CAPITOL LAKE RESTORATION ANALYSIS

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ENTRANCO Engineers
ENVIRONMENTAL AND TRANSPORTATION CONSULTANTS

CAPITOL LAKE
RESTORATION ANALYSIS

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Entranco Engineers
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I

INTRODUCTION

Capitol Lake (Figure 1) was formed in 1951 with the completion of the 5th Avenue dam. The lake provides a valuable recreational and aesthetic resource to the state of Washington and also represents an important economic asset as one of Washington State's most important fish rearing areas.

Capitol Lake has encountered a variety of problems since its formation. Historically, the primary problems have included:

- Coliform bacteria counts occasionally in excess of acceptable standards established for recreational contact sports. As a result, continued recreational use of the lake has been questioned.
- Excessive sediment deposition within the lake basin by the incoming Deschutes River and Percival Creek flows. The resultant loss of lake volume (at a rapid rate) threatens the existence of Capitol Lake.
- An abundance of nutrients available for plant growth (eutrophication). Excessive growth of aquatic plants can impact the beneficial uses of the lake through reduced water clarity and the production of dense algal mats and weed beds.

The water quality problems of Capitol Lake have led to frequent closures of a public swim area maintained by the City of Olympia in the north lake basin. Because of the chronically poor water quality of Capitol Lake, a swim area restoration project was undertaken in 1982. The objective of the restoration was to provide a positive control of water quality within the swim area to ensure continuous use of the area throughout the swimming season.

Recently, another water quality problem within Capitol Lake has been identified. In September of 1981, a fish kill was observed near the tide gate dam of Capitol Lake. Subsequent investigations by the Washington State Department of Ecology identified specific water quality problems originating within the lake as the cause of the fish kill. It was observed that stagnant marine water in a north basin depression resulted in the production of hydrogen sulfide gas, a substance toxic to fish.

Concern regarding the chronic water quality problems of Capitol Lake and the relatively recent appearance of the hydrogen sulfide fish kill mechanism within the north lake basin prompted the current study.

Early in 1982, a task force was created by Governor Spellman to provide an up-to-date analysis of the causes, consequences, and solutions to previous and newly identified problems of Capitol Lake. The interagency task force included the Governor's office; Washington State Departments of General Administration, Ecology, Fisheries, and Game; the Washington State Conservation Commission; the U.S. Department of Agriculture, Soil Conservation Service; Thurston County Conservation District; Thurston County Public Works Department and Department of Human Services; and the Cities of Olympia and Tumwater. The Department of General Administration secured Referendum 39 funds for the current study.

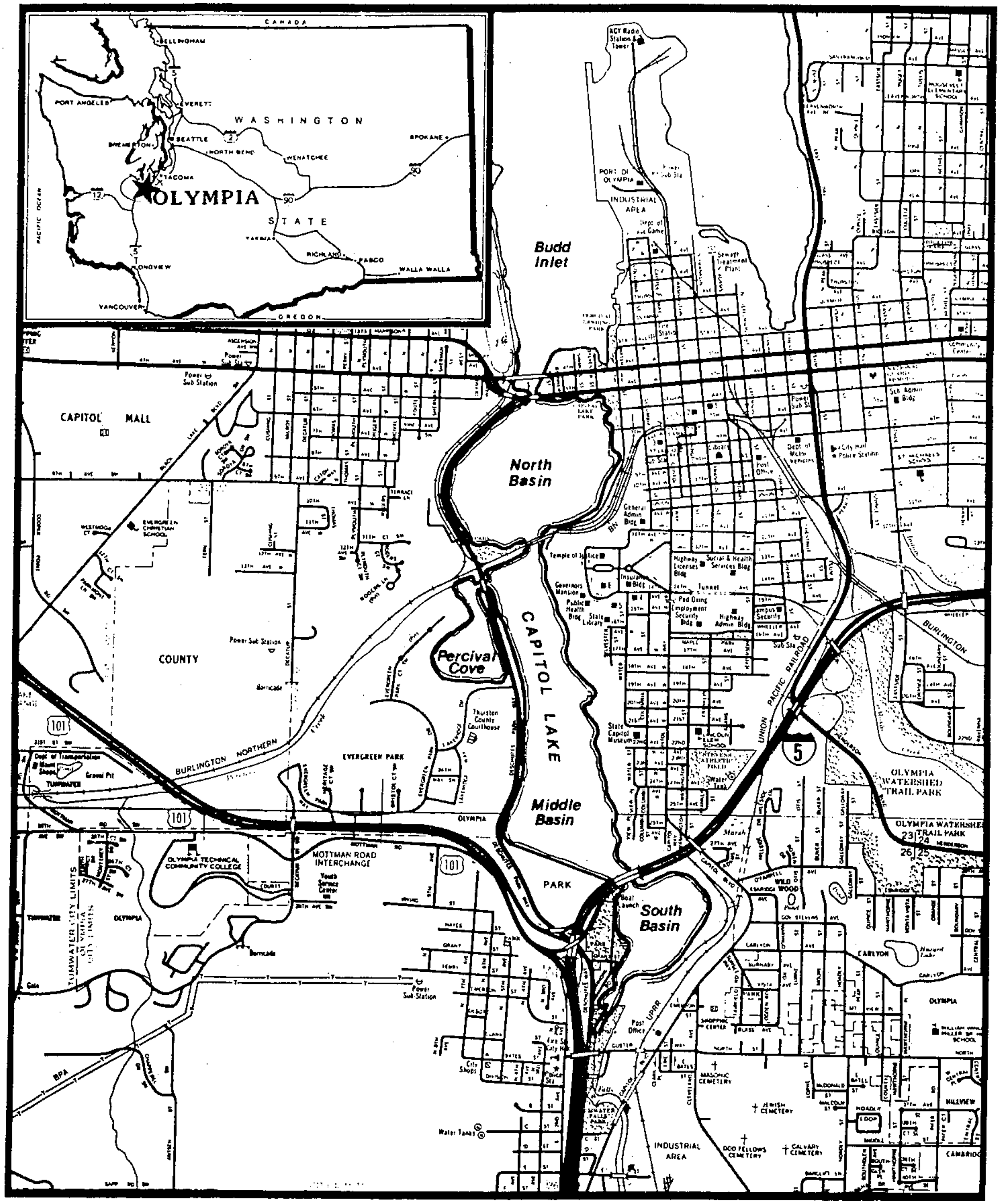
Entranco Engineers was retained by the Department of General Administration as a member of the task force to provide an updated assessment of Capitol Lake. Specifically, it was intended that a study be conducted to address:

1. Prevention of the fish kill mechanism associated with the north basin depression (the tide gate crater).

2. The current rate of sediment deposition within the lake basin and the performance of previous attempts to control or manage the sediment entering the lake.

3. The current extent, cause, and potential mitigation of the water quality problems (high bacteria counts and nutrient enrichment) that have historically plagued the lake.

4. The performance of the Capitol Lake swim beach restoration completed in 1982.



NORTH

CAPITOL LAKE RESTORATION PROJECT
THURSTON COUNTY OLYMPIA, WASHINGTON

Figure I

PROJECT LOCATION

ENTRANCO Engineers

To meet these objectives, Entranco Engineers reviewed the results of previous studies and any other historical data that was available. A monitoring program was conducted from March through August 1983 to define the current status of Capitol Lake problems and to generate additional data required. Through integration of historical and current data, restoration alternatives for the lake were defined and the performance of the swim area restoration program was assessed.

A summary of the historical data review and an assessment of the current status, with appropriate recommendations, are included in the following text under the specific problems addressed. A description of the monitoring program of the current study is included in Appendix A, along with the objectives and methods employed. Data generated by the various monitoring tasks are tabulated in Appendix B.

Because of the economic importance of Capitol Lake for commercial and sport fisheries, additional consideration was provided regarding the effect of recommended solutions on the existing fisheries. A summary of the fisheries implications is included in Appendix C.

II

SUMMARY AND CONCLUSIONS

A summary of the Capitol Lake restoration analysis and recommended restoration plan is presented in the following summary matrix. A brief definition of the problems, their cause(s), recommended solutions, cost estimates, and predicted benefits is included. Current state-of-the-art techniques have been used to define the complex ecological system of Capitol Lake. Additional studies will continue to be required as new techniques or data become available concerning the interaction or effects of diverse factors influencing the lake. The information presented in the summary matrix represents the best estimates of cost and benefit that can be identified at the present time and are based upon recently collected and historical data. The total implementation cost for the first three years of operation, assuming that all recommendations are implemented, is estimated at $1,908,000. Long-term operational and maintenance dredging is estimated at $600,000 per year.

The basic intent of this recommended plan is to preserve the existing status of beneficial uses provided by Capitol Lake, including fish rearing, flood control, recreation, tourism, aesthetics, and wildlife habitat. It is recognized that certain restoration elements have the potential to produce adverse environmental impacts. It is also recognized that many significant engineering issues remain to be resolved prior to actual implementation. For example, the recommended dredging program, as presented, is largely conceptual and additional information is required before final decisions can be made regarding the exact locations and extent of dredging, dredging methods, and the location, frequency, and size of dredge spoil staging and final disposal facilities. Additional consideration should also be given to a cost/benefit comparison of sediment control techniques in the watershed versus in-lake dredging, since the success of the former could have a significant impact on the extent of the latter. It is

SUMMARY MATRIX OF
CAPITOL LAKE RESTORATION ANALYSIS
AND RECOMMENDED RESTORATION PLAN

PROBLEM	CAUSE	SOLUTION	COST	BENEFITS
Fish Kills				
Two fish kills were observed in Budd Inlet just downstream from the tide gate structure at Capitol Lake during the summer of 1981.	Operation of the tide gate in conjunction with fish rearing, aquatic plant control, and swim area management has resulted in the creation of a 40-foot deep crater on on the lake side of the tide gate structure. During certain summer tidal cycles, stratified saltwater within the crater becomes stagnant and depleted in oxygen. Under these conditions, hydrogen sulfide gas is formed. This gas is toxic to fish and has been identified as the cause of at least two fish kills in Budd Inlet.	The installation of a 12-inch siphon between the tide gate crater and Budd Inlet will permit water from the the crater to be discharged to the marine side at a rate exceeding the inflow of marine water to the lake side. Thus, a freshwater, non-stratified, well-oxygenated water condition will be maintained in the crater. A pump option is recommended in the event of siphon failure.	The cost of siphon withdrawal with pump option is estimated at $150,000.	Fish kills associated with the tide gate crater phenomenon would be eliminated by a technique requiring relatively little maintenance. Please note that fish kills associated with other unrelated fish kill mechanisms would not be affected.
Sedimentation				
Despite the construction of two sediment traps in 1979, the middle and north basins of the lake are filling in at a rate of 1 foot every 11 to 13 years. In the absence of corrective action, the lake would fill during the next 80 to 100 years. Sedimentation in Percival Cove is an ongoing maintenance problem that inteferes with fish rearing activities.	The Deschutes River carries 40,000 to 55,000 cubic yards of sediment per year into Capitol Lake. Thurston County Conservation District and Soil Conservation Service (1984) studies identify streambank erosion as the major cause of sedimentation with recent increases in flow and sedimentation rates possibly due to timber harvesting in the watershed. Natural erosion in Percival Creek may be worsened by recent and anticipated future land use development in this watershed.	Continue maintenance dredging of middle basin sedimentation trap. Initiate a long-term maintenance dredging program for the entire middle lake basin. Dredge approximately 100,000 cubic yards of material every two years. Conduct additional engineering analyses to resolve technical and environmental issues. In-stream bank protection may be evaluated under pilot-scale testing. Development of a comprehensive drainage basin plan is recommended for the control of sedimentation problems in Percival Creek Cove. The need for addtional forestry management will be determined from the results of future monitoring.	Engineering analysis at $113,000. The first 2-year dredge cycle is estimated at $1,200,000 and will continue at this rate throughout the duration of the program. Estimate subject to revision based upon additional engineering analysis. The cost of Percival Creek drainage basin planning is estimated at $250,000.	Existing fish rearing, flood control, recreation, tourist and aesthetic values of Capitol Lake would be maintained by means of the proposed long-term dredging program. These beneficial uses may be lost or significantly altered in the absence of corrective action. Streambank protection may reduce costs of long-term dredging program. A Percival Creek drainage basin plan may mitigate annual maintenance dredging costs in Percival Cove and will also protect against potential impacts associated with future development.

SUMMARY MATRIX OF
CAPITOL LAKE RESTORATION ANALYSIS
AND RECOMMENDED RESTORATION PLAN
(Continued)

PROBLEM	CAUSE	SOLUTION	COST	BENEFITS
Eutrophication				
Excessive nutrient inputs (ususally phosphorus or nitrogen) can promote excessive algal and aquatic weed growth in lakes, resulting in impaired recreational utility and appearance. Algal identified as significant water quality problems in Capitol Lake.	Phosphorus is considered the most manageable nutrient from a lake restoration perspective. An evaluation of all phosphorus loading sources to Capitol Lake has revealed a total phosphorus load of 20,500 kg P yr^{-1}, resulting in a mean annual phosphorus concentration of 41 mg P m^{-3}. Approximately 14,760 kg P yr^{-1} (72%) of total loading is associated with natural or uncontrollable sources. The remaining controllable sources, including brewery discharges (14%), dairy wastes (10%), and Percival Cove source (4%, suspected to originate in sediment nutrient release mechanisms and/or suspension of fish food or excrements) account for 5,740 kg P yr^{-1}, or 28% of annual phosphorus loading to Capitol Lake. The significance of these sources with respect to total loading to the lake increases during the productive summer months.	CD/SCS has already made contact with dairy owners and remedial actions have been taken voluntarily. DOE is coordinating with the brewery to evaluate alternative control strategies. No definitive course of action has been agreed to at the present time. Sediment nutrient release in Percival Cove could be controlled by aluminum sulfate application but potential risks to fish rearing make such treatment unlikely. Pilot-scale studies could be performed to evaluate fish impacts. Dredging to nutrient-poor substrate or the seasonal diversion of Percival Creek flows may eliminate or reduce this nutrient source.	Restoration measures taken by dairy owners or the brewery will be accomplished without the benefit of public funds. The cost of an aluminum sulfate treatment in Percival Cove is estimated at $28,000. Costs of dredging within the cove are assumed incorporated with the costs addressed under dredging for sedimentation control. Potential costs of Percival Creek flow diversion have not been determined.	Control of 5,740 kg P yr^{-1} would result in a change in mean annual lake phosphorus concentration to 31 mg P m^{-3}, a 24% reduction. Control of this amount of phosphorus would result in even more significant changes in phosphorus concentrations during summer recreation months, from 38 mg P m^{-3} to 22 mg P m^{-3}, a 42% reduction. Such phosphorus reductions would potentially result in a 53% reduction in algal concentrations and a 78% improvement in water visibility (from 1.4 to 2.5 meters). Actual improvements will be dependent upon the degree of treatment provided for each of the identified sources.
Bacteria				
Water quality studies conducted in 1977 revealed numerous violations of the lake quality standard for fecal coliform bacteria. More recent studies by DOE in 1982 revealed <u>no</u> bacterial standard violations.	DOE has indicated that a major sewage lift station in the vicinity of Tumwater was found inoperable and that sewage was overflowing into the lake. This problem has since been corrected. Correction of this problem is believed to be the major factor responsible for reduced bacterial concentrations in Capitol Lake. Another sewer system failure at 7th Avenue in Olympia has also been corrected.	No additional corrective action is recommended at this time. However, long-term surveillance monitoring is recommended.	A complete performance monitoring program, including provision for sediment, bacteria, flow, and nutrient monitoring, is estimated to cost $107,000 for a 2-year period.	Surveillance of the public health characteristics and other water quality parameters of Capitol Lake.

SUMMARY MATRIX OF
CAPITOL LAKE RESTORATION ANALYSIS
AND RECOMMENDED RESTORATION PLAN
(Continued)

PROBLEM	CAUSE	SOLUTION	COST	BENEFITS
Swim Area				
The Capitol Lake swim area, under the jurisdiction of the City of Olympia, has been closed to swimming on several occasions prior to 1982.	Swim area closures imposed by the Thurston Regional Health Department were enforced primarily because of poor water clarity and the associated risk of drowning. Poor visibility was attributed to excessive algae concentrations and associated with high nutrient loading and poor water circulation.	In 1982, the City of Olympia constructed a hypalon curtain to encircle and isolate the swim area. Additional improvements were included to provide dilution, disinfection, and nutrient removal. The first full year of operation was completed during the summer of 1983. The effectiveness of operation and maintenance measures was evaluated as a part of this restoration analysis. Recommendations for improved cost effectiveness are identified.	No cost.	Improved cost effectiveness of swim area water quality treatment and improved recreational utility.
TOTAL PROJECT COST			$1,908,000 Includes $60,000 for environmental review process	

intended that unresolved engineering and environmental impact issues will be adequately addressed during the final design and environmental review process prior to implementation.

Finally, it should be noted that in the process of identifying the recommended restoration plan, due consideration was given to the no-action alternative. However, there appears to be a consensus among the members of the project team and participating review agencies that the no-action alternative would not adequately protect or preserve the most important beneficial uses of the lake: fish rearing, recreation, and flood control (provided by the storage capacity of the lake basin in conjunction with the option to "drain" the lake to accommodate high river flows during periods of high tides).

Additional summary discussion is provided for each problem category in the following narrative.

TIDE GATE CRATER

An engineering analysis was conducted to identify solutions for the tide gate crater. It is recommended that a siphon be used to withdraw marine water from the lake, thereby preventing stagnation within the crater. It is also recommended that the system be designed to allow the possible future addition of a pump should the withdrawal by siphon prove inadequate. Continuous monitoring of conductivity and dissolved oxygen within the crater is recommended (at least initially) to evaluate capabilities of the system.

In the interim, until the proposed permanent restoration plan for the tide gate crater can be implemented, it is recommended that the operating procedures defined by Seigle (1983) and utilized during 1983 be employed. Under these procedures, the lake is lowered and the crater is intentionally flushed with marine water when low dissolved oxygen concentrations are found within the crater. Because of the undefined variables associated with this option, it is advised that long-term dependence on it be avoided.

There is a potential for additional scour in the crater if marine backfilling is allowed when the tide elevation is substantially greater than the lake surface elevation. It is recommended that during future backfilling operations the maximum allowable head differential be 2 feet. Once the incoming tide elevation is 2 feet higher than the lake, the gates should be closed. Under such conditions, it is assumed that the backfilling procedure may have to be extended over two or possibly three tidal cycles.

SEDIMENTATION

The average rate of sediment deposition in Capitol Lake during the period 1975-1983 is 54,800 cubic yards per year. The current sedimentation estimate indicates an increase over previous studies. Although the majority of sediment loading to Capitol Lake is contributed by natural erosion processes (Moore and Anderson, 1979), the Thurston County Conservation District and Soil Conservation Service (CD/SCS, 1984) have raised the possibility that timber harvesting practices may be responsible for increased river flows and corresponding increases in sediment yield. However, there is insufficient data to determine whether measured increases in sediment deposition rate are not due to variation in weather patterns or to changes in land use practices.

The sediment traps created in 1978 accumulate approximately 22,000 cubic yards per year, or 40 percent, of sediment deposited in Capitol Lake. The remaining 60 percent (33,000 cubic yards per year) represents the deposition of finer, untrapable sediment throughout the middle and north basins.

Despite the presence of the traps, the average loss of depth in the middle and north lake basins is estimated to be 0.09 and 0.08 foot per year, respectively. This is equivalent to a 1 foot loss in depth every 11 to 13 years.

The south basin sediment trap is not performing as well as it was intended, with removal rates estimated at 25 to 50 percent of design efficiency. Since construction of the south basin trap, the river has deposited sediment in the approach channel to the trap and along the eastern boundary of the trap. This deposition has effectively eliminated the intended beneficial effects of the south basin trap. In contrast, the middle basin trap appears to be functioning at about 85 percent of design efficiency. It is estimated that overall trap removal efficiencies can be adequately met through maintenance of the middle basin trap only. Efforts required to improve the south basin trap probably would not be warranted by any potential increase in overall trap removal efficiency. Hence, it is recommended that the existing south basin trap be abandoned. In the absence of any additional dredging, it is expected that in time the south basin would reach a dynamic equilibrium with respect to sediment deposition such that the amount of sediment entering the basin would equal the amount of sediment passing into the middle basin.

It is worth noting that although the existing trap may be abandoned, the periodic removal of sediments from accessible depositional areas in the south basin via a front-end loader during a lake drawdown may be practical. The sediments removed (assumed hydraulically graded) may have a commercial value, thereby reducing the cost of removal. In addition, the recovery of material from the south basin may provide a greater allowable time period between the required maintenance dredging of the middle basin trap. However, additional consideration is warranted regarding time constraints associated with the drawdown operation and the potential commercial value of the material to be removed.

Despite routine maintenance of the traps, sediment will continue to be deposited in other areas of Capitol Lake. The deposition will impact the current use of Capitol Lake as a valuable resource. It is recommended that a comprehensive long-term dredging program be developed to manage the entire lake basin and to preserve existing beneficial uses (flood control, fish rearing, recreation, and tourism).

Percival Creek does not significantly contribute to the overall sedimentation problem of Capitol Lake. Sediment deposition by the creek does, however, impact the fish rearing operation in Percival Cove. Much of the sediment is the result of streambed and bank erosion, particularly along the lower reach of the stream where the gradient is steep. Increased development within the Percival Creek watershed has altered the natural hydrology of the stream. It is recommended that a basin-wide drainage management program be adopted to mitigate present and future impacts related to watershed development.

EUTROPHICATION (NUTRIENT ENRICHMENT) ANALYSIS

The amount of productivity (algal growth) is typically governed by the essential nutrient that is in least supply. Phosphorus or nitrogen are usually identified as the limiting nutrient in freshwater systems. Capitol Lake presumably demonstrates a tendency toward phosphorus limitation as indicated by the inorganic nitrogen to orthophosphorus ratios observed in the Deschutes River (the dominant factor influencing Capitol Lake). However, the productivity of the lake is also limited by physical factors such as the short hydraulic residence time and periodic marine backflushing. For the purpose of assessing the restoration potential of Capitol Lake, it is assumed that the practical management or control of algal productivity may be achieved through reductions of phosphorus (whether initially limiting or not) to the point where corresponding reductions in productivity are realized.

The current nutrient (total phosphorus) loading to Capitol Lake is estimated to be 20,507 kg/yr. This value is less than previous estimates of 33,750 kg/yr (CH2M Hill, 1978) and 39,500 kg/yr (Orsborn et al, 1975). The decrease may denote a reduction in nutrient loading, an improvement in the accuracy of the nutrient loading estimate, or dissimilarities between periods of study. Based on the phosphorus loading estimates, Capitol Lake may be classified as eutrophic.

The dominant nutrient sources are the Deschutes River (70 percent), the Pabst Brewery (14 percent), and Percival Creek (8 percent).

Nutrient loading by the Deschutes River is considered to be the result of (natural) surface runoff or groundwater discharge in the watershed, non-point loading from specific land use practices, and phosphorus bound up in the excessive sediment load of the river. Dairies monitored in the Deschutes River watershed contribute an estimated 14 percent of the nutrient load carried by the river (10 percent of the total loading to Capitol Lake). CD/SCS is currently working with land owners to reduce nutrient loading from these sources.

The brewery had not been identified as a nutrient source by previous studies. The constant point source discharge by the brewery is particularly significant during the summer months when the incoming river flow to Capitol Lake is typically low, providing for less dilution of the brewery discharge. Brewery officials estimate that up to 60 percent of the phosphorus in the discharge may be attributed to antiscaling compounds added to prevent excessive iron buildup in the pipes. The Washington State Department of Ecology is currently working with the brewery in identifying means by which the nutrient loading can be reduced.

The nutrient loading provided by Percival Creek is assumed to originate primarily from direct surface runoff or groundwater discharge in the watershed and possibly the loading provided by Black and Trosper lakes at the headwaters of the creek.

An unidentified loading source contributing an estimated 3.6 percent of the total nutrient loading to the lake was located in Percival Cove. It is suspected that the source may be the result of fish feeding activities as a part of the fish rearing operations conducted in the cove. Sediments in the cove are high in nutrients, presumably due to the deposition of unused food and fish excrement. Sediment nutrient release or the resuspension of unused fish food may account for the nutrient source within the cove.

The brewery, dairies, and Percival Cove are considered to be the three most controllable sources of phosphorus to the lake. During the productive summer months (May through September), these sources may represent as much as 50 percent of the total loading to the lake.

Analyses with empirical trophic state models indicate that restoration efforts directed toward reducing total phosphorus loading from controllable sources will provide subsequent improvements in water quality. The actual magnitude of the improvements is dependent upon the effectiveness of specific nutrient control measures applied.

BACTERIA

Stormwater bacterial loading has the potential to elevate the bacterial densities of Capitol Lake above the maximum acceptable levels. However, such impacts are considered short lived and localized. Stormwater loading occurring during the summer months when the hydraulic residence time of the lake is longest may have the greatest potential to significantly increase fecal coliform densities within the lake.

Runoff from the monitored dairies discharging into the Deschutes River represents a significant loading source of fecal coliforms. However, due to the remoteness of the dairies from Capitol Lake and the dilutional capacity of the river, it is questionable whether the dairies represent a significant bacterial loading source to the lake.

With the exception of one discharge (NPDES Permit No. 002), the Pabst Brewery does not represent a significant bacterial source to the Deschutes River and Capitol Lake.

Two point discharges exhibited high bacterial densities: Pabst Brewery discharge 002 and the City of Olympia 7th Avenue storm sewer (base flow). Both discharges indicated the possibility of contamination by human sources. However, it is recognized that additional data collection and analyses are required before the nature or significance of the identified discharges can be determined. It is recommended that additional monitoring be conducted on these discharges. It is also recommended that a long-term surveillance monitoring program be conducted within the lake to ensure that existing conditions are maintained.

SWIM AREA

The swim area restoration has resulted in corresponding water quality improvements. However, the full effectiveness of the restoration was not observed due to the operating conditions of the past summer. The impermeable curtain surrounding the swim area was shifted during lake drawdown in 1983. Consequently, gaps in the barrier permitted an exchange of untreated lake water with the swim area throughout the operating season.

The basic operating mode employed during the 1983 season was the use of City of Olympia drinking water to dilute the swim area. As a result, the water temperature within the swim area was somewhat colder than the lake.

The use of sodium aluminate (as a flocculant removing material from the water) during the 1983 season was sporadic and essentially unmonitored. Difficulties were encountered in handling and dispersing the chemical.

Primary recommendations for the operation of the swim area for use during the next season include:

1. Realigning the curtain to completely seal off the swim area from Capitol Lake.

2. Operating the swim area using dilution with treated swim area water rather than City of Olympia drinking water. (Design Options 3 and 4).

3. Using aluminum sulfate (alum) rather than sodium aluminate to treat the swim area. Use of alum should also be quantified.

The swim area should again be monitored under these modified operating conditions to define the full potential of restoration efforts.

Additional consideration may be given to reducing the swim area volume (to exclude areas not used for swimming during the past season) and to evaluate the effectiveness of the current system for providing adequate mixing of the water volume contained within the swim area.

III
TIDE GATE CRATER

INTRODUCTION

On September 9, 1981, a fish kill was observed on the marine side of the Capitol Lake tide gate. The fish were reported to have begun dying when the gates were opened and water flowed out of the lake (Tracy, 1981). It was estimated that 266,000 herring, 47,000 shiners, sculpins, flounder, and blennies, and 100 salmonids were killed. A subsequent fish kill (of presumably lesser magnitude) was reported on September 12, 1981. Following investigations, it was concluded that the water quality problems responsible for the fish kills originated within the north basin of Capitol Lake. Specifically, a large depression (or crater) in the north lake basin was discovered, where marine water that entered Capitol Lake was allowed to stagnate.

FISH KILL MECHANISM ASSOCIATED WITH CRATER

Tracy (1981) and Singleton (1982) have described the conditions responsible for the water quality problems within the crater. Saltwater intrusion into Capitol Lake occurs when the tide elevation is higher than the effective lake elevation. Saltwater enters the lake through leaks in the tide gate seals and the opening or closing of the gates when the tide elevation is sufficient to produce a marine inflow. The denser saltwater settles into the tide gate crater (the deepest part of the lake) where it remains undisturbed until additional marine water enters the lake. While the saltwater remains in the crater, bacterial respiration consumes dissolved oxygen. If the oxygen is depleted, anaerobic bacteria begin to produce hydrogen sulfide (H_2S) as a metabolic byproduct. Hydrogen sulfide is very toxic to aquatic life (the Environmental Protection Agency criterion for protecting aquatic life is 0.002 mg/l undissociated H_2S). In addition, H_2S exerts an immediate oxygen demand upon contact with aerated water. In the chemical process that ensues, H_2S is oxidized to colloidal sulfur and/or the sulfate ion. Hence, H_2S presents an additional threat to aquatic life through the chemical scavenging of available dissolved oxygen.

Entry of fresh marine water into the crater occurs regularly, hence the stagnant conditions leading to the depletion of oxygen and the production of H_2S are usually avoided. However, during the period preceding the September 9, 1981 fish kill, the maximum elevations of the high tides were not sufficient to permit saltwater entry into the lake. Consequently, the crater became anaerobic, and when there finally was a flushing of the hole, the oxygen-depleted water containing H_2S was released, causing the observed fish kill.

CRATER FORMATION

Capitol Lake is periodically flushed with marine water. The purpose of the saltwater flushing is to control rooted aquatic plants that at one time were abundant throughout the middle lake basin. The practice began in 1971 and has been found to be very effective in controlling the plants (Finn, 1972; Finn and Tarr, 1975). The marine backfilling practice has also been used as a means to rapidly restore the lake level following a drawdown to accommodate maintenance activities within the basin and to promote the movement of anadromous fish out of the basin. The backflushing procedure is identified as an important operational option for management of the lake by concerned agencies.

Typically, during a routine marine flushing operation, the lake is allowed to drain to the elevation of the tide gate dam sill (-17 feet elevation, MSL). The gates are then opened during an incoming tide. The flow of marine water into the lake results in energy being released into the north basin. This energy is dissipated through turbulence and scouring of the basin floor, resulting in formation of the crater. The size and rate of crater formation are dependent upon the magnitude of the head differential encountered during each backfilling and the volume of the crater as it relates to energy dissipation.

In 1975, Arvid Grant and Associates identified the maximum depth of the crater to be -29 feet (MSL) in a map prepared for General Administration. A Washington State Department of Ecology survey conducted in 1982 reported the maximum depth of the crater to be -32 feet (MSL) (Singleton, 1982). As a part of the present study, the crater was again surveyed following the backfilling operation of June 1983. A recording fathometer was used to document bottom contours while a survey crew positioned along the shore provided the horizontal control for the depth readings. The survey data have been incorporated with the topographic maps of the lake basin provided to the Department of General Administration. A comparison of the 1983 crater survey results with data provided by Singleton (1982) is presented in Table 1.

Table 1
Volume Estimates of the
Tide Gate Crater

	Volume (m^3)		
Contour Interval	1975*	1982*	1983
-30 to -32 (MSL)	0	23	0
-25 to -30	56	536	492
-20 to -25	665	1,766	1,721
-15 to -20	2,445	2,987	2,825
Total	3,166	5,312	5,038

* Singleton (1982).

The change in crater volume was substantial between 1975 and 1982 (a 68 percent increase). The differences between the 1982 and 1983 surveys are considered to be within the margin of error generated by mapping techniques and are therefore insignificant. It is worth noting, however, that a volume increase within the magnitude of detectible limits did not occur under the 1983 backfilling conditions.

The potential for further enlargement of the tide gate crater was estimated from conditions monitored during the 1983 backfilling. The velocity of incoming marine water was recorded in the vicinity of the crater along with the head differential existing between the lake surface elevation and the tide. The potential for bed scour was determined from the relationship between the velocities encountered at the bottom of the crater (extrapolated from measured values), critical scour velocities (based upon the d_{50} sediment particle size distribution of sediment samples obtained in the crater), and the head differential encountered during the backfilling operation.

The results of the analyses are presented in Tables 2 and 3. It appears that the potential of bed erosion within the existing crater is marginal. When the head differential existing between the lake and tide elevation is greater than 2 feet, bottom velocities are slightly greater than those required to produce erosion. During the recent backfilling, the maximum head differential was approximately 3 feet.

Table 2
Velocities Encountered Along the
Bottom of the Crater During 1983 Backfilling

d H* (Feet)	Velocity** (Feet per Second)
1	0.4 to 0.8
2	0.6 to 1.1
3	0.7 to 1.4

* d H is the difference in elevation between the lake surface and the tide.

** Velocities are extrapolated from measured values obtained in the water column above the bottom.

Table 3
Velocities Causing Potential Scour
at Sediment Sampling Stations
Downstream from Tide Gate (1)

Station	Distance Downstream From Tide Gate (2)	d_{50} Sediment Size (mm)	Eroding Velocities (3) (feet per second)
4	80	3.3	1.2 to 1.8
6	100	1.0	0.65 to 0.9
8	160	0.7	0.55 to 0.75
10	300	0.6	0.50 to 0.70

(1) Downstream is in reference to the incoming marine water.

(2) Along a transect running perpendicular to the tide gate structure and through the deepest part of the crater.

(3) Obtained from Mavis and Laushey Curve and Shields Curve (ASCE, 1975).

The sediment samples obtained indicate a progressively smaller grain size at locations farther away from the tide gate structure. Hence, under the estimated bottom velocities, the greatest potential for additional scour (along the transect) would occur along the southern periphery of the crater. However, it is estimated that if, during future backflushing operations, the head differential is not allowed to exceed 2 feet, then the increase in the crater volume will be minimal or negligible. Under such conditions the backfilling procedure may have to be extended over two or possibly three tide cycles.

CRATER ALTERNATIVES

Various alternatives for restoring the tide gate crater and/or mitigating the potential adverse impact it represents to water quality were examined. The basic approaches considered were:

- The prevention of water quality deterioration within the existing crater by means of aeration, mixing, or withdrawal of the saltwater held by the crater.
- The filling in of the crater to prevent future water quality problems from occurring.
- The prevention of water quality deterioration within the existing crater by means of modified tide gate operations.
- No action.

The following are brief descriptions of the various tide gate crater alternatives that have been examined. Table 4 provides a concise summary of all alternatives and their associated costs.

Alternative A

Description: Mechanical floating surface aeration. A surface aerator would be situated over the crater. Water would be lifted from below the surface and discharged into the air, thereby oxygenating the water.

Comments: The depth of the crater exceeds the zone of influence of even a very large aerator. Therefore, Alternative A has been eliminated from further consideration.

Alternative B

Description: Subsurface manifold aeration. A flexible PVC pipe network (1/2-inch diameter) would be placed along the bottom of the crater. An air compressor located in or near the tide gate control house would provide air to the system. Air diffusing from the pipe network would destratify and aerate the crater.

Comments

1. Continuous monitoring of conditions within the crater would be required in order to determine when the system needs to be operated. It is suggested that dissolved oxygen and conductivity be the parameters monitored.

2. Submerged components are susceptible to damage if excessive bottom velocities (due to large head differentials between the lake and tide elevations) occur.

3. Assumes pipe network can be placed with a boat and diver.

4. Biota using pipe network as a substrate or sedimentation may clog diffusers if the system is used infrequently.

5. The oxygen demand created by conditions within the crater has not been determined. This alternative assumes adequate oxygenation would be provided.

6. Special consideration may be required to prevent nitrogen supersaturation in fish.

Alternative C

Description: Floating circulation. A 40 horsepower stainless steel mixer would be situated over the crater. Water drawn from near the lake surface would be pumped downward, creating a water jet that would serve to hydraulically mix the crater with oxygen-rich lake water.

Comments

1. Continuous monitoring of dissolved oxygen and conductivity within the crater would be required in order to determine when the system needs to be operated.

2. The mixer can be held in position by stainless steel cables attached to concrete anchors with accommodations to account for lake level fluctuations.

3. Special handling of the mixer may be required during drawdown or backfilling.

4. Armoring may be required immediately below the mixer to prevent erosion by the water jet.

5. Flotables present during high flow periods of the Deschutes River may damage the unit.

Alternative D

Description: Anchored pump manifold circulation. A PVC pipe network (8-inch diameter) would be placed along the bottom of the crater. A 20 horsepower pump would supply oxygen-rich lake water to the system. Diffusion of fresh water from the pipe network would destratify and, to an extent, aerate the crater. The pump could be located at the bottom of the crater (housed in a 60-inch steel casing) or at the tide gate control structure.

Comments

1. Continuous monitoring of dissolved oxygen and conductivity within the crater would be required in order to determine when the system needs to be operated.

2. A foundation constructed within the crater might be required to support the pipe network and the pump (if it is located within the crater). See Alternative F, comment 4 for discussion of special considerations required for construction within the crater.

3. Submerged components would be susceptible to damage if rapid backflushing continues.

4. Biota using the pipe as a substrate or sedimentation may clog diffusers if the system is used infrequently.

5. Overall costs of the system are approximately the same regardless of whether the pump is situated at the bottom of the crater or at the tide gate control structure. Operation and maintenance costs could be higher for the former alternative.

Alternative E

Description: Saltwater withdrawal by a siphon, with an option for the addition of a pump. A PVC pipe (12-inch diameter) with an inlet at the deepest part of the crater and an outlet on the marine side below the lake surface elevation would provide removal of marine water from the crater through the action of a siphon. The system would be designed to remove the crater volume before stagnating conditions occur.

Comments

1. The use of a siphon rather than a pump is preferred due to the elimination of capital and operation/maintenance costs associated with pumping.

2. Discharge by the siphon would be dependent upon the elevation of the outlet when not submerged or the difference between the marine and lake surface elevations when submerged. The maximum flow for an outlet placed 8 feet below the lake surface is estimated to be 5.0 cubic feet per second. The daily flow rates and total volume of water removed from the crater would depend on the tidal cycles. The greatest potential for adverse water conditions within the crater occurs during periods when the higher-high tides are not sufficient to produce a marine flow into the lake. It should be noted that these high-risk periods coincide with periods of maximum discharge capabilities of the siphon. A siphon discharge system appears to have the capabilities to remove all marine water from the crater during high-risk periods.

3. Potential problems that may arise with the siphon system include: a repeated loss of the prime and/or difficulty in maintaining the prime; inadequate discharge rates under rapidly deteriorating environmental conditions; and a limited ability to provide aeration of the effluent before discharge to Budd Inlet.

4. In the event the siphon discharge capabilities prove inadequate in meeting the discharge requirements, a pump would be added to the existing pipe network (with relatively minor alterations) to provide a positive solution.

5. Continuous monitoring of dissolved oxygen and conductivity within the crater would be required (at least initially) for the siphon discharge to evaluate the effectiveness of the system. Should withdrawal be intermittent, continuous monitoring would be used to determine when the system needs to be operated.

6. Submerged components of the system can be designed to withstand the high velocities that may be encountered during backfilling.

7. Assumes the pipe and anchoring can be placed with a boat and diver.

8. The siphon does not appear to represent any danger to fish passage. However, provisions would be made in the design to provide for the addition of fish passage barriers should any adverse effects on fish be noted during operation. The use of pump withdrawal would require a screened intake to prevent fish uptake.

9. The siphon can be passed through the existing fish weir structure. The crown of the siphon should be situated below the lake surface elevation (if possible) to prevent negative pressures and to reduce the potential for air leaks leading to the loss of prime. The discharge outlet can be incorporated into the existing fish weir structure or the discharge can be directed into the flow passing through the tide gates.

10. A check valve can be placed in line to prevent marine water from flowing back into Capitol Lake (when the tide elevation is greater than the lake surface elevation).

11. An intake manifold may be required to ensure uniform removal of the crater volume. Trenching may also be required to prevent isolated pockets of marine water from remaining unaffected by the withdrawal from the deepest part of the crater.

12. The siphon can be primed manually using a system of valves in combination with direct filling by City of Olympia water.

Alternative F

Description: Filling in the tide crater. The depression would be filled with material dredged from other areas of Capitol Lake (Option 1) or filled with imported material (Option 2). Armoring would be placed on top of the fill to prevent future erosion.

Comments

1. It is assumed for Option 1 that material to fill the crater could be obtained from the dredging of the lake basin. (A dual benefit may be realized with the removal of sediment from other areas and the simultaneous filling of the crater.)

2. Material for Option 2 is available from local gravel pits.

3. It is estimated that approximately 12,000 cubic yards of fill (excluding armoring) would be required to fill the crater to the -14 foot (MSL) elevation (includes four-foot allowance for the compaction of existing sediments).

4. It is assumed the lake basin would have to be drained before construction activity within the crater could proceed. Two options for draining the lake (and crater) have been considered. The first option requires the lake to be drained (by opening the tide gates), after which four to five large diameter, three-phase pumps would be used to withdraw the residual lake volume and transport the remaining flow from the Capitol Lake watershed to Budd Inlet. The feasibility of this option is questionable due to the potentially large flows that may have to be pumped to Budd Inlet and the expense and difficulty anticipated in getting the pumps in and out of the basin. Consequently, this option has been eliminated from further consideration.

   The second option considered would require construction of a sheet pile dam at the railroad trestle separating the north and mid-lake basins. It is estimated that after the lake has been drained (by opening the tide gates), placement of the dam at the trestle will allow three or four working days within the crater before the storage capacity of the mid and southern lake basins will be exhausted. The storage time estimate assumes an inflow to the lake basin of 100 cfs. Once the storage capacity has been met, sections of the dam can be temporarily removed, allowing the lake to be drained again. It is estimated that the sheet pile dam may have to be used up to four times (four storage-release cycles) before construction within the crater is complete. Limited pumping would be required to remove the residual water from the north basin. The alternatives that require construction in the crater include the capital cost of draining the lake in this manner. However, should one of the alternatives that require the sheet pile dam at the trestle be selected, a geotechnical evaluation will be required to determine if the railroad embankment could serve as a temporary dam. In addition, control of the Deschutes River flow during low flow months may be of concern from a fisheries standpoint. Dilution of Budd Inlet water with Deschutes River water is important in maintaining acceptible dissolved oxygen levels in the inlet. Cessation of lake discharge for periods up to four days may contribute to oxygen depletion in Budd Inlet, thus promoting the potential for fish kills.

5. At the present time, the crater serves to dissipate energy released during the backfilling of the lake with marine water. When the crater is filled in, the energy that is no longer dissipated will serve to create increased water velocities over the surface of the fill material. It is estimated that backflushing velocities at the surface of the fill may be as high as 25 fps (under worst-case conditions, with the head differentials up to 15 feet and partial gate openings promoting a hydraulic jet). Rocks weighing between 1 and 3 tons would be required to properly armor the area in front of the tide gates. Rocks of sizes up to 1.5 tons are locally available. Larger rock may be extremely difficult to obtain locally. It is assumed 1.5 ton rock would be sufficient.

6. It is assumed with the existing design that the erosional energy will be dissipated over the armored area and that erosion will not occur in surrounding areas. Additional data would be required to verify this assumption.

Alternative G

Description: Modified tide gate operations and facilities. Under this alternative, modifications would be made to the tide gate with the intent of eliminating saltwater intrusion. Modifications would include: (1) replacement of tide gate seals; (2) modification of the fish weir to preclude saltwater entry during high tides and automation to prevent saltwater entry during fish runs; and (3) modification of tide gate oprations to provide 12 inches of head differential between lake and marine waters prior to gate opening to prevent saltwater intrusion resulting from density gradients across the freshwater/ saltwater interface.

Comments

1. Total elimination of saltwater intrusion into lake is not considered feasible due to the desired options for lake management. However, minimizing the volume of marine water routinely entering the lake may be beneficial to alternatives requiring the control of crater conditions (Alternatives B, C, or D) or the removal of marine water (Alternative E).

2. Continuous monitoring of dissolved oxygen and conductivity within the crater would be required in order to determine the presence of saltwater leakage and/or the development of low dissolved oxygen concentrations.

3. Special construction considerations, primarily involving flow control, are required to replace tide gate seals and make revisions to the fish weir.

4. Proposed modifications to tide gate operations and the fish weir need to be evaluated with respect to flood control and fish passage, respectively.

Alternative H

Description: Operational control/no action. The tide gates and lake would continue to be managed as they were during the 1983 summer (Seigle, 1983). The lake is lowered and the crater intentionally flushed with marine water when low dissolved oxygen concentrations are found within the crater.

Comments

1. During probable high-risk periods the conditions within the crater would be monitored daily. High-risk periods would be identified from the tide charts as those periods during which the successive high tide elevations are not adequate to permit marine intrusion into the lake.

2. Should the dissolved oxygen concentrations within the crater drop to dangerous levels, the lake would be lowered 0.25 foot and then be allowed to partially fill with marine water during the next high-high tide. It is assumed that the flushing will replenish the stagnating crater volume with fresh marine water.

3. Should anaerobic conditions within the crater be encountered or anticipated, concerned agencies will be notified, with further action pending a complete analysis of the situation and potential options.

4. The probability of H_2S production with the depletion of oxygen within the crater will be reduced under the specified operating procedures. However, the extent to which this alternative will provide a positive control is questionable.

5. The accurate assessment of environmental conditions and the provision of adequate lead time to enact mitigating measures is essential. Variables potentially affecting the success of this alternative include:

- Forecast tide elevations may not be accurate due to weather influences such as barometric pressure and wind conditions.

- Budd Inlet water quality may be questionable. Hence, the quality of the marine water relied upon to replenish the crater volume may not be sufficient to mitigate the deterioration of environmental conditions occurring.

- Extenuating circumstances can affect field data collection, interpretation, and/or the correct assessment of existing situation by concerned parties.

RECOMMENDED ALTERNATIVE

The siphon discharge alternative (with pump option) is the recommended alternative for the tide gate crater restoration. Figure 2 illustrates the recommended alternative. The removal of saltwater from the north basin provides a relatively low-cost, positive control of environmental conditions within the crater. Discharge may be continuous or intermittent as provided by operational controls.

It is estimated that the flow carried by the siphon will permit the discharge of the crater volume before water quality problems originate. The removal of water from the crater may also serve to promote hydraulic mixing of the crater, thereby avoiding the stagnating conditions implicated in the water quality problems.

Performance monitoring of the siphon discharge capabilities will be required following implementation. It is recommended that the dissolved oxygen and conductivity of the crater be monitored on a continuous basis.

TABLE 4
CRATER ALTERNATIVES WITH
PRELIMINARY COST ESTIMATES

ALTERNATIVE	DESCRIPTION	CAPITAL COST	ANNUAL OPERATION AND MAINTENANCE COSTS
A	Mechanical floating surface aeration	$100,000	$3,600
B	Subsurface manifold aeration	100,000	3,600
C	Floating circulation	125,000	3,600
D	Anchored pump manifold circulation	210,000	4,300
E	Saltwater withdrawal by siphon (with pump option)	150,000	3,100
F	Filling in crater with Capitol Lake dredge spoils	400,000	--
	Filling in crater with imported fill material	500,000	--
G	Modified tide gate equipment and/or operations	150,000	1,500
H	Operational Control/No Action	--	Unknown

Notes

1. Capital costs address the costs associated with the implementation of each alternative, including the costs associated with the continuous monitoring equipment.

2. Annual operating costs assume 720 hours of operation (equivalent to continuous operation for one month). Costs associated with the continuous operation of monitoring equipment have not been included.

3. Maintenance costs include an annual inspection and routine maintenance of the system and the replacement of pumps, mixers, or compressors once every five years.

4. Alternative E includes cost of pump as a maximum cost scenario.

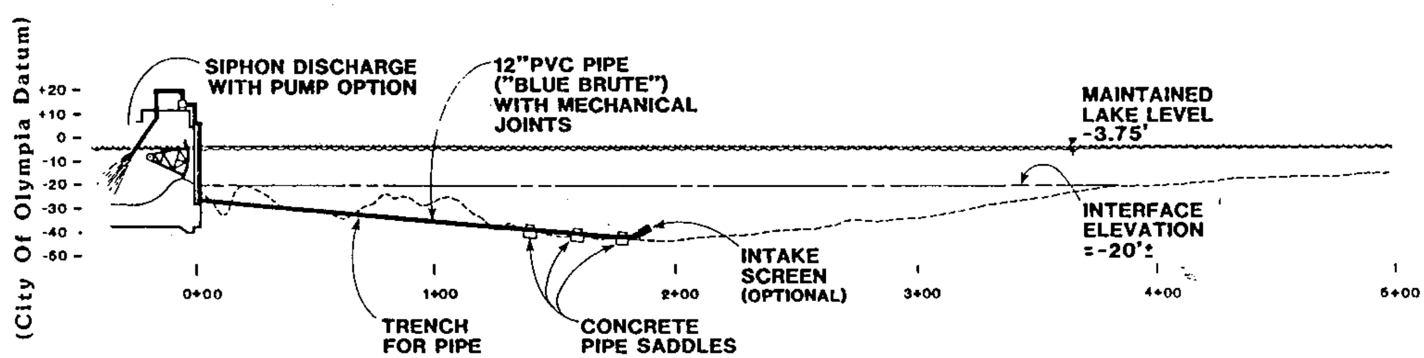


Figure 2

RECOMMENDED RESTORATION ALTERNATIVE
FOR THE TIDE GATE CRATER

Should the capabilities of the siphon discharge appear limited or questionable during the initial use period, the existing system can be modified to incorporate pump withdrawal. The use of a pump will result in higher capital and operational/maintenance costs. For initial design purposes, it is assumed the use of pump withdrawal (if required) will be intermittent as dictated by the environmental conditions within the crater.

The use of the siphon discharge (with pump option) will provide a permanent control of the tide gate crater water quality problems. However, until a permanent restoration plan can be implemented, it is recommended that the operating procedures defined by Seigle (1983) and presented as Alternative H be utilized in the interim.

It is also recommended that efforts be made to prevent the crater volume from increasing. During future backflushing operations the head differential (between the lake level and tide elevation) should not exceed two feet. It is estimated that under such conditions, the lake may be filled over an extended time period of two or three tide cycles.

IV
SEDIMENTATION

INTRODUCTION

Capitol Lake essentially serves as a settling basin for the drainage originating within the Deschutes River and Percival creek watersheds. The accumulation of sediment within the lake has the potential to limit recreational and commercial use of the lake as valuable resource. In addition, use of the lake basin for flood control (provided by the storage capacity of the lake basin in conjunction with the option to "drain" the lake to accommodate high river flows during periods of high tides) may be limited by sedimentation.

Methods to manage or control the sedimentation occurring within Capitol Lake have been addressed by previous studies (Byrne and Stevens, 1973; Orsborn et al, 1975; and CH2M Hill, 1976). Following recommendations of these studies, portions of the lake basin were dredged in 1978-79 to serve as sediment traps. Traps were created in the south basin and also in the southern portion of the middle basin just downstream from the I-5 bridge. These traps are intended to provide for the management and control of heavier (trapable) sediments originating within the Deschutes River watershed.

Development within the Percival Creek watershed has greatly increased the quantity of sediment carried by the creek (Kramer, Chin and Mayo, 1972, 1973). Although the quantity of sediment carried by the creek is not a significant source of sediment to Capitol Lake, the deposition of sediment at the mouth of the creek is interfering with the Department of Fisheries rearing operation in the cove. A sediment trap located at the mouth of Percival Creek has been created in an effort to manage the sediment deposition occurring.

The present study was directed toward identifying the amount of sediment deposited in Capitol Lake between 1975 and 1983, the performance of the existing sediment traps, and the potential for sediment loading by the Percival Creek watershed.

SEDIMENT DEPOSITION IN CAPITOL LAKE

A topographic survey of Capitol Lake was made during the 1983 lake drawdown. Comparisons were made between the 1983 survey data and a survey conducted in 1975 (Arvid Grant, 1975). Changes in Capitol Lake volume occurring since 1975 were used to estimate sedimentation rates. The volume of sediment accumulation in the south and middle basin traps was determined from 1978-79 post-dredging data (obtained from the Department of General Administration) and a 1983 bathymetric survey of the traps. Updated topographic maps of the lake basin at a scale of 1 inch to 100 feet have been provided to the Department of General Administration. A summary of the Capitol Lake sedimentation analysis is presented in Table 5. The specific methods and assumptions employed in deriving the estimates are as follows:

- Sediment deposition was calculated from the total trap accumulations (since 1978) and the change in depth of the remaining lake area (since 1975).

- The change in lake depth was calculated from the differences observed between cross sections generated by the 1975 and 1983 topographic surveys. Two cross-sections per basin (assumed to be representative of overall conditions) were used for the north and middle basin. The change of depth between the 1975 and 1983 surveys was determined at points located every 40 feet along the cross sections. The observed mean and the probable (P = 0.95) range of depth change (derived from the confidence interval about the mean) for the two basins is as follows:

Middle Basin: (outside of trap)	Depth change = 0.73 feet (decrease) (0.61 - 0.85 feet)
North Basin:	Depth change = 0.66 feet (decrease) (0.56 - 0.77 feet)

- It is assumed that sediment deposition in the south basin in areas outside of the traps occurred at a rate similar to deposition rates of the middle basin. However, such deposition is assumed to have occurred in areas that are not susceptible to scour at high Deschutes River flows (est. 60% of total non-dredged area in the south basin).

- The observed changes in depth are assumed to represent net accumulation during the period between 1975 and 1983. The volume change was calculated by multiplying depth change times the lake surface area of the appropriate area.

- Overall, Percival Creek solids loading is assumed to be negligible in relation to the annual loading by the Deschutes River.

The "total accumulation" estimates (361,200 cubic yards) presented in Table 5 do not include the sediment deposited after 1975 and removed in the 1978 dredging. It is assumed that the accumulation rates in these areas were the same prior to the dredging. Consequently, the "annual rate" estimates presented in Table 5 include the observed trap accumulation rate (for 4.5 years) as an average annual rate between 1975 and 1983. Over the eight-year period, the estimated total deposition to Capitol Lake (at a rate of 54,800 cubic yards/year) is 438,400 cubic yards.

TABLE 5
DEPOSITION OF SEDIMENT IN
CAPITOL LAKE BETWEEN 1975 AND 1983

BASIN	ACCUMULATION[1] IN TRAP(S)	ACCUMULATION[2] OUTSIDE OF TRAPS	TOTAL ACCUMULATION
South			
Total (cu. yd.)	36,000	18,900 (15,800 - 22,000)	54,900 (51,800 - 58,000)
Annual Rate (cu. yd. yr.$^{-1}$)	8,000	2,400 (2,000 - 2,700)	10,400 (10,000 - 10,700)
Middle			
Total (cu. yd.)	63,500	136,300 (113,900 - 158,700)	199,800 (177,400 - 222,200)
Annual Rate (cu. yd. yr.$^{-1}$)	14,100	17,000 (14,200 - 19,800)	31,100 (28,300 - 33,900)
North			
Total (cu. yd.)	--	106,500 (90,300 - 124,200)	106,500 (90,300 - 124,200)
Annual Rate (cu. yd. yr.$^{-1}$)	--	13,300 (11,300 - 15,600)	13,300 (11,300 - 15,600)
TOTAL (cu. yd.)	99,500	261,700 (220,000 - 304,900)	361,200 (319,500 - 404,400)
ANNUAL RATE (cu. yd. yr.$^{-1}$)	22,100	32,700 (27,500 - 38,100)	54,800 (49,600 - 60,200)

1 Based on deposition since 1978/79 dredging (4.5 years).

2 Based on deposition since 1975 (8 years). Parenthetical values indicate the 95 percent confidence interval about the mean value.

Assuming that the 1975 volume of Capitol Lake was 2140.8 acre-feet (CH2M Hill, 1976) (3,453,872 cubic yards) and that the volume of dredge material removed was 249,548 cubic yards (COE, 1979), then the net lake volume loss since 1975 is 117 acre-feet (188,760 cubic yards) at an annual deposition rate of 54,800 cubic yards/year. At the current rate of sediment deposition, it is estimated that Capitol lake may completely fill in approximately 60 years (excluding any sediment control efforts).

The current sedimentation rates represent average values over the eight-year period examined. The actual sedimentation rate is quite variable from year to year. The presence of the sediment traps may have reduced the sedimentation rates in other portions of the lake (downstream from the traps). However, the extent or magnitude of the reduction cannot be determined from available data. Most of the accumulation observed in the middle and north basins is assumed to represent the deposition of "nontrappable" sediment. Hence, the lake is expected to continue to fill at or near the observed rates despite the presence and maintenance of the traps.

Table 6 provides a comparison of the current sedimentation estimates with the results of lake volume change analyses presented in previous studies. The larger estimate of 54,800 cubic yards/year implies that an increase in the sedimentation rate has occurred. The lack of continuous flow data prevented the calculation of average Deschutes River flows for the 1975-83 period. However, the information presented in Table 6 suggests an average flow for the period in excess of 425 cfs occurred. CD/SCS (1984) raised the possibility that an increase in Deschutes River flows resulting from timber harvesting practices may have been responsible for an increase in streambank erosion and sedimentation. However, there are insufficient monitoring data available to verify the suspected changes and/or causes of changes in Deschutes River hydrology. At the present time, it can only be assumed that the observed increase in the Capitol Lake sedimentation rate is attributable to increased flows in the Deschutes River.

TABLE 6
COMPARISON OF CURRENT CAPITOL LAKE
SEDIMENTATION ESTIMATES WITH PREVIOUS STUDIES

REFERENCE	PERIOD ANALYZED	ANNUAL SEDIMENTATION RATE (cu yd/yr^{-1})	AVERAGE DESCHUTES RIVER FLOW DURING PERIOD OF INTEREST (cfs)
Present Study	1975-1983	54,800 (49,600-60,200)	(not determined)
SCS for DOF*	1950-1955	52,600	425*
Walker and Bryne (1970)	1952-1970	41,000	388*

* From Orsborn et al, 1975.

Overall, it is estimated that the lake may remove between 60 and 80 percent of the suspended sediment transported by the Deschutes River (based upon observations made during field monitoring). Therefore, the material accumulated by the lake represents a fraction of the total loading by the Deschutes River. Estimates of the total sediment loading by the Deschutes River were derived from the sediment accumulation estimates of Capitol Lake in conjunction with assumed removal efficiencies. Table 7 provides a comparison of current estimates with previous studies.

The variability of the sediment loading characteristics of the Deschutes River is evident in the data presented. Much of the variability reflects the different flow conditions encountered during the various periods of study. For example, using continuous flow data and the sediment discharge relationship established by Nelson (1974), Orsborn et al (1975) have shown that in one three-week high-flow period (January 16 through February 5, 1964) more sediment was transported by the Deschutes River than the previous two years combined.

The current estimates by Entranco Engineers and CD/SCS (1984) are considerably higher than previous estimates. As discussed by CD/SCS, the increase in sedimentation estimates may be attributed, in part, to recent changes in the Deschutes River hydrology. The differences between the current Entranco and CD/SCS estimates may be the result of the relative accuracy or sensitivity of the methods used.

Field inspection of Capitol Lake during drawdown in June of 1983 provided a qualitative assessment of the performance of the sedimentation traps. An aerial photograph of the southern portion of Capitol Lake (during drawdown) is presented in Figure 3. In the south basin the intended primary channel (#1 in Figure 3) leading away from the training groin has become restricted by bank sloughing and subsequent blockage by fallen trees and trapped debris. As a result, during high flows, much of the water entering the south basin can be expected to be passed by the secondary channels (#2), thereby "shortcircuiting" through the basin.

TABLE 7
COMPARISON OF CURRENT DESCHUTES RIVER
SEDIMENT LOADING ESTIMATES WITH PREVIOUS STUDIES

REFERENCE	METHOD	ANNUAL LOADING Cu. Yd. $Yr.^{-1}$ (Tons $Yr.^{-1}$)
Present Study	Interpretation oflake volume change and solids retention estimates for the lake ranging between 60 and 80% of the suspended "nontrapable" sediment loading.	63,000-76,000 (78,124-94,240)*
CD/SCS (1984)	Analysis of measured streambank erosion over a 9-year period and USGS estimates for watershed erosion.	40,000 (49,600)*
Nelson (1974)	Suspended sediments measurements with an assumed bed load equal to 10% of suspended load.	31,000** (25,000)
Present Study	Interpretation of suspended sediment data presented by Nelson (1974) and flow duration curves to obtain sediment transport estimates. A bed load of 10% of suspended load is assumed.	27,500* (34,000)
Moore and Anderson (1979)	Suspended sediment measurements during 1977 (Stanley, unpublished data referred to by Moore and Anderson, 1979).	18,650* (23,131)

* Assumes dry density of 1.24 tons/cubic yard (dry wt./wet volume) from Orsborn et al, 1975.

** Assumes "deposited" sediment density of 0.81 tons/cubic yard.

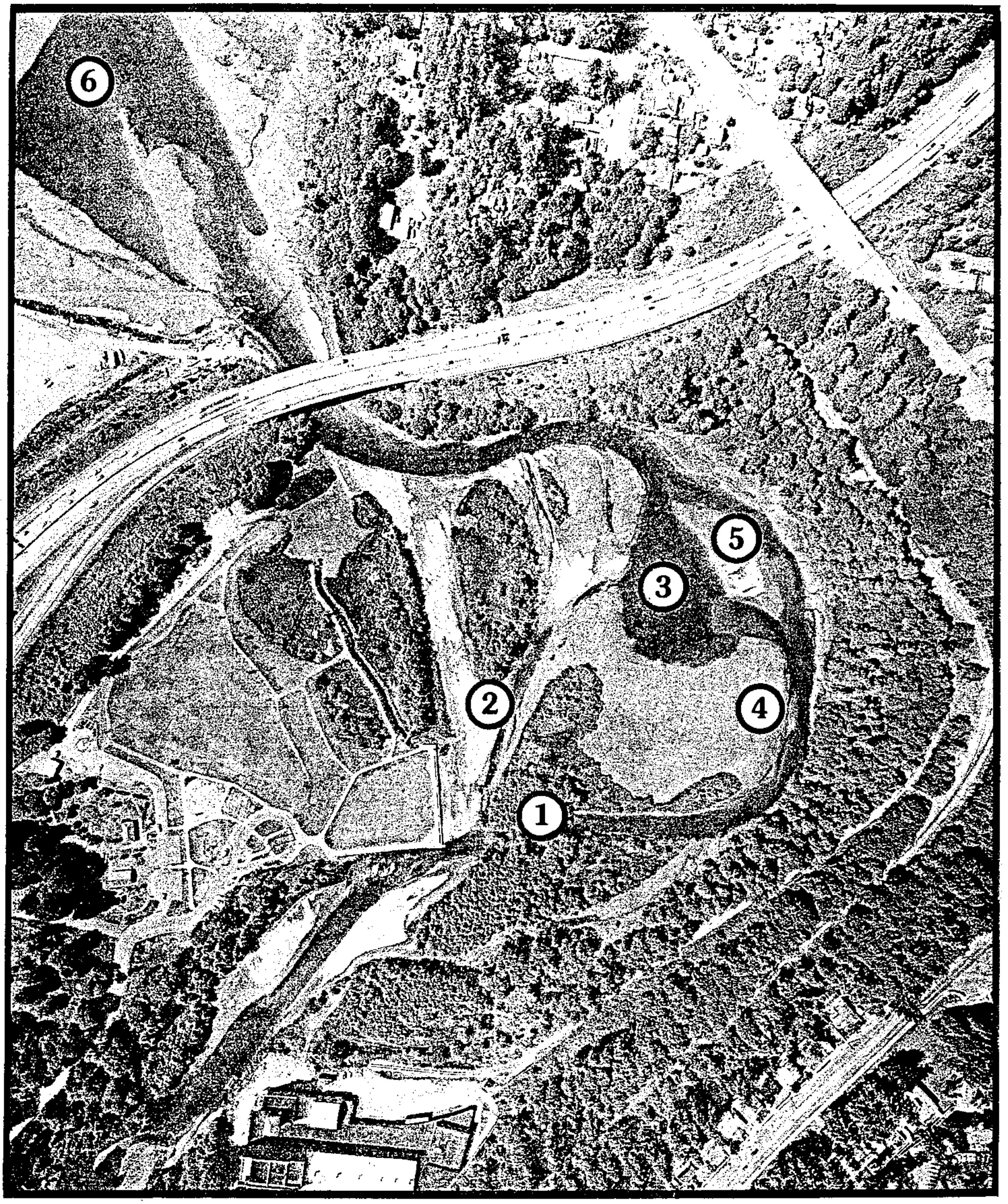
Note: Footnotes accompany estimates generated by the conversions presented. The values presented in the original report are not footnoted.

TABLE 7
COMPARISON OF CURRENT DESCHUTES RIVER
SEDIMENT LOADING ESTIMATES WITH PREVIOUS STUDIES
(Continued)

REFERENCE	METHOD	ANNUAL LOADING Cu. Yd. Yr.$^{-1}$ (Tons Yr.$^{-1}$)
Orsborn et al (1975)	Calculated sediment discharge using relationships defined by Nelson (1974) for the following years:	
	1961	25,194* (31,240)
	1962	3,335* (4,136)
	1963	19,161* (23,760)
	January 16 - February 5, 1964	23,242* (28,820)

* Assumes dry density of 1.24 tons/cu. yd. (dry wt./wet volume) from Orsborn et al, 1975.

Note: Footnotes accompany estimates generated by the conversions presented. The values presented in the original report are not footnoted.



NORTH

CAPITOL LAKE RESTORATION PROJECT
THURSTON COUNTY OLYMPIA, WASHINGTON

ENTRANCO Engineers

Figure 3
SOUTH PORTION
OF CAPITOL LAKE
AT DRAWDOWN, 1983

Flow passing through the intended primary channel (#1) follows along the eastern edge of the basin and typically along the periphery of the sediment trap (#3). The positioning of the trap in relation to the present flow pattern may limit the optimum use of the trap. Sedimentation patterns in the area indicate that the portion of the trap in the vicinity of the flow has received considerable deposition, while portions of the trap away from the mainstream have received minimal deposition. It appears that one of the original approach channels (#4) has been filled in with sediment, thereby limiting the effectiveness of the trap. The presence of the sediment bar (#5) may also limit the current efficiency of the trap by isolating portions of the dredged basin from much of the passing flow.

It should be noted that the final design for the south basin trap was not consistent with the proposed designs in preliminary studies. Initial proposals all identified improvements required for the primary channel leading away from the training groin (Byrne and Stevens, 1973; Orsborn et al, 1975; and CH2M Hill, 1976). Such improvements included the widening and deepening of the channel and the provision for bank protection between the islands. However, final design and actual construction incorporated only minor modifications along the intended primary channel. These design changes have significantly impaired the performance of the south basin trap.

The sediment trap location in the middle basin (#6) is performing as expected. A large bar has formed at the upstream end of the trap, indicating the area of primary deposition.

SEDIMENT DEPOSITION IN PERCIVAL COVE

The potential for sediment deposition in Percival Cove resulting from stormwater runoff in the Percival Creek watershed was examined.

Percival Creek was monitored during three storm events. It appears that at the present time there is a negligible solids contribution by runoff from developed areas. However, the increased volumes of runoff resulting from development of the watershed has the potential to cause erosion of the existing streambed. Most of the sediment problems associated with Percival Creek are assumed related to specific events such as bank sloughing resulting from high-flow conditions. Percival Creek is particularly susceptible to channel erosion along its lower reach, where a number of high, steep banks exist and the gradient of the creek is steep.

OPTIONS FOR SEDIMENT CONTROL

Four basic options have been identified for addressing the sedimentation problems of Capitol Lake.

Option 1

No Action; allow current sedimentation pattern to continue.

Objective: Allow the lake to change to a river environment.

Benefits/Consequences: A "no-cost" alternative. At the current sedimentation rate, it is estimated that the lake could fill within 60 years (assuming no mitigating measures taken). The loss of lake volume (and potential storage volume) would create problems associated with flood control during high river flows in conjunction with high tide periods. In addition, it is assumed that sediment accumulation within the basin would reach a steady state whereby the sediment now removed by the lake would be transported (and presumably deposited) in Budd Inlet, thereby increasing maintenance dredging by the Port of Olympia. Other beneficial values (fish rearing, tourism, aesthetics, recreation) would be lost or substantially altered from current or planned uses.

Option 2

Continue sediment trap dredging.

Objective: Reduce the lake sedimentation rates by removing material deposited in sediment traps.

Benefits/Consequences: The estimated length of time before the lake fills would be lengthened (in accordance with the volume of material trapped and removed). Theoretically, assuming the maintenance of the sediment traps would result in the control of 25 to 40 percent of the deposited sediment, the projected time of lake filling would be increased from 60 up to 80 to 100 years. Hence, it can be assumed that the longevity of current benefits (recreation, aesthetics, fisheries, flood control, etc.) would be enhanced. The remaining lake basin will, however, continue to receive sediment deposition.

Option 3

Establish a comprehensive lake dredging program whereby the entire lake basin (including the sediment traps) is dredged on a routine basis.

Objective: Maintain the integrity of Capitol Lake as a commercial and recreational resource.

Benefits/Consequences: Sediment can be removed at a rate equal to or greater than the rate of sediment deposition. The current fishery, flood control, recreation, aesthetics, and commercial uses of the lake can be maintained and/or enhanced.

Option 4

Reduce sediment loading within the Deschutes River watershed through conservation methods addressed by CD/SCS (1984).

Objective: Reduce in-lake sedimentation through control at the source.

Benefits/Consequences: Effective streambank protection measures could offset dredging volumes and costs. However, concern has been expressed regarding the effectiveness of structural streambank protection efforts. If the current sedimentation problems are the result of erosive energies caused by increased river flows, then bank protection efforts may only serve to redirect the energy elsewhere. It has been recommended by CD/SCS (1984) that low impact bank protection techniques be implemented by conservation crews while a monitoring program is conducted to evaluate the effectiveness of the techniques. Should the low-impact techniques be ineffective, then major structural streambank protection efforts may be given further consideration. It is also recommended that, upon justification by future monitoring, additional watershed management practices be evaluated to address the impacts on runoff resulting from current or future land use practices.

RECOMMENDATIONS

Deschutes River/Capitol Lake Sedimentation. The current sediment deposition estimates identify sedimentation as a major continuing problem threatening the existence of Capitol Lake. The results of the present study indicate that, under current loading rates and sediment control techniques (the periodic dredging of traps), the lake will fill within 100 years. Impacts resulting from sediment deposition will interfere with the current use of the lake before the projected filling time. It is therefore recommended that a long-term sediment control management program be initiated.

CD/SCS (1984) has addressed the potential to control sedimentation within the Deschutes watershed. In general, the techniques identified involve land use management strategies and/or in-stream control measures such as bank protection. The extent to which such measures may be successful in reducing sedimentation in Capitol Lake is questionable at the present time. Although such efforts may reduce the current sedimentation rates, sediment will continue to be deposited within Capitol Lake. As a result, in-lake control measures will be required.

The sediment traps remove heavier sediments, thereby reducing sediment deposition in other parts of Capitol Lake. Hence, the continued use of sediment traps as a management tool is advised. However, the usefulness of the south basin sediment trap is questionable. The current analysis indicates that modifications of the existing south basin trap would be required before its present efficiency could be increased. It is doubtful, however, whether the efforts required to improve the trap would be justified by subsequent improvements in the combined efficiency of the south and middle basin traps. It is estimated that the trap accumulation rates could be maintained at or near current levels through the maintenance of the middle basin trap only. Hence, for the purpose of sediment management, it is recommended that the south basin trap be abandoned. In the absence of any additional maintenance dredging, the south basin would reach a state of dynamic equilibrium where the amount of sediment entering the basin is equivalent to the amount of sediment passing into the middle basin. This implies that the south basin would be allowed to become a river environment. Additional consideration concerning tradeoffs in beneficial uses is, however, recommended before such a management plan is finalized. It is worth noting that although the existing trap may be abandoned, the periodic removal of sediments from other depositional areas in the south basin may be practical. It is possible that a front-end loader may be used to remove sediments during lake drawdown periods. The sediments removed (assumed hydraulically graded) may have a commercial value, thereby reducing the cost of removal. In addition, the recovery of such material from the south basin may provide for a greater allowable time period between the required maintenance dredgings of the middle basin trap. Additional consideration is warranted, however, regarding time constraints associated with the drawdown operation and the potential for commercial value of the material to be removed.

Fine (untrapable) sediments will continue to be deposited throughout Capitol Lake despite maintenance of sediment traps. The current study indicates an average annual loss of depth for the 1975-83 period of 0.09 foot for the middle basin and 0.08 foot for the north basin (a one-foot loss of depth every 11 to 13 years). Thus, a long-term, comprehensive dredging program for the entire lake basin is recommended.

It is beyond the scope of the current study to address specific details regarding a comprehensive dredging program. A thorough environmental assessment will be required to identify the impacts and tradeoffs relating to current beneficial uses. A complete engineering analysis will also be required before the technical aspects of such a program can be defined. Byrne and Stevens (1973) and CH2M Hill (1976) have provided analyses of dredge operations that may be used in Capitol Lake. Many of the observations presented are applicable today, with the exception of the economic analyses and possible changes regarding the availability of equipment and/or possible dredge spoil disposal options. Based upon the recommendations presented, it is assumed that a hydraulic dredge (such as a Mudcat) would be used. The disposal of dredge spoils requires the selection of suitable deposition sites in and/or out of the lake basin. Because of the anticipated volume of dredge spoils to be generated by a comprehensive dredge program, out-of-basin sites will probably be required for final disposal.

In theory, the amount of sediment removed should be equivalent to the amount of incoming sediment in order to maintain the current status of the lake. The current estimates of sediment deposition indicate that between 50,000 and 60,000 cubic yards/year will have to be removed annually by a comprehensive dredge program. It should be noted, however, that the successful control of sedimentation within the Deschutes River basin (as addressed by CD/SCS, 1984) would result in lower sedimentation rates within Capitol Lake. A thorough cost benefit analysis is required to assess the optimum degree of watershed control efforts versus the in-lake sediment control offered by a comprehensive dredge program.

The use of out-of-lake dredge disposal sites may require a lake basin staging area where the dredge spoils can be dewatered and conditioned prior to removal for placement at a final disposal site. The frequency of dredging operations will be governed by the time required for the conditioning of the dredge spoils prior to removal from the staging area and the volume of dredge spoil staging area available in the lake. The preliminary assumption is that a biannual dredge cycle (a dredging operation once every two years) will provide the optimum conditioning of dredge spoils. A biannual cycle will also enable the dredging operation to receive routine budgetary consideration. Dredging on a biannual basis will required the removal of two years' worth of sediment deposition (100,000 to 120,000 cubic yards, assuming current sedimentation rates continue) during each dredging operation.

Provisions have been made for a dredge spoils staging area in the recently completed middle basin park. The staging facilities are designed to handle 50,000 cubic yards at a time, a volume that presumably was based upon the routine maintenance dredging of the sediment traps, with sediment accumulation volumes based on previous studies. It may be possible to modify the existing staging facilities or operating procedures to accommodate the proposed comprehensive dredging plan. Additional analyses are required, however, before the potential of the middle basin staging area can be determined.

A comprehensive dredging program should be flexible to adapt to the dynamic sedimentation patterns of the Deschutes River. The program would incorporate the routine maintenance of sediment traps as well as the staged rehabilitative dredging of other areas of the lake basin. As an example, a conceptual plan for a comprehensive dredge program has been developed. For purposes of the plan, the following assumptions have been made:

- The south lake basin will not be dredged. In time it will achieve a dynamic equilibrium with respect to sediment deposition. The status of the south basin should continue to be monitored.

- The middle basin sediment trap will be routinely dredged.

- The rehabilitative dredging of other areas of the lake basin will occur on a priority basis. Sediment accumulates at a greater rate in the middle basin; therefore, sediment will be removed from the middle basin during the first phase of the program. After the first phase is complete, there will be an option to repeat the initial cycle or to dredge other areas of the lake such as the north basin.

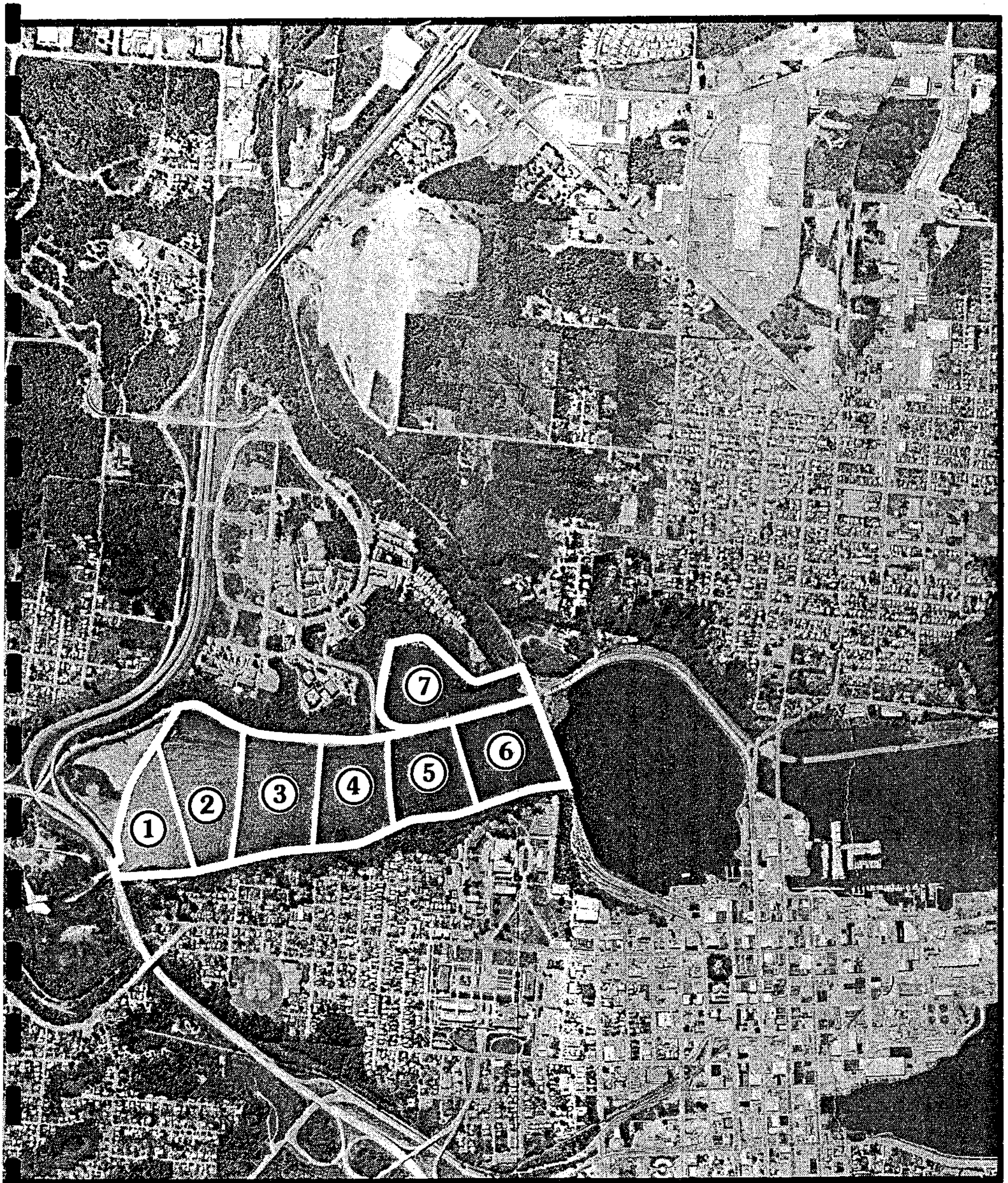
- Dredging will be conducted on a biannual basis with approximately 100,000 to 120,000 cubic yards of sediment removed every two years.

- Sediment will be conditioned at an in-lake staging area. It is assumed the facilities located at the middle basin park can be modified to accommodate the anticipated volumes or that new staging facilities will have to be constructed.

- Dredging of Percival Cove will be included in the dredge program.

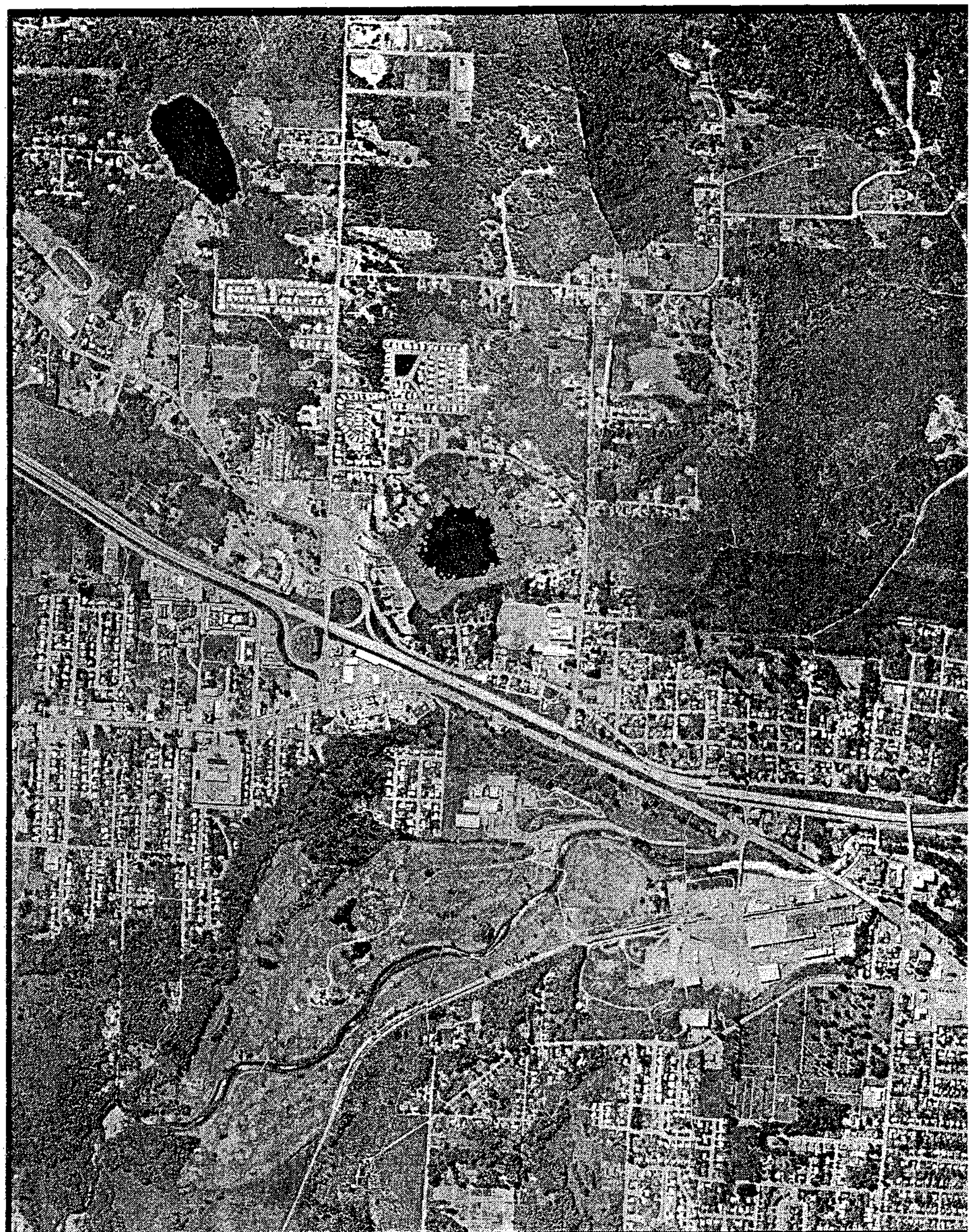
- Routine monitoring will be required to identify changes in sediment deposition rates and to permit a means by which the dredging program can be modified to meet appropriate needs.

Figure 4 provides an illustration of the first phase of the conceptual dredging plan. The middle basin has been divided into six sections and included with Percival Cove to identify a total of seven individual areas. Each section is approximately 20 acres and represents the portion of the lake basin that would be dredged during an individual dredge operation. Assuming the removal of 100,000 to 120,000 cubic yards during each operation, the estimated depth increase in each section after dredging is 3 to 4 feet. The first phase would cover a time span of 18 years and would initially be designed to accommodate the schedule presented in Table 8. Section 1 (in Figure 4) contains the existing sediment trap in the middle



ESTORATION PROJECT
OLYMPIA, WASHINGTON

Figure 4
CONCEPTUAL LONG-TERM DREDGING PLAN



NORTH➤

CAPITOL LA
THURSTON CO

(1) Proposed Dredge Zone

ENTRANCO Engineers

TABLE 8
POTENTIAL DREDGE SCHEDULE FOR CONCEPTUAL PLAN

AREA TO BE DREDGED (FIGURE 4)	YEAR TO BE DREDGED*
1	0
2	2
3	4
1	6
4	8
5	10
1	12
6	14
7	16
1	18

* Assumes biannual dredging program commencing with dredging of Section 1.

basin. At the current trap sediment accumulation rate of 20,000 cubic yards/year, the trap would have to be dredged every six years, with 120,000 cubic yards removed each dredging.

At the end of the first phase, there will be an option to repeat the initial cycle or to dredge other areas of the lake. Information provided by a routine sediment monitoring program will assist in prioritizing the areas to be dredged during the next phase of the program.

The time frame for the implementation of a comprehensive dredging program is undefined. The decision to institute a dredging program may be deferred to some future date when the current resource value of the lake becomes significantly impacted. The optimum depth to which the lake should be maintained is questionable and subject to the needs determined by specific uses. CH2M Hill (1976) identified an optimum depth of 6 feet. Currently there are areas within the middle basin that are less than 6 feet deep. The ability to delay the dredge maintenance decision is also influenced by the volume of the dredge spoil staging area and the rate of desired dredging. Therefore, the need to institute a comprehensive dredge program appears to already exist at the present time.

Percival Cove Sedimentation. Continued development of the Percival Creek watershed is likely to increase the sedimentation problems of Percival Cove. At the present time the three jurisdictions within which the basin lies (Thurston County, City of Tumwater, and City of Olympia) have adopted and implemented drainage control practices to mitigate drainage impacts. For significant developments, the jurisdictions require the contractor to employ erosion control measures during the construction period. They also require the installation of permanent storm runoff control facilities, such as ponds or underground tanks, to moderate the increased runoff rate. Facilities are currently designed to meet a 10-year to 100-year criterion. That is, the outlet of the facility is sized to keep the runoff rate equal to or less than that expected from a storm with a 10-year return frequency under natural (predeveloped) ground cover conditions; and the facility volume must be sufficient to contain a 100-year storm.

It is commendable that Tumwater, Olympia, and Thurston County have, like many communities in the Pacific Northwest, adopted the concept of on-site drainage control. However, this policy may be viewed as a short-term approach until a comprehensive basin-wide planning approach can be implemented. The specific need for a basin-wide drainage program is supported by the following observations:

- A stream channel under natural conditions is in a state of quasi- or dynamic equilibrium with its flow regime. It is generally thought that the channel is in equilibrium with a peak flow rate and volume having a return frequency of approximately two years; this flow is called the dominant flow. Increasing urbanization, without effective hydraulic controls, will significantly increase the dominant flow; the channel will therefore respond by establishing a new equilibrium which can only occur by erosion of the channel. If developed runoff rates are controlled to only a 10-year return frequency, the sediment flow in the developed basin would still be significantly greater than that which existed prior to development.

- An on-site facility is typically designed and located without consideration of the effect of the timing of its discharge on either adjacent facilities or on the historic runoff regime of the stream itself. Theoretical and field studies have demonstrated that the placement of on-site facilities in a random fashion throughout the basin using the same design criterion will not necessarily mitigate the impacts of development (McCuen, 1979; Hardt and Burges, 1976; Minton, 1983). In fact, depending upon its location in the basin, the facility may make peak rate conditions in the stream worse than if the facility had not been installed.

- The Rational Method, which is typically used to determine the 10-year design runoff, commonly overestimates the true value, particularly for moderate to well-drained soils. As a result, the outlet may be over-sized, allowing peak discharges which are greater than a 10-year storm.

- The desired hydraulic condition for the basin can best be maintained by the careful sizing and placement of "regional" ponds located at a few points within the basin, complemented by on-site facilities where needed. Ideally, the design criteria are varied with each facility as a function of its location and relationship to the other facilities. Basin-wide hydraulic modeling is required to define such relationships.

The current problem of sedimentation within Percival Cove demonstrates the existing need to maintain the natural hydrologic conditions of Percival Creek. It is recommended that a basin-wide management plan be developed to help identify (and reduce) existing problems and to mitigate problems likely to occur with continued development of the watershed. Development of such a plan should include the following elements:

Define Existing Conditions. The current state of the basin must be defined. This would include, but would not necessarily be limited to, the following: determination of existing and proposed land use; examination and evaluation of the existing physical and biological condition of the stream channel and riparian areas; determination of the location and relevant hydraulic parameters for the existing system of storm sewers, road ditches, and on-site drainage control facilities; and identification of areas of localized flooding; development of a topographical map for the basin, preferably to one-foot contours. In addition, the dominant flow for the predevelopment and existing flow regime should be estimated. The creek must be gaged at key locations, in particular at the outlets of the three lakes and the mouth. Data should be collected for at least one, and preferably two, rainy seasons.

Determine Biological Maintenance Goals. A consensus must be reached as to which specific reaches of the creek will be maintained in a manner that will ensure the survival of the anadromous fishery as well as riparian habitat. This determination affects the location and design of runoff control facilities. It may also affect land use controls on land immediately adjacent to important reaches. The establishment of goals requires both technical evaluation and citizen value judgment.

Prepare a Hydrologic/Hydraulic Model. The most effective method for evaluating the effect of increased runoff and the tradeoffs between the costs of a particular set of design criteria and technical solutions, and which predeveloped natural conditions will be maintained or rehabilitated, is by the use of a hydrologic/ hydraulic computer model. Several models have been used successfully on Western Washington streams. The preferred model can be calibrated for Percival Creek using the information gathered in the first element outlined above.

Identify and Evaluate Technical Solutions. The hydrologic/hydraulic model can be used to identify and evaluate technical solutions. The final solution typically consists of a mixture of structural and non-structural solutions. Structural solutions include the construction of storm sewers and runoff retention/detention facilities. Nonstructural solutions consist of such measures as erosion control ordinances, protection of riparian land by public purchase or taxing policy, ongoing public education, and maintenance and enforcement programs.

Citizen Involvement. Participation of a citizens committee is critical to the successful development of a drainage plan. A basin-wide public education and input program is also a must. Support must be developed for the ultimate public decision of investing public dollars for the proposed solutions. Public input is also necessary in the identification of alternatives and the definition of biological goals.

Formation of a Storm Drainage Utility or Authority. A recently completed report (Thurston Regional Planning Council, 1983) recommends that Olympia, Lacey, Tumwater, and Thurston County institute a regional coordination program. Experience elsewhere in Western Washington has shown, with few exceptions, that comprehensive drainage plans, particularly those that are multi-jurisdictional in character, are not effectively implemented unless two conditions exist. One is a dedicated, stable source of funding, such as permit review and stormwater service charges. These dollars are needed for ongoing planning and public education, administrative costs of plan implementation, and facility inspection and maintenance. The second condition is the identification of one public agency responsible for implementation of the plan. The traditional local government structure results in dispersion of responsibilities among several departments. The result is reduced effectiveness of off-road drainage control.

V
EUTROPHICATION

INTRODUCTION

The excessive growth of algae and rooted aquatic plants in Capitol Lake was observed during the mid to late 1960's. A citizens' committee (CLCC, 1969) established to assist the City in formulating lake recreational objectives identified the problem as a central concern. Kral (1970) noted the concerns of the committee, stating that rooted aquatic plants were a particular problem in the middle and southern basins. A figure presented by Finn (1972) indicated extensive areal coverage on both sides of the middle basin in 1971. Kral (1970) also reported ". . . colonies of algae appeared in unsightly yellow and green masses . . . in 1969." However, because of limited funds, control measures were limited at that time to dealing only with the rooted aquatic plants.

Saltwater flushing, begun in 1971, was found to be very effective in controlling rooted aquatic plants (Finn, 1972; Finn and Tarr, 1975). The extensive areal coverage observed during the late 1960's and early 1970's has been substantially reduced, although some sections of the middle basin continue to support abundant plant growth. Saltwater flushing has also been credited with controlling algal growth (CH2M Hill, 1978).

The present study was directed toward identifying factors contributing to the abundant growth of algae in the lake. The potential for primary productivity (plant growth) may be evaluated through an analysis of the nutrients available for growth. Typically, the amount of productivity is governed by the essential nutrient that is in least supply (the limiting nutrient concept). In fresh-water systems, nitrogen or phosphorus is usually the limiting nutrient controlling productivity.

Previous studies have attempted to identify the limiting nutrient in Capitol Lake. Orsborn et al (1975) concluded that productivity within Capitol Lake appeared to be nitrogen limited. CH2M HIll (1978), however, suggested that both nitrogen and phosphorus were limiting. It was observed that there appeared to be a shift in limiting nutrients from one part of the growing season to the next. Both studies recognized other factors potentially limiting algal productivity in Capitol Lake, such as the saltwater flushing or the short hydraulic residence time of the lake.

From a lake restoration perspective, phosphorus is generally recognized as the most manageable nutrient controlling algal productivity (Vollenweider, 1968; Sawyer, 1971; Schindler, 1977; and others). Techniques to control phosphorus are more effective than those directed toward controlling nitrogen. As pointed out by Schindler (1977), natural mechanisms (nitrogen fixation) tend to compensate for deficiencies of nitrogen in eutrophied lakes. Furthermore, the control of nitrogen may promote the competitive advantage for bluegreen algal species which are the most objectionable from a water quality standpoint. Bluegreen algae are capable of using gaseous (atmospheric) nitrogen as an auxiliary source, whereas the more desirable green algae are capable of utilizing only the dissolved forms of nitrogen available to both types of algae. Hence, reductions of nonatmospheric nitrogen sources will tend to limit green algal populations, thereby enabling the "unaffected" bluegreen populations to increase in the absence of competition for other common resources.

For the purpose of the present study, it is assumed that the practial management or control of algal productivity in Capitol Lake may be achieved through reductions of phosphorus (whether initially limiting or not) to the point where corresponding reductions in productivity are realized. Consequently, field monitoring efforts and data analyses have been primarily directed toward identifying the sources of phosphorus to Capitol lake.

NUTRIENT AND WATER BUDGETS

A review of historical data was conducted to determine the nutrient (total-phosphorus, or TP) and water budgets for Capitol Lake. A monitoring program (described in Appendix A) was conducted from March through August 1983 to help define the current nutrient status of the lake and to provide information not available in the historical data base. Table 9 provides a summary of the derived nutrient (TP) and water budgets. The definitions, assumptions, and data base employed in obtaining the estimates are as follows:

Deschutes River

The total drainage area is approximately 162 square miles. The phosphorus loading estimate presented is based upon data reported by the USGS for the stations "near Olympia" (water years 1972, 1975, 1977) and "E Street Bridge" (water years 1978-1983). A total of nine years' worth of data were used to derive mean monthly TP concentrations.

The annual TP loading estimate provided is based upon the mean monthly TP concentrations in conjunction with the mean monthly river flows. The loading range indicated represents the probable (P = 0.95) range of the annual loading that may be expected due to the variability observed in existing data.

Percival Creek

The total drainage area of the basin is approximately 10 square miles. An average TP concentration of 30 mg/m^3 was observed during the present study. Monitoring during storm events did not reveal any significant increases over the observed background TP concentrations. Hence, the present extent of development within the Percival Creek basin appears to have a negligible effect on the nutrient loading carried by the creek.

TABLE 9
CAPITOL LAKE NUTRIENT AND
WATER BUDGETS: INPUTS

SOURCE	ANNUAL FLOW (m^3/yr x 10^6)	TOTAL-P LOADING* (kg/yr)	PERCENT OF TOTAL Flow	PERCENT OF TOTAL Loading
Deschutes River	356.99	14,334 (8,737 - 19,931)	85.1	69.9
Percival Creek	52.48	1,565 (1,236 - 2,062)	12.5	7.6
Pabst Brewery	4.65	2,935 (1,221 - 5,549)	1.1	14.3
Percival Cove	-	738 (489 - 987)	-	3.6
Capitol Lake Basin Runoff	2.14	444 (256 -622)	0.5	2.2
Miscellaneous Point Discharges and Groundwater	1.96	177	0.4	0.9
Birds	-	273 (45 - 500)	-	1.3
Precipitation	1.50	24	0.4	0.1
Marine Influence	-	17	-	0.1
	419.72	20,507 (12,206 - 29,869)	100.0	100.0

* Parenthetical values represent the potential loading range based upon the variability in the data.

The flow of Percival Creek averaged about 14.7 percent of concurrent Deschutes River flows (at the time of routine sample collection; 12 observations). The annual TP loading estimate presented is based upon the observed mean TP concentration (30 mg/m^3) in conjunction with an assumed flow of 14.7 percent of the mean monthly Deschutes River flows. The loading range indicated represents the probable (P = 0.95) range of the annual loading that may be expected due to the variability observed in the TP data and the Percival Creek/Deschutes River flow relationship.

Pabst Brewery

A total of four permitted discharges (NPDES permit numbers 001 through 004) were monitored over a two-week period. TP estimates for each discharge were obtained from time-composited samples. A total of four samples per discharge were taken, with two composites obtained during weekdays (assumed indicative of production cycle discharges) and two composites obtained during weekends (assumed indicative of nonproduction cycle discharges). There did not appear to be any substantial differences between weekday and weekend composites. Flow estimates were obtained from instantaneous measurements taken at the time of composite sample recovery.

A fifth discharge was discovered during the course of the study and has been included in brewery loading estimates. The discharge referred to as "UI" is located between permitted discharges 001 and 002. Grab samples and instantaneous flow measurements have been used to determine the TP loading by UI.

Table 10 presents a summary of the TP loading by the brewery discharges monitored. The range of loading indicated represents the probable (P = 0.95) range of the annual loading that may be expected due to the variability observed in the TP and flow measurement data. It is worth noting that the permit flows (daily averages) differed from the instantaneous measurements. For the purpose of comparison, the annual TP

TABLE 10
DISCHARGE AND TOTAL PHOSPHORUS (TP)
LOADING SUMMARY FOR PABST BREWERY OUTFALLS

DISCHARGE	FLOWS (cfs) Permit	FLOWS (cfs) Measured	MEAN TP CONCENTRATIONS (mg/m^3) ±95% CONFIDENCE INTERVAL	TP LOADING (kg/yr) At Permit Flows	TP LOADING (kg/yr) At Measured Flows
001	2.1	1.43 ± 1.08	204 ± 62	365 (256-511)	256 (37 - 584)
002	0.1	0.48 ± 0.47	289 ± 53	26 (21-31)	124 (4 - 292)
003	1.2	1.77 ± 0.20	914 ± 193	986 (767-1,205)	1,460 (1,022-1,935)
004	0.3	1.42 ± 0.33	814 ± 689	219 (34-402)	1,022 (110-2,628)
UI	-	0.11	805 ± 291	--	73 (51-110)
	3.7	5.21 (3.13-7.29)		1,669* (1,129-2,259)	2,935 (1,221-5,549)

* Includes the UI discharge.

loading based on the daily average permit flows has been included. The range of TP loading using the permit flows is contained within the range generated by the instantaneous flow measurements.

Percival Cove

A comparison of TP concentrations in the inflow and outflow of Percival Cove indicated the possible existence of a loading source within the cove. A TP mass balance conducted around the cove provided quantified data demonstrating a net export of TP. The mean annual loading estimate is based upon the average of values obtained by TP mass balance analyses conducted for each sampling date. The range presented approximates the probable (P = 0.95) annual loading that may be expected due to the data variability.

Capitol Lake Basin Runoff

The loading indicated represents the TP loading resulting from stormwater runoff in the Capitol Lake basin. An annual runoff volume of 2.14×10^6 m^3 was estimated based upon a total drainage area of 1.3 square miles, runoff coefficients varying between 0.2 (for undeveloped areas) to 0.9 (for highly developed areas), and an annual rainfall of 52 inches. TP concentrations were obtained from samples obtained during storm events monitored during the present study. Table 11 provides a summary of the storm runoff TP concentration according to the station monitored, land use from which the runoff originates, and the characteristics of the discharge. Limited data available for stormwater runoff from residential areas (discharged by a culvert) necessitated the use of additional data presented by Sylvester (1959). TP loading resulting from stormwater runoff was obtained using estimated annual runoff volumes in conjunction with the appropriate land-use-related TP concentrations. The loading range represents the probable (P = 0.95) range of the annual loading that may be expected due to the variability of TP concentrations presented in Table 11.

Miscellaneous Loading Sources, Point Discharges, and Groundwater Inflow

Table 12 summarizes the loading estimates from miscellaneous sources within the lake basin. Point discharges monitored during the present study include the 7th Avenue storm sewer and Simmons Road and Deschutes Parkway creeks. All stations were used for stormwater runoff monitoring. However, the stations demonstrated a relatively constant base flow during nonstorm periods. The annual TP loading per site was estimated from the base flow observed in conjunction with the TP concentrations present in a grab sample obtained from each site.

Estimates for the Capitol Lake stream plant discharge are based on the daily average permit flow and the average of effluent TP values reported by Moore (1982) and Singleton (1982).

Data provided by Moore (1982) were used to estimate the TP loading from additional point discharges within the Capitol Lake basin. A total of 15 discharges (excluding the 7th Avenue storm sewer and the steam plant discharge) were sampled during the March 1982 lake drawdown. It is assumed that the data obtained represent wet month residual flows (not represented by the Capitol Lake basin runoff estimates) occurring from November through March.

A net inflow of groundwater is assumed to be due to the presence of year-round artesian wells within the lake basin. A total flow equivalent to ten 30 gpm wells is assumed, along with a TP concentration of 76 mg/m^3. The TP concentration is based on samples obtained from the City of Olympia Well #1 by Entranco Engineers (1981).

Birds

It is recognized that nutrient loading by waterfowl utilizing the lake habitat may be substantial. For the purpose of computing an annual nutrient budget, it is estimated that the bird population utilizing Capitol

TABLE 11

TOTAL PHOSPHORUS (TP) CONCENTRATIONS IN STORM RUNOFF ENCOUNTERED AND/OR USED IN THE PRESENT STUDY

STATION	LAND USE/DISCHARGE	MEAN TP CONCENTRATION ±95% CONFIDENCE INTERVAL
Simmons Road	Residential; Highway/ Open Channel	403 ± 268 mg/m^3
Deschutes Parkway	County Courthouse/ Open Channel	161 ± 57
7th Avenue Storm Sewer	Commercial/Culvert	138 ± 47
Tumwater Storm Sewer	Residential/Culvert	292

Sylvester (1959)	Residential/(Assumed Culvert)	208 ± 87

TABLE 12
MISCELLANEOUS TOTAL PHOSHPORUS (TP)
LOADING SOURCES TO CAPITOL LAKE

DISCHARGE	FLOW ($m^3/yr^1 \times 10^4$)	TP (mg/m^3)	TP LOADING ($kg\ TP/yr^1$)
7th Avenue Storm Sewer	4.5	318	14
Simmons Road	35.7	24	9
Deschutes Parkway	4.5	58	3
Capitol Steam Plant	0.2	650	1
Miscellaneous Basin Point Discharges	136.1	77	105
Groundwater	60.0	76	46
		Total	178

Lake is the equivalent of between 500 and 1,000 annual residents. The estimates of TP production by waterfowl range from 0.04 kg/bird/year (CH2M Hill, 1978) to 0.5 kg/bird/year (Uttormark et al, 1974).

Precipitation

The TP loading to the lake by precipitation considers only that rain falling directly onto the lake surface. A lake surface of 281 acres, an annual rainfall of 52 inches, and a TP content of 16 mg/m^3 were used to obtain the loading estimate.

Marine Influence

The TP loading resulting from the June 1983 backflushing of Capitol Lake was estimated from data collected during and after the event. The total volume of marine water entering the lake was derived from the observed change of lake volume during backfilling in conjunction with concurrent freshwater inflows. Between the start of the backfilling on June 13 until the desired lake elevation was reached on June 16, an estimated 1,135 acre-feet of marine water entered the lake. It was observed that approximately 90 percent of the marine water was discharged from the lake basin within four days after the backfilling. This is attributed to the relative elevation of the outlet (14 feet below the lake surface) whereby the denser marine water was discharged while the less dense incoming freshwater occupied the upper lake volume. Once the freshwater/saltwater interface dropped to the level of the outlet, the remaining marine water (occupying the lake volume below the tide gate sill) was removed at a slower rate. By June 27, an estimated 12 acre-feet of marine water (1.1 percent of initial volume) remained within the lake.

A TP depositional rate was calculated from the comparison of the incoming marine TP concentrations (94 mg/m^3) and the flow weighted average of incoming freshwater TP concentrations (37 mg/m^3). Assuming dilution ratios characterized by conductivity and volume analyses, it was found that a net

TP reduction occurred in the marine water. It is assumed that the reduction represents the sedimentation of TP in the marine water at an equivalent rate of 4 mg TP/m^3/day. As a result of the backflushing, an estimated 17 kg of TP was deposited in Capitol Lake.

The indicated accumulation of TP in Capitol Lake may reflect the uptake of inorganic phosphorus by the sediment as described by Edmondson (in Finn and Tarr, 1975). The potential for deposited TP to contribute to the productivity of the lake is undetermined. It had been suspected that the deposition of the marine phosphorus may promote phosphorus loading by the sediments through increases in sediment nutrient release rates (Entranco Engineers, 1983). However, in the revision of the nutrient budget (incorporating the current field monitoring data), the overall contribution by the sediments to the in-lake TP concentration appeared to be negligible (or below detectable limits), with the exception of the Percival Cove sediments, as discussed at a later point.

The relatively constant inflow of marine water due to the leakage of the tide gate seals (estimated to be the equivalent of a mean flow of 10 cfs over the duration of the gate closure) is assumed to be removed from the lake quickly once the gates are opened again. Hence, the TP loading represented by the tide gate leakage is assumed to be negligible.

NUTRIENT BUDGET ANALYSIS

The derived phosphorus budget identifies the Deschutes River as the dominant loading source to Capitol Lake. Field reconnaissance by CD/SCS in early 1983 identified potentially significant nutrient and bacterial loading sources within the Deschutes River basin. A total of six dairies were located, two of which were considered to have drainage problems potentially impacting the Deschutes River quality. Chambers Creek was also identified as a potentially significant loading source due to the amount of development that has occurred within the creek's watershed. Following the recommendations by CD/SCS, drainages from the two dairies (referred to as the Vail Road and Rixie Road dairies) and Chambers Creek (at Rixie Road) were monitored routinely during the course of the study. Runoff from the Tumwater Valley Golf Course was also monitored to document potential impacts on the Deschutes River water quality. Table 13 provides a summary of the monitored sources with their relative impact on the Deschutes River TP load indicated.

The loading estimates presented in Table 13 for the two dairies and Chambers Creek are based upon information collected from March through August, with extrapolation from available data to estimate the loadings expected for the months of September through February. Extrapolation involved the use of March TP concentrations (assumed to be representative of "wet month" conditions) and runoff patterns following the mean annual flow pattern of the Deschutes River from September through February.

The loading estimate presented for the Tumwater Valley Golf Course in Table 13 is based on surface runoff. It was originally intended to analyze the impact of the golf course on the groundwater discharging to the river. However, difficulties were encountered in obtaining what may be considered representative groundwater samples from the area. It was observed that due to the minor slope of the land utilized by the golf course (in turn affecting groundwater slope and flow of groundwater to the river) that the primary impact of the golf course would be through surface runoff. Hence, samples of surface runoff were obtained and an annual TP loading was estimated from observed TP concentrations and the expected runoff volume. A mean TP concentration of 374 mg/m^3 was observed in surface runoff samples. Information concerning the rate and timing of fertilizer application to the golf course has not been obtained. Consequently, it is not known whether the observed nutrient concentration in the runoff is representative. An annual runoff volume of 6,054 m^3 was estimated based upon a runoff coefficient of 0.1, a total contributing area of 493,646 square feet, and an annual rainfall of 52 inches.

TABLE 13
MONITORED SOURCES CONTRIBUTING
TO THE ANNUAL NUTRIENT LOADING
OF THE DESCHUTES RIVER

	TOTAL PHOSPHORUS (kg TP/yr)	PERCENT OF ANNUAL RIVER LOAD	PERCENT OF TOTAL LOADING TO LAKE
Estimated Annual Deschutes River Loading	14,334	100.0	69.9
Monitored Sources Contributing to Annual Load:			
Vail Road Dairy	1,551	10.8	7.5
Rixie Road Dairy	483	3.4	2.4
Chambers Creek	264	1.8	1.3
Golf Course Runoff	2	<0.1	<0.1

The results indicate that the Vail Road dairy in particular represents a significant TP loading source to the Deschutes River. The Rixie Road dairy loading is substantially less due, presumably, to the treatment provided by a wetland before discharge to the Deschutes River. Chambers Creek appears to be of relatively good quality. The golf course drainage is indicated to be relatively insignificant to the overall TP load carried by the river.

The remaining (unaccounted) TP load carried by the Deschutes River is considered to be the result of: (1) natural surface runoff or groundwater discharge in the watershed; (2) nonpoint loading resulting from specific (unmonitored) land use practices; and (3) the phosphorus bound up in the excessive sediment load carried by the river.

The discharge by Pabst Brewery into the lower stretch of the Deschutes River is identified as the second largest TP loading source to Capitol Lake. The existence of a point loading source along the lower reaches of the Deschutes River has been evident in previous studies (CH2M Hill, 1978; Orsborn et al, 1975). The brewery, however, had not been specifically identified as the source. Analysis of the data in the present study indicates that TP loading contributed by the brewery accounts for the previously unidentified source.

Primarily cooling water is being discharged by the brewery. It is estimated that as much as 60 percent of the TP content in the discharge may originate from an antiscaling compound used by the brewery to control iron deposition in the pipes. The compound presently used contains phosphate compounds. The origin of the remaining 40 percent of the TP observed in the discharge has not been disclosed.

The TP loading provided by Percival Creek is the third largest source for Capitol Lake. It is suspected that the TP load carried by the creek originates primarily from direct surface runoff or groundwater discharge in the watershed and possibly the loading provided by Black and Trosper lakes at the headwaters of the creek.

Of the remaining TP sources identified in Table 9, only Percival Cove warrants additional discussion. The analyses conducted using current data indicate the existence of a nutrient source within the cove. The Washington State Department of Fisheries conducts fish feeding activities within Percival Cove from September through April as part of fish-rearing operations. Approximately 68,100 kg of fish food are added to Percival Cove annually, with the TP content of the food equal to 69.4 mg/gm thus representing an annual TP loading of 4,726 kg (CH2M Hill, 1978). Some of the TP contained within the food can be expected to be deposited within the cove in either the form of unused fish food or fish excrements. The sediments of the cove are relatively rich in nutrients as compared with other areas of the lake (CD/SCS, 1984). Phosphorus loading within the cove (during non-fish feeding months) may be the result of sediment nutrient release mechanisms and/or wind-induced resuspension of unused fish food or wastes.

Table 14 provides a summary of the current Capitol Lake TP budget, with the results of previous studies included for comparison. A decrease in the TP loading is evident between 1975 and 1983. It is not known whether this trend indicates a reduction of TP loading or is the result of dissimilarities existing between the periods of analysis. As expected, the Deschutes River has consistently been identified as the dominant loading source to Capitol Lake. The identification of the brewery as the second largest loading source is a significant finding of the current study.

MODEL ANALYSIS

The current trophic status of Capitol Lake can be evaluated through the use of the Vollenweider-type model:

$$P = \frac{L\ (1-R)}{\bar{z}\ A\ p}$$

TABLE 14
COMPARISON OF TOTAL PHOSPHORUS (TP)
BUDGET ESTIMATES FOR CAPITOL LAKE

	CURRENT ESTIMATES (1983)	CH2M HILL (1978)	ORSBORN ET AL (1975)
Import (kg TP/yr)	20,525	33,750	39,500
Export (kg TP/yr)	16,831*	(not provided)	45,200
Retention (kg TP/yr)	3,695*	(not provided)	-5,700
Specific Loading (g TP/m^2/yr)	18.6	37.5	34.8
Observed In-Lake TP concentration (mg/m^3)	41	60	57
Dominant Import Sources	Deschutes River (69.9%); Pabst Brewery (14.3%); Percival Creek (7.6%)	Deschutes River (71%); Percival Creek and fish feeding (29%)	Deschutes River (94%); Percival Creek (6%)

* Based upon empirical estimate of phosphorus sedimentation of 0.18 (18%).

where: P = mean concentration of TP within the water column under steady state conditions (mg/m^3)

L = TP loading to the lake (kg/yr^1)

R = lake sedimentation coefficient (dimensionless fraction of TP loading retained by the lake)

$\overline{z}$ = mean lake depth (m)

A = lake surface area (km^2)

p = lake flushing rate (volume exchanges/yr)

For the Capitol Lake analysis, a mean depth of 2.2 m, a surface area of 1.1 km^2, and an average flushing rate of 138 volume exchanges per year were used. The retention coefficient (R) was empirically calculated using the data generated by the monitoring program. An expected in-lake TP concentration was calculated using a simple mixing model in conjunction with all quantified TP loading occurring during a time period equal to the concurrent hydraulic residence time of the lake. The difference between the actual observed TP concentration of the lake and the expected value is indicative of the retention coefficient, R. Based upon the analysis, the annual retention coefficient is estimated to be 0.180.

Figure 5 illustrates the relationship defined by the model. The mean annual loading rate of 20,507 kg TP/yr corresponds to a predicted mean annual TP concentration of 41 mg/m^3. For comparison, the mean TP concentration for the duration of the current study period (excluding samples obtained after the backfilling) was 40.9 mg/m^3. Hence, the model appears to be a suitable tool for predicting the response of Capitol Lake to reductions in TP loading. The potential loading range presented is based upon the variability in the data observed in the nutrient budget derivation (Table 9). The loading range corresponds to a potential mean annual in-lake TP concentration of 24 to 60 mg/m^3.

Capitol Lake is considered to be mesoeutrophic to eutrophic, based upon the mean TP concentration in conjunction with the trophic state index defined by Carlson (1977). However, it is suspected that within Capitol Lake,

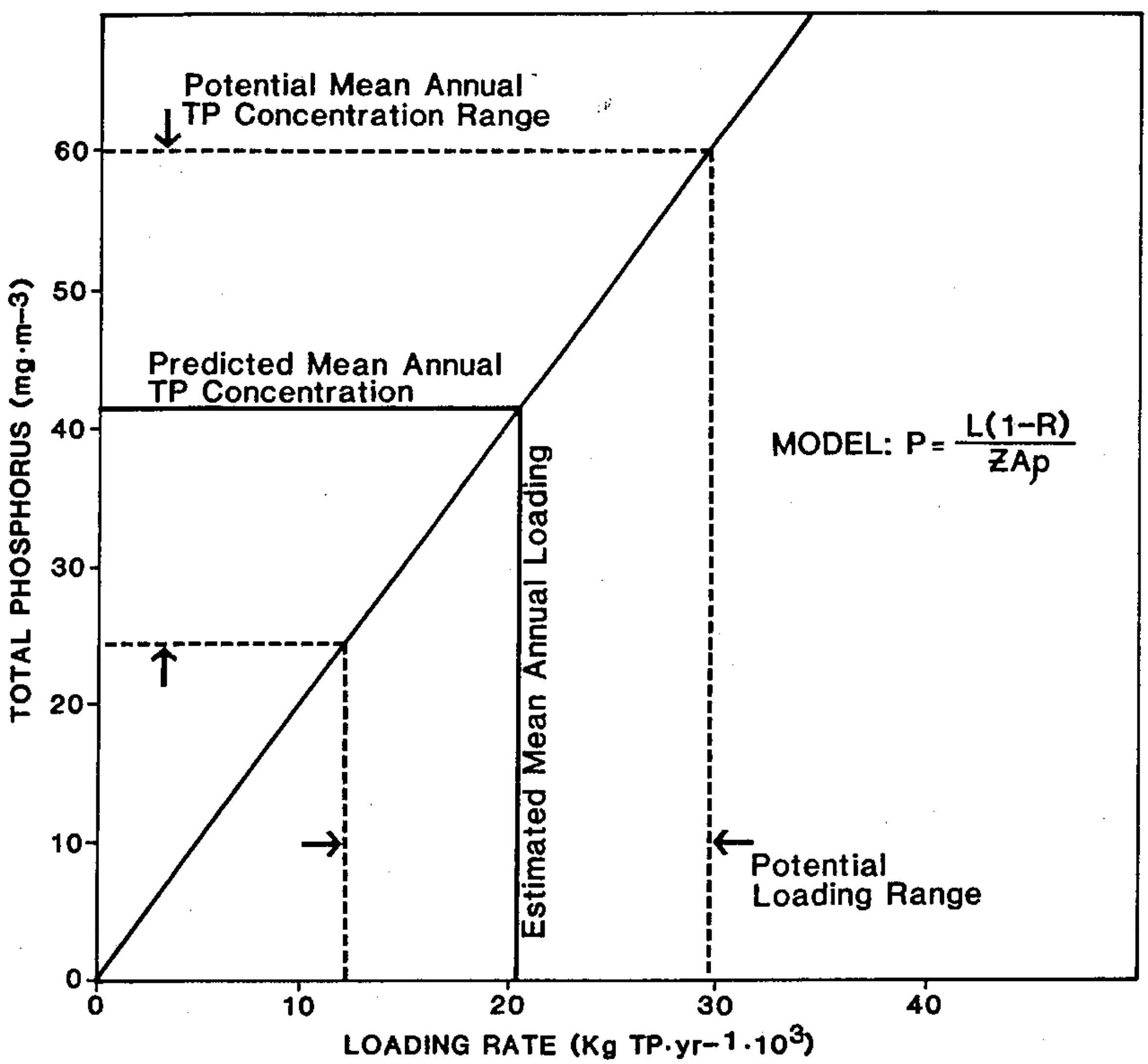


Figure 5

RELATIONSHIP OF TOTAL -P CONCENTRATION WITHIN CAPITOL LAKE AND TOTAL -P LOADING RATE AS DEFINED BY VOLLENWEIDER'S MODEL

algal productivity is limited to an extent by physical factors. As pointed out by Orsborn et al (1975), Capitol Lake, although eutrophic, does not exhibit typical characteristics due to the short hydraulic detention time and the periodic saltwater flushing.

Because of the short detention time of the lake, the seasonal nutrient loading is considered more important in establishing the relative importance of loading sources. With a mean annual volume exchange rate of 138 times/year, nutrient loading occurring during the winter months does not have a significant influence on the plant productivity occurring primarily during the summer. The TP loading to Capitol Lake was analyzed on a monthly basis in an effort to determine the relative seasonal signficance of the sources (based upon field data analyses integrated with historical data available). Table 15 provides a summary of the monthly loading by the primary sources. From the data presented, it can be seen that the magnitude of the loading changes considerably throughout the year. The Deschutes River remains the dominant source, although the relative magnitude of the loading provided by the river decreases during the low-flow summer months. As the river flows decrease, the importance of constant flow point discharges increases. Thus the relative magnitude of the brewery nutrient loading increases substantially during the summer months.

RECOMMENDATIONS

A restoration strategy was developed for the control of algal productivity in Capitol Lake. As discussed at the onset of the eutrophication analysis, it is assumed that the practical management (with regard to quantity and quality) of algal populations may be achieved through reductions in phosphorus loadings. The basic premise is that within Capitol Lake phosphorus loadings can be reduced to the point where the nutrient becomes limiting to growth regardless of whether initially limiting or not. In an attempt to verify this premise, relative nitrogen and phosphorus concentrations were examined in the Deschutes River over the study period.

Miller et al (1978) defined a water to be nitrogen limiting for algal growth at an inorganic nitrogen (IN) (NH_3-N + NO_2-N + NO_3-N) to orthophosphate (OP) ratio (IN/OP) of less than 10:1. At IN/OP ratios of greater than 12:1, phosphorus was considered limiting. Ratios of IN/OP observed in samples collected from the Deschutes River over the study period ranged between 9.1 and 27.5, with a mean of 15.2. During the productive months (May through August), the mean IN/OP ratio was 14.9, with a range of 9.1 to 18.8. Only one sample obtained over the course of the study indicated potential nitrogen limitation. Three samples demonstrated ratios in the balanced range (10 to 12), while seven samples had ratios indicating potential phosphorus limitation. Thus, it appears that the Deschutes River as the dominant factor influencing Capitol Lake water quality tends to be phosphorus limiting. As a result, a restoration strategy directed toward control of phosphorus loading may be expected to provide reductions of current productivity levels.

Three nutrient (TP) loading sources that are reasonably controllable have been identified. The sources, along with a summary of their significance and restoration potential, are as follows:

Source: Pabst Brewery

Significance: Contributes an estimated 14.3 percent of the annual TP loading to Capitol Lake. The relative significance of the brewery discharge increases substantially during the low-flow months when much of the algal productivity of the lake occurs. It is estimated that the brewery may contribute as much as 34.7 percent of the total loading to Capitol Lake during these periods. The brewery is a point source discharge. Control of point sources is more effective than control of nonpoint sources.

TABLE 15
TOTAL PHOSPHORUS (TP) LOADING TO
CAPITOL LAKE ON A MONTHYLY BASIS

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Total Monthly Loading (kg TP)	3,510	2,926	2,323	1,614	983	845	762	735	694	792	2,058	3,265
Percent Contribution by Identified Sources:												
Deschutes River	80.5	79.0	73.1	68.4	53.7	51.1	47.8	46.4	43.7	43.6	72.7	79.2
Dairies (1)	10.8	11.2	8.2	12.3	19.7	5.3	3.3	6.8	7.3	11.9	9.0	8.9
Pabst Brewery (2)	7.1	7.8	10.7	14.9	25.3	28.5	32.7	33.9	34.7	31.4	11.7	7.6
Percival Creek	6.9	7.7	9.2	9.4	10.0	8.0	6.6	5.6	5.8	7.4	6.7	7.3
Percival Cove	1.8	1.9	2.7	3.7	6.4	7.1	8.3	8.6	8.6	8.0	2.9	1.9
Miscellaneous	3.7	3.6	4.3	3.6	4.6	5.3	4.6	5.5	7.2	9.6	6.0	4.0

(1) Dairies also included in the total loading by the Deschutes River.

(2) Assumes loading at measured flows. If permit flows are used, the monthly loading by the brewery ranges between 4.2 and 23.2% of total monthly loadings.

Restoration Strategy/Potential: The Washington State Department of Ecology is currently working with Pabst Brewery in an effort to reduce nutrient loading. Potential restoration options include: the use of a nonphosphate antiscaling compound and/or the diversion of the discharge to the City of Olympia Sewage Treatment Plant during the low-flow, productive summer months.

Source: The monitored dairies located in the Deschutes River watershed.

Significance: Contribute an estimated 14.2 percent of the annual Deschutes River TP load (9.9 percent of total loading to Capitol Lake). Estimated contribution during the months when most primary productivity occurs ranges between 3.3 and 19.7 percent of the total loading to Capitol Lake. May be effectively controlled through changes in land use and livestock management practices.

Restoration Strategy/Potential: CD/SCS is currently working with land owners to reduce nutrient loading through on-site treatment and modified land use practices. Preliminary assessment indicates a substantial reduction in nutrient loading from these sites may be achieved.

Source: Percival Cove.

Significance: Contributes an estimated 3.6 percent of the annual TP loading to Capitol Lake. During productive summer months the source may be contributing as much as 8.6 percent of the total loading to Capitol Lake.

Restoration Strategy/Potential: It is suspected that the Percival Cove loading source is related to the fish rearing operations within the cove. Nutrient (TP) release by enriched sediments or the suspension of fish food and wastes are likely sources. Potential restoration options for the loading mechanisms indicated include sealing off the sediments with an aluminum sulfate (alum) treatment or the removal of nutrient-rich sediments through dredging.

The Department of Fisheries opposes the use of alum in Percival Cove due to potential risks it may pose to the fish rearing operation (WDOF, 1983). It has been advised that if sediment nutrient release is the cause of the Percival Cove phosphorus loading source, then the sediments may be removed by dredging, or the cove may be isolated during the productive months (by short-circuiting the Percival Creek flow to the lake), thereby reducing or preventing the export of phosphorus from the cove.

Overall, the above sources represent approximately 28 percent of the total annual TP loading to Capitol Lake. Assuming these sources could be totally eliminated (thereby resulting in an annual TP loading of 14,765 kg), the mean annual in-lake TP concentration would be reduced from 41 to 31 mg/m^3 (Figure 5).

More important, however, is the seasonal loading reduction provided. Mean monthly TP concentrations were determined through the manipulation of the previously presented TP mass balance model. In Figure 6, the in-lake monthly TP concentrations (for the productive months) are presented according to observed (1983) and predicted values under various TP loading scenarios. From the data presented, it can be seen that the identified controllable sources may be responsible for up to 49 percent of the in-lake TP concentration during the months of peak algal productivity.

Attempts have been made to quantify potential changes in Capitol Lake water quality resulting from reductions or elimination of the "controllable sources." In order to do so, empirical trophic state models developed by Carlson (1977) were used to define selected water quality parameters as a function of predicted post-restoration TP concentrations. Specifically, the models relate chlorophyll-a (a measure of algal productivity) and Secchi disk readings (a measure of water clarity) with TP concentrations. The Carlson models used are as follows:

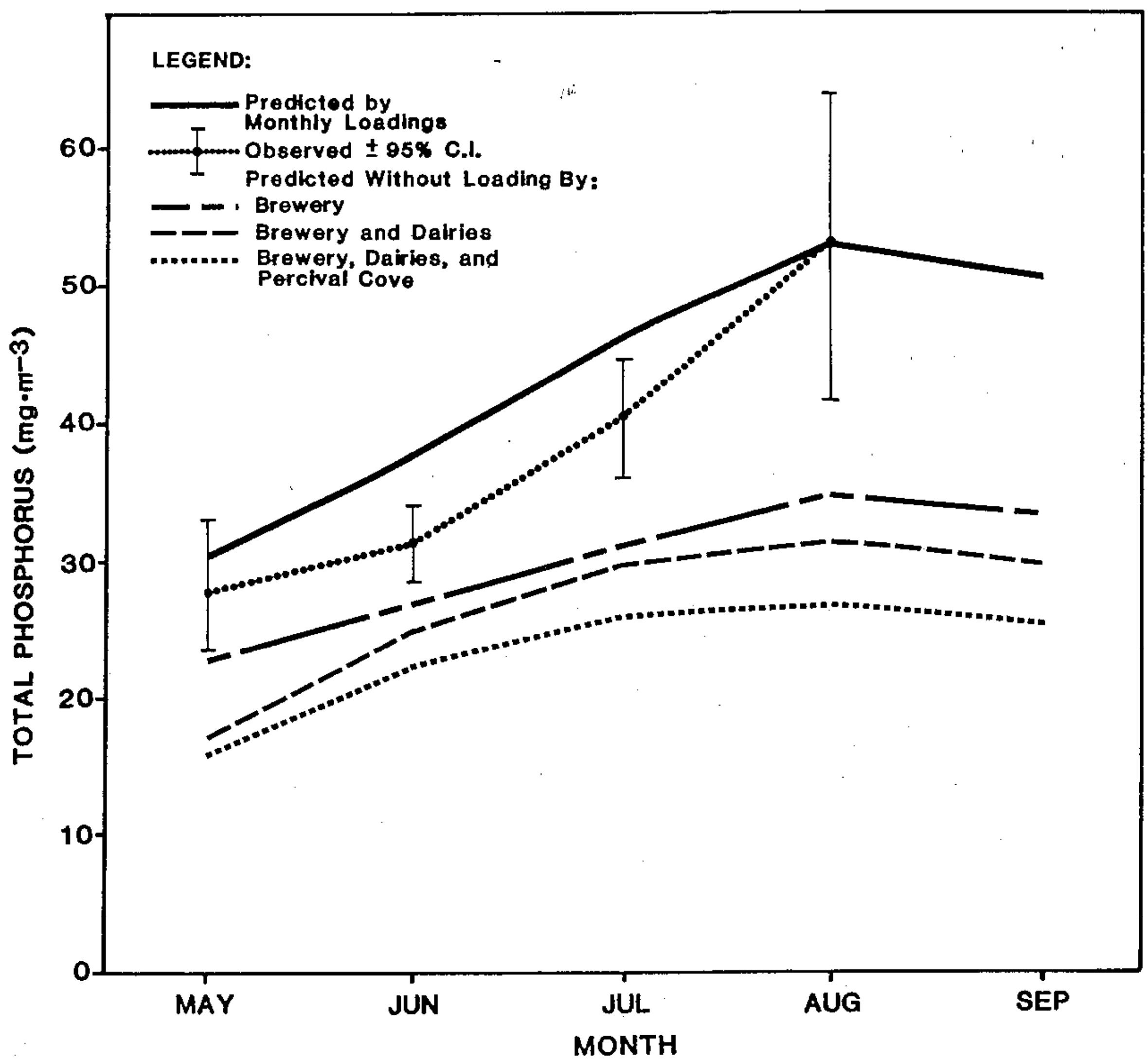


Figure 6

MEAN MONTHLY TOTAL PHOSPHORUS CONCENTRATIONS IN CAPITOL LAKE OBSERVED AND PREDICTED BY IDENTIFIED LOADING SCENARIOS

$$\ln Chla = 1.449 \ln TP - 2.442$$

and

$$\ln SD = 3.876 - 0.98 \ln TP$$

where:

$\ln Chla$ = natural log of chlorophyll-a concentrations (mg/m^3)

$\ln SD$ = natural log of Secchi disk readings (m)

$\ln TP$ = natural log of total phosphorus concentrations (mg/m^3)

The suitability of Carlson's models was determined by comparing observed and predicted values for the monitored 1983 productivity season (May through August). Table 16 presents the comparative data by lake basin and the overall conditions. The productivity of the south basin was substantially less than the predicted productivity under the observed TP concentrations. It is suspected that the extremely short hydraulic detention time of the south basin served to restrict the algal populations of the water column. It is also worth noting that during the 1983 productivity season, large floating algal mats (primarily Hydrodictyon) were observed in the south basin. The distribution of the mats appeared to be controlled by factors such as surface winds rather than hydraulic flushing. Water quality samples obtained from the south basin did not include the algal mats. Hence, the south basin samples underestimated the actual algal production.

In the middle and north basins, the Carlson trophic state models appear to be more sensitive in predicting existing conditions. Overall (combining the middle and north basin data), the model demonstrated a reasonable fit to the observed data.

The Carlson trophic state models were used to predict water quality improvements corresponding to TP loading reductions. For purposes of the analysis, potential loading reductions ranging up to 100 percent of the identified "controllable sources" were examined. An initial TP

TABLE 16
COMPARISON OF PREDICTED AND OBSERVED
VALUES FOR TROPHIC STATE
PARAMETERS OF CAPITOL LAKE BASINS

	SOUTH[1] BASIN	MIDDLE[2] BASIN	NORTH[3] BASIN	OVERALL[4]
Total Phosphorus (mg/m^3):				
Observed	42.5	42.3	31.5	38.0
Chlorophyll-a (mg/m^3):				
Observed	3.8	13.1	18.1	15.1
Predicted	19.7	19.8	12.9	16.9
Secchi Disk (m):				
Observed	1.8	1.3	1.6	1.4
Predicted	1.2	1.2	1.6	1.4

1 Lake stations 1SB and 2I5.

2 Lake stations 3MB1 and 4MB2 and 5RR.

3 Lake stations 6NBT and 8TG.

4 Excluding the south basin.

concentration (at 0 percent reduction) of 38 mg/m^3 is assumed. Figure 7 illustrates the projected changes in chlorophyll-a and Secchi disk values during productive months) associated with TP loading reductions. Also shown are the conditions observed during the monitored 1983 productivity season (at a mean TP concentration of 38 mg/m^3). Discrepancies existing between observed conditions (at 0 percent removal) and predicted conditions are considered the result of model calibration error or are reflective of additional productivity controls (such as basin hydraulic detention time).

A potential decrease in chlorophyll-a (during the productive months) of up to 8 mg/m^3 is indicated. Subsequent improvements in water clarity range up to 1.1 meter (3.6 feet).

The Carlson trophic state models indicate that within Capitol Lake restoration efforts directed toward reducing TP loading will provide improvements in water quality. The actual magnitude of the improvements is dependent upon the effectiveness of specific nutrient control measures applied. At the present time, the extent to which the identified "controllable sources" can be practicably reduced is unknown.

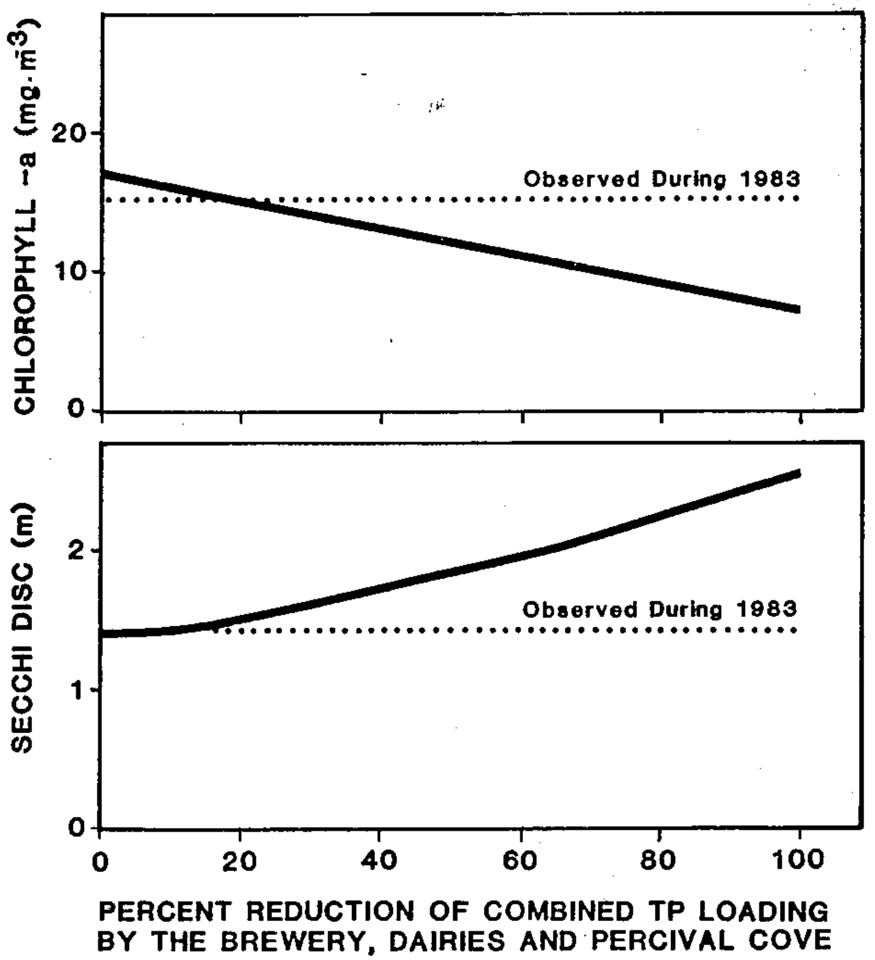


Figure 7

PREDICTED WATER QUALITY IMPROVEMENTS ASSOCIATED WITH TOTAL PHOSPHORUS (TP) LOADING REDUCTIONS

VI
BACTERIA

INTRODUCTION

In the past, bacterial counts in excess of acceptable health standards have repeatedly raised concerns about the recreational use of Capitol Lake. A study conducted by CH2M Hill (1978) identified the dominant coliform bacterial loading sources as the Deschutes River and the waterfowl population using the lake. It was suggested that a potentially significant loading source existed along the lower 0.6 mile of the Deschutes River. A faulty sanitary lift station was identified as the source of this contamination and has since been repaired.

An additional bacterial loading source in the north basin (adjacent to the swimming area) was identified by Moore (1982). High coliform bacteria counts were observed in the discharge from the 7th Avenue storm sewer. Apparently, broken sanitary and storm sewer lines were responsible for the contaminated discharge. The faulty lines were repaired by the City of Olympia during the spring of 1983.

Bacterial sampling conducted by the Department of Ecology during the summer of 1982 revealed no bacterial standards violations (Singleton, 1982). It was concluded at that time that "the sources of the lake's fecal coliform problems have been or are in the process of being eliminated." The recent repair of the sewer lines by the City of Olympia is expected to have provide additional reductions in the Capitol Lake bacterial concentrations. Consequently, it is assumed that pathogenic organisms are no longer a major water quality problem in Capitol Lake.

CURRENT ANALYSIS

As a part of the present study, potentially significant point and/or nonpoint bacterial loading sources were examined. Monitoring was conducted to determine the magnitude of bacterial loading from stormwater runoff, dairy operations within the Deschutes River watershed, the Chambers Creek watershed (discharging into the Deschutes River), and point discharges from the Pabst Brewery. Table 17 presents the results of monitoring stormwater runoff at the stations indicated. Also included are data obtained from the residual or base flow observed at stations located within the Capitol Lake basin. Table 18 provides the bacterial data for samples obtained at stations located along the Deschutes River (monitored as recommended by CD/SCS and previously discussed under the eutrophication analysis).

According to the water quality standards acceptable for Capitol Lake (and the Deschutes River), fecal coliform densities shall not exceed a geometric mean value of 100 organisms/100 ml, with not more than 10 percent of the samples exceeding 200 organisms/100 ml. Stormwater runoff to Capitol Lake appears to have the potential to elevate the fecal coliform densities of the lake to levels in excess of the specified standards. In particular, the lake basin stations (Deschutes Parkway, Simmons Road, and the 7th Avenue storm sewer) demonstrated the highest bacterial densities. The actual impact of stormwater bacterial loading is, however, dependent upon the amount of runoff generated by a specific storm event, the concurrent density of the lake bacterial population already present, survival rates, and the hydraulic residence time of the basin. Most of the stormwater loading occurs during the winter when the hydraulic residence time of the lake may be as short as one day or less. Hence, the bacterial loading resulting from a winter storm event would typically result in only short-term impacts.

Bacterial loading from summer storm events may have a greater temporal impact due to the longer residence time of the lake (up to 11 days under current estimates of low flows and existing lake volume). However, generally there is a decrease in the magnitude and frequency of storms

TABLE 17
GEOMETRIC MEAN OF BACTERIAL SAMPLES
OBTAINED AT STORMWATER MONITORING SITES

STATION	n[1]	BACTERIAL DENSITIES (MPN/100 ml) Total Coliform	Fecal Coliform	Fecal Streptococci
Percival Creek:				
Mottman Road	3	1,719	61	75
Walkbridge	3	1,676	90	125
Percival Ditch:				
Mottman Road	3	6,280	53	70
Deschutes Parkway:				
Stormflow	5	7,599	303	630
Base Flow	1	460	9	20
Simmons Road:				
Stormflow	5	32,542	1,408	2,005
Base Flow	1	460	75	210
7th Avenue Storm Sewer[2]:				
Stormflow	6	74,273	1,725	2,078
Base Flow	1	240,000	7,500	460

1 Number of samples.

2 Monitored after repairs completed during the spring of 1983.

TABLE 18
GEOMETRIC MEAN OF BACTERIAL SAMPLES
OBTAINED AT STATIONS LOCATED WITHIN
THE DESCHUTES RIVER WATERSHED

STATION	n[1]	BACTERIAL DENSITIES (MPN/100 ml) Total Coliform	Fecal Coliform	Fecal Streptococci
Vail Road Dairy	6		894	
Rixie Road Dairy	6		209	
Chambers Creek	6		20	16
Pabst Brewery, NPDES Permit No.:				
001	3	3	3	3
002	4	27,706	6,928	1,425
003	4	409	37	7
004	4	20,961	104	71
UI[2]	1	930	9	9

[1] Number of samples.

[2] A nonpermitted discharge discovered during study.

contributing to runoff during the summer months. Thus, the actual potential for significant stormwater bacterial loading during the summer may be limited.

The ratio of fecal coliform to fecal streptococci densities has been used to indicate contamination of human origin (Geldrich, 1966). Typically, a ratio in excess of 4 to 1 has been assumed indicative of human sources (although the accuracy of the ratio is not widely accepted). In the one sample obtained from the 7th Avenue storm sewer base flow, a ratio of 16 to 1 was observed. However, the ratio is based upon only one sample and, as such, is questionable. At the present time, it can only be concluded that the results suggest that a potential problem may still exist with the storm sewer. Additional data collection and analyses are required before the nature or significance of the discharge can be verified.

The runoff from the dairies (in particular the Vail Road dairy) exhibits high fecal coliform densities (Table 18). Consequently, the dairies appear to be significant bacterial loading sources to the Deschutes River. However, the actual impact of the dairies upon the bacterial populations of Capitol Lake is questionable due to: (1) the survival rates of bacterial populations in relation to the relative distances of the loading sources from the lake; and (2) the dilutional capacity of the river. Bacterial loading from the dairies may be reduced in conjunction with phosphorus control practices.

Brewery discharges 002 and 004 provided geometric means of fecal coliform populations in excess of the acceptable limits for Capitol Lake and the Deschutes River (Table 18). However, the flow-weighted geometric mean density for the combined discharge from the brewery (excluding 002) indicates a potential mean fecal coliform density between 14 and 46 organisms per 100 ml. This value is below the maximum acceptable level of 100 organisms per 100 ml in the receiving water. Hence, the combined loading provided by discharges 001, 003, and 004 and UI does not significantly increase the bacterial density of the receiving water.

The bacterial densities observed in brewery discharge 002 were orders of magnitude greater than the other brewery discharges. The discharge has the smallest flow (0.1 to 0.5 cfs) of the permitted discharges, yet the magnitude of bacterial densities indicates a potential for a significant impact on the receiving waters. In addition, a fecal coliform to fecal streptococci ratio of 22.7 to 1 suggests possible contamination of human origin. Caution is again advised, however, when interpreting these results. Although the potential for human contamination is indicated, additional monitoring of the discharge and source evaluation is required to verify its significance.

RECOMMENDATIONS

The results indicate that two discharges--Pabst Brewery discharge 002 and the City of Olympia 7th Avenue storm sewer--may be contaminated by human sources. It is recommended that additional monitoring be conducted to verify the significance of these discharges. It is also recommended that long-term surveillance monitoring be conducted throughout the lake basin to ensure that desirable existing conditions are maintained.

VII

SWIM AREA RESTORATION PERFORMANCE ANALYSIS

INTRODUCTION

The Capitol Lake swim area restoration was completed in 1982. Improvements included the placement of an impermeable curtain isolating the swim area from the rest of the lake, installation of equipment to treat and recirculate water contained within the curtain, and provisions for the discharge of City of Olympia drinking water into the swim area. A total of four basic operating conditions are identified in the swim beach restoration operation manual as submitted to the City of Olympia (Puget Constructors, 1982).

1. Dilution Flushing

   City drinking water is flushed throughout the swimming area, providing a complete volume exchange within 16 hours (at a flow rate of 1,900 gpm).

2. Deep Water Treatment

   Sodium aluminate or aluminum sulfate is mixed with City water and then added to the deep-water section of the swim area. The chemical addition provides for the removal of colloidal material (including bacteria) and nutrients. Specific dosages are dependent upon selected water quality parameters such as pH and alkalinity. It is anticipated that an initial treatment at the start of the season would be followed by treatments dictated by subsequent changes in the swim area water quality.

3. Shallow Water Dilution with Treated Water

Water from the deep area is withdrawn, filtered, disinfected, and recirculated to the shallow section. Treatment is accomplished by passing the recirculation water through rapid sand filters, followed by a sterilizing UV treatment. The volume of the shallow area is replaced once every nine hours at an estimated recirculation rate of 130 gpm.

4. Shallow Water Dilution with Treated Water and City Water

City water is combined with treated water and then discharged to the shallow section. The addition of City water ensures that a positive hydraulic head is maintained on the swim area side, thereby precluding excessive entrance of untreated lake water into the swim area. An estimated 70 gpm is added to the total flow to the swim area (200 gpm). The volume of the shallow section is replaced once every 6 hours with City and treated water combined (once every 18 days with City water alone).

OPERATION DURING 1983 SEASON

Conditions during the summer of 1983 restricted effective implementation of the aforementioned options. The lake drawdown in June resulted in the displacement of the curtain (caused by the lake level dropping faster than the swim area could drain). Consequently, large gaps formed in the curtain barrier and permitted a greater exchange of untreated lake water with the swimming area. Hence, the efficient treatment of the "isolated" water body contained within the swim area was reduced.

The primary operating mode employed during the summer of 1983 was Option 1, dilution flushing. Large volumes of City water were added to the swim area throughout the summer. Excessive use of City water during the day resulted in reduced water pressure elsewhere in the City distribution system. As a preventative measure, the swim area began to utilize the City water dilution option during low demand periods (6:00 p.m. through 8:00 a.m.).

The frequent use of City water also resulted in lower water temperatures within the swim area. The cold water temperature was a common complaint during the 1983 season.

The use of sodium aluminate during the 1983 season was sporadic and essentially unmonitored. The chemical was at times added to the shallow section as well as the deep section. This practice is in conflict with the originally intended use of chemical flocculants as a deep-water treatment (Option 2). Observations by City of Olympia personnel regarding the ineffectiveness of sodium aluminate to preserve water clarity in the shallow section (due to users stirring up the settled floc) probably resulted from the improper distribution procedures.

Difficulties were encountered in handling and dispersing sodium aluminate. It was observed that the chemical was difficult to use and appeared to come out of solution in the barrels. Dosages were estimated by visual inspection of water clarity and floc formation. No attempts were made to quantify the amount of chemical added or the response of the swim area water quality parameters.

PERFORMANCE EVALUATION/RECOMMENDATIONS

The water quality of the swim area was monitored during the summer of 1983 to evaluate the performance of the swim area improvements. The results provide insight regarding the effectiveness of the specific conditions and operating procedures of the past season. Extrapolation of the results to evaluate the intended operating options is, however, restricted due to the circumstances involved and the lack of any quantified operating records (i.e., dilution rates, chemical addition, etc.).

Five samples were obtained between June 27 and August 18 from the swim area (deep water section) and Capitol Lake just outside the curtain. A summary of the data collected is presented in Table 19. A paired t test ($P = 0.95$) was used to evaluate differences between the swim area and Capitol Lake.

TABLE 19
MEAN ($\overline{x}$) AND STANDARD DEVIATION (s) OF DATA
COLLECTED FOR THE SWIM AREA PERFORMANCE EVALUATION

	SWIM AREA		CAPITOL LAKE	
	($\overline{x}$)	(s)	($\overline{x}$)	(s)
Chlorophyll-a (mg/m^3)	11.1	(5.4)	14.3	(6.9)
Secchi Disk (m)	1.8	(0.5)	1.5	(0.1)
Temperature (°C)	17.4	(1.9)	18.5	(2.0)
Alkalinity (mg/l as $CaCO_3$)	52.8	(5.2)	47.6	(3.6)
pH (-log [H^+])	8.0	(0.6)	8.8	(0.3)
Conductivity (umhos/cm)	251.3	(87.2)	271.3	(126.1)
Fecal Coliform (MPN/100 ml):			(Not Monitored)	
Deep Section	18.8	(12.8)		
Shallow Section	20.5	(16.9)		

The swim area had significantly lower temperatures; lower chlorophyll-a concentrations (a measure of algal populations); and greater water clarity, with Secchi disc readings significantly greater than Capitol Lake. Fecal coliform samples (analyzed by Thurston County Health) indicated bacterial populations in the swim area were below State standards.

From the results, it is concluded that the swim area restoration has resulted in corresponding water quality improvements. In view of the frequent closures during past years, the fact that the swim area managed to remain open for the duration of the 1983 season provides testimony to the success of the restoration. However, proper operation of swim area restoration program elements should result in significantly greater water quality improvements than observed in 1983. Additional improvements could be realized with adjustments to the curtain, changes in current operating procedures, and potentially minor changes in the swim area design. Specific recommendations include:

(1) Operate the swim area using design options 3 and/or 4. City water usage will be reduced, thereby providing lower operating costs and warmer water temperatures within the area. Design options 3 and 4 are considered the preferred operating procedures (Puget Constructors, 1983).

(2) Use aluminum sulfate (alum) rather than sodium aluminate. Sodium aluminate costs approximately 80 percent more than alum. In addition, sodium aluminate is typically more difficult to obtain. Some of the handling problems encountered during the past season may be attributed to the viscous (resistence to flow) nature of sodium aluminate. The heating of sodium aluminate to 21° C (70° F) may be required to permit flow through feed lines (ASCE, 1977). By comparison, liquid alum should be maintained at temperatures above 7° C (45° F) to ensure ease of handling.

The use of alum should be monitored. It has been suggested that the alum dosages be coordinated with monitoring provided by City of Olympia Wastewater Treatment Plant personnel to ensure acceptable dosage rates (Dennis Burke, personal communication). Alum should be used as a deepwater treatment only as dictated by the existing operating manual.

(3) Realign curtain to completely seal off the swim area from Capitol Lake. Upon prior notice of lake drawdowns, the curtain should be loosened from its anchors to enable swim area water surface elevation to drop at a rate comparable to the lake surface drop. A City employee should be present at the swim area during lake drawdowns in case additional adjustments need to be made (Puget Constructors, 1982).

(4) Provide additional performance monitoring during the 1984 operating season. The performance of the swim area should be monitored when the area is being fully operated as intended. The quantification of operating procedures should be included to ensure the accurate interpretation of monitoring data. Specific quantifiable operating parameters include the alum dosages and the dilution or recirculation rates.

Additional improvements deserving further analysis or consideration include:

(1) Reduce the area enclosed by the curtain. The portion of the enclosed area not currently used for swimming could be excluded by repositioning the curtain. A reduction of the swim area volume may provide reduced operating costs and/or increased treatment efficiencies. However, a substantial reduction of the swim area volume may reduce the area's dilution capabilities during periods of intense user activities.

(2) Evaluate the mixing/circulating capabilities of the existing system. The occurrence of stagnant areas is suspected (Don Clark, personal communication). The use of an intake manifold on the existing system may enhance circulation. The multiple-port withdrawal of water from the deep section may help prevent the formation of stagnant areas. However, additional information concerning the performance of the existing system is warranted before the practicality of such a modification can be determined.

VIII

RECOMMENDED RESTORATION PLAN SUMMARY AND IMPLEMENTATION PROGRAM

The proposed restoration plan consists of ten individual tasks. To ensure effective use of limited public and private financial resources, these tasks have been prioritized. Assuming that it would be desirable to implement all of the tasks, the prioritization system may be considered as an approach to implementation phasing. Presented in this chapter is a brief description of each task, with the estimated cost and possible funding sources, the agency proposed to be responsible for implementation, and the agencies that should participate in an advisory capacity. A brief summary of the recommended restoration plan is presented in Table 20.

FIRST-PRIORITY LEVEL TASKS

Task 1A: Siphon (with pump option) Withdrawal of Marine Water from the Tide Gate Crater

Description: The removal of marine water from the tide gate crater before it becomes stagnant is the recommended alternative for preventing the Capitol Lake fish kill mechanism. The use of a siphon is recommended, with allowance provided in the design for the addition of a pump, should the siphon discharge prove inadequate.

Participating Agencies: The Department of General Administration is identified as the lead agency, with the Departments of Fisheries and Game providing advisory assistance.

Estimated Cost and Funding Source: The estimated capital cost of the siphon (pump option) alternative is $150,000, with $3,100 annual operation and maintenance (O & M) costs. These figures assume the initial purchase,

TABLE 20
SUMMARY OF PROPOSED RESTORATION PLAN

TASK	DESCRIPTION	COST	IMPLEMENTING AGENCY	ADVISORY AGENCIES	POTENTIAL FUNDING SOURCES
	Recommended First-Priority Level Tasks				
1A	Siphon/Pump Withdrawal of Marine Water from Tide Gate Crater	$ 150,000	General Administration	Department of Fisheries Department of Game	Referendum 39, General Administration
1B	Percival Creek Drainage Master Plan	250,000	Thurston County, City of Olympia, City of Tumwater	Department of Fisheries Department of Game	Referendum 39, Local Jurisdiction
1C	Deschutes River Watershed Management Program:				
	Agricultural Management Practices	Private Funding	Thurston County Conservation District	Thurston County Conservation District, Department of General Administration, Department of Ecology, Department of Fisheries, Department of Game, Department of Natural Resources, U.S. Geological Survey, U.S. Forest Service	Private
	Forestry Management Practices	Undetermined	Undetermined		Undetermined
	In-Stream Bank Protection	Undetermined	Thurston County Conservation District		Undetermined
1D	Industrial Point Source Control of Nutrient Loading	Private Funding	Pabst Brewery	Department of Ecology	Private
1E	Long-Term Middle Basin Dredging and Disposal Program - Engineering Analysis	113,000	General Administration	Department of Ecology, Department of Fisheries, and Department of Game	Referendum 39, General Administration
	Recommended Second-Priority Level Task				
2A	Environmental Impact Statement	60,000	General Administration	Department of Ecology, Department of Fisheries, and Department of Game	Referendum 39, General Administration, and/or local jurisdictions
	Recommended Third-Priority Level Tasks				
3A	Implementation of Long-Term Middle Basin Dredging and Disposal Program	1,200,000 (1)	General Administration	Department of Fisheries, Department of Game	Referendum 39, General Administration
3B	Percival Cove Alum Treatment	28,000	General Administration	Department of Fisheries, Department of Game	Referendum 39, Undetermined Local Share
3C	Performance Monitoring of Lake Restoration Efforts	107,000	General Administration	Department of Ecology, Department of Fisheries, Department of Game, and City of Olympia	Referendum 39, General Administration
	TOTAL	$1,908,000			

(1) Assumes removal of two years sediment deposition with a dredging cycle of once every two years.

installation, and operation of the pump option. Therefore, the cost estimates present a maximum cost scenario. Should the siphon discharge prove adequate, the capital and O & M costs will be less.

O & M costs cover an annual inspection and routine maintenance of the system, replacement of the pump once every five years, and an operating cost for 720 hours of operation (equivalent to continuous operation for one month). Costs associated with the continuous operation of monitoring equipment have not been included.

It is assumed the Referendum 39 Lake Restoration Program can provide 75 percent of the required funding, the remaining 25 percent may be provided by the Department of General Administration or in-kind services.

Task 1B: Percival Creek Watershed Master Plan

Description: Development within the Percival Creek watershed has the potential to increase runoff and thereby alter the natural hydrology of the stream. Subsequent increases in the magnitude and/or frequency of peak flows in Percival Creek will erode the streambed or banks and transport greater amounts of sediment to Percival Cove. It is recommended that a comprehensive plan be developed to mitigate adverse impacts associated with increased runoff within the watershed. The proposed plan should define existing conditions, identify changes in the stream's hydrology relating to land development, and assess the means by which the increased magnitude and frequency of peak flow events can be mitigated.

Participating Agencies: The responsibility for developing a comprehensive drainage plan as well as its eventual implementation rests with the jurisdiction within which the Percival Creek watershed lies: the Cities of Olympia and Tumwater and Thurston County. The allocation of responsibility among the three jurisdictions is undetermined at the present time.

Because of the importance of a comprehensive drainage plan to the Percival Cove fish rearing operation, it is recommended that the Departments of Fisheries and Game participate in an advisory capacity.

Estimated Cost and Funding Sources: The estimated cost of developing the Percival Creek watershed management plan is $250,000. Included is the cost associated with establishing a metropolitan drainage utility. Unknown at this time is the cost of any physical improvements that may be proposed by the plan.

It is assumed that the task is eligible for 75 percent funding support from the Referendum 39 program. The remaining 25 percent would be provided by the three local jurisdictions. The jurisdiction could contribute according to the percentage of basin land area or population that resides in each basin or some combination of both criteria.

It is also possible that total funding could be provided by the three jurisdictions. Again, each jurisdiction would contribute according to an agreed upon formula.

Task 1C: Deschutes River Watershed Management Program

Description: It is recommended that efforts be directed toward controlling nutrient and sediment loading by the Deschutes River watershed. Nutrient loading sources resulting from agricultural land use practices have been identified. Steps are currently being taken to mitigate these sources by private land owners cooperating with the Thurston County Conservation District. Hence, the future emphasis of a Deschutes River watershed management program is directed toward sediment control and surveillance monitoring.

Most of the Deschutes River sediment loading occurs during high flows and may be due primarily to natural erosional processes. Increased runoff volumes and rates resulting from forestry management practices have been identified as a potential cause of increased river flows (CD/SCS, 1984). However, there is insufficient data to directly substantiate this contention at the present time. Long-term river monitoring (as recommended by CD/SCS, 1984) may eventually provide the data necessary to clearly establish the influence of timber harvest practices on Deschutes River hydrology.

In-stream bank protection has also been considered as a means of reducing current sediment loading (CD/SCS, 1984). However, the cost effectiveness of such techniques is uncertain at the present time. Evaluation of various techniques through limited or pilot-scale applications may be considered.

Participating Agencies: The Thurston County Conservation District is identified as the lead agency, coordinating with private landowners to mitigate impacts from agricultural land use practices. The Conservation District would also be involved with monitoring efforts and implementation of in-stream bank protection. Other agencies serving in a regulatory or advisory capacity include the Washington State Departments of General Administration, Ecology, Fisheries, Game, and Natural Resources; the U.S. Geological Survey; and the U.S. Forest Service.

Estimated Cost and Funding Sources: It is assumed that the cost of instituting agricultural management practices will be borne by private landowners. CD/SCS (1984) has identified some of the costs associated with various measures that may be included in a watershed management program, although the cumulative costs (and potential funding sources) are undetermined at the present time.

Task 1D: Industrial Point Source Control of Nutrient Loading

Description: Point source discharges by Pabst Brewery have been identified as significant nutrient loading sources to Capitol Lake. Point source control is more effective than nonpoint source control. Hence, the discharges identified are recognized as the major controllable nutrient loading source to Capitol Lake.

Participating Agencies: It is assumed that Pabst Brewery Company would be able to ascertain the best practical methods for reduction of nutrient discharge. It is recommended that a plan be developed that is in accordance with discharge permit criteria established by the Department of Ecology.

Estimated Cost and Funding Sources: The estimated cost is unknown at the present time. It is assumed that associated costs will be borne by the Pabst Brewery.

Task 1E: Engineering and Environmental Analyses of Long-Term Capitol Lake Basin Dredging Program

Description: The implementation of a long-term dredging program is required to maintain a lake environment in Capitol Lake. It is recommended that existing sediment traps be maintained (with the possible exception of south basin trap) and that rehabilitative dredging be conducted in other areas of the lake. An engineering analysis is required to select a long-term dredging schedule (both spatial and temporal), equipment, staging facilities, required treatment of dredge spoils effluent and options available for dredge spoils disposal. An environmental analysis is required to incorporate environmental concerns in the design and implementation of the dredge program.

Participating Agencies: Department of General Administration would have lead authority. The Departments of Fisheries, Game, and Ecology would serve as advisory agencies.

Estimated Cost and Funding Sources: The estimated cost is $113,000, including Department of General Administration coordination and administrative costs. It is assumed that 75 percent of the costs would be provided by Referendum 39. The remaining 25 percent would be provided by the Department of General Administration or in-kind services.

SECOND-LEVEL PRIORITY TASKS

Task 2A: Environmental Impact Statement

Description: An environmental impact statement (in accordance with state and federal laws) is required for the implementation of the restoration tasks identified.

Participating Agencies: The lead agency would be the Department of General Administration. The Departments of Fisheries, Game, and Ecology would provide advisory support.

Estimated Costs and Funding Sources: The estimated cost is $60,000, including the Department of General Administration's coordination and administrative costs. It is assumed that 75 percent funding support by the Referendum 39 program may be provided. The remaining 25 percent would be provided by the Department of General Administration or in-kind services. In addition, funding may be provided by the local jurisdictions deriving benefits from the restoration of Capitol Lake.

Task 3A: Implementation of the Long-Term Capitol Lake Basin Dredging Program

Description: Task 3A is the implementation of the program addressed under the first-priority level task, 1E.

Participating Agencies: The Department of General Administration would be the lead agency. The Departments of Fisheries, Game, and Ecology would serve in an advisory capacity.

Estimated Costs and Funding Sources: It is assumed that costs would accrue every two years under the preliminary dredge plan. At current sediment deposition rates (assuming 50,000 cubic yards per year) and an assumed removal cost of $12 per cubic yard, it is estimated that the equivalent annual cost will be $600,000, or $1,200,000 per dredging operation every two years. Included are the Department of General Administration's coordination and administrative costs.

The conservative cost estimate for dredging (at $12 per cubic yard) was used in the absence of specific information that will be provided by the recommended engineering analysis (Task 1E). It is assumed that the dredge spoils will be handled twice, with an intermediate staging area within the lake basin used to condition the spoils prior to final removal and deposition. The potential commercial value of the dredge spoils is not considered in the initial cost estimate.

Should efforts directed toward controlling sediment loading within the Deschutes River watershed prove effective, the costs associated with a lake basin dredging program would be reduced.

Seventy-five percent funding support may be provided by Referendum 39. The remaining 25 percent could be provided by the Department of General Administration.

Task 3B: Percival Cove Alum Treatment

Description: It is suspected that nutrient (phosphorus) release from enriched sediments within Percival Cove is contributing to algal production within Capitol Lake. It has been recommended that aluminum sulfate (alum) be used to seal off the bottom of the cove, thereby reducing the current phosphorus loading to Capitol Lake.

The effective life span of an alum treatment is estimated to be three to five years. An alum treatment may serve as an interim control measure until additional restoration efforts can be implemented. The inclusion of Percival Cove in the proposed long-range dredging program (Task 3A) may also provide effective control of the Percival Cove phosphorus source.

The Department of Fisheries opposes the use of alum within the cove due to the potential risks to the fish rearing operation. Hence, implementation of the proposed alum treatment is unlikely at the present time.

Small-scale pilot studies may be useful in assessing the impact of alum on the fishery.

Participating Agencies: It is assumed that the Department of General Administration would serve as the lead agency, with the Department of Fisheries serving in an advisory capacity.

Estimated Cost and Funding Sources: The total cost of a Percival Cove alum treatment is estimated to be $28,000. Additional costs may be incurred by preliminary tests required to determine potential impacts of alum on the salmonid fish rearing operation. Included in the initial cost are the Department of General Administration's coordination and administrative costs.

It is assumed that 75 percent funding support may be provided by Referendum 39. Likely funding sources for the remaining 25 percent are undetermined.

Task 3C: Performance Monitoring of Lake Restoration Efforts

Description: Performance monitoring is recommended to evaluate the effectiveness of lake restoration efforts and/or the response of the lake to changes in nutrient and sediment loading. Performance monitoring is contingent upon the implementation of restoration efforts.

Participating Agencies: The Department of General Administration would be the lead agency. The Departments of Ecology and Fisheries and the City of Olympia would serve in an advisory capacity.

Estimated Cost and Funding Sources: The total cost of a two-year performance monitoring program is estimated to be $107,000, including the Department of General Administration's coordination and administrative costs. It is assumed that Referendum 39 may provide 75 percent funding support. The remaining 25 percent would come from the Department of General Administration.

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APPENDIX A

MONITORING PROGRAM

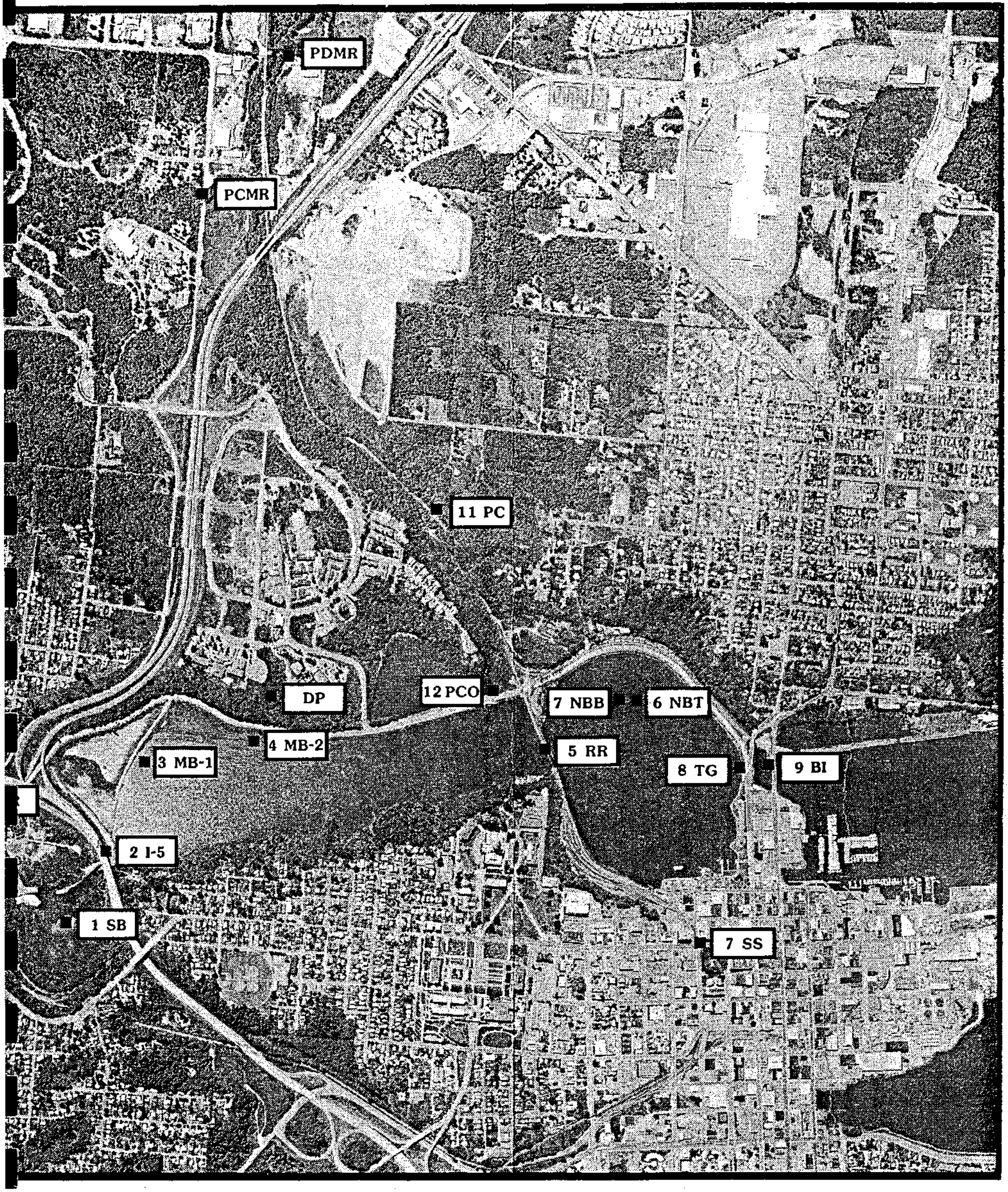
APPENDIX A
MONITORING PROGRAM

A brief summary of the field monitoring activities conducted during the present study is provided. The specific sampling stations used and the type of sample obtained at each site are included in Figure A1. Chemical analyses were conducted by AM Test Laboratories of Seattle, Washington. The field monitoring equipment used is identified in Table A1. The following is a description of individual tasks included under the monitoring program.

1 SB	South Basin	Lake Monitoring Station	Depth Composited Sample
2 I-5	Interstate 5 Bridge	Lake Monitoring Station	Depth Composited Sample
3 MB-1	Middle Basin #1	Lake Monitoring Station	Depth Composited Sample
4 MB-2	Middle Basin #2	Lake Monitoring Station	Depth Composited Sample
5 RR	Railroad Bridge	Lake Monitoring Station	Depth Composited Sample
6 NBT	North Basin, Top	Lake Monitoring Station	Grab Sample At Surface
7 NBB	North Basin, Bottom	Lake Monitoring Station	Grab Sample Above Bottom
8 TG	Tide Gate	Lake Monitoring Station	Depth Composited Sample
9 BI	Budd Inlet	Lake Monitoring Station	Depth Composited Sample
10 DR	Deschutes River	Lake Monitoring Station	Grab Sample Below Falls
11 PC	Percival Creek	Lake Monitoring Station	Grab Sample At Walkbridge
	Percival Creek At Walkbridge	Stormwater Runoff Monitoring Station	Time Composited Sample During Storm Events
12 PCO	Percival Cove Outlet	Lake Monitoring Station	Depth Composited Sample
DP	Deschutes Parkway	Stormwater Runoff Monitoring Station	Time Composited Sample During Storm Events
SR	Simmons Road	Stormwater Runoff Monitoring Station	Time Composited Sample During Storm Events
7 SS	7th Avenue Storm Sewer	Stormwater Runoff Monitoring Station	Time Composited Sample During Storm Events
PDMR	Percival Ditch At Mottman Road	Stormwater Runoff Monitoring Station	Time Composited Sample During Storm Events
PCMR	Percival Creek At Mottman Road	Stormwater Runoff Monitoring Station	Time Composited Sample During Storm Events
TVGC	Tumwater Valley Golf Course	Variable Stations	Surface And/Or Subsurface Drainage Grab Samples
PB	Pabst Brewery	Five Discharges Monitored	Time Composited and Grab Samples
	Stations Not Shown:		
VRD	Vail Road Dairy	Grab Sample Of Drainage Near Deschutes River	
RRD	Rixie Road Dairy	Grab Sample Of Drainage Near Deschutes River	
CC	Chambers Creek	Grab Sample At Rixie Road	

Figure A-1

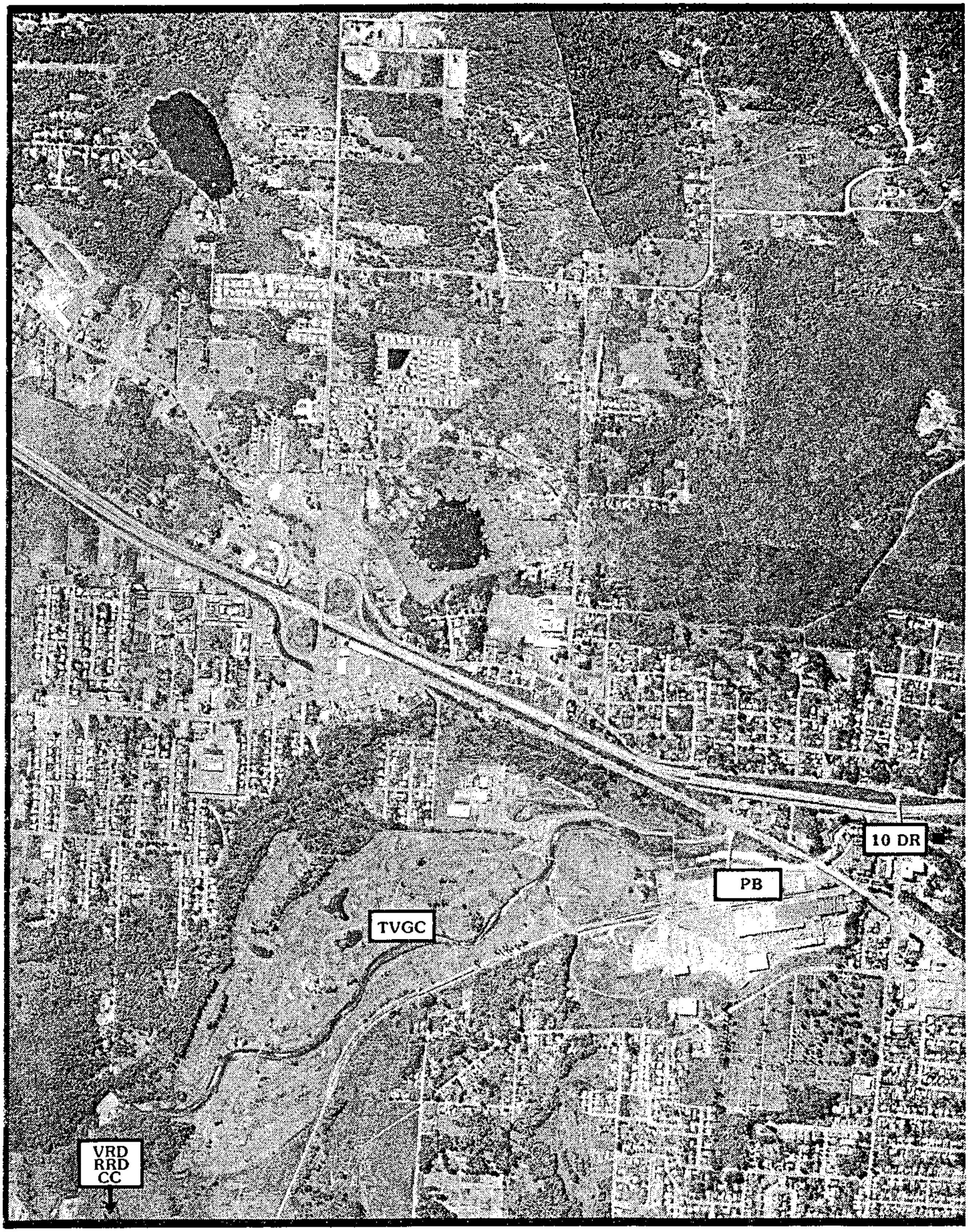
LEGEND



STORATION PROJECT
OLYMPIA, WASHINGTON

Figure A-1

MONITORING STATIONS



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ENTRANCO Engineers

TABLE A1
SUMMARY OF METHODS

Field Methods

Temperature was measured with a YSI Model 51B combined temperature/oxygen meter.

pH was measured with an Orion Model 407A specific ion meter.

Conductivity was measured with a Chemtrix Type 77 conductivity meter.

Alkalinity was measured according to Standard Methods 14th ed., p. 278.

Dissolved oxygen was measured with a YSI Model 51B combined temperature/oxygen probe. EPA Methods, p. 56.

Transparency was measured with a Secchi disk (eight-inch diameter).

Turbidity was measured with an HF model meter.

Flow was measured with Leupold-Stevens continuous recording water level recorders, a Marsh-McBirney Model 201 water current meter, and an ISCO Model 1870 flow meter.

Time composited samples were obtained with ISCO Models 1580 and 1680 automated samplers.

Task: Capitol Lake Monitoring

Objectives: Determine existing nutrient and suspended solids loading, sedimentation and/or export rates; identify magnitude of current algal productivity with respect to available nutrients; and predict potential changes corresponding to changes in nutrient loadings.

Description: A total of 12 Capitol Lake inlet and outlet stations were monitored from March through August (Figure A1). Samples were obtained bimonthly. Physical and chemical analyses conducted included orthophosphorus (OP), total phosphorus (TP), total suspended solids (TSS), and chlorophyll-a (Chl-a) at all sites. Nitrite and nitrate (NO_2+NO_3) and ammonia (NH_3) chemical analyses were conducted on samples obtained only at the 10 DR and 12 PCO stations. Field data collected included: conductivity, temperature, dissolved oxygen (DO), pH, Secchi disk readings, and turbidity.

Task: Stormwater Runoff Monitoring

Objective: Evaluate the impact of stormwater runoff on Capitol Lake.

Description: A total of six stations (Figure A1) were monitored during storm events occurring from March through May. Physical and chemical analyses conducted included TP, OP, TSS, and settleable solids (SS). Bacterial analyses included total coliform (TC), fecal coliform (FC), and fecal streptococci (FC). Continuous flow data was also collected.

Task: Pabst Brewery Monitoring

Objective: Evaluate the impact of industrial discharges upon Capitol Lake.

Description: A total of four discharge pipes (NPDES permit numbers 001 through 004) were monitored routinely (Figure A1). An additional discharge was discovered and sampled periodically. Each routinely monitored discharge was sampled over a two-week period, with composite samples collected during weekdays and weekends. Grab samples were collected at the time of composite sample change. Chemical analyses of the composite sample included TP and NO_2+NO_3. Analyses conducted on the grab samples included OP, NH_3, TC, FC, and FS. Conductivity, temperature, and instantaneous flow measurements were also recorded.

Task: Tumwater Valley Golf Course Monitoring

Objective: Determine the impact of drainage from the golf course.

Description: It was originally intended to monitor subsurface flow into the Deschutes River. Difficulties were encountered in obtaining what were considered representative samples; hence, monitoring was directed toward surface runoff. Stations monitored were variable. Existing surface flows (from the golf course lakes and drainage ditches) were sampled in addition to runoff sampled during storm events. Samples were analyzed for TP, OP, NH_3, and NO_2+NO_3. Instantaneous flow measurements were also obtained.

Task: Chambers Creek Monitoring

Objective: Determine the nature of water quality in Chambers Creek discharging into the Deschutes River.

Description: Chambers Creek was routinely sampled at Rixie Road. Samples were obtained monthly from March through August. Chemical and physical analyses included TP, OP, NO_2+NO_3, and TSS. Bacterial analyses included FC and FS. Field data was collected for DO, pH, temperature, conductivity, and turbidity. Instantaneous flow measurements were also obtained.

Task: Dairy Monitoring

Objective: Determine the quality of runoff from selected dairy operations within the Deschutes River watershed.

Description: Two dairies were sampled routinely, with one located just off Vail Loop Road and the other located off Rixie Road. Samples were obtained monthly from March through August. Chemical and physical analyses included TP, OP, NO_2+NO_3, and TSS. Bacterial analyses included FC and FS. Field data was collected for DO, pH, temperature, conductivity, and turbidity. Instantaneous flow measurements were also obtained.

Task: Swim Area Restoration Performance

Objective: Evaluate the performance of the swim area restoration completed in 1982.

Description: Data was collected from the Capitol Lake swim area during routine lake sampling from June through August. Swim area samples (obtained from the deep section) were analyzed for Chl-a. Bacterial samples (obtained from the shallow and deep areas) were analyzed for FC. Thurston County Health conducted the bacterial analyses. Field data included temperature, DO, alkalinity, Secchi disk readings, conductivity, and turbidity. Concurrent Capitol Lake data (for comparison) were obtained from just outside the swim area curtain. Lake samples were not analyzed for bacterial counts.

APPENDIX B

TABULATED DATA

12-29-83

CAPITOL LAKE DATA

STATION	DATE	ORTHO P mgP/m3	TOTAL P mgP/m3	CHL-a mg/m3	SECCHI D m	DEPTH m	TURBIDIT NTU	SUS SOLI mg/l	pH	CONDUCT. umhos/c	TEMP. Deg.C	D.O. mgO2/l
1-SB	03-15-83	32.0	51.0	1.40	0.0	3.2	8.0	4.8	7.40	0	0.0	0.0
	03-30-83	2.5	61.0	5.56	0.2	1.2	43.0	43.2	7.60	0	8.5	12.8
	04-18-83	21.0	35.0	1.16	1.5	1.5	3.9	0.5	7.20	0	13.0	10.2
	04-27-83	12.0	26.0	3.43	2.5	2.5	3.5	2.4	7.25	0	11.0	10.9
	05-12-83	16.0	22.0	2.12	1.7	1.7	2.8	3.4	0.00	0	11.5	10.2
	05-24-83	24.0	41.0	1.75	1.5	1.5	2.4	2.4	7.60	120	15.0	9.6
	06-15-83	27.0	45.0	2.43	2.0	2.0	5.1	5.6	7.25	12000	15.0	9.4
	06-27-83	15.0	31.0	3.19	2.6	2.6	2.4	1.6	7.60	140	15.0	10.0
	07-07-83	24.0	45.0	1.83	2.5	2.5	2.7	1.6	7.50	200	13.5	10.6
	07-21-83	28.0	41.0	3.00	1.2	2.3	3.0	3.0	7.60	130	14.5	9.4
	08-04-83	23.0	74.0	4.91	2.8	3.7	3.2	3.2	7.28	198	15.0	9.1
	08-18-83	28.0	46.0	2.20	2.4	2.4	3.0	3.0	7.70	130	16.0	8.6
2-IS	03-15-83	31.0	54.0	1.08	0.0	3.7	8.0	6.0	7.40	0	0.0	0.0
	03-30-83	2.5	64.0	3.10	0.2	3.4	34.0	52.4	6.90	0	8.5	13.3
	04-18-83	24.0	38.0	1.72	2.6	3.1	3.2	0.5	7.30	0	12.0	11.2
	04-27-83	14.0	28.0	1.62	3.3	3.3	2.9	1.6	7.40	0	10.8	11.8
	05-12-83	18.0	24.0	2.33	3.1	3.1	2.5	1.4	0.00	0	11.5	11.4
	05-24-83	21.0	38.0	3.15	3.2	3.2	2.5	2.8	8.00	125	15.0	10.3
	06-15-83	34.0	74.0	6.27	1.9	2.5	6.5	11.0	7.30	26000	15.0	9.4
	06-27-83	18.0	35.0	4.04	2.7	2.7	2.8	3.4	7.90	140	14.5	10.2
	07-07-83	22.0	45.0	3.96	2.7	2.7	3.0	2.7	7.70	150	13.5	10.2
	07-21-83	26.0	40.0	3.49	2.7	1.3	2.6	3.6	7.70	110	15.0	10.2
	08-04-83	6.0	75.0	5.56	2.5	2.5	3.7	3.8	8.23	159	15.0	9.9
	08-18-83	11.0	34.0	11.10	2.8	2.0	4.2	6.3	8.40	140	16.5	9.5
3-MB-1	03-15-83	27.0	49.0	0.58	0.0	2.0	9.0	6.0	7.45	0	0.0	0.0
	03-30-83	2.5	63.0	8.32	0.2	1.5	39.0	35.2	7.30	0	8.5	12.8
	04-18-83	21.0	37.0	0.94	1.3	1.3	3.8	0.5	7.80	0	13.0	10.9
	04-27-83	14.0	27.0	2.56	1.7	1.7	3.2	2.0	7.25	0	12.0	11.4
	05-12-83	13.0	21.0	3.35	2.3	2.3	2.5	2.3	0.00	0	13.0	10.2
	05-24-83	12.0	35.0	14.60	2.0	2.0	4.0	3.4	8.40	123	18.5	10.6
	06-15-83	30.0	51.0	6.20	1.9	1.9	5.5	8.7	7.50	15000	16.0	9.4
	06-27-83	13.0	31.0	15.80	1.2	2.1	4.7	0.0	8.70	230	18.0	9.4
	07-07-83	18.0	44.0	3.22	1.2	2.0	6.2	6.9	8.10	180	16.5	9.1
	07-21-83	19.0	41.0	5.50	1.9	1.3	3.2	3.2	8.00	140	16.5	9.6
	08-04-83	8.0	51.0	17.90	1.0	1.0	7.8	15.0	7.90	172	19.7	9.6
	08-18-83	5.0	29.0	20.70	2.0	1.5	5.0	7.6	9.20	160	21.0	10.4

NOTE: "0" values denote data not obtained during sampling.

CAPITOL LAKE DATA

12-29-83

STATION	DATE	ORTHO P mgP/m3	TOTAL P mgP/m3	CHL-a mg/m3	SECCHI D m	DEPTH m	TURBIDIT NTU	SUS SOLI mg/l	pH	CONDUCT. umhos/c	TEMP. Deg.C	D.O. mgO2/l
4-MB-2	03-15-83	32.0	72.0	2.99	0.0	0.0	16.0	34.0	7.42	0	0.0	0.0
	03-30-83	2.5	64.0	6.10	0.2	1.5	40.0	43.2	7.20	0	8.5	12.8
	04-18-83	22.0	48.0	4.81	1.3	1.3	7.0	12.7	7.70	0	13.0	10.8
	04-27-83	14.0	25.0	2.45	1.3	1.3	3.5	2.0	7.50	0	12.3	11.4
	05-12-83	10.0	26.0	8.86	1.3	1.3	7.2	10.4	0.00	0	14.0	10.4
	05-24-83	20.0	42.0	16.50	1.0	1.1	8.2	11.2	8.30	118	19.0	11.4
	06-15-83	23.0	40.0	2.62	0.8	0.8	4.5	6.0	7.60	5300	16.0	9.0
	06-27-83	15.0	36.0	24.40	1.0	1.2	5.2	6.2	8.60	245	18.0	9.5
	07-07-83	21.0	62.0	10.40	1.0	1.2	7.3	10.0	8.10	200	17.0	9.1
	07-21-83	0.0	37.0	0.00	1.2	1.2	3.2	0.0	8.20	145	18.0	9.6
	08-04-83	13.0	82.0	8.47	0.6	1.3	16.2	23.0	8.20	160	19.9	7.2
	08-18-83	12.0	52.0	23.30	0.9	1.3	8.2	11.0	8.10	180	21.5	9.0
5-RR	03-15-83	28.0	52.0	0.86	0.0	4.6	8.0	4.4	7.30	0	0.0	0.0
	03-30-83	2.5	49.0	6.97	0.3	5.2	23.0	20.4	7.40	0	8.5	12.8
	04-18-83	19.0	38.0	3.65	1.7	4.5	4.4	1.4	7.80	0	14.2	10.2
	04-27-83	12.0	28.0	3.05	2.8	4.8	2.9	0.5	7.45	0	12.2	11.0
	05-12-83	9.0	20.0	10.30	2.0	5.0	2.9	4.4	0.00	0	13.0	11.0
	05-24-83	14.0	41.0	11.80	1.6	4.6	3.8	2.8	8.20	125	17.5	11.3
	06-15-83	47.0	72.0	3.59	2.1	4.3	3.8	9.2	7.45	24000	16.0	9.2
	06-27-83	10.0	27.0	15.00	1.2	4.7	3.4	4.2	8.65	420	17.0	9.7
	07-07-83	14.0	49.0	12.40	1.3	4.7	4.8	5.6	8.40	210	16.0	7.8
	07-21-83	13.0	42.0	13.70	1.4	4.2	3.6	4.6	8.40	220	17.5	9.4
	08-04-83	25.0	88.0	8.71	2.2	4.4	3.7	5.8	7.90	7012	18.9	9.2
	08-18-83	5.0	32.0	17.10	1.4	4.6	5.0	8.6	8.60	1400	21.0	10.8
6-NBT	03-15-83	30.0	54.0	4.60	0.0	0.0	8.0	4.0	7.28	0	0.0	0.0
	03-30-83	2.5	41.0	2.42	0.4	0.0	15.0	12.4	7.40	0	10.0	12.2
	04-18-83	19.0	31.0	5.49	1.9	0.0	3.8	0.5	7.85	0	14.5	14.5
	04-27-83	9.0	28.0	11.70	1.9	0.0	3.9	4.0	7.30	0	12.7	12.7
	05-12-83	2.5	16.0	19.70	1.6	0.0	3.4	2.4	0.00	0	15.0	15.0
	05-24-83	10.0	26.0	16.30	1.8	0.0	2.8	2.8	8.50	139	19.0	17.5
	06-15-83	30.0	45.0	2.87	2.2	0.0	3.2	4.4	7.80	9400	17.0	8.9
	06-27-83	9.0	26.0	13.50	1.4	0.0	3.4	4.4	8.70	460	18.5	9.7
	07-07-83	11.0	34.0	8.11	1.3	0.0	3.5	3.5	9.00	220	17.5	9.1
	07-21-83	12.0	30.0	21.70	1.3	0.0	2.8	4.2	8.40	200	19.0	9.4
	08-04-83	6.0	45.0	11.30	2.3	0.0	2.6	3.4	8.90	162	0.0	0.0
	08-18-83	2.5	21.0	15.50	1.4	0.0	3.8	9.2	9.20	200	22.0	10.6

NOTE: "0" values denote data not obtained during sampling.

12-29-83

CAPITOL LAKE DATA

STATION	DATE	ORTHO P mgP/m3	TOTAL P mgP/m3	CHL-a mg/m3	DEPTH m	TURBIDITY NTU	SUS SOLID mg/l	pH	CONDUCT. umhos/cm	TEMP. Deg.C	D.O. mgO2/l
7-NBB	03-15-83	33.0	55.0	1.11	3.0	8.0	5.4	7.18	0	0.0	0.0
	03-30-83	15.0	44.0	2.12	4.0	15.0	15.4	7.30	0	9.5	11.8
	04-18-83	20.0	31.0	3.54	4.0	4.2	0.5	0.00	0	12.3	10.4
	04-27-83	13.0	30.0	8.19	3.4	4.1	5.2	7.40	0	12.0	11.2
	05-12-83	2.5	18.0	24.90	3.5	4.4	6.0	0.00	0	13.6	10.8
	05-24-83	10.0	22.0	15.10	4.1	3.4	2.4	7.90	142	15.5	10.8
	06-15-83	63.0	90.0	5.18	3.8	2.8	16.0	7.75	34000	15.7	8.2
	06-27-83	8.0	32.0	15.00	4.2	4.1	5.2	8.65	480	15.0	9.2
	07-07-83	10.0	44.0	12.00	3.6	4.5	5.2	8.90	240	16.0	6.6
	07-21-83	12.0	31.0	13.00	3.6	3.4	9.8	8.00	220	16.5	7.0
	08-04-83	12.0	78.0	15.50	3.7	3.5	10.0	8.90	162	0.0	0.0
	08-18-83	2.5	35.0	24.40	4.0	5.4	8.8	8.70	550	18.5	7.0
8-TG	03-15-83	31.0	52.0	1.11	0.0	8.0	4.0	7.50	0	0.0	0.0
	03-30-83	2.5	49.0	3.17	0.0	29.0	22.0	7.50	0	9.0	0.0
	04-18-83	20.0	37.0	3.54	0.0	4.3	0.5	7.50	0	13.0	10.2
	04-27-83	10.0	27.0	13.20	0.0	3.1	4.4	7.70	0	0.0	0.0
	05-12-83	2.5	21.0	38.00	0.0	4.0	6.5	0.00	0	15.0	0.0
	05-24-83	13.0	33.0	21.90	0.0	2.2	3.4	8.40	140	0.0	0.0
	06-17-83	2.5	32.0	8.53	0.0	0.0	5.2	0.00	0	0.0	0.0
	06-27-83	10.0	31.0	11.00	0.0	4.0	4.4	8.50	460	17.5	9.2
	07-07-83	11.0	34.0	12.20	0.0	3.8	4.4	8.90	220	17.0	9.8
	07-21-83	15.0	28.0	13.80	0.0	3.0	4.4	8.40	205	0.0	0.0
	08-04-83	2.5	52.0	7.31	0.0	2.6	6.4	9.11	162	0.0	0.0
	08-18-83	5.0	44.0	42.60	0.0	6.6	10.0	8.20	320	18.5	9.4
9-BI	03-15-83	66.0	77.0	1.20	0.0	6.0	10.6	7.50	0	0.0	0.0
	03-30-83	62.0	76.0	7.00	0.0	4.0	13.2	0.00	0	9.5	0.0
	04-18-83	48.0	63.0	2.82	0.0	2.3	1.2	7.60	0	13.0	0.0
	04-27-83	32.0	43.0	4.87	0.0	2.6	5.6	8.00	0	12.3	11.2
	05-12-83	41.0	56.0	18.60	0.0	2.8	6.6	0.00	0	11.5	9.0
	05-24-83	69.0	96.0	6.02	0.0	2.2	5.2	8.10	39000	12.0	9.8
	06-13/15-83	62.0	94.0	5.44	0.0	1.6	26.0	7.70	44000	13.0	7.0
	06-27-83	69.0	91.0	4.87	2.0	2.1	22.0	8.10	38000	14.5	9.2
	07-07-83	56.0	74.0	4.43	0.0	2.2	7.4	8.00	32500	14.5	7.5
	07-21-83	69.0	107.0	2.21	0.0	1.8	7.2	8.00	40000	14.5	6.2
	08-04-83	43.0	68.0	6.22	0.0	2.4	5.4	8.50	18000	0.0	0.0
	08-18-83	92.0	121.0	10.80	0.0	1.8	8.2	7.60	22000	16.5	5.5

NOTE: "0" values denote data not obtained during sampling.

CAPITOL LAKE DATA

STATION	DATE	ORTHO P mgP/m3	TOTAL P mgP/m3	AMMONIA mgN/m3	NO2+NO3 mgN/m3	CHL-a mg/m3	TURBIDI NTU	SUS SOL mg/l	pH	CONDUCT umhos/	TEMP. Deg.C	D.O. mgO2/l	FLOW cfs
10-DR	03-15-83	26.0	48.0	0.0	0.0	0.71	8.0	9.0	7.50	0	0.0	0.0	739
	03-30-83	27.0	61.0	26.0	293.0	3.96	32.0	56.0	7.10	0	9.0	0.0	1669
	04-18-83	20.0	34.0	20.0	422.0	0.37	3.0	0.5	7.20	0	13.0	10.2	275
	04-27-83	14.0	26.0	25.0	162.0	3.64	2.8	3.2	7.30	0	13.0	11.3	245
	05-12-83	20.0	28.0	190.0	360.0	6.36	1.9	6.4	0.00	0	13.0	10.4	227
	05-24-83	23.0	42.0	10.0	280.0	6.03	1.5	2.2	7.70	110	16.5	10.9	179
	06-15-83	23.0	38.0	10.0	321.0	9.20	2.2	6.6	7.80	135	16.4	9.7	155
	06-27-83	18.0	38.0	23.0	316.0	5.79	2.2	8.0	7.85	100	16.0	9.9	172
	07-07-83	23.0	51.0	14.0	328.0	4.59	3.9	5.8	8.00	140	14.0	10.2	160
	07-21-83	31.0	44.0	12.0	269.0	5.90	5.0	9.8	8.10	110	17.0	9.6	182
	08-04-83	24.0	67.0	11.0	245.0	7.35	2.2	5.4	8.75	180	0.0	0.0	136
	08-18-83	30.0	70.0	18.0	310.0	4.15	3.4	14.0	7.65	110	19.0	9.2	120
11-PC	03-15-83	13.0	42.0	0.0	0.0	5.21	3.0	2.9	7.45	0	0.0	0.0	113
	03-30-83	12.0	29.0	0.0	0.0	10.20	4.0	8.4	7.50	0	10.0	11.8	120
	04-18-83	12.0	26.0	0.0	0.0	6.32	2.8	3.8	7.40	0	15.0	9.5	54
	04-27-83	7.0	25.0	0.0	0.0	18.20	4.2	3.6	7.45	0	14.5	10.6	48
	05-12-83	2.5	15.0	0.0	0.0	10.60	3.3	3.6	0.00	0	14.8	9.0	41
	05-24-83	5.0	30.0	0.0	0.0	11.30	3.0	6.2	8.00	89	17.5	9.6	30
	06-15-83	2.5	30.0	0.0	0.0	11.50	4.2	7.2	7.70	95	17.5	9.6	26
	06-27-83	14.0	28.0	0.0	0.0	8.42	3.6	5.6	7.70	100	17.5	9.7	25
	07-07-83	9.0	28.0	0.0	0.0	17.10	4.5	5.2	7.40	105	16.0	10.0	23
	07-21-83	9.0	25.0	0.0	0.0	9.59	3.8	5.4	7.50	96	19.0	9.4	23
	08-04-83	8.0	42.0	0.0	0.0	4.68	2.1	3.0	7.55	140	0.0	0.0	19
	08-18-83	20.0	34.0	0.0	0.0	1.91	1.4	0.5	7.50	100	18.0	8.2	12
12-PCD	03-15-83	13.0	35.0	0.0	0.0	5.11	3.0	12.0	7.50	0	0.0	0.0	
	03-30-83	2.5	34.0	29.0	190.0	9.60	4.0	6.4	7.10	0	10.0	11.2	
	04-18-83	15.0	63.0	64.0	129.0	8.82	3.5	0.5	7.50	0	13.0	9.0	
	04-27-83	8.0	32.0	42.0	58.0	19.70	3.4	1.2	7.20	0	13.0	9.8	
	05-12-83	6.0	61.0	105.0	63.0	26.00	4.0	4.8	0.00	0	13.0	10.8	
	05-24-83	17.0	57.0	20.0	17.0	13.90	2.8	5.4	8.60	90	17.0	9.8	
	06-15-83	2.5	32.0	24.0	124.0	9.48	3.8	5.6	7.65	740	18.2	9.3	
	06-27-83	8.0	26.0	20.0	50.0	11.40	4.2	5.2	8.10	200	17.5	8.6	
	07-07-83	13.0	37.0	14.0	13.0	5.12	5.4	5.4	8.40	160	17.0	8.1	
	07-21-83	23.0	61.0	14.0	89.0	12.10	5.2	6.2	7.80	140	19.0	8.4	
	08-04-83	45.0	95.0	8.0	5.0	4.46	4.3	7.4	8.40	181	0.0	0.0	
	08-18-83	47.0	117.0	9.0	5.0	36.00	6.4	14.0	8.80	160	22.0	9.2	

NOTE: "0" values denote data not obtained during sampling.

11-22-83

STORMWATER RUNOFF DATA

STATION	DATE	ORTHO PHOS mgP/m3	TOTAL PHOS mgP/m3	SET.SOLIDS mg/l	SUS.SOLIDS mg/l	BACTERIA TC/100ml	BACTERIA FC/100ml	BACTERIA FS/100ml	PEAK FLOW cfs
PER CRK-MR	03-08-83	9.0	33.0	0.3	16.5	2400	23	150	38.0
	03-10-83	9.0	27.0	0.1	6.0	460	23	30	33.0
	03-29-83	11.0	54.0	30.0	28.0	4600	430	93	41.0
PER DTCH-MR	03-08-83	12.0	35.0	0.1	14.0	4300	23	40	118.0
	03-10-83	8.0	34.0	0.1	4.0	24000	43	40	128.0
	03-29-83	8.0	33.0	0.1	6.8	2400	150	210	106.0
PER CRK-WB	03-08-83	11.0	35.0	0.2	20.0	930	150	90	142.0
	03-10-83	11.0	29.0	0.1	7.0	1100	75	90	162.0
	03-29-83	10.0	33.0	0.3	11.0	4600	64	240	157.0
DES PKWY	03-08-83	14.0	82.0	0.5	166.0	0	0	0	0.5
	03-08-83	2.5	195.0	0.3	78.0	9300	43	210	1.8
	03-29-83	2.5	110.0	0.8	154.0	24000	240	210	10.0
	04-23-83	2.5	145.0	0.8	73.0	0	0	0	3.7
	04-27-83	34.0	62.0	0.0	0.0	0	0	0	0.6
	05-02-83	37.0	247.0	0.4	66.0	2400	1100	2400	5.6
	05-07-83	11.0	241.0	1.2	413.0	11000	930	390	5.0
	06-10-83	64.0	72.0	1.8	263.0	4300	240	2400	0.0
(BASE FLW)	05-31-83	52.0	58.0	0.1	0.5	460	9	20	0.1
SIMONS RD	03-29-83	6.0	215.0	1.3	222.0	24000	93	150	3.0
	05-07-83	2.5	466.0	5.0	934.0	24000	240	1100	1.1
	05-07-83	25.0	730.0	6.0	954.0	24000	2400	2100	8.4
	05-09-83	12.0	143.0	0.9	120.0	24000	4300	3900	1.4
	06-10-83	100.0	459.0	2.0	341.0	110000	24000	24000	3.3
(BASE FLW)	05-23-83	14.0	26.0	0.1	3.0	460	75	210	0.5
7th SS	05-07-83	13.0	115.0	0.7	119.0	24000	240	4600	0.0
	05-07-83	14.0	162.0	0.7	160.0	24000	240	750	0.0
	05-09-83	35.0	107.0	0.1	27.0	110000	9300	3900	15.0
	05-14-83	15.0	132.0	1.2	19.4	240000	2300	460	5.2
	06-10-83	94.0	243.0	1.3	76.0	240000	9300	1400	13.6
(at C LK)	06-10-83	352.0	1,130.0	0.0	659.0	46000	2300	9300	0.0
	06-11-83	0.0	113.0	0.3	27.0	0	0	0	8.1
(BASE FLW)	05-31-83	289.0	318.0	0.1	2.8	240000	7500	460	0.1

NOTE: "0" values denote data not obtained during sampling.

BREWERY DISCHARGE DATA

12-29-83

STATION	DATE	ORTHO P mgP/m3	TOTAL P mgP/m3	AMMONIA mgN/m3	NO2+NO3 mgN/m3	COND.-C umhos/c	COND.-G umhos/c	TEMP. Deg.C	BACTERIA TC/100m	BACTERIA FC/100m	BACTERIA FS/100m	FLOW cfs
001	07-11-83	180.0	211.0	215.0	18.0	160	190	23.0	3	3	3	2.2
	07-15-83	170.0	180.0	143.0	5.0	190	210	22.0	3	3	3	1.2
	07-18-83	167.0	256.0	153.0	25.0	180	190	22.0	3	3	3	1.6
	07-22-83	197.0	169.0	51.0	23.0	205	195	23.0	0	0	0	0.7
002	08-12-83	182.0	309.0	151.0	85.0	0	0	0.0	2400	2400	2400	0.2
	08-15-83	188.0	290.0	215.0	52.0	160	160	31.0	110000	9200	93	0.3
	08-19-83	252.0	241.0	78.0	39.0	150	150	20.0	240000	240000	4300	0.6
	08-22-83	200.0	315.0	133.0	60.0	140	140	20.0	9300	430	4300	0.8
003	07-25-83	260.0	1,070.0	57.0	123.0	205	220	26.0	93	23	7	1.5
	07-29-83	255.0	950.0	56.0	5.0	200	210	30.0	930	23	3	1.7
	08-01-83	257.0	815.0	69.0	22.0	190	220	27.0	75	9	39	1.9
	08-05-83	245.0	820.0	100.0	5.0	0	0	27.0	4300	390	3	1.7
004	08-15-83	341.0	355.0	147.0	105.0	0	220	25.0	9300	22	260	1.5
	08-19-83	905.0	770.0	43.0	31.0	200	210	24.0	9300	220	93	1.4
	08-22-83	650.0	1,400.0	107.0	87.0	0	230	23.0	240000	240	75	1.0
	08-26-83	264.0	730.0	80.0	55.0	220	220	25.0	9300	93	15	1.7
UI	08-19-83	197.0	670.0	58.0	5.0	0	0	0.0	930	9	9	0.1
	08-22-83	232.0	875.0	0.0	0.0	0	180	25.0	0	0	0	0.0
	08-26-83	0.0	870.0	0.0	0.0	0	0	0.0	0	0	0	0.1

NOTE: "0" values denote data not obtained during sampling.

"Cond. C" depicts the conductivity of the composite sample.

"Cond. G" depicts the conductivity of the grab sample.

11-22-83

TUMWATER VALLEY GOLF COURSE DATA

STATION	DATE	ORTHO PHOS mgP/m3	TOTAL PHOS mgP/m3	AMMONIA mgN/m3	NO2+NO3 mgN/m3
DDO	04-20-83	17.0	30.0	30.0	1,940.0
DD1	04-20-83	15.0	26.0	36.0	1,190.0
	05-26-83	9.0	34.0	65.0	1,090.0
DDR-2	04-20-83	10.0	30.0	20.0	1,210.0
	05-26-83	11.0	26.0	67.0	630.0
POND	06-10-83	9.0	38.0	350.0	468.0
RUNOFF-1	06-10-83	196.0	404.0	290.0	408.0
	06-17-83	140.0	245.0	46.0	405.0
	07-01-83	224.0	473.0	172.0	454.0
RUNOFF-2	06-10-83	536.0	891.0	1,050.0	82.0

NOTE: DDO, DDI and DDR-2 denote sampling stations along a drainage ditch running along the west side of the golf course. The locations progress downstream with DDO at the head of the stream (near the golf course boundary) to DDI (by the club house) and DDR-2 (at the outfall to the Deschutes River.

The pond station is at the outfall from one of the golf course lakes and the runoff stations are at drainage outfalls during storm runoff periods.

DAIRIES AND CHAMBERS CREEK DATA

12-29-83

STATION	DATE	ORTHO P mgP/m3	TOTAL P mgP/m3	AMMONIA mgN/m3	NO2+NO3 mgN/m3	TURBIDI NTU	SUS SOL mg/l	pH	COND. umhos/	TEMP DEG C	D.O. mg/l	BACTERI FC/100	BACTERI FS/100	FLOW cfs
VAIL DARY	03-17-83	64.0	138.0	228.0	1,140.	8.50	18.0	6.5	0	0.0	0.0	93	0	13.2
	04-04-83	69.0	129.0	234.0	1,230.	6.00	8.7	6.7	108	10.0	0.0	1100	0	15.6
	05-10-83	94.0	164.0	785.0	1,460.	12.00	10.8	6.6	0	12.3	5.2	2400	0	13.7
	06-14-83	41.0	66.0	308.0	1,070.	4.40	2.9	6.8	140	12.3	4.6	930	23	6.4
	07-11-83	39.0	56.0	225.0	1,490.	3.80	3.4	6.9	170	12.5	4.4	930	0	4.0
	08-22-83	128.0	183.0	1,000.	700.0	6.10	3.0	6.8	150	12.0	4.4	2400	0	3.0
RIXI DARY	03-17-83	51.0	73.0	48.0	2,000.	3.20	16.0	6.9	0	0.0	0.0	93	0	9.5
	04-04-83	40.0	62.0	29.0	1,810.	2.60	7.8	6.3	101	9.5	0.0	240	0	11.2
	05-10-83	32.0	47.0	23.0	710.0	4.20	8.4	6.8	0	11.0	10.5	240	0	6.5
	06-14-83	28.0	49.0	11.0	1,560.	2.70	12.0	6.9	105	10.7	10.6	240	430	3.8
	07-11-83	31.0	30.0	21.0	2,070.	2.10	7.6	7.0	140	13.0	10.2	150	0	2.6
	08-22-83	28.0	46.0	25.0	1,350.	1.60	3.4	7.4	110	10.8	10.0	430	0	2.2
CHAMB CRK	03-16-83	2.5	39.0	49.0	340.0	1.00	3.6	6.4	0	0.0	0.0	23	43	25.4
	04-20-83	8.0	34.0	35.0	221.0	1.70	2.8	6.8	0	13.3	8.4	4	4	9.6
	05-10-83	10.0	48.0	41.0	229.0	1.40	3.8	6.8	0	12.0	7.8	75	7	4.0
	06-14-83	19.0	25.0	12.0	506.0	1.10	0.5	6.7	86	10.0	7.5	9	9	2.3
	07-11-83	18.0	21.0	10.0	830.0	0.60	1.0	6.7	100	9.5	12.2	39	43	1.1
	08-22-83	17.0	31.0	18.0	525.0	1.10	1.0	6.8	92	10.5	6.2	23	43	1.5

NOTE: "0" values denote data not obtained during sampling.

12-29-83

SWIM AREA PERFORMANCE DATA

STATION	DATE	CHL-a mg/m3	SECCHI D m	TURBIDITY NTU	ALKALINIT mgCaCO3/	pH	CONDUCT. umhos/cm	TEMP. Deg.C	D.O. mgO2/l	BACT-S FC/100ml	BACT-D FC/100ml
CAPL LK	06-27-83	10.4	1.4	3.6	43.0	8.60	450	17.5	9.4	0	0
SWM AREA	06-27-83	9.8	2.1	2.0	51.0	7.65	380	17.0	8.9	3	3
CAPL LK	07-07-83	5.8	1.4	4.4	47.0	8.90	220	17.0	9.4	0	0
SWM AREA	07-07-83	7.6	2.4	2.3	54.0	7.90	230	15.5	9.9	0	0
CAPL LK	07-21-83	23.6	1.4	2.8	48.0	8.40	205	18.0	9.2	0	0
SWM AREA	07-21-83	20.1	1.8	2.4	55.0	7.70	200	17.0	8.9	41	31
CAPL LK	08-04-83	13.8	1.7	0.0	47.0	0.00	0	0.0	0.0	0	0
SWM AREA	08-04-83	6.5	1.1	0.0	45.0	0.00	0	0.0	0.0	11	14
CAPL LK	08-18-83	18.0	1.4	0.0	53.0	9.20	200	21.5	11.8	0	0
SWM AREA	08-18-83	11.6	1.6	0.0	59.0	8.90	195	20.0	8.6	27	27

NOTE: "0" values denote data not obtained during sampling.

Bact-S depicts bacterial densities observed in shallow section samples while Bact-D depicts densities in deep water samples.

APPENDIX C

FISHERY CONSIDERATIONS

RECEIVED
JAN 12 1984
ENTRANCO ENGINEERS

FISHERY CONSIDERATIONS OF THE TIDE GATE CRATER, NUTRIENT, AND SEDIMENTATION ANALYSES

SUBMITTED TO: ENTRANCO ENGINEERS
1515 116TH AVE. N.E.
SUITE 200
BELLEVUE, WA 98004

JANUARY, 1984

FISHERIES PRODUCTION & SYSTEMS PLANNING
South Kitsap Mall, 209B, 1700 Hiway 160
Port Orchard, WA 98366

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INTRODUCTION

Entranco Engineers has recently evaluated alternative methods for controlling water quality problems associated with the tide gate operations, the tide gate crater, nutrient levels, and sedimentation within Capitol Lake. Their evaluation provided recommended alternatives for dealing with these problems. It is the purpose of this report to: 1) provide a general understanding of the fishery associated with Capitol Lake and Percival Cove, and 2) review the recommended alternatives with respect to beneficial and adverse impacts on the fishery.

The information presented in this report was derived from a series of meetings and discussions with Entranco Engineers, Washington State Department of Fisheries and Department of Game personnel, and Task Force Agency meetings. It should be understood that the issues and recommendations provided herein may change, as final engineering designs of the recommended alternatives have not been prepared. However, future engineering of problems associated with Capitol Lake should accommodate the considerations discussed in this report.

The contribution of the Deschutes/Percival Creek watershed is of extreme importance in terms of its contribution to Washington commercial and sport fisheries. The value of the chinook contribution is estimated at 3,555,000 dollars per year in Washington State alone. Natural production of coho salmon and steelhead trout increase the yearly value contributed by the Deschutes/Percival Creek watershed in excess of 5,000,000 dollars per year.

I

FISHERY USE OF CAPITOL LAKE

Washington Department of Fisheries Rearing Operations

The State of Washington Department of Fisheries (WDF) conducts rearing of juvenile fall chinook salmon in Percival Cove. It is the second largest release site in terms of numbers of fall chinook and first in terms of pounds of fall chinook in the State of Washington. Percival Cove (an advanced release pond) has been modified in an attempt to improve water flow conditions throughout the cove and to retain fish via screens at the outlet. There are two distinct groups which utilize Percival Cove, a yearling chinook program, and a 0-age chinook or zero program.

The yearling fall chinook which are approximately one year of age are transferred from George Adams and/or McKernan hatchery to Percival Cove between October 1 and November 30, depending upon water quality conditions in the cove. The yearly goals are 1.1 million released fingerlings for this group. These fish are fed until the following April when space requirements for the second batch of chinook (0's) require that these fish be released to make room.

The release procedures require that yearling chinook be forced out of Percival Cove and Capitol Lake into Budd Inlet through a bumping process. Artificial feeding is stopped and the screens at the exit of Percival Cove are removed. Capitol Lake is then drawn down over a three-day period, dropping the lake elevation approximately four feet. On the fourth day a complete drawdown takes place to the sill of the tide gate structure at which time the majority of the yearling chinook are liberated into Budd Inlet.

The second group of chinook to be reared in Percival Cove (the 0's) arrive during the latter part of April as three month old fish. They currently remain in Percival Cove until the first week in June. The release goal for this group is 7 million fish, however each year the number varies as the fish scheduled for this program are excess fish (cuts) from a number of hatcheries in the Puget Sound drainage basin. In 1983, approximately 8 million were released from Percival Cove.

In 1982 the release process for the 0's was somewhat altered based upon a request by the City of Olympia. In June the screens were pulled from Percival Cove and the 0-age chinook were allowed to migrate on their own into Capitol Lake. The actual bumping process did not take place until July at which time the residual chinook (0-age) were flushed out. WDF feels that this procedure (1982) was quite successful over the previous year's procedure of bumping, in early June, immediately after pulling the screens. WDF observations indicated that the 0-age chinook were dispersed fairly evenly throughout Capitol Lake from the tide gate south to the Olympia Brewery. The fish feed on naturally occurring organisms found in Capitol Lake. The release procedure desired for 0-age chinook from Capitol Lake into Budd Inlet is accomplished through volitional migration over the tide gate structure or fish weir. There are no known problems with juvenile chinook exiting Capitol Lake through the tide gates. Should water quality problems develop in Capitol Lake or in Budd Inlet, WDF requires the capability to draw down Capitol Lake to force fish out of the lake and/or improve water quality conditions. This capability is also required of other agencies involved in the management of Capitol Lake for maintenance or emergency situations. Lake drawdowns conducted prior to June may cause severe losses to the 0-age chinook due to their inability to tolerate saltwater conditions.

In 1984 0-age chinook plants are planned for both Percival Cove and Capitol Lake. The hatcheries programmed for supplying these fish include:

McAllister Creek Hatchery -	4 million
Coulter Creek Hatchery	1.5 million
Skykomish Hatchery	1.5 million
Total Plants	7 million

These numbers might vary somewhat from year to year as program requirements or facility production change.

In previous years, observations have been made by WDF personnel that recorded juvenile fish (salmonid) use throughout the entire lake system. These observations have been partially recorded in an EIS (Capitol Lake Restoration and Recreation Final EIS by Department of General Administration, Washington) published in 1977 (see Figure 1).

The flow curtain installed in Percival Cove is designed to direct Percival Creek water flow into the stagnant portions of Percival Cove, however it is only partially effective and large dead spots still occur. Three major tears have occurred on this curtain within the previous two years. This is partially attributable to the heavy sediment load which has deposited on the curtain. The original curtain (900' total length) is operating at 120' total length.

Between the discharge of yearling fish at the beginning of April and the planting of 0-age fish in Percival Cove in May, a 2-3 week period occurs where the cove is drained and maintenance activities take place. The maintenance activities consist of sediment removal within Percival Cove. These sediments are placed in other areas of the cove to level out bottom contours. Upon completion of cove maintenance, filling procedures take place through manipulation of tide gates and Deschutes River flows. The rate of filling is dependent upon the Deschutes River flows at this period of time. The range is from 2 to 6 days for complete filling of Capitol Lake and Percival Cove from its drawdown levels. The lake may be down from 8 to 14 days. The 1983 drawdown occurred during the first week in March as requested by the City of Olympia for maintenance work on storm drains.

Washington Department of Game Operations

Washington State Department of Game (WDG) manages migratory fish species within the Deschutes basin (which includes the Deschutes River and Percival Creek drainage) primarily on a natural propagation basis. The exceptions are rainbow trout, which are planted in Trosper and Black Lake which may revert to steelhead behavior, and a summer run steelhead fry plant that has

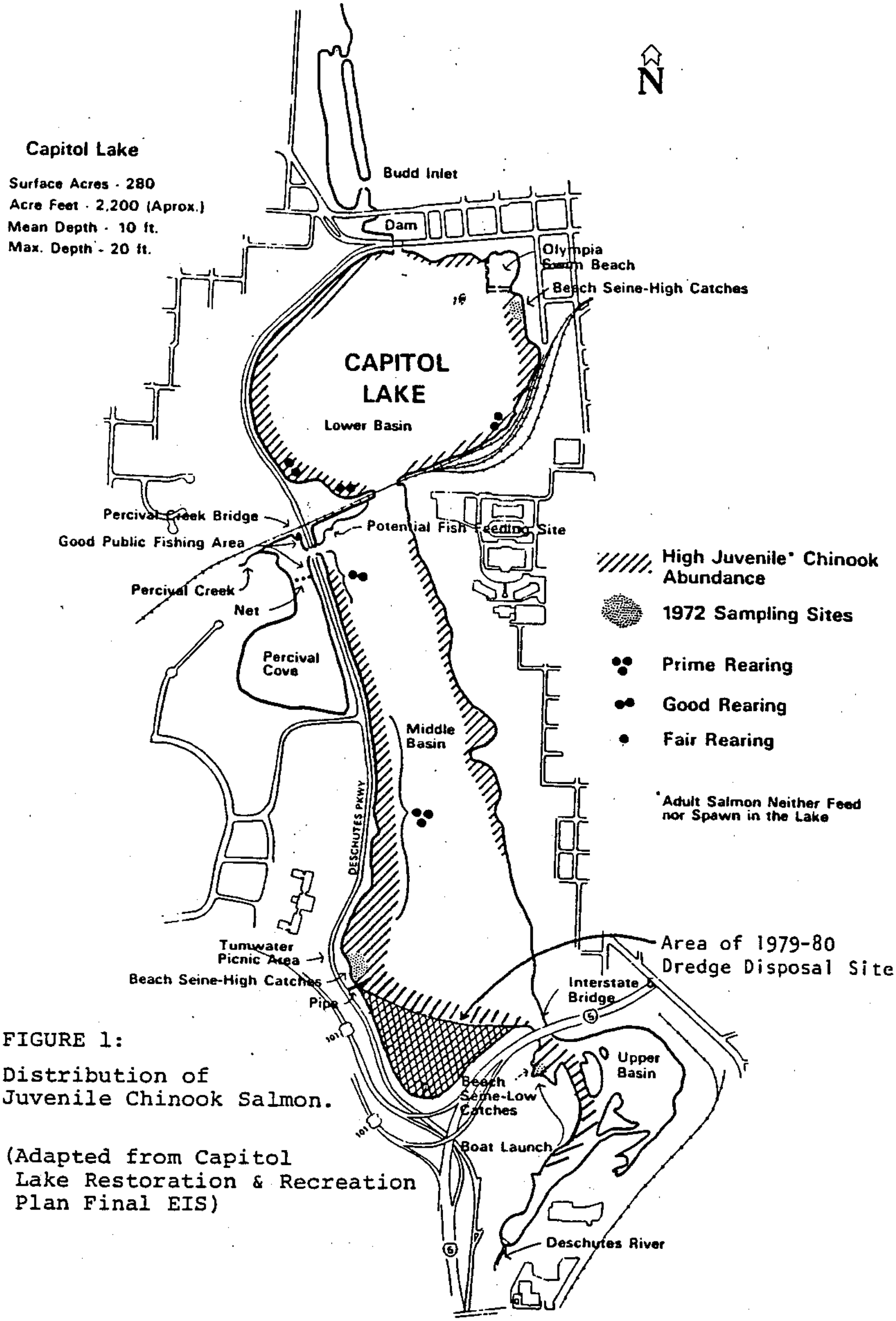

FIGURE 1:

Distribution of Juvenile Chinook Salmon.

(Adapted from Capitol Lake Restoration & Recreation Plan Final EIS) been initiated in 1982. The major migratory species managed by WDG is the winter run steelhead trout. This species has historically migrated into Percival Creek from December 15 through April 30 and into the Deschutes River from December 1 until April 30. Adult steelhead migrating up the Deschutes River pass through the Tumwater Falls ladder which is kept open after chinook spawning season is concluded. Adult steelhead moving into Percival Creek pass through a passage facility located at Percival Cove which is currently operating in the open position. On occasion this passage facility is blocked to prevent juvenile chinook escaping out of the Percival Cove rearing facility. This blockage makes the passage facility into a trap and holding area.

Outmigration of smolts from Percival Creek occurs during the month of April. These smolts average 9" to 12" in Percival Creek and 7" to 9" in the Deschutes River system. Downstream smolts moving through Percival Creek during the month of April would normally enter Percival Cove when 0-age chinook are being reared. In 1982, WDF put a fine mesh net in place to allow these smolts to pass by Percival Cove and into Capitol Lake.

In 1982, WDG began a reestablishment program for summer run steelhead which were thought to be in the system historically. Fry plants were made in the Deschutes River with runs expected 3-4 years in the future.

Sea-run cutthroat trout are another species managed by the Washington Department of Game. These fish are an important part of the sport fishery within the Deschutes River basin (including Capitol Lake). The sea-run cutthroat trout are moving through the tide gate structure on a year round basis with spawning occurring in the Deschutes River and Percival Creek. The sport fishery in Capitol Lake is closed during the month of April to protect the downstream steelhead migrants.

Adult Returns to Capitol Lake

All migratory adult trout and salmon entering the Deschutes basin pass through the Capitol Lake tide gate structure located under the 5th Avenue W. bridge in Olympia. The migratory period for these fish are as follows:

Fall chinook salmon	-	Sept. 1 - Nov. 15
Coho salmon	-	Sept. 15 - Dec. 31
Winter run steelhead trout	-	Dec. 1 - April 30
Summer run steelhead trout	-	June 1 - Aug. 31
Sea-run cutthroat trout	-	Year-round

When the fish ladder, which is adjacent to the tide gates, is operating, 50-60% of all adult fish entering Capitol Lake bypass the fish ladder and enter through the tide gate system. The other 40-50% enter via the fish ladder through a V trap into a holding box or pen. This holding pen was installed in 1982 by WDF as an accommodation to the Indian fishery and WDF management biologists. The trap provides the capability to give male chinook adults to the Squaxin Indian Tribe and to enumerate the run for determination of fish quantities passing through the tide gate. The ability to provide excess males to the Squaxin Indian Tribe (which has fishing rights in Budd Inlet) provides additional protection for females which may have been caught in the gill net fishery and severely stressed during handling as they were removed. The fish ladder is operated from September 1 through December when 90% or better of the adult chinook are expected to pass through Capitol Lake. The associated trap at the end of the fish ladder is temporary in nature and is installed only for the adult chinook run.

After the chinook enter the tide gate trap or Capitol Lake, there may be one to two months time differential before these fish are ripe enough to spawn. These fish migrate to the Deschutes River trapping facilities located at Tumwater Falls or to Percival Cove. Recent tag experiments indicate that approximately 65% ± 15% of the adults migrate to Percival

Cove and the remaining 35% ± 15% migrate to the Tumwater Falls facilities. In 1982 adult chinook were not intentionally released upstream in Percival Creek or the Deschutes River. Adult coho and steelhead were passed up Percival Creek for natural spawning.

Adult coho returns at the Tumwater Falls site are passed up river with the exception of tagged fish captured for management (WDF) purposes. Adult coho returns for the last six years are as follows:

1977	6800
1978	2300*
1979	7000
1980	3000
1981	4300
1982	8900

WDF observes good survival of this stock with excellent contribution to all fisheries.

The fish way gate which can influence the lake elevation and is located at the upper end of the fish ladder is set at its bottom configuation of -5 (City of Olympia datum) to allow for attraction and passage water during the September 1 to November 15 period. The remainder of the year it is put in the upper position of 0.

In 1981, 14 million eggs were taken from returning fall chinook into the Deschutes River system. In 1982, 8.2 million eggs were taken. The adult fish may be dry spawned at the Percival Cove trap site or a beach seine may be pulled to collect milling adults for transfer to the Tumwater Falls adult holding facility. The green eggs and sperm are then taken to Adams, McKernan or Minter Creek hatcheries for incubation until the eyed stage. At the eyed stage a percentage of these eggs may be distributed to Simpson, Skagit, Mcallister, Minter Creek, and/or Hood Canal hatcheries for additional incubation and fry rearing.

II
TIDE GATE CRATER ALTERNATIVES

Restoration Alternatives

The preliminary analysis of the Tide Gate Crater development and the potential solutions for resolving associated water quality problems with the crater have been detailed for the Department of General Administration by Entranco Engineers. These alternatives were reviewed for their ability to resolve the problem of anoxic conditions created within the hole, cost effectiveness, yearly maintenance considerations, and the impacts to the fishery. This analysis led to the selection of a recommended alternative - saltwater withdrawal by siphoning - over the other alternatives. It has been further recommended that this alternative be accompanied by certain management practices associated with operation and maintenance of the tide gate structure.

The State of Washington Department of Fisheries (WDF) preferred the alternative of filling the hole as the most acceptable solution, however, recognizing that the cost of such a solution may be prohibitive, they recommended saltwater withdrawal by siphoning as the second most viable solution of the seven alternatives presented. It is WDF's position that the other alternatives presented would create an estuarine environment within Capitol Lake which may not be suitable for salmonid rearing operations.

Recommended Alternatives

The recommended alternative for tide gate crater restoration is saltwater withdrawal by siphoning as determined by Entranco Engineers (Entranco Engineers, 1983). This method involves the installation of a 12" diameter line which would pull water from the bottom of the crater and discharge it into Budd Inlet just north of the tide gate structure.

There are a number of issues associated with this method which need to be taken into consideration during future engineering and implementation of this alternative. These issues are as follows:

1) It may be necessary to install an intake screen on the intake end of the pipe system if auxiliary pumping should be incorporated in the future. This screen should be designed so that the approach velocity shall not exceed .5 feet per second. This design criteria is with the assumption that backflush capabilities be provided for the screen apparatus. Because of the distinct possibility that fry may be present in Capitol Lake, the screen opening should not exceed 1/8" in the narrow direction. Johnson well screen is an acceptable manufacturer for such devices as indicated by the Washington Department of Fisheries.

2) There is concern that the screen may prematurely plug up causing higher velocities than originally designed for. This plugging may be caused by heavy filamentous algae production observed in Capitol Lake and the high amount of detritus material moving into the lake. Should this be the case, the pumping system might require a mechanism whereby automatic flushing be conducted either on a frequent basis, or as requested by a sensory system.

3) The movable fish weir should pose no problem to migratory chinook if properly designed and operated. Adult steelhead generally move during higher tidal cycles. If the fish weir cuts off river flow at a +16.0' tide or higher, no problems are anticipated.

4) Reductions in salinity intrusion into Capitol Lake should significantly increase chironomid populations. Studies (Engstrom-Heg, 1968) discuss mortalities associated with such saltwater intrusions. Whenever feasible, lake refilling should be conducted using freshwater only. It is recognized that this recommendation may create conflicts with other management objectives for Capitol Lake such as weed control and freshwater flushing of Budd Inlet.

Management Considerations for Tide Gate Operations

1) It is desirable to have the ability to fill Capitol Lake as rapidly as possible. WDF needs to open the tide gates for either bumping processes or rapid flushing at any time of the year. This ability is necessary to resolve water quality problems that may develop in Budd Inlet or as part of the rearing operations for Percival Cove and/or Capitol Lake.

2) Any changes to the fish weir system should not impact the ability to install the temporary fish trap which was used successfully in 1983.

3) For design purposes, assume that the fish weir is in operation on a year-round basis. WDG has indicated their desire to see the fish weir in operation year-round. However, to prevent saltwater intrusion during the high winter tides, it has been the practice to cease fish weir operations after December. It may be possible to automate the fish weir such that seawater intrusions are prevented and year-round passage is available.

4) A "trash rack" provision needs to be incorporated in front of the fish weir to protect the movable weir and the system during high flow runoff.

5) Coordination between all agencies prior to scheduled and/or emergency drawdowns of Capitol Lake should take place.

III

SEDIMENTATION AND NUTRIENT ANALYSIS

The sedimentation analysis conducted by Entranco Engineers concluded that the most effective method for controlling sedimentation in Capitol Lake would be to establish a comprehensive lake dredging program whereby the entire lake basin (including the sediment traps) is dredged on a routine basis. As the dredging plan is developed, certain considerations must be met in order to protect the health of juvenile chinook residing in the lake. As mentioned earlier (see Figure 1) the lake is utilized fairly uniformly, especially along the littoral areas, for feeding by juvenile salmon. With WDF's program changes to include the lake for natural rearing of 0-age chinook, it is imperative that adequate consideration be given to protection of their food base.

The diet of juvenile chinook salmon was documented by Robert Engstrom-Heg (Engstrom-Heg, 1968) as consisting primarily (85%) of the pupae of Chironomus tentans with chironomid larvae and adults comprising almost 95% of the total weight of stomach contents.

To reduce impacts of dredging on fish rearing programs relying upon natural food production, the following recommendations are presented:

1) Determine those areas of the lake which contain higher populations of chironomids through dive surveys/grab samples, etc. Develop a dredging plan which protects the more productive areas to the extent possible.

2) Determine total food requirements for rearing juvenile chinook salmon. Estimate total natural food production within Capitol Lake. Model the dredging plan to protect the appropriate

percentage of bottom area to allow sufficient food base.

3) Avoid dredging of the littoral areas where feeding has been observed in heavy concentrations and where insect production is expected to be highest.

4) Timing of dredging should occur during periods of least impact to the total fishery. As anadromous fish are present year-round, the winter period from December through February has the least amount of "traffic" with the greatest amount of river water for flushing available and is associated with naturally occurring high turbidity. Steelhead (winter run) are migrating through the system during this period. Dredging may affect any winter sport fishery in the lake and the ability for these fish to pass through the Capitol Lake system. WDG has suggested conducting dredging on a four day per week basis and extending the total period of dredging through March. The final dredging plan should address impacts to the winter steelhead run and, if possible, accommodate this run via such methods as siltation curtains, timing, etc.

5) Monitoring of chironomid recolonization should be conducted during the two year period between dredging programs.

The nutrient analyisis conducted by Entranco Engineers concluded that the limiting nutrient was phosphorus which was projected from several controllable sources including Percival Cove. The method of control recommended for Percival Cove is an aluminum sulfate treatment. However, the effects of such a treatment on juvenile salmonids, especially with high rearing densities, is unknown. Such a treatment is not advised unless further studies on the effects of such a treatment would be conducted. Dredging of Percival Cove may reduce phosphorus content while improving fish rearing capabilities for WDF. This alternative coupled with an improved water distribution system for the cove would greatly enhance fish rearing operations.

The proposed dredging program may reduce or preclude the need for saltwater flushing as a method of weed control. If dredging deepens the lake to a level which prohibits adequate light penetration, then weed growth would be restricted. If this occurs, the reduced saltwater intrusions will enhance chironomid populations in the north basin which should contribute to the fishery.

It has been proposed that the cost of additional fishery analyses, as recommended above, be covered under the engineering and/or environmental impact assessment elements of the Phase II program as budgeted in the Entranco report.

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