Capitol Lake RESTORATION

Design Engineering Report

Prepared For
DEPARTMENT OF GENERAL ADMINISTRATION
STATE OF WASHINGTON

JULY 1976

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PREFACE

In response to increasing concern about sedimentation in Capitol Lake, the Department of General Administration requested funds to develop a program to restore Capitol Lake. Funds for the study and engineering necessary to develop the restoration program were approved during the 1975 first extraordinary session of the Washington State Legislature.

To assist the department in developing this program, a consulting firm has prepared a specific plan of action. This design engineering report describes the development and final form of the plan.

Based in part upon an extensive survey by Washington State University, four alternative concepts for restoration were developed by the consultant and evaluated according to cost, engineering feasibility and effectiveness, environmental impact, energy consumption, and compliance with established planning goals. The concept which best satisfied these criteria was chosen as the recommended plan.

The process for program selection included discussion with or review by the following organizations:

- The Capitol Lake Coordinating Committee
- Washington State Department of General Administration
- Washington State University
- U.S. Army Corps of Engineers
- Washington State Department of Ecology
- Environmental Protection Agency
- Port of Olympia
- Washington State Department of Fisheries

This restoration plan for Capitol Lake is the basis for a recreation plan also prepared for the Department of General Administration. The proposed recreation plan would provide landscaping and recreation facilities both in the new lakeside areas created by the restoration program and in the rest of the visual lake basin. The recreation plan is described in a separate document.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were reached after studying ways of restoring Capitol Lake to a condition of long-term usefulness:

- Selective dredging of 360,000 cubic yards of sediment from the upper and middle basins and Percival Cove will be necessary for the lake's initial restoration.
- Approximately 50,000 cubic yards of accumulated sediment will need to be removed from sediment traps in the lake every 2 years.
- Disposal of initial dredge spoils and 20 years' worth of maintenance dredge spoils is possible at selected lakeshore disposal locations.
- Chemical additives to the dredge slurry will be necessary to remove suspended solids and reduce turbidity of return water.
- A hydraulic dredge will provide the most efficient means of removing the sediment.

The following activities are recommended to achieve lake restoration.

- Prepare and submit necessary permits for dredging and related activities
- Prepare plans and specifications for initial dredging and construction
- Initial dredging and construction should be performed by a private contractor. The state should purchase a small dredge (a Mud Cat WC-15 was assumed in our analysis) to be used in this work. The work will include dredging of sediment traps in the upper and middle basins and Percival Cove; selective dredging of the middle basin and Percival Cove; debris removal from all three basins; protective groin construction; and preparation of disposal sites.
- Preparation of sites for disposal of maintenance dredge spoils should also be performed by a private contractor.

- Biennial maintenance dredging should be performed by the state.

- The gravel pit north of Percival Cove should be acquired as a possible disposal site.

- To prepare for the possibility that in-basin disposal sites are not available when needed, the state should acquire an out-of-basin site, right-of-way to the site, and the additional pipe and pumps to transport the dredged material to this site.

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INTRODUCTION

BACKGROUND INFORMATION

Capitol Lake is located in Olympia, Washington, immediately south of Budd Inlet. Formation of the lake was authorized in 1949 by the state legislature, and the lake began filling in 1951 following construction of a dam at the Fifth Avenue Bridge. The Deschutes River and Percival Creek empty directly into Capitol Lake. The lake's location is shown in figure 1.

Capitol Lake is separated into three basins: upper, middle, and lower. Percival Cove lies west of the middle basin and drains into it.

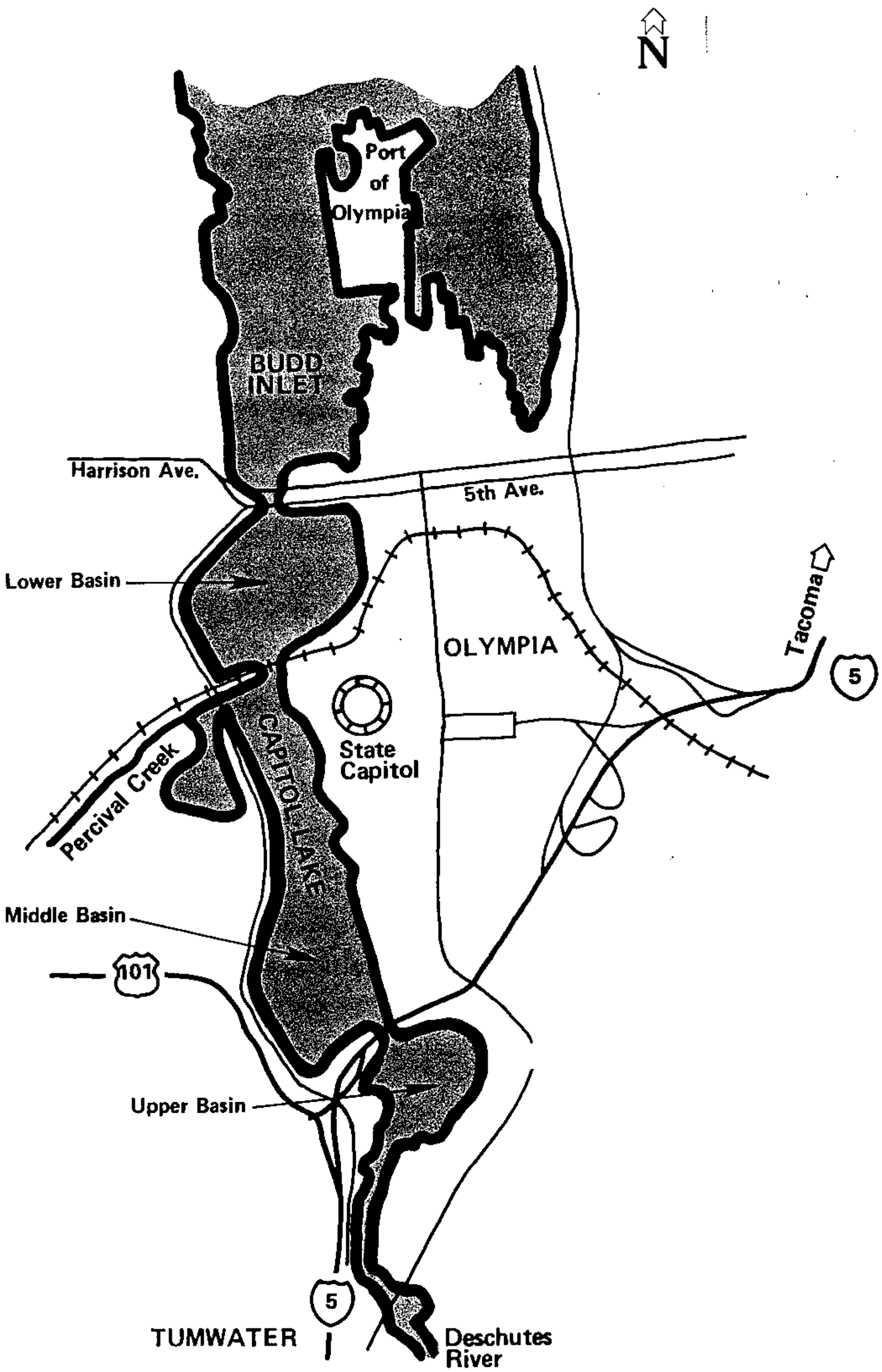
An extension of the state capitol campus, the lake provides an attractive setting for Washington's governmental seat. Because most of the lake's shoreline is publicly owned and remains undeveloped, numerous recreational activities take place in and around its waters. The lake is one of the state's most important fish-rearing impoundments, with the annual fall migration of spawning Chinook salmon drawing crowds of spectators.

The accumulation since 1951 of sediment from the Deschutes River and Percival Creek has significantly reduced the volume of Capitol Lake. Basin volumes have dropped by 77 percent in the upper basin, 13 percent in the middle, and 6 percent in the lower. These volume reductions have been caused by depth reductions of about the same percentages.

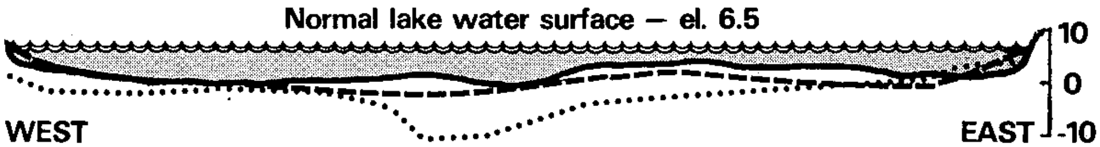
Sandbars and islands have been formed by the sediment, seriously reducing the lake's ability to produce natural fish food and restricting active water sports. Total sediment accumulation has been estimated at 1 million cubic yards. Cross sections indicating sediment accumulation are shown in figure 2. A U.S. Geological Survey report[1] gave the following description of the sedimentation process.

> On the average, about 30,000 cubic yards of sediment is deposited in Capitol Lake each year. Assuming that the deposited sediment in the lake weighs 60 lbs/ft^3 and that 25,000 tons of sediment are deposited annually, the lake would fill with sediment in about 130 years, barring any dredging operations. The filling would be a progressive process; the upper part of the lake at the river's mouth would be filled first in an estimated 6-8 years, then the middle segment in about 60 years, and finally the lower part next to Budd Inlet.

U.S., Department of the Interior, Geological Survey, *Sediment transport by streams in the Deschutes and Nisqually River Basins, Washington*, 1974.



Vicinity Map 1

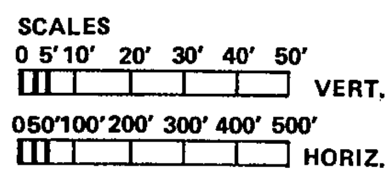


SECTION-MIDDLE LAKE

SECTION-UPPER LAKE

LEGEND

- 1975 Bottom
- 1970 Bottom
- 1949 Bottom



Most of the sediment transported to Capitol Lake originates in the upper basin; land-use practices in the lower basin probably have minor effect on the magnitude of sediment deposition in the lake. Much of the increase in erosion in the upper basin is the result of logging, road construction, and alteration of stream channels.

OBJECTIVE AND SCOPE

The objective of the design engineering phase was to develop a plan to restore Capitol Lake to a condition of long-term usefulness. This restoration should include improvement of the lake's recreational and visual resources, preservation of its biological and wildlife resources, and improvement of its fish production.

Previous investigations[1,2] recommended that this restoration be accomplished by selectively removing sediment to increase the water depth, by creating new land areas, and by controlling future sedimentation by means of sediment traps. The conclusions and recommendations of a restoration study by Washington State University are shown in appendix B.

RESTORATION PLAN DEVELOPMENT

The following activities were undertaken to develop a restoration plan:

- Review previous reports and available data and information
- Perform field and laboratory investigation of the lake sediments
- Investigate techniques applicable to lake dredging
- Identify and investigate disposal locations
- Identify sediment properties and analyze methods for disposal of dredge spoils
- Develop dredging and disposal alternatives and prepare preliminary cost estimates

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1 Hydraulics Research Section and Environmental Research Section, Washington State University. September 1975. *Hydraulic and water quality research studies and analysis of Capitol Lake sediment and restoration problems.* A report for the Washington State Department of General Administration.

2 Byrne, P. J. 1973. *Engineering investigation for rehabilitation of Capitol Lake, Olympia, Washington* (Publication and Plans).

- Analyze the dredging and disposal alternatives to develop a preferred dredging and disposal plan

- Present recommendations in a report

As documented in the WSU report, the location and quantity of sediment removal are important to the restoration objectives. Therefore, early in the project the following potential sediment-removal concepts were identified and selected for further evaluation:

- Selectively remove sediment from the middle basins and provide sediment traps in the upper and middle basins

- Remove sediment in the upper basin to 1949 contour and provide a sediment trap in the middle basin

- Leave the upper basin in its existing condition and provide a sediment trap in the middle basins

- No action in the entire lake, allowing the lake to fill and gradually form a marsh and river channel

Study of these concepts led to development of a preferred restoration plan based on selective removal of the sediments. This restoration plan included dredging concepts, a disposal plan, and a maintenance plan. Two alternative restoration plans were also developed and evaluated to cover the contingency of some recommended disposal sites not being available when needed.

CONCEPTS FOR INITIAL DREDGING

Dredging was recommended by the WSU report as the best means of restoring Capitol Lake to a condition of long-term usefulness. A program consisting of initial dredging in 1977 followed by periodic maintenance dredging was developed after a review of the WSU study and discussions with the Capitol Lake Coordinating Committee, Department of General Administration and Department of Fisheries. The WSU report examined sedimentation, water quality, and water quantity to provide a data base upon which planning, design, and management decisions could be made for the dredging and maintenance of Capitol Lake.

This chapter describes the alternative concepts that were evaluated during development of a recommended initial dredging plan.

SEDIMENT TRAP CONCEPTS

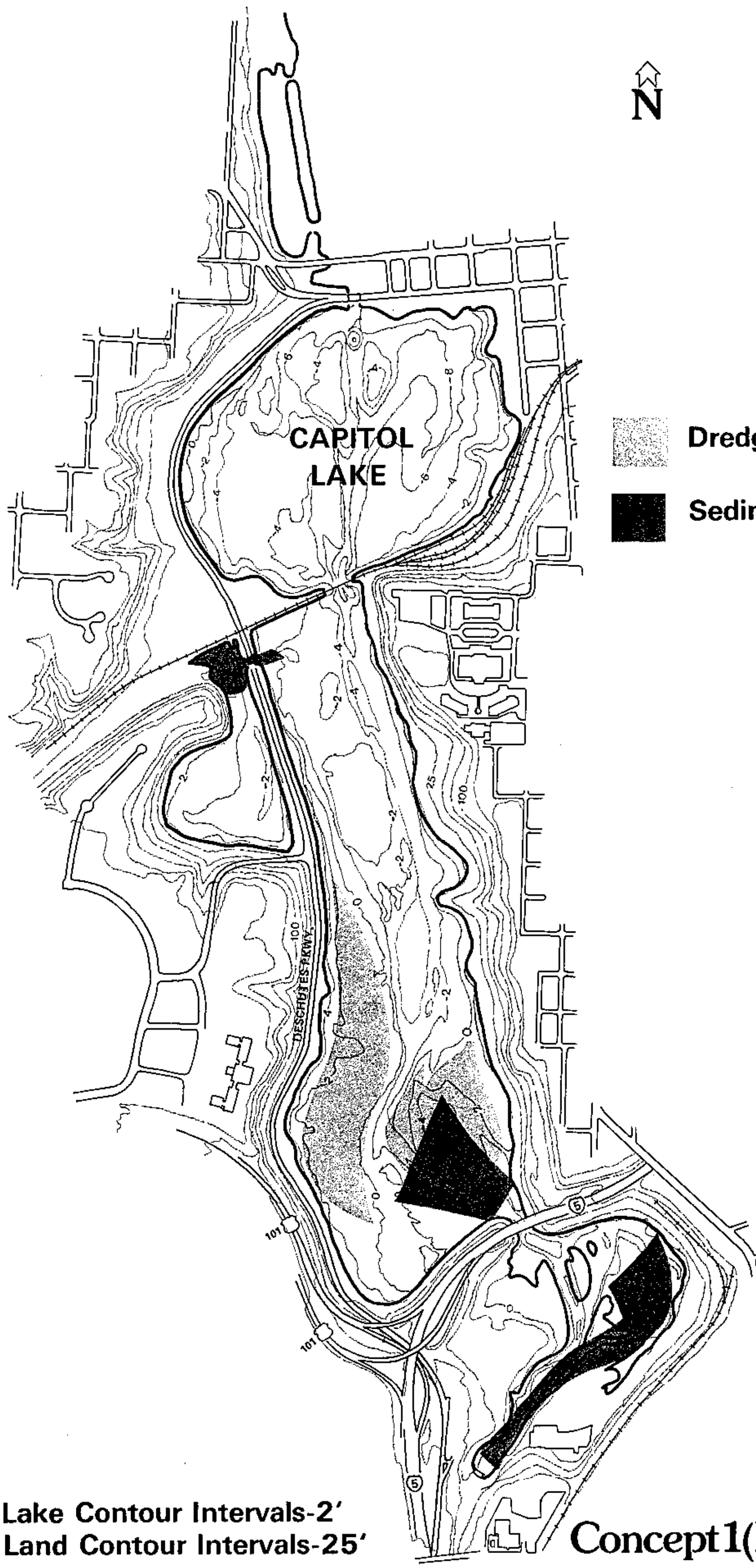
Sediment traps are needed to catch and hold incoming sediment in order to prevent sediment from accumulating in restored areas. The sediment trap works by providing an area for the river to expand, lose velocity, and drop a large part of its sediment load. Sediment traps also provide a convenient place to hold sediment until it can be removed by maintenance dredging. Three alternative sediment trap concepts were developed and evaluated.

Concept 1

This concept (figure 3) was evaluated during the WSU hydraulic and water quality study. The plan calls for a gradually widening river channel from the lower falls to the site of a sediment trap in the east side of the upper basin. Filling between the two existing islands and construction of a protective groin are required to channel the river into the sediment trap area. Erosion protection is also needed along the south side of the newly formed island. About 159,000 cubic yards of material would be excavated.

The WSU study concluded that this concept provides a very efficient sediment trap. After the two existing islands are joined and the groin constructed, the main flow will pass through a primary channel around the south end of the island into the area east of the island. Much of the sediment load will be deposited in the sediment trap in this area.

Immediately after the project is completed, some of the flow will pass between the island and west shore. However,



Dredge to 6′ water depth

Sediment trap

Lake Contour Intervals-2′
Land Contour Intervals-25′

Initial Dredging Concept 1 (Recommended) 3 sediment will quickly fill this secondary channel, and the bulk of the flow will then pass around the south end of the island. The sediment in this secondary channel can easily be dredged during maintenance dredging.

The protective groin is an important part of this concept. During high flood flows, the groin will make sure the flow continues around the south end of the island and across the sediment trap.

A sediment trap is also necessary in the middle basin immediately north of the I-5 bridge. This trap would catch and hold some of the finer sediments passing through the upper basin. Some of the very fine sediments will pass through the middle and lower basins and into Budd Inlet. During annual drawdown and flushing of Capitol Lake, large quantities of sediment are carried from the upper basin to the middle basin as the water level drops. This movement will continue under this dredging concept, but the sediment will collect in the middle basin sediment trap. The total quantity to be dredged in forming the middle basin trap is approximately 97,000 cubic yards.

Much of the present marshland on the lakeshore and islands would be retained under Sediment Trap Concept 1.

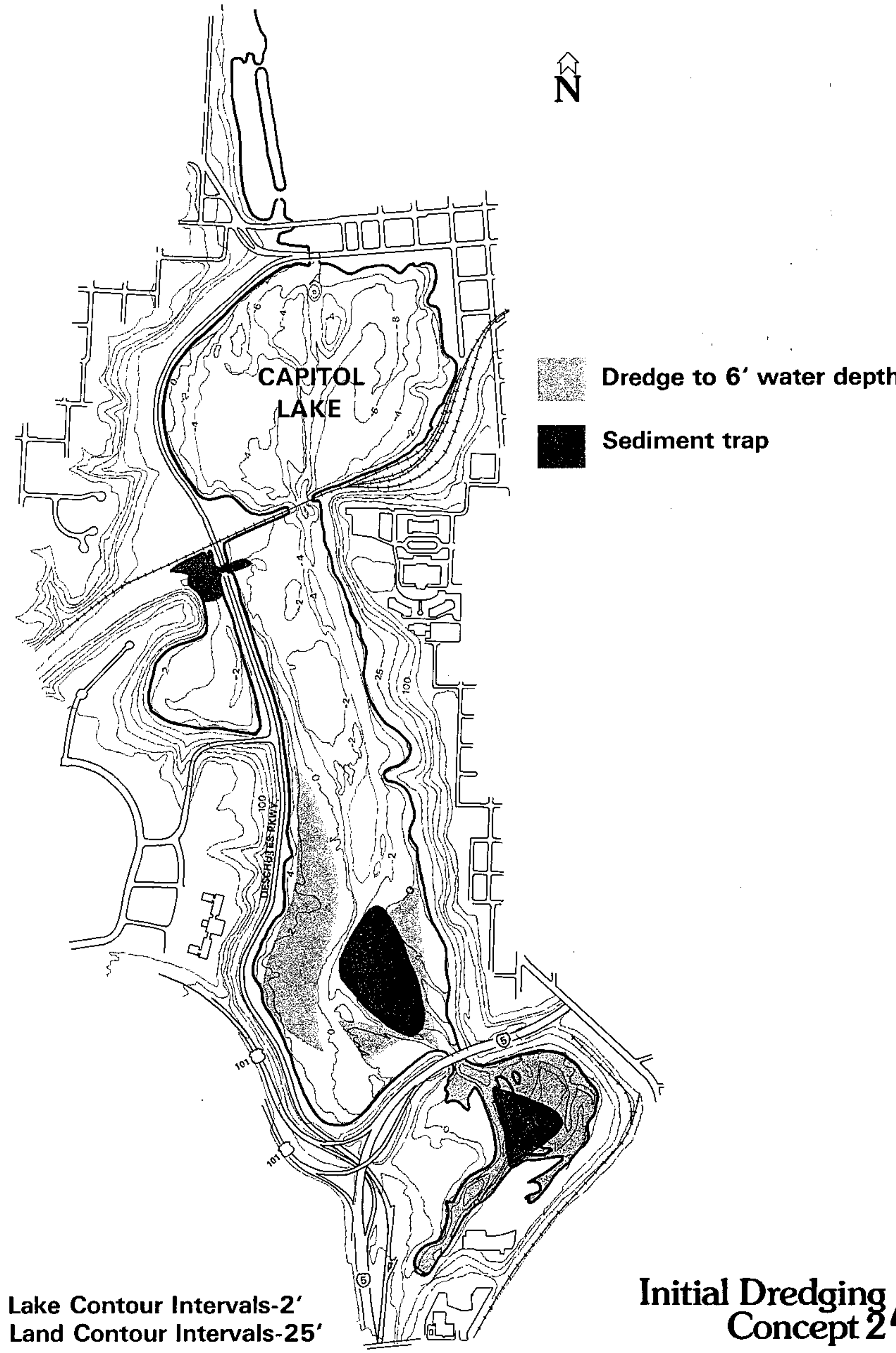
Concept 2

This concept[1] (figure 4) would dredge all of the upper basin and remove the existing islands. A sediment trap would be located at the mouth of the river; the rest of the basin would be dredged to a 6-foot depth. Approximately 170,000 cubic yards of excavation are required with this concept.

The WSU study concluded that the sediment trap and hydraulics of this concept are not as efficient as in Concept 1. The flow will continue to expand and lose velocity in the upper basin after passing across the sediment trap, allowing finer sediment to settle out between the sediment trap and the middle lake. All the islands and marshlands would be removed under this concept, but the water surface of the upper basin would be completely restored.

As in Concept 1, a sediment trap would be required in the middle basin to hold the sediment passing through the upper basin.

[1] Orsborn, J. F. January 1976. *Supplemental sediment tests of Capitol Lake hydraulic model.* A report for the Washington State Department of General Administration.



Initial Dredging Concept 2 4

Concept 3

This concept[1] (figure 5) would involve no dredging in the upper basin. The WSU study concluded that the upper basin will completely fill with sediment, debris and aquatic growth under this concept. The sediment which had been collecting in the upper basin would then accumulate in the middle basin. During drawdown of Capitol Lake, there would be redistribution of the upper basin bed materials either into low areas of the upper basin or into the middle basin sediment trap. The WSU studies found that the rate of this sand movement through the upper basin into the middle basin varied as a function of water discharge and lake level, with more material being moved at higher flows. Approximately 180,000 cubic yards of material would be dredged in forming the middle basin sediment trap.

CONCEPTS FOR SELECTIVE DREDGING OF THE MIDDLE BASIN

Several areas of the middle basin need to be dredged in order to remove shallow areas that are hazardous to active water sports. A minimum depth of 6 feet was considered adequate for such recreational activities after discussions with the Capitol Lake Coordinating Committee and the Department of General Administration.

Considering water quality, biological conditions, and fish-feeding requirements, it was decided there was no need for dredging deeper than 6 feet. Field observations indicated light levels are adequate for weed growth as deep as 16 feet. Sediment nutrients such as nitrogen, phosphorus and organic contents were determined to be independent of sediment depth over the range sampled. It was concluded that factors such as saltwater flushing of the lake limit weed growth more effectively than do water or sediment depth. Fisheries needs are also satisfied by water depths of 6 to 8 feet, according to the Department of Fisheries, and dredging to 1949 depths would destroy a significant amount of fish-feeding area.

General dredging of the middle basin to a 6-foot depth should include the east shoreline. Dredging should not be done within 150 feet of the west shoreline because of the marginal stability of the loose sand and silt in that area.[2] This will protect the adjacent roadway and existing fishery habitat. The bottom will be tapered to provide a gradual slope from the shoreline. The selective dredging of the middle basin would remove about 85,000 cubic yards of fine sand and silt.

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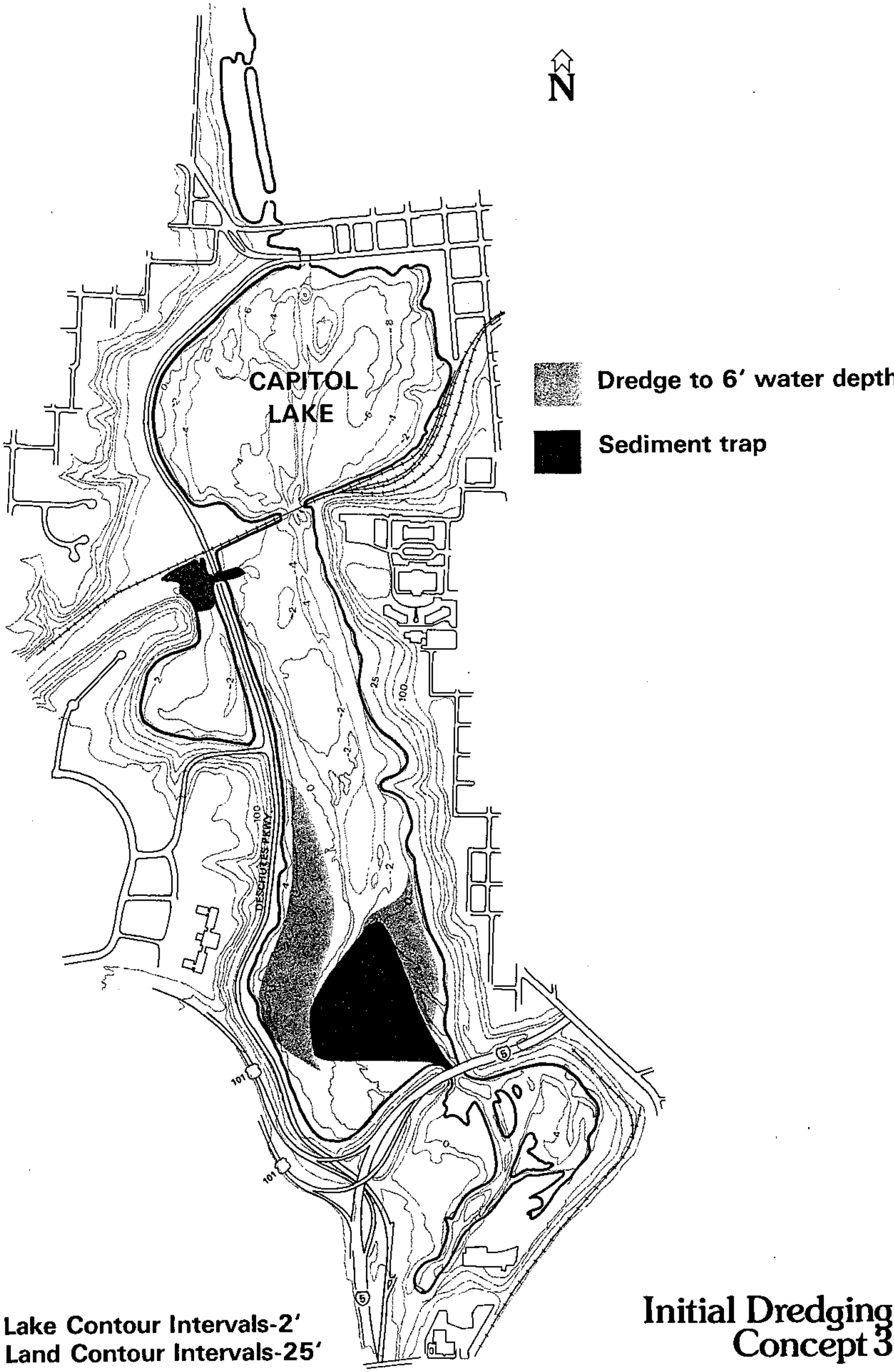
1 Orsborn, J. F., op. cit.
2 Byrne, P. J., op. cit.



Lake Contour Intervals-2′
Land Contour Intervals-25′

Initial Dredging
Concept 3

LOWER BASIN CONCEPTS

No dredging is recommended for the lower basin. Water depths are already greater than the 6 feet needed for recreational activities. The WSU study has concluded that dredging this basin would provide no benefit for water quality or circulation. The lower basin is already considered good fish-feeding area by the Department of Fisheries, and the agency does not favor dredging this basin.

Sediments in the lower basin have received little study. The WSU researchers did not perform intensive studies in this basin because there was no dredging proposed for it; they did emphasize the limited extent of existing sediment data. The report said that if more than general inferences are needed, more detailed studies of sediment composition may be advisable.

A report[1] on recently completed supplemental flow and sediment tests considered the possibility of changing the location of the river channel in the lower basin. The report concluded that guiding water flow with a bottom channel will not improve circulation because a channel guides only the slower bottom velocity layer and not the surface layers. A new deep channel would also be difficult to maintain.

PERCIVAL COVE DREDGING CONCEPTS

Percival Cove is presently used as a fish-rearing area by the Department of Fisheries. Sediment from Percival Creek has accumulated near the cove outlet, preventing the complete drawdown of the cove needed to drive young salmon from the cove into the lake. The cove should be dredged to remove approximately 20,000 cubic yards of this sand and gravel to allow complete dewatering and to provide a sediment trap for future deposits from Percival Creek.

RECOMMENDED INITIAL DREDGING

The concepts for the dredging of Percival Cove, the selective dredging of the middle basin, and the recommended sediment trap (Concept 1) have been combined into a recommended concept for initial dredging as shown in figure 3. The WSU study has concluded that this concept is most efficient on the basis of hydraulics and sedimentation. This concept also retains much of the existing marshland in the upper basins while providing a deepwater area for lake-oriented activities on the east side of the upper basin.

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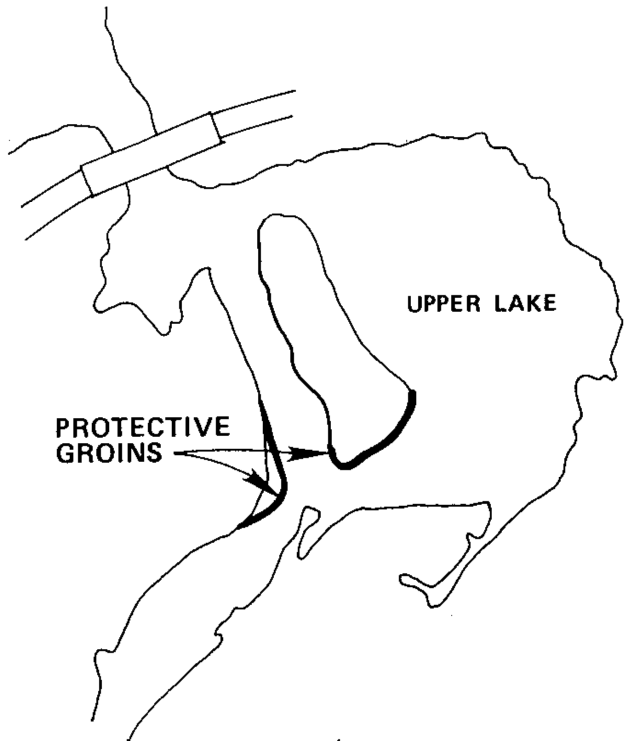
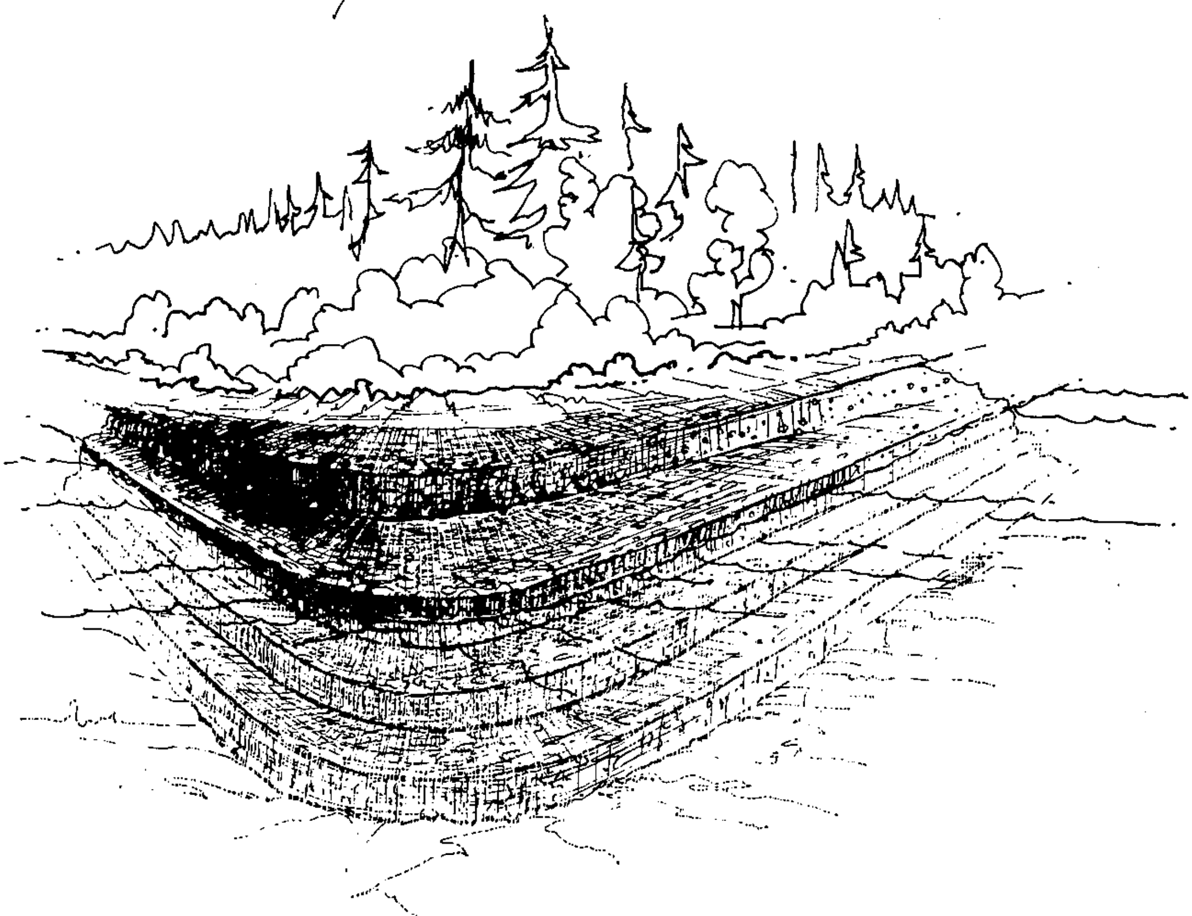
1 Mih, Walter C. 21 May 1976. *Supplemental flow and sediment tests of Capitol Lake hydraulic model.* A report for the Department of General Administration.

Gabions--wire baskets filled with rocks--are recommended for the protective groins at the Tumwater Park and on the south side of the upper basin island. Because gabions are flexible, they are advantageous for erosion-prone areas such as this. Figure 6 shows a typical protective groin before revegetation and the locations of the two groins in the upper basin.

The existing islands, the fill between, and the protective groin should be brought up to a maximum elevation of 14.0 feet above mean sea level. This elevation should put the top of the island above the estimated flood elevation reached during a flow of 6,000 cubic feet per second. The flood elevation was estimated based on a simulated hydrograph presented on page 43 of the WSU study.

Hydraulic model studies by WSU indicated that the recommended dredging of the upper and middle basins could increase the lakewater's mean residence time by 2 to 4 days. This could increase algae growth at low flow periods.





Protective Groins Before Revegetation 6

EXCAVATION TECHNIQUES

Four different techniques were studied for removing sediment and transporting it various distances over land and water to spoils disposal sites. They are:

- Hydraulic pipeline dredge with pipeline direct to disposal area
- Dragline - Sauerman bucket to shore; includes on-shore reloading to truck and hauling to spoils disposal area
- Floating clamshell dredge; includes spoils barge to onshore landing and unloader conveyor, and truck haul to spoils disposal area
- Tractor-scraper and earthmoving equipment; includes lake drawdown and drying out period

The tractor-scraper earthmoving and the hydraulic pipeline dredge are the only two systems which do not require re-handling of the spoils and transfer into a second conveyance for in-basin disposal. However, use of the tractor-scraper technique would require drawing down the water surface of the lake to a low level and holding it for several months during the summer for drying before the tractor-scrapers could venture onto the soft bottom sediments. This method is unacceptable because of the pressure of fisheries and recreation uses of the lake.

TECHNIQUE DESCRIPTION

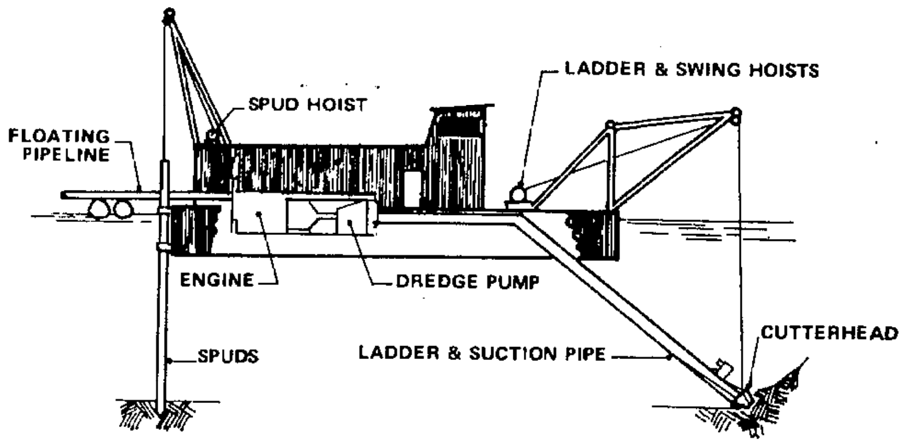
The three underwater excavation techniques are described below and are shown in figure 7.

Hydraulic Suction Dredge

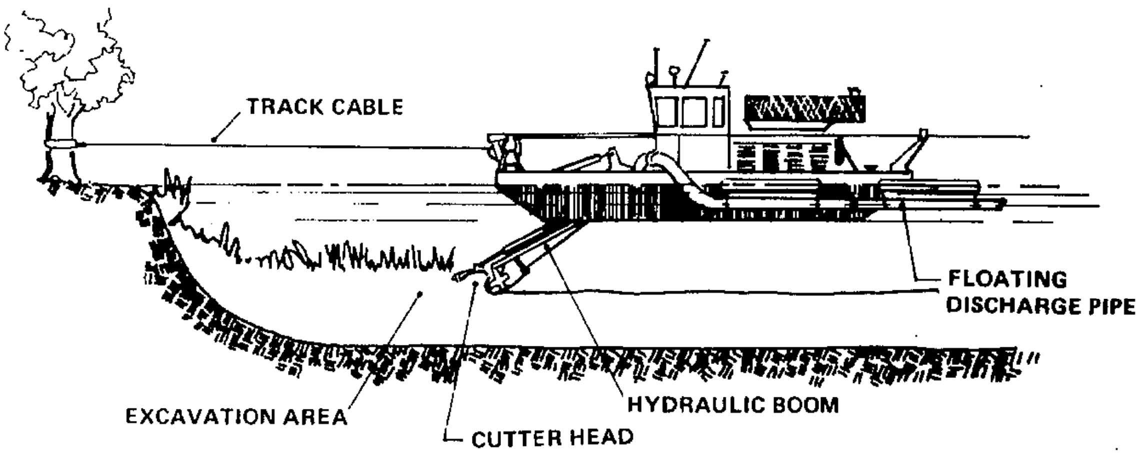
The major elements of this system consist of a cutterhead, a suction pipe, and a pump mounted on a floating hull and discharging through a pipeline to a disposal area. In operation, the cutterhead loosens the sediment on the bottom, mixes it with water to form a slurry, and moves it to the entrance of the suction line. The pump sucks the slurry up the suction line and pushes it through the discharge pipeline.

This dredge moves over the area to be excavated by pivoting on spuds alternately set down into the bottom and raised at the stern corners of the hull. Mooring lines attached to anchors set out at an angle to each bow are used with deck winches to swing the dredge about the spud pivot. At the completion of a swing, the alternate spud is lowered, the pivot spud is raised, and a pull against the opposite mooring line "walks" the dredge ahead.

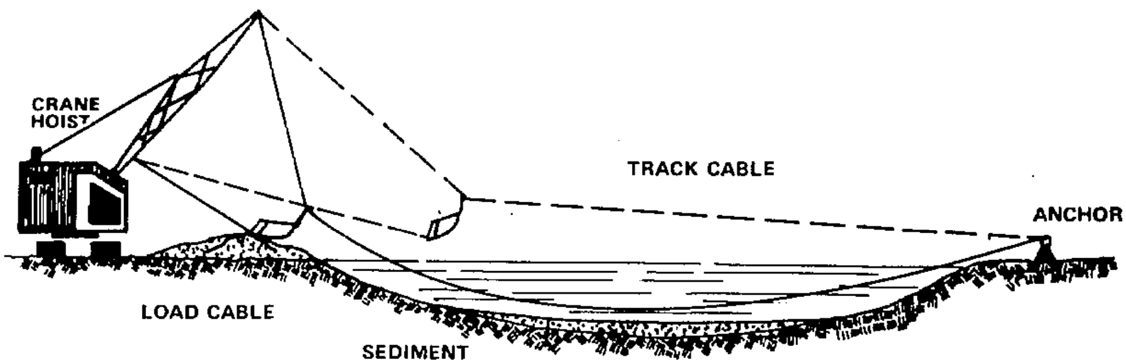
HYDRAULIC CUTTERHEAD DREDGE



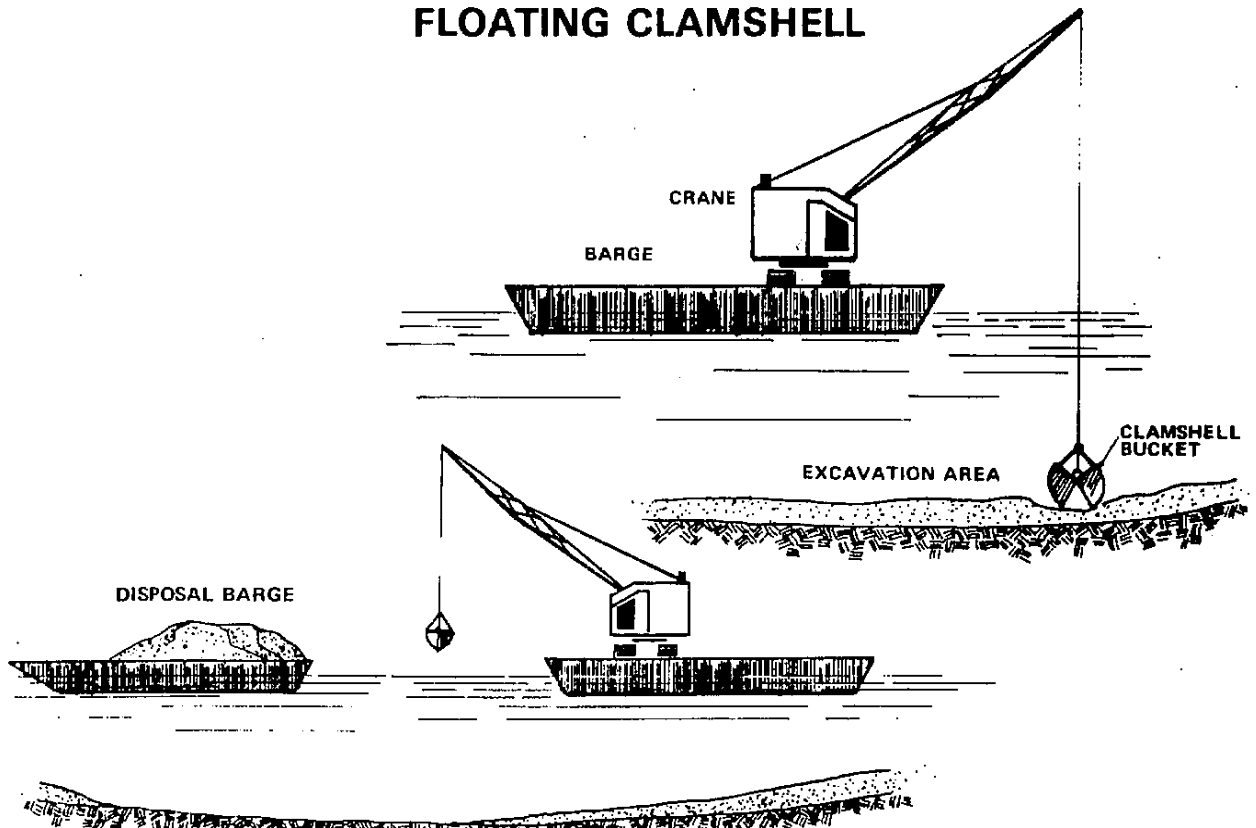
MUD CAT



SAUERMAN BUCKET INSTALLATION



FLOATING CLAMSHELL



Certain small dredges of the Mud Cat type move in a straight line by winching along a guide wire, stretched between anchors on each shore or between anchored buoys. The Mud Cat cutterhead has a width of about 8 feet which determines the spacing between successive settings of the guide wire.

The discharge pipeline may be floated over water with pontoons and laid on the surface of the ground to reach disposal areas up to 6,000 feet away. Booster pumps in the discharge line could extend the reach to more than 12,000 feet.

Auxiliary equipment will include a barge for fuel oil and pipe storage, a tug and derrick barge for setting out and moving anchors, removing obstructions and picking up debris from the shoreline; and a bulldozer for spreading and compacting spoils in disposal areas.

Only portable dredge hulls can be used in Capitol Lake because of the dam at Budd Inlet. Portable dredge hulls with 8-inch, 10-inch, 12-inch, 14-inch, and 16-inch pump discharge diameter are available by contract and portable dredges of the 6-inch Mud Cat type are available under contract, lease, or purchase arrangements.

Dragline - Sauerman Bucket

This system operates on the same principle as the common dragline except that its reach is extended through the use of a special track cable which may be anchored up to 800 feet away. In operation, the bucket, which has no bottom, rides out on trolleys on the taut track cable to the far side of the excavation area. There the track cable is slacked off, allowing the bucket to descend to the lake bottom. The hoist then drags the bucket back along the lake bottom to the near shore where the track cable is again tightened, lifting the bucket and dumping its load on the shoreline.

The major problem with the system is the difficulty of re-handling the sloppy excavated materials. Since the Sauerman bucket has no bottom, these materials cannot be loaded directly into other vehicles for transport to disposal areas. Reloading this material with conventional equipment is both inefficient and costly, and large areas along the shoreline are required for drying out prior to reloading.

The dragline-Sauerman bucket is not considered suitable for application at Capitol Lake. The middle basin, with only one accessible shoreline, has a minimum width of 800 feet and a maximum width of about 1,600 feet, while this equipment has a practical reach of only about 1,000 feet. The upper basin would require operating reaches of up to 1,200 feet and frequent moves to excavate the desired sediments traps and channels. Also, the accessible shoreline of both basins is too narrow for drying or reloading operations.

Floating Clamshell Dredge

This equipment includes a boom, a hoisting mechanism, and a clamshell bucket supported by a floating hull. It may consist of a land-type portable crane mounted on a barge. Because it cannot transport excavated material beyond the reach of the boom, it relies on spoils barges and a tug to deliver the excavated material to shore. At the landing, the excavated material must be transferred to other vehicles for delivery to the disposal areas.

The floating clamshell dredge would also be used to remove sunken logs, stumps, large rocks and other debris encountered during dredging, and to remove debris which has accumulated along the shoreline.

TECHNIQUE COMPARISON

The following is a summary of the advantages, disadvantages, and costs of each of the underwater techniques.

Large Hydraulic Dredge

Advantages

- Production rate highest; unit cost lowest.
- With booster pumps and discharge pipeline, range is almost unlimited.
- Moves spoils direct from excavation to disposal area; no rehandling or transfer, no truck traffic increase.
- Can sweep a wide area without resetting anchors.
- Has good depth control.

Disadvantages

- Adds several volumes of water to spoils for transport; effluent flow rate is high.
- System may be easily clogged by debris.

- Mobilization costs highest.
- Equipment not adapted to shallow cutting or slope trimming.

Small Hydraulic Dredge

Advantages

- Same advantages as large hydraulic dredge except production rate and unit cost.
- Effluent flow rate is less than that of large dredge.
- Mobilization cost less than that of large dredge.
- Small discharge lines easily laid and moved by small crew, light equipment.

Disadvantages

- Same disadvantages as large hydraulic dredge except effluent flow rate and mobilization cost.
- Guide wire system used on Mud Cat type requires frequent resetting of anchors and overlapping cuts in resistant materials.
- Very susceptible to clogging by small debris.
- Production rate is much lower than large dredge.
- Unit costs are much higher than large dredge.
- Reliability less and repairs more frequent than large dredge.

Dragline-Sauerman Bucket

Advantages

- Mobilization costs low; uses readily available excavation equipment plus some additional rigging.
- Has ability to make shallow cuts and trim slopes.
- Can handle boulders and large pieces of debris.

Disadvantages

- Large land area required for crane and for receipt and transfer of spoils.
- Limited reach of system; not practical in lake over 1,000 feet wide.
- Requires frequent moves of both haul-back anchor and crane to cover shallow dredging over a wide area as in middle basin.
- Requires a second loading operation when spoils have been placed on shore; bucket not adapted to loading directly into trucks or other vehicles.
- Production rate is low.

Floating Clamshell Dredge

Advantages

- System adds very little water to spoils; small return flow.
- Best system for removing debris, sunken logs, and boulders.
- Equipment readily available in the area; mobilization costs low.

Disadvantages

- Range is limited to reach of crane boom; transfer barge and reloading required at shore.
- Rate of production low compared to hydraulic dredges.
- Slope trimming and shallow cuts are difficult.

Costs

Costs and production rates of the three techniques are compared below.

Excavation Technique	Cost Range ($/Cubic Yard)	Production (Cubic Yards/Hour)
Hydraulic Dredge	$ .50-1.50	75-600
Dragline-Sauerman Bucket	3.90-9.50	40-55
Floating Clamshell	5.75-7.50	40-55

RECOMMENDATIONS

The technique found most effective and least costly was the hydraulic pipeline dredge. This technique combines the work of excavation, transport, and discharge of spoils into a single operation. Both the large and small hydraulic dredges are less costly than the other techniques, and would work well for this operation.

DISPOSAL

The sediment dredged from Capitol Lake will be removed in a slurry form and will require disposal under controlled conditions at either inland or shoreline disposal sites. About 360,000 cubic yards of material will be removed from the lake during initial dredging. Maintenance dredging over a 20-year period will remove 500,000 to 600,000 cubic yards based on an average removal rate of 50,000 to 60,000 cubic yards every 2 years.

DREDGE SLURRY TREATMENT

The dredged material can be pumped either to inland disposal sites or to selected sites along the shoreline. At both locations the settleable solids should be removed from the dredge slurry and the turbidity of the return flows reduced to be approximately equal to that of the receiving waters. The background turbidity of Capitol Lake varies seasonally. Periods of low turbidity occur during the dry weather season of May to October, when solids concentrations range from 2 to 12 mg/l. During periods of high discharge, November to January, the solids concentration can reach 100 mg/l. The middle and lower basins generally exhibit greater turbidity than the upper basin.

The dredge slurry pumped to the proposed disposal sites will require ponds or containment areas to remove the settleable solids and reduce the turbidity of the return flows. The Capitol Lake disposal areas could use a flow-through system to remove the solids. In this system, the slurry enters at one end of a pond and slowly flows through the pond. Larger particles settle out as the slurry flows through the pond, allowing the return water to be free of settleable solids. The flow-through system allows continuous dredging operation.

The smallest particle that will settle out in a flow-through system of practicable size has a diameter of approximately 0.005 mm. On the average, about 16 percent of the dredged material may be smaller than 0.005 mm and would not settle out in this system. To remove particles larger than 0.005 mm, a 2- to 3-acre pond would be sufficient if a 6- or 8-inch dredge were used, and a minimum area of 10 acres would be required if a 16-inch dredge were used.

If the particles smaller than 0.005 mm leave the pond with the return flow, the concentration of the return flow will be about 3.1 percent by weight (31,000 mg/l). We expect that return flows having concentrations of approximately 3 percent by weight will produce visible turbidity in the lake if discharged at the surface. The visibility of this turbidity would be reduced or eliminated by discharging the return flows underwater into deep areas of the middle basin. However, in either case about 16 percent, or 57,600 cubic yards, of the dredged material would be returned to the lake by this turbidity. To make the particle concentration of the return flows approximately equal to the concentration of Capitol Lake water, liquid chemical polymers must be added to the dredge slurry. These polymers will cause the particles smaller than 0.005 mm to rapidly settle in a containment area instead of returning to the lake.

Laboratory settling tests were performed on lake soil samples using Magnifloc M573C cationic liquid polymer; Magnifloc M905 nonionic liquid polymer; and a combination of these. One of the soil samples tested was mixed to represent the average composition found in the Capitol Lake sediments. Another soil sample was composed of clays and silts extracted from Capitol Lake samples and was prepared to simulate the suspended solids in the return flow.

Each of the polymers and the combination were successful in settling the fine particles and reducing the turbidity to less than 100 Jackson Turbidity Units, or an approximate concentration of 100 mg/l. The combination appeared to give the best results. The polymers can be added either to the overflow water from an initial settling pond or to the initial dredge slurry. Polymers can be used effectively at both inland and shoreline disposal sites. Because considerable variation in clay content is anticipated during the daily flows, the polymer dose rate should be monitored and possibly adjusted several times a day.

DISPOSAL SITES

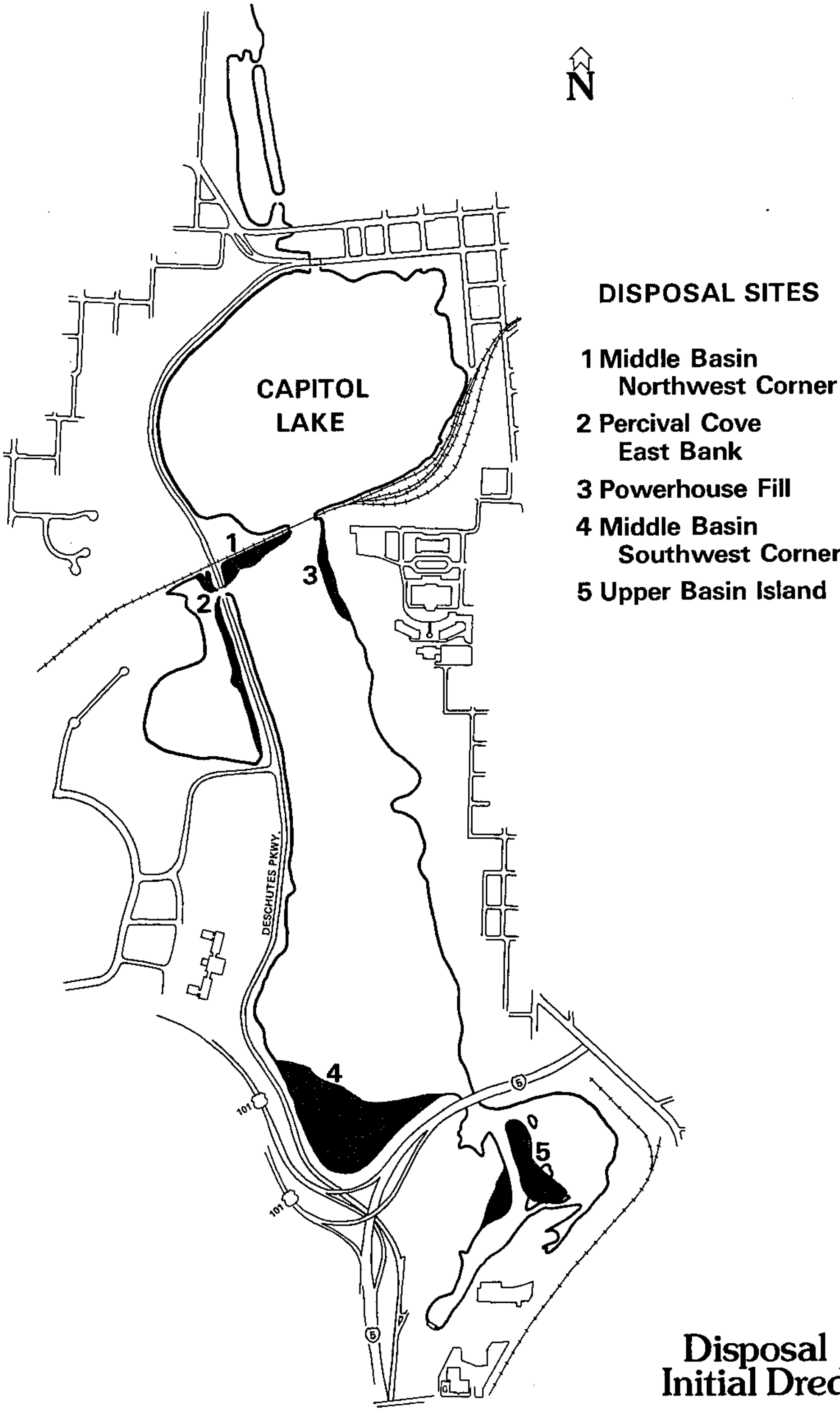
Potential disposal sites were separated into the following categories:

- Lakeshore and in-basin sites
- Port of Olympia sites
- Out-of-basin sites

Lakeshore and In-basin Sites

Lakeshore sites include those locations around the perimeter of the lake where disposal is considered a possibility. Pumping costs for these sites would be less than for pumping material out of the basin or to the Port of Olympia.

Lakeshore sites considered suitable for disposal of materials during the initial dredging in 1977 and maintenance dredging in 1979 are shown in figure 8. These disposal locations were evaluated during the WSU hydraulic study, which indicated the location of these fills would not adversely affect



Disposal Sites
Initial Dredging 8

circulation patterns in Capitol Lake. Discussions with the Department of Fisheries personnel indicated these disposal locations would have minimum impact on natural fish-feeding areas. All lakeshore sites will require containment dikes or baffles with overflow weirs to help reduce turbidity of the return flows.

Other potential lakeshore and in-basin disposal sites are shown in figure 9. These lakeshore sites have been evaluated by WSU to determine their effect on circulation patterns.[1] The results were used in the selection process for disposal sites. The capacities of the lakeshore sites are shown in table 1 and are separated into sites suitable for disposal of initial dredge spoils and sites that should be considered for disposal of maintenance dredge spoils.

Table 1. CAPACITIES OF LAKESHORE DISPOSAL SITES

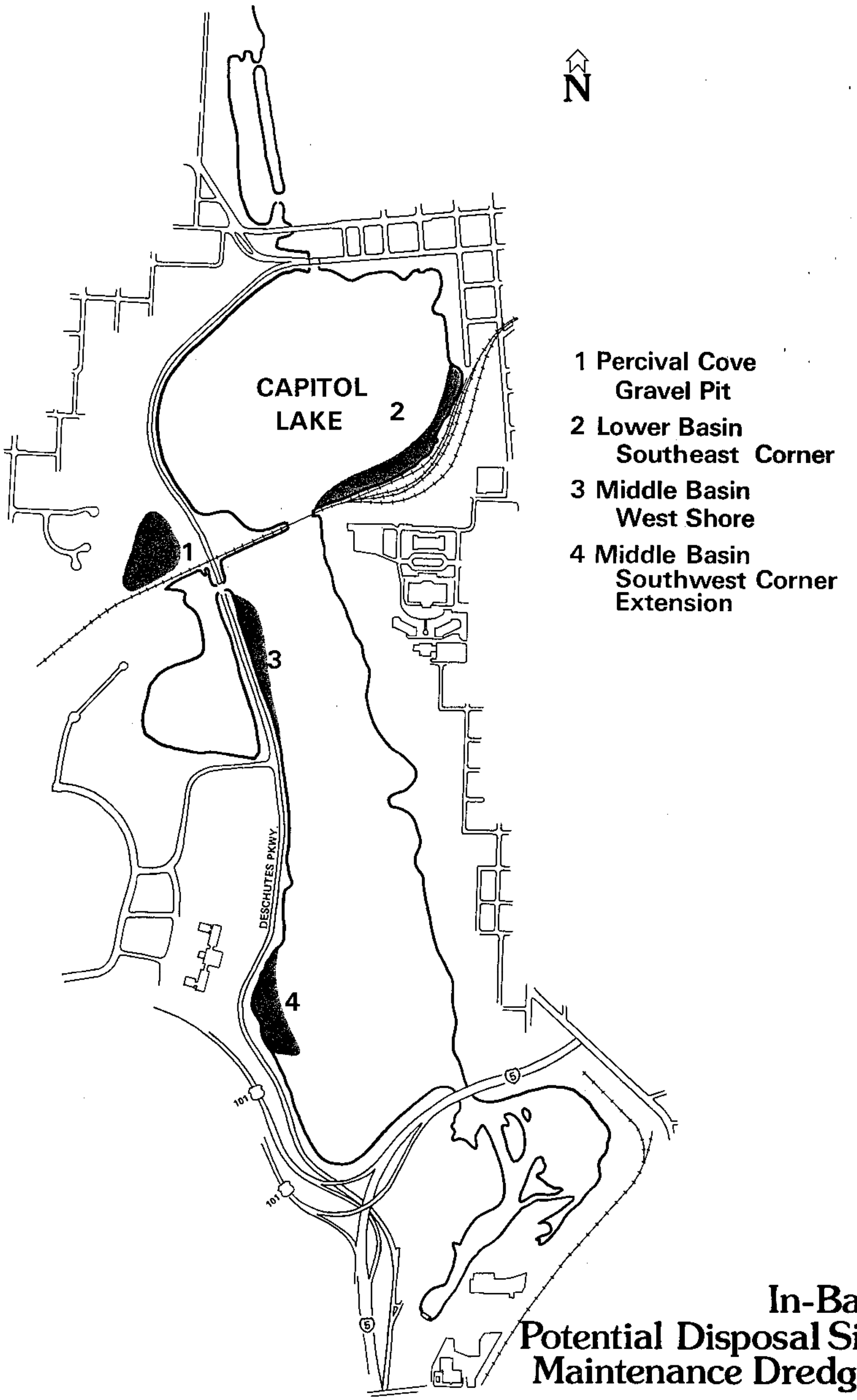
A. Suitable Sites, Initial Dredging

	Location on Fig 8	Capacity (Cu Yds)	Assumed Final Elevation (Ft Above Mean Sea Level)
Upper basin islands	5	40,000	14
Middle basin, southwest corner	4	286,600	18
Percival Cove, east bank	2	25,400	14
Middle basin, northwest corner	1	46,400	12
Powerhouse fill	3	6,800	12

B. Potential Sites, Maintenance Dredging

	Location on Fig 9	Capacity (Cu Yds)
Middle basin southwest corner extension	4	69,000
Middle basin, west shore	3	30,000
Lower basin, southeast corner	2	140,000
Percival Cove gravel pit	1	203,000

1 Mih, Walter C., op. cit.



In-Basin
Potential Disposal Sites
Maintenance Dredging 9

The differences in composition of the soil samples (see appendix A) suggest that the lakeshore fills will be heterogeneous with some sections of the fill coarse grained and others fine grained. Segregation of the materials discharged from the dredge pipe can be minimized by frequent relocation of the discharge end of the pipe.

Differential settlement of the fills as a result of the variability of materials will occur. Because these fills are not considered structural fills, differential settlement should have no influence on their development as recreational areas. Should any future plans include structures on these fills, the bearing capacity and settlement should be considered at that time.

No settlement of the I-5/SR 101 interchange is anticipated after dredge spoils are deposited in the southwest corner of the middle basin. A review of CH2M HILL boring logs and boring logs in the WSU report indicates the highway fill was built on sand or gravel that would prevent any adverse impacts. If the highway department decides to widen the north side of the interchange, the bottom of the widened area should be placed before the dredge spoils are deposited. The bottom part of the highway's widening fill could be placed up to an elevation equal to the final proposed elevation of the dredge spoils fill. The dredge spoils deposited in the northwest corner of this fill are not expected to have an adverse impact on the Deschutes Parkway.

The schedule for interchange widening is not definite at this time. If the dredge spoils fill is ready to be placed before the highway project is funded, the cost of providing an adequate foundation for the highway widening fill should be included in the Capitol Lake restoration costs. However, if the highway fill is funded before the Capitol Lake construction begins, the highway department will pay for the highway widening fill.

The dredge spoils fill next to the Deschutes Parkway where it passes Percival Cove are not expected to contribute to settlement or instability of the parkway embankment. Borings made near Percival Cove indicate sand and gravel at shallow depths. The dredge spoil fill is not expected to cause settlement or lateral displacement of the parkway embankment.

Dikes and containment areas will be required for the gravel pit north of Percival Cove. The filling of this area should proceed in stages. A section of the site should be diked and filled, and the fill allowed to drain and consolidate before additional fill is placed. Filling of the site can proceed vertically if each lift is no more than 3 or 4 feet thick.

Port of Olympia Sites

Port of Olympia sites that were investigated are summarized in table 2.

West Waterway Channel

A site was identified in the southwest corner of Budd Inlet. Owned by the Port of Olympia, the site is bounded on the east by an existing railroad embankment. Estimated capacity is approximately 200,000 cubic yards. Other potential areas also exist along the west shore of Budd Inlet, but considerable diking would be required before these sites could be filled. Spoils could be pumped to all these sites.

East Bay Marina

The port's planned East Bay Marina (figure 10) will require over 500,000 cubic yards of fill material. The actual schedule for marina construction depends on shoreline permit appeals, the Corps of Engineers dredge plan for Budd Inlet, and construction of the new Olympia sewage treatment plant. The availability of Capitol Lake dredge spoils would need to be coordinated with the East Bay Marina schedule. A fill constructed from the dredge spoils would be quite compressible. Before structures could be placed on the fill, the bearing capacity and settlement characteristics need to be evaluated.

Out-of-Basin Sites

All potential out-of-basin sites are summarized in table 2. Some are shown in figure 10.

Olympia Brewery

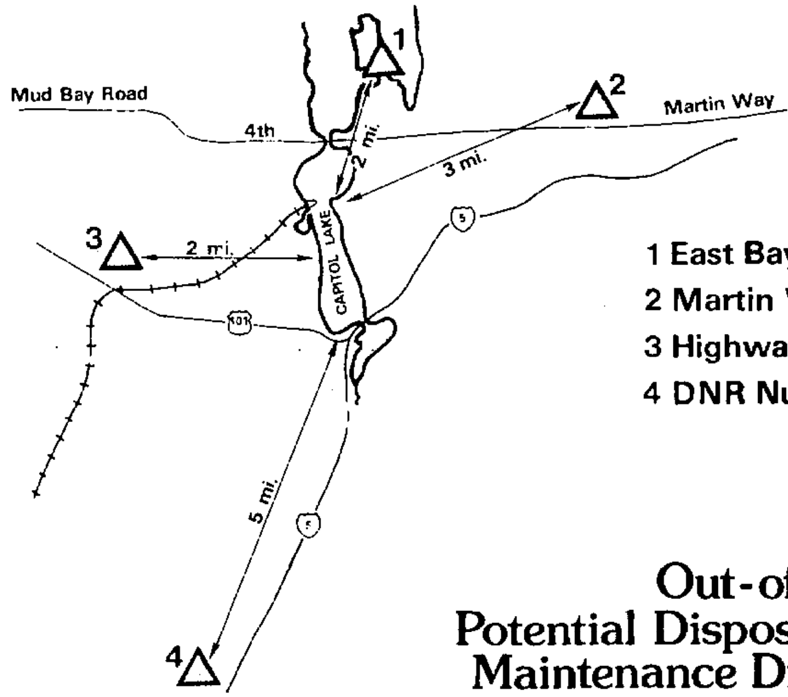
Previous investigations indicated that the Olympia Brewery had two sites available for disposal, both near the Olympia golf course. Their combined area is 75 acres, and total volume is approximately 1 million cubic yards. Recent discussions with brewery officials revealed they are no longer interested in using the areas as disposal sites.

Grand Mound Gravel Pits

The Washington State Highway Department has identified about eight gravel-borrow pits in the Grand Mound area, approximately 12 miles south of Olympia. These pits range from 1

Table 2. PORT OF OLYMPIA AND OUT-OF-BASIN SITES INVESTIGATED FOR DISPOSAL

Disposal Site	Capacity Estimate (cu yds)	Distance From Lake (miles)	Owner	Contact	Remarks
Dana Passage	300,000	10	Department of Natural Resources	Doug McGoon	900-ft radius must contain all spoil.
West Waterway Channel	526,000	Adjacent	Port of Olympia	Gene Siebold	Probably not available when needed.
East Bay Marina	509,000	2.0	Port of Olympia	Gene Siebold	Probably not available when needed.
Olympia Brewery	905,000	2.5	Olympia Brewery	Bob Meters	This site is no longer available.
Grand Mound Pits	200,000	12	State Highway Department	Don Johnson	Rail access to Case Road Pit.
Highway 101 Pit	500,000+	2.0	Evergreen Corp.	Jim Whisler	Diking required along railroad.
Department of Natural Resources Nursery	240,000	5	Department of Natural Resources	Walt Nelson	Material should be suitable for growing seedlings.
Ft. Lewis Pit	1,000,000	17	U.S. Army	Orin Hebert	Rail siding would be needed.
Nelson's Farm	500,000+	10	Ron Nelson	Ron Nelson	Rail siding may be available.
Martin Way Site	1,000,000	3	Gillingham & Jones	Dave Antsen	Future shopping center; truck access only
Burlington Northern Railroad site		3	BNRR	Art Kemp	Area is now wooded; 27 acres.



1 East Bay Marina
2 Martin Way Site
3 Highway101 Pit
4 DNR Nursery Site

Out-of-Basin Potential Disposal Sites Maintenance Dredging 10

to 6 acres. One pit identified as the Case Road Pit is larger than the others, with a capacity of approximately 177,000 cubic yards. The department expressed no objections to filling the sites. The distance from Capitol Lake to these pits is considered excessive for disposal of dredged material.

Highway 101 Pit

Highway 101 Pit is located at the intersection of the Northern Pacific Railroad and U.S. 101, north of Percival Creek (figure 10). The size of the site is estimated at 10 to 12 acres. The pit is located slightly over 2 miles from Capitol Lake. Although there is an elevation difference of about 175 feet between the site and the lake, pumping the spoils to the site is considered feasible. The ground surface at the site is uneven, with moderate elevation differences. Grading and dike construction would be necessary to make the site usable.

Department of Natural Resources Nursery

This site is located on Lathrop Road about 5 miles south of the lake (figure 10). The fill material would be used for leveling of the DNR Nursery landscape. At present the site has some very low pockets, one of which has a small pond in it. This pond may need to be drained before filling the site. Before DNR would accept fill, the dredged material must be shown suitable for raising seedling Douglas fir trees. The capacity of this site is estimated at only 240,000 cubic yards, but more fill could be put on if it were spread over the entire area DNR owns and if all the property were raised 1 to 2 feet.

Fort Lewis Pit

This is a large abandoned gravel pit remaining from Interstate 5 construction. Its capacity could exceed 1 million yards if the pit were filled to the grade of the surrounding area. Transportation of the fill by rail would require construction of a rail siding, but a gravel road adjacent to the site could be used for this purpose.

Nelson's Farm

Nelson's Farm is located about 10 miles south of Capitol Lake on the Union Pacific railline. A very low, rocky farm, it would be greatly improved by filling with sandy or loamy soil. A rail siding lies adjacent to one of two sites at that location. Both sites have very good access to the railline and to old U.S. 99. Because rail sidings adjacent to the land are not owned by Ron Nelson, permission would have to be obtained elsewhere before they could be used. Mr. Nelson requires that the quality of the fill material be good enough to support agriculture before he would agree to accept it.

Martin Way Site

Owned by Gillingham and Jones Inc., this site is a large open-space area west of Olympia on Martin Way east of the Washington Natural Gas Company office (figure 10). A creek once flowed through the hollow, but the area is now relatively dry with a small marshy area in the middle. Storm drainage from Martin Way is routed to this area.

The site was partially filled by a highway construction job 1 or 2 years ago. The area is zoned for commercial use; if it is filled it will become more desirable for development as a shopping center. Access to the site would be by truck only.

Burlington Northern Railroad Site

This is a site in Lacey about 3 miles from Capitol Lake. Located behind the Georgia-Pacific warehouse near Interstate 5, it is a wooded area of 27 acres. It must be logged before fill could be accepted, but the logging may pay for itself because most of the woods consists of valuable deciduous trees. There is a rail siding at the site. Material could also be pumped in, possibly along the railroad right-of-way. Because it is presently unknown how deep the site could be filled, its capacity is unknown. However, logging the site may be an environmental drawback.

Dana Passage

Dana Passage lies 10 miles from Capitol Lake and is the only deepwater disposal site nearby. Discussions with Ron Lee of Environmental Protection Agency (EPA) and Doug McCoun of Department of Natural Resources (DNR) indicate that the site can be used only if it can be ascertained that the fill material will not cause environmental damage. To do this, an elutriate test must be performed to show that materials detrimental to the aquatic environment would be resuspended in concentrations not greater than 1-1/2 times the concentrations already in the area. In addition, the dredge material should be confined to a circle of 900-foot radius around the disposal site itself.

Barges must be loaded in the west bay of Budd Inlet at the harbor area and towed to the disposal site. Barges with a normal capacity of 1,500 to 2,000 tons draw 10 feet. This means draft barges must be positioned for loading at high tide and would each be capable of making only two trips a day.

Other Contacts

The following agencies were contacted but knew of no possible disposal sites.

Thurston County Roads Department
City of Olympia
Weyerhaeuser
Segale Construction Company
Thurston County Farm Bureau
Thurston County Agriculture Extension Agency
Olympic National Forest Service
Washington State Department of Agriculture
Washington State Department of Fisheries
Washington State Department of Parks and Recreation

Recommended Sites

The lakeshore sites in figure 8 and the gravel pit north of Percival Cove (figure 9) are considered acceptable sites within the basin. The gravel pit site should be examined in more detail to evaluate the type of disposal operation most suitable. The port's East Bay Marina is also a possibility and should be examined with regard to pipeline locations for moving the spoils to the port.

Of the out-of-basin sites, the one considered the best possibility is the Highway 101 Pit. The other sites shown on figures 9 and 10 are good possibilities and could be looked at in more detail.

The following factors snould be considered before final out-or-basin site selections are made:

Availability of in-basin sites
Availability of out-of-basin sites
Capacity
Environmental considerations
Future use of the site
Permits
Cost

MAINTENANCE DREDGING

The frequency of maintenance dredging and the quantity of material to be dredged depend on the flow of the Deschutes River.

From information compiled in the Washington State University study, 80 to 85 percent of the sediment transported into Capitol Lake occurs during river flows greater than 1,000 cubic feet per second--a flow exceeded only about 8 percent of the time at Olympia. The average annual flow, which occurs about 30 percent of the time, is 405 cfs, based on data from 1951 to 1963.

Washington State University has developed a relationship to predict suspended sediment concentrations from instantaneous river discharge.[1] Based on this relationship, they estimate the average annual sediment load at 32,560 tons per year. Assuming an average dry density of 75 to 100 pounds per cubic foot, the average annual sediment load could range from 24,000 cubic yards to 30,000 cubic yards per year. Extremes could vary from 4,000 to 60,000 cubic yards per year.

The upper basin sediment trap described in Concept 1 will have a sediment capacity of approximately 60,000 cubic yards before redredging is required. Although the amount of the average annual sediment load that will be deposited in the upper basin cannot be reliably estimated with the existing information, in general, the upper and middle basins will retain more of the sediment load after the trap is built than is retained now.

Of the total sediment load carried into the lake, the coarse particles, such as sand and gravel, should settle in the upper basin sediment trap. Finer sands and coarse silts should settle in the middle basin sediment trap. Fine silts and clays will be carried into the lower basin and, in some cases, out into Budd Inlet.

Maintenance dredging should be planned initially for a 2-year frequency. After several years, a trap efficiency can be determined and the maintenance dredging frequency adjusted if necessary. Annual inspection of the channel leading into the upper basin sediment trap may be required. The condition of the protective groins should also be inspected annually.

The middle basin sediment trap will contain finer sediments which will escape the upper trap. The middle basin trap has a capacity of about 97,000 cubic yards. It should be dredged every 5 to 10 years, or as required. Maintenance dredging of Percival Cove will be needed occasionally to remove accumulated sediment.

1 WSU Report, figure B-2, p. 251.

RESTORATION PLAN AND COST ESTIMATES

A recommended plan and two alternative plans for the lake's restoration were developed by combining the previously discussed concepts for initial dredging, disposal, and maintenance dredging. The alternative plans provide for the contingency that lakeshore sites would not be available for sediment disposal. The following criteria were used in developing the plans:

Cost
Environmental impact
Energy consumption
Probability of implementation
Reliability
Convenience of operation
Conformity with Capitol Lake restoration goals

RECOMMENDED PLAN

Initial Dredging (Concept 1)

Dredging would be performed selectively in the upper and middle basin. The Deschutes River channel from the lower falls to the upper basin would be gradually deepened and widened. The channel would empty into a sediment trap dredged in the east side of the upper basin. Island modifications and channel training structures would also be required.

A sediment trap would also be dredged in the southern end of the middle basin. The middle basin would be dredged to a minimum water depth of 6 feet to within 150 feet of the west shoreline. Percival Cove would be dredged to allow complete drainage during annual drawdown. Initial dredging and construction work would be performed by a private contractor using a state-owned dredge.

Maintenance Dredging

The upper basin sediment trap would need dredging every 2 years on the average. Maintenance dredging in the middle basin sediment trap would take place approximately every 5 to 10 years. All maintenance dredging would be performed by the state using a state-owned dredge.

Disposal

All initial dredging spoils should be deposited around the lakeshore. Maintenance dredging can also be deposited at designated sites around the lakeshore as long as space remains available. Disposal at all lakeshore sites would be accomplished by pumping the spoils through a pipeline from the dredge to the site. Chemical polymers should be added to the dredge spoils to promote rapid settling and reduce turbidity of return water. All fills will require containment dikes or silt curtains to reduce the turbidity of the dredge water before it reenters the lake.

The existing gravel pit north of Percival Creek should be purchased for use as a material handling and disposal site. The decision on whether to purchase the U.S. 101 gravel pit should be made between 1985 and 1999.

Groin Construction

The southeast corner of Tumwater Park will require erosion protection. A protective groin made of gabions (strong wire mesh containers filled with rocks) is proposed for this area to prevent shoreline erosion and to route the current toward the sediment trap. Gabions are also proposed for shore protection on the south end of the island in the upper basin.

Debris Removal

Logs and deadheads are thought to exist in unknown quantities in the lake sediments. The debris will be located and removed by a barge-mounted crane.

DISPOSAL ALTERNATIVE 1

Initial and maintenance dredging would be the same as in the recommended plan.

Initial dredge spoils would be pumped out of the basin or to a potential disposal site at the Port of Olympia. Maintenance dredging disposal would take place in lakeshore disposal sites.

DISPOSAL ALTERNATIVE 2

Initial dredging and maintenance dredging would be the same as in the recommended plan.

Disposal would be the same as in the recommended plan except that after lakeshore disposal sites are filled, maintenance dredge spoils would be deposited outside the basin. An out-of-basin site should be purchased under this alternative. For purposes of comparison, it was assumed that maintenance dredging for the first four biennia would be in-basin and for the last five biennia, out-of-basin.

IMPLEMENTATION OF RECOMMENDED PLAN

The implementation of the recommended plan could proceed in separate stages.

Phase I

The initial dredging would provide sediment traps in the upper and middle basins, and would remove sediment from shallow areas in the middle basin. Percival Cove would be dredged to allow complete drainage during the annual lake drawdown and to provide a sediment trap at the mouth of Percival Creek. Debris and deadheads would be removed from all basins. The protective groins would be built in the upper basin.

Dike construction and site preparation around the initial dredging disposal areas would be performed in phase I. After the initial dredging is completed, the disposal areas would be graded as recommended in the *Recreation Plan Design Report* proposed for Capitol Lake and seeded to protect against erosion.

Phase I should be performed by a private contractor experienced in dredging and earthwork. A contractor would use a small state-owned dredge and complete the work within a 12- to 15-month period. Arrangements with the contractor would be made to train state personnel in operation of the dredge. Our estimates are based on a Mud Cat WC-15 dredge. The state should acquire the existing gravel pit just north of Percival Creek for use as a potential sediment disposal site.

Phase II

The disposal sites selected for biennial maintenance dredging should be prepared. Site preparation for each of the disposal sites can be performed on an as-needed basis each biennium. At the end of each biennial maintenance period, some site grading would be necessary at the disposal site.

Phase III

The state should also acquire the U.S. 101 gravel pit as an out-of-basin disposal site. Sediment quantity estimates indicate an out-of-basin disposal site may be required between 1985 and 1999.

Biennial Maintenance Dredging

Future accumulation of sediment will need to be removed from the upper basin sediment trap every 2 years, and from the middle basin sediment trap every 5 to 10 years depending on rate of accumulation.

The most economical maintenance dredging can be performed with a state-owned dredge of about 6-inch discharge diameter. Our estimates are based on a Mud Cat WC-15. Each maintenance dredging can be completed within 2 to 3 months, depending on the rate of sediment accumulation.

COST ESTIMATES

Preliminary Cost Estimates

Preliminary cost estimates were developed for the recommended plan and for alternatives 1 and 2. The costs are summarized in table 3 and are arranged in phases that include the following activities:

Phase I

Initial dredging, including mobilization
Purchase of dredge (only for estimates of dredging with state-owned equipment)
Land purchase of out-of-basin disposal site (alternative 1 only)
Property surveys in Percival Cove and upper basin
Site preparation
Groin construction
Debris removal
Land purchase of in-basin pit

Phase II

Maintenance dredging site preparation
Purchase of dredge (recommended plan--initial construction with contractor's equipment)

Phase III

Land purchase out-of-basin, and survey (recommended plan and alternative 2)

Biennial Maintenance Activities

Mobilization
Maintenance dredging

The preliminary cost estimates are total costs over a 20-year period and are based on 1976 prices. The estimates include bond fees, taxes, and contingency, but do not include bond interest and repayment.

Table 3. PRELIMINARY COST ESTIMATES

	Recommended Plan Initial Disposal in Basin Maintenance Disposal in Basin		
	Dredge With State-owned Equipment	Initial Const by Private Contractor; Maintenance Dredging by State	All Const by Private Contractor
Phase I	$1,510,800	$1,283,800	$1,283,800
Phase II	671,000	1,050,500	671,000
Phase III	154,800	154,800	101,800
Subtotal	$2,336,600	$2,489,100	$2,056,600
Biennial Maintenance Dredging (20-year period)	$ 763,200	$ 763,200	$1,750,000
Total	$3,099,800	$3,252,300	$3,806,600

	Alternative 1 Initial Disposal out of Basin Maintenance Disposal in Basin		Alternative 2 Initial Disposal in Basin Maintenance Disposal in and out of Basin	
	Dredge With State-owned Equipment	All Const by Private Contractor	Dredge With State-owned Equipment	All Const by Private Contractor
Phase I	$1,964,000	$1,571,100	$1,510,800	$1,283,800
Phase II	671,000	671,000	671,000	671,000
Phase III	--	--	154,800	101,800
Subtotal	$2,635,000	$2,242,100	$2,336,600	$2,056,600
Biennial Maintenance Dredging (20-year period)	$ 763,200	$1,750,000	$ 933,500	$2,279,200
Total	$3,398,200	$3,992,100	$3,270,100	$4,335,800

It was assumed that a small dredge (Mud Cat WC-15) would be used for the maintenance dredging regardless of whether the work was done by private contract or with state-owned equipment. The higher maintenance costs for maintenance dredging by private contractor reflect the higher mobilization for a private contractor and the higher unit costs of dredging. The contractor's unit costs would include his overhead and profit and the amortization costs of equipment. The state is not expected to have these costs.

The preliminary cost estimates show that the recommended plan with state-owned equipment has the lowest total cost. The costs of all alternatives are further compared in table 4 according to present value, 20-year cumulative cost, and inflated 20-year cumulative cost. For the present value figures, the cash flow for 20 years was discounted to 1976 estimated price level using a 7-percent discount rate. For cumulative costs, the cash flow for 20 years was calculated using 1976 costs. Inflated cumulative costs were reached by calculating the cash flow for 20 years using 1976 costs and average inflation of 6 percent per year.

Table 4. COST COMPARISON FOR VARYING DOLLAR VALUES.

	Recommended Plan			Alternative 1		Alternative 2	
	State-owned Equip.	Initial Dredging by Private Contract, Maintenance with State Equipment	All by Private Contract	State-owned Equip.	All by Private Contract	State-owned Equip.	All by Private Contract
Present value in 1976 $ at 7% discount rate (millions of dollars)	2.52	2.63	2.77	2.88	2.99	2.61	3.04
Cumulative cost in in 1976 $ (millions of dollars)	3.05	3.20	3.76	3.36	3.95	3.22	4.29
Cumulative cost inflated at 6% (millions of dollars)	4.01	4.21	5.67	4.22	5.79	4.36	6.74

Recommended Plan Costs

On the basis of the cost comparisons in tables 3 and 4, the option of doing the initial and maintenance dredging with state-owned equipment has the least cost. The detailed cost estimate for this option to the recommended plan is shown in table 5. A cash flow chart and annual costs are shown in figure 11.

Table 5. RECOMMENDED PLAN COST ESTIMATE (DREDGING WITH STATE-OWNED EQUIPMENT)

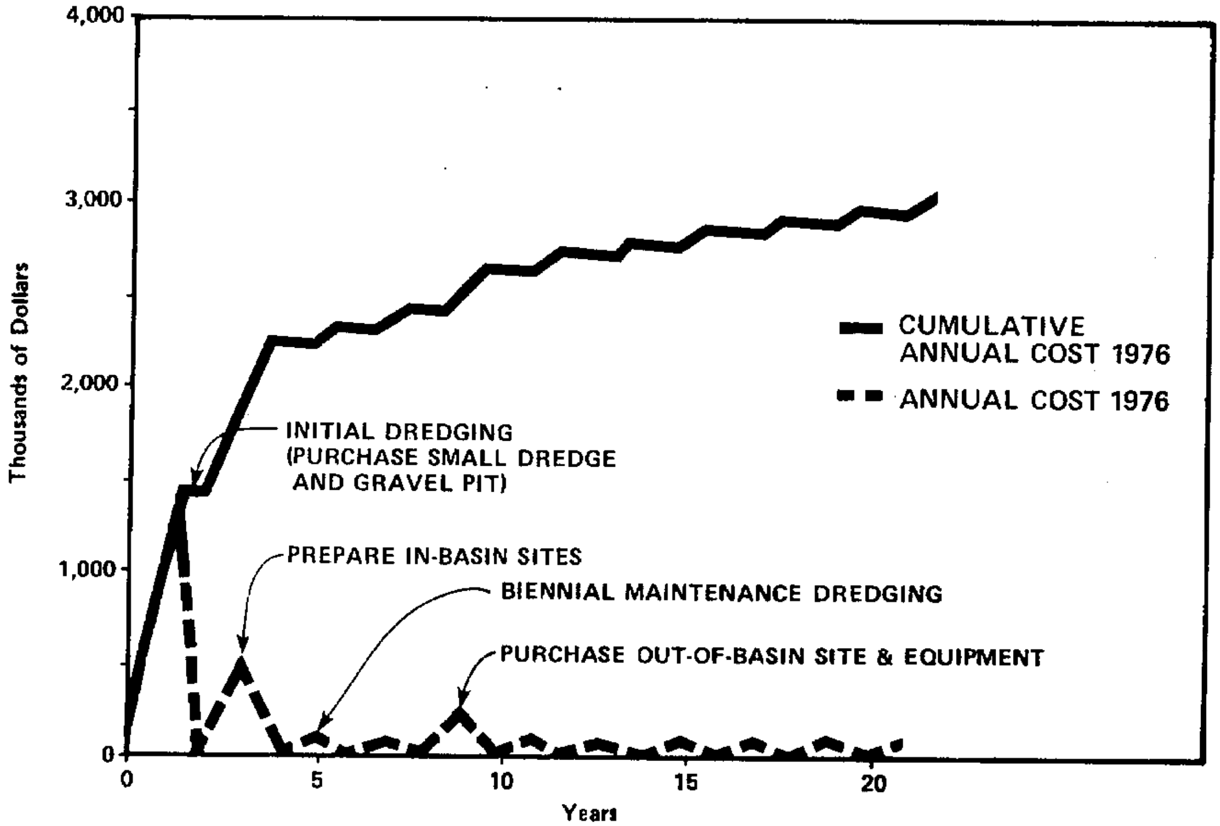
PHASE I	
Initial Dredging and Restoration	$1,083,800
■ Dredge upper and middle basins and dispose in-basin	
■ Dredge Percival Cove and dispose along east bank of cove	
■ Remove debris and deadheads from all basins	
■ Construct groin in upper basin	
Purchase Small Dredge and Support	301,900
Acquire Gravel Pit In-Basin	125,100
Total Phase I	$1,510,800
PHASE II	
Prepare In-Basin Sites for Maintenance Dredging	$ 671,000
Total Phase II	$ 671,000
PHASE III (ENSUING COSTS, 1985-1999)	
Acquire Out-of-Basin Disposal Site	$ 101,800
Acquire Additional Pipe and Booster Pump	53,000
Total Phase III	$ 154,800
Total for Restoration	$2,336,600
BIENNIAL MAINTENANCE DREDGING	
Maintenance Dredging Every 2 Years For 20 Years With Small Hydraulic Dredge (Average $76,320 Per Biennium)	$ 763,200

NOTES:

All prices as of July 1976, with no escalation included beyond July 1976.

All above prices do not include previous appropriation of $425,000, of which $300,000 required to complete engineering design.

Prices include fees, taxes, and contingency.



Note: Initial Construction by Private Contractor Using State Owned Dredge; Maintenance Dredging by State

Cash Flow and Annual Costs for Recommended Plan 11

Capitol Lake

Appendix A

APPENDIX A
CAPITOL LAKE GEOTECHNICAL INVESTIGATION

A geotechnical investigation in Capitol Lake was performed to identify the physical and chemical characteristics of the sediments.

FIELD SAMPLING

Sediment samples were collected from 37 test holes ranging in depth from 1 to 22 feet below the lake bottom between 20 November 1975 and 5 December 1975. A portable drilling barge, drilling equipment, and two men were supplied by Anderson Drilling, Inc., of Bellevue, Washington, under subcontract to CH2M HILL. CH2M HILL provided jetting and coring equipment, an inflatable rubber boat, and a geologist and/or engineering technician. The drilling barge was used to investigate 15 test holes in the upper basin and 18 test holes in the middle basin. Four test holes were made in Percival Cove. The test hole locations are shown in figure A-1.

Samples were collected in all but three test holes using a 2-foot clear plastic tube (2-inch OD and 1/16-inch wall) attached to the bottom of a 3/4-inch pipe. The sample tube was jetted into the lake bottom to the desired sample depth, then hand pushed or driven approximately 2 feet using an 18-lb sliding hammer. A ballcheck valve was inserted in the 3/4-inch pipe, and the sample was withdrawn from the test hole. Jetting was performed using a pump having a capacity of 60 gpm at 100 psi.

Standard penetration tests were performed in test holes 9, 22, and 23. This test consists of a 140-lb hammer falling 30 inches to drive a 2-inch OD split-barred sampler 18 inches. The number of blows required to drive the sampler the final 12 inches was recorded as the driving resistance (N value). The standard penetration tests were not used in all test holes because sample recovery was very difficult. There was better sample recovery when the clear plastic tubes were used.

LABORATORY TESTING

Physical Properties

Physical tests on the sediments included visual classifications as well as particle size analysis by means of sieve and hydrometer analysis according to ASTM D 422.[1] Specific gravities are given in table A-1.

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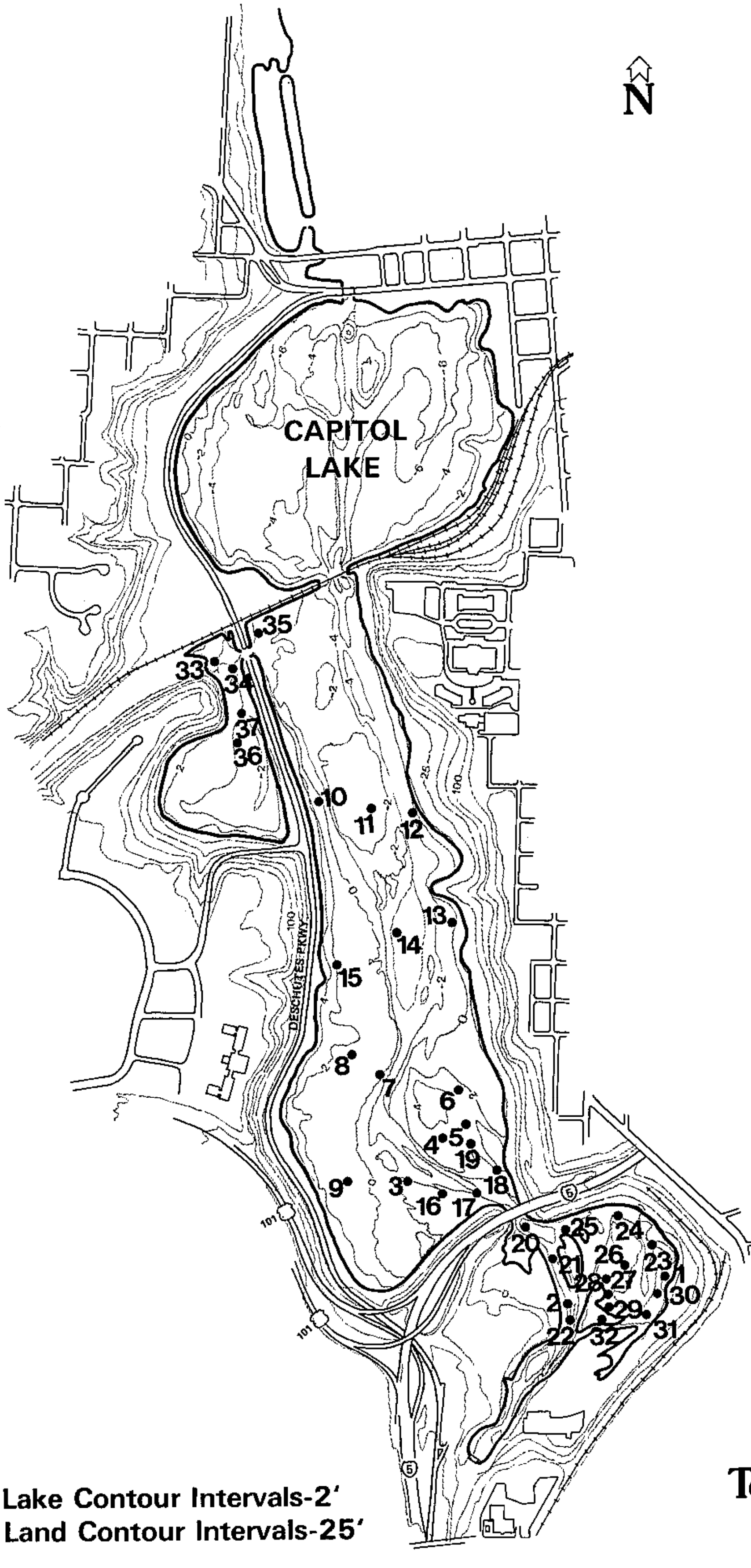
1 American Society of Testing Materials classification.



Lake Contour Intervals-2′
Land Contour Intervals-25′

Test Boring Location **A-1**

Table A-1. SPECIFIC GRAVITIES

Location	Depth (ft)	Specific Gravity
TH 6	4.0-4.9	2.62
TH 7	4.0-5.3	2.63
TH 12	4.0-5.0	2.62
TH 34	0-1.5	2.65
TH 37	1.0-1.6	2.72

The particle size results and classification are listed in table A-2 and are shown in figure A-2. Grain size curves are included at the end of this appendix.

The sediments are primarily sands and silts. However, small amounts of gravel, clay, and organics were identified in some of the samples. Coarse sediments (sand and gravel) were found at the extreme east and west sides of the upper basin--areas which are considered mainstream channels. The sediments are finer (sand and silt) near the center of the upper basin. Silts were identified near the island and shoaling areas of the upper basin. Thin layers of coarse sediments found in areas of predominately sand and gravel suggest the main channel has meandered in the upper basin since the lake was formed. Some wood chips were found in the upper basin samples.

The sediments in the middle basin are fine sands and silts which are generally finer than in the upper basin. Some isolated layers of sand were identified in the middle basin.

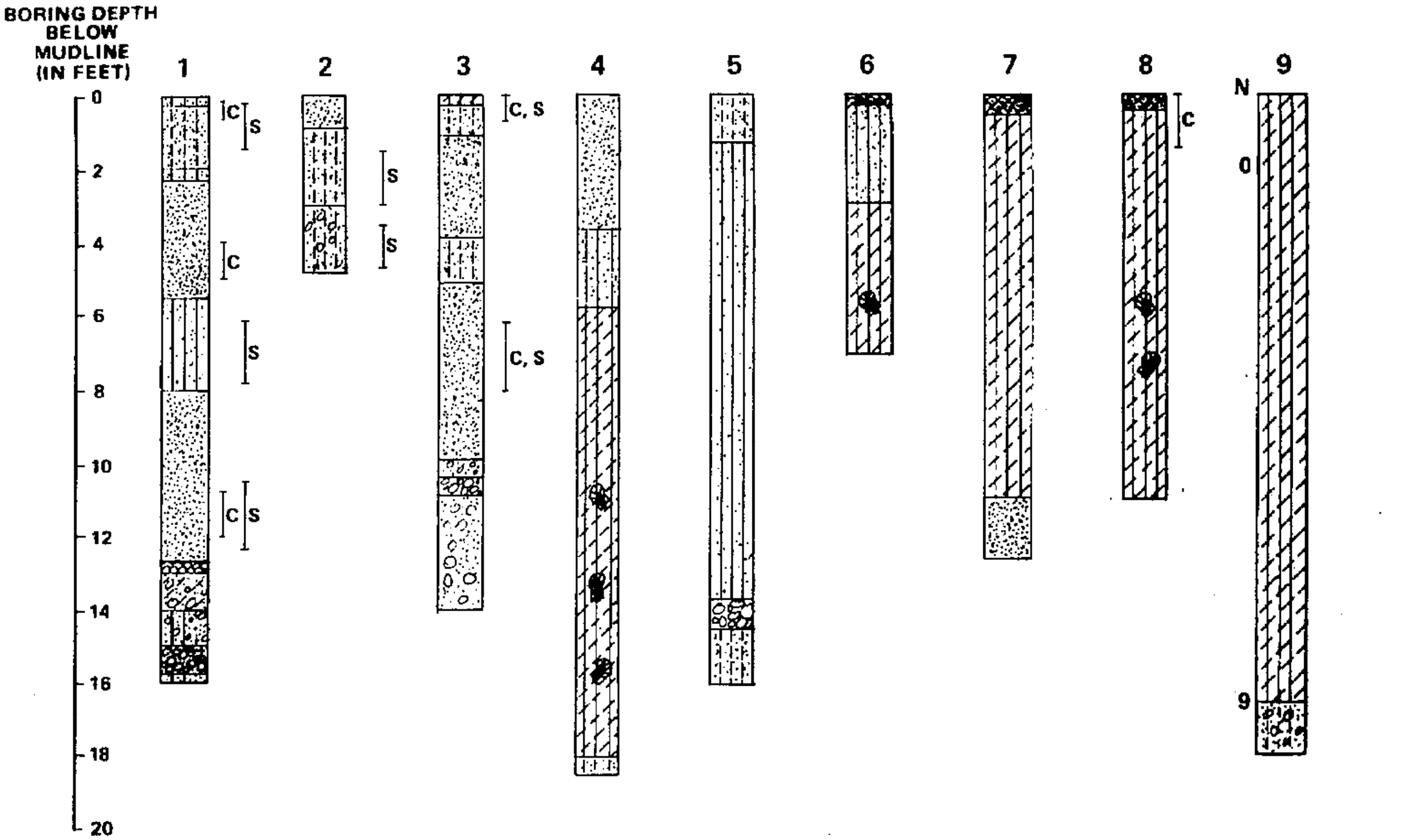
Chemical Properties

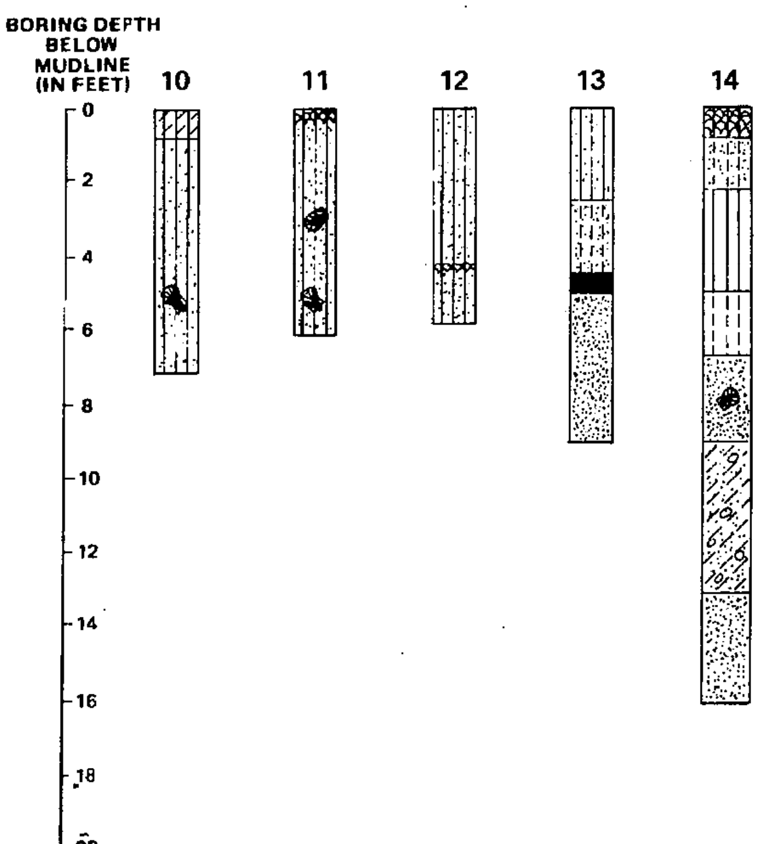
Bulk analysis of the sediment's chemical properties was performed on 11 of the samples collected from the upper and middle basins to provide sediment background data to assess the impact of dredge spoil disposal and return waterflow. The analysis included the following tests:

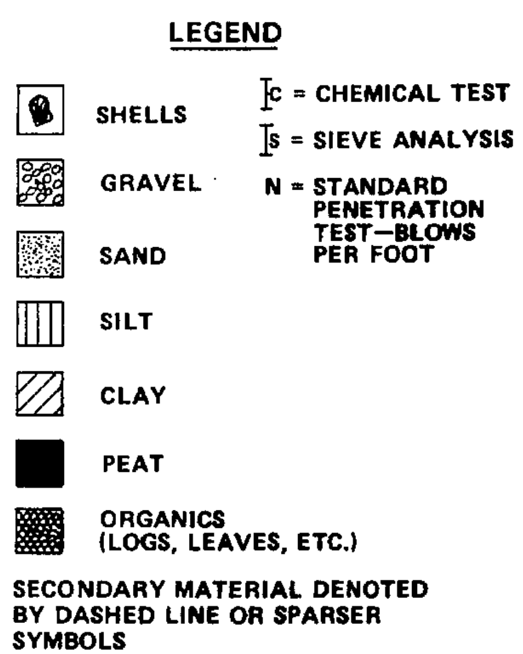
- total solids
- total volatile solids
- initial dissolved oxygen (DO) demand
- chemical oxygen demand (COD)
- oil and grease
- Kjeldahl nitrogen
- total phosphorus
- mercury
- lead
- zinc
- copper

Table A-2. PHYSICAL PROPERTIES

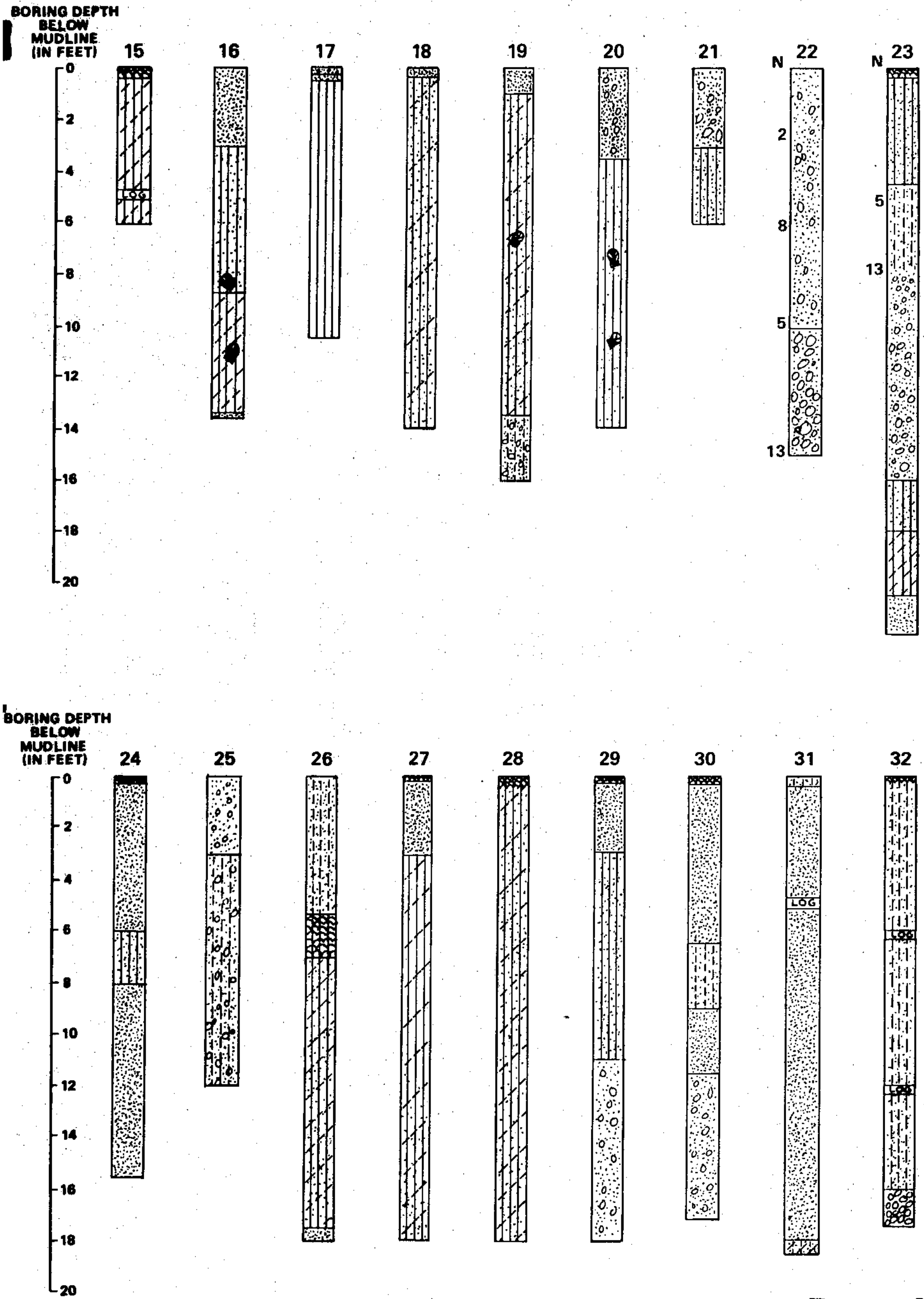
Test Hole Number	Sample Depth (ft)	Percent Gravel >5mm	Percent Sand .074-5mm	Percent Silt .005-.074mm	Percent Clay <.005mm	Unified Classification	Agricultural Classification	Percent Passing No. 200 Sieve
1	0-0.2	0	60	30	10	Silty fine sand (SM)	Sandy loam	40
	1.1 1.3	3	86	6	5	Silty fine sand (SP-SM)	Gravelly sand	11
	6.0-7.7	0	52	39	9	Silty fine sand (SM)	Sandy loam	48
	10.5-12.2	45	51	3	1	Gravelly sand (SP)	Gravelly sand	3
2	1.3-3.0	2	67	18	13	Silty fine sand (SM)	Sandy loam	31
	3.4-4.7	1	87	8	4	Silty sand (SP-SM)	Gravelly sand	12
3	0-1.0	1	87	8	4	Silty sand (SW-SM)	Gravelly sand	12
	4.0 5.2	0	50	36	14	Silty fine sand (SM)	Sandy loam	50
6	1.0-1.3	0	16	63	21	Sandy silt (ML)	Silty loam	84
	4.0-4.9	1	7	69	23	Clayey silt (ML)	Gravelly silty loam	92
7	0.5-1	0	7	70	23	Clayey silt (ML)	Silty loam	93
	4.0-5.3	0	2	67	31	Clayey silt (ML)	Silty loam	98
12	0.5-0.8	0	33	57	10	Sandy silt (ML)	Sandy loam	67
	4.0-5	1	22	60	17	Fine sandy silt (ML)	Loam	77
13	0-2.0	0	25	53	22	Sandy Silt (ML)	Silty loam	75
19	2.0-4.0	0	14	63	23	Silt (ML)	Loam	86
	6.0-8.0	0	29	54	17	Sandy silt (ML)	Sandy loam	71
26	0-2.0	0	78	18	4	Silty fine sand (SM)	Loamy sand	22
	8.0-10	0	23	60	17	Fine sandy silt (ML)	Loam	77
34	0-1.5	26	70	2	2	Gravelly sand (SP)	Gravelly sand	4
37	1-1.6	0	9	66	25	Clayey silt (ML)	Silty loam	91



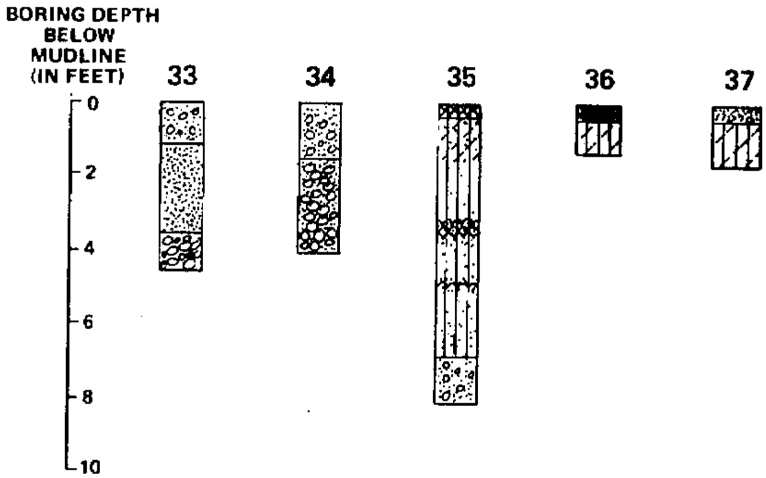




Test Boring Logs A-2



Test Boring Logs
(Continued)



BORINGS FOR PERCIVAL COVE

cadmium
sulfide
PCB (polychlorinated biphenyls)
TCH (total chlorinated hydrocarbons)

The amounts of mercury, lead, copper, zinc, and cadmium found in the samples were reviewed with the Environmental Protection Agency. Because these amounts were below the minimum EPA values, an elutriate analysis was considered unnecessary.

The tests performed and the measured values are shown in table A-3. Minimum values of some of the parameters that the EPA generally uses for comparative purposes are given in table A-4.

Table A-4. **EPA CHEMICAL PARAMETERS**

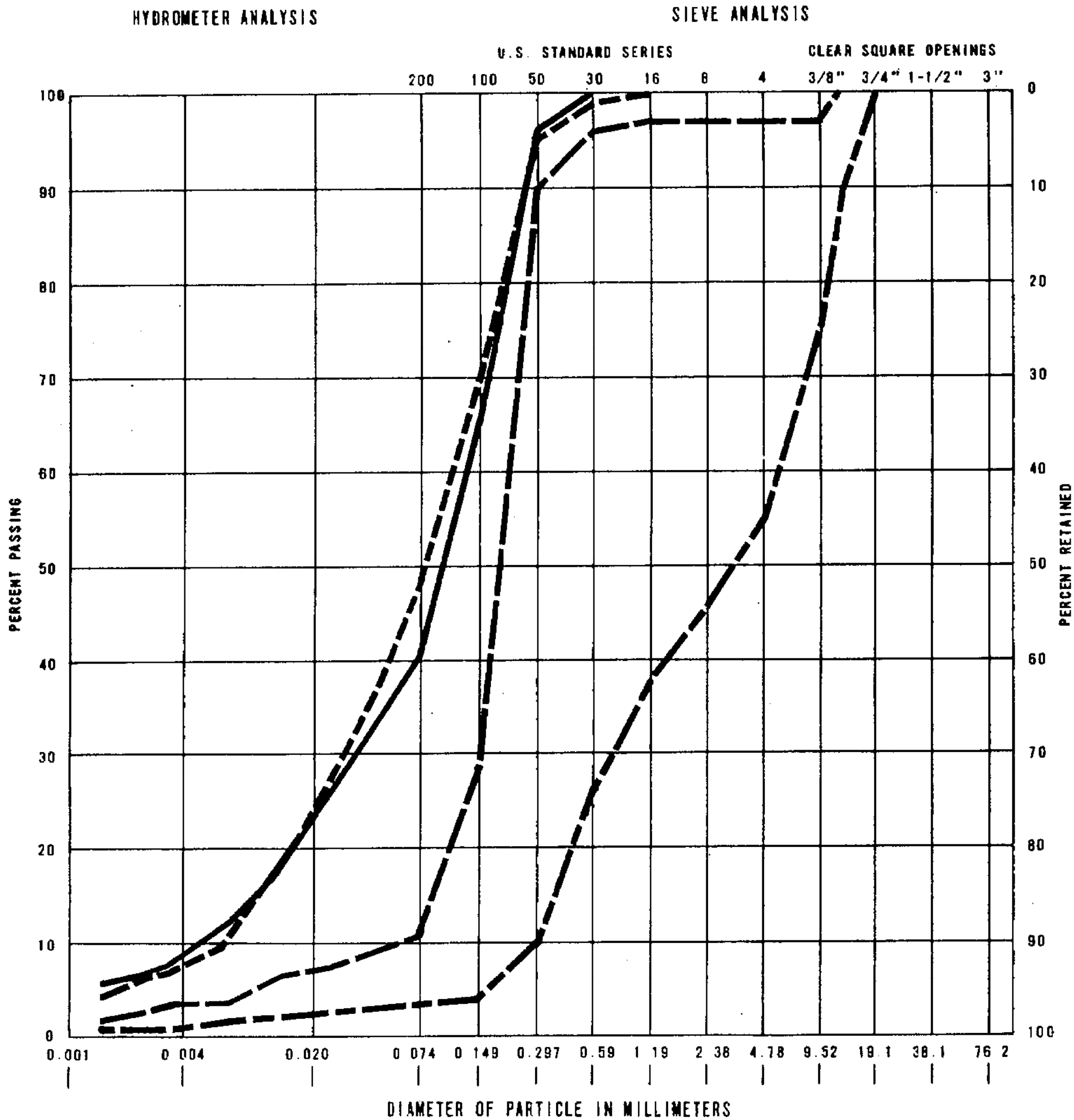
Volatile solids	%	6.0
COD	mg/kg	50,000
Kjeldahl nitrogen	mg/kg	1,000
Oil-grease	mg/kg	1,500
Mercury	mg/kg	10
Lead	mg/kg	50
Zinc	mg/kg	50

Minimum values for other EPA parameters have not been published. These other parameters are important and are generally evaluated by the EPA on a case-by-case basis.

Table A-3. CHEMICAL PROPERTIES

Test Hole Number	Date	Laboratory Sample Number	Depth Feet	Total Solids Percent	Total Volatile Solids Percent	Initial Oxygen Demand mg/kg	Chemical Oxygen Demand mg/kg	Oil and Grease mg/kg	Kjeldahl-N mg/kg	Total Phosphorus mg/kg
					- - - - - - - - - - - - Dry Weight Basis - - - - - - - - - - - -					
1	11/75	C75-373	0-0.5	40	8.9	690	80,300	4,200	1,500	553
		C75 375	4.0-4.9	57	2.8	850	84,700	1,500	1,980	400
		C75-374	10.7-12.0	86	1.1	42	3,650	920	100	66
3	11/75	C75-376	5.1-6.2	78	1 4	100	12,900	900	300	69
		C75-377	9.0-10.3	60	5.8	790	55,600	1,300	1,100	447
4	11/75	C75-380	0-1.4	66	3.8	250	25,200	1,600	690	139
		C75-379	12-14.5	53	3.3	360	77,400	1,100	1,590	370
8	11/75	C75-381	0 1.4	51	6.8	690	64,900	1,700	1,950	420
13	11/75 12/75	C75 382	0-1.4	51	8.1	430	95,500	3,600	1,580	474
27	11/75	C75-385	0-2	74	1.65	77	6,650	1,300	178	294
	12/75	C75-384	8-10	56	5.06	317	72,300	1,830	1,496	304

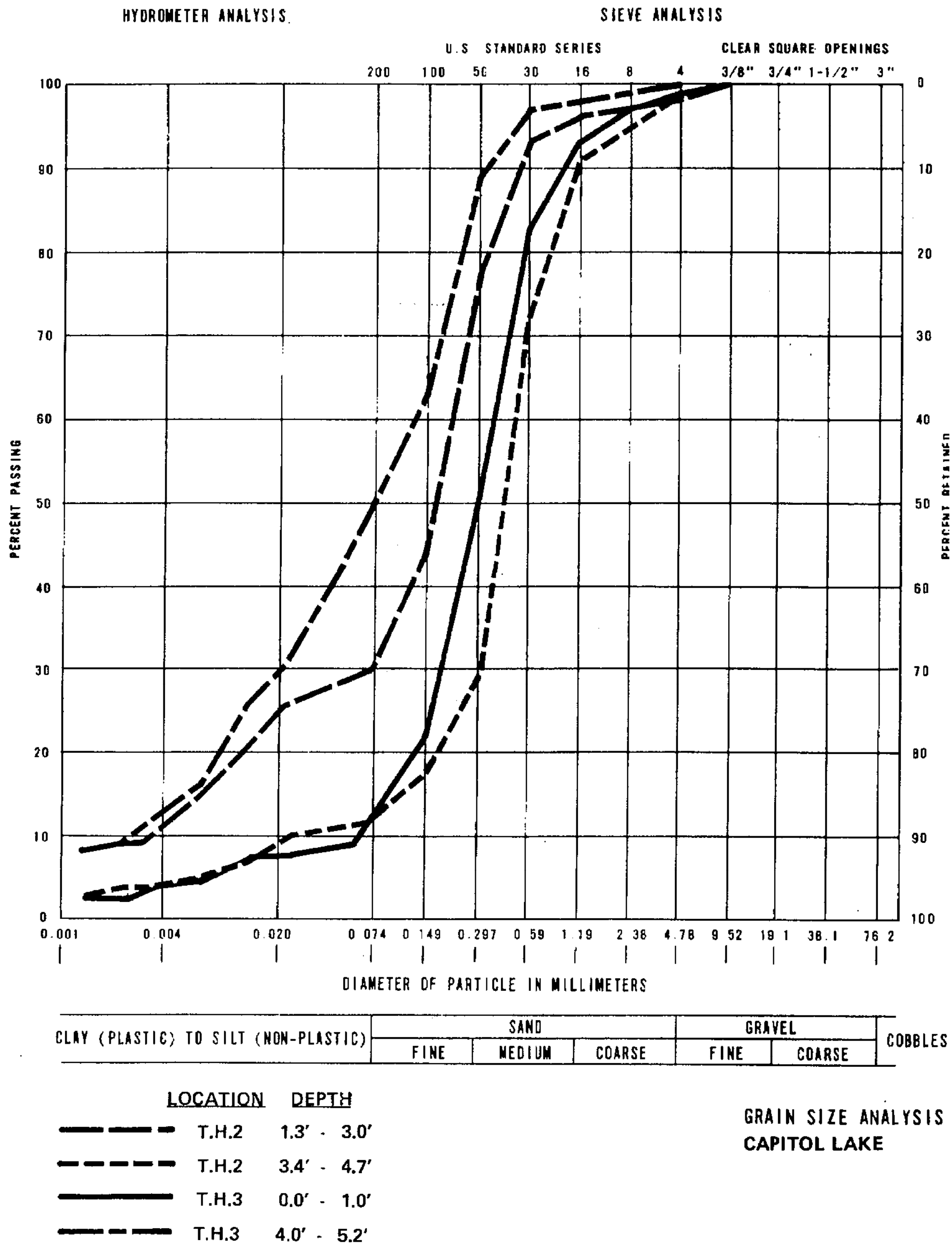
Test Hole Number	Laboratory Sample Number	Mercury mg/kg	Lead mg/kg	Copper mg/kg	Zinc mg/kg	Cadmium mg/kg	Sulfide mg/kg	PCB ppb	TCH ppb
		- - - - - - - - - - - - Dry Weight Basis - - - - - - - - - - - -							
1	C75-373	0.045	11	28	47	0.29	2	0.4	1.2
	C75-375	0.315	9	19	48	0.30	9	-	
	C75-374	0.026	4	8	32	0.09	<1	-	-
3	C75-376	0.166	7	10	24	0.18	2	0.2	0.6
	C75-377	1.03	11	23	47	0.52	135	-	-
4	C75 380	0.039	6	13	27	0.28	6	-	-
	C75-379	0.059	4	20	36	2	36	-	-
8	C75 381	0.238	11	20	43	0	174	1.8	2.6
13	C75-382	0.365	10	16	38	0.99	36	-	-
27	C75-385	0.042	3	17	17	0.2	5.5	4.0	4.8
	C75-384	0.013	<2	25	25	0.70	49	-	-



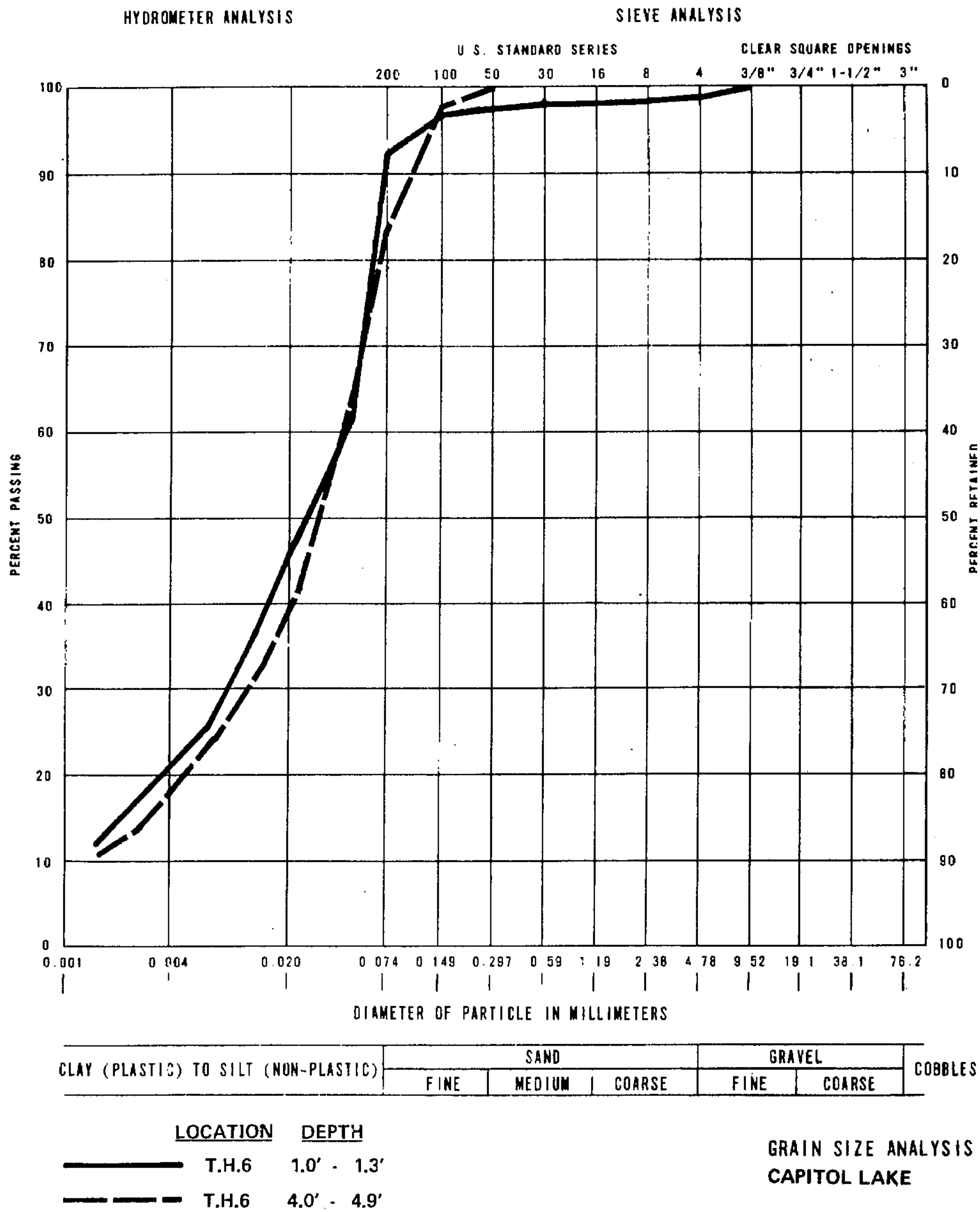
CLAY (PLASTIC) TO SILT (NON-PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

LOCATION	DEPTH
T.H.1	0.0' - 0.2'
T.H.1	1.1' - 1.3'
T.H.1	6.0' - 7.7'
T.H.1	10.5' - 12.2'

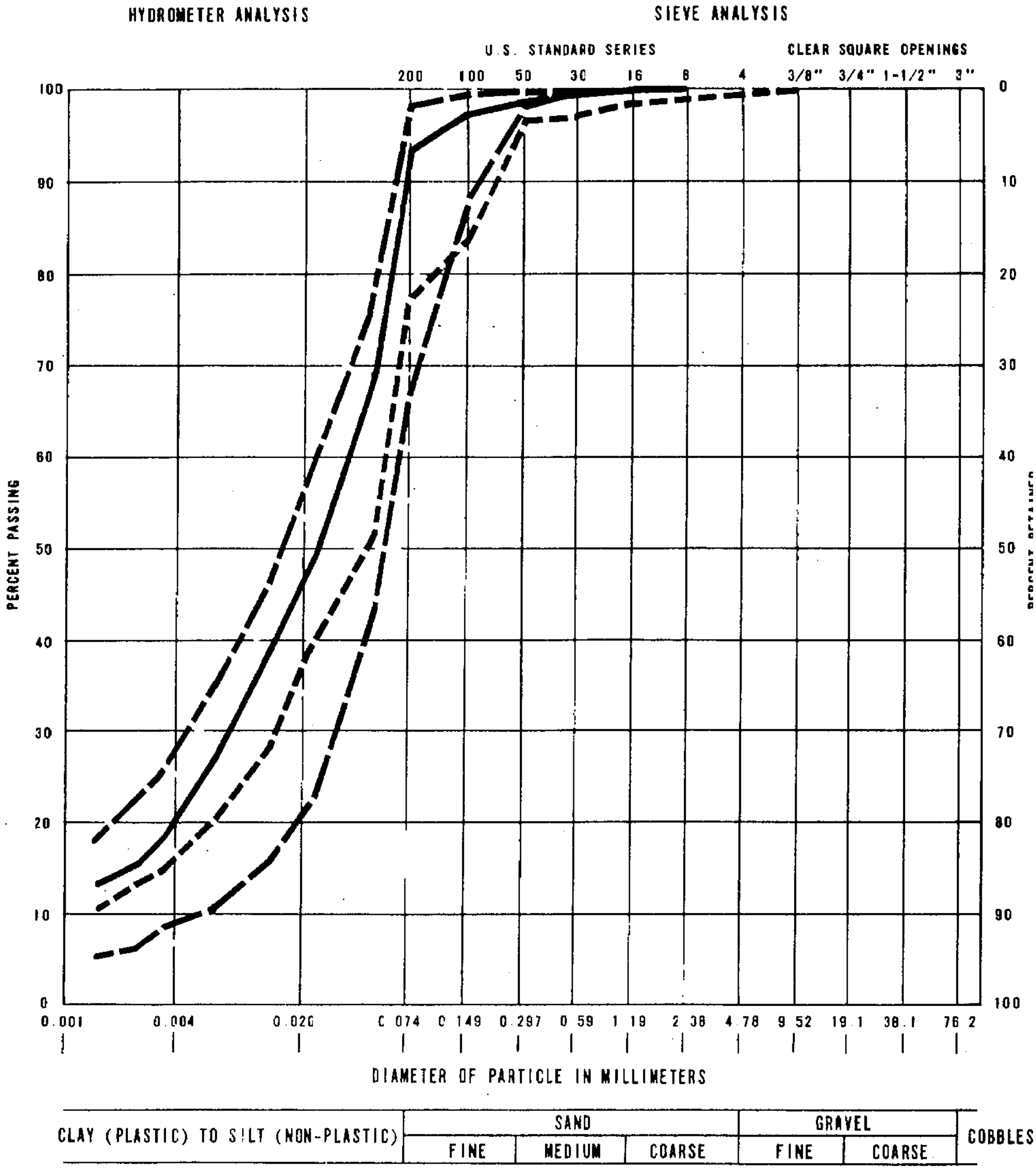
GRAIN SIZE ANALYSIS
CAPITOL LAKE



GRAIN SIZE ANALYSIS
CAPITOL LAKE

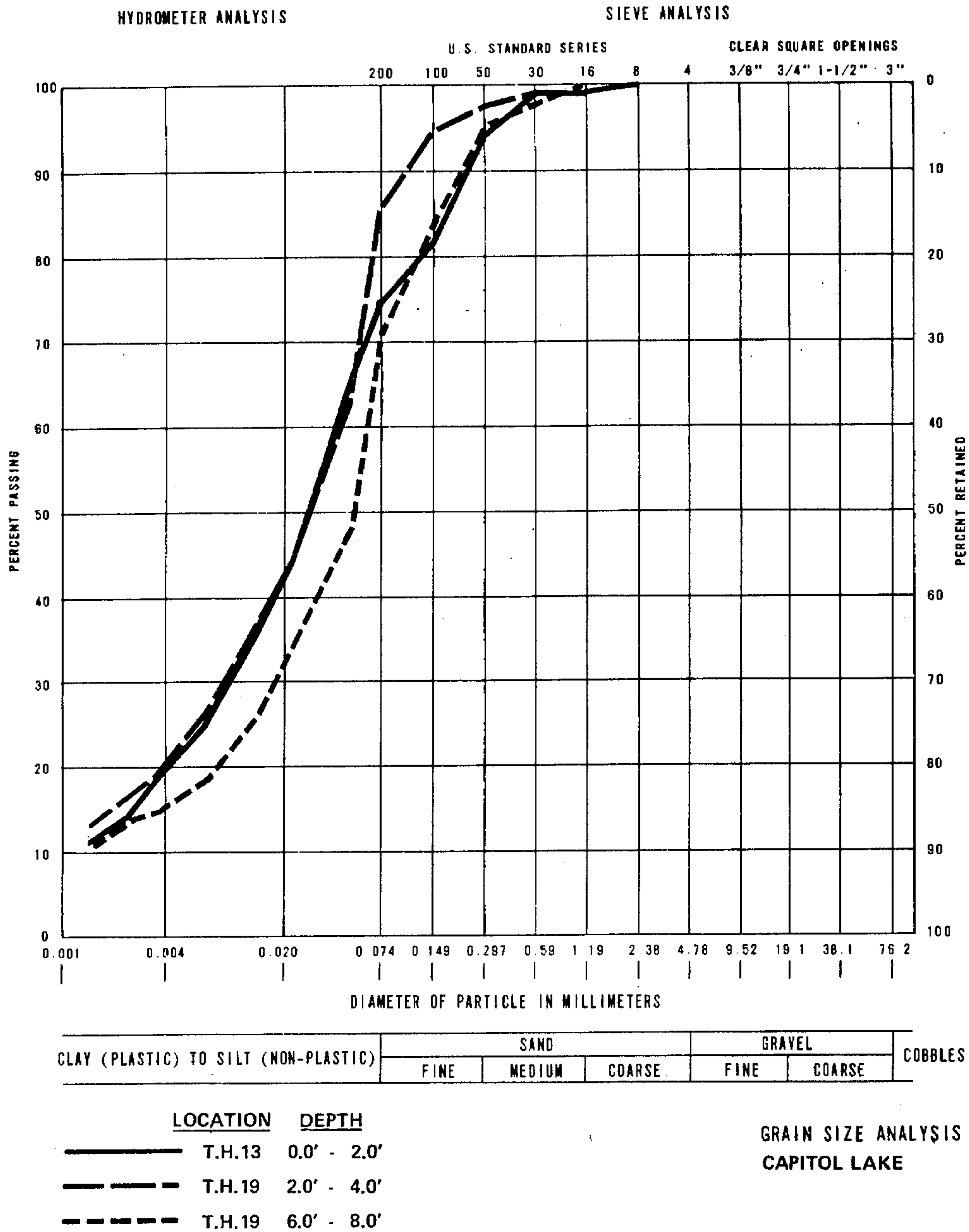


GRAIN SIZE ANALYSIS
CAPITOL LAKE

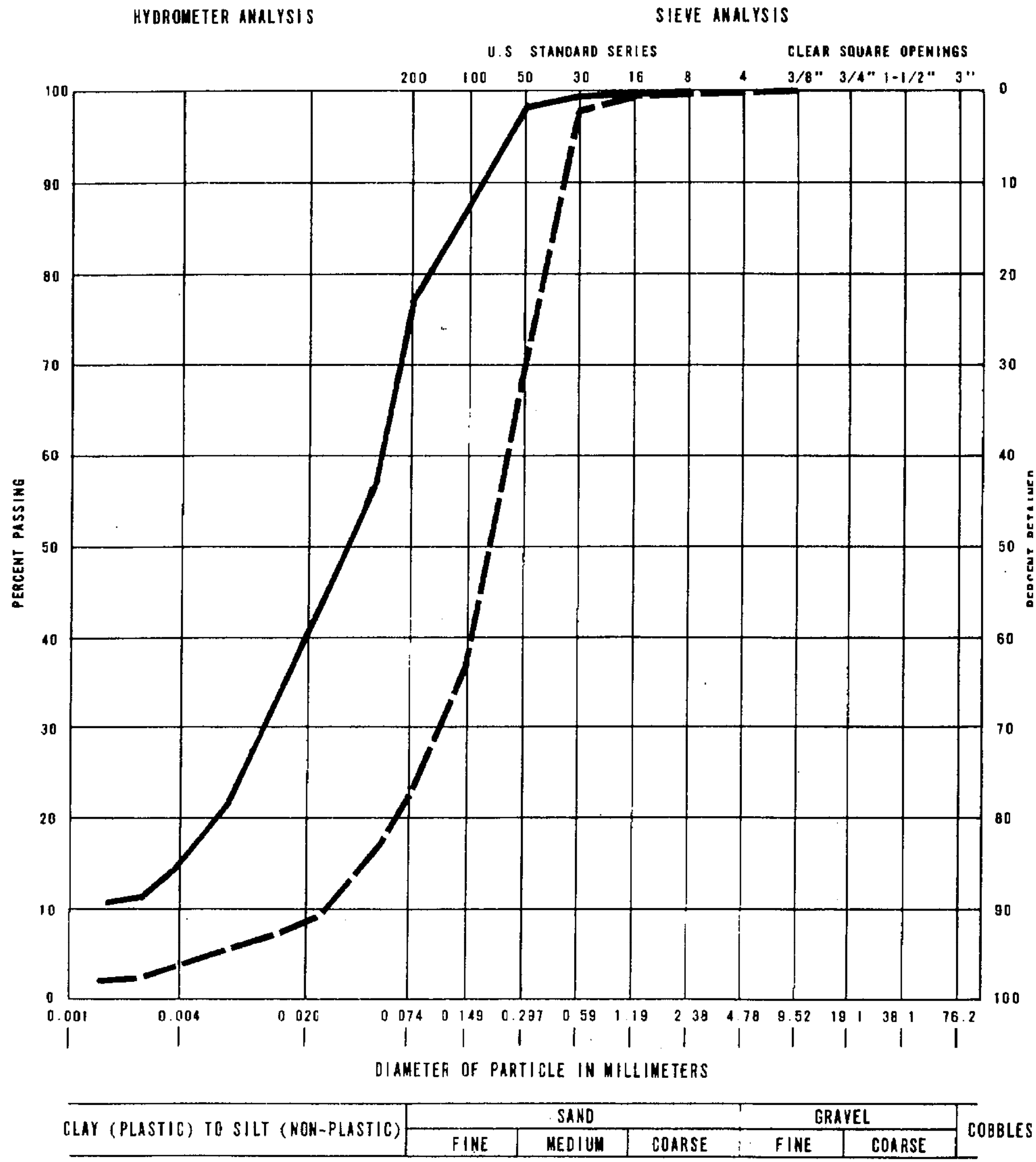


LOCATION	DEPTH
T.H.7	0.5′ - 1.0′
T.H.7	4.0′ - 5.3′
T.H.12	0.5′ - 0.8′
T.H.12	4.0′ - 5.0′

GRAIN SIZE ANALYSIS
CAPITOL LAKE

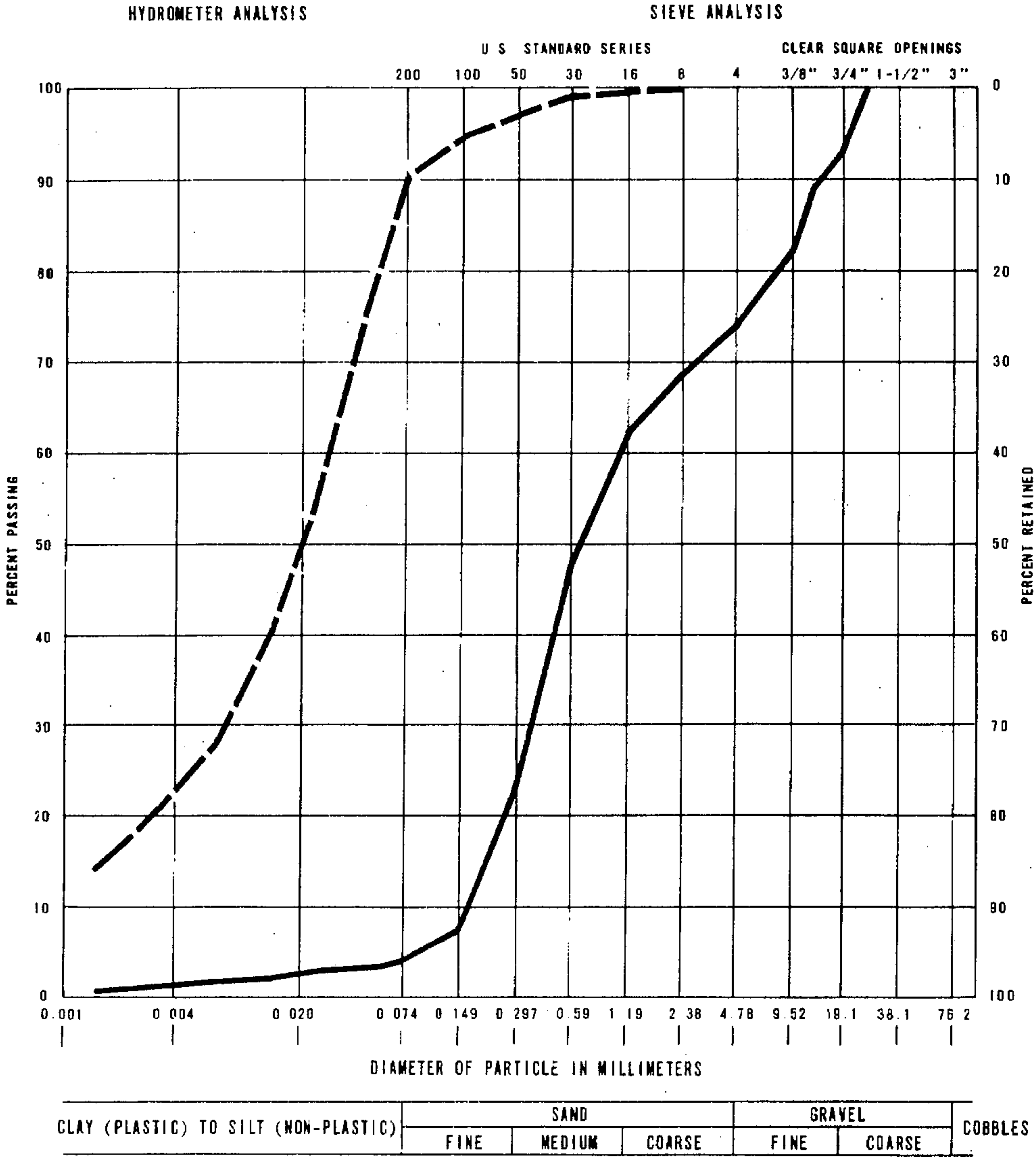


GRAIN SIZE ANALYSIS
CAPITOL LAKE



LOCATION	DEPTH
T.H.26	0.0' - 2.0'
T.H.26	8.0' - 10.0'

GRAIN SIZE ANALYSIS
CAPITOL LAKE



LOCATION	DEPTH
T.H.34 (solid line)	0.0' - 1.5'
T.H.37 (dashed line)	1.0' - 1.6'

GRAIN SIZE ANALYSIS
CAPITOL LAKE

Capitol Lake

Appendix B

APPENDIX B

CAPITOL LAKE HYDRAULICS AND SEDIMENT STUDY BY WASHINGTON STATE UNIVERSITY

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the sedimentation, water quantity and water quality studies, and interaction during the project with the various agencies and groups having an interest in Capitol Lake, the following conclusions and recommendations have been developed. Detailed background information is in the body of the report.

1. Capitol Lake is a valuable and versatile resource to the State of Washington due to its location in the capitol city, its aesthetic appeal, its good water quality, and as an integral component of the capitol campus.	VALUABLE RESOURCE OF GOOD QUALITY
2. The lake, as an integral part of the Deschutes River, has been established as a Class A water system by the Washington Department of Ecology.	CLASS A
3. In addition to its inherent aesthetic appeal, two major uses of the lake (public recreation and anadromous fish rearing) establish the general requirements for water quality maintenance.	MAJOR USES
4. According to the criteria of nutrient loading and surface area to volume ratio, the lake would be expected to be relatively eutrophic, tending to support significant rooted weed and floating algae populations. However, the very short hydraulic retention time, compared to other lakes of similar morphology, substantially reduces the potential for algae growth problems.	SHORT RETENTION TIME ENHANCES QUALITY
5. Several physical features of the lake are dominant in establishing the fundamental character of the lake and its overall quality.	PHYSICAL FEATURES

5a.	The lake is essentially a wide spot at the mouth of the river with an artificial boundary (the dam) maintaining the interface between fresh and salt water.	WIDE SPOT IN RIVER
5b.	The salt water barrier is and has been managed to allow an annual influx of salt water for anadromous fish release that also appears to be important to controlling development of rooted aquatic plants. This control is of particular importance in the Lower and Middle Basins.	SALT WATER BARRIER
5c.	The Deschutes River, contributing approximately 90 percent of total water input to the lake, is relatively nutrient rich and carries a relatively high sediment load, both varying in proportion to flow rate.	NUTRIENTS AND SEDIMENT HIGH
5d.	The lake serves as a settling basin for most of the river's sediment load and the annually deposited sediments have a significant influence on the character of the biological system in the lake.	SEDIMENT AND BIOLOGICAL SYSTEM
5e.	Hydrographic characteristics of the river are such that the lake is annually flushed and portions are scoured by flood flows about ten times larger than the mean annual flow. This flushing is important to limiting the build up of organic detritus in the bottom of the lake.	FLUSHING AND DEPOSITION

6.	The complete dredging of Capitol Lake to its pre-dam depth and volume conditions is not necessary to enhance the utility of the lake. The reduction in depth of the Middle (and especially the Lower) Lake has not seriously impaired their usefulness except in a few localities. The sand bar which has formed just downstream of the Highway 1-5 bridge is an example of one of the local problems. Also, increasing the lake	DREDGE TO ENHANCE UTILITY

volume increases the detention time of flow through the lake, thereby decreasing the flushing efficiency. Therefore, it is recommended that:

DREDGE THE UPPER LAKE AS SEDIMENT TRAP

6a. The Upper Lake should be dredged to serve as an effective sediment trap for coarser materials while maintaining much of the Upper Lake in its present state for passive forms of recreation.

OTHER LAKES DREDGE AS NEEDED

6b. The Middle and Lower Lakes should be dredged according to physical needs for removing hazards, providing shoreline access and economically balancing dredging with fills.

7. Effects of dredging on water quality and major lake uses are not expected to be significant:

EFFECTS OF DREDGE ON RESIDENCE TIME AND WEED GROWTH

7a. Mean residence time in the lake will be increased in proportion to the increase in lake volume by dredging. In a well-mixed system such an increase would favor the development of increased algae growth. However, due to the relatively poor mixing in the lake (particularly during low flow/ high productivity periods) the change in mean residence time is not expected to produce significant long-term changes in weed and algae growth patterns in the lake.

ALLOW FINE SEDIMENTS TO KEEP DOWN WEED GROWTH

7b. One of the major changes to be made in the lake is to alter the natural sediment deposition pattern so as to minimize continued filling of the lake after the initial dredging. Continued annual sediment deposition is judged to be a significant factor in limiting rooted weed development particularly in the Middle Lake. The effect of proposed dredging and sediment removal facilities will be to trap and remove heavier sediment components in the Upper Basin. Lighter sediment fractions are expected to continue to be deposited particularly through the south end of the Middle Basin where the effect on limiting weed growth is most significant.

7c. Permanent changes in the characteristics of bottom substrate, particularly as related to bottom organism habitat, are not expected to result from planned restoration measures.

NOT CHANGE BOTTOM HABITAT

7d. Chemical composition of bottom sediment samples taken from areas to be dredged in the Upper (south) and Middle Basins indicates that temporary impairment of water quality may be expected during initial restoration dredging. Adverse effects on water quality can be minimized if appropriate attention is given to scheduling and management of dredging and filling operations. Dredging conducted toward the end of the annual high flow period is suggested.

AVOID ADVERSE EFFECTS DURING DREDGING--SCHEDULE AS HIGH RECEDES

8. Bottom sediment samples taken from areas of the Upper and Middle Basins where dredging is anticipated have been analyzed for composition as a function of depth.

BOTTOM SEDIMENTS CONSISTENT

8a. Nutrient and organic composition is relatively independent of sediment depth.

8b. Variation of sediment composition with depth is not of sufficient magnitude to warrant establishing dredging depths on this basis.

9. Light penetration observations, particularly in the Middle Basin, suggest that light limitation alone would probably not be sufficient to control weed growth at depths as great as 20 feet or more.

LIGHT PENETRATION AND WEEDS

10. Items 8 and 9 above indicate that depth of planned dredging should be established on factors other than potential biological or water quality effects (i.e., physical, economical, boating needs, etc.). The primary biological effects are those related to weed and algae growth, and potential effects on natural fish food organisms and fish habitat. As pointed out in Item 9, the deepest dredging considered cannot be justified solely for minimizing weed growth. Shallower depths favor both economics and fish and fish food habitat. Thus, depth decisions will presumably be made to optimize these considerations with recreational requirements.

BASES FOR DREDGING

11. The generally acceptable pattern of water quality through the Middle and Lower Basins, established in part by the gradual dispersion of cooler river water which follows the deep channel even into the Lower Basin, suggests the advisability of not disrupting river water channelization completely within the Middle Basin. Thus, the dredging depth profiles in the Middle Basin should recognize this factor and retain a deep channel throughout the basin length.

COOLER WATER--RETAIN DEEP CHANNEL

12. The combination of the above characteristics, under normal hydrographic conditions and annual salt water flushing, can be expected to maintain relatively high quality conditions in the lake without significant problems of aquatic plants or algae blooms.

HIGH QUALITY MAINTAINED

13. The annual drawing down of Capitol Lake is essential to initiate the movement of juvenile salmon from Percival Cove into Puget Sound. Associated water quality benefits are discussed under water quality

ANNUAL DRAWDOWN BENEFICIAL

conclusions. This type of management practice, when conducted in a coordinated fashion to benefit both fisheries and recreation, is a beneficial action not normally available in most lakes. Therefore, it is recommended that the drawdown and flushing of Capitol Lake should continue on a designed schedule based on Department of Fisheries recommendations as they relate to Deschutes River streamflow and optimum salmon size for release into Budd Inlet.

ANNUAL DRAWDOWN BENEFICIAL

14. Annual influx of salt water near the commencement of the weed growth season is judged to be a significant factor in controlling development of rooted aquatic vegetation. Continuation of this management practice--allowing salt water flushing to as high an elevation as possible--is strongly recommended.

FLUSHING WITH SALT WATER

15. The shoreline fills, considered as alternate disposal sites for dredged materials in the Middle and Lower Lakes, will have little effect on the circulation pattern. Some of the other alternative fills, such as the two in the southwest corner of the Middle Lake will both help and hinder the circulation depending on their size and location. Therefore, it is recommended that only fill A1 (medium sized) be placed in the Middle Lake and that fill B (north of A1) not be placed. Fill B has a tendancy to impair the circulation pattern in the southwest corner of the Middle Lake, whereas fill A1 improves the circulation. All other fills in the Middle and Lower Lakes will have very little, if any, effect on lake circulation and no adverse effects locally on flow.

SHORELINE FILLS: SOME HELP, SOME HINDER

16. The effects of all suggested lake fill locations have little potential for adverse effects on water quality,

FILLS AND QUALITY

FILLS AND QUALITY

but fills will reduce areas now available for fish rearing and boating. The importance of using lake shoreline areas for dredge spoil deposition because of economic considerations is recognized as is the potential benefit of providing additional shoreline area for recreational use. Similarly, it is important to recognize potentially adverse effects of reducing lake surface area on fisheries and recreational uses of the lake.

MAN-CAUSED SEDIMENT IN PERCIVAL CREEK

17. The transitional exposure of raw earth and loose, unprotected fills in subdivisions in the Percival Creek drainage basin can create a serious sediment problem in the Percival Cove fish rearing area. Every reasonable step should be taken by the appropriate jurisdictions to guarantee that potential man-caused erosion is minimized through the use of protective devices such as sediment trap areas at the construction site, and at the mouth of Percival Creek.

FISH REARING AND FUTURE WATER QUALITY

18. Fish rearing activities contribute significant quantities of nutrients and organic materials to the lake system with potential for increasing weed and algae growth. However, under normal hydrographic conditions and at current levels of fish rearing, significant water quality impairment has not been observed. Should fish rearing activities be increased in magnitude, further studies should be conducted to properly detail the impact on water quality.

FUTURE I-5 BRIDGE WORK

19. It is anticipated that future modifications to the highway I-5 bridge over the outlet of the Upper Lake will need to be made. The hydraulic model studies of the Upper Lake have shown that the highest velocities occur in the vicinity of the bridge opening. The new

configuration of the Upper Lake has been designed to reduce, or not increase, any local velocities which now exist. Therefore, in designing for the widening of the I-5 bridge, it is recommended that consideration be given to the protection and maintenance of flow patterns, especially just south of and through the bridge, so that the sediment trapping efficiency is not reduced and the island geometry is not altered.