake, Olympia, Washington*

	North Basin	Middle Basin	Upper Basin	Capitol Lake
1970 Surface Area, acres	104.56	145.95	28.58	283.75
1949 Volume, acre-ft	1191.14	1189.87	291.31	2672.32
1970 Volume, acre-ft	1113.37	1033.19	67.69	2204.25
Change in Volume, acre-ft	77.77	156.68	223.62	458.07
Percent Change Volume	6.40	13.20	77.00	17.10
Average Water Depth 1949, feet	11.40	8.20	8.75	9.40
Average Water Depth 1970, feet	10.60	7.10	2.04	7.80
Sediment Accumulation, cubic yards	125000.00	252000.00	362000.00	739000.00
Percent of Total Sediment	16.90	34.20	48.90	100.00
Average Yearly Accumulation, cubic yards				41000.00**

*This table is reproduced from Reference 2.

**Assumes all sediment was accumulated since the completion of the dam at 5th Avenue in 1952.

To provide a quick summary of the amounts of sediment which have accumulated in the lower (north), middle, and upper basins between the times when hydrographic surveys were made in 1949 and 1970, Table 3 has been reproduced from reference 2. The 1949 depth survey can be considered indicative of the conditions when the dam was constructed at 5th Avenue. The 1970 conditions have changed in the past four years by further sedimentation predominantly in the upper basin with spillover into the middle basin just downstream of the I-5 bridge. Although the construction of the highway fill and bridge occurred in 1956, there was no survey of the entire lake made at that time to determine a more accurate rate of accumulation. But, Table 3 is very adequate for showing the average rates of accumulation in each basin and how the percent of sediment accumulation decreases from the upper to the lower (north) basin.

Development of Sediment Load Analysis

To improve on predictive capability of sediment loads in the Deschutes River, the average suspended concentration graphs of the Deschutes River near LaGrande, Rainier, and Olympia were analyzed in terms of river basin geomorphic parameters, and averages of precipitation and streamflow. The The three gaging stations average suspended sediment concentrations (QS), shown in Figure 9, are related to the concurrent instantaneous river discharge (QI) at those stations. The measurements upon which these average graphs are based show variabilities ranging between 25 and 50 percent between LaGrande and Olympia. But the average rating curves reproduced in Figure 9 should be indicative of long-term average conditions. The three equations for the rating curves in Figure 9 and the values of suspended river discharges of 1000 through 7000 cfs are presented in Table 4.

Table 4. Suspended Sediment Concentration and Discharges at Three Stations in the Deschutes River Basin

Station	QS (mg/liter)	QI (cfs)						
		1000	2000	3000	4000	5000	6000	7000
LaGrande	$QS = 0.00034(QI)^{1.83}$	105.4	374	785	1374	1999	2788	3719
Rainier	$QS = 0.002(QI)^{1.55}$	89.7	274	492	788	1080	1436	1828
Olympia	$QS = 0.000082(QI)^{1.93}$	49.4	187	411	742	1102	1564	2112

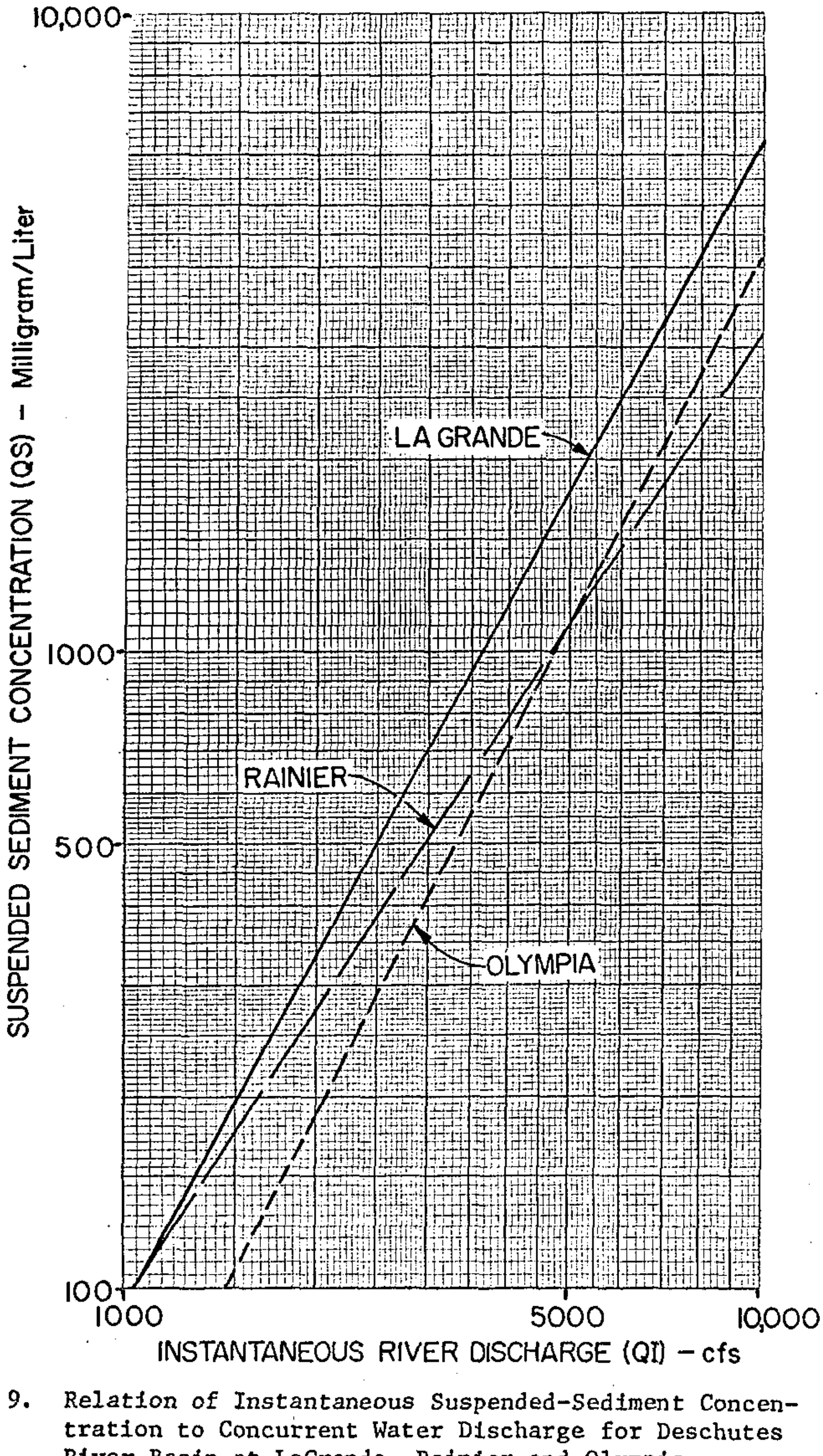


Figure 9. Relation of Instantaneous Suspended-Sediment Concentration to Concurrent Water Discharge for Deschutes River Basin at LaGrande, Rainier and Olympia (Graphs from Figs. 6, 7 and 8 in Reference 4)

The suspended sediment concentrations were then plotted for each station at the river discharge values between 1000 and 7000 cfs against a "river parameter" as shown in Figure 10. The estimated bed load transported by the Deschutes River amounts to only about 10 percent of the suspended load.[4] The river parameter combines first-order stream length (L1), total stream length (LT), basin relief (H), and drainage area (A) at each station. The suspended sediment concentration at Rainier is lower than the concentration at Olympia at high discharges; but the reverse is true for lower discharges.

Referring back to Figure 9, this relationship is seen to be the result of the different slopes on the suspended sediment rating curves at Rainier and Olympia. The two rating curves cross at a river discharge of about 5500 cfs and from that discharge the concentration of suspended sediment is larger at Olympia than Rainier. The largest river discharges experienced at the two stations were 6650 cfs at Olympia in 1964, and 5620 cfs at Rainier in 1955. The LaGrande gage has only been maintained since the Geological Survey suspended sediment study began in 1971.[4] As mentioned earlier, about 85 percent of the sediment is transported by river discharges greater than 1000 cfs which occur only about 8 percent of the time.

Considering the slopes (n) of the dashed lines in Figure 10, each representing an instantaneous river discharge, then each line can be written in equation forms as

$$QS = C[(L1)(LT)(H)(A)]^{-n}\Big|_{1000}^{7000} . \qquad (7)$$

Or, using the abbreviation (RP) for the river parameter [(L1)(LT)(H)(A)], Eq. (7) can be written for each river discharge as

$$QS = C/(RP)^{n}. \qquad (8)$$

Using the relationship in Figure 8 and Eq. (2) of $(LT) = 0.232(P{\cdot}A)^{0.67}$, this can be substituted into Eq. (8) to relate sediment loads to annual precipitation. Also, Eq. (1) could be inserted to relate sediment load to average annual flow.

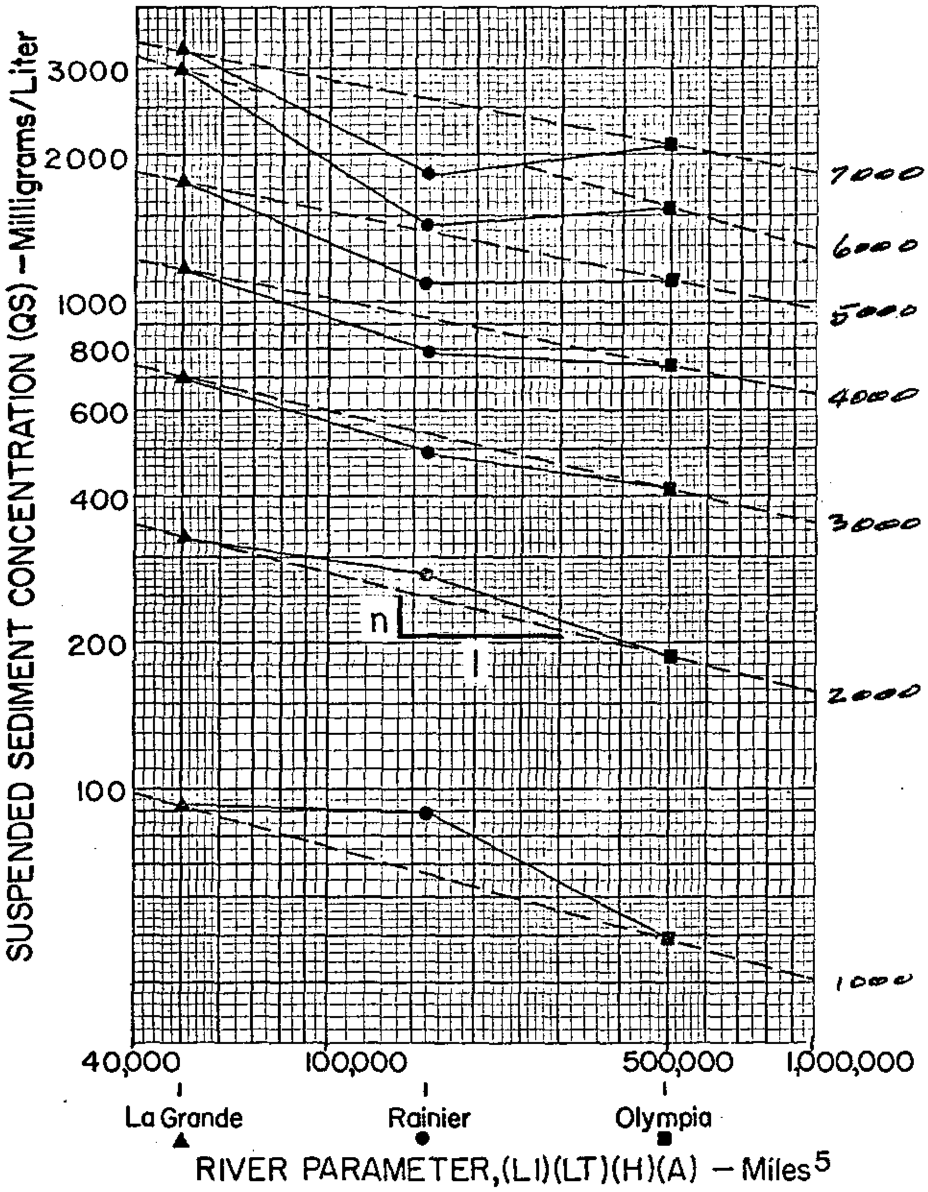


Figure 10. The Suspended-Sediment Concentration Discharge Related to the River Parameter (First-Order Stream Length, Total River Length Elevation Relief, and Basin Area) for the 3 Stations in the Deschutes River Basin

The coefficient (C) in Eq. (8) varies as a function of the instantaneous discharge and so do the slopes of each of the dashed discharge lines (n) in Figure 10. The relationships between the coefficient (C), the slopes of the graphs (n) and river discharge (QI) are shown in Figures 11 and 12.

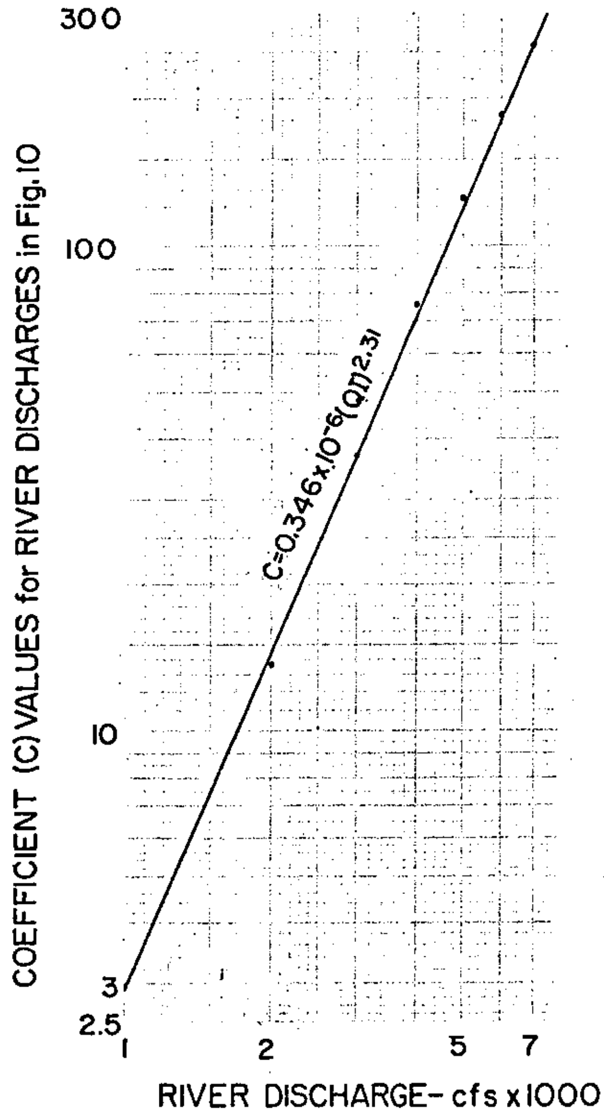


Figure 11. Coefficients for Each River Discharge Equation in Fig. 10

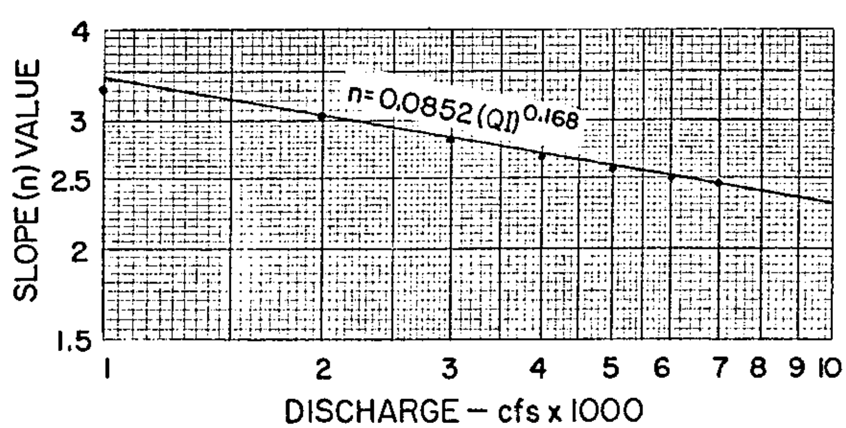


Figure 12. Slopes of River Discharge Lines (n) in Fig. 10 Related to Discharge

The slopes of the lines in Figure 10, as displayed in Figure 12, decrease with discharge. This indicates that as river discharges get larger there is less variation in sediment concentration between the upper and lower portions of the Deschutes River basin.

Calculation of Annual Sediment Loads

Using the relationships in Figure 9 between suspended sediment (QS) and instantaneous river discharge (QI), sediment load estimates were made for the average flow-duration curve near Olympia (from Figure 5), and for water years* 1961, 1962 and 1963. Also, the sediment load was calculated for the storm between January 16 and February 5, 1964, when the maximum flood of record occurred at Olympia in Figure 13. Results of these calculations are summarized in Table 5.

Table 5. Calculated Sediment Discharges of Deschutes River at Olympia

Time Period	Suspended Sediment (tons)	Estimated Total Sediment Load* (tons)
1961	28,400	31,240
1962	3,760	4,136
1963	21,600	23,760
Jan. 16 - Feb. 5, 1964	26,200	28,820
Average Value**	29,600	32,560

*Based on estimated bed load equal to 10 percent of suspended load.

**Based on duration curve in Figure 5.

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*Water year: Oct. 1 to Sept. 30 of following year denoted by calendar year number in which January occurs.

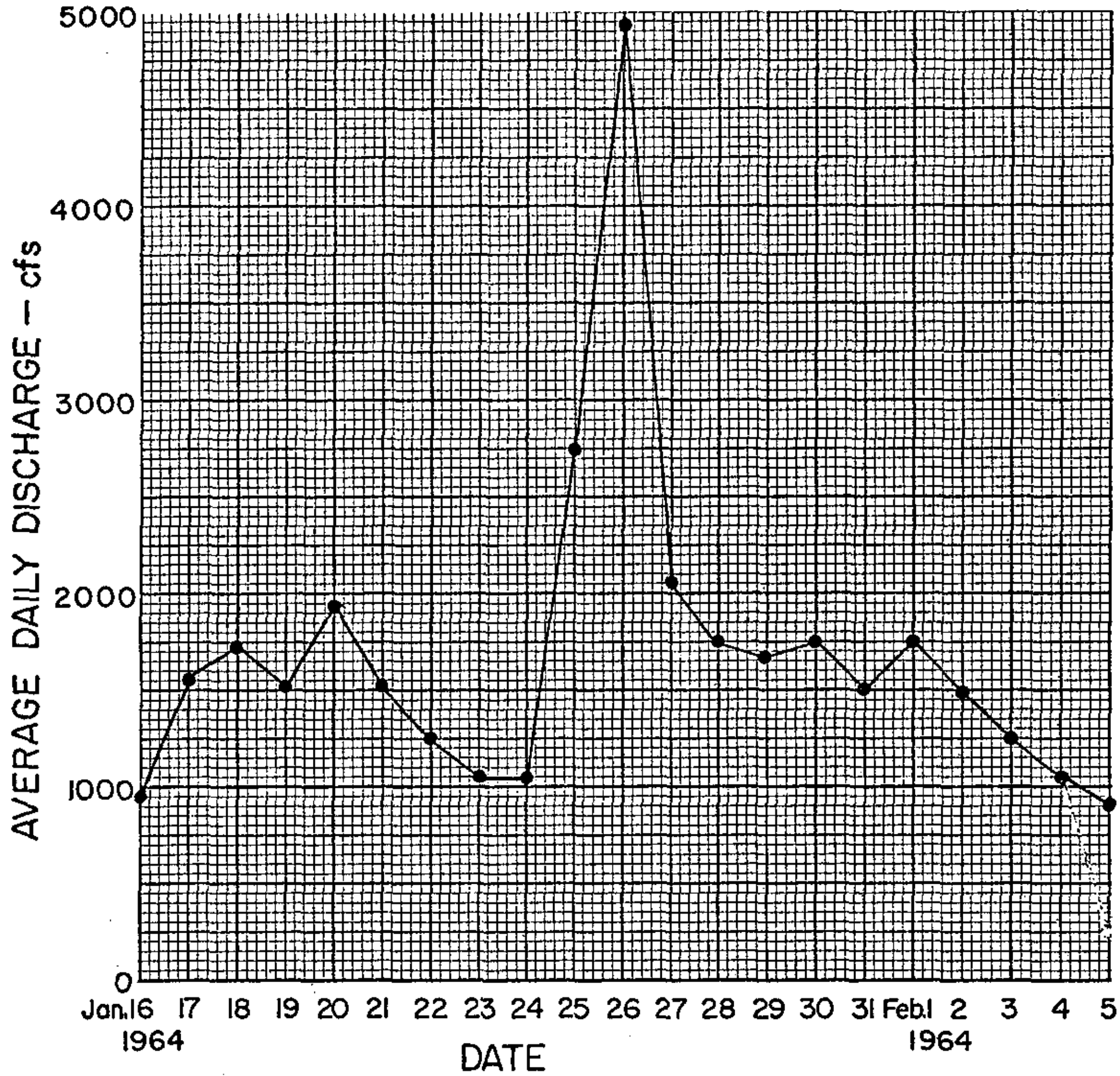

Figure 13. Hydrograph of Daily Flows in Deschutes River near Olympia, Washington, Jan. 16 to Feb. 5, 1964

The average value of 32,560 tons per year would be about 30 percent higher than the 25,000 tons estimated in reference 4. Without knowing the in-place weight of the sediment deposited in the lake, a conversion from tons per year to cubic feet per year could be made only for assumed values of in-place specific weight. Therefore, four samples of deposition were taken as part of this study at locations shown in Figure 14. The analysis of these sediment samples is presented in Table 6.

Table 6. Wet Density of Deposited Sediment

Sample No.	Wet Volume (cc)	Wet Weight (grams)	Dry Weight (grams)	Wet Density gram (cc)	Wet Density ton (cu yd)
1	1203	1924	1200	1.59	1.34
2	261	417	260	1.60	1.35
3	591	1027	709	1.74	1.47
4	220	354	196	1.57	1.32
			Average:	1.63	1.37

Based on the average submerged weight of the largest sediment sample, the average annual sediment discharge of 32,560 tons per year would be equivalent to 23,766 cubic yards per year. An analysis of variability of this load can be made by noting the variation in annual sediment tonnage in Table 5.

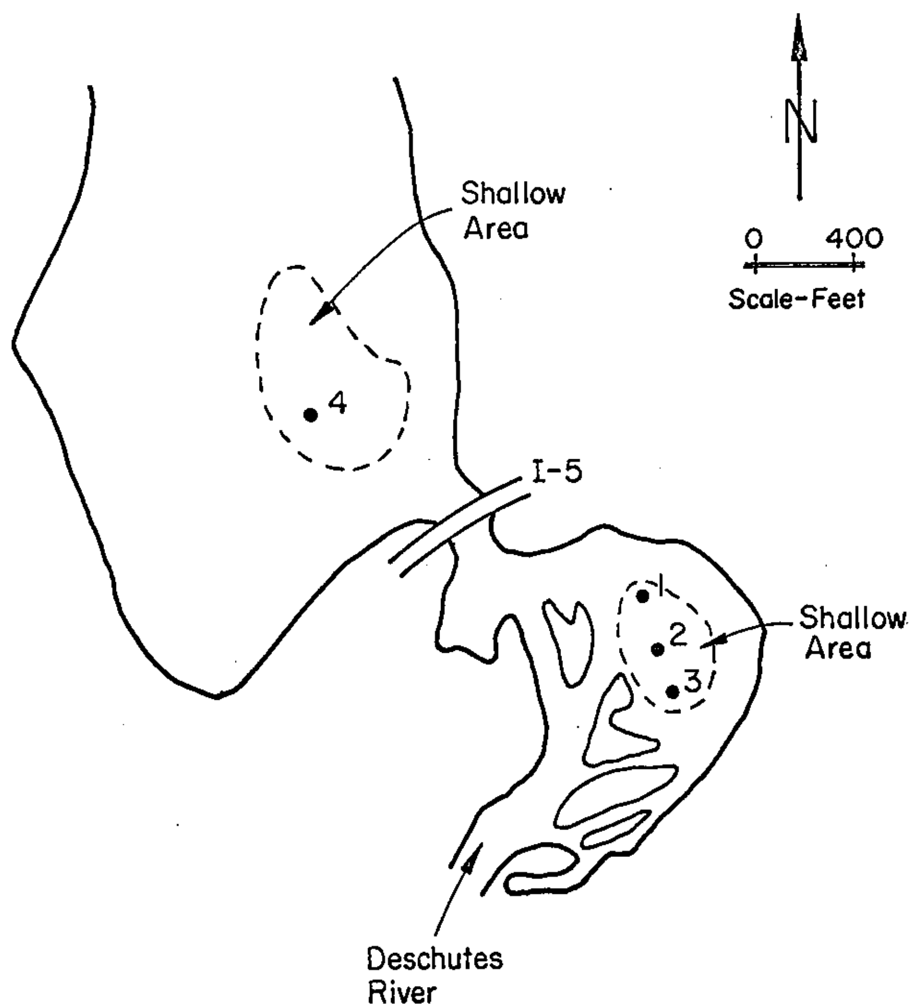

Figure 14. Four Samples of Deposition Taken as Part of this Study at Different Locations

IV. ALTERNATIVES FOR MAINTENANCE OF THE LAKE

Many alternative methods for the maintenance and initial dredging of Capitol Lake have been addressed in the report used as reference 3, "Engineering Investigation for Rehabilitation of Capitol Lake, Olympia, Washington" dated April, 1973. This report was prepared by Patrick J. Byrne and Associates of Olympia, and it provided an excellent basis upon which more detailed analysis and research were conducted on the various alternatives. For this preliminary sedimentation report, some of the proposals from the 1973 Byrne report have been given more detailed consideration as described in the following sections.

For the maintenance dredging of the upper lake, there are three main alternatives considered, and each one of them can have some modifications.

Alternative 1: The same as the periodic dredging part of proposal No. 2 in the consultant's report.[3] Briefly, an upper basin sump near the middle of the upper basin will be dredged once every two years to remove a total of 40,000 cubic yards each time at a cost of $110,800 as of 1977 according to the consultant's timetable. The dredging work would be contracted. It has been estimated that 50 percent of the sediment would pass into the middle basin. The middle basin sump located north of the I-5 bridge would need to be redredged once every 20 to 30 years. The east half of the upper basin would be closed off allowing silt removal operations to be conducted without adding turbidity to the lake water. There would be permanent bed sills, gates and sheet piling to facilitate the temporary closure and maintain channel alignments and island shapes. The cost of these structures would be $134,000 in 1975, and the cost of initial dredging of the entire lake would be $1,926,960 in 1975.

Alternative 2: A permanent piping system will be laid under the areas in the upper basin sump where sediment tends to accumulate. The size of the pipe is six inches and there are six separate pipes, each connecting to slurry pumps. This arrangement of piping is shown in Figure 15. One end of the pipe is open for dredging.

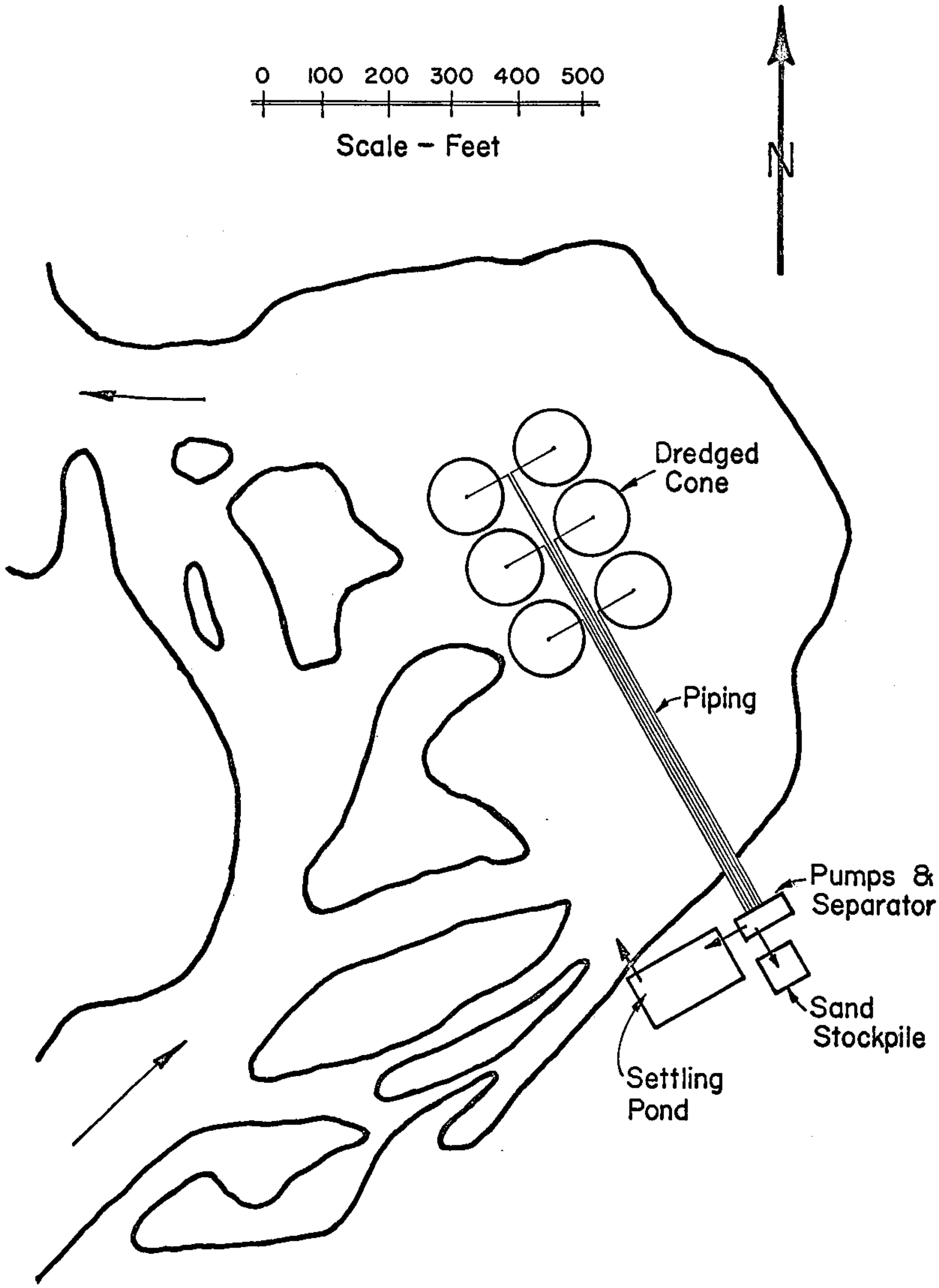

Figure 15. Dredging System for Maintenance (Alternative No. 2)

The pipe opening is laid at 30 feet below the present bottom of the lake at elev. -40. It will dredge out a 30-foot deep cone. Laboratory pumping tests on fine sand comparable to the material found in the upper lake have determined the angle of repose is 32°. The radius of the cone can be determined from the angle of repose and the depth is to be equal to 48 feet. The volume of each cone is 2,800 cubic yards. With six cones, the total volume is 17,150 cubic yards. To remove the yearly sediment accumulation of 40,000 cubic yards, the pumping system should be operated three times a year. If six slurry pumps are pumping at the same time, about three days of pumping are required to complete the dredging. Some sediment will still pass on to the middle basin but at a much reduced rate. It is estimated that the middle basin sump north of the I-5 bridge will need dredging once every 30 to 40 years.

At the dredging inlet there are water jets to help loosen up the sediment (as shown in Figure 16). One of the jets will be placed below the pipe and directed downward which will cause a pocket

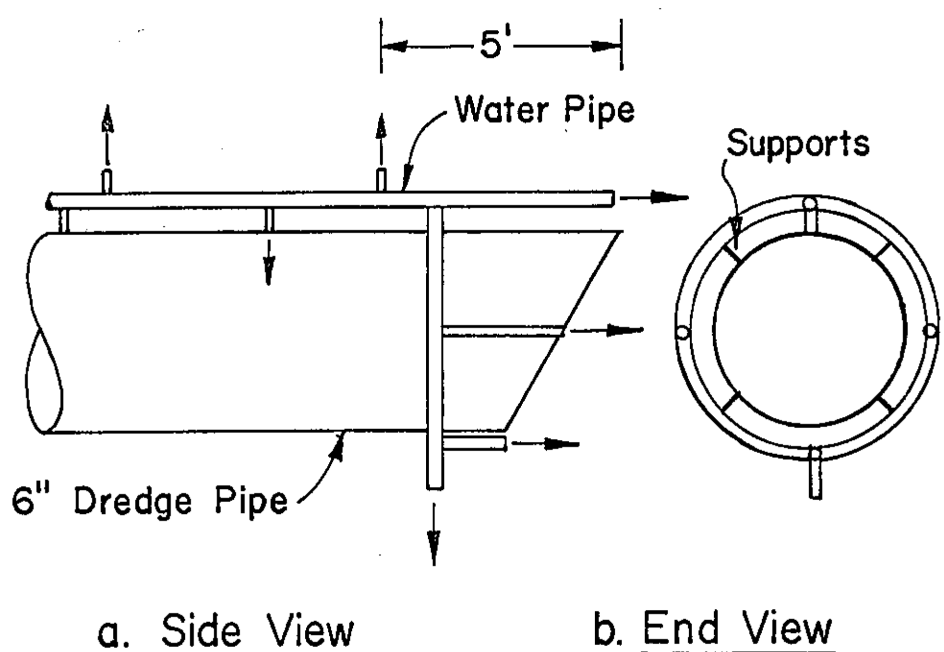

Figure 16. Inlet Jets for Alternative No. 2 Dredging System

below the pipe inlet for the accumulation of rocks. The few large rocks in the area are deposited upstream or in the deeper existing channel close to the east bank of the upper basin. The flow in the dredge lines can be reversed by using the auxiliary high head pump which supplies the small jet lines. The advantage of this system is that the dredging operation will be relatively simple and the manpower requirement for this operation is small. It can be handled by the State maintenance crew. The environmental impact is small. It is a clean and quiet dredging operation and will not increase the turbidity in the lake. After the discussion with the State fishery personnel, it is felt that a deeper suction dredge will not be detrimental to fish. The installation cost of this system has not been estimated.

Alternative 3: The State would purchase a "Mud Cat" dredging machine. One machine and 1500 feet of pipe cost approximately $70,000 in 1973. This machine would be used to dredge sediment accumulation on the east side of the upper basin. The capacity of the machine is 800 cubic yards per day. To remove 40,000 cubic yards of yearly accumulation takes 50 days. With additional pipes and a booster pump, the shallow area north of the I-5 bridge can be dredged. This machine needs two operators and could be operated by State maintenance personnel. This small dredge could be used to do maintenance dredging elsewhere in Capitol Lake and in other lakes. A place to park and store the Mud Cat must be provided.

Disposal of Dredged Material

The cost of disposal is substantial and will increase in the future after the nearby dumping sites are filled. If the dredge spoil is separated into sand and mud, the possibility of recycling this material is enhanced. A separation facility and stockpile area could be located near the southeastern shore of the upper basin. The dredged spoil would go through a a screen separator* to separate sand and larger material as shown in

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*Such as Gross-Flow Sieve by Kason Corp., 231 Johnson Ave., Newark, N.J. 07108 or Hydrasieve Screens by Bauer Bros. Co., Springfield, Ohio 45501. Hydrocyclone can also be used at a higher cost.

Figure 17. These materials will be dropped on a conveyor belt to a stockpile area. The remaining material and water will flow to a settling pond. Small amounts of suitable chemicals will be added to promote settling of the mud. The clear water will be skimmed off the surface and returned to the lake by an overflow weir and conduit as shown in Figure 18. Once the material is separated into sand and mud, it should be possible to find a company or a governmental agency willing to remove it for a fee which will reduce the disposal cost.

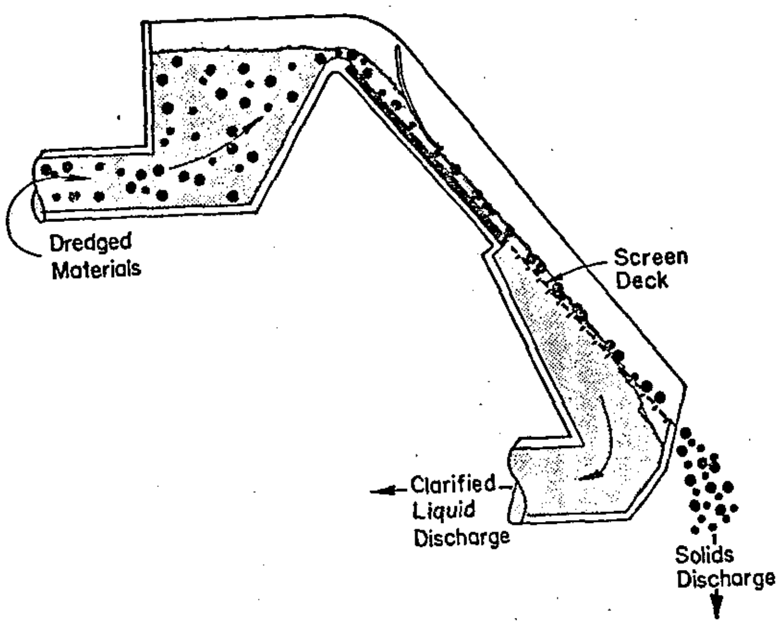

Figure 17. Screen Separator

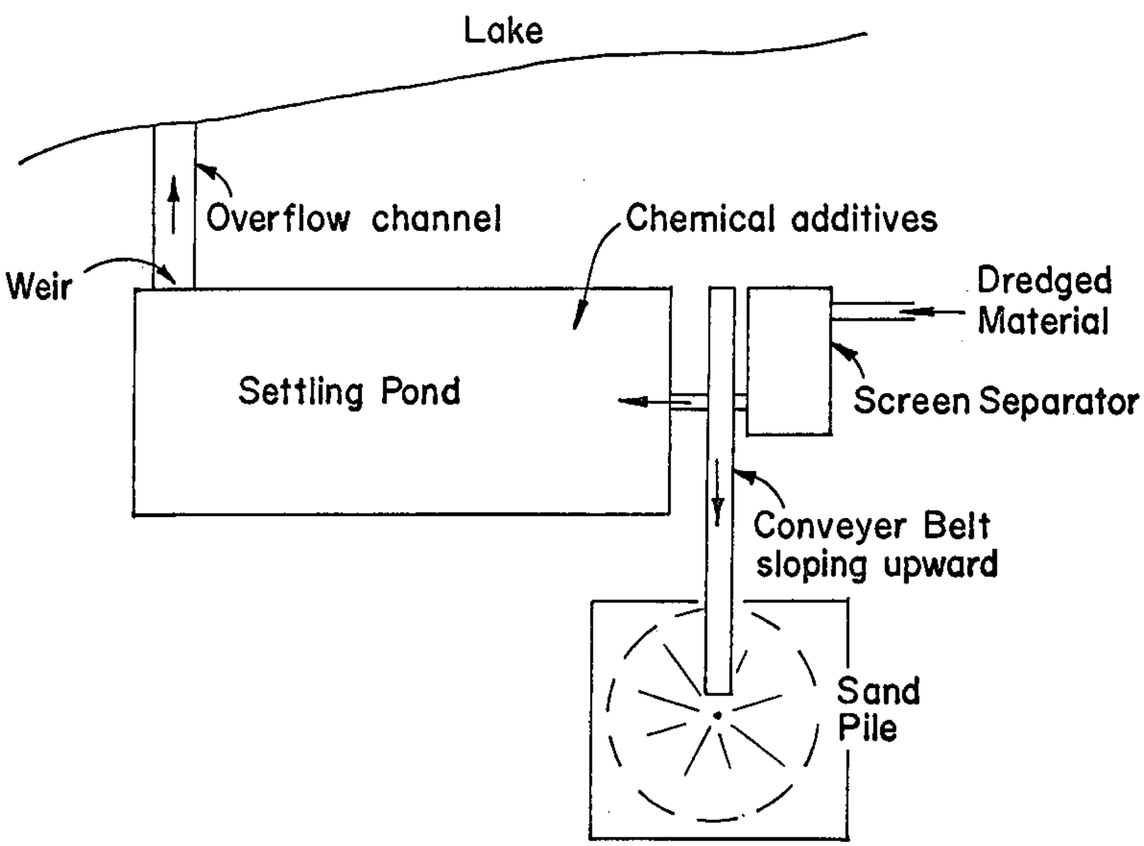

Figure 18. Treatment Facility for Dredged Materials

V. PRELIMINARY RECOMMENDATIONS

Initial Dredging

A. Initial dredging should be done by a private contractor, not by State personnel.

B. The lower (or north) basin between the railroad and the dam should not be dredged. The lower basin has reached an equilibrium condition and the existing condition does not interfere with its use. Net sediment accumulation is very small in this basin.

C. The middle basin should be dredged according to the initial dredge plan for the middle basin in the consultant's report.[3]

1. The shallow area north of the I-5 bridge should be removed and dredged to elev. -20 feet.
2. Remove the shallow area near the east shore of the middle basin and dredge to the 1951 condition in this area.
3. Remove the shallow area near the west shore according to the plan in the consultant's report.[3]
4. Dredge other shallow problem areas in the middle basin.
5. The southwest corner is a stagnate flow area and will be difficult to maintain. It should be filled to create a park area. A portion of the dredged spoil can be deposited here after riprap is used to close off the corner (see Fig. 19).

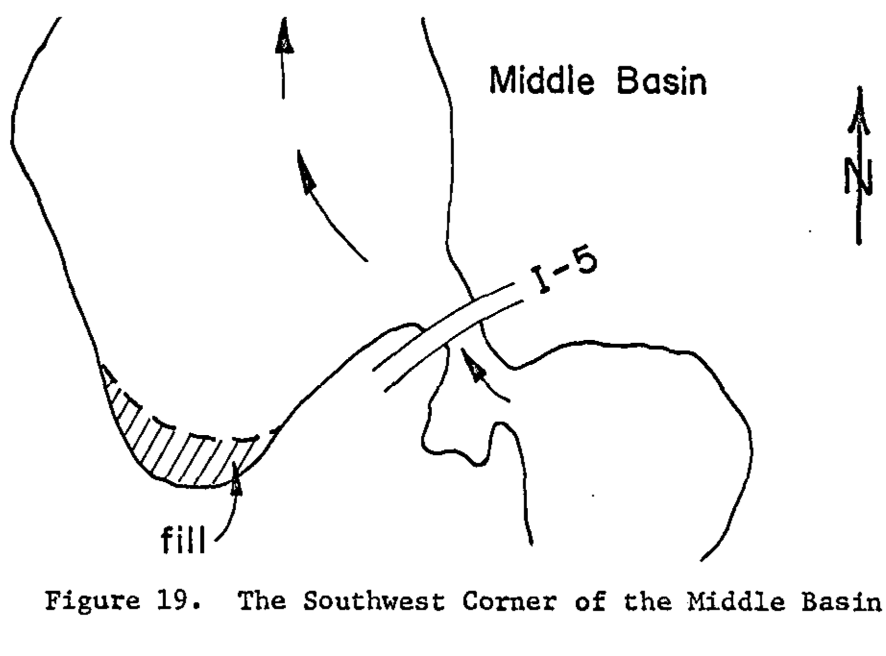

Figure 19. The Southwest Corner of the Middle Basin

D. The upper basin will not be "initially" dredged except concurrently to carry out the maintenance dredging outlined below.

Maintenance Dredging

A. Maintenance dredging should be done by State maintenance crew.
B. Alternative 2 is recommended. However, if the installation cost and maintenance is found to be too high, Alternative 3 should be used.
C. Even though the upper basin will trap a large amount of sediment, some material will move into and through the middle basin. Therefore, it can be anticipated that the middle basin will have to be dredged on a maintenance schedule, or according to the initial dredging plan once every 30 or 40 years.

Spoil Treatment

Treatment facilities should be provided near the upper basin.