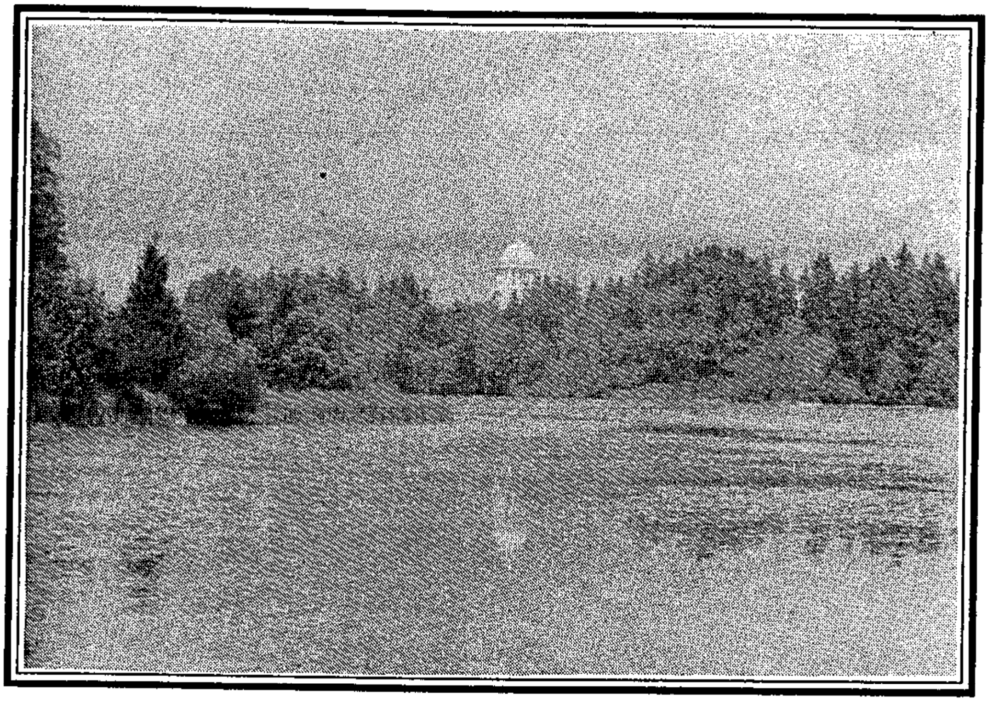
Washington State
Department of General Administration

WETLAND DEVELOPMENT FEASIBILITY ANALYSIS



C A P I T O L   L A K E

NOVEMBER 1990

ENTRANCO ENGINEERS, INC.

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CAPITOL LAKE

WETLAND DEVELOPMENT
FEASIBILITY ANALYSIS

Prepared for

Department of General Administration
State of Washington

Prepared by

ENTRANCO ENGINEERS, INC.

in association with

Jones & Stokes Associates
B-twelve Associates
Terra Associates, Inc.

November 1990

EXECUTIVE SUMMARY

The 1989 Legislature directed the State of Washington Department of General Administration to evaluate the feasibility of creating wetlands in the south and middle basins of Capitol Lake as a possible means of (1) improving water quality in the north basin, (2) deferring costly maintenance dredging, and (3) enhancing fish and wildlife habitat. The feasibility of three alternative wetland development concepts is evaluated in this report:

- River Delta Freshwater Wetlands
- Diked Freshwater Wetlands
- Estuary Salt-Tolerant Wetlands

Each of these concepts is described briefly below and key advantages and disadvantages are summarized.

CONCEPT I - RIVER DELTA FRESHWATER WETLANDS

Under this concept, maintenance dredging would be postponed. This would allow the south and middle basins to gradually fill over an estimated 60-year time frame. Sediment deposits would fill the lake progressively from south to north in the same manner that river deltas are formed. The south and middle basins would gradually change into a broad flat freshwater wetland with the Deschutes River meandering through it. Freshwater plant communities would be protected from saltwater flushing following lake drawdown by construction of a submerged saltwater control weir (underwater dam) located just downstream of the railroad trestle that separates the north and middle basins.

Advantages - River Delta Freshwater Wetlands

- Estimated maintenance dredging cost savings of approximately $20 million over the 60-year period.
- Enhanced wetland wildlife habitat for waterfowl, shorebirds, and other birds and mammals.
- Ultimate potential for enhanced recreational opportunities with trails, observation platforms and educational displays.
- Opportunity to plant and cultivate wetland plants suitable for traditional native American cultural uses.

Disadvantages - River Delta Freshwater Wetlands

- Possibility of increased flooding in downtown Olympia and in Tumwater Historic Park - could be mitigated by dike construction and associated improvements along the west shore of the south basin and the east shore of the north basin. Construction of flood control facilities are likely to have adverse impacts on the

Heritage Park Plan, Olympia's Capitol Park Renovation Project, and Tumwater Historic Park. Mitigation could cost several million dollars.

- Aesthetic impacts associated with loss of middle basin as a reflecting pool for the Capitol building.
- Added capital ($1.4 million) and additional annual maintenance costs of the saltwater control weir..
- Some water quality degradation in the north basin - could be offset by improved pollution control in the lake and watershed. Costs associated with improved pollution control would be covered by other existing funding programs.
- Maintenance dredging and associated costs - resumed in 60 years upon completion of wetland filling. This would include the cost of excavation construction of the middle basin sediment trap and could involve construction of a new sediment trap in the north basin. Fine sediment would be transported to Budd Inlet.
- Additional efforts required for pest control of undesirable plants, insects, and waterfowl disease.
- Environmental (SEPA) and permit reviews (12 months to 3 year process) and additional environmental and engineering studies - required for approval and implementation.
- Additional annual maintenance costs for new trails and flood control facilities.

CONCEPT II - DIKED FRESHWATER WETLANDS

Under this concept maintenance dredging would continue. Dredge spoils would be used to construct dikes and topographic features within diked areas that would support desirable wetland communities (primarily emergent and shallow pond communities). The ultimate development time is estimated at 60 years. Water circulation within the wetland areas would be controlled to provide some water quality treatment by the wetlands. A water diversion dam would have to be constructed in the vicinity of the I-5 bridge. Ultimately, about 80 percent of the middle basin would be filled with diked wetland "cells". A main river channel would be retained down the center of the middle basin to carry flood flows. In view of limited cost savings, absence of water quality benefits, adverse impacts to existing wetlands, and doubtful permit approval, this concept has been deemed non-feasible.

Advantages - Diked Freshwater Wetlands

- Estimated maintenance dredging cost savings of approximately $7 million over the 60 year period (disposal of dredge spoils in-lake would preclude remote disposal costs).
- Enhanced wetland wildlife habitat for waterfowl, shorebirds, and other birds and mammals.
- Ultimate potential for enhanced recreational opportunities with trails, observation platforms and educational displays.
- Opportunity to plant and cultivate wetland plants suitable for traditional native American cultural uses.

Disadvantages - Diked Freshwater Wetlands

- As initially envisioned, this concept was developed with the prospect of maximizing water quality treatment by wetlands. However, the ultimate wetland surface area would be too small to provide adequate treatment for Deschutes River flows. Therefore, this concept would not produce significant water quality benefits.
- Adverse impacts to existing wetlands with diking and filling.
- Costs associated with construction of a diversion dam, fish ladder and associated pipe works - could cost several million dollars. These facilities may also have adverse aesthetic impacts.
- Possibility of increased flooding in downtown Olympia and in Tumwater Historic Park - could be mitigated by dike construction and associated improvements. Along the west shore of the south basin and the east shore of the north basin, construction of flood control facilities are likely to have adverse impacts on the Heritage Park Plan, Olympia's Capitol Park Renovation Project, and Tumwater Historic Park. Mitigation costs could be several million dollars.
- Aesthetic impacts associated with loss of middle basin as reflecting pool.
- Some water quality degradation in north basin - could be offset by improved pollution control in lake and watershed. Costs associated with improved pollution control would be covered by other existing funding programs.
- Maintenance dredging and associated costs - would be increased back to present levels in 60 years upon completion of dike construction. This would include the cost of excavation construction of the sediment trap in the middle basin and could involve construction of a new sediment trap in the north basin. Fine sediment would be transported to Budd Inlet.
- Additional efforts required for pest control of undesirable plants, insects, and waterfowl disease.
- Environmental (SEPA) and permit reviews (12-month to 3-year process) and additional environmental and engineering studies - required for approval and implementation. Obtaining Corps 404 and Shoreline permits for this concept is considered unlikely.
- Additional annual maintenance costs for trails and flood control facilities.

CONCEPT III - ESTUARY SALT-TOLERANT WETLANDS

Under this concept, maintenance dredging would be postponed. This would allow the south and middle basins to gradually fill with river sediment over an estimated 60-year time frame. The tide gates would be modified to permit saltwater into the reservoir with every tidal cycle. The reservoir water levels would be managed to limit water level fluctuations to three feet. This would minimize aesthetic and shoreline erosion impacts. This concept, using saltwater flushing, would change the freshwater system into an estuary. Saltwater tolerant plants would become established.

Advantages - Estuary Salt-Tolerant Wetlands

- Estimated maintenance dredging cost savings of approximately $20 million over the 60-year period.
- Significant water clarity improvements in the north basin due to the influence of saltwater flushing in reducing algae growth.
- Reduced flood impact potential to Tumwater Historical Park in the south basin.
- Enhanced wetland wildlife habitat for waterfowl, shorebirds, and other birds and mammals.
- Ultimate potential for enhanced recreational opportunities with trails, observation platforms and educational displays.

Disadvantages - Estuary Salt-Tolerant Wetlands

- Possibility of increased flooding in downtown Olympia - could be mitigated by dike construction and associated improvements along the west shore of the south basin and the east shore of the north basin. Construction of flood control facilities are likely to have adverse impacts on the Heritage Park Plan, Olympia's Capitol Park Renovation Project, and Tumwater Historic Park. Mitigation costs could be several million dollars.
- Aesthetic impacts associated with ultimate loss of middle basin as reflecting pool for the Capitol building.
- Potential adverse impacts to 10 million salmon fingerlings which now rear in the lake due to premature release of fish into Puget Sound.
- Colder marine water would discourage swimming use.
- Costs associated with modifications to tide gate controls.
- Costs associated with mitigation of tidal shoreline erosion impacts in the north and middle basins could be in the $1-2 million range.
- Capital costs estimated at $20.000 for saltwater control improvements to the outlet structure for Percival Cove—needed to protect fish rearing operations.
- Aesthetic and potential public safety impacts of exposure of 20-30 acres of mudflats during low tide.
- Aesthetic impacts of low-tide rip-rap exposure on Heritage Park Plan, Capitol Lake Park Renovation, and Tumwater Historic Park.
- Loss of in-lake freshwater fishing.
- Maintenance dredging and associated costs - resumed in 60 years upon completion of wetland filling. This would include the cost of excavation/construction of the sediment trap in the middle basin and could involve construction of a new sediment trap in the north basin. Fine sediment would be transferred to Budd Inlet.
- Environmental (SEPA) and permit reviews (12-month to 3-year process) and additional environmental and engineering studies - required for approval and implementation.

ACKNOWLEDGEMENTS

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The development of study objectives, scope of work and reviews of draft reports was greatly enhanced by the cooperative efforts of the members of the Wetland Technical Advisory Committee:

Nick Cockrell	Washington Department of General Administration
Bob Arndt	Washington Department of General Administration
Randy Acker	House of Representatives
Bill Robinson	House of Representatives
Allen Moore	Washington Department of Ecology
Brian Benson	Washington Department of Fisheries
Jeff Skriletz	Washington Department of Wildlife
Jeff Dickison	Squaxin Island Tribe
Gregg Grunenfelder	Thurston County
Rick Nelson	Thurston County Conservation District
Leonard Smith	City of Tumwater
Joanne Richter	City of Olympia

The consultant team for the study was comprised of the following firms and individuals:

Entranco Engineers, Inc.
- Dale Anderson
- Ralph Nelson
- Jory Oppenheimer
- David Morency
- Gretchen Johnson
- Stacie Martella

Jones & Stokes Associates, Inc.
- Jonathan Ives
- Glen Grette
- Dyanne Sheldon

Layton & Sell
- Jack Sell

Terra Associates
- Bill Bailey

B-Twelve Associates, Inc.
- Susan Burgemeister
- Todd Tressler

The following special advisors also provided assistance with technical analyses and reviews of draft reports:

Richard Horner, Ph.D.	University of Washington
Alyn Duxbury, Ph.D.	University of Washington
Steven Chapra, Ph.D.	University of Colorado
John Orsborn, Ph.D., P.E.	Washington State University

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FEASIBILITY ANALYSIS OVERVIEW

HISTORY OF LAKE FORMATION

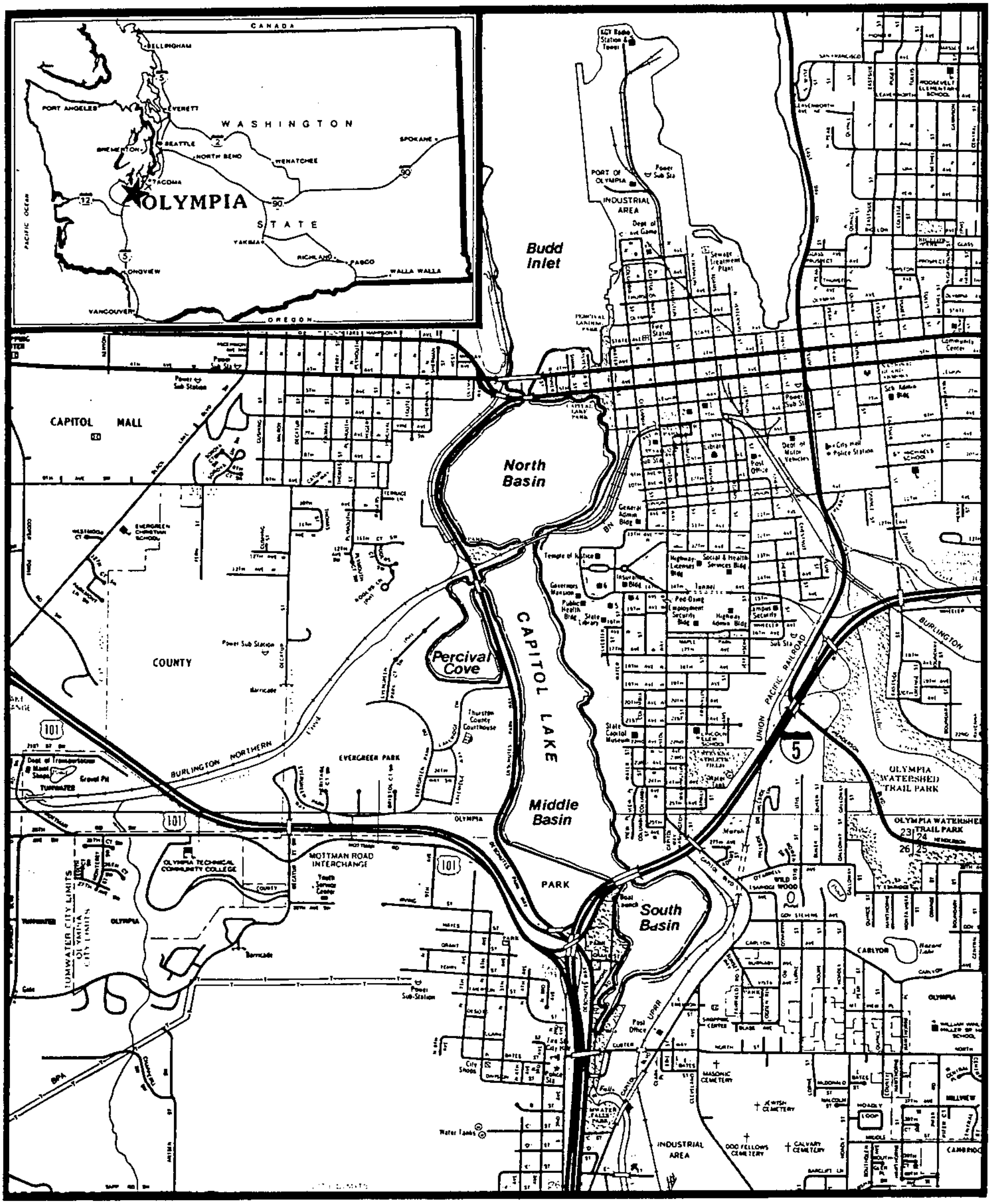
Capitol Lake was originally conceived by architects Wilder and White in 1911 as a part of their proposed Capitol Campus plan. In the late 1930s the state legislature took action to implement this plan and initiated the Deschutes Basin Project. The Deschutes Basin Project involved the purchase of tidelands, the construction of a dam to create a lake reflecting pool for the Capitol Campus, and the construction the Deschutes Parkway and public access facilities. Additional funding was authorized by the legislature in 1947 to complete the project, and Capitol Lake was ultimately created in 1951 with the construction of the dam/tide gate structure under the 5th Avenue bridge. (Refer to figure 1 for project vicinity.)

The completion of the dam and creation of Capitol Lake provided a number of benefits to the State of Washington and the residents of Olympia, Tumwater and Thurston County. These benefits included:

- Elimination of unsightly tideflats and associated odors;
- A Capitol Campus reflecting pool and improved aesthetics;
- Public access and recreational opportunities such as swimming, boating, and fishing;
- Improved flood control for the City of Olympia; and
- New fish rearing facilities in Percival Cove.

RECENT LAKE MANAGEMENT HISTORY

Although the creation of Capitol Lake provided these various benefits, this newly created resource was not without its problems. In the late 1960s and early 1970s a variety of lake management problems were recognized by the State of Washington Department of General Administration. These problems included the shoaling of the south basin as a result of heavy sediment loading to the lake from the Deschutes River, and the development of algae blooms and extensive beds of aquatic weeds. These and other problems, including periodically high bacterial concentrations and periodic fish kills, led to a series of water quality studies and lake management programs beginning in the early 1970s and evolving through the 1980s. As a result of various scientific and engineering studies, several lake management practices have been implemented. They are summarized in the following pages.



NORTH

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Figure 1

PROJECT LOCATION

Eutrophication Control

Washington State University (1975) recommended that the tide gates be opened periodically (three times) during summer months to permit saltwater inflow to the lake as a means of limiting the growth of freshwater weeds and algae. Lake "bumping" (lowering and refilling with saltwater) also facilitated the release of fish from the Percival Cove rearing facilities. This dual purpose practice was followed with apparent success until about 1985 when the Washington State Department of Fisheries (WDF) discontinued bumping for fish management purposes. Since 1985, lake drawdown has been practiced only occasionally, as needed in conjunction with construction, maintenance, or study activities. There appears to be a need to reconsider the use of bumping for water quality benefits. Bumping would probably have prevented the severe algae blooms observed in the lake in 1989 (C. Ikerd, pers. comm.).

Entranco Engineers (1984) recommended that nutrient (phosphorus) loading sources, including brewery discharges and runoff from dairy operations, be controlled as a means of reducing algae blooms in the lake. It is not certain whether either of these recommendations have been implemented to date.

Sediment Control

Washington State University (1975) also recommended the construction of sediment traps in the south (upper) and upper middle basins. The traps were constructed in 1978 by the removal of 200,000 cubic yards of sediment from the south and middle basins. In addition, a dredge spoil disposal area was created by diking a portion of the southwest corner of the middle basin. The dredge spoil disposal area and associated improvements is now known as the Capitol Lake Interpretive Center. About 57,000 cubic yards of accumulated sediments were dredged from the middle basin trap in 1985 at a cost of $328,900; the south basin trap has not been dredged since it has not trapped sediment as expected (Entranco Engineers 1984).

In addition to the relatively coarse sand and gravel materials that are accumulating in the south and upper middle basins, Entranco Engineers (1984) discovered that fine sediments (silts and clays) are accumulating in the lower (northern) reaches of the middle basin and in the north basin at rates of approximately one foot every 10 to 12 years. Based on this information, Entranco Engineers (1984) recommended that a long term maintenance dredging program be implemented, involving about 50,000 cubic yards per year at an estimated annual cost of $600,000 (1984 dollars). This recommendation has yet to be fully implemented.

Bacterial Control

Bacterial levels in Capitol Lake have fluctuated significantly over time. CH_2M Hill (1978) reported fecal coliform concentrations exceeding the lake class standard of 100 organisms per 100 milliliters at a number of sampling locations over a 12 month monitoring period. They identified the Deschutes River, waterfowl, and various shoreline pipe discharges as potential sources of bacteria.

However, subsequent monitoring by the Washington State Department of Ecology (WDOE) (Singleton 1982) revealed that fecal coliform concentrations were generally below the lake class standard. There are unconfirmed reports that a failing sanitary lift station in Tumwater was responsible for high fecal coliform levels at the time of the

CH_2M Hill study. Assuming that the lift station was repaired prior to the WDOE study, this would explain the lower fecal coliform levels reported by the WDOE.

Entranco Engineers (1984) identified dairy runoff, brewery discharges (one of five outfall pipes) and the City of Olympia 7th Avenue storm drain as sources of fecal coliform bacteria. Sanitary cross connections to the 7th Avenue storm drain were reportedly corrected by the City of Olympia in the mid-1980s; however, no measures have been taken to reduce bacterial loadings from the brewery or dairy operations.

Despite the WDOE findings of lower in-lake bacterial levels and the corrective measures identified above, in 1985 the City of Olympia measured consistent violations of the fecal coliform standard in the swimming area along the eastern shore of the north basin. As a result, the City closed the swimming beach to further use. It has not been reopened since.

Based on recent history, there is some question as to the need for additional efforts to control bacterial levels in the lake.

Dissolved Oxygen Control

In 1982 the WDOE discovered that the process of lake "bumping" had resulted in the formation of a deep "crater" on the lake side of the tide gate and that this crater was linked to water quality and fish kill problems in Budd Inlet. The crater allowed stagnant water conditions to persist, with associated loss of dissolved oxygen and formation of toxic hydrogen sulfide gas. Under certain flow and tidal cycle conditions this toxic water was released to Budd Inlet and resulted in fish kills.

In 1983 Entranco Engineers, working cooperatively with the WDF, developed a siphon concept for providing enhanced water circulation through the crater, thus preventing stagnant conditions responsible for fish kills. The siphon was constructed in 1986 and has operated successfully ever since. No other dissolved oxygen problems are known at this time and no other control measures are needed.

Ongoing Lake Management

In 1986 representatives of the City of Olympia, City of Tumwater, Thurston County, the Governor's Office, and Department of General Administration organized the Capitol Lake Restoration (CLR) Committee. Their purpose was to gather and reevaluate existing information on Capitol Lake and to develop a management plan aimed at the preservation and enhancement of the resource. The Committee produced the Capitol Lake Restoration Committee Report and Proposed Action Plan in 1989. Key recommendations contained in the Plan are summarized below:

- Create a Capitol Lake Management/Action Committee.
- Investigate methods to improve lake circulation.
- Perform regular maintenance dredging .
- Develop shoreline vegetation control regulations.
- Establish a water quality monitoring program.
- Implement stormwater quality controls .
- Implement stormwater maintenance programs.
- Pursue enforcement actions against illegal discharges.
- Monitor brewery discharges.

- Include phosphorus control in brewery permits.
- Reduce nutrient loading from fish rearing operations.
- Monitor pipe outfalls and correct as needed.
- Participate in the Timber/Fish/Wildlife process.
- Map logging in the watershed and recommend limits.
- Focus Conservation District efforts in the watershed.
- Focus stream corridor conservation team on the river.
- Correct streambank erosion problems along the river.
- Study impacts of Black Lake on Percival Creek/Lake.
- Study impacts of Percival Creek on Percival Cove/Lake.
- Develop a preservation strategy for wetlands .
- Follow the Puget Sound Water Quality Planning process.
- Evaluate the feasibility of wetland creation.

On-Going Watershed Management

Thurston County is planning to complete a watershed plan for the Deschutes River under the provision of WAC 400-12, "Local Planning and Management of Nonpoint Source Pollution". Although the formal planning process has not yet been initiated, the County has initiated the following actions:

- The County has requested the Puget Sound Cooperative River Basin Team (PSCRBT) to (1) conduct an inventory of forestry, rural, and agricultural land uses in the watershed; (2) identify potential nonpoint sources of pollution associated with each land use category; and (3) recommend potential best management practices (BMPs) for nonpoint pollution control.

- The County also has obtained a grant from the WDOE to perform 18 months of baseline water quality monitoring in the Deschutes River watershed in an effort to better define nonpoint source water quality problems. Once the monitoring effort has been completed, the County plans to initiate the WAC 400-12 watershed planning process.

In addition to these efforts by Thurston County, the Squaxin Island Tribe is involved in studies aimed at identifying the location, causes, impacts, and potential mitigation measures for mass wasting (landslide) sites in the watershed.

PURPOSE OF THIS STUDY

During the process of developing the Capitol Lake Restoration Committee Report and Proposed Action Plan (1989), the CLR Committee was presented with a proposal suggesting the development of wetlands in the middle basin of Capitol Lake. This proposal was submitted by Mr. Steve Shanewise, a private consultant. Mr. Shanewise argued that the maintenance dredging program was very costly and that, as an alternative to this approach, the middle basin should be allowed to fill naturally with sediment and to become a freshwater wetland. According to the proposal, this management approach would have the following benefits:

- Considerable cost savings ($600,000 per year) would be realized with the interruption of maintenance dredging operations until some time in the distant future.

- Wetland water quality treatment provided by the middle basin would benefit swimming and other contact recreation in the north basin.

- Existing viable fisheries operations would be maintained.

- The north basin would be retained as an open water recreational resource for such activities as boating, swimming and visual aesthetics. The reflecting pool function of the lake would be retained in the north basin.

- The wetland formed in the middle basin would represent a valuable new recreational and wildlife habitat feature and could be integrated into existing trail and park/open space features.

Since the CLR Committee did not have adequate information or expertise to evaluate the Shanewise proposal, the Committee recommended that the feasibility of wetland creation be assessed at some point in the future. In 1989 the state legislature allocated funds specifically for this purpose and a team of consultants, led by Entranco Engineers, Inc., was selected by the Department of General Administration to perform this study and evaluate wetland development feasibility in Capitol Lake.

In the process of considering the feasibility of wetland development in Capitol Lake, the Entranco study team and the Wetland Technical Advisory Committee (a committee comprised of city, county and state representatives organized to advise the Department of General Administration with respect to the course of the study) decided that the feasibility analysis should not necessarily be limited to the "Shanewise" concept, but should also include other potentially viable concepts. As the study progressed, three alternative wetland concepts emerged:

- Concept I - River Delta Freshwater Wetlands
- Concept II - Diked Freshwater Wetlands
- Concept III - Estuary Salt-tolerant Wetlands

Each of these concepts is briefly described in the following section.

In order to be considered viable a given wetland concept should meet the following criteria:

- It should reduce or temporarily defer maintenance dredging costs.
- It should improve water quality in the north basin or at least should not result in significant adverse impacts.
- It should not adversely impact fish rearing or passage in Capitol Lake or Percival Cove or should mitigate such impacts.
- It should not result in any other significant adverse impacts or should include means of mitigation.

It should be noted that in addition to the wetland feasibility analysis, the consultant contract also included an evaluation of nonpoint source control measures for the Deschutes River/Capitol Lake Watershed, and an evaluation of erosion control measures for the north basin of Capitol Lake. The findings and recommendations of these other study efforts are contained in separate, companion documents.

ALTERNATIVE WETLAND CONCEPTS EVALUATED

Concept I - River Delta Freshwater Wetlands

This concept has been defined to a considerable extent in the preceding discussion. Under this concept, maintenance dredging would be discontinued and the middle basin would be allowed to fill with sediment under the influence of natural processes. Sediment accumulation in the middle basin would be similar to river delta deposits, with the basin filling progressively from south to north. As the basin filled with sediment, increasing portions of the basin would become sufficiently shallow to support freshwater emergent wetland vegetation (refer to figures 2 and 3). This plan would require a control structure or underwater dam between the north and middle basins as a means of precluding adverse saltwater impacts on middle basin freshwater wetlands during refilling operations following lake drawdown. Potential benefits associated with this alternative have been addressed previously (see page 5).

Concept II - Diked Freshwater Wetlands

A potential limitation with Concept I is that the river will become increasingly channelized as the middle basin fills progressively with sediment; and as the river becomes increasingly channelized the potential for wetland water quality treatment in the middle basin will become progressively reduced. This Concept I limitation led to the consideration of Concept II - Diked Freshwater Wetlands (refer to figures 4 and 5). Under this concept maintenance dredging would be continued and dredge spoils would be used to create diked wetland cells similar to the existing dredge spoil disposal area at the south end of the middle basin. The potential advantage of this approach is that wetland hydrology could be controlled through engineering design to minimize channelization and short-circuiting of flow, to maximize hydraulic residence time in the wetland, and thus maximize wetland water quality treatment potential. The primary disadvantages of this approach are (1) continuation of maintenance dredging and associated costs; (2) the cost and construction impact of a flow diversion structure dam in the south basin; and, (3) the cost, construction, and environmental impact of wetland (lake) filling in the middle basin. In other respects, this concept would be similar to Concept I.

Concept III - Estuary Salt-tolerant Wetlands

The Estuary Salt-tolerant Wetlands Concept would involve reprogramming the tide gate controls to allow marine water to flush in and out of the lake basin with every tidal cycle, similar to the concept developed by Bernard et al. (1986). Under this concept the maximum reservoir elevation would be retained at its present level, but the reservoir would be allowed to lower by three feet with every ebb tide and refill with saltwater up to the normal water surface elevation with every flood tide. As with Concept I, maintenance dredging in the middle basin would be discontinued until some time in the future and the middle basin would be allowed to develop as an estuarine marsh wetland (refer to figures 6 and 7). Allowing tidal flushing would result in improved water quality in the north basin since the saltwater would not allow nuisance freshwater algae and plants to grow. Since the tide gates could be used to maintain a low water reservoir, there would be very little sediment exposure at low tide and visual impacts and odors would be limited, compared to total reservoir drawdown.

COMPARATIVE ANALYSIS AND CONCLUSIONS

The three wetland concepts described above are compared in a matrix table (table 1). The advantages and disadvantages of each alternative are summarized in the table. On the basis of the this information and the more extensive analysis provided in the body of this document, several conclusions have been reached, and are discussed below.

Concept I - River Delta Freshwater Wetlands

The River Delta Freshwater Wetland Concept is considered feasible. It would make it possible to discontinue maintenance dredging operations for a period of 30 to 85 years and save the associated costs. However, it would not result in any significant water quality benefits to the north basin and could result in minor adverse impacts once the wetland became fully developed. A significant disadvantage of this concept would be the aesthetic impact of the loss of the middle basin as a reflecting pool for the Capitol Campus. However, there are those who may prefer the aesthetic appeal of wetlands in place of the open water lake environment.

This concept would require the mitigation of increased flood impact potential in the City of Olympia and at Tumwater Historic Park for the 100-year flood event. It would also require the construction of a saltwater control weir (underwater dam) in the vicinity of the railroad trestle separating the north and middle basins. These costs and the costs associated with regulatory reviews and approval would offset deferred maintenance dredging cost savings. No significant adverse impacts are expected to fish or wildlife. Wildlife habitat would actually be increased/enhanced.

Ultimately, as the middle basin becomes full of sediment, the rate of sediment accumulation will increase in both the north basin and in Budd Inlet, and maintenance dredging operations will have to be resumed, and costs incurred.

Concept II - Diked Freshwater Wetlands

The concept of using dredge spoils from maintenance dredging operations to create wetlands is considered nonviable. This concept would only partially defer dredging costs (the cost associated with remote disposal) and it would not produce any significant water quality treatment benefits to the north basin. This concept would involve the construction of a relatively costly flow diversion dam and fish ladder in the vicinity of the I-5 bridge. It would also create potential adult fish attraction problems at the wetland discharge points and could create problems with fish stranding in the constructed wetlands. Furthermore, it appears doubtful that regulatory approvals could be obtained for filling natural wetlands (Capitol Lake) to create man-made wetlands.

Concept III - Estuary Salt-tolerant Wetlands

The "Estuary" concept is considered feasible, assuming that fishery concerns can be resolved. This concept would make it possible to defer maintenance dredging costs as with Concept I. It would also result in water quality improvements in the north basin as a result of increased marine water flushing. As with Concept I, deferred maintenance dredging costs would be offset by regulatory review and approval and impact mitigation costs.

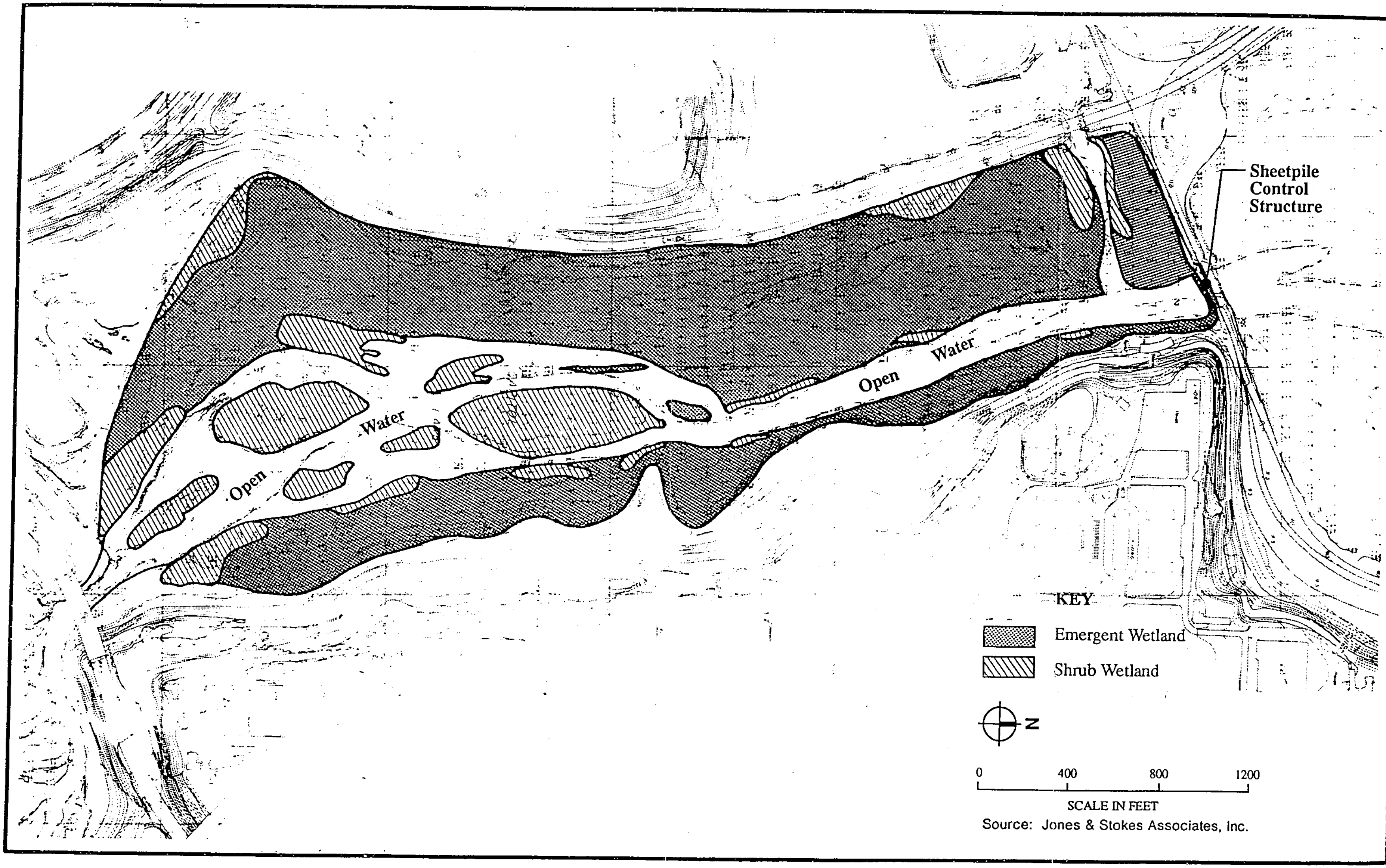

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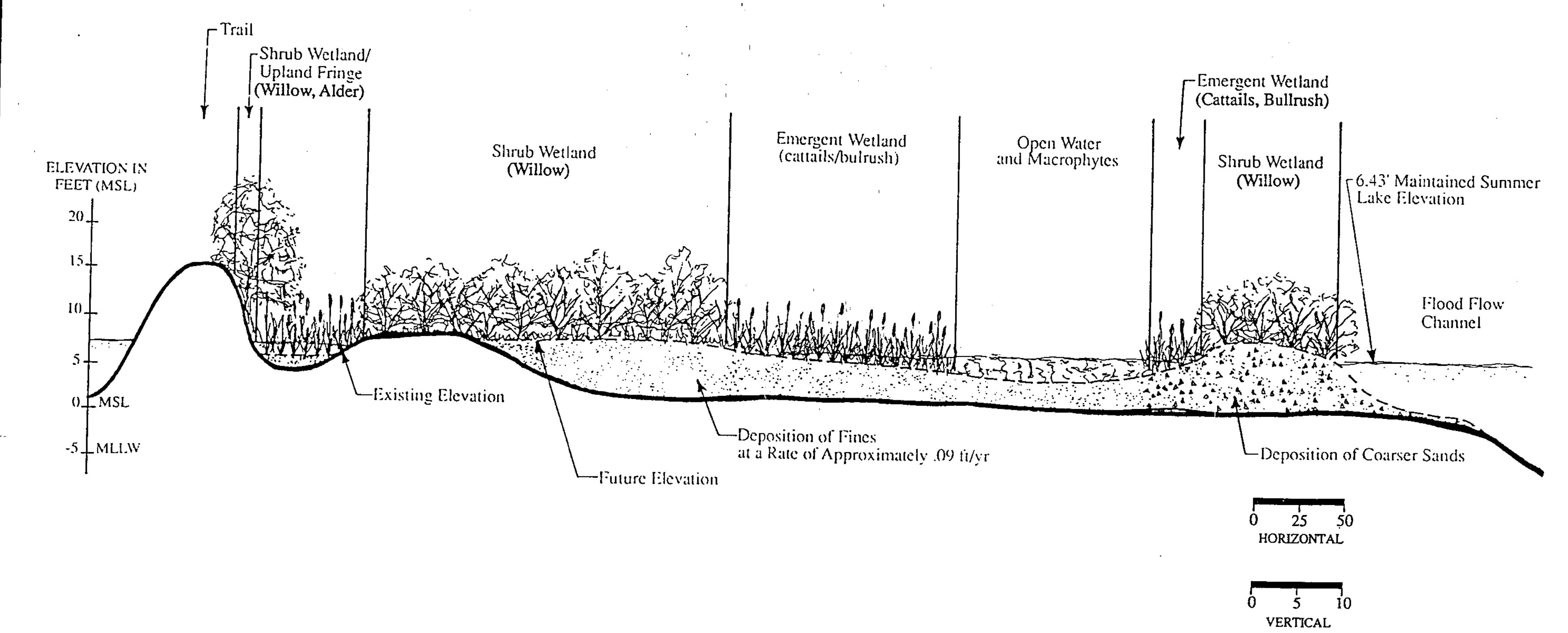
Figure 2

CONCEPT I PLAN VIEW -
RIVER DELTA FRESHWATER WETLANDS



Source: Jones & Stokes Associates, Inc.

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Figure 3

CONCEPT I PROFILE -
RIVER DELTA FRESHWATER WETLANDS

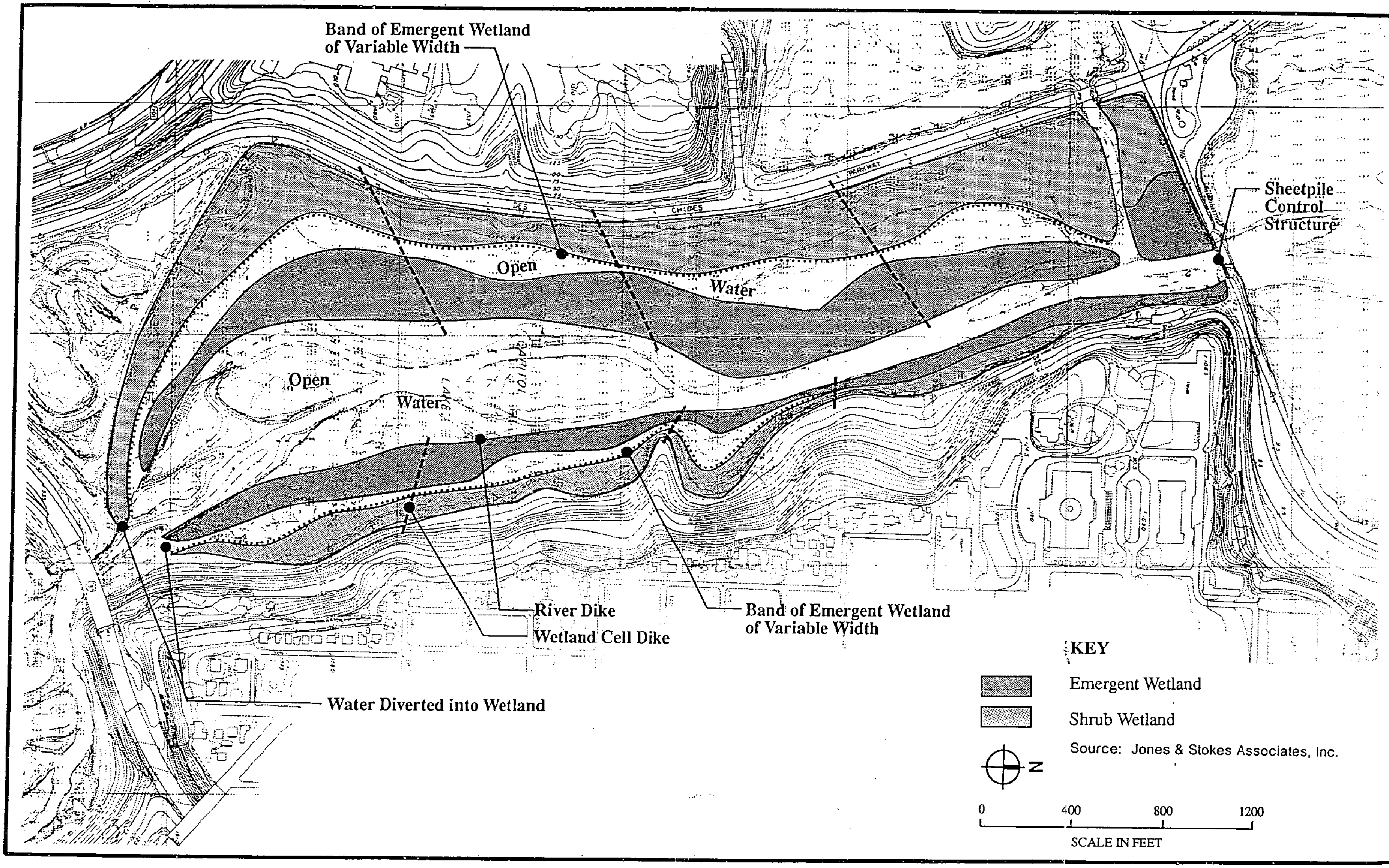

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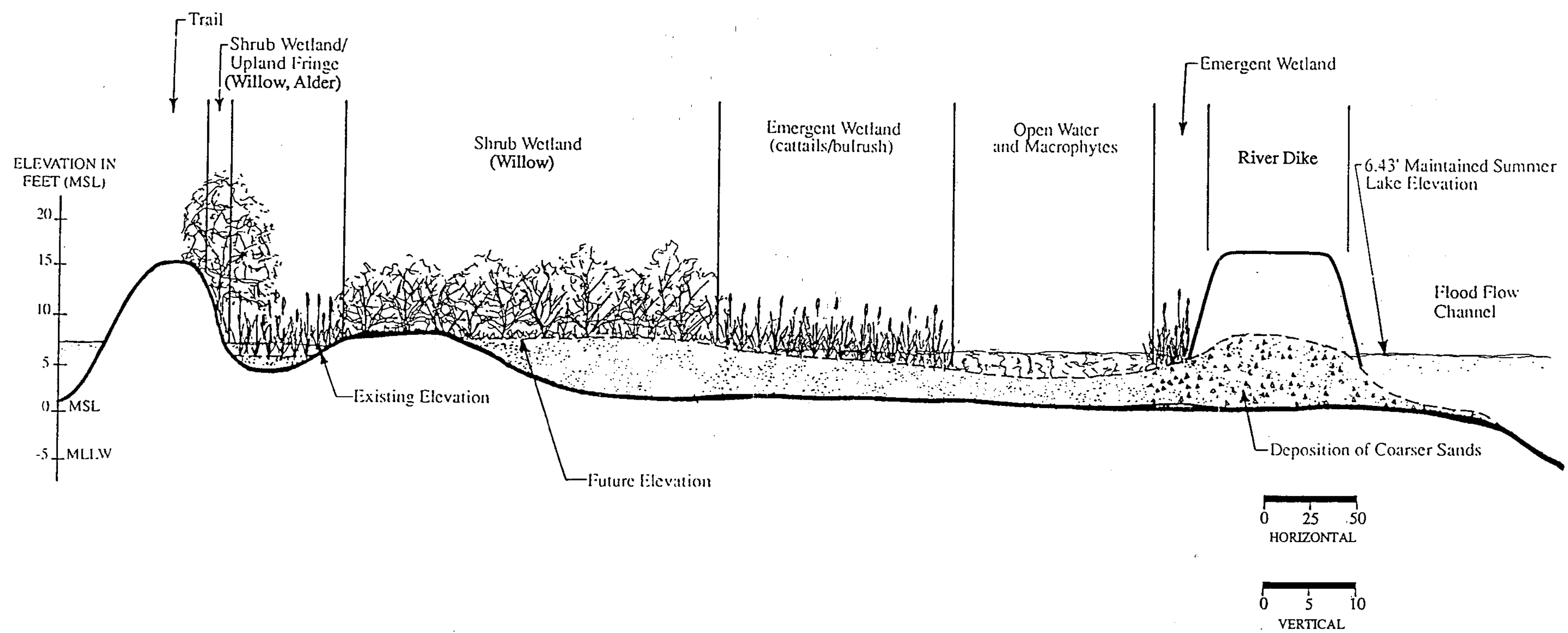
Figure 4

CONCEPT II PLAN VIEW - DIKED FRESHWATER WETLANDS



Source: Jones & Stokes Associates, Inc.

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Figure 5

CONCEPT II PROFILE - DIKED FRESHWATER WETLANDS

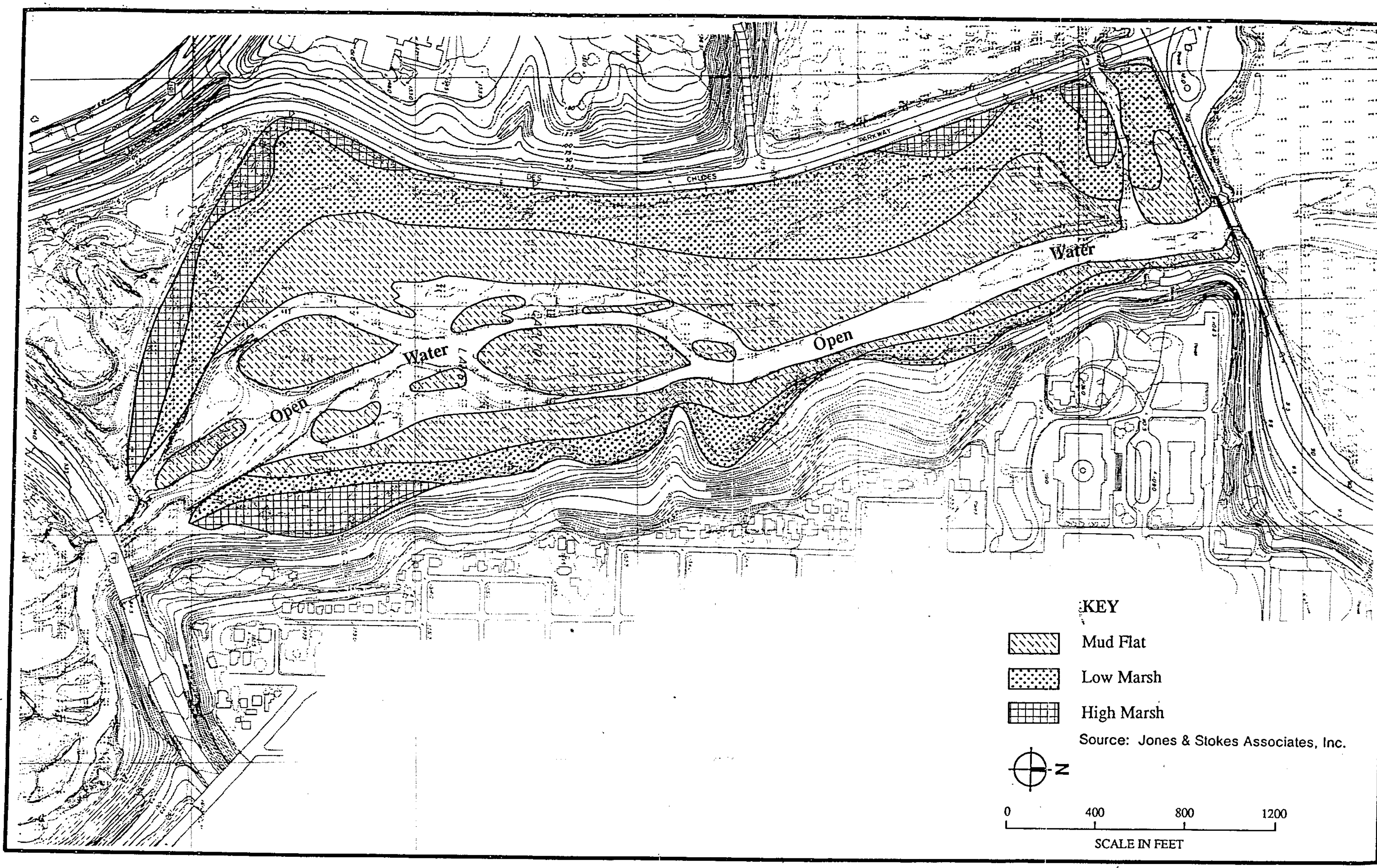

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Figure 6

CONCEPT III PLAN VIEW -
ESTUARY SALT-TOLERANT WETLANDS

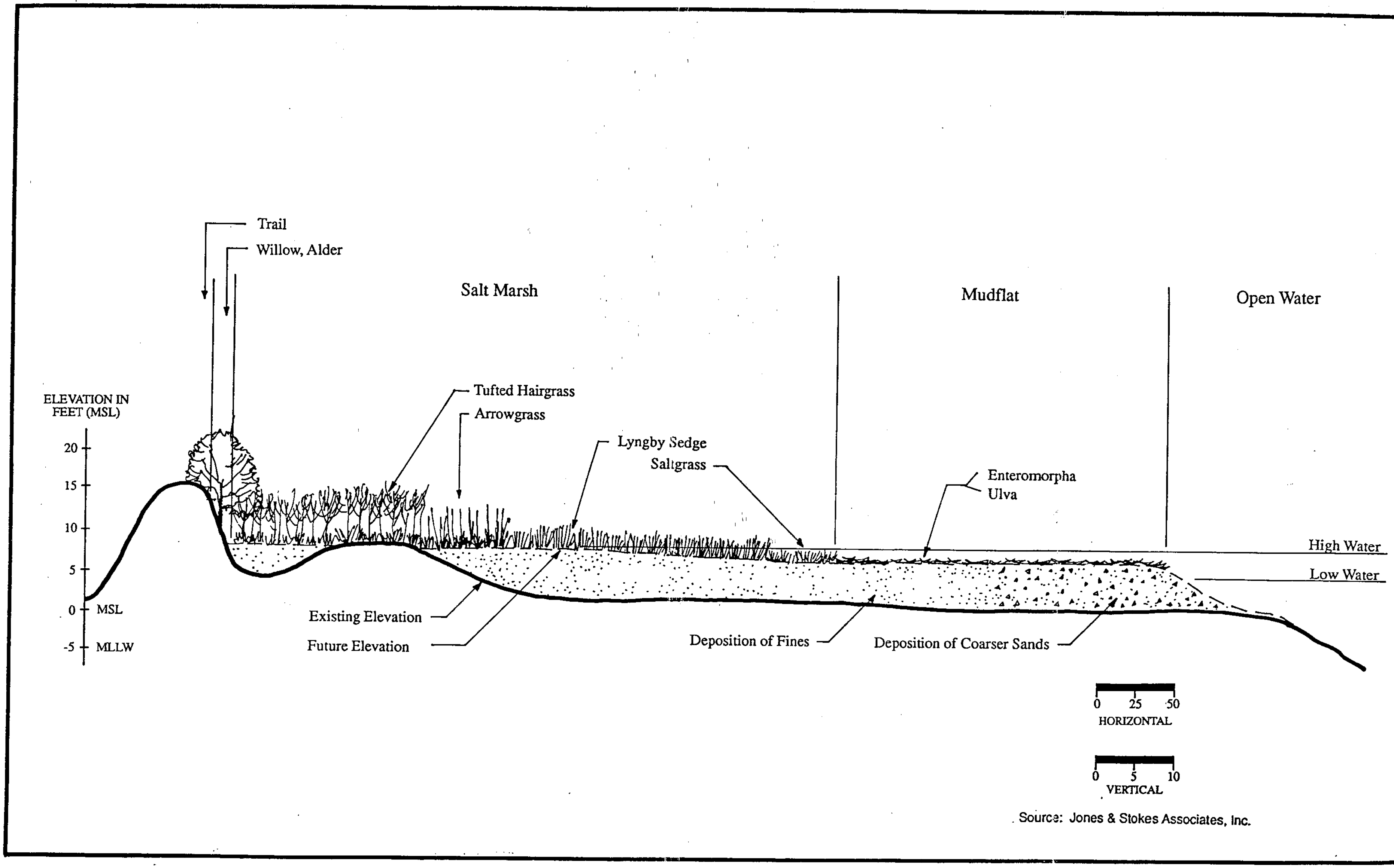

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Figure 7

CONCEPT III PROFILE - ESTUARY SALT-TOLERANT WETLANDS

Potential aesthetic impacts would be limited by fixing the lower reservoir level to 3.43 MSL, three feet lower than the normal water surface. This would prevent the exposure of significant sediment areas in the near term. As with Concept I, ultimate wetland development would eliminate the reflecting pool aesthetic value of the middle basin.

Flooding impacts would be similar to those for Concept I and would require mitigation, except that flooding potential will probably be reduced in the south basin as a result of increased river scour and subsequent sediment export during low-tide water levels. Potential shoreline erosion impacts caused by daily tidal action would require mitigation using riprap, geotextiles, and bioengineering techniques.

Fish rearing operations in Percival Cove could be maintained with the construction of a stop log flow control structure at the Deschutes Parkway bridge. There are potential fishery concerns with (1) the effects of tidal flushing on the 10 million fingerlings presently held in the lake during the spring, and (2) loss of habitat for freshwater fish.

Certain freshwater mammals, including beaver and muskrat, would be lost or displaced with this alternative. Otherwise, increased saltwater wetland habitat should benefit waterfowl and shorebirds.

As with Concept I, sediment loading rates to the north basin and Budd Inlet would increase and maintenance dredging would ultimately have to be resumed, and costs incurred.

Table 1
Comparison of Wetland Development Alternatives

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Time of Formation	Variable river sediment loading of 20,000 to 55,000 cubic yards per year provide a basis for estimating corresponding times to fill the middle basin of 30-85 years.	Same as Concept I. Sediment accumulated in the middle basin trap would be used to construct dikes and create desired wetland topography within the dikes.	Same as Concept I.
Estimated Dredging Cost Savings* *Note: The specified dredging cost savings are based upon a plan that has never been fully implemented. This analysis assumes that the proposed maintenance dredging plan would be implemented. The implementation of Concepts I, II, and III will involve offsetting costs required for regulatory review and mitigation of direct and indirect impacts as further described in this table and in Chapter 2.	Maintenance dredging costs are estimated at $12 per cubic yard (Entranco Engineers 1984). Depending on the rate of sediment loading, dredging cost savings would range from $240,000 to $660,000 per year or $19.8 to $20.4 million over the period of 30-85 years. These costs would not be incurred with Concept I. At the end of the specified filling period, maintenance dredging will have to be resumed in the middle basin and may have to be conducted in the north basin as indicated under the "Sediment Control" section of this table and in Chapter 2.	With dredge spoil disposal occurring in Capitol Lake, the cost per cubic yard is expected to be lower at about $8 per cubic yard. Total dredging cost would range from $160,000 to $440,000 per year or $12 to $13.2 million over the 30-85 year development period. The net cost savings is estimated at $6 to $6.8 million dollars. At the end of the specified filling period, maintenance dredging will have to be resumed in the middle basins and may have to be conducted in the north basin as indicated under the "Sediment Control" section of this table and in Chapter 2.	Same as Concept I.
Potential Water Quality Treatment Benefits	No significant change in water quality treatment benefits would be realized compared to existing lake treatment. Existing lake residence times are very short (0.5 to 4.3 days) so that pollutant removal rates are dominated by physical	A flow diversion structure dam would have to be constructed in the vicinity of the I-5 bridge in order to provide controlled flow to constructed wetlands. The cost of this structure is estimated at $1.25 - 4.0 million. No significant water	Tidal marine flushing would result in a freshwater/marine water mix in the reservoir with marine water influence dominating during the period of low river flow (June-October) and fresh water influence becoming increasingly significant

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Potential Water Quality Treatment Benefits (Continued)	settling processes. Water residence times are too short for wetland biological removal processes to be significant compared to physical processes.	quality treatment benefits would be realized. Potential water quality treatment benefits of controlled flow would not be realized because of excessive hydraulic loading (river inflow) rates.	during the period of high river flows (November-May). During the growing season, water quality would generally be better with increased marine influence. Water temperature and chlorophyll *a* levels would be lower. June-September temperatures would range from 13.0 to 16.5° C compared to existing lake temperatures of 17-22° C. Chlorophyll a levels would range from 2.2 to 18.6 mg/m^3 compared to existing lake levels of 7.3 to 42.6 mg/m^3 (May-August). June-September secchi disk visibility would increase from existing lake levels of 1.3 to 2.2 meters to 1.3 to 6.0 meters.
Potential Water Quality Impacts	Filling in of the middle basin is expected to result in increased phosphorus (from 40.5 to 45.5 mg/m^3) and chlorophyll a (from 10.6 to 15.5 mg/m^3) levels and reduced water clarity in the north basin during summer months. This prediction assumes no additional phosphorus control. Increased wetland habitat could result in increased waterfowl/usage and increased fecal coliform levels in the north basin. No significant changes are expected with other water quality parameters such as	Same as Concept I.	Increased marine flushing would result in lower dissolved oxygen levels in the north basin, reflecting seasonably low levels in Budd Inlet of 5.0 to 6.0 milligrams per liter. Historical data (Entranco Engineers 1984) suggests that fecal coliform bacterial levels would range from 3-43 organisms/100 ml during the June-August period, with possible waterfowl increases as with Concept I.

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Potential Water Quality Impacts (Continued)	temperature, pH, dissolved oxygen, or turbidity, except for possible increases in temperature and possible decreases in dissolved oxygen that might result from inefficient water exchange in the near shore zone.		
Potential Flood Control Impacts	The combined influence of high tides, 100-year river flows, and filling of the middle basin will result in an increased flood elevation in the north basin of 0.81 feet from 10.90 to 11.71 feet. Without mitigation, this could result in increased flooding impacts in downtown Olympia. Flood impact potential for Tumwater Historic Park is also expected to increase as sediment filling progresses in the south basin. Mitigation of potential flood impacts may involve dike construction along the eastern shore of the north basin, new underground stormwater detention in downtown Olympia, and/or the construction of a lift station. Mitigation of potential flood impacts at Tumwater Historical Park could also be mitigated by diking. These mitigation costs could involve several million dollars.	Potential flooding impacts to Olympia would be the same as Concept I. Construction of a flow diversion facility in the vicinity of the I-5 bridge could increase potential flood impacts to Tumwater Historic Park. Mitigation of potential flood impacts may involve dike construction along the eastern shore of the north basin, new underground stormwater detention in downtown Olympia, and/or the construction of a lift station. Mitigation of potential flood impacts at Tumwater Historical Park could also be mitigated by diking. These mitigation costs could involve several million dollars.	Same as Concept I except that reduced sediment accumulation in the south basin would reduce potential flood impacts to Tumwater Historical Park. Mitigation of potential flood impacts may involve dike construction along the eastern shore of the north basin, new underground stormwater detention in downtown Olympia, and or the construction of a lift station. These mitigation costs could involve several million dollars.

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Fish Rearing and Passage	No fish passage problems would occur with this alternative. Habitat quality would be improved with increased wetland edge effect. Poor water exchange in near shore areas could result in higher water temperatures and lower dissolved oxygen levels which could have negative impacts on fish.	Diked wetlands could create some fish passage problems including attraction of adult fish at the wetland discharge points and possible fish stranding behind the dikes. Fish passage would also have to be provided the flow diversion structure. These potential problems could probably be mitigated with proper design and management. Concept II does offer the potential for creating enhanced salmonid rearing habitat in deep marsh wetlands behind the dike.	The estuary concept would require improvements to the outlet at Percival Cove to prevent water level fluctuation impacts on net-pen operations. A flow control (stop log) structure would be required. The cost of these improvements, including engineering, is estimated at $20,000. Tidal fluctuations could adversely impact the 10 million salmon fingerlings that are presently held in the lake from March-June. Tidal flushing would minimize holding times and could affect survivability and the numbers of returning adults. Three-foot tidal fluctuations will also result in significant loss of habitat for freshwater fish.
Lake Circulation	A flow diversion structure could be constructed downstream of the railroad trestle to increase the efficiency of water exchange on the east and or west shores of the north basin as a means of improving water quality in the relatively stagnant nearshore zone.	Same as Concept I.	Circulation in the north basin would improve dramatically with increased marine circulation. A flow diversion structure would not be required. Modified tide gate controls would be required in order to achieve the proposed estuarine circulation. The three-foot tidal exchange that would occur twice a day would expose lake bottom sediments. The limit of exposure would be relatively narrow in most locations because the lake shoreline is relatively steep

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Lake Circulation (Continued)			in most locations. Greatest lake bottom exposure would occur along the southwest margins of the middle basin. Increased sediment exposure would represent a potential public safety problem that could be mitigated by posting the shoreline with warning signs.
Saltwater Flushing	It may be possible to limit saltwater intrusion and adverse impacts to freshwater wetland plants in the middle basin following drawdown by allowing the lake to refill primarily with river water and not marine water. This would require about 3-10 days filling time and could adversely affect dissolved oxygen levels in Budd Inlet. An alternative control approach would involve the construction of a flow control weir (submerged dam) at the railroad trestle, which separates the north and south basins. Estimated weir construction costs are $1.4 million.	Constructed dikes would provide adequate saltwater control for Concept II freshwater wetlands.	Saltwater flushing would be encouraged with the estuary concept in the hope of promoting salt-tolerant wetland plants.
Sediment Control Note: When maintenance dredging is resumed, the middle basin trap will have to be reconstructed and may require construction of a new sediment trap in the north basin.	Maintenance dredging would be resumed after the 30-85 year middle basin filling time. It may be desirable to resume dredging when the mean depth of the middle basin reaches 2-3 feet. Two sediment traps may be necessary—one at the south end of the middle basin and one at the north basin. Once the	Same as Concept I.	Sediment control would generally be the same as with Concept I. However, during the first couple of years, there would probably be significant sediment transport from the south basin to the middle basin. During low water elevations and high river flows, existing sediment deposits in the south basin

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Sediment Control (Continued) Note Continued: Trap construction would involve added cost.	middle basin fills the sediment loading rate to the north basin is expected to increase from a range of 4.900-13.300 cubic yards per year to a range of 15.200-41,500 cubic yards per year. Dredge-spoil disposal costs may increase due to inflation, availability of disposal sites, and increased regulatory controls in the future.		will be scoured and transported downstream.
Geotechnical Considerations	Limited data required best professional judgment in estimating pile depth for the saltwater control wier. Confirmation is needed prior to final design.	Same as Concept I.	See Erosion Control.
Erosion Control	Existing shoreline erosion impacts would not be significantly changed. Impacts could be mitigated in part by lowering the normal summer lake elevation by approximately 0.5 foot from 6.43 feet MSL to 5.93 feet MSL. Refer to North Basin Shoreline Erosion Control report (Entranco Engineers, 1990) for additional information.	Same as Concept I.	Shoreline erosion could increase significantly with daily reservoir fluctuations of 3 feet. Potential impacts would be greatest in the vicinity of the railroad trestle, near the I-5 bridge, and in the south basin; but would also occur along the Deschutes Parkway and entire north basin shoreline. Shoreline erosion impacts could be mitigated using a combination of riprap geotextiles and bioengineering techniques at an estimated cost of $1-2 million.
Pest Control	The potential exists for certain undesirable biological changes to occur in response to the development of freshwater wetlands. Increased areas of stagnant water may result in increased mosquito populations and increased control efforts. The same is true	Same as Concept I.	The estuary concept would not provide suitable habitat conditions for mosquitoes or purple loose strife. No additional control would be necessary.

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Pest Control (Continued)	for the undesirable plant invader, purple loosestrife. With increasing waterfowl use of newly created wetlands, there is some possibility that avian botulism could become a waterfowl disease management problem.		
Wildlife	Wildlife habitat would be enhanced for such species as waterfowl, shorebirds, otter, raccoon, muskrat, beaver, and other species.	Same as Concept I. However, regulatory agencies will probably consider filling with dredge spoils as an unacceptable adverse impact to existing wetland habitat.	The estuary concept would result in significant habitat changes to salt water plant animal species. Water-loving mammals such as muskrat and beaver would be eliminated from the north and middle basins. Waterfowl and shorebirds would not be significantly affected.
Aesthetics	The middle basin would gradually be converted from a lake to a wetland environment. Ultimately, the reflecting pool aspect of the middle basin would be lost. The middle basin would ultimately look similar to the existing south basin. Flood control mitigation dikes would likely result in adverse aesthetic impacts to the Heritage Park Plan, Olympia's Capitol Park Renovation Project and the Tumwater Historic Park.	Same as Concept I. In addition, the construction of wetland dikes and diversion dam and pipe works could be considered as an adverse aesthetic impact.	Same as Concept I. In addition, certain portions of the reservoir bottom (estimated at 20-30 acres) would be exposed twice per day with each tidal cycle. Exposed sediments would occur in both the north and middle basins, although primarily in the middle basin in the vicinity of the Capitol Lake Interpretive Center. The exposed area will increase gradually in the middle basin as it fills with sediment. Exposed areas are expected to be colonized by salt-tolerant plants. Exposure of rip-rap banks along the north basin would create adverse aesthetic impacts to the proposed Heritage Park Plan and Capitol Lake Park Renovation.

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Recreation	Recreational opportunities could be enhanced with trails, observation platforms, and educational displays. New trails could link the wetland with existing park facilities. Open water fishing in the middle basin would be replaced with river bank fishing opportunities. New facilities would require additional maintenance costs.	Same as Concept I.	Similar to Concept I. In-lake fishing for obligate freshwater species would be lost and replaced by a fishery based on marine species. However, the marine species are not likely to be of any sport fishing interest. Fishing for anadromous salmonids would continue, but opportunity may be reduced as the estuary fills with sediment.
Historic and Cultural Resources	Wetland plants suitable for native American cultural uses could be planted and cultivated in the wetland.	Same as Concept I.	No culturally valuable plants could be promoted under the estuary concept.
Multi-jurisdictional Management	The lake wetland environment would continue to be managed by the State Legislature and the Department of General Administration through consultation with other affected agencies and the public. Long-term management decisions would be coordinated by the Capitol Lake Management Committee.	Same as Concept I.	Same as Concept I.
Regulatory and Permit Considerations	SEPA review would be required as well as the following permits: • Shoreline • Dam Safety • Hydraulic Project Approval A 404 permit (estimated permit process is 12 months to 3 years) may be required if the saltwater control structure involves	SEPA and possibly NEPA review would be required. In addition, the following permits would be required: • Shoreline • Dam Safety • Hydraulic Permit Approval • Section 404 Permit (estimated permit process is 12 months to 3 years)	Same as Concept I, except that the saltwater structure and training groin would not be a consideration, and permit review of Percival Creek outlet control and shoreline erosion control measures would be required. The cost of additional geotechnical, engineering and environmental analysis is estimated at $500.000.

Evaluation Criteria	CONCEPT I River Delta Freshwater Wetlands	CONCEPT II Diked Freshwater Wetlands	CONCEPT III Estuary Salt-tolerant Wetlands
Regulatory and Permit Consider-ations (Continued)	filling or if a circulation training groin is implement-ed, or if north shore diking is required for flood impact mitigation. Additional engi-neering and environmental analysis is recommended for proper SEPA review. The cost of additional geo-technical, engineering and environmental analysis is estimated at $500,000.	Filling of the middle basin with dredge spoils may not be possible under existing state and federal wetland protection regulations. Ad-ditional engineering and environmental analysis would be required for prop-er SEPA/NEPA review. The cost of additional geo-technical, engineering and environmental analysis is estimated at $500,000.	

2
WETLAND DEVELOPMENT FEASIBILITY / IMPACT EVALUATION

BIOLOGICAL PARAMETERS

Water Elevations/Vegetation

Freshwater Wetland Types

The critical factor effecting the development of freshwater wetland communities is the hydrology. The presence/absence of water, the seasonality, and the depth and duration of any flooding or drawdown affect the composition and structure of the plant community.

Most species in the Northwest are tolerant of winter flooding. Species are primarily dormant in the non-growing season, therefore the presence of increased winter water depths will not drown species. Water depth past the beginning of the growing season, generally considered to be the first of March (earlier for selected species), is important for determining the survivability of most species. The relationship between water levels and individual species tolerances for plant species native to Capitol Lake is shown in Appendix D.

The following generalizations can be made regarding the conditions necessary for establishing the following freshwater wetland vegetation communities (note that water depths refer to depths during the major portion of the growing season, March through July):

- *Open water/deep water marsh*: generally considered those areas with water depths of 3 feet or greater; may include the presence of floating or floating leaved (rooted in the substrate) macrophytes;

- *Shallow marsh (emergent)*: those areas with water depths of less that 3 feet with rooted vegetation which emerge through standing water surface. The presence of water is generally year-round, although there may be periodic droughts which completely dry the system. Vegetation is generally characterized by adapted grasses and grass-like plants, some forbs, and occasionally scattered shrubs;

- *Wet meadow*: those areas where surface water (if present), will only be present during the winter months. Vegetation is characterized by grasses, sedges, rushes, and forbs; and

- *Scrub/shrub*: those areas characterized usually by at least seasonal standing water and a dominance of shrub species.

Within shallow marsh/emergent communities, water depth is the critical factor often influencing the species composition within the community. Certain species, such as hardstem bulrush (*Scirpus acutus*) will grow through several feet of standing water. Other species, such as dagger-leaf rush (*Juncus ensifolius*) prefer water depths of less than a few inches to none.

The relationship between species survivability and water depth is critical with regard to the proposed function of sediment entrapment within the emergent vegetation community. If an emergent community is successfully established, significant adverse impacts could occur with the subsequent deposition of sediment, which would not only bury the rhizomes but would also manifest a change in the hydrologic regime. A change in elevations and hydrologic regime may change the water profile within the system, which may no longer provide appropriate conditions for the target species. Thus use of a wetland for entrapment of large quantities of sediment will cause a change in the species composition and perhaps a change of wetland community, based upon changes in the water regime and depths during the growing season.

In addition to water quantity, water quality will also affect species composition. Certain species such as common cattail (*Typha latifolia*) and yellow flag (*Iris pseudacorus*) are quite tolerant to poor water quality. According to unpublished findings of the Puget Sound Wetland and Stormwater Management and Research Program, species such as *Carex* are very sensitive to degraded water quality and changes in hydrology, and will quickly be eliminated from a wetland community when changes in water quality or quantity occur.

Estuarine Wetland Types

The following wetland types and plant species are typically found in Puget Sound estuaries. The elevation levels listed are referenced to Mean Sea Level (MSL) and have been adjusted for tide conditions in the Olympia area based on professional judgment.

- *High marsh:* typically located in the portion of the intertidal zone that is inundated infrequently, from the uplands (about +12) down to about +7. Species common to southern Puget Sound and known to be present near Budd Inlet, include tufted hair grass (*Deschampsia caespitosa*) and arrow grass (*Triglochin maritimum*).

- *Low marsh:* typically located from about the mean higher high water mark (+7) to about (+3). Species common to southern Puget Sound include pickleweed (*Salicornia virginica*), arrow grass, Lyngby Sedge (*Carex lyngbyei*), and saltgrass (*Distichlis spicata*).

- *Mudflat:* typically located at about +3 and below. This zone is typically only vegetated by annual plants such as sea lettuce (*Entromorpha*) unless rocks are present to allow attachment of rockweed (*Ulva*). Eelgrass (*Zostera japonica*) can be present from about -3 to -12 (MSL) under proper conditions. Specifically, eelgrass thrives in areas of moderate currents and sediment deposition, and clear water.

Unlike freshwater wetlands which are adapted primarily to seasonal inundation, estuarine vegetation is adapted to the twice daily pattern of inundation imposed by the tides. Because tides can be predicted with accuracy, the zonation within estuarine wetlands can often be predicted. In addition to tides, daily and seasonal fluctuations in salinity can exert an important influence on the distribution and composition of the plant community. Salinity in an estuary is affected by the interaction of the topography with the salt wedge and freshwater inputs. Therefore, the salinity profile within a physically complex estuary is more difficult to predict than in a simpler system.

Feasibility/Impact Evaluation

Concept I - River Delta Freshwater Wetlands. The ultimate configuration for Concept I wetlands is illustrated in figures 2 and 3 (plan and profile). Under Concept I the following can be assumed: that as dredging is curtailed, the south basin will fill with larger grained material and fines will accumulate within the vortex areas of the middle basin. The deposition rate of these fines is not known; therefore, it is not possible to accurately speculate as to how soon substrate levels will change in order to provide conditions suitable for rooted macrophytes (waterlily; *potamogeton*). In addition, if rooted macrophytes take hold, deposition over time may limit their ability to flourish or reproduce because of constantly changing substrate conditions.

Shallower depths are required for emergent species—they will establish around the sides of the basin—as long as deposition of sediments does not cause continued stress to the species.

An undetermined amount of time would be required for the sediments in the middle basin to accumulate to depths that would allow the growth of emergent vegetation. It is likely that rooted aquatic floating-leaved vegetation may not establish to any significant degree within the basin because annual change in the substrate and bottom morphology will preclude the ability of these species to take root.

It is unknown what time frame would be required to establish beneficial emergent species such as cattails on the depositional areas. The "shorelines" of depositional areas will provide growing conditions which will change annually. The species which tend to colonize these areas are pioneer and weedy species tolerant to a wide variety of conditions. Such species often include Himalayan blackberry (*Rubus discolor*), horsetail (*Equisetum arvense*), willow (*Salix* spp.), and red alder (*Alnus rubra*).

The existing islands in the south basin include red alder, black cottonwood (*Populus trichocarpa*), and cattail. In addition, because of the relatively steep slopes and limited extent of vegetation, there is little wetland/water interface as the water flows around the margins of the islands, not through the standing vegetation.

Concept II - Diked Freshwater Wetlands. The ultimate development configuration for the Diked Freshwater Wetland Concept is illustrated in figures 4 and 5. For Concept II the optimum water depths could be established by the placement of dredge materials and by proper engineering of water circulation through the wetlands. Just as with Concept I, it would not be possible to stabilize these sediments until they reached a depth which would allow the growth of rooted vegetation.

Concept III - Estuary Salt-tolerant Wetlands. With the estuarine alternative, the daily and seasonal pattern of salinity that would result from operation and the small fluctuations in tidal level anticipated, present conditions very different from a normal estuary in Puget Sound. The uncertainty in these variables makes it difficult to predict with any certainty the wetland community that would result from this concept. The estuarine wetland zonation referred to earlier in this report may not apply to the proposed situation. In effect, the water level control proposed for the estuarine alternative redefines biologically important water levels, such as mean higher high water, to which estuarine plants have adapted.

For simplicity, we have assumed that under the estuarine alternative, mixing of salt and freshwater would occur, resulting in salinity similar to other estuaries in Puget Sound. If this assumption is not correct, it is unlikely to have a drastic effect on the conclusions because the plant communities in estuaries are typically dominated by euryhaline species. The limited tidal fluctuation under this alternative presents a more perplexing problem than does salinity. One possible result under the estuarine alternative, is that normal vegetation zones may shift to higher levels than under a situation where tidal fluctuations would occur throughout the normal range. For example, mudflat vegetation may predominate at elevations that greatly exceed normal because the water level would be maintained at a much higher level than normal. Further, the period of exposure between inundations could influence vegetation that can colonize the site. For example, if a mudflat vegetated by sea lettuce were to develop in the intertidal zone between +6.5 and +3.5, it would need to be hardy enough to withstand the "baking" effect of the sun until the next high tide flooded the area. Under normal conditions this type of vegetation grows lower and would be subject to much shorter periods of exposure.

Overall it is unclear as to the exact configuration the wetland would take under this concept, although it is expected that the vegetation would initially be in a narrow fringe or band due to the present elevations in the basins of Capitol Lake. The wetland that forms initially may be wider under this concept than the others due to the water level fluctuation. Several wetland scenarios are possible under this concept:

1. A high marsh with a mudflat and extensive shallows could evolve. Essentially no low marsh would occur because the period between inundation may be too long to allow those species to become established. The high marsh would create a fringe between +7 and + 6, below which mudflat would extend to below +3.5.

2. A wetland with high marsh, low marsh, and mudflat components could evolve. The high marsh would likely be very narrow—between +7 and +6, while the mixed low marsh and mudflat would extend down to +3.5.

3. A relatively wide low marsh could develop in the intertidal zone, while a permanently flooded vegetated mudflat develops downslope. The low marsh could extend from above +7 down to +3.5 feet.

Figures 6 and 7 show the ultimate wetland community assuming the second scenario. Over time the mudflat and low marsh would increase in area due to deposition, but the high marsh, which is located above the typical water level, would increase very slowly. The fluctuation of water levels could allow more uniform growth of the wetlands than under the other alternatives because the sediments would be trapped among the higher elevation vegetation during the high tides.

As with Concept I, deposition would occur primarily in the south and middle basins. The north basin would be influenced by the changing salinity and water levels, but little vegetated wetland would develop due to the depth of the basin and its steep sides. In the middle basin, the vegetated zone would ultimately dominate. The vegetated portion of the wetland would likely be comprised of a more limited number of species than a natural wetland due to the greater magnitude of daily and seasonal salinity fluctuations. It is possible that the area would be dominated by Lyngby sedge, a hardy euryhaline species. The locations within the basin where wetlands would develop would be influenced by the course that the river cuts through the basin.

In contrast to the previous alternatives, much of the existing wetlands in the north basin, middle basin, and Percival Cove would die due to the changing salinity under the estuarine alternative (see table C-2 in Appendix C for tolerance of existing freshwater wetland species). The south basin might be affected to some degree, but would not likely be affected to the same extent because of its elevation above the salt wedge and the proximity of the freshwater inputs. Impacts to Percival Cove could be avoided by use of a stoplog structure to exclude the salt wedge and maintain the freshwater characteristics of the cove.

Conclusions

Wetland vegetation grows in response to seasonal water depths, slope, soils, and hydrologic regime. Wetlands in riverine systems are dynamic systems, with shorelines, areas of deposition, and areas of erosion changing annually. Open water/deep marshes generally have water depths greater than 3 feet; shallow emergent marshes have water depths of less than 3 feet; while scrub/shrub areas are characterized by seasonal standing water or high groundwater during the growing season.

Vegetative diversity occurs in a wetland because of variations in elevation, slope, water depth, and salinity. Under Concept I, conditions suitable for wetland vegetation will occur first in the south basin and, with time, in the middle basin. The wetland cell concept will allow for the development of conditions suitable for a variety of wetland plant types.

The estuarine concept (Concept III) would provide an additional type of wetland in the system and would increase overall wetland diversity in the three basins. However, the community that evolves would likely be less diverse than a normal estuary due to the highly variable conditions.

Wildlife Habitat

Introduction

Wildlife habitat is a function of the physical and biological features of an area. Wildlife species use and populations occur in response to the availability of essential environmental components—food, cover, and water. Wetlands provide habitat for a wide variety of wildlife, with the wildlife species occurring in response to the vegetation (which provides food and cover) and the availability of water.

Freshwater Wetland Types

Three broad wetland types are assumed for this study—emergent, open deepwater marsh, and scrub/shrub. Because of the predominance of standing or flowing water in emergent and open deepwater marshes, wildlife use in those types tends toward aquatic avifauna (e.g., waterfowl), terrestrial avifauna which utilize wetlands for a part of their life requirements (e.g., red-winged blackbird which nest in cattails), and mammals that live in (e.g., muskrat and otter), or utilize wetlands for a part of their life requirements (e.g., raccoon). Wildlife use in scrub/shrub wetlands tends to be more stratified in response to the availability of multiple layers of vegetation provided by groundcover, shrubs and small trees. Examples of wildlife species common to scrub/shrub wetlands include raccoon, voles and deer mice, green heron, common flicker, black-capped chickadee, and warblers. Oftentimes scrub/shrub wetlands represent an early stage of a forested wetland, a wetland type that, with time, may become more dominant in Capitol Lake. Species that typically occur in forested wetlands include the species previously described for scrub shrub wetlands plus those species dependent on a more stratified ecosystem (e.g., red-tailed hawk, pileated woodpecker, band-tailed pigeon, and owls).

Ideal wildlife habitat includes a diversity of vegetation, which in turn provides habitat for a wider variety of wildlife. Vegetative diversity can be achieved through variation in physical features of the wetland such as water depth and topography, establishment of scattered islands to provide conditions suitable for grass and trees, and variations in the timing and duration of drawdown and flooding. The variations in water depth result in concentric zones of plant species surrounding deep openwater ponds.

Criteria

Several general rules apply regarding habitat diversity:

- Water and vegetated areas should be interspersed to provide the greatest wildlife value (Weller and Fredrickson 1974);
- Most wildlife species favor marshes having a ratio of 1:1 cover-water interspersion (Weller 1978); and
- Variable plant structure (i.e., plants of varying heights and life forms) provides the greatest habitat value (Beecher 1942).

Feasibility/Impact Evaluation

Concepts I and II - River Delta and Diked Freshwater Wetlands. Under proposed wetland Concepts I and II wildlife values would be expected to slowly change over time in response to the physical and biological changes brought about by deposition and filling. These changes will include a reduction in open water habitat with increases in conditions suitable for macrophytic growth (rooted floating plants). Because the shallow floating plants will be attractive to waterfowl, seasonal increases in waterfowl numbers can be expected.

Under Concept I, wildlife habitat changes would be expected to occur much more slowly than under Concept II, since habitats will develop only in response to suitable water depths and depositional patterns.

Under Concept II, substrate for vegetative growth will occur more rapidly than from natural deposition and greater variability in habitats is expected as a result of the ability to establish a variety of elevations and water depths.

Concept III - Estuary Salt-tolerant Wetlands. As stated previously, the estuarine concept would dramatically change the wetland community in the middle basin. The wildlife community inhabiting the middle basin would be expected to undergo a change parallel to that in the plant community. For some types of animals this may be of little significance. For example, waterfowl use of the estuarine wetland would be expected to continue to be heavy. Species dependent upon freshwater (e.g., beaver, muskrat) would be displaced or confined to the remaining freshwater wetlands in the south basin. High quality habitat for shorebirds would increase. The changes wrought by implementation of this concept would be rapid, followed by slow establishment of the new habitats and species.

It is difficult to predict whether the value of wildlife habitat would be greater or less than under other concepts. The direction of the impact would hinge on whether a productive estuarine system could become established. The fluctuations in salinity may determine the productivity of the habitat and the species present. For example, the bivalve Macoma is an important food item for birds; however, if freshwater persists in the estuary over long periods (<4 parts per thousand salinity for 15+ days) bivalves would not become established on the mudflats.

Conclusions

Wildlife use of wetlands is the result of a host of physical and biological conditions including hydrology, soils, topography, salinity, and vegetation. Wildlife species diversity and populations will be respond to the availability of suitable food, cover, and water. Ideal wetland wildlife habitat includes water and vegetated areas interspersed at a ratio of 1:1 and having plant structure varying in height and life form.

Under Concept I, wildlife habitat changes are expected to occur most dramatically first in the south basin as sediments are deposited, followed by elevational changes in the middle basin sufficient to provide conditions suitable for growth of macrophytes and emergents. Concept II will allow for the development of a variety of water depths, slope and elevations that could lead to a more diverse habitat than would occur under Concept I.

Under the Concept III, changes in the wildlife community compared to existing conditions are expected, but they are difficult to predict due to the uncertainty inherent with the proposal. In general, species favoring upland and freshwater marsh habitats would be replaced by species favoring estuarine conditions.

Fish Rearing/Passage

Introduction

Capitol Lake is used as habitat, a migration corridor, and a semi-natural rearing facility by several species of salmonids. The use of the lake by fish is one of its most valuable existing functions and any wetland creation concept must minimize the potential for adverse impacts to these uses. However, wetlands can provide important habitat and benefits for salmonids.

Concerns fall into three categories: fish passage, stranding/predation, and maintenance or replacement of the semi-natural rearing program for chinook.

Due to the diversity of fish species and life history stages that may be using Capitol Lake, it is appropriate to consider providing effective passage in the channel during all seasons of the year.

For this project, stranding of juveniles and smolts is considered to be a much more likely problem than is stranding of adults, because the water level fluctuations in the wetlands are expected to be fairly small, due to the control structure at the north end of the north basin. Therefore, the recommendations listed in the criteria section are based on juveniles and smolts rather than adults.

The Washington Department of Fisheries presently stocks up to 8 million chinook salmon fry in Capitol Lake, which are fed for several weeks prior to emigrating of their own volition. Ensuring compatibility of the proposed project with the existing chinook salmon rearing program or a replacement program will be a means of avoiding a major impact. It is likely that WDF would be flexible in accepting any proposal that would assure production of numbers of adults similar to those produced by the present program.

The primary enhancement opportunity is afforded by creating additional habitat for naturally rearing coho salmon and cutthroat trout in an actively or passively created wetland.

Criteria

Fish Passage. The design criteria listed in this section are based on the assumption that adult salmonids must have upstream access to the river at all times of the year. Juvenile salmonids must have free access within the middle basin.

If designs require diversion of flows, passage for adults will be required at the diversion structures. Providing passage with a fish ladder should be a routine design problem. Assuring appropriate attraction flows at the fish ladder may be more problematic if a large proportion of water is diverted during a period of upstream migrating for adults.

Depending on lake levels, a bypass channel may be needed between a fish ladder on the diversion structure and the ponded level of the lake. If bypass channels are required, they should also be designed to pass adult salmonids during most times of the year.

An additional concern relative to fish passage is the configuration of the outlet of the wetland to the lake. If flows are too concentrated at the outlet, adult salmon will be attracted into the wetland during their upstream migration. This could lead to delay or stranding of upstream migrating adult salmon. If the wetland outlet is separated into several outlets, adults will be more inclined to continue upstream to the bypass channel. Such a solution for adult passage would, however, conflict with the need to convey smolts through the wetland (see below).

Smolt Stranding. Downstream migrating smolts could be diverted into wetlands and either stranded or subjected to higher rates of predation. The species most likely to be affected is coho salmon. As many as 100,000 wild coho smolts migrate down the river each spring.

The stranding issue for a wetland that includes diversions is more difficult than for an average project involving temporary inundation of a detention pond or riparian wetland. In the typical case, rearing fish are subject to stranding as water levels drop after relatively infrequent storm events. With diversions, smolts could be diverted into a wetland with the flow.

Several options exist for reducing the potential for stranding smolts. These include screening, time restrictions on diversions, and providing transportation through the wetland.

Screening the diversion is not expected to be a cost-effective option due to the large volumes of water being screened, and not acceptable from a regulatory perspective. Further, clogging of screens would likely to be a serious problem.

The most effective way to minimize stranding would be to minimize the numbers of fish diverted into the wetland by reducing the volume diverted or changing the season of operation. The potential for stranding in wetlands will be proportional to the volume of flow diverted. Fish will likely be diverted in similar proportions to the flow. Stranding would be minimal outside of the the mid-March to early June time frame.

Another approach would be to configure the wetland so that the diverted fish can easily be conveyed through the wetland and are not directed into shallow water. A wide deep channel (minimum depth about 5 feet) or open-water wetland with perceptible velocity (>0.10 fps) is desirable to collect and convey the bulk of the smolts through the wetland. To minimize stranding, the emergent wetlands should have areas with a large proportion of standing water with abundant cover and a minimum depth of about 1 foot. Open water areas should be connected by channels to allow ingress and egress. Standing water would have to persist until about early June to allow for emigration of smolts. Egress channels connecting the standing water could be small (3 feet wide by about 2 feet deep) if overhanging vegetative cover is abundant and the distance is short (<100 feet). If cover is sparse or the distance is long, the channels should be a minimum of 3 to 4 feet deep with steep sloped sides, to minimize predation by wading birds. These features in conjunction with some control of the time of diversion would likely be sufficient to get most of the smolts through the wetlands without experiencing high mortalities.

Rearing Area Requirements For Chinook Salmon. For this analysis, it was assumed that the upper range of the existing level of stocking (eight million fry) must be maintained within the system. Possible solutions could range from replacing or providing a rearing area equal to that under the present program to intense hatchery culture of fish. The following area criteria for chinook fry were determined in consultation with staff of the WDF Hatchery Division (P. Seidel, pers. comm.).

Hatchery Culture. Based on WDF criteria, two acres of pond would be needed for an intense hatchery operation in an earthen pond. This would require capital expenditures and maintenance including cleaning of fish waste from the bottom of the pond and the construction of a waste treatment facility. It is unlikely that such a facility would be compatible within a wetland due to overall level of activity at such a facility.

Net Pen Culture. Two types of net pen culture operations could be considered to replace the present program: salt water pens, or pens in the lake. Either option would entail major capital and operating expense. The use of net pens in the lake would be difficult due to the lack of depth (10 to 12 feet is about minimum) and the currents (P. Seidel, pers. comm.). Saltwater pens for chinook fry have recently been used by WDF with good success. However, to replace production of eight million fish would require about 160 pens (assuming 50,000 fish per pen) over six to eight acres, an operation three to four times larger than the current WDF tribal program near Squaxin Island.

The numbers of fish required for rearing and the size of the facility could be reduced by shifting from releasing chinook fry to a program focused on yearlings. The reduction would be possible because the yearlings survive to adulthood at a much higher rate than do the fry; therefore, fewer fish would need to be reared to contribute the same catch of adults. Such a shift would entail additional political concerns because the adult fish from these programs tend to contribute to different fisheries depending on the length of the rearing period. Specifically, fish reared to the yearling stage tend to contribute to sport fisheries within Puget Sound, while fish released earlier contribute to fisheries outside the sound. The WDF currently has tagged groups of fish in the ocean (the bulk will return to the fishery by 1991) from fry operation in Capitol Lake and the yearling program at Squaxin Island. Data from these tag groups would allow calculation of the number of yearlings required to replace the present production. Even with a switch to a program focused on yearlings, the operation would be a substantial effort.

Semi-natural Rearing. For the semi-natural concept, 20 to 25 acres of pond would be needed. This acreage requirement is based on an area equivalent to Percival Cove, which in the past was used to rear about six to nine million chinook fry. The WDF encountered serious predation problems by birds at that level of stocking in Percival Cove because raising of fry began immediately after release of the yearlings that had been raised in the cove for six months. The birds stayed well into spring to feed on the fry after learning to feed on the yearlings, rather than leaving the area about mid-April. Predation would likely be much lower with a fry-only program where timing of fish stocking (after mid-April) could be controlled.

With the present program, the WDF gets its best visible feeding response from fish near the I-5 bridge at the south end of the middle basin. An interesting feature of the present rearing program is that chinook fry are not constrained to stay within the feeding area or the lake. Further, the success of the program is dependent upon the fry feeding long enough that their survival during their early marine residence period is maximized. The WDF's success with feeding at that site may be related to flow conditions at the site (the river current is likely still perceptible at that point) and the natural feeding behavior of chinook fry, which typically rear along the margins of large rivers prior to emigrating to the ocean. Any semi-natural rearing program associated with wetland creation would need to be designed to either contain the fish within an area, or provide conditions that encourage fish to stay. Chinook fry appear to prefer moderate velocities rather than still water (Bovee 1978). A slight water velocity (0.1-0.25 fps) is probably desirable for encouraging the fish to stay and feed.

The rearing area should be maintained at a depth similar to the current depth of the middle basin (about eight feet) to provide some protection from avian predators.

It may be feasible to incorporate a semi-natural rearing concept directly into a wetland design, but waste build-up may pose problems for fish and water quality.

In general, either intense culture or a 20- to 25-acre feeding operation would likely provide greater benefits than the existing program conducted by the WDF. Presently, it is not known how many chinook fry actually stay in the lake for the rearing period. A large portion likely leave the lake immediately after stocking and receive little benefit from the feeding program. Several alternatives may exist—for example, with a smaller area and more control over the fish, fewer fry may be need to be raised to yield the same return as presently.

Flow requirements for rearing the fish were not calculated. It is expected that no flow limitations would occur during the spring. However, isolated pockets of poor water circulation could eliminate some areas of open water wetland from providing rearing space for chinook.

Natural Rearing in the Wetland

Coho salmon and cutthroat trout would benefit the most from the creation of high quality rearing habitat (natural, no feeding) in the wetlands. A mixture of open water ponds with seasonally inundated wetlands that provide complex cover would be desirable to provide habitat for coho fry and all life stages of cutthroat trout. Ponds would need to be connected with small, well vegetated channels (minimum three to five feet wide by two to four feet deep with steep side slopes) to provide effective passage and protection from avian predators. In general, few fry would be stranded while rearing if water level fluctuations were minimized and levels were dropped slowly.

Depth and water velocity preferences are presented below for several species based on Bovee (1978).

	Coho Fry	Juvenile Cutthroat
Depth (ft)	1-5	1-5
Velocity (fps)	0-1	0-3.0

If cover, depth, and velocity criteria are met in the open water wetlands, the quality of the habitat (on a unit area basis) will be improved over the existing conditions. However, it is not known at what point the loss of lake area would negate the increase resulting from creation of wetland.

Feasibility/Impact Evaluation for Fisheries

Concept I - River Delta Freshwater Wetlands. Few fish-related concerns arise with Concept I. The proposed saltwater control weir would not create any fish passage problems. No stranding concerns are expected. Over time, the area available for raising chinook salmon would decrease, but a noticeable effect is not anticipated until many years in the future. The fish habitat that would develop along the depositing river bars would be suitable for chinook salmon, but it is likely that this habitat would not be used to an appreciable extent since there are no wild spawning chinook in the system and those fed by the WDF would likely be fed downstream from the new river bars. Overall, this alternative would lead to a slow reduction in habitat within the lake for chinook. For species other than chinook, the wetland habitat resulting from this concept would be of higher quality than the existing rearing habitats in the lake. The species which could benefit the most are coho salmon and cutthroat trout. However, coho do not appear to make extensive use of the lake for rearing under present conditions. The present use by cutthroat trout is hypothesized to be high, but documentation is lacking.

Concept II - Diked Freshwater Wetlands. A fish passage concern would arise for Concept II at the diversion structure. However, a fish ladder should be a routine design consideration at this diversion. In general, fish passage concerns will probably not be the controlling issue relative to the proportion of water that can be diverted into a wetland, except during the early fall (early September) when flows are low and adult fall chinook attempt to ascend the Deschutes River. Instead, stranding of smolts during their downstream migration will be of greater concern. The potential for stranding of coho salmon smolts appears to be the most serious fisheries constraint for this project. It will likely be very difficult to define an acceptable solution to the stranding problem if the proposal involves diversion of substantial (> 15 to 20 percent) portions of the river flow during periods of smolt out migration. If criteria relative to timing of diversion and configuration of the wetland are incorporated into the design, few smolts should be adversely affected.

The present rearing program for chinook salmon would be displaced at some point during the project. Alternatives likely exist for creating a semi-natural rearing program of less than 20 to 25 acres. The key to designing an effective program would be creating conditions that will encourage the fish to remain. It is likely that the results of the present program could be replaced by feeding one to two million chinook for a known period of time, rather than feeding eight million for an unknown period. In such a case, area requirements could be reduced from 20 to 25 acres to 5 to 6 acres.

Creation of the wetlands would improve habitat for coho and cutthroat on a per area basis. It is not known at what point the filling of the lake to create a smaller area of wetlands would lead to a net loss of habitat. Based on professional judgment, such a wetland would be two to three times more productive than an equivalent area of lake.

As with Concept I, the benefits of the increase in habitat associated with Concept II are dependent on the level of use by coho salmon and cutthroat trout.

Concept III - Estuary Salt-tolerant Wetlands. Under Concept III, fish passage, and stranding would not be issues. As with Concept I, the chinook rearing program would continue until a point in the future when habitat area would probably decrease. Concept III could affect the rearing program in two ways. First, fry could be flushed out or motivated to emigrate during the ebb tides. Second, the chinook fry might experience greater mortality at stocking than they do at present due to shock from the partial salinity; however, the WDF has had acceptable mortalities (ten percent) for fry transferred directly to Puget Sound (salinity about 27 parts per thousand). There could also be benefits to the rearing program if prey resources for chinook increase under this alternative. It is expected that the epibenthic organisms used by small chinook during their early life history would increase in abundance.

Adult sea run cutthroat (in the saltwater adapted stage) would likely use the area, but use by presmolt juveniles would decrease, as would use by coho. The effects on coho are expected to be small due to the present small level of use in the area; however, the benefits for cutthroat are more difficult to gauge because the level of present use is less well understood.

The estuarine alternative could affect the present WDF program of capturing adult chinook salmon at the outlet of the north basin. Capture would be more difficult if large numbers of fish entered the lake via the floodgate during flood tides. Chinook could still be captured at the fish ladder near the Brewery; however, the quality and value of the fish might be much lower after they have entered freshwater. Acceptable means and locations of capture could probably be identified if implementation of this concept affected catches.

Unlike Concepts I and II, dramatic changes would occur to the fish and invertebrate fauna in the lake. The freshwater fish community, other than the salmonids, would be replaced by more euryhaline species. Examples include: Starry flounder (*Platichthys stellatus*), English sole (*Parophrys vetulus*), shiner perch (*Cymatogaster aggregata*), sticlklebacks (*Gasterosteus aculeatus*), snake prickleback (*Lumpenus sagitta*), and sculpins (*Cottus sp. and Leptocottus armatus*). Few of the new marine species are expected to have significant recreational value.

The abundant crawfish would decline and possibly be replaced by marine crustaceans. Various species of clams, crabs, worms and other invertebrates may also become established. However, the environment may be unsuitable to allow establishment of substantial populations of bivalves or crabs that are of direct interest to humans.

Insect, Noxious Weed, and Disease Control

The Washington State Department of Health, the WDOE, the King County Department of Health, the Environmental Protection Agency Water Division, and Metro were contacted to assess the potential impacts of Concepts I, II, and III on insect and disease control. All of the above agencies agree that there will be an increase in the mosquito population if either Concept I or Concept II is selected. This increase should not effect public health and welfare, but only create a nuisance to users during the summer months when the lake is most actively used. Mosquitos on the west side of the Cascades do not carry any diseases that pose a hazard to humans.

Deer reside in the hills and valleys surrounding Capitol Lake (L. Baum, pers. comm.). These deer have been sited drinking and eating at Capitol Lake in the late evening. If a wetland were to be created in the middle basin, that would be an increase in deer habitat and food. This new habitat could lead to an increase in deer around Capitol Lake, which could increase the amount of ticks in the Capitol Lake area. Some deer ticks have been found to carry Lyme disease which is a health problem to humans.

Avian botulism can occur wherever birds—particularly waterfowl—are subjected to shallow warm water and anaerobic sediments. Conditions which promote botulism include shallow water depths, lack of flushing, alkaline soils, decomposing vegetation, high aquatic insect populations, and heavy bird use during the period from late July through mid-September.

The three concepts are fairly similar in terms of their potential for creating conditions suitable for avian botulism. Overall, botulism could occur under any concept, but is not expected to be a serious limitation of any of the concepts due to the timing of waterfowl use and regular flushing. Concepts II and III would involve more regular and predictable flushing and might entail less risk than would the Concept I.

A control program for purple loosestrife was conducted in Capitol Lake during the summer of 1990 (Zugner, pers. comm.). The program included chemical and mechanical control at a cost of about $13,000. A concerted effort of weed control for three to four years would likely be necessary, including continued use of herbicides, to control this noxious weed. An annual effort costing up to $25,000 per year for four years could be necessary. Efforts would also need to be focused on the area upstream of the south basin to eliminate known seed sources.

Under both freshwater wetlands concepts the loosestrife control program will need to be intensive to avoid invasion by this species. Under the estuarine concept, less area would need to be treated, but a control program would be needed to protect the freshwater wetlands that are expected to occur in the south basin and Percival Cove.

PHYSICAL PARAMETERS

Topography

Introduction

Topographic constraints for wetland establishment within Capitol Lake are dictated by available land area, water surface elevation and fluctuation, soil type, fisheries concerns, and vegetation type. As long as the hydrologic and soil regimes necessary for plant growth are met, wetlands can be established on a wide variety of slopes. Freshwater wetlands in their natural state occupy land forms with slopes ranging from totally flat to slopes slightly steeper than 4:1 (horizontal:vertical). Wetland establishment on steep slopes is limited by the potential for soil erosion and the lack of permanency of water. No specific information equating wetland type and land slope is available. The more productive wetlands appear to be established on flatter slopes, where smaller grained particles which are associated with nutrients are not continually flushed from the wetland. Completely flat land, however, results in a system where nutrient import and export is minimized by the lack of inflow and outflow. Zero gradient wetlands also present fish stranding problems, particularly if water level fluctuations occur.

Open Water

In order to maintain open water areas, water depths must be great enough to prevent the establishment of vegetation. In general, water depths of greater than 3 feet have been shown to preclude growth of most emergents. To achieve this, steeper side slopes than those present in the surrounding wetland are preferred within open water areas. The maximum steepness to prevent soil erosion on the sideslopes is dictated by soil type and water level fluctuation. Most local soils are susceptible to erosion when exposed at slopes steeper than 3 or 4:1. When factoring in the increased erosion potential brought on by water level fluctuation, it is recommended that slopes within open water areas be 5 to 8:1. The upper regions of the slope should be flattened to ease wildlife access and vegetation establishment.

Emergent Wetland

In general, emergent wetlands occur in low gradient landscapes. Although some slope is desirable to allow water and nutrient inflow, grades are usually flat enough to allow deposition of fine grained material responsible for transport of many nutrients. These flatter gradients also increase the contact time between the wetland substrate and the soluble nutrient fraction carried within the water column. As water quality functions of the wetland are a major concern, slopes which maximize pollutant removal should be considered. Research concerning vegetated swales for pollutant removal recommends slopes between 25 and 50:1. Completely flat gradients, however, limit the nutrient flux within the wetland and also tend to cause fish stranding problems, particularly if water level fluctuations are common. Given these criteria, slopes within the emergent portion of the wetland should be no steeper than 15:1, and could be as flat as 50:1.

Scrub/Shrub Wetlands

Scrub/shrub communities are less vulnerable to water level fluctuations than are emergent communities (Walters et al. 1980). Given this, these plant communities can be located on steeper slopes than those favored by emergent communities. The maximum steepness is dictated by the availability of water and the potential for soil erosion. Assuming that the proper hydrologic regime can be achieved, vegetated slopes no steeper than 5:1 could maintain healthy scrub/shrub communities without significant soil erosion problems. As long as the other concerns are addressed (fish stranding, water movement, etc.) there appears to be no lower limit as to the slope requirements of these communities.

Estuarine Wetlands

Estuarine wetlands are very sensitive to slope. Our experience indicates that slopes of 20:1 and flatter are probably the best for establishment of estuarine wetlands, unless there is a high degree of protection from wave action. A slope of 15:1 should be considered about a maximum for a protected area. The existing slopes in the south and middle basins meet this criterion, and new slopes formed by subsequent deposition in this area are expected to be similar. Slopes and elevations in the north basin are not expected to be suitable for estuarine wetlands in the foreseeable future.

Feasibility/Impact Evaluation

Concept I. For Concept I, which allows natural deposition of sediment in the middle basin, the primary topographic constraint would be the steepness of the slope on the leading edge of the deposition zone. This area would presumably achieve a slope similar to the angle of repose of the sediment. This slope would likely be too steep to establish wetland plants.

Concept II. Under the diking and filling scenario (Concept II), the design criteria previously discussed for each of the wetland types are applicable.

Concept III. Slopes appropriate for establishment of estuarine vegetation presently exist in the south and middle basins. Establishment of wetland vegetation increases deposition in those areas and hastens the evolution of greater areas of vegetation.

Conclusions

Topographic design criteria for successful wetland establishment are secondary to other factors influencing design, except for the estuarine alternative (Concept III). Of primary concern is the achievement of elevations which allow proper soil saturation and inundation. If this can be achieved, and slopes are not so steep as to cause erosion, the topography of the site is of minor importance. The desired topography is often driven by the goals of the project. If water quality is the goal, relatively flat, uniform slopes are preferred. If wildlife habitat is a primary concern, undulating topography with variable slopes and ground elevations which promote vegetation diversity is desirable. If fish habitat is a component of the wetland, open water channels and ponds with overhanging vegetation and steep side slopes are needed. Therefore, it is necessary to prioritize the goals of the project before decisions concerning topography are made.

Soils

Introduction

The following section applies only to freshwater wetlands. Soils requirements for estuarine wetlands are less well understood than for freshwater systems; however, estuarine wetlands at the mouths of all the major river systems of western Washington developed on river-transported sediments similar to those present in Capitol Lake. Therefore, it is expected that the sediments that are deposited in Capitol Lake would also support an estuarine wetland.

Wetland (hydric) soils are defined by the Soil Conservation Service (SCS) as soils that in their undrained condition are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation. Wetland soils can be generally classified into mineral and organic soils. Mineral soils have less than 20 to 35 percent organic matter on a dry weight basis. Many factors combine to produce a suitable wetland soil; quantification, however, of these factors is not possible in most cases. In general, wetland soil parameters can be divided into physical and chemical factors.

Physical Factors

The primary physical soil factor for mineral soil is soil texture. Soil texture, or particle size composition, influences many of the other physical factors and some of the chemical parameters of the soil. Texture, however, has not been the focus of wetland soil research. It has been documented that wetland plants grow well in a wide variety of textures (Mitsch and Gosselink 1986). Loam soils (10 to 30 percent clay, 30 to 50 percent sand, and 30 to 50 percent silt) appear to be the best soils (Disraeli and Fonda 1979; Mitsch and Gosselink 1986). Heavy soils with over 50 percent clay tend to limit root penetration and should be avoided. Similarly, coarse textured soils (gravels and sands) should be avoided because of their lack of nutrients and inability to hold sufficient quantities of water, particularly during drawdown. In areas where newly established plants are subject to floating out of the planting surface, sandier soils have been shown to provide a more stable planting medium. It is therefore recommended that sandy loams be used in areas where prolonged inundation and/or moving water may be present.

Although peaty organic soils support wetland plants, they are not the preferred wetland soil for wetland creation. Physically, these soils possess a loose soft texture which, upon inundation, provides inadequate support for planted vegetation (Allen et al. 1989). In addition, these soils are susceptible to erosion.

In summary, not enough is known about the needs of individual hydrophytes or plant communities to make specific recommendations for establishment of emergent versus shrub communities. Research has shown that as long as the textural extremes are avoided, i.e., gravels or clays, and hydrologic considerations are met, wetlands can be established in a wide variety of soil types.

Chemical Factors

The individual chemical reactions which occur in wetland soils have received considerable study. Unfortunately, interactions among the different individual reactions are poorly understood. Chemical characteristics vary widely among wetlands, and within the same wetland throughout the year. Because of this, design criteria for specific plant communities are not available. Some data are available which define chemical conditions within existing wetland systems. In general, the principals and levels utilized in standard landscape practice are applicable to created wetlands. Highly organic soils should be avoided because although they generally have high levels of nutrients, the nutrients are often unavailable to plants because hydrogen ions occupy action exchange sites. These soils can also possess pHs too low for many plant species.

The primary chemical factors which should be considered in wetland creation are pH, action exchange capacity (CEC), and nutrient (nitrogen and phosphorus in particular) content. PH is usually between 4 and 6.5. Local experience has shown that low pHs, below 4, can lead to plant mortality. CEC varies tremendously in wetland soil; organic soils have high CECs, but the exchange sites are dominated by hydrogen and many of the nutrient cations are unavailable to plants. Mineral soils usually possess a much lower CEC, but the sites are dominated by the major cations. Wetland soils generally possess CEC values ranging from 15 to over 100.

Design criteria for nutrient content have also not received much study. Soils to be used in wetland creation should be tested for macro nutrients by a suitable plant laboratory and levels should be compared to those expected for vegetation species with known nutrient requirements. Unless the soil is considered sterile, silty soils should contain enough essential nutrients to ensure plant growth. It should be noted that the chemical reduction which occurs upon saturation of mineral soils increases the availability of macro nutrients. Nutrient supplementing of wetland soils has not shown to dramatically increase growth except when coarse grained or nearly sterile soils are used. Soils suspected of having been exposed to toxics should be tested or not be used.

Soil Preparation

If soil needs to be imported to achieve appropriate elevations, certain procedures should be followed to ensure that soil is appropriate for planting. Transport of loam and organic soils can result in structural changes to the soil which may affect nutrient availability and water storage capacity. In general, the less the soil is handled, the better the resulting growth medium. Careful handling can also preserve seeds, tubers, and plant parts within the native soil which may become established in the created wetland. Subsoils excavated for import should be tested due to the possibility of low nutrient content.

Prior to placement of soils, some studies have found that oxidation of wetland soils followed by inundation increases nutrient availability (Southern Tier Consulting 1987). This can be accomplished by temporarily stockpiling soils prior to placement in the created wetland. When placing the soil, care should be taken to achieve an overall density similar to undisturbed soils of the same texture. Over compaction by machinery can cause root penetration problems, while excessive tilling can destroy structure or produce high soil pore to solid ratios.

Once soils are placed and final grades achieved, a waiting period should be observed prior to planting to allow the soils to stabilize. The length of this period will vary depending on a number of factors, primarily soil texture. Organic and heavy texture soils tend to expand and contract during the first few months following placement. Prior to planting, pH measurements should be taken from the soil profile to ensure that movement and exposure to oxygen have not altered soil acidity significantly.

Feasibility/Impact Evaluation

Concepts I and II. Research regarding specific soil criteria to ensure the success of created wetlands is in its infancy. Most of the studies which considered soil factors did so as a minor aspect of the overall wetland creation. The limited amount of information available suggests that fertile topsoil without excessive amounts of clay or coarse material is the most ideal planting medium for wetland plants. If this general recommendation is followed, the precise soil make-up appears to be far less important than achieving the appropriate hydrologic regime and selecting proper plant materials.

In general, the soils available in the middle basin appear to possess physical properties appropriate for wetland establishment. Nutrient levels also appear to be within an acceptable range. Lead and copper levels may be above those typically found in wetland soils, perhaps as a result of urban stormwater runoff contributions to the lake. Additional testing and data comparison is necessary to allow a complete assessment. Soils in the south basin are coarser than those found in most wetlands and are not considered ideal for wetland establishment.

Wetland Circulation

Introduction

Wetlands are maintained by surface water or high groundwater regimes. Flowing surface water will be the most dominant source in Capitol Lake. Studies have shown that wetlands in nonflowing (stagnant) conditions have low productivities and that wetlands that are in slowly moving strands or are open to flooding rivers have high productivities (Brinson et al. 1981; Mitsch and Gosselink 1986).

Principals of Wetland Hydrology

Wetland hydrology has an effect on chemical and physical aspects of wetlands. Four basic principals apply:

1. Hydrology leads to a unique vegetation composition but can limit or enhance species richness;

2. Primary productivity in wetlands is enhanced by flowing conditions and a pulsing hydroperiod and is often depressed by stagnant conditions;

3. Organic accumulation in wetlands is controlled by hydrology through its influence on primary productivity, decomposition, and export of organic matter; and

4. Nutrient cycling and nutrient availability are both significantly influenced by the hydrologic conditions (Mitsch and Gosselink 1986).

Water in natural riverine wetlands is typically distributed through a series of braided channels, back waters and side channels. Flow varies seasonally based on runoff and precipitation. Vegetation growing within wetland areas adjacent to these channels is adapted to the variability in water availability. Because wetlands are dynamic systems, the location and volume of water moving through natural wetlands varies with the change in channel morphology, elevations, and the quantity of water.

In artificial or "managed" wetland systems such as waterfowl refuges, water levels and circulation are established and controlled through the use of canals, tide gates, check dams, diversion structures and levees. Wetland areas are managed as "units", with water distributed according to the overall management objective for those units. For example, the timing, duration, and depth of flooding on shallow emergent flats that provide fall and winter food for migratory waterfowl differs from water management on deep openwater and emergent marshes designed to provide nesting habitat for water birds and diving ducks.

Water distributed to artificially created wetland systems can be through a series of diversion channels and ponds, or as a "sheet flow" across emergent flats or a combination of these. Ideally water is distributed using gravity or tidal conditions. At Capitol Lake, it is assumed that water will be diverted at the south end of the middle basin using a diversion structure that will allow a portion of the Deschutes River flow to enter wetland cells located along the western portion of the middle basin. Water from the diversion structure could be conveyed into the wetland via a channel. Water from the channel could then be distributed via a "manifold" system to provide sheet flow, and through channels connecting to deepwater ponds. The ponds must include both inlets and outlets to provide passage for juvenile fish. Water would then "discharge" from the wetland at the north end of the middle basin.

Feasibility Impact Evaluation

Hydrology is perhaps the single most important factor in natural and created wetlands. Water moving through natural wetlands causes changes in channel morphology (due to scouring and deposition), elevations, and the location and quantity of water.

Water in created wetlands can be more tightly controlled but factors such as fish passage and potential stranding and water quality improvement are more critical.

Concept I. It is assumed that Concept I would have adequate circulation and water movement to maintain wetland vegetation. This concept will probably not provide sufficient emergent vegetation to allow for substantial water quality improvement, particularly during the early years of development. As time progresses, and the middle basin is filled, the river will become increasingly channelized and wetland treatment benefits will progressively diminish (refer to the water quality discussion on page 65).

Concept II. With Concept II there would be no insurmountable problems in terms of providing adequate circulation to support wetland vegetation. However, this concept would involve special circulation considerations. One of the most significant potential advantages associated with Concept II would be the ability to regulate and control circulation to maximize hydraulic short-circuiting and maximize water quality treatment benefits. This would require the construction of a flow diversion structure in the vicinity of the I-5 bridge, a structure that would divert a significant portion (90 percent) of low flows from the river channel into and through the wetlands. Depending on the method of construction, this structure could cost anywhere from $1.25 to $4.0 million. Unfortunately, the hydraulic loading rate (the amount of river water requiring treatment per unit of wetland surface area per unit time) is too great for the potential wetland treatment area. This is one of the principal reasons why the study team has concluded that Concept II is not feasible.

Concept III. Under Concept III, circulation would be effectively provided by tidal flushing. It is assumed that the tide gate controls could be modified to allow saltwater inflow between elevations 3.43 and 6.43 MSL on the incoming tide. Preliminary calculations indicate that such tidal flushing will result a water regime dominated by saltwater, with saltwater representing anywhere from 60 to 90 percent of lake volume between April and September, depending on the magnitude of river flows. Although the lake could be lowered even further to provide even greater saltwater flushing, increasing amounts of sediment surface would be exposed with potential adverse aesthetic and odor impacts. Tidal drawdown to 3.43 MSL would only expose about 20 to 30 shoreline acres, primarily in the southwest portion of the middle basin.

Increased sediment exposure would also represent an increased public safety risk. People could be tempted to walk out on exposed sediments and could become stuck in the muddy silt type sediments that occur in some locations. This problem could be mitigated by posting the shoreline with warning signs.

Lake Circulation

Unless the project includes measures to improve circulation in the north basin, existing poor circulation is expected to continue along the far east and west shorelines. Thus, any water quality benefits derived from wetland treatment would not necessarily be reflected in the vicinity of the former City of Olympia swimming area. Improvements in this situation could be made by providing an engineering solution for improving circulation along the eastern shoreline zone, or perhaps by constructing a swimming area closer to the point where good circulation exists in the vicinity of the railroad trestle crossing. Improved circulation to the eastern shore of the north basin (the site of the former public swim area) could be achieved by expanding Marathon Park and constructing a training groin similar to the one in the south basin.

A major design consideration relates to the need to maximize contact between wetlands and the water that flows through the lake (the better the contact the better the treatment efficiency), while at the same time providing adequate hydraulic capacity in a main channel high flows. Under the wetland Concept I it is anticipated that the river would meander across the middle basin as the basin began to fill with sediments and as sand bars were formed, similar to the present condition in the south basin. In general, it would be difficult to enhance water wetland interaction; the majority of flow, even during low flow periods, would tend to follow the main channel without substantial wetland contact. There might be engineering approaches for enhancing contact. Under Concept II (diked wetlands), some portion of the low summer (June-August) flow would have to be diverted into the wetland (the greater the flow diverted to the wetland, the greater the treatment potential, assuming adequate residence times - see the "Wetland Treatment Potential" discussion on page 70). Diking would have to be constructed so that a high flow channel would be maintained down the center of the basin (see figure 4). Flow diversion to the wetland might be possible by constructing a dam-type structure in the vicinity of the I-5 bridge (see "Wetland Treatment Potential" for related discussion).

Assuming the construction of a dam-type structure, a fish ladder could be constructed similar to the one at the tide gate structure in order to facilitate fish passage. It has been assumed that 10 cfs would be adequate flow to operate the fish ladder.

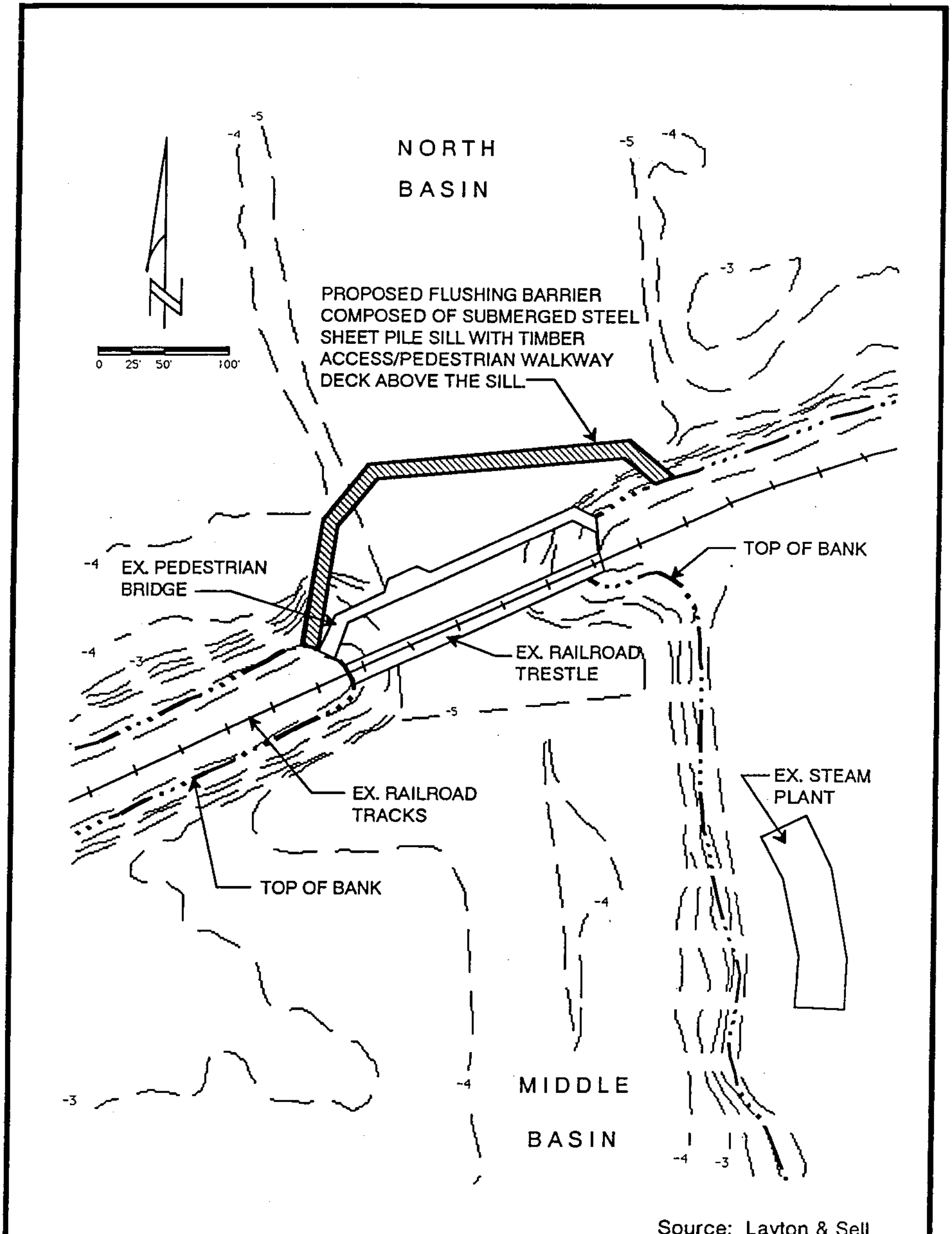
Refer to the previous discussion of "Wetland Circulation" for the proposed circulation issues associated with Concept III.

Saltwater Flushing

Under existing management conditions, saltwater is no longer intentionally used to control freshwater aquatic plants or algae. However, Capitol Lake is periodically drawn down, for maintenance and other related reasons, and refilled with saltwater. An important question is whether or not periodic (once every 1 to 3 years), temporary (influence lasting about 2 to 4 weeks) saltwater exposure would have any adverse impact on wetland plants. If there would be no significant impact, then there would be no need to provide saltwater control. This issue is primarily relevant to Concept I since saltwater would be excluded by the dikes under Concept II.

Saltwater control would be possible, if needed. One possible option would be to use tide gate management to preclude saltwater backfilling; thus, the lake would be filled with river water only. This procedure has the potential for adversely impacting water quality (dissolved oxygen levels) in Budd Inlet during the period of refilling, when the dilutional benefits of the river flow would be cut off. This impact could be lessened by drawing the lake down earlier during the year when river flows are higher and the refilling time is reduced. Whether this creates scheduling conflicts with drawdown objectives is not certain. It should be apparent that this approach would not be feasible if lake "bumping" is reinstituted as a means of plant and algal control in the north basin.

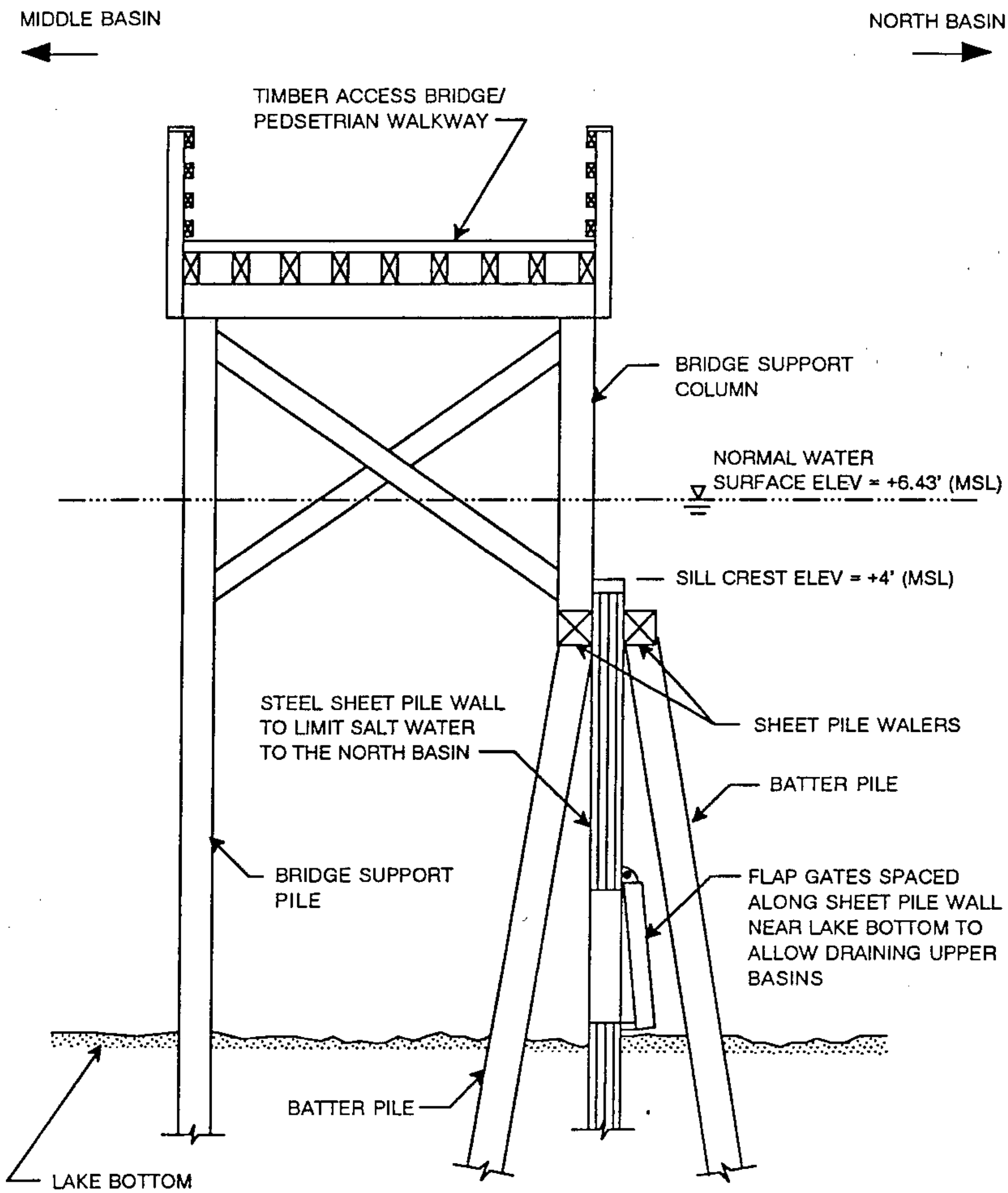
In the event that tide gate management is not a suitable saltwater control approach, it does appear that a sheet pile structure could be constructed just downstream from the train trestle crossing that separates the middle and north basins (see figures 8 and 9). This means of control would probably be cost-effective (costs have been estimated at $1.4 million) and feasible from an engineering perspective (refer to "Construction and Geotechnical Considerations", page 63). The sheet pile structure would probably have to be designed as a submerged weir with flap gates near the bottom that would allow the middle basin to drain during drawdown. Since the top of the weir would be located about 3 feet below the normal water surface elevation, fish passage would not be a problem.



ENTRANCO ENGINEERS, INC.

Figure 8

SALT WATER FLUSHING BARRIER LOCATION



SCALE: 1" = 5'

Source: Layton & Sell

Figure 9

SALT WATER FLUSHING BARRIER SECTION

The structure would have to be designed in a manner that would not interfere with the passage of flood flows (a dam safety permit may be required) and it would have to be designed to withstand the impact of logs, stumps and other debris. Most debris would probably be trapped by the railroad trestle as it is under existing conditions, however, some debris would probably make it to the sheet pile structure. During high flows water depth may be sufficiently deep that debris would not hang up on the structure. Debris removal will be required at least once per year and perhaps more frequently depending on the amount of debris material delivered by the river.

In order to insure proper design, additional geotechnical and engineering studies would be required.

Control of saltwater flushing does not apply to Concept III (see page 52).

Flood Control

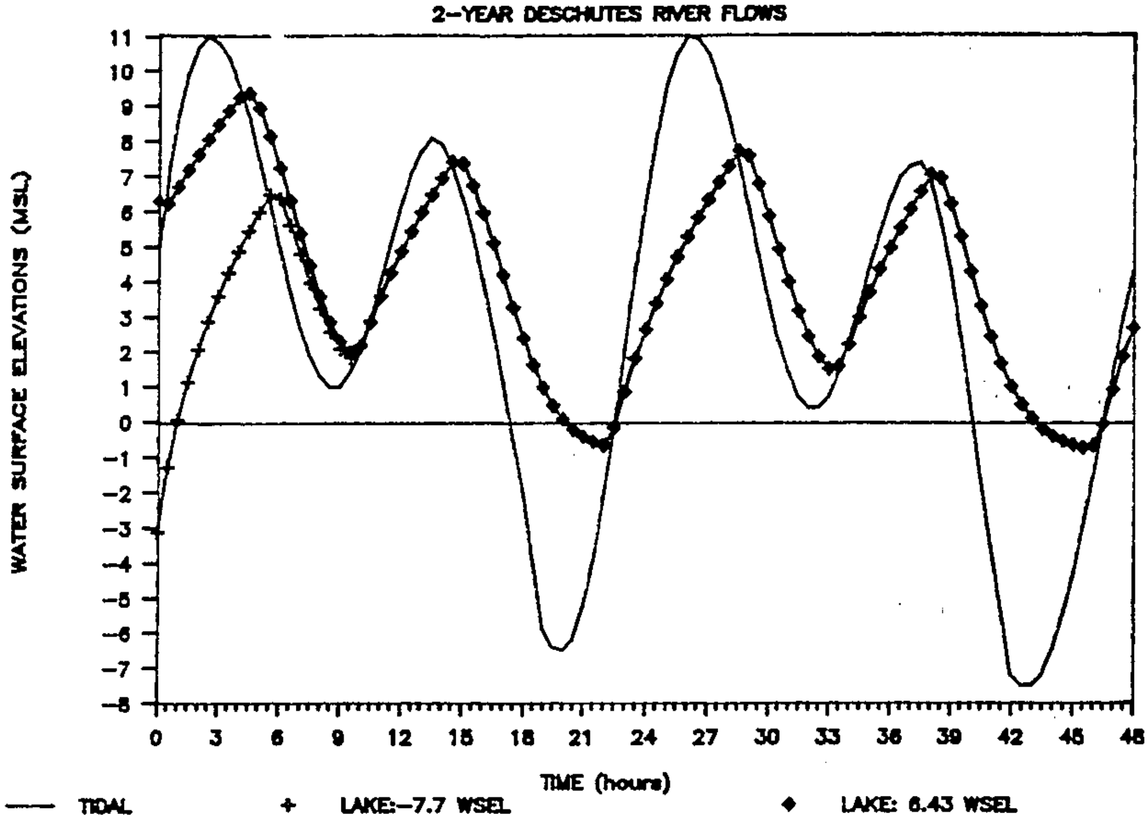
On the basis of preliminary flood impact analyses (refer to Table 2 and figures 10 and 11), it appears that flood storage capacity in Capitol Lake, even assuming total drawdown prior to flooding, provides relatively little flood control benefit during the 100-year flood. This is because lake volume is relatively small compared to the combined volumes of flood flows produced by the Deschutes River and Percival Creek. A preliminary computer model analysis indicates that the lake volume is consumed in only 2.8 hours and that peak lake elevations are controlled by corresponding tidal elevations. Once the normal lake volume is consumed, it continues to fill until it reaches an elevation about 1.5 feet higher than the tidal elevation. At this lake elevation there is sufficient head differential for the lake to begin to discharge at rates high enough to keep up with the rate of inflow. As indicated in table 2, the maximum lake elevation is only 0.46 feet lower (10.90 feet MSL) when the lake is drawn down all the way (-7.7 MSL), than the maximum elevation (11.36) that occurs if the lake is maintained at 6.43 MSL prior to flooding.

The model was also run assuming that the middle basin was filled to elevation 6.43 MSL, in order to evaluate the potential impact of wetland development. The results for the 100-year storm event indicated that the maximum flood elevation would increase by approximately 0.35 to 0.80 feet to elevations 11.70 and 11.71 (see table 2).

Table 2
Summary of Lake Level Data: Capitol Lake

Flow Condition	Maximum Tide Elevation (MSL)	Starting Elevation (MSL)	Maximum Lake Level (MSL) Existing	Maximum Lake Level (MSL) Middle Basin Filled	Change in Elevation (feet)
2-year Flow	11	-7.70	7.74	9.21	1.47
	11	6.43	9.37	10.23	0.86
100-year Flow	11	-7.70	10.90	11.70	0.80
	11	6.43	11.36	11.71	0.35

Figure 10
Tidal and Lake Levels,
2-Year and 100-Year Deschutes River Flows



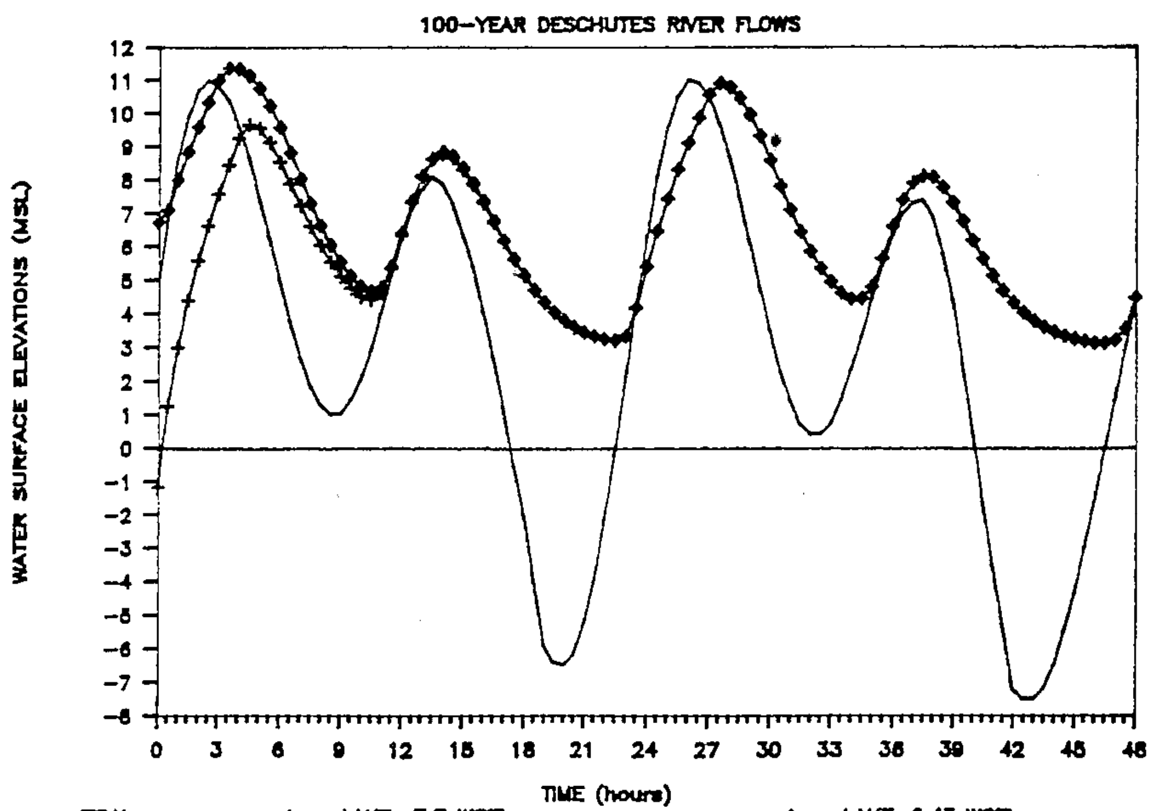
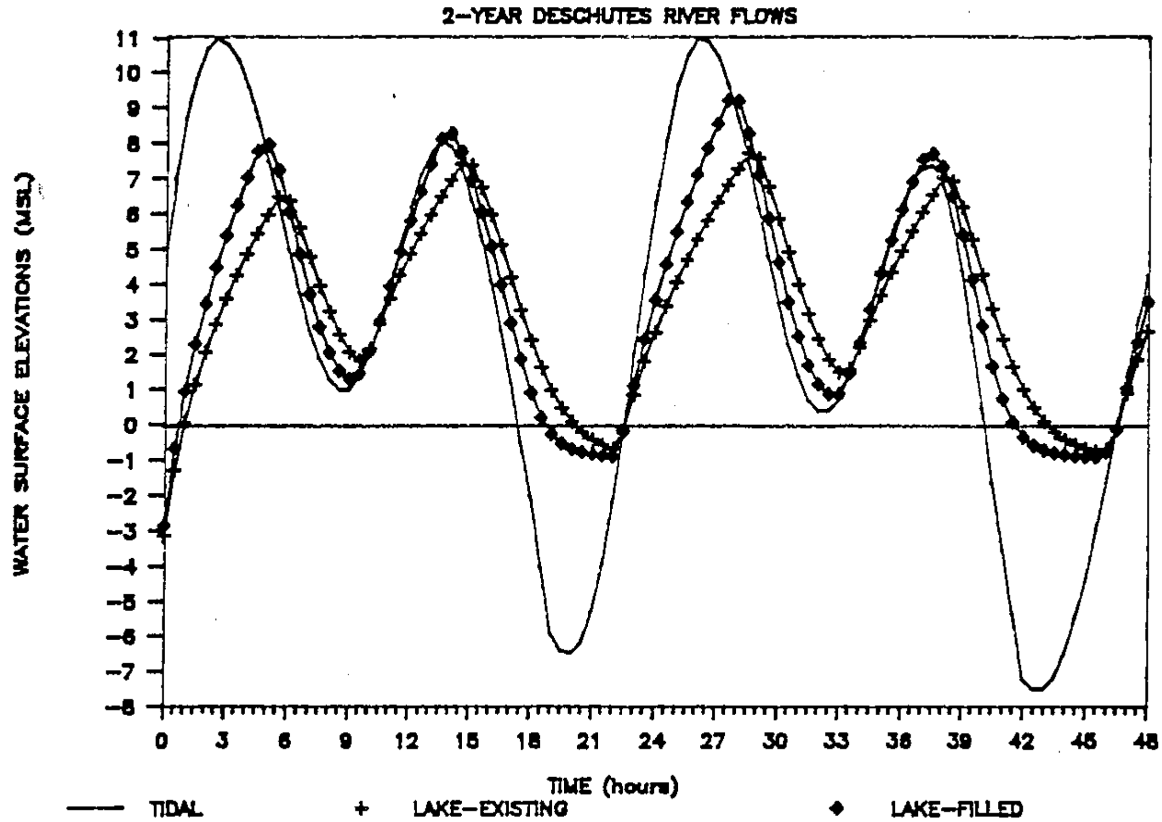
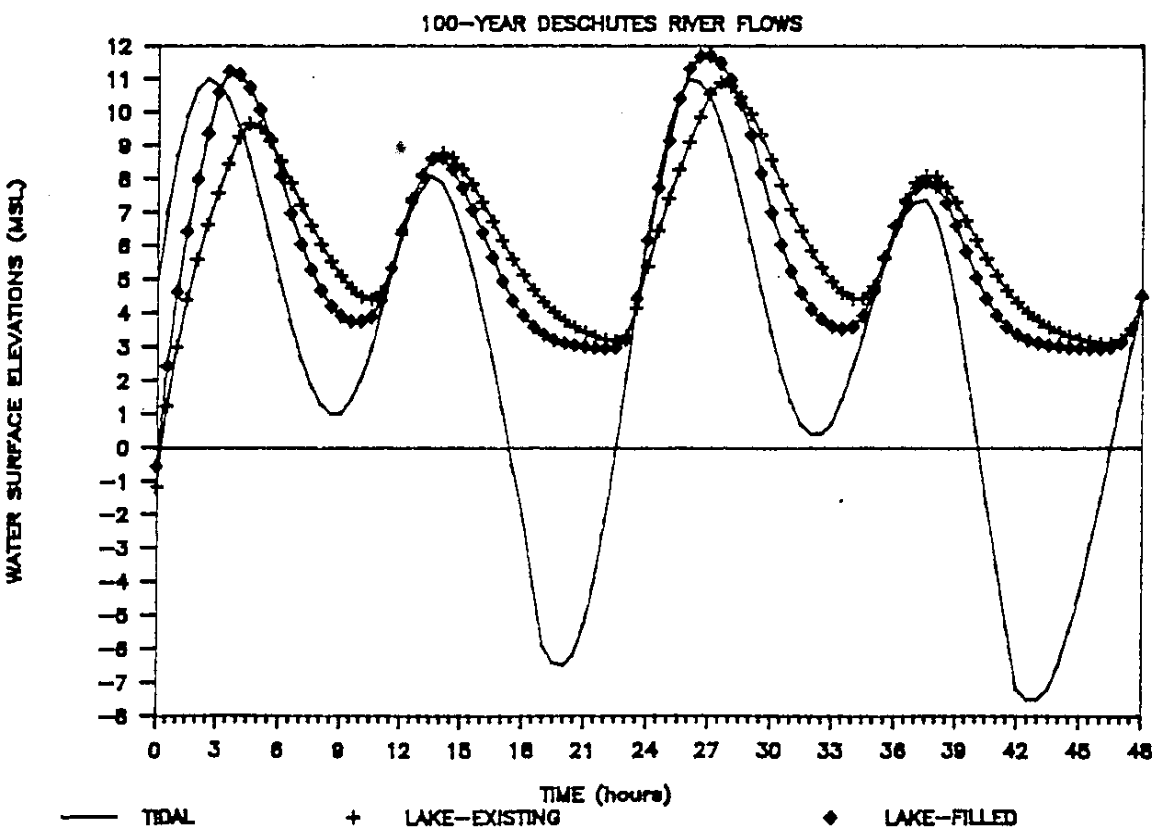


Figure 11
Comparison of Different Starting Water Surface Elevations,
2-Year and 100-Year Deschutes River Flows





The City of Olympia has estimated the 100-year flood elevation at approximate elevation 11.0 MSL, based upon federal flood hazard studies. During the recent January 9, 1990 flood, flood elevations in the City apparently reached elevations about 11.0 MSL. Flood damage occurred along Columbia and Water Streets as it typically does; however, flood damage was apparently not extensive.

Since Concepts I, II and III would ultimately result in filling of the majority of the volume of the middle basin, the potential flood impacts of the three concepts are expected to be similar. The increase in flood elevation of 0.35 to 0.80 feet is considered a significant impact when compared with existing flood elevations. Mitigation of potential flood impacts in the City of Olympia could be provided by constructing flood control dikes along the eastern shore of the north basin. This would require concurrent construction of underground detention storage in downtown Olympia and/or one to several stormwater lift stations. These flood impact mitigation measures could interfere with the proposed Heritage Park Plan and Capitol Lake Park Renovation.

Potential flood impacts of Tumwater Historical Park, in the south basin, could also be mitigated by dike construction. It should be noted that potential flood impacts in the south basin could be reduced with Concept III given the potential for high river flows to transport existing sediment deposits downstream into the middle basin during low tidal elevations.

Finally, it should be noted that structures located in the existing flood plain are already exposed to the risks of flood impact and damage.

Sedimentation Control

Introduction

Estimates of future sedimentation rates and lake basin filling rates have been calculated from historical data. Two fundamental concepts form the basis of the predictions:

1. The rate of sedimentation to the lake is highly variable over time and is affected by changing land use activities (e.g. forestry), by seasonal and yearly changes in precipitation and river/stream discharge rates, and other factors. This variability is reflected in the range of previous estimates of sediment loading rates to the lake—from 20,100 (Moore and Anderson 1979) to 54,800 cubic yards per year (Entranco Engineers 1984). Part of this variability is also attributed to different methods of estimation and sources of error associated with each method (refer to discussion, page A.19).

2. The rate of sedimentation and lake basin filling decreases in the downstream direction. This is due to the fact that coarse sediment particles, having greater volume, are the first to settle out as the energy of the Deschutes River dissipates upon entry to the lake. Finer particles, having less volume, settle out farther downstream. However, the rate of settling is also affected by basin size and hydraulic residence time. The larger middle and north basins have longer hydraulic residence times that give more time for small particles to reach the bottom and to settle out of the water column.

The rates of sediment accumulation derived by Entranco Engineers (1984) for each of the three basins was used as the basis for making future predictions. According to Entranco (1984), the rates of sediment accumulation in the south, middle and north basins over an eight year period were 10,400, 31,300, and 13,300 cubic yards per year, respectively. These rates are based upon the total lake loading estimate of 55,000. The loading to a given basin is expected to be proportional to the annual lake loading so that the sediment distribution would be 3,800, 11,400, and 4,800 cubic yards per year, respectively, for the south, middle and north basins for a total annual loading rate of 20,000 cubic yards per year.

Given the relatively small volume of the south (upstream) basin, and its relatively high sediment loading rate, it was assumed that this basin would be the first to fill. Dividing the south basin volume by the range of sediment accumulation rates gives a filling time estimate of 15 to 40 years (see table 3). During this same time frame the middle and north basins are also filling (at different rates) and volume is being lost at the rates initially indicated above. However, it has been assumed that once the south basin is filled, there is no net sediment accumulation in the south basin over time (some sediment may accumulate in low flow seasons/years and then be flushed to the middle basin during high flow seasons/years), and that sediment that was accumulating in the south basin is then transported to the middle basin. Thus, once the south basin is filled, the sedimentation rate to the middle basin increases by an amount equal to the former rate of sediment loading to the south basin (i.e. the middle basin sedimentation rate increases from the range 11,400-31,300 to the range 15,200-41,700 cy/yr). It is assumed, however, that the rate of sediment loading to the north basin is not appreciably affected until the middle basin begins to reach its filling limit.

Table 3
Estimated Time of Filling for Three Capitol Lake Basins Assuming Two Different Annual Sedimentation Rates

Sedimentation Rate	Estimated Time of Filling (years)		
(cu. yd. per year)	South Basin	Middle Basin	North Basin
55,000*	15	30	60
20,000**	40	85	165

* Entranco (1984) rounded to nearest thousand
** Moore and Anderson (1979) rounded to nearest thousand

Using these assumptions, another estimate can be made of the times required to fill the remaining middle basin volume at the higher sediment loading rates. These times are additive to the times estimated to fill the south basin and total 30 to 85 years (table 3).

Once the middle basin fills, the assumption is made that the sedimentation rate formerly applied to the middle basin subsequently becomes the filling rate to the north basin, and that sediment formerly deposited in the north basin subsequently gets transported to Budd Inlet.

These assumptions were made and calculations performed to estimate future sediment loading and basin filling rates.

Feasibility Impact Evaluation

Concept I - River Delta Freshwater Wetlands. As indicated in table 3 the south and middle basins would take 15 to 40 and 30 to 85 years, respectively, to fill, depending on variable river discharge and changing land use activities in the watershed. Filling is expected to occur progressively from the south to the north in the form of a river delta deposit in the middle basin with very gradual downgradient slopes. As the middle basin becomes more and more shallow, hydraulic residence times will decrease and there will be an increasing tendency for sediments deposited during low flows to be scoured, resuspended and transported downstream during high flows. This will occur primarily during winter months coincident with existing high turbidity and suspended sediment loading from the watershed, and will not have an appreciable adverse impact on aesthetic and or contact recreation uses during the spring, summer, or early fall period. This tendency will be offset to the degree that deposited sediments become stabilized by colonizing wetland vegetation. In its ultimate development configuration, the wetland will function as a floodplain area.

The sedimentation rate to the north basin is expected to approximate the sum of existing sedimentation rates to the south and middle basins (15,200 to 41,700 cubic yards per year), while the sedimentation rate to Budd Inlet would be expected to increase by an amount equal to the present rate of sediment deposition to the north basin (about 4,800 to 13,300 cubic yards per year).

Prior to complete filling of the middle basin, the cost of maintenance dredging (presently estimated at $12 cubic yard or $240,000 to $660,000 per year, depending upon the rate of sediment loading) would not be incurred. Once the middle basin was filled, or nearly filled, it would become necessary to resume maintenance dredging in the middle basin as a means of reducing the rate of sediment deposition to the north basin. It is assumed that the middle basin trap could be reconstructed at such time as the middle basin becomes full and that this trap would remove about 6,300 to 14,100 cubic yards of material per year. Even with the middle basin trap in place, the north basin would continue to accumulate finer sediment at rates of about 8,900 to 27,400 cubic yards per year. Thus, the north basin would also require maintenance dredging. Dredging would have to remove 20,000 to 55,000 cubic yards annually in order to keep pace with the rate of sediment loading to the reservoir. It is assumed that dredge spoils would have to be handled twice: once to remove them from the lake and deposit them in the middle basin dredge spoil disposal area, and once to transport them to a remote disposal site. These costs are crude estimates that should be refined with the development of a master dredging plan at the time that maintenance dredging is required. Obviously, the cost per cubic yard for future dredging will be higher as costs are affected by inflation and potentially more stringent environmental review and mitigation requirements.

Periodic maintenance dredging of the south basin would probably also be required. As the south basin fills in with sediment, flood impacts might become more severe in the vicinity of Tumwater Historical Park, and maintenance dredging may be needed to control this impact. Increased sediment deposition to Budd Inlet will also require increased maintenance dredging in these marine waters. Once maintenance dredging is resumed, associated water quality, benthic organism, and disposal impacts will also resume.

Concept II - Diked Freshwater Wetlands. Under this concept, maintenance dredging and associated costs would continue at a rate of approximately 20,000 to 55,000 cubic yards per year. The time of wetland creation would be the same as with Concept I, unless surplus dredging was conducted over a short period of time as needed to construct the dikes and fill them to the desired grade. Hydraulic dredging operations would be limited to two months out of the year to avoid adverse impacts to the fishery. Water quality and benthic organism impacts would occur at the dredge site, and existing lake shoreline areas would be diked and filled to create a controlled freshwater marsh/pond habitat. Water quality impacts could be mitigated by the use of silt curtains at the dredge site and by appropriate design of sediment settling facilities behind the dikes. If appropriate, sedimentation could be enhanced through the use of precipitating agents like aluminum sulfate.

Potential water quality benefits would be no better than for Concept I. Treatment would ultimately be about the same for high winter flows carrying the majority of annual sediment load to the lake. During winter flows the dikes would be over-topped and the wetlands would function as a flood plain as described for Concept I. Treatment efficiency would theoretically be better during low flows given the potential to utilize engineering design practice as a means of reducing short-circuiting and enhancing sheet flow through the wetland. However, even low summer flows are too high to provide proper residence times through the available wetland treatment area under this concept. Moreover, efficient summer flow sediment removal rates would have little benefit to annual sediment removal rates since the majority of sediment is transported during the winter high flow period.

Increased sedimentation rates would ultimately occur in the north basin and Budd Inlet as with Concept I.

Concept III - Tidal Estuary Wetlands. Sediment loading to Capitol Lake would not be significantly different under the estuary concept. However, there would be some differences in the manner in which sediment is deposited and distributed in the lake, and there may also be some differences in the rate of sediment loading to Budd Inlet. First, under the estuary concept, the rate of sediment accumulation in the middle basin may slow somewhat, once the sediment level exceeds the low tidal elevation of 3.43 feet. Reduced accumulation rates may result from tidal erosion and outflushing of mudflat sediments with each low tidal cycle. Although this secondary tidal erosion/ sedimentation process will have some influence on net sediment accumulation rates in the middle basin, the effect is not expected to produce any significant differences in the filling time of the middle basin as compared to Concept I.

Second, if the reservoir is managed at a lower water elevation, three feet lower than its present elevation, then increased erosional activity would be expected in the south basin during periods when the tide is low and river discharge is high. During such times high river flows would tend to scour sediment deposits in the south basin and carry them into the middle basin and beyond. A new equilibrium would probably be established in one or two years. During the initial scouring process, increased turbidity and reduced water clarity would be expected in the middle basin, north basin and Budd Inlet. Under such a management scenario, the river would continue to scour the south basin and it is predicted that this process would eliminate the need for future maintenance dredging in the south basin. In the absence of increased sediment accumulation in the south basin, potential future flooding impacts in the south basin would also be lessened.

Under the estuary concept there would also be some potential for sediment resuspension in the north basin as saltwater enters the reservoir on the incoming tide. This could result in increased turbidity in the north basin and subsequent transport of sediment back to Budd Inlet. This process would not be expected to result in any significant increase in sediment loading to Budd Inlet since the erosional forces are not expected to be very great, given the fact that maximum head differences between the marine and reservoirs sides of the tide gate would be no greater than two to three feet. This potential impact could also be mitigated by covering the backwash zone with material capable of resisting erosional forces.

As with the other concepts, maintenance dredging would need to be reestablished upon the filling or near-filling of the middle basin. Maintenance dredging would involve a middle basin trap and north basin dredging and would have the same impacts already addressed above for Concept I. Overall increases in sediment loading to Budd Inlet would also be expected to be similar to those described for Concept I.

As with the freshwater wetland concepts, the sediment trap efficiency of the middle basin is expected to increase with the establishment of wetland vegetation; again, this will be offset by decreasing residence times in the middle basin as it becomes filled with sediment.

Construction and Geotechnical Considerations

Concept I - River Delta Freshwater Wetlands

Under this concept, a control structure to keep salt water out of the middle basin would be built. Maintenance dredging would cease and sediments would be allowed to accumulate throughout the south and the middle basins.

The control structure for Concept I would be a submerged weir of steel sheet piling designed to be overflowed. The most convenient location for this control structure is just downstream of the railroad bridge that separates the middle and the north basins.

The railroad bridge is supported on timber piles. Where timber piles have been driven satisfactorily, sheet piling likely can be installed easily for either permanent or temporary use. The length required for the sheeting should consider the underseepage from the maximum head difference between the basins, as well as subsurface soil conditions. In the absence of site specific soil test core data, a pile depth of 50 feet has been assumed. This would require confirmation prior to final design. Otherwise, no unusual problems in designing or constructing the facility are foreseen.

Concept II - Diked Freshwater Wetlands

Under the second concept, a wetland protected by a dike would be constructed in about 60 percent of the middle basin adjacent to the west shore. Maintenance dredging would provide material to construct the dike and fill the wetland.

Dikes to contain the wetland would be constructed of gravelly sand obtained from maintenance dredging of the sediment traps in the middle and the south basins. This dredge spoil normally is pumped to the primary pond at the southwest corner of the middle basin. Just prior to the subsequent round of dredging, the primary pond is excavated and the sand spoil trucked off the site. The primary pond currently contains about 57,000 cubic yards of sand spoil from the last dredging. This would provide sufficient fill for about 2,000 linear feet of dike. The next dredging should provide a similar quantity.

Constructing dikes from dredge spoil recovered from the primary pond has several advantages. The dike construction would not interfere with the normal dredging operations. Delivering sand with fairly low water content to the dike construction area would allow the dikes to be built with minimal volume. Since most of the fine-grained fraction in the original dredge spoil settles out in the secondary pond, constructing dikes using only the cleaner primary pond sands should minimize turbidity problems in the middle basin.

One disadvantage of building dikes from dredge spoil recovered from the primary pond is that it requires double handling of the material. It is possible to build dikes directly from the dredge slurry, thus avoiding the double handling. However, discharging raw dredge slurry at the dike construction areas may cause unacceptable turbidity levels in the middle basin. It may be possible to control turbidity by using a small dredge and adequate silt screens. Alternatively, sands for dike construction can be removed from the dredge slurry using cyclone separators or other means and the fines-laden overflow pumped to a confined area for disposal. Any operations of this type will add significantly to normal dredging costs.

Wetland-containing dikes in the middle basin would be supported on loose silts varying from a few to many feet in thickness. The performance of these silts as foundation materials is uncertain. Silts that are very soft may be displaced by sand fill placed for the dikes. Vane shear tests reported by Rittenhouse-Zeman and Associates, Inc. (1982) suggest that silt strengths should generally be high enough to support low dikes without excessive displacement. Displacement of silts could greatly increase the volume of sand required to raise the dikes.

The stability of the dikes will be most critical during construction. Thereafter, the silts will consolidate under the weight of the dikes, their strength will increase, and the dikes will become more stable. Post-construction consolidation of the silts may cause substantial subsidence of the dike crests. Regrading the crests a few years after construction may be necessary.

As previously indicated, Concept II would also require the construction of a flow control diversion structure in the vicinity of the I-5 bridge. This structure could be constructed from riprap and/or concrete. Based on soils information available, no unusual geotechnical design constraints would be encountered.

<u>Concept III - Tidal Estuary Wetlands</u>

Concept III will result in twice-daily tidal fluctuations in the near shore zone and increased frequency of higher erosional velocities in the vicinity of the tide gate, railroad trestle and I-5 bridge. The western shoreline, which supports the Deschutes Parkway may be particularly vulnerable to daily water level fluctuations. Increased shoreline erosion will probably require increased protection using a combination of riprap, geotextiles and bioengineering techniques.

Water Quality

This section addresses bacteria and phosphorus, since sediment control has already been addressed above. Based on the results of the Wetland Technical Advisory Committee (WTAC) questionnaire, the study team has assumed that bacterial control is the highest priority water quality objective. This is because of the interest in reestablishing contact recreation (swimming) in the north basin and the associated public health considerations. Phosphorus control, although second in priority, is also considered important since phosphorus-stimulated algal blooms can result in high turbidity conditions that are both unsafe and distasteful to swimmers; algae blooms can also interfere with aesthetic appreciation and other beneficial uses.

Attempts to control water quality in Capitol Lake should include an aggressive nonpoint source control program in the watershed in addition to wetland treatment (if feasible) or other in-lake treatment measures, such as north basin circulation improvements.

Fecal Coliform Bacteria

Concept I - River Delta Freshwater Wetlands. Freshwater wetlands would probably not result in any significant reduction of fecal coliform bacteria originating from the Deschutes River. This prediction is based on the fact that existing river concentrations are relatively low (geometric mean = 16 organisms per 100 ml), and that river/wetland hydraulic interactions would not be conducive to wetland treatment during low flow summer periods. Under the ultimate wetland configuration, the river would be expected to create a relatively isolated channel through the wetland area during summer months. Since wetland treatment is generally expected to increase with increased residence time, there would be little or no treatment benefit under the ultimate wetland configuration, unless engineering measures were employed to enhance river/wetland interaction. However, even measures aimed at increasing hydraulic residence time would probably produce little treatment benefit given the relatively small wetland area compared to the high river flow (refer to discussion, pages 70 to 73).

While potential bacterial removal benefits are small, the creation of wetlands might even result in increased bacterial levels in the system. Increased waterfowl usage of Concept I wetlands might actually increase bacterial loadings to the north basin of Capitol Lake. There is also some evidence from other studies that sediment resuspension may result in increased bacterial levels in the water column (T. Determan pers. comm.). Therefore, as the middle basin becomes increasingly shallow, sediment resuspension may become an increasingly significant factor in bacterial loading to the north basin and Budd Inlet. However, this effect is likely to be greatest during high flow periods and should not cause interference with contact recreation in the north basin.

In general, reductions in bacterial concentrations in the north basin are more likely to result from improved control of nonpoint sources (waterfowl and pipe discharges) and from improved circulation rather than from wetland creation, per se. Such measures may be necessary to maintain bacterial levels that are sufficiently low that swimming and other forms of contact recreation are not adversely impacted.

Concept II - Diked Freshwater Wetlands. As with Concept I, there is little potential bacterial control benefit. Again, this is due to short hydraulic residence times in the wetland even during low summer flows and existing low concentrations in incoming

Deschutes River water. As with Concept I, created wetlands would probably attract additional waterfowl and could result in increased fecal coliform loading to Capitol Lake. Sediment resuspension would be less significant given controlled diversion flows into and out of the wetland. Again, various nonpoint source control measures are likely to be more effective in controlling fecal coliform bacteria than wetland treatment.

Concept III - Tidal Estuary Wetlands. In general, the estuary concept would be expected to result in reduced fecal coliform levels in the north basin. This would be attributable to reduced bacterial survival rates in saltwater and increased exposure to ultraviolet radiation (T. Determan pers. comm.; Bernard et al. 1986). Increased ultraviolet light exposure would occur as an indirect result of reduced algal growth and improved water clarity (see discussion page 68). The tendency for bacterial levels to decline under saltwater influence could be offset to some degree by increased waterfowl and/or shorebird contributions associated with enhanced wetland bird habitat in the middle basin. As with Concept I, sediment resuspension could result in increased water column bacterial levels over time.

Phosphorus Control and Eutrophication - Concepts I and II

Introduction. The following discussion pertains specifically to Concepts I and II. The water quality effects on the north basin of Capitol Lake would be the same for either concept. A separate discussion of the water quality feasibility and impacts of tidal flushing (Concept III) follows this discussion.

Modeling Considerations. In order to predict the potential eutrophication control benefits and/or impacts of creating wetlands in the middle basin, it was determined that a simple phosphorus mass balance model could be employed (Reckhow and Chapra 1983). First, however, it was deemed necessary to confirm the applicability of a phosphorus mass balance model, given that hydraulic residence times are very short in Capitol Lake. Short hydraulic residence times imply that flushing rates could be growth limiting rather than phosphorus concentrations.

In order to confirm the relationship between total phosphorus concentrations and algal production in the lake, mean annual phosphorus and chlorophyll *a* concentrations were calculated for the three water quality studies that have been performed on the lake since 1975 (CH_2M Hill 1978; Entranco Engineers 1984; and Orsborn, et al. 1975). Although the relationship is determined by only three data points, there is a good linear regression where:

$$\text{Chl } a = [TP] \times 0.92 - 26.4$$

This exercise provides reasonable confirmation of the TP-Chl *a* relationship; it also confirms the applicability of a mass balance model, which is used to predict mean annual or steady-state TP concentrations in the lake under different hydraulic and TP loading scenarios. Given the relatively good relationship between observed mean annual TP and Chl *a* levels in the lake, model predicted TP concentrations can be used, with confidence, to predict corresponding levels of algal production (mean annual chlorophyll a) in the lake.

The next step in the modeling process involved the calibration of the model (Reckhow and Chapra 1983) for existing phosphorus loading, hydraulic loading, and physical configuration as follows:

$$P = \frac{W}{VsAs + Qout}$$

Where:

P = Steady state lake phosphorus concentration (mg/m^3)

W = External phosphorus loading to the lake (kg/year)

Vs = Apparent phosphorus settling velocity (m/year)

As = Lake surface area (m^2)

Qout = Lake outflow discharge rate (m^3/year)

Since all values are known for Capitol Lake except for Vs, the equation is solved for Vs as follows:

P = 40.5 mg/m^3 (mean annual TP, Entranco Engineers 1984)

W = 20,507 kg P/year (total annual TP loading, Entranco Engineers 1984)

Vs = unknown

As = $9.263 \times 10^5 m^2$

Qout = 409×10^6 m^3/year (Entranco Engineers 1984)

And Vs = 105 m/year

Having determined the apparent settling velocity as an unknown, the model is calibrated and can be used for predictive purposes.

Before using the model for predictive purposes, there are several limitations that should be understood. First, the predictive value of any water quality model is less reliable as one attempts to predict conditions that are increasingly distant in future time. This is because other factors, such as climate or land use patterns and practices in the watershed, can change dramatically over time, thus altering what the calibrated (present time) model is assuming to be constant. Second, the predictive value of the model is less reliable for future conditions involving a greater number or kind of changes from the calibrated condition. Typically, mass balance models are used to predict changes in lake phosphorus concentration that would be expected to result from a change in phosphorus loading only. In the case of Capitol Lake the model is not only being used to predict the effect of change in loading, but also the effect of change in total lake surface area and volume. Finally, the simple mechanistic model assumes complete mixing of water in the lake/reservoir, which is an assumption that is not entirely valid for Capitol Lake. For these reasons, the predictions of the modeling exercise for Capitol Lake should be interpreted with appropriate caution.

The calibrated model was used to evaluate a number of predictive scenarios as summarized in table 4. Assuming that the middle basin is filled, water quality actually worsens in the north basin because residence time decreases, less phosphorus settles to the lake bottom, and the concentration in the water column increases. The reason that wetlands do not enhance water quality is because the surface area and volume of the middle basin is too small to provide adequate residence time for wetland treatment (refer to the Wetland Treatment Potential section for additional discussion). The predicted increase in north basin TP and chlorophyll *a* is especially significant because it pushes the chlorophyll *a* level above the eutrophic threshold of 10 mg/m^3 (Wetzel 1983). Water quality in the north basin is degraded further, but only slightly more, if "worst case" wetland phosphorus loading is added.

The model was also used to determine the amount of phosphorus loading that would achieve "good" water quality or "mesotrophy". Loading levels were predicted for both the existing lake configuration and for the north basin (assuming that the middle basin is filled). The model indicates that a loading level of 17,820 kgP/year would reduce chlorophyll levels to about 6 mg/m^3 for the existing lake configuration and that a loading level of 15,845 kgP/year would result in similar chlorophyll a levels in the north basin (again assuming that the middle basin is filled). This means that loading reductions of 2,687 kgP/year and 4,662 kgP/year would be needed. It is interesting to note that elimination of phosphorus loading from the brewery (2,935 kgP/year) and fish feeding activities (738 kgP/year) would be sufficient to achieve desired load reductions for the existing lake configuration. An additional load reduction of 989 kgP/year would be necessary to achieve mesotrophic conditions in the north basin.

In summary, the creation of freshwater wetlands in the middle basin would result in some worsening of the trophic status (increased TP and chlorophyll *a*) of the north basin. This impact could be mitigated by additional control of external phosphorus sources. Mitigation could also be provided by enhancing water circulation (exchange) in the north basin as previously suggested.

Marine Tidal Flushing - Concept III

This discussion is focused on such parameters as temperature, dissolved oxygen, secchi disk visibility and chlorophyll *a*. The reader is referred to previous sections for discussions of sediment and bacteria.

Predictions made in this section regarding the potential effects of tidal flushing are based on (1) preliminary saltwater/freshwater volume ratios during the growing season (April - September) which indicate saltwater dominance (60 to 90 percent of reservoir volume) with the proposed tidal control approach; and (2) a comparison of historical water quality data for the north basin of Capitol Lake and Budd Inlet. The basic assumption is that north basin water quality would be dominated by saltwater influence under Concept III and would therefore be more likely to reflect the quality of Budd Inlet than the existing north lake basin. It is important to establish saltwater dominance under Concept III in order to demonstrate the feasibility of supporting saltwater wetland plants under this scenario. It should be noted that existing water quality in south Budd Inlet is heavily influenced by discharges from the LOTT sewage treatment plant. Therefore, extrapolation to future considerations (30 to 85 years) involves the assumption that no changes in LOTT operations will be made that will result in any significant deterioration in marine water quality.

Table 4
Eutrophication Modeling Analysis(1)

Cases Evaluated	Model Parameters: W (kgP/yr.)	Vs (m/yr.)	As ($m^2 \times 10^5$)	Qout (m^3/yr. $\times 10^6$)	Results Predicted: Mean Annual TP (mg/m^3)	Mean Annual Chl *a*(2) (mg/m^3)
Calibration(3) for Whole Lake Existing Conditions	20,507	105	9.26	409	40.5	10.6
Predict North Basin Quality Assuming Middle Basin Filled	20,507	105	3.92	409	45.5	15.5
Predict North Basin Quality Assuming TP Load Controls for Fish Feed/Brewery(4)	16,834	105	3.96	409	34.1	5.0
Predict North Basin Impact of Increased Wetland TP Loading(5)	20,687	105	3.92	409	46.0	15.9
Loading to Whole Lake Necessary to Achieve Good Quality(6)	17,820	105	9.26	409	35.2	6.0
Loading to North Basin Necessary to Achieve Good Quality(6)	15,845	105	3.92	409	35.2	6.0

(1) Note: see text for model equation and definition of model parameters.

(2) A chlorophyll *a* value of 10.0 is considered the eutrophication threshold value. Chlorophyll *a* levels exceeding 10.0 are typically associated with visible floating algae blooms.

(3) Calibration: Vs, apparent settling velocity is calculated as unknown; all other values obtained from Entranco (1984). Note: This calibration analysis was based on the original nutrient loading estimate of 20,507 KgP/yr (Entranco Engineers 1984) and not the updated loading estimate of 21,245 KgP/yr (Table A-8). This difference is only 3.6% and should not have a significant bearing on results as presented.

(4) Brewery = 2,935 kg/yr., fish feed = 738 kg./yr. (Refer to Table A-8).

(5) Worst case wetland loading estimated at 180 kg/yr.

(6) Good water quality = mesotrophy = 6 mg/m^3 chlorophyll *a* according to Wetzel (1983). Corresponding TP concentration from Capitol Lake TP/Chl *a* regression equation: Chl = 0.92 (TP) - 26.4.

In general, increased marine water flushing in the north basin would, in addition to producing the obvious increase in salinity, result in reduced temperatures, reduced chlorophyll *a* levels, decreased turbidity (increased visibility), and somewhat lower dissolved oxygen levels than levels typically observed in the north basin under present management conditions. These differences are summarized in table 5. Although dissolved oxygen levels could reach lower levels, the WDOE data indicates that levels have not reached critically low values (less than 5 mg/l) in lower Budd Inlet during the past five years and no adverse impacts to fisheries would be expected. The only other potential adverse impact could be to any future swimming use in the north basin. With increased marine water influence, maximum water summer water temperatures would reach about 18 to 19 degrees C (64 to 66 degrees F). This is somewhat cooler than the maximum 21 to 22 degrees C (70 to 72 degrees F) temperatures observed in the middle of the north basin. Obviously, the cooler marine water temperatures could reduce the number of potential swimmers in the north basin, assuming that the City swimming beach is reopened.

Table 5
Comparison of Select Water Quality Parameters in Budd Inlet and the North Basin of Capitol Lake*
(April through August)

Parameter	Budd Inlet	North Basin
Temperature (°C)	13.0 - 16.5	12.7 - 22.0
Dissolved Oxygen (mg/l)	5.5 - 11.2	8.9 - 17.5
Turbidity (NTUs)	1.6 - 2.8	2.2 - 6.6
Chlorophyll *a* (mg m^3)	2.8 - 18.6	3.5 - 42.6

* Data Sources: Entranco Engineers (1984)
WDOE Ambient Water Quality Data (1984 - 1990)

Wetland Treatment Potential

The following discussion was originally developed under the assumption that enhanced wetland treatment could be promoted in a properly designed and flow regulated wetland such as the Diked Freshwater Wetlands concept (Concept II). Clearly, the following discussion would not apply to Concepts I or III.

Wetland treatment potential in Capitol Lake is relatively difficult to determine. The majority of information available for assessing this potential is based on case studies of the use of wetlands (either natural or manmade) for the treatment of domestic wastewater or urban stormwater runoff. Since treatment efficiency is in part related to the concentration of pollutants coming into a wetland, the use of these literature sources becomes suspect from the outset because stormwater and wastewater would typically contain much higher concentrations of fecal coliform bacteria, phosphorus or sediments than the main flow sources entering Capitol Lake (Deschutes River and Percival Creek) especially during summer low flow months. Even though the comparison of existing case study literature is tenuous, it can serve to provide a sense of treatment potential.

Treatment potential for any wetland is dependent on a number of variables, including size, hydrology, plant species, and soils characteristics. The dominant criteria, however, normally involve factors affecting water residence time in the wetland. Longer water residence times generally favor increased sedimentation rates for the removal of particulate pollutant fractions. Longer water residence times also increase contact with vegetation and sediments, which enhances the biochemical assimilation and other processes affecting removal of dissolved materials.

The literature generally provides information on the percent removal of various pollutants as a function of water residence time. However, the data is not always presented in comparable units from one study to the next. For example, some studies relate pollutant removal efficiencies to a ratio of wetland surface area to drainage basin surface area. Since the volume of runoff is generally proportional to the size of the tributary drainage area, this approach is an attempt to provide an indirect means of accounting for factors affecting water residence times. In other cases, pollutant removal efficiencies may be compared with the rate of inflow per unit wetland area or volume. Several of these literature studies have been selected to use as a means of evaluating the wetland treatment potential of the middle basin of Capitol Lake; they are described below.

In order to make this comparison, some basic assumptions have been made about the ultimate size of wetlands that might be developed in the middle basin and the amount of Deschutes River water that might be treated. The middle basin presently occupies about 112 acres, not including the dredge spoil disposal area in the southwest corner. For the purposes of this feasibility analysis, it has been assumed that approximately 20 percent of this area could be converted to wetlands; the remainder would be reserved to provide a high flow channel down the middle of the basin. With respect to flow rates it has been assumed that about 90 percent of the summer (June, July, August) flow could be diverted into the wetland, with the remaining 10 percent being required for fish passage to the upstream portions of the Deschutes River. Based upon these criteria, it has been assumed that a range of river flows between 100 and 300 cubic feet per second (cfs) would be used to assess potential wetland treatment benefits. Having made these basic assumptions, comparisons with literature values are possible.

The first comparison was made with wastewater literature based upon data presented in "Design Manual for Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment" (USEPA 1988). The treatment evaluation data presented in this document compares hydraulic surface loading rates (m^3 hectare-day) with percent removal for biochemical oxygen demand (BOD) and suspended solids (SS). While these are not the pollutant parameters of interest to the Capitol Lake project, the treatment evaluation can still be performed to illustrate relative treatment potential. The USEPA report presents results for six different case studies with hydraulic loading rates ranging from 140 to 2,525 m^3 ha-day and corresponding BOD and SS removal rates of 37 to 91 percent and 21 to 92 percent, respectively. As might be expected, the wetland with the highest hydraulic loading rated provided the lowest BOD and SS removal rates. Thus the treatment efficiencies of 37 and 21 percent were associated with the 2,525 m^3 ha-day hydraulic loading rate. By comparison, the hydraulic loading rates for the Capitol Lake wetland would range between 6,000 and 18,000

m^3 ha-day, or 2 to 7 times greater than the highest hydraulic loading reported in the USEPA study. One might conclude that treatment efficiencies in the Capitol Lake wetland would be considerably less than the 37 and 21 percent values reported in the USEPA study.

Another comparison was made with the study by Willenbring (1985), "Wetland Treatment Systems - Why do Some Work Better Than Others?" Willenbring compared the treatment efficiencies of five wetlands that were used to treat both agricultural and urban runoff. He compared percent removal rates for total phosphorus (TP) and total suspended solids (TSS) against the ratio of tributary drainage area to wetland area (TDA/WA). TDA/WA values ranged from 16.5 to 109.0. Corresponding removal rates for TP and TSS ranged from 9 to 59 percent and 27 to 92 percent, respectively. Unfortunately, the results reported by Willenbring do not show as strong a relationship between the TDA/WA ratio and treatment efficiency as one would expect, indicating that other factors were more significant. Nevertheless, if one considers the TDA/WA value for the Capitol Lake wetland of 1,400, it becomes readily apparent that the available wetland treatment area in Capitol Lake is very small compared to the tributary drainage area (126,000 acres). This assessment also tends to suggest that the wetland area is too small to effectively treat the volume of water coming from such a large tributary watershed.

Another comparison was made with data contained in a 1989 Metro report, "Considerations for the Use of Wet Ponds for Water Quality." In this report Metro compared treatment efficiencies for nine stormwater treatment facilities across the country (data was obtained from USEPA reports associated with the National Urban Runoff Program). The Metro report includes comparisons of percent removal for various pollutants, including total suspended solids (TSS) total phosphorus (TP) and other parameters, with average detention time (ADT) in days. Values for average detention time ranged from 0.37 to 96 days. Corresponding TSS and TP removal rates ranged from negative values (indicating net export from the wetland) for both TSS and TP, up to 91 and 79 percent, respectively. In this comparison there was a relatively strong relationship between ADT and treatment performance, with the best treatment occurring in the facility with the longest detention time, and the worst treatment (wetland actually exporting TSS and TP to downstream waters) occurring in the facility with the lowest detention time. By comparison, the Capitol Lake wetland would have a detention time ranging from 0.3 to 1.4. Based upon the values given in the Metro report, the Capitol Lake wetland might be expected, at best, to achieve TSS and TP removal rates of 32 and 18 percent, respectively, and, at worst, might even result in net export downstream.

This literature review seems to indicate that the potential Capitol Lake wetland treatment area is too small compared to the total flow. It seems appropriate, therefore, to also evaluate the amount of flow that could be treated and the level of treatment potential afforded for a flow volume less than the total flow. Flow rates were considered that would provide TP removal rates in excess of 25 percent and 50 percent, respectively. Again, the analysis is tenuous; however, it appears that treatment of about 30 percent of the summer low flow would produce TP removal efficiencies of about 25 percent; and that treatment of 12 percent of the summer low flow would result in removal efficiencies of about 50 percent. Given the fact that substantial percentages of the total flow would be directed into the north basin without treatment, the net treatment effectiveness would only be about 6 to 8 percent of the total phosphorus load. Again, the analysis indicates relatively insignificant potential treatment benefits. And again, the reader should be reminded that the potential for net wetland export is indicated in the studies discussed above.

Finally, it is of some interest to note that the simple mechanistic lake model (refer to the previous Water Quality discussion) indicates that approximately 20 percent of the annual external phosphorus load to Capitol Lake is lost to the sediments while the remaining 80 percent is carried downstream to Budd Inlet. This number is in the same range of percent removal values that have been derived from literature studies and supports the conclusion that 20 percent phosphorus removal is probably the maximum removal rate one would expect to observe in Capitol Lake. Since the existing lake basin, which has relatively little wetland habitat, is providing this level of treatment, one might conclude that physical sedimentation removal processes are dominating. Although increased wetland plant coverage might tend to increase phosphorus trap efficiency, it is quite likely that such benefits would be offset by decreasing lake volumes and corresponding reductions in overall residence items and sedimentation efficiencies. The ultimate conclusion is that a freshwater wetland in the middle basin of Capitol Lake would probably not provide any increase in water quality treatment benefit beyond what the existing open water lake environment provides. (Note: this is not a conclusion that would necessarily apply to another lake system having longer residence times.)

INSTITUTIONAL CONSIDERATIONS

Multi-jurisdictional Management

In the event one or more wetland development concept is determined to be feasible, and in the event that the Department of General Administration (DGA) determines that there is good reason to consider the implementation of a given alternative, an Environmental Impact Statement (EIS) and permit review process would be required as outlined in the next section. If one or more wetland development alternatives is considered feasible, then it would seem appropriate to continue the Wetland Technical Advisory Committee or continue this function under the framework of the Capitol Lake Restoration Committee in order to ensure continued cooperative dialogue among the interested and affected organizations. The committee could be expanded to include other representatives (for example, representatives of other state or federal agencies or representatives of the general public) at the discretion of the Department of General Administration. Again, the intent would be to identify that course of action with greatest potential benefit, least environmental impact, and least cost, that would still meet overall resource management objectives.

Regulatory and Permit Considerations

The development of wetlands in the middle basin of Capitol Lake would, in all likelihood, require the preparation of an EIS by the DGA. In the event that one or more concepts are determined to be feasible, the DGA would make a threshold determination based upon the perceived potential for adverse impacts.

The EIS (assuming that one would be prepared), would identify the various permits needed for project approval and would address the planning level concerns for each permit process. Depending upon the concepts under consideration in the EIS, a variety of permits might be required, including:

- Corps of Engineers 404 Permit
- Corps of Engineers Section 10 Permit
- Shoreline Master Development Permit

- Hydraulic Project Approval (HPA)
- WDOE Dam Safety Permit
- WDOE Water Quality Modification Permit

Environmental and permit review processes could vary considerably in terms of the complexity, time requirements, and cost, depending upon the alternative. A preliminary assessment of each of the wetland development concepts is presented below.

Concept I. Concept I would probably require SEPA review. Significant environmental issues include: (1) aesthetics (loss of the reflecting pool and overall change in lake character and views); (2) flood control; (3) fish and wildlife; (4) downstream sediment and water quality impacts; and, (5) recreation. It is not certain at this time whether any in-lake construction would be involved; however, there is the possibility that a sheet pile structure would be proposed for the control of saltwater intrusion into the middle basin. If the sheet pile structure was proposed, the HPA, Dam Safety, and Shoreline Permits would probably be required and a Section 10 Permit might also be required. Since no wetland filling is envisioned with this alternative, a Corps 404 permit would not be required. Given that some public sentiment has already been expressed in opposition to the filling of the middle basin, one would reasonably expect those public sentiments to be expressed during the SEPA and permit review processes.

Concept II. Since Concept II would involve substantial wetland filling, Corps of Engineers 404 and Section 10 permits would undoubtedly be required, as well as Shoreline and other permits listed above. The Corps 404 permit process would authorize project review by not only the Corps, but other federal agencies as well, including the USEPA, US Fish & Wildlife Service, and National Marine Fisheries Service. A project of this nature, involving the filling of a major water resource with dredge spoils, even for the seemingly beneficial purpose of creating wetlands, could be quite controversial. The SEPA review process could be expected to be complex, time consuming, and costly.

Concept III. Concept III review considerations would be similar to those for Concept I but would also include impacts to wildlife and shoreline erosion.

BENEFICIAL USES

Potential aesthetic and recreational impacts would be similar under either Concept I, II or III and would involve the loss of the middle basin of Capitol Lake as an open water body, along with existing recreational benefits, and as a reflecting pool for the Capitol Building. There is considerable opportunity to mitigate this potential impact with appropriate attention to landscape and park planning and design. There is perhaps somewhat greater opportunity with Concept II to arrive at a landscape and recreation plan that would meet the greatest number of objectives. It is assumed that mitigation would involve a landscape plan that would incorporate planned trail connections between existing parks, and that would maximize passive recreational opportunities for such activities as bird watching, walking, jogging, shoreline fishing, and pubic education (particularly about wetlands, their functions and values, etc.). More specific considerations are discussed below.

Recreation

Public Access. The primary circulation systems serving the lake will not be impacted. However, all three concepts would result in a band of vegetation along the shoreline of the middle basin, limiting access to the water's edge. In most shoreline conditions the greatest draw for recreational activity occurs at the water's edge. In the preliminary stages of Concepts I and II, pioneer species such as blackberry may discourage activity along the shoreline. Later, the distance between the upland and open water will be separated by the scrub shrub and emergent zones, creating a significant barrier between the upland and open water. This condition can be mitigated by providing pedestrian circulation through a cross section of the wetland so that users may experience the water's edge. The band of vegetation expected along the shoreline of Concept III may have less of an impact. The salt marsh vegetation would not be as high as the vegetation expected in the scrub/shrub and emergent zones of Concepts I and II. Views to open water would be more accessible. In this case, visual access to open water may suffice for physical access.

Recreational Benefits. No new recreational opportunities emerge from the three concepts. However, there will be an opportunity to expand the interpretive program offered through the Capitol Lake Interpretive Center. The expanded program could focus on the cross section of new wetland communities created. All three concepts propose the creation of greater and more diverse areas of wildlife habitat. Opportunities for wildlife observation will therefore increase. It is doubtful that either of these elements alone will revitalize recreational activity at the lake.

Seasonal usage of the lake would not be expected to change as a result of implementing Concepts I, II, or III. However, a probable increase in the mosquito population may discourage use during peak summer months. The picnic areas of Marathon Park are most susceptible to this nuisance factor.

Concepts I and II strengthen the linkage between the south and middle basins. Extending the wetland into the middle basin expands the passive recreational and interpretive opportunities of the south basin.

Recreational Activities. The programmed activities of Capitol Lake Park, Marathon Park, and Tumwater Historic Park should not be impacted. Interpretive opportunities for the Capitol Lake Interpretive Center will increase with the expanded wetland in the middle basin.

Boating opportunities in the middle basin will be limited to canoeing and kayaking with the reduction of open water.

No change in the recreational fishery resource is expected with Concepts I and II. The recreational value of the fishery resource will be reduced if Concept III is selected. Euryhaline species which will replace the fresh water species expected with Concepts I and II have less recreational value.

Water quality is not expected to improve sufficiently to reestablish the swimming opportunity at the north basin of Capitol Lake.

Aesthetics and Landscape Design

Visual Impacts. The area of open water in the middle basin will be reduced with all three wetland concepts. This will impact one of the primary visual characteristics of the lake. The reflection of the Capitol Building and forested slopes in the open water of the middle basin will no longer claim a significant role in the mid-ground of internal and distant views.

Currently, the open water in the middle basin functions as a reflective surface of the Capitol Building and the forested slopes surrounding the lake. With the establishment of scrub/shrub and emergent zones, or of a salt marsh zone and mudflats, the visual character of the middle basin will change. The scrub/shrub and emergent plant communities proposed in Concepts I and II will provide a highly textured mosaic of vegetation which will command more visual attention. This is less true of the salt marsh plant community proposed in Concept III.

Landmarks such as the railroad trestle, the steam plant, I-5, and the Deschutes Parkway will remain prominent within the internal views of the middle basin.

Auditory Impacts. The auditory experience in the middle basin will change with the increase of habitat proposed by all three concepts. There will be an increase in the population of song birds. Larger areas of vegetation will result in a greater awareness of the wind. It is also possible that with channelization through the middle basin, the movement of water may be a component in the auditory experience. It is possible that these elements in combination will soften the predominance of traffic noise heard from I-5 and from the Deschutes Parkway.

Site Planning Compatibility. All planning efforts are consistently designed to either emphasize the natural environments of the south and middle basin or to formalize the connection between Capitol Campus and downtown Olympia. Current park planning is focused on Capitol Lake Park located in the northeast corner of the north basin. The plan builds on the State Capitol Heritage Park Plan and is expected to revitalize the park as a focal point of the community. Concepts I, II and III do not present any conflicts to the design direction of current or historic planning efforts.

The native landscape patterns found in the south basin will be extended into the middle basin if Concepts I and II are selected. This will strengthen the linkage between these two basins. Concept III will reestablish a historic landscape pattern within the middle basin with the creation of the salt marsh and mudflats.

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Appendix A

EXISTING CONDITIONS

APPENDIX A
EXISTING CONDITIONS

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APPENDIX A
EXISTING CONDITIONS

BIOLOGICAL PARAMETERS

Vegetation Types and Wildlife Habitat

Capitol Lake is a complex of natural habitats in an urbanized area. An inventory was made of the vegetation and wildlife habitat of the Capitol Lake area as part of this study. The inventory area ranged from the upper (south) basin, downstream from Tumwater Falls, to the control structure separating Capitol Lake from Budd Inlet. Data was gathered on April 5 and 6, 1990 during a field trip conducted by B-twelve Associates. Vegetation and wetland types were mapped using field observations and aerial photographs (figures A-1 and A-2). An extensive list of plants and animals found in and around Capitol Lake, from CH_2M Hill (1977), is included in Appendix C. Also included in Appendix C is a summary table of existing wetland plants showing their sensitivity to salinity and water level fluctuations.

<u>Emergent Wetland Vegetation</u>

<u>North Basin</u>. The lake shore of the north basin is abrupt and has very little vegetation except for narrow bands and small patches of emergent plants. The dominant species are soft rush (*Juncus effusus*) and yellow flag (*Iris pseudacorus*). There are also individual Willows (*salix* sp.) scattered along the shore. Ornamental plantings and lawn extend almost to the water's edge. The forested slopes northwest of this basin support red alder and big-leaf maple (*Alnus rubra* and *Acer macrophyllum*). There are several forested wetlands to the west of the north basin, characterized by red alder (*Alnus rubra*) with a dense shrubby understory of salmonberry (*Rubus spectabilis*) and Indian plum (*Oemlaria cerasiformis*). Overall, this basin has little habitat value except for waterfowl and other birds tolerant of human presence and activity.

<u>Middle Basin</u>. A narrow band of emergent and scrub-shrub wetland vegetation grows along the western shore. Vegetation on wooded slopes to the west of the Deschutes Parkway is deciduous alder forest at the toe of the slope, and coniferous Douglas fir forest at the top of the slope. A forested wetland lies to the north of the intersection of Deschutes Parkway and the railroad tracks. It is dominated by red alder (*Alnus rubra*) with a few black cottonwood (*Populus balsamifera*). The shrubby understory is made up primarily of salmonberry (*Rubus spectabilis*), with *Oemlaria cerasiformis*, *Sambucus racemosa*, and *Equisetum* spp. The eastern shore of the middle basin is characterized by steep forested slopes. There are alternating stands of coniferous, deciduous, and mixed forest. The south end of the middle basin is a roughly triangular area which has been impacted by having been dredged and filled. The southwest corner of this area is open water. It receives heavy use by waterfowl (buffleheads and mallards were observed). This would also be suitable habitat for wading birds such as heron. The southern part contains a mosaic of scrub-shrub and emergent vegetation. Dominant species are cattail (*Typha latifolia)*, reed canary grass (*Phalaris arundinacea*), and willows (*Salix* spp.). The northeast part has been filled with dredge spoils from other parts of the lake. The vegetation here is typical of waste places and is composed of grasses and weedy species such as dandelion (*Taraxacum officionale*), Yarrow (*Achillea millefolium*), and scotch broom (*Cytisus scoparius*). There is also an open stand of small lodgepole pine (*Pinus contorta*) in this area.

Percival Cove. Percival Cove is located to the west of the middle basin and is hydrologically connected to it. It is a lacustrine system which has been excavated and impounded and is used as a fish rearing area. Waterfowl and a kingfisher were observed in this area. We expect that great blue heron and other wading birds would use this area as habitat. Douglas Fir forest extends nearly to the water's edge along the western shore. There is a narrow strip of cattails (*Typha latifolia*) along the shore. To the west is nearly pure red alder (*Alnus rubra*) forest at the toe of the slope and Douglas fir forest at the top of the slope. The vegetation along the right-of-way for Deschutes Parkway consists of mowed grasses and ornamental shrubs.

Percival Creek flows into the cove from the west. It is split into two channels and forms a broad riparian corridor. This wetland is comprised of forested vegetation (*Alnus rubra* is dominant). In the understory are reed canary grass (*Phalaris arundinacea*), skunk cabbage (*Lysichitum americanum*), piggyback plant (*Tolmia menziesii*), salmonberry (*Rubus spectabilis*), and indian plum (*Oemlaria cerasiformis*). It is structurally diverse and provides excellent habitat for songbirds, small mammals, and waterfowl. In addition, there are snags and stumps for woodpeckers.

South Basin. This portion of Capitol Lake is characterized by islands of vegetation in the Deschutes River. Sediment drops out in this basin because water velocity slows considerably below the falls. The southernmost three islands are forested wetland dominated by red alder (*Alnus rubra*) and black cottonwood (*Populus balsamifera*). The vegetation on the islands in the northern part of the basin is made up of mixed scrub-shrub and emergent vegetation. Dominants are willows (*Salix* spp.), cattails (*Typha latifolia*), and reed canary grass (*Phalaris arundinacea*). The principal subordinates on these islands are black cottonwood (*Populus balsamifera*) and red alder (*Alnus rubra*). Upland adjacent to this area is deciduous alder and cottonwood forest. Farther up slope is coniferous Douglas fir forest. The south basin supports a wide variety of mammals, birds, amphibians and fish. We observed Canada geese, mallards, coots, gulls, and red-winged blackbirds. This area is also excellent habitat for mammals such as river otter and muskrat.

Submergent Wetland Vegetation

A number of genera of aquatic vascular plants occur in or along the margins of Capitol Lake, including *Potamogeton pectinatis*, *Potamogeton folisus*, *Potamogeton crispus* and *Elodea canadensis*. The following observations were made during a general survey conducted by Washington State University (WSU) in August 1974.

The dominant submergent species of the north and middle basins was *Potamogeton pectinatis*, which grew heaviest along the west shores of these basins. This species was also found at lower densities throughout the southern arm of Percival Cove, along the eastern margin of the south basin, and in spots along the eastern margins of the north and middle basins.

The dominant submergent macrophyte of both south basin and Percival Cove is *Elodea canadensis*, although *Potamogeton pectinatus* occurs in significant numbers in both areas. *Potamogeton foliosus* is also a significant member of the south basin vegetation. Underwater observations in one shallow portion of the middle basin indicate very sparse growth of *Elodea canadensis*. *Potamogeton crispus* was observed at one location on the northwest side of the middle basin, but is not regarded as a significant member of the aquatic flora of Capitol Lake. *Lemna gibba*, a small floating leaved species, was also observed growing among *Typha latifolia* stands.

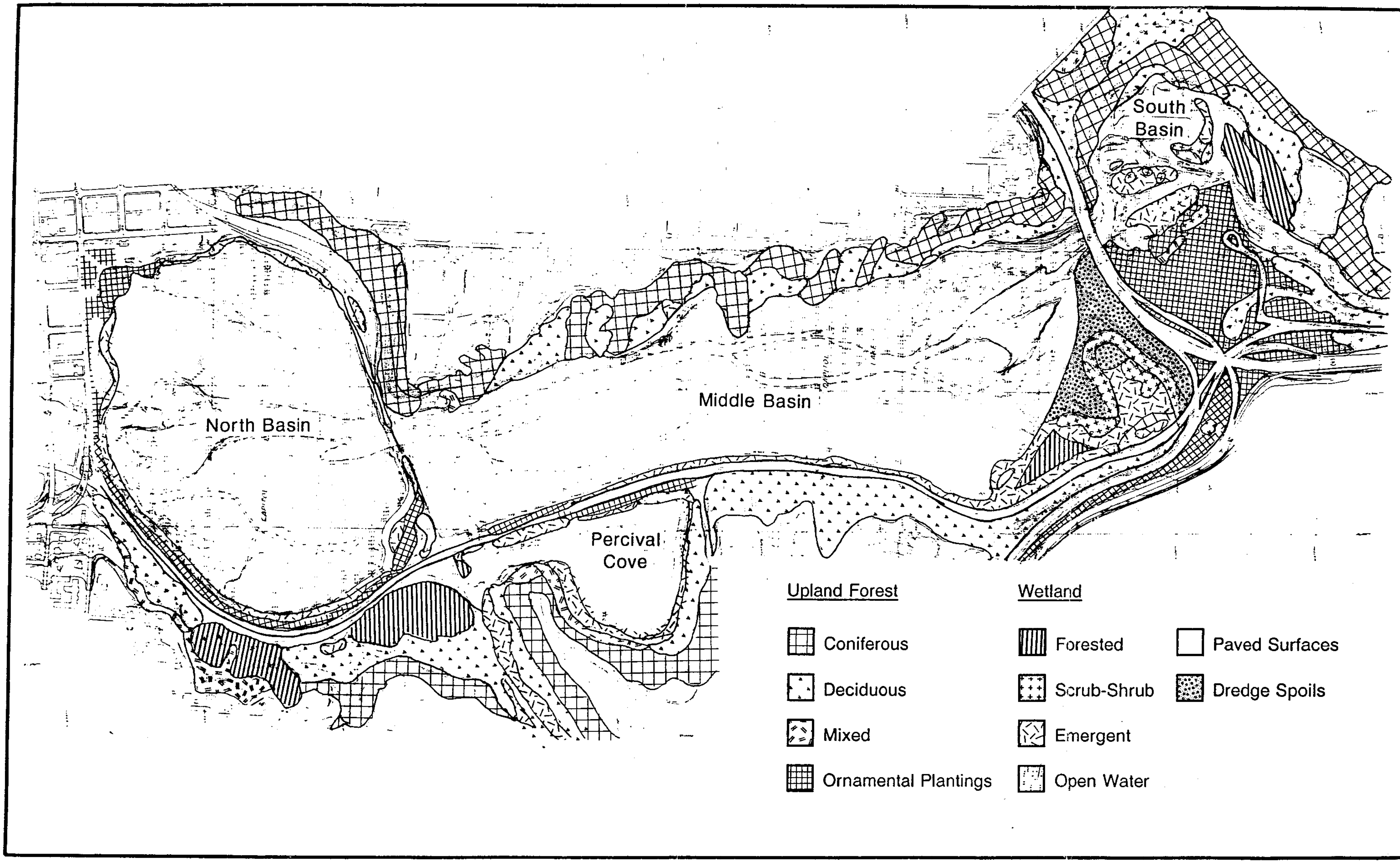

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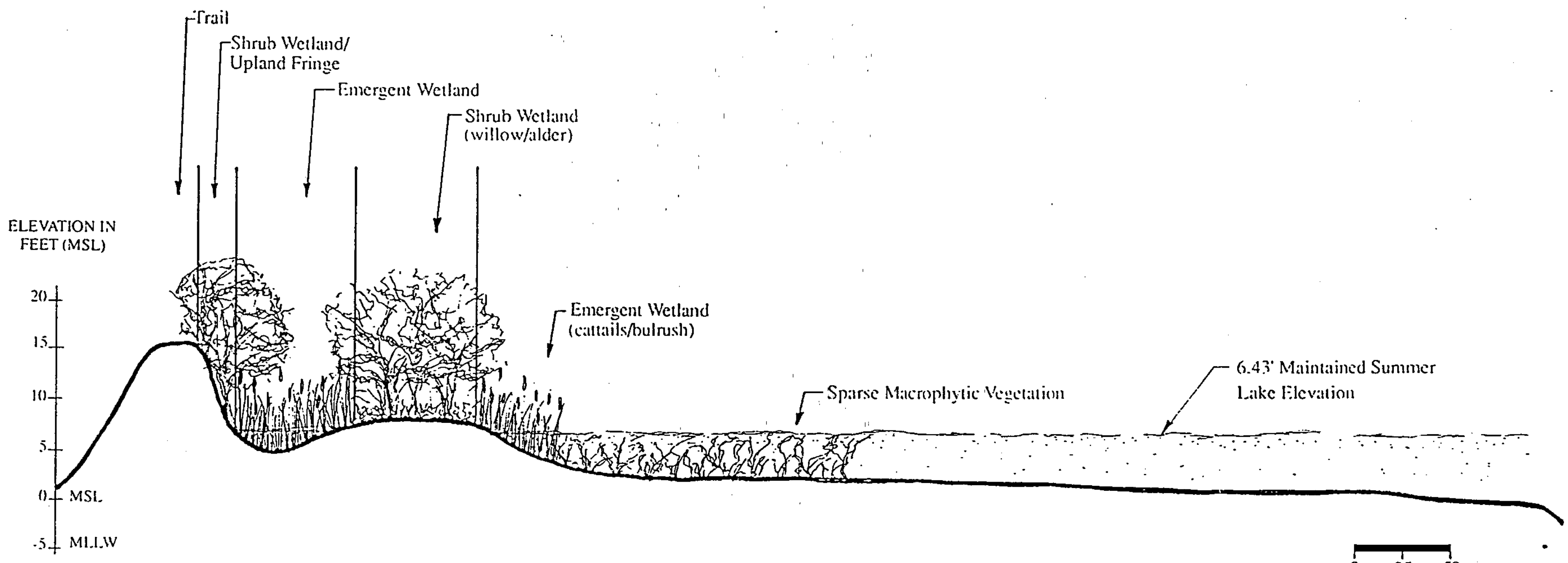
Figure A-1

EXISTING VEGETATION TYPES



Source: Jones & Stokes Associates, Inc.

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Figure A-2

PROFILE - EXISTING ELEVATIONS AND WETLAND COMMUNITIES
MIDDLE BASIN, CAPITOL LAKE

A general observation is that the macrophytes in Capitol Lake are restricted to shallow margins and are not dense enough to interfere with recreational activities. *Potamogeton pectinatus*, which is common in the north and middle basins, is salt resistant and is apparently able to survive periodic salt water flushing. Light limitation and sedimentation apparently limit its distribution to the margins of the basins. Although limited observations on the distribution of *Elodea canadensis* were made, the observation that it was never collected in the dredge samples in the north or middle basin indicates a very limited range. *Elodea canadensis* is probably controlled by salt water flushing and occurs mainly in the upper basin and Percival Cove, which are not affected by salt water flushing.

Public complaints about rooted macrophytes in 1969 led to a three year program of macrophyte control. The principal noxious species were *Elodea canadensis* and *Potamogeton pectinatis*. The principal areas of infestation appeared to be along the east side of the middle basin, the ski launch area in the southwest section of the middle basin, and the boat launch area of the south basin. No quantitative data was given on the density of macrophyte growth. A one year growing season chemical treatment was tried and was largely unsuccessful. The use of periodic salt water flushing since 1970 has succeeded in controlling, but not eliminating, macrophyte growth.

Fisheries

Overview

Chinook, coho, and chum salmon, as well as steelhead and cutthroat trout, occur in Capitol Lake. Adults and juveniles of these species migrate through and/or rear in the lake. In addition, small numbers of sockeye salmon (generally less than 30 adults) pass through the Deschutes fishway each fall on their upstream spawning migration. The Washington Department of Fisheries (WDF) uses the lake as a rearing facility for hatchery-produced juvenile chinook salmon. The lake also hosts resident populations of rainbow and cutthroat trout, largemouth bass, and carp.

Capitol Lake is shallow, with a five to ten foot average depth, and a mud bottom. The south basin is filling with river sediments (sand and fine gravel). The water quality of the lake is typically adequate for fish due to the continuous flushing of the river; however, fish kills have occurred in the north basin near the outlet.

Description of Resource

Adult salmon enter the lake in the fall on their upstream migration to spawning grounds in either the Deschutes River or Percival Creek. Adult steelhead and searun cutthroat trout enter the lake from fall to early spring. A portion of the run of adult chinook salmon is captured at the fish ladder at the outlet of the north basin by WDF personnel. Deschutes River adult salmon and steelhead are captured at the Tumwater Falls fishway trap as they migrate upstream. These fish (except chinook) are passed upstream to spawn naturally in the Deschutes River.

Chinook salmon entering the trap are retained and the eggs and milt collected for a hatchery program operated by WDF. The eggs are transported to other hatcheries for incubation and hatching. Each year, seven to eight million chinook fry (juveniles less than one year of age) are planted in Capitol Lake in mid-April. These fish are fed until late May or early June, when they emigrate to Puget Sound. The WDF concentrates the feeding effort in the vicinity of the I-5 bridge, where the juvenile chinook show the greatest feeding response. A small portion of their diet is composed of natural food items produced in the lake. The hatchery program is very viable and supports important commercial, sport, and tribal fisheries in the ocean, Puget Sound, Budd Inlet, and Capitol Lake. In addition, this hatchery program provides eggs for other south Puget Sound hatcheries and for the program at the Squaxin Island net pens. A net pen operates in Percival Cove, where the WDF in cooperation with the Olympic Salmon Club, raises approximately 150,000 yearling chinook (juveniles greater than one year of age) between October and May each year.

Capitol Lake provides rearing habitat for juvenile salmonids of the other species in the Deschutes River and Percival Creek. The majority of the juvenile salmonids spend a relatively short period in the lake as they emigrate in the spring and early summer. However, juvenile coho, sockeye, steelhead, and cutthroat may be rearing in the lake all months of the year.

It is presumed that the lake is used by searun and resident cutthroat trout in relatively high numbers. Large numbers of coho juveniles or pre-smolts are not suspected to be using the lake as rearing habitat, based on production studies conducted by WDF (P. Seidel, pers. comm.). Chum salmon fry emigrate to the marine environment soon after hatching and their period of residence in the lake is likely very short. Juvenile sockeye are suspected to use the lake for rearing, but their numbers are small based on the low numbers of spawning adults. Steelhead juveniles probably do not use the lake to any significant degree for rearing as they prefer moving-water habitat.

Capitol Lake supports a popular sport salmon fishery each fall for chinook, coho, and chum salmon. Steelhead also provide sport fishing opportunity each winter and early spring. Hatchery rainbow trout that are planted annually in Black Lake by the Washington Department of Wildlife (WDW) migrate down Percival Creek in unknown numbers to Capitol Lake. These fish are present in sport fisherman's creels along with the cutthroat trout, largemouth bass, and carp.

<u>Juvenile Salmonid Behavior</u>

This section describes and contrasts the typical behavior and habitats selected by the different species of juvenile salmonids. This understanding is necessary for assessing impact of the alternatives associated with the wetland project.

Juvenile chinook salmon rear along the gravel bars of mainstem rivers from March through early summer. The fish can also be found in the medium to low velocity fringe areas of streams as they rear and emigrate to saltwater. Juvenile chinook often rear in estuaries, feeding on epibenthic zooplankton and insects.

Juvenile coho salmon rear in a variety of habitats during their one and one-half year freshwater residence. These fish are typically rearing in small streams during the spring, summer, and fall months. When flows are low in summer, they may also be found rearing in the mainstem river and groundwater-fed habitats. In the winter, juvenile coho redistribute within the drainage, often seeking refuge from high flows in off-channel ponds, lakes, or spring-fed streams.

Juvenile steelhead trout spend an average of two years in the freshwater environment. In the spring and summer these fish occupy the riffles of streams and mainstream rivers. The remainder of the year they rear in the pools. Steelhead juveniles typically prefer moving water and make little use of shallow lakes and beaver ponds.

Cutthroat trout juveniles rear in freshwater for two to nine years before emigrating to saltwater in the spring. The mechanisms of the seaward migration are not well understood, but some individuals never emigrate and become residents. These fish use both streams and lakes for rearing and are frequently found in shallow lakes and beaver ponds.

Special Status Species

The Olympic mudminnow (*Novembra hubbsi Schultz*) is a Federal Candidate 2 and a Washington State Protected Species that has been documented in Capitol Lake. Two specimens were collected in an incline plane screen trap operated at the base of the lower falls near the old Olympia Beer Brewery site in March 1956. It is inconclusive whether these fish were displaced from habitat upstream of the lake or whether they were residing in the lake at the time of capture. There has been no further documentation or sightings of this species in Capitol Lake or the Deschutes River. It should be noted that the presence of spiny ray species (e.g., largemouth bass) in areas used by mudminnows. can result in the decimation of mudminnow populations (McAllister, pers. comm.). Saltwater flushing of Capitol Lake may also have been detrimental to mudminnows residing in the lake.

PHYSICAL PARAMETERS

Topography

The topography of Capitol Lake is shown in figure A-3. The lake basin was originally formed in 1951 with the construction of the 5th Avenue Bridge and tide gate, creating a freshwater reservoir out of the former tidal estuary. Since that time a number of other construction projects have had a substantial influence in shaping the basin, including the Burlington Northern Railroad trestle that separates the north and middle basins, the Deschutes Parkway which forms the western shoreline and separates Percival Cove from the main body of the lake, the I-5 fill that separates the middle and south basins, and a variety of shoreline fills associated with park development and dredge spoil disposal (Tumwater Historic Park, Capitol Lake Interpretive Center, Marathon Park, and Capitol Lake Park).

Steep banks rise from the lake elevation of 6.5 feet mean sea level (MSL) to elevations of 100 to 150 feet along all sides of the lake, except along the northeast shore of the north basin and the western shore of the south basin, where adjoining shorelines exhibit very gradual upslope gradients. The entire lake has a surface area of 229 acres (north = 97 acres, middle = 112 acres, and south = 20 acres). The average depths of the north, middle and south basins are 10.6, 6.3 and 5.0 feet, respectively. The average depths of the three basins reflect the influence of sediment deposition from the Deschutes River. Coarse materials of greater volume result in greater rates of sedimentation and lake basin filling in the south (upper) end of the lake; similarly, the lowest rates of sedimentation and lake basin filling are occurring in the north (lower) basin.

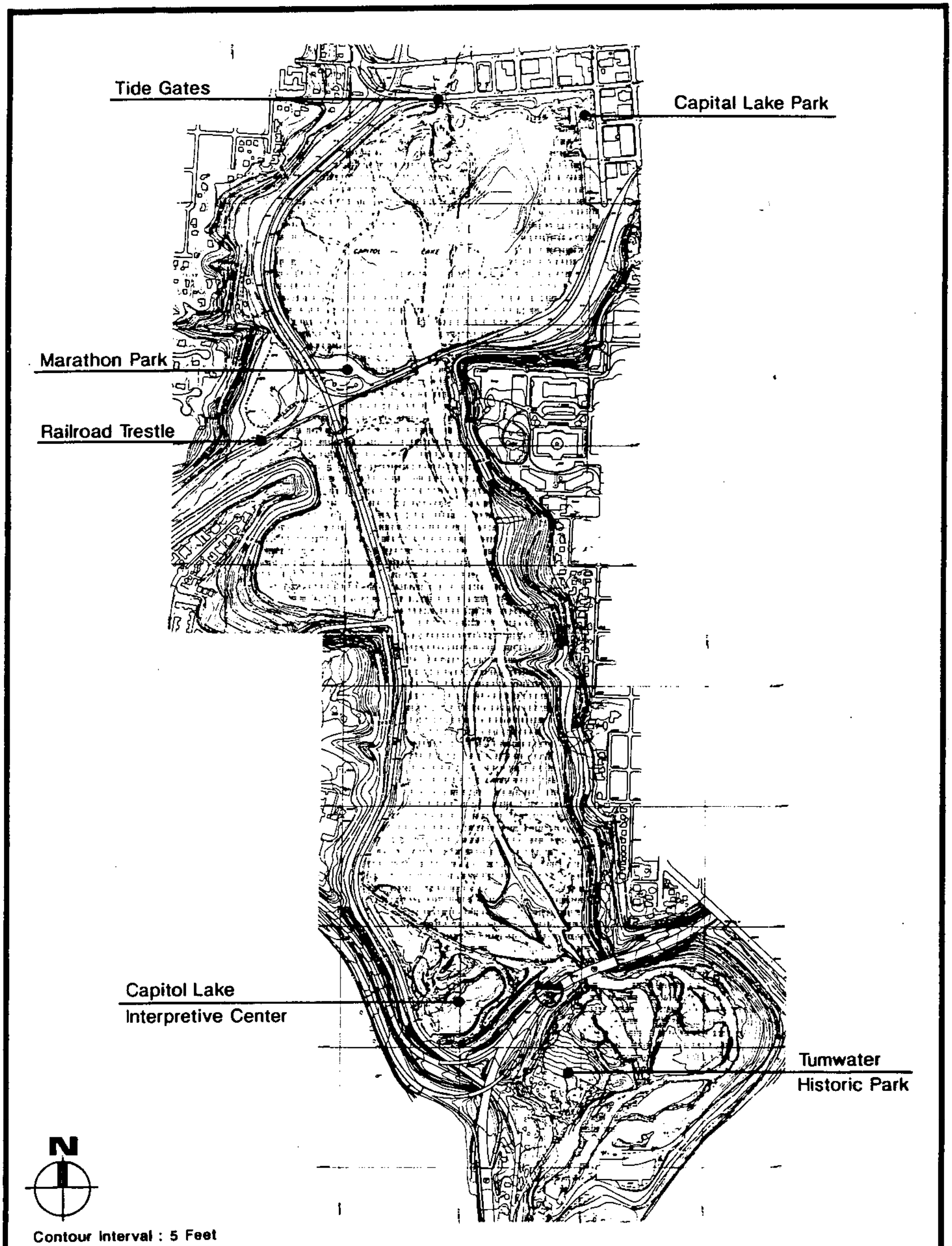

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Figure A-3

CAPITOL LAKE TOPOGRAPHY

Soils

Because lake bottom materials have not been sampled for the present study, information from previous Capitol Lake studies is summarized. CH_2M Hill (1978) sampled 37 locations to depths up to 20 feet, including 15 in the south basin, 17 in the middle basin, and five around Percival Cove. Rittenhouse-Zeman & Associates, Inc. (1982) drilled 22 standard penetration test borings, all in a limited area at the southwest corner of the middle basin. No soil samples have been taken from the north basin.

The soils near the bottom in the south and the middle basins are representative of the Deschutes River sediment load in recent decades. They include both the bed load and much of the suspended load. Sediment transport is greatest during high winter flows. Generally, most of the bed load, sand and small gravel, settles out in the south basin. CH_2M Hill's samples indicate clean sands, gravelly in places, in areas with the fastest current. Backwater areas contain silty sands with virtually no gravel. Several borings in the south basin, apparently outside the normal channels, encountered deep deposits of clayey silt.

Near the mudline in the middle basin, borings encountered mostly silts and clayey silts, with minor amounts of sand. These soils are all very soft and weak. Sands likely reach the middle basin only when stream flows are high and the normal sedimentation areas in the south basin are filled. At these times, fine sands accumulate just north of the I-5 bridge, as is occurring at the present time. As the south basin continues to aggrade, the sandy areas in the middle basin will move northward. Where this has already occurred, the sands probably overlie soft silts and clayey silts.

There are dense sands from an earlier geologic period under the middle basin, typically twenty or more feet below the present mudline.

Lake Circulation

The circulation pattern of Capitol Lake was studied by WSU (1975) using dye tests in a scaled down physical model. Results of the tests revealed a general pattern of a flow-through channel passing down the center of the lake, with recirculating eddies created along both sides (figure A-4).

In the south basin, flow is directed along the east shoreline by the training groin that was constructed in 1978. The diversion channel has been obstructed by sloughing island banks, leaning trees, and accumulating log jam debris so that the majority of flow though the south basin is now directed into a secondary, high-flow bypass channel passing along the western shoreline. A recirculating current is created on the downstream side of the islands.

In the middle basin, flow enters along the eastern shoreline, then gradually angles westward, reaching the western shoreline at about the midpoint of the basin. At this point there is a slight change of direction, with the flow heading directly towards the bridge opening adjacent to the eastern shore. Three distinct vortexes (or circular backwater currents) are identified: a large one adjacent to the western shore in the southwest corner of the lake; a smaller one located along the eastern shore at the midpoint of the lake; and a much smaller one located along the western shore in the northeast corner of the basin. Observations made during the Entranco study (1984) tended to confirm this general circulation pattern in the middle basin. Photographic records

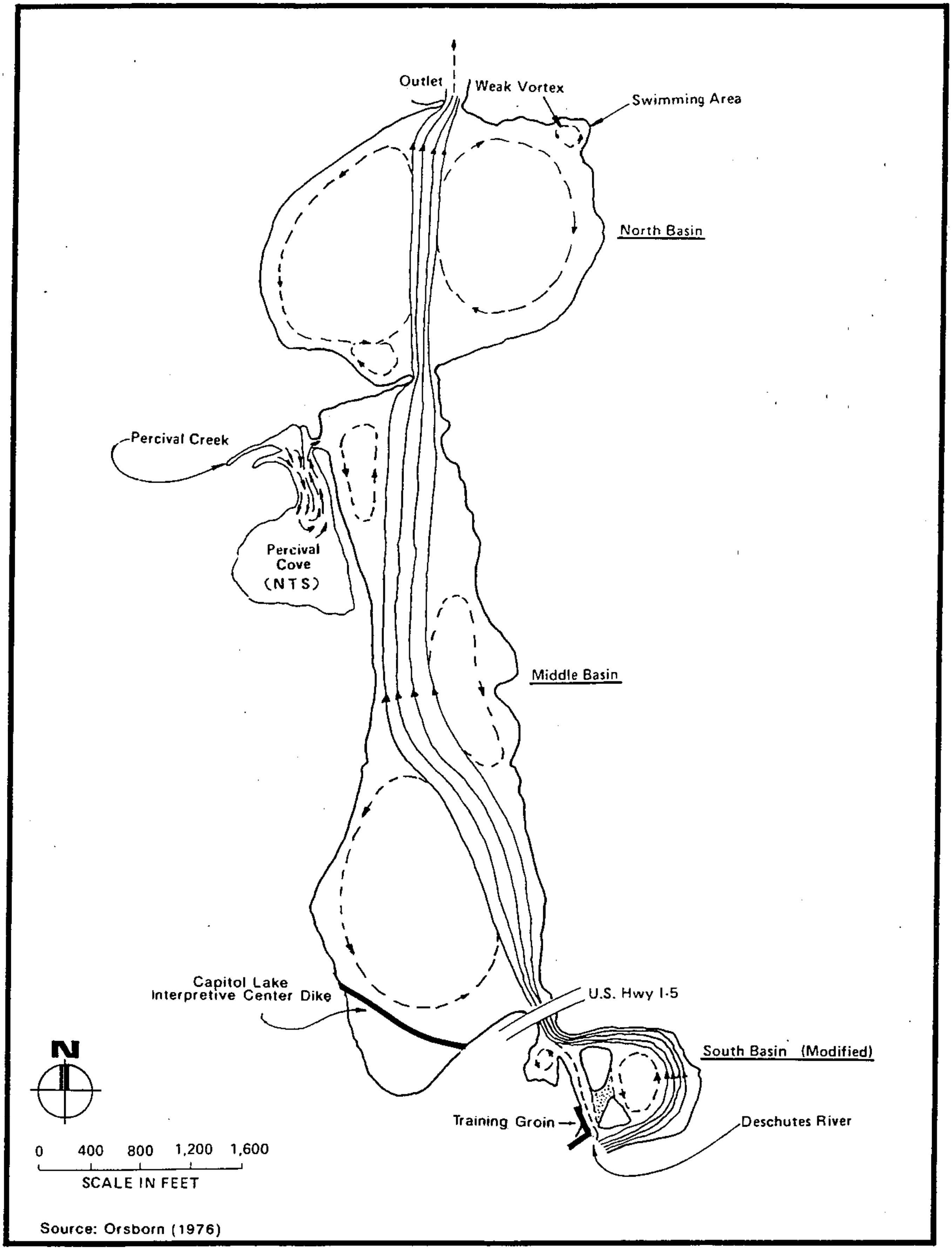

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Figure A-4

CAPITOL LAKE FLOW PATTERN

reveal a definite visual demarcation between the main channel flow and the backwater areas during the spring of 1983, with main channel waters appearing turbid and light brown in color due to suspended sediment transport. Stagnant conditions were also visually noted during routine monitoring at stations located in the vicinity of the large vortex at the southwest corner of the lake.

Circulation is similar in the north basin, with a dominant central "channel" and large recirculating eddies on either side (figure A-4). Poor circulation (poor water exchange with the main river flow) along the east shore of the north basin has historically been considered as a factor contributing to poor water quality in the swimming area at Capitol Lake Park.

Submerged aquatic macrophytes also influence the circulation pattern of the lake. During the study of Capitol Lake (Entranco 1984), rooted aquatic macrophytes such as *Potamogeton* were present in the more stagnant areas of the middle basin. The macrophytes can restrict flow, thus further reducing free mixing with the Deschutes River flows passing through the middle basin.

The average residence time on an annual basis is estimated to be 2.6 days, based on lake volume and average freshwater inflow. Table A-1 presents typical residence times obtained by dividing the average daily flow by the lake volume. The residence times shown are based on the assumption that the entire lake is completely mixed. Within Capitol Lake there is a tendency for river flows to channel through the central axis of the lake, as shown in figure A-4, without mixing with the entire lake volume. The WSU study (1975) concluded that the typical travel time through the center portion of the lake was up to an order of magnitude shorter than estimates of residence time based on complete mix. Conversely, certain eddy areas may have much longer residence times.

Table A-1
Mean Residence Times in Capitol Lake

	Estimated Residence Time (days)			
Month	South Basin	Middle Basin	North Basin	Total Lake Residence Time
October	0.3	2.1	2.6	5.0
November	0.1	0.7	0.9	1.7
December	0.1	0.5	0.7	1.3
January	0.1	0.5	0.6	1.2
February	0.1	0.4	0.5	1.0
March	0.1	0.6	0.8	1.5
April	0.1	0.8	1.0	1.9
May	0.2	1.2	1.5	2.9
June	0.3	1.9	2.4	4.6
July	0.4	2.7	3.4	6.5
August	0.5	3.3	4.2	8.0
September	0.5	3.4	4.3	8.2

Water Elevations

The water surface elevation of Capitol Lake is controlled by the operation of tide gates located at the 5th Avenue dam. Currently the lake level is maintained at 6.43 feet MSL (-3.5 feet City of Olympia datum) during the summer months and at 5.43 feet MSL (-4.5 feet City of Olympia datum) during the winter months (C. Ikerd, pers. comm.).

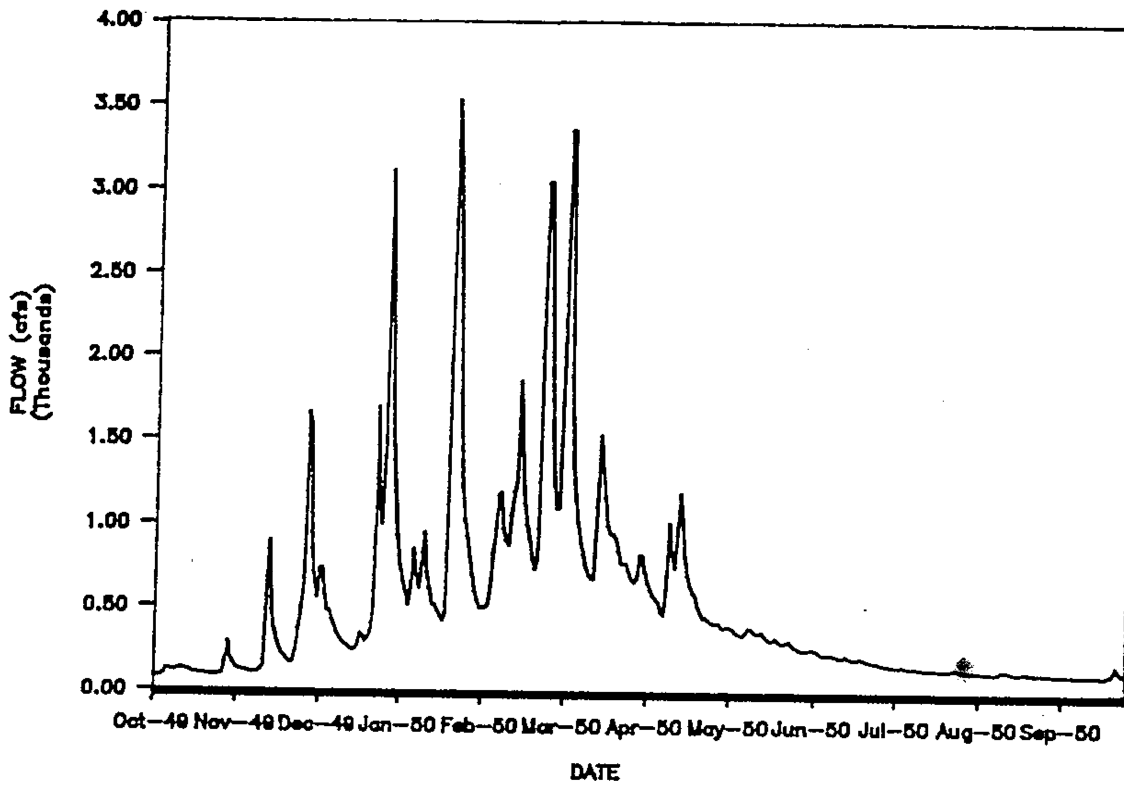
The tide gates are closed when the tide elevation exceeds the lake level. Typically the gates are closed a couple of times each day, with the duration of the closure ranging from 20 minutes to 3 hours (C. Ikerd, pers. comm.). Actual closure times are dependent upon tide elevations and river flows. The higher the tide, the longer the gates are closed. Similarly, the lower the flows, the longer the gates are closed. Data collected by Entranco during the 1983 Capitol Lake study indicated that the gates usually remained closed for a period of about 3 hours (Entranco Engineers 1984).

When the gates are closed, the lake level rises in accordance with the amount of freshwater entering the lake. The Deschutes River dominates all inflows to Capitol Lake, contributing an estimated 85 percent of the annual freshwater budget. Average daily flows in the Deschutes River range from approximately 100 cfs during the summer to 850 cfs during the winter. At the extreme, recorded flows ranged from a low of 70 cfs up to a maximum of 6,650 cfs during the period from 1945 to 1964. Table A-2 summarizes recorded Deschutes River flows. Figure A-5 illustrates the range of daily flows that can be encountered over the course of a year.

Table A-2
Summary of Average Daily Flows
Recorded at the Deschutes River from 1945 to 1964
(USGS Station 12080000, Deschutes River near Olympia)

	Recorded Flows (cfs)		
Month	Average	Maximum	Minimum
October	175	932	70
November	501	3,700	77
December	669	3,770	83
January	787	4,930	221
February	852	4,200	160
March	586	3,360	239
April	466	1,760	218
May	311	1,030	143
June	191	391	110
July	132	312	84
August	107	181	74
September	106	268	77

Figure A-5
Flow of Deschutes River Near Olympia



Source: Earth Info, Inc. (USGS data)

The only other noteworthy inflow to Capitol Lake is Percival Creek. During the 1983 study by Entranco (1984), concurrent flow monitoring in the Deschutes River and Percival Creek indicated that Percival Creek flows were approximately 14.7 percent of the Deschutes River flows.

Water level changes during periods when the gates are closed were estimated by computing the total inflow volume and dividing by the lake surface area. Table A-3 summarizes the estimated lake level changes under average and maximum-daily inflow conditions. The observed lake level changes are based on data collected at the tide gate during the 1983 study. As noted, the observed data does not necessarily reflect the lake level changes in the middle and south lake basins.

When the gates open, the lake level drops to the maintained level. During the 1983 study, the water surface typically dropped over a short period of approximately one hour. The total typical duration of elevated lake levels (including the rise and fall) was approximately four hours.

Table A-3
Estimated Capitol Lake Level Fluctuations
Corresponding to a 3-Hour Gate Closure Time
(feet)

Month	Based Upon Maximum Daily Flows [1]	Based Upon Average Daily Flow	1983 Study [2]
October	0.92	0.17	NA
November	3.67	0.50	NA
December	3.74	0.66	NA
January	4.89	0.78	NA
February	4.17	0.85	NA
March	3.33	0.58	0.50
April	1.75	0.46	0.20
May	1.02	0.31	0.25
June	0.39	0.19	0.25
July	0.31	0.13	0.20
August	0.18	0.11	0.20
September	0.27	0.10	0.20

(1) Flows are based upon Deschutes River recorded data with a 14.7 percent adjustment (increase) to account for Percival Creek.

(2) 1983 data was collected at the north basin tide gate (Entranco 1984). Water surface elevation changes do not necessarily reflect changes in the middle and south basins.

Flood Control

Capitol Lake provides flood protection for low lying areas adjacent to the lake. Peak flows in excess in 2,000 to 3,000 cfs can be expected on an annual basis. During periods when high flows coincide with high tides, the lake serves to hold the incoming river flows until the tide elevation drops and the gates are opened. If adequate storage is not available, adjacent areas (including part of the city of Olympia) can flood.

Under existing conditions lake elevations may reach as high as 11.36 feet MSL during 100-year flow conditions. Flooding has occurred at the sites indicated in table A-4.

Table A-4
Historically Flood-Prone Areas in the
Vicinity of the North Basin of Capitol Lake

Location	Approximate Elevation
North Shore Parking Lot	8.0 feet MSL
East Shore Railroad Tracks	9.0+ feet MSL
Water Street	9.5 - 10.5 feet MSL
Columbia Street	10.0+ feet MSL
5th Avenue	11.0+ feet

Under current practice, the lake level is lowered when high flows are expected in the Deschutes River. The lake level can be dropped all the way if a major flood is expected (C. Ikerd, pers. comm.).

Coordination with the WDF is required to lower the lake level since the lake is currently being used for fish rearing. During the recent flood event of January 9, 1990, fisheries allowed 10,000 fingerlings to die when the lake level was lowered before the flood.

Table A-5 presents peak flows predicted for the Deschutes River. The recurrence interval represents the average frequency of occurrence for that particular flow. For example, a 2-year flow is expected to occur on the average once every two years. The predictions were statistically derived from flows recorded from 1945 to 1964. During that period, the maximum recorded flow was 6,650 cfs (on January 26, 1964).

Table A-5
Predicted Flood Flows for the Deschutes River
(USGS 1985)

Recurrence Interval (years)	Flow (cfs)
1	1,878
2	3,803
5	4,926
10	5,644
25	6,529
100	7,813

WSU (1975) estimated the 2- and 100-year Percival Creek flows to be 150 and 360 cfs, respectively.

The range of lake level fluctuations during flood flows depends upon the magnitude of the flow and the timing with respect to high tides. During high flows, the lake level can rise approximately one inch every five minutes (C. Ikerd, pers. comm.).

Table A-6 presents a range of lake level fluctuations that could occur under different flows and durations of tide gate closure. The larger lake level changes under the longer gate closure times (e.g. 3 and 6 hours) may not be realistic, because at some point in time, the lake level would exceed the tide, and the gates could be opened.

Table A-6
Estimated Capitol Lake Level Changes
Associated with Peak Flows in the Deschutes River

Recurrence Interval (years)	Flow (cfs)	Lake Level Rise (ft.) for Duration of Gate Closure			
		1-hour	2-hour	3-hour	6-hour
1.01	1,878	0.5	1.0	1.5	2.9
2	3,803	1.0	2.0	2.9	5.2
5	4,926	1.3	2.5	3.6	6.5
10	5,644	1.5	2.9	4.1	7.2
25	6,529	1.7	3.3	4.6	8.1
100	7,813	2.1	3.8	5.4	9.2

The values shown in table A-6 are based upon a starting elevation of 6.43, the typically maintained lake level. If the lake level was dropped prior to the flood flow, the elevation changes would tend to increase due to the fact that there is relatively less volume at lower levels. For example, it is estimated that if the lake is lowered more than 6 feet prior to the flood flow, the 10-year flow over a one hour duration would cause a 2.8 foot rise as opposed to a 1.5 foot rise beginning at the typically maintained lake level. The ending elevation, however, would be less.

Future flood elevations and/or the duration of gate closure could be changed if the predicted increase in sea level occurs. It is estimated that the mean sea level could rise by 1.5 to 6.5 feet by the year 2100 as a result of global warming. Higher tides would result in longer gate closures, thereby potentially causing higher water levels in Capitol Lake. Changes in the operation of the tide gates or the maintained lake level could offset some of the potential for flooding from the lake site.

Saltwater Flushing

Beginning in 1971, Capitol Lake was flushed three times a year with saltwater from Budd Inlet. There were three reasons for conducting saltwater flushings. First, the release of fish reared in Percival Cove was enhanced by lake drawdown in early March and late May or early June. Second, annual maintenance dredging within Percival Cove and/or other maintenance activities within Capitol Lake conducted in August, required that Capitol Lake be backfilled with saltwater. Third, it was thought that saltwater flushing was effective in reducing algal blooms and aquatic macrophyte growth (CH_2M Hill 1978; Entranco 1984; Orsborn et al. 1975; Singleton 1982).

Routine saltwater flushing was discontinued as a regular practice in the mid-1980s when the WDF determined that "bumping" was no longer a necessary fish management practice. Although there are still occasions when drawdown and salt water flushing could be practiced to enhance water quality, the lake is no longer being "bumped" for this purpose. (This issue requires the attention and resolution of the Capitol Lake Management Committee.)

The practice of saltwater flushing, however, continues as an option under special conditions. Since 1985, Capitol Lake was twice flushed with saltwater (C. Ikerd, pers. comm.). In 1988, the City of Olympia requested that the lake be drawdown to conduct maintenance operations within the swimming area in the north basin (C. Ikerd, pers.

comm.). The lake was backfilled with the saltwater following the maintenance of the swimming area. (C. Ikerd, pers. comm.).

The procedure for lake drawdown and saltwater flushing is as follows: first, optimal conditions for saltwater flushing are identified, that is, a very high tide that is preceded by an extremely low tide. Regulating agencies are then contacted by the tide gate operator (including the Departments of Wildlife, Fisheries, and Ecology, and the Puget Sound Pilot Association) as well as the selected private individuals who maintain boats on Capitol Lake. The lake is drained at low tide and filled on the incoming high tide. The time it takes to fill the lake is mainly dependent on the tide and Deschutes River and Percival Creek flows.

A large depression near the tide gates has formed as the result of allowing saltwater flushing to occur under a condition of too large of a head differential between the lake and Budd Inlet. That is, increased velocities in the tide gate area resulted in a zone of scouring. To prevent enlarging this deep hole, the lake is now filled when the head differential is less than two feet and at a rate not to exceed six to eight inches increase in lake elevation every hour. The lake is assumed to have a surface area of 220 acres. Tide gate operators monitor velocities through the tide gates to ensure that additional scouring within the depression does not occur.

During low flows, tide gate operators monitor the deep hole for hydrogen sulfide gas (H_2S) concentrations. High levels of H_2S, formed in the stagnant, anoxic depression near the tide gates, were blamed for causing fishkills within Budd Inlet in 1981 (Singleton 1982). A siphon placed in the deep hole in 1986 is apparently providing a sufficient exchange of water within the scoured area. Following installation of the siphon, H_2S concentrations have not exceeded the WDOE criterion.

Sedimentation Control

Because Capitol Lake serves as a settling basin for the Deschutes River and Percival Creek basins, sedimentation control within Capitol Lake has been a continual concern since the dam was built in 1951 (Orsborn et al. 1975; Singleton 1982). Several studies have estimated sediment loads into Capitol Lake (Entranco 1984; Kilian 1989; Moore and Anderson 1979; Nelson 1970; Sullivan et al. 1987; WSU 1975). These estimates are shown in table A-7. The wide range in sediment loading estimates between these studies is mainly the result of using different methods to evaluate sediment loading from the Deschutes River and/or accumulation in Capitol Lake. The three most common methods for estimating sediment loading are: 1) the product of flow and suspended solids concentration (this method underestimates total sediment loading, because the contribution of bedload sediment is excluded.); 2) soil volume loss in the stream channel as measured by streambank inventories or sediment loss in the watershed (to properly use this method, sediment loss from both the stream channel and the watershed must be included.); and 3) change in lake volume over time (this method is generally the most accurate representation of sediment loads reaching the lake. It requires, however, that the bottom area of the lake be mapped.)

The primary source of sediment into Capitol Lake is the Deschutes River. The major causes of sediment loading to the river are attributed to forest related activities and in-stream bank erosion.

Table A-7
Summary of Various Studies Relating to Sediment Loading from the Deschutes River to Capitol Lake*

Study	Year	Annual Sediment Loading (cubic yards)
Puget Sound Task Force	1970	25,900
Nelson	1970	20,900
Walker and Bryne	1973	28,300
Orsborn, et al. (WSU)	1975	41,000
Moore and Anderson	1979	20,100
Entranco Engineers	1983	54,800
Thurston Conservation Dist.	1983	39,500
Kilian	1989	56,700

* Source: PSCRBT 1989.

As part of a stream corridor management plan, the Thurston County Conservation District evaluated sedimentation within the Deschutes River (McNicholas 1984). The Conservation District focused on river hydrology, erosion, and sediment transport. Based on a combination of field work and interpretation of historic aerial photos, the Conservation District determined that 140 river bank erosion sites were contributing an estimated 35,000 to 40,000 cubic yards of sediment erosion annually (with an estimated 78 percent of this material reaching Capitol Lake). In addition, the District identified 49 sites where debris jams (log jams and associated material) were problematic, and 128 sites where leaning trees (caused by channel undercutting and erosion) were creating problems.

The latest inventory of sediment sources, conducted by the Puget Sound Cooperative River Basin Team (PSCRBT) concluded that erosion from forest harvest activities is likely to be a significant contributor of sediment to Capitol Lake (Kilian 1989). Forestry is the major land use within the watershed. Improvements resulting from implementation of TFW (Timber Fish/Wildlife) riparian management zones (WAC 22-30-020) are expected to decrease sedimentation in the upper watershed (Kilian 1989). Debris flows or mass failures, and increased runoff, were also cited as major sources of sediment.

Regardless of the source of sediment within the Deschutes River Basin, these sediment loads represent a significant loss of depth within the middle and north basins of Capitol Lake. It was estimated that these basins are filling in at a rate of 0.08 to 0.09 feet per year (Entranco 1984). Because the more coarse material settles out before the finer sediment, the three lake basins have different rates of sedimentation. The rate at which sediment is deposited decreases with distance from the point where the Deschutes River enters Capitol Lake. Entranco (1984) estimated that sediment accumulation rates to the south, middle, and north basins were 10,400; 31,100; and 13,300 cubic yards per year, respectively.

To reduce the impact of this sedimentation rate, two sediment traps were constructed in 1978. The traps were built in the south basin and the southern end of the middle basin. The south basin trap has since been abandoned and is no longer maintained. This action resulted from changes made from the original design, which reduced the effectiveness of the trap. The sediment trap in the middle basin is functioning as expected, and is performing at about 85 percent of the design efficiency (Entranco 1984).

The only maintenance of the middle basin trap since 1978 occurred in 1987, when 57,000 cubic yards of sediment, approximately equal to the amount of sediment deposited annually in Capitol Lake, were dredged at a cost of $328,900 (B. Arndt, pers. comm.). The rate of accumulation in this trap (6,300 cubic yards per year) is much less than the previous estimate of 14,100 cubic yards per year (Entranco 1984). This may be indicative of an inadequate dredging frequency. Despite the existence of the traps, it is estimated that 60 percent of the incoming sediment is carried beyond the trap and deposited within the middle and north basins (Entranco 1984). Although recommended by Entranco (1984), further dredging of the area outside the trap area is not presently occurring.

Although Percival Creek contributes relatively little sediment to Capitol Lake, Percival Cove has been dredged on a yearly basis to maintain adequate depths and distribute flows within the cove. This dredging has been done in connection with use of the cove for fish rearing. This maintenance dredging was discontinued in 1983, because it became impractical during higher flow conditions in April (K. Keown, pers. comm.).

The amount of sediment entering Budd Inlet is lower than pre-Capitol Lake conditions because, as mentioned above, Capitol Lake essentially functions as a settling basin for the Deschutes River and Percival Creek. The last major dredging operation within Budd Inlet was the removal of about one million cubic yards of sediment in the early 1980s to build the East Bay Marina. Periodic maintenance dredging activities occur on an infrequent basis—about every 10 to 15 years. The most recent maintenance dredging activity within Budd Inlet also occurred in the early 1980s, when approximately 20,000 cubic yards of sediment were removed (D. Malin, pers. comm.).

Water Quality and Loading

Historically, water quality problems in Capitol Lake have included:

- Excessive sedimentation (refer to section on Sedimentation Control);
- Eutrophication (high phosphorus and algae levels and corresponding poor water clarity);
- Bacterial contamination; and
- Toxic H_2S concentrations within the deep crater (refer to section on Saltwater Flushing).

Since sediment and H_2S problems are addressed under separate headings, this section is limited to a discussion of eutrophication and bacterial contamination.

When evaluating the water quality issues for Capitol Lake, the following unusual properties of the lake become important:

1. The lake has an extremely low detention time, with an average annual detention time of 2.6 days (CH_2M Hill 1978). (Refer to the section on Lake Circulation for further information on detention times within each basin). Capitol Lake functions partially as a shallow lake and partially as a river. The relatively high flushing rate complicates eutrophication analysis for Capitol Lake since both nutrient supply and flushing rate may contribute to algae growth limitations, whereas nutrient supply alone limits algae growth in most lakes.

2. The previous management practice of flushing the lake with saltwater three times each year influences the algal productivity. Salt flushing has been demonstrated as an effective means of controlling algal blooms and macrophyte abundance.

3. The lake is located in a former tidal flat that is a natural area of sediment deposition and high productivity (CH_2M Hill 1978).

Eutrophication

Nutrient levels in Capitol Lake are characteristic of a eutrophic lake. The high flushing rate, however, complicates this classification. Mean annual total phosphorus (TP) concentrations average 40.6 mgP/m^3 (Entranco 1984). Earlier studies reported mean TP concentrations of 40 to 60 mgP/m^3 in the three basins (WSU 1975, CH_2M Hill 1978). Higher concentrations typically occur in the summer during low flow conditions.

Each of the three major studies that evaluated nutrient limitation within the lake differed as to which nutrient was limiting algal growth. The 1975 WSU study concluded that nitrogen (N) was the limiting nutrient, while the 1978 CH_2M Hill report stated that nutrient limitation varied seasonally. Entranco (1984) assumed that P was the nutrient that should be managed, largely because of the difficulty in controlling nitrogen sources. This rational for restricting the analysis of nutrient limitation to P is maintained in this study.

Annual TP loading to the lake is relatively high at 19 to 37 g/m^2 yr (CH_2M Hill 1978; Entranco 1984; WSU 1975). The major sources of phosphorus to Capitol Lake are the Deschutes River, Percival Creek, and the Pabst Brewery. Table A-8 presents a summary of total phosphorus (TP) loadings from each source. The Deschutes River dominates the nutrient loading and the river is estimated to contribute about 67 percent of the total TP loading to the lake (Entranco 1984, CH_2M Hill 1978). The monthly TP loading to Capitol Lake from the Deschutes River is shown in figure A-6, page A.24. Most of the loading from the river occurs during the winter period between November and March.

The Pabst Brewery is estimated to contribute a significant amount of phosphorus, particularly during the summer months, when it contributes about 30 percent of the total phosphorus loading. The major source of phosphorus is an antiscaling compound used by the brewery to control iron deposition in the pipes. Phosphorus data for the brewery effluent is limited, because nutrient monitoring is not included in the NPDES (National Pollutant Discharge Elimination System) permit regulating brewery effluent. Although the NPDES permit for the brewery expired three years ago, there are no current plans for rewriting the permit. The most recent (1986) phosphorus data collected from the brewery outfalls confirms the high concentrations reported by Entranco (1984). Total phosphorus concentrations in recent samples ranged from 260 mgP/m^3 to 820 mgP/m^3 (G. Cloud, pers. comm.). Corresponding flow data, from which loading data can be calculated, was not immediately available.

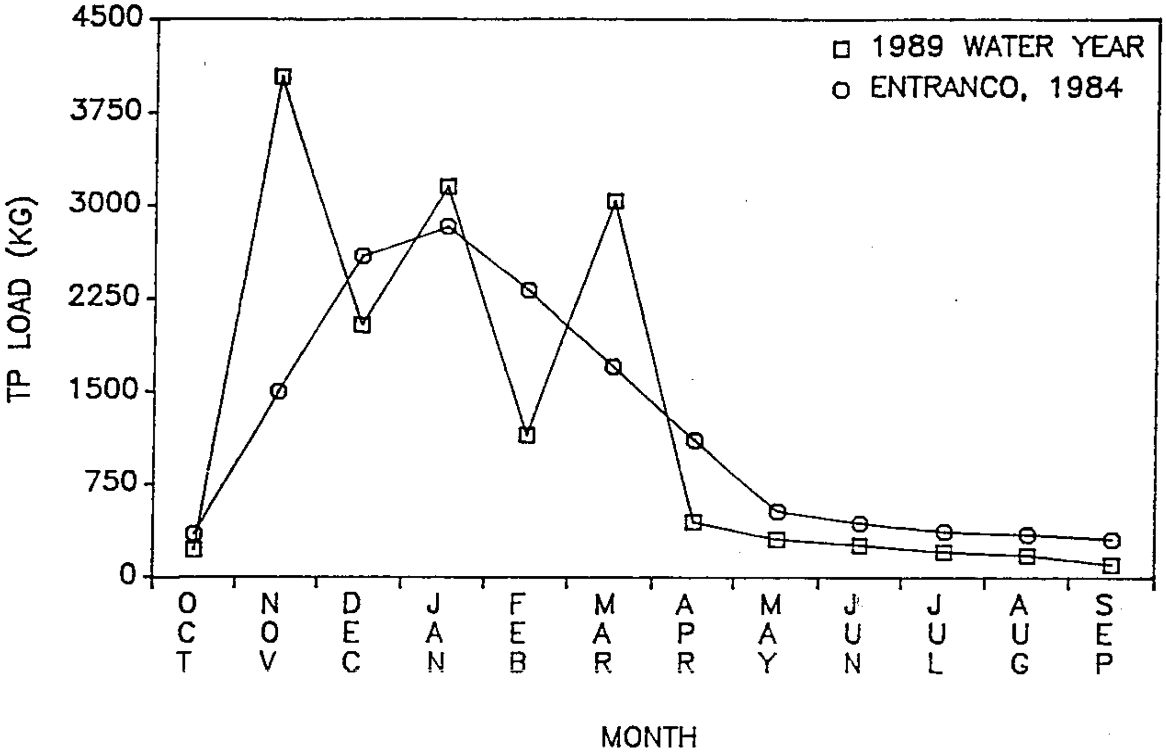
Table A-8
Capitol Lake Nutrient and Water Budgets: Inputs *

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	67.4
Percival Creek	52.48	1,565 (1,236 - 2,062)	12.5	7.4
Pabst Brewery	4.65	2,935 (1,221 - 5,549)	1.1	13.8
Percival Cove	- -	738 (489 - 987)	- -	3.5
Capitol Lake Basin Runoff	2.14	444 (256 - 622)	0.5	2.1
Miscellaneous Point	1.96	177	0.4	0.8
Discharge and Groundwater				
Birds	- -	273 (45 - 500)	- -	1.3
Fish Feed	--	738	--	3.5
Precipitation	1.50	24	0.4	0.1
Marine Influence	- -	17	- -	0.1
	419.72	21,245 (12,944-30,607)	100.0	100.0

* Updated to account for fish feed TP loading.
** Parenthetical values represent the potential loading range based upon the variability in the data.

Ten percent of the phosphorus loading to the lake originates from Percival Creek and Percival Cove. Phosphorus loading within the cove is the result of relatively phosphorus-rich sediments and fish feeding activities. Before the transfer of most of the fish operations within the cove to Squaxin Island, fish feeding activities contributed 68,100 kg/yr of fish food to the cove (Entranco 1984). Despite the relocation of a majority of the fish rearing operations, approximately 66,000 kg/yr of fish food are still used to maintain the remaining fisheries in the cove (K. Keown, pers. comm.), an amount representing about 1,980 kg TP/yr. However, since some of the fish food ends up in fish tissue and some ends up in bottom sediments, not all of the 1,980 kg can be allocated to the phosphorus budget. For purposes of estimating fish food contributions, the authors have assumed that the 738 kgP/yr contributed by Percival Cove is all attributable to fish feeding. (This value was empirically derived from measurements of TP loading upstream and downstream from the cove (Entranco Engineers 1984). Another 738 kgP/yr has been attributed to fish feeding that is presently being conducted near the I-5 bridge. (The total quantity of fish food applied at this location is also averaging about 66,000 kgP/yr.).

Figure A-6
Monthly TP Loading from Deschutes River to Capitol Lake



Average annual chlorophyll *a* levels in Capitol Lake range from 8 mg/m^3 in the middle basin to 14 mg/m^3 in the north basin (Entranco Engineers 1984). *Amphanizomenon* sp. were reported, but levels did not reach nuisance concentrations (WSU 1975). In the most recent analysis of algae composition, the dominant genera of algae were *Anabaena*, *Cyclotella*, and *Stichococcus* (CH_2M Hill 1978). Occasional accumulations of floating algae mats in the swimming area were caused by wind patterns, which concentrated algae in this section of the north basin.

Bacterial Contamination

Bacterial contamination has been one of the most studied water quality problems in Capitol Lake. High coliform levels occurred primarily during the 1950s and 1960s. The swimming area was closed in 1985 as a result of high fecal coliform counts, and has not been reopened. Monitoring of the swim area was discontinued following its closure.

Major sources of bacterial contaminants include the Deschutes River and waterfowl (CH_2M Hill 1978). Although a single bird is estimated to produce 3.9×10^{10} fecal coliforms per year (CH_2M Hill 1978), the actual contribution to a receiving water is difficult to evaluate. Actual fecal coliform numbers in receiving waters are expected to be considerably lower because of sedimentation and die-off rates and because not all the excreta enter the water directly.

Fecal coliform counts in the Deschutes River have been low over the last three years, ranging from 1 to 81 org./100 ml (WDOE, STORET data). The geometric mean of fecal coliform counts of monthly samples taken in the Deschutes River between 1984 and 1989 was 16/100 ml (Deschutes River at E Street Bridge; WDOE, STORET data). Livestock in the watershed are the most likely source of high bacterial loading to the river itself, although failing septic tanks, birds and wild animals are also potential contributors. Intermittent, but sometimes significant sources, include the storm sewers feeding into the lake, brewery discharges, and Percival Creek. Sufficient data does not exist to quantify the present waterfowl contribution or the intermittent sources.

These various sources of fecal coliform lead to dissimilar concentrations across the three basins of the lake and widely varying water quality (CH_2M Hill 1978). For example, Singleton (1982) reported no bacterial violations during the summer of 1982. Earlier that year, sampling of outfalls to the lake by the WDOE reported two storm drains that had high bacterial counts (Memo from A. Moore to J. Thomas, April 13, 1982). A storm drain discharging near the swimming area was repaired in 1983. Further monitoring of this area indicated that discharges occasionally had high counts. It was concluded that the observed levels are typical of urban stormwater runoff (Capitol Lake Restoration Committee 1989). Relatively recent data (mid-1970s to 1984) indicated, however, that bacterial levels were often within the criterion established for contact recreation. As shown in table D-1 (Appendix D) fecal coliform values within the swimming area were generally low. As stated by Orsborn et al. (1975), "Although the data are very limited, quality in the swim area was observed to be generally good with counts consistently below the 200 organisms/100 ml maximum level recommended for body contact recreation". Singleton (1982) also found that the swimming area generally had good water quality. Thus, the current levels of bacterial contamination within Capitol Lake need to be clarified. Sampling by the Thurston County Health Department during the July 1990 drawdown has provided some additional insight to this issue.

Additional fecal coliform data was collected from Capitol Lake and some of the immediate pipe outfalls to the lake during the July 1990 drawdown (sampling locations and data are reported in Appendix D). Fecal coliform concentrations ranged from 0 to 310 organisms per 100 ml in the north basin of Capitol Lake, including both open water and nearshore samples. The geometric mean was calculated at 21.2 organisms per 100 ml, and not more than ten percent of the samples exceeded 200 organisms per 100 ml. This recent data indicates that the lake meets state lake class water quality criteria for fecal coliform bacteria.

The data does indicate that nearshore samples are likely to have higher bacterial levels. All the open water stations had fecal coliform concentrations of 10 organisms per 100 ml, while two shoreline stations had levels of 140 and 310 organisms per 100 ml. The sample with the highest concentration was taken near Marathon Park and may reflect the influence of waterfowl (geese) activity in the area. Higher nearshore levels may also be due to the influence of various pipe outfalls. Three pipe outfall samples in the north basin exhibited very high concentrations at 2,625, 6,450, and greater than 160,000 organisms per 100 ml. Finally, higher nearshore concentrations may also reflect reduced water exchange rates in the nearshore zone. These results tend to suggest the need for improved control of nonpoint sources of bacterial loading to the north basin, and for improved circulation.

INSTITUTIONAL CONSIDERATIONS

Multi-jurisdictional Management

The Washington State Department of General Administration has overall management jurisdiction for Capitol Lake, a resource that was originally constructed to serve as a reflecting pool for the Capitol Campus. Since Capitol Lake functions as a multipurpose lake/reservoir, and since Thurston County and the cities of Olympia and Tumwater border on the lake, it is not surprising that management decisions affecting the lake are multi-jurisdictional.

The cooperative management spirit that exists between state and local government is reflected in the composition of the Capitol Lake Restoration (CLR) Committee, a committee formed in 1986 for the purpose of restoring and preserving Capitol Lake. The committee is comprised of representatives from the City of Olympia, the City of Tumwater, Thurston County, the State Department of General Administration, and the Office of the Governor. The CLR Committee has recommended that multi-jurisdictional management of Capitol Lake continue in the future through the formation of a Capitol Lake Management or Action Committee. Such a committee might be comprised of representatives of key organizations with past involvement in lake management issues, as shown below.

ORGANIZATION	PRINCIPAL INTEREST
Department of General Administration	Overall management, flood control, water quality, sediment control and maintenance dredging.
Department of Ecology	Water quality, wetlands, shorelands, NPDES permits.
Department of Wildlife	Game, fish, shorebirds, waterfowl, other birds, mammals, water quality and other factors affecting resources under their jurisdiction.
Department of Fisheries	Salmonid fish, water quality, and other factors affecting resources under their jurisdiction.
The Squaxin Island Tribe	Fisheries and water quality.
Thurston County, Cities of Olympia, Tumwater	Flooding, water quality, shorelands, parks and recreation, stormwater control.

These are the government organizations that usually have the greatest interest in the management of Capitol Lake and, as in the case of the present study, the Department of General Administration typically involves each of these agencies in an advisory committee forum to assist in the development and execution of lake management decisions. The intent is to make decisions that maximize benefits and minimize adverse impacts to all lake users.

In addition to this core group of organizations, there may be others who have an interest in a particular decision or lake management issue. For example, the inclusion of nonpoint source control issues automatically attracts the interests of the Department of Natural Resources, parties to the Timber Fish Wildlife agreement, private and public land owners, the Thurston County Conservation District, Puget Sound Water Quality Authority, and others.

Whenever dredging and the potential for wetland filling is involved, the Department of Natural Resources, which has jurisdictional responsibility for the State's ownership of the lake bottom, will have interest. Similarly, the U.S. Army Corps of Engineers and Port of Olympia would be interested in placement of fill and dredging. The same is true for interest from other federal agencies such as the U.S. EPA and the U.S. Fish and Wildlife Service. Management decisions on Capitol Lake could also draw the interest of the Port of Olympia, environmental groups like the Sierra Club and Audubon Society, and the general public.

Regulatory and Permit Considerations

The following permits or review processes could be involved in the review of wetland development within the Capital Lake basin, depending on the particular alternative under consideration.

- SEPA Review (EIS is presumed)
- Shoreline Master Development Permit
- U.S. Army Corps of Engineers (COE) Section 404 and 10 Permits
- WDOE Dam Safety Permit
- WDOE Water Quality Modification Permit
- Hydraulic Project Approval (HPA) Permit

The SEPA process would involve review of the whole project; the COE permits would involve review of jurisdictional wetlands and navigable waterways, and the Shoreline permit would involve review of the lake, its associated wetlands, the 100-year floodplain, and inland 200 feet from the lake shore.

It is our understanding the Department of General Administration processes SEPA reviews for standard projects. General Administration would seek input from other affected agencies including the Departments of Ecology, Wildlife, and Fisheries; the Squaxin Island Tribe; and affected cities and counties.

The SEPA process (through the EIS) would establish the impacts and mitigation requirements for each alternative. Included in the SEPA review would be the requirements for specific permits.

After the SEPA process was completed, the development would require a Substantial Shoreline Development Permit. The City of Olympia and the City of Tumwater shoreline sections would conceivably require separate permits. Both the SEPA and Shoreline reviews would require public notice and public hearings. Scheduling and notice of the public hearings would have a bearing on the time frame of the overall project.

Agencies which would or could be involved in the SEPA review permit process include:

- Federal: U.S. EPA
U.S. Fish & Wildlife
National Marine Fisheries

- State: Dept. of Ecology
  Dept. of Fisheries
  Dept. of Wildlife
  Dept. of Natural Resources

- Local: Olympia
  Tumwater
  Thurston County

- Other: Squaxin Island Tribe (the tribe input is actually advisory only, but carries very substantial weight).
  Washington Dam Safety might also review and condition the permit.
  Dept. of Transportation, if roads or rail is affected.

Agency contacts are as follows:

U.S. Army Corps of Engineers
Karen Northup
(206) 764-3495

Department of Wildlife
David Mudd
(206) 753-3318
Jeff Skriletz
(206) 264-5051

The Squaxin Island Tribe
Jeff Dickison
(206) 426-9783

City of Olympia
Planning Department
Marziah Kiehn
(206) 786-5745
Environmental Coordinator
Paula Ehlers
(206) 786-5745

Department of Ecology
Darryl Anderson
Mary Berg
(206) 459-6790

Department of Fisheries
Steve Keller
(206) 753-2537
Earl Finn
(206) 753-3629

Thurston County
Fred Knox
Cathleen Burgess
(206) 786-9783

City of Tumwater
Gerald Petheram
(206) 754-4180

BENEFICIAL USES

Aesthetics

<u>Introduction</u>

Capitol Lake offers a rich cross-section of sensory, biological, recreational, and cultural resources which all contribute to its high aesthetic value. The perception of a place is shaped by sensory stimuli, cultural context, and one's experience of the place. These factors combine to create the identity of the place. One's recognition of that identity is based on the strength of these cultural, sensory, and experiential factors.

Cultural Factors

History. Capitol Lake was formed in 1951 by the completion of the 5th Avenue dam. Prior to the construction of the dam, the site consisted of the tidal mud flats at the mouth of the Deschutes River. Today, the three basins of the lake are defined by the cross-section of transportation corridors and the steep slopes surrounding the site. The abundance of wildlife and natural processes in a moderately urban context greatly influence the character of the lake. The site has been developed incrementally over time.

Many master planning efforts and studies have proposed a range of design traditions. In 1911, the architectural firm of Wilder and White developed a site plan designed in the tradition of the City Beautiful Movement. This tradition is based on the perception that nature is formal and geometric in its origin. The Wilder and White plan featured a formal landscape linkage between the Capitol Building and downtown Olympia along the east shore of what is now the north basin. This plan also called for the creation of Capitol Lake as a reflecting pool for the Capitol Building. Later, a less formal plan was developed by the Olmstead Brothers. In contrast to the Wilder and White Plan, the Olmsteads proposed a more informal, organic landscape featuring open bodies of water, groups of trees, and large open lawn areas.

In 1967 Rich Haag and Associates prepared the Open Space and Recreation Plan for Capitol Lake. Haag's proposal encouraged protection of the steep forested slopes surrounding the lake, and greater public access. The plan also proposed a stronger linkage between the lake and Percival Cove, with the intention of preserving the native landscape. Richard Carothers Associates (RCA) developed the Capitol Lake Middle Basin Recreation Site in 1981. The RCA plan proposed development options for the fill area in the southwest corner of the middle basin. Passive recreational activities were recommended, with emphasis on interpretation of the natural and manmade processes which influence Capitol Lake. Jones & Jones, Architects and Landscape Architects, prepared the State Capitol Heritage Park Plan in 1986. This plan builds on the Wilder and White Plan by developing a formal linkage between the Capitol Campus and downtown Olympia. The firm of Jones & Jones currently is working on a master plan for Capitol Lake Park for the City of Olympia. This plan will be compatible with the State Capitol Heritage Park Plan, and will revitalize this important focal point of the community.

All planning efforts subsequent to the original Wilder and White, and Olmstead Brothers plans are consistently designed to either emphasize the natural environment of the middle and south basins or to formalize the connections between Capitol Campus and downtown Olympia along the north basin's east shore.

Surrounding Adjacent Land Use. The upland west of the north basin is residential and zoned R-1. The upland west of the middle basin is zoned as the Evergreen Park PUD and is the location of the Thurston County Administration Building Complex. The predominant use of the area within the city limits of Tumwater around the southwest corner of the south basin is residential. According to Gerald Petheram, City of Tumwater Parks and Recreation Manager, the southeast corner of the south basin may be sold to private developers who propose to build a commercial retail complex in association with the old brewery. The upland east of the middle basin is residential and zoned R-2. The Capitol Campus on the upland east of the middle and north basins is zoned CS-H. The east edge of the north basin is zoned RM-H. Predominate use of this area is by the Burlington Northern railway, and a recycling plant. Downtown Olympia abuts the northeast corner of the north basin and is zoned CW.

The entire lake edge is designated as either an urban or conservancy shoreline under the Shoreline Master Program.

<u>Sensory Factors</u>

<u>External Views</u>. All three basins of Capitol Lake figure prominently in the middle ground of panoramic views as seen from the ridges surrounding the lake. These views are enhanced by the reflection of the surrounding landscape in open water, including reflections of the Capitol Building. The most significant of these views include:

- Views north from the Thurston County Administration Building featuring Percival Cove, the north basin, downtown Olympia, the marina, Budd Inlet, and the Olympic Mountains in the distant ground.

- Views north and west from Capitol Campus featuring the north and middle basins, downtown Olympia, Budd Inlet, and the Olympic Mountains in the distant ground.

- Views from residential areas on the ridges surrounding the lake featuring views of all three basins.

<u>Internal Views</u>. The three basins of the lake and the forested slopes surrounding the lake dominate most views seen from within the site. A band of mature coniferous trees along the ridge line of the forested slopes provides a backdrop. Along portions of the ridge where these conifers have been removed, the scenic quality of views is diminished (i.e., on the ridge to the west of the north basin). The Capitol Building, the steam plant, downtown Olympia, the Deschutes Parkway, the Burlington Northern Railroad, I-5, and Percival Cove figure prominently in many viewsheds.

- *North Basin:* The north basin functions as a reflecting pool for the Capitol Building. Views from this area are expansive rather than intimate.

  Views from the north shoreline feature the Capitol Building, its reflection, and the forested slopes on either side of the middle basin. Views into the middle basin are blocked by the railroad trestle.

  Views from the west shoreline feature the forested slope east of the middle basin, the steam plant for the Capitol Campus, the Capitol Dome, and the skyline of downtown Olympia.

  Views from the south shoreline feature the 5th Avenue bridge, downtown Olympia, and the Marina. The view is framed by the forested slopes on either side of the north basin.

  Views from the east shoreline feature the Burlington Northern railway lines, the State parking lot, the recycling center on Water Street, and downtown Olympia. The forested ridge on the west side of the north basin forms the backdrop to this view.

- *Middle Basin:* Limited access to the east shore of the middle basin prohibits documentation of views from that area. The open water of the middle basin and the forested slopes to the east and west dominate all views from the west shore. The railroad trestle, the steam plant, I-5, the Deschutes Parkway, and Percival Cove figure prominently in many views from the middle basin. Views form this area are generally expansive with the exception of more focused views of Percival Cove. The middle basin also provides some reflected views of the Capitol Building from some perspectives.

- *South Basin:* Access to the south basin is limited to its west shoreline. Most views are generally contained by the forested slope east of the south basin and by I-5 to the north. More intimate views of the wetland along the southwest corner of the shoreline can be appreciated as seen from under the canopy of many trees. The old brewery, the falls, the Deschutes River, and the support structures for I-5 are focal points. The barrenness of the unplanted slopes along I-5 results in a visual contrast to the otherwise established landscape.

Auditory. Auditory factors which influence the character of Capitol Lake include:

Cultural:

- Vehicular traffic noise generated from I-5, Highway 101, the Deschutes Parkway, the 4th and 5th Avenue Bridges, and downtown Olympia.
- Railway traffic noise from the Burlington Northern line.
- The human voice with highest intensities near children's play areas.
- The sound of flowing water at the 5th Avenue bridge.

Natural:

- Song birds
- Wind
- Fish jumping in the lake
- The waterfalls at the old brewery

Tactile. The generally soft texture of the lake and wetland vegetation offer a sharp contrast to the harder surfaces of the constructed elements surrounding the site.

Identity Sense of Place

North Basin. The experience of the north basin is heavily influenced by its close proximity to downtown Olympia, the Capitol Campus, and the marina in Budd Inlet. Because of its strategic location it may be perceived as a destination point and activity node. The ability to travel the full circumference of the north basin separates this portion of the lake as a discreet experiential unit.

Middle Basin. Access to the middle basin is limited to the west shoreline. Vehicular and pedestrian circulation occurs contiguously along the Deschutes Parkway corridor. Limited formal parking options are available. These conditions create a perception that the middle basin functions as a link between destination points. The circulation corridor separates Percival Cove from the middle basin. Percival Cove attracts attention but is inaccessible to all but viewing opportunities.

The Capitol Lake Interpretive Center in the southwest corner of the middle basin is similar in character to the wetland in the south basin. Pedestrian circulation under the I-5 bridge links these two parks together to form two components of one experiential unit.

South Basin. Focused middle distance views and a topographically contained space define the character of the south basin. The program and access of the south basin allow it to be perceived as a destination.

Recreation

Introduction

Recreational opportunities within the regional envelope surrounding Capitol Lake are abundant. Because of the direct linkages to downtown Olympia, the Capitol Campus, Budd Inlet, historic sites in Tumwater, and the mouth of the Deschutes River, Capitol Lake exhibits an extraordinary potential for recreational development. Within the City of Olympia park system, Capitol Lake is the only fresh water lake that is predominantly in public ownership. Greater access to the lake's facilities, improving the water quality to maximize recreational use, and implementation of a comprehensive planning approach are issues which may influence proposed development of the lake.

The lake's recreational resources are used by the downtown business community, State employees, residents of the surrounding neighborhoods, and downtown shoppers. Predominate uses include but are not limited to: picnicking, walking, jogging, cycling, bird watching, fishing, and boating.

Parks

Capitol Lake Park. Capitol Lake Park is an urban park serving the district of downtown Olympia, the Capitol Campus and the surrounding residential communities. It is owned by the State and leased by the City of Olympia. It is located in the northeast corner of the north basin at the intersection of 5th Avenue and Water Street. To the west and south of the park are large State parking lots. The historic focus of the park was the swimming beach. When the pollution levels of the lake became too high, the swimming program was eliminated. The City of Olympia attempted to improve water quality within the swimming area by installing an impervious curtain wall and other supportive technologies. The program designed to maintain water quality within the swimming area was not adequate, however, and the swimming facility was closed. Since swimming is no longer allowed, there is a perception that the park has lost its focus. The park is presently programmed to include beach activities, informal open lawn play, a children's play area, picnicking, strolling, non-motorized boating, and rest rooms. Sailing classes are offered during the summer months. The north basin is the only lake within the Olympia parks system where a sailing program is offered.

The landscape architecture firm of Jones and Jones in Seattle, Washington is currently developing a master plan for Capitol Lake Park. The goal of the design is to develop a plan which will complement the objectives set forth in the State Capitol Heritage Park Plan. This plan, developed by Jones and Jones in 1986, builds on themes established in the original site plan developed for the Capitol by Wilder and White in 1911. The Wilder and White plan established the need to create a formal linkage between the Capitol Campus and Downtown Olympia.

The most recent master planning effort by Jones and Jones on Capitol Lake Park features an esplanade, a planting of submerged vegetation along the shoreline, and access to non-motorized boating activity. Swimming has not been included in the program. The exclusion of this program element is subject to the review of the Olympia City Council.

Marathon Park. Marathon Park is located in the southwest corner of the north basin, and is bounded by the Deschutes Parkway on the west and the Burlington Northern right-of-way on the south. The cross-section of these two transportation corridors separates the park from the middle basin and Percival Cove. The park was the site of the finish line for the Olympic Trials of the marathon event in 1984. Large open lawn areas, and an informal ornamental landscape treatment enhance passive recreational opportunities. The park is programmed to include informal open lawn play, picnicking, strolling, boating, and rest rooms. Shoreline erosion and gradual loss of parkland is a concern at Marathon Park.

Capitol Lake Interpretive Center. This park is built on the fill area located in the southwest corner of the middle basin, and is bounded on the west by the Deschutes Parkway and on the south by the DOT right-of-way for I-5. The focus of the interpretive center is to educate visitors on the environmental processes and human manipulation of Capitol Lake. An informal trail system leads visitors through a wetland and provides viewing opportunities of the abundant bird population. A large portion of the park is being utilized as a staging area for the current construction of I-5. The park is programmed to include two fishing and viewing docks, interpretive panels discussing the dredging and filling operations conducted at Capitol Lake, informal wildlife observation, beekeeping, and rest rooms.

Tumwater Historical Park. Tumwater Historical Park is located on the west shoreline of the south basin and is bounded by the WSDOT right-of-way for I-5 on the north and the Deschutes Parkway on the west. A neighborhood park with a historical focus, the park combines open lawn space and a wetland trail system to provide visitors with a broad range of passive recreational opportunities. Historic structures include original pioneer homesteads. Views of the old brewery across the Deschutes River provide additional interest. The park is programmed to include two children's play areas, a large picnic shelter, rest rooms, benches, basketball, open lawn play, boat launch, interpretive signage focussing on the history of the site, a wetland trail system, bird watching towers, and an exercise trail. Pedestrian circulation links the park to the Capitol Lake Interpretive Center.

Transportation Circulation

The major access point off of I-5 both north and southbound is Exit 103. The entire west edge of the lake can be accessed by the Deschutes Parkway. The northeast corner of the north basin can be accessed by 5th Avenue and Water Street.

Parking lots occur in Capitol Lake Park, Marathon Park, and Tumwater Historical Park. Formalized off-street parking is provided at the Capitol Lake Interpretive Center. Informal parking is possible along the Deschutes Parkway.

Public transportation provides access to within walking distance of most areas of the lake. Pedestrian access to the shoreline is available in all four parks. The trail system of Capitol Lake is composed of a loop trail around the north basin, a trail along the west edge of the middle basin, and trails through Capitol Lake Interpretive Center and Tumwater Historical Park. No pedestrian access is available on the east shores of the middle and south basins.

Most of the trail system around the north basin and along the west side of the middle basin is paved and suitable for walking, jogging, cycling, and roller skating. The balance of the trail system throughout Capitol Lake Interpretive Center and Tumwater Historical Park is composed of a combination of paved surfaces and compacted earth or crushed rock. Some of these paths are suitable only for walking or jogging.

Canoes and kayaks may be launched from the shoreline of all four parks on the lake. Sailboats may be launched in the north basin. A boat launch is located in the WSDOT right-of-way adjacent to Tumwater Historical Park.

Linkages

Strengthening the linkages between the variety of recreational programs available on Capitol Lake with adjacent uses would increase the recreational value of the resource. Many studies have identified the need to strengthen the linkage between the north basin and downtown Olympia, the marina, and the Capitol Campus. The Burlington Northern Railroad right-of-way functions as the major barrier to pursuing this effort.

Percival Cove and Percival Creek are currently inaccessible to all but viewing opportunities. The Deschutes Parkway separates this resource from the lake.

There is no access to the east shore of the middle and south basins. Opening this shoreline to pedestrian access has been recommended in many studies.

Currently, there are no regional trail systems which connect to the recreation resources available at Capitol Lake.

The Deschutes Corridor Recreation Plan developed in 1986 by the Thurston Regional Planning Council in 1986 provides a plan for recreational uses along the Deschutes River. The plan encompasses the Deschutes River Corridor from Rich Road to Budd Inlet. The plan encourages increased access, improved fishing and boating opportunities, and trail linkages between Capitol Lake, Tumwater and the Deschutes River Corridor.

Fisheries Resources

Capitol Lake supports an important fish rearing operation. Many features of this operation provide educational and recreational opportunities.

Events

Capitol Lake is the site of many annual community events. The biggest of these is the Capitol Lake Fair. Activities include a carnival, craft displays, live music, food venders, and a parade. Approximately 5,000 people per day attend this event. Capitol Lake Park is the site of an annual picnic for employees of Washington State. Concerts are also held in the park. Tumwater Historical Park is the site of a 4th of July celebration for the City of Tumwater.

Appendix B

RESOURCE LIST

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RESOURCE LIST

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Appendix C

PLANTS OBSERVED AT CAPITOL LAKE

Table C-1
Plants Observed at Capitol Lake

Acer circinatum	Vine Maple
Acer macrophyllum	Big Leaf Maple
Achillea spp.	Yarrow
Alnus rubra	Alder
Arbutus menziesii	Madrona
Aster spp.	Unknown Composite
Athyrium filix-femina	Lady Fern
Betula spp.	Birch
Cornus canadensis	Bunchberry
Corylus cornuta	Beaked Hazelnut
Crataegus douglasii	Black Hawthorne
Cytisus scoparius	Scotch Broom
Dactylis glomerata	Orchard Grass
Equisetum arvense	Field Horsetail
Equisetum hyemale	Scouring-Rush
Festuca spp.	Fescue
Galium spp.	Bedstraw
Gaultheria shallon	Salal
Holodiscus discolor	Oceanspray
Iris pseudacorus	Yellow Iris
Juncus effusus	Rush
Lysichitum americanum	Skunk Cabbage
Mahonia nervosa	Oregon Grape
Mentha arvensis	Field Mint
Oemleria cerasiformis	Indian Plum
Oenanthe sarmentosa	Water Parsley
Phalaris arundinacea	Reed Canary Grass
Philadelphus lewisii	Mock Orange
Phleum pratense	Timothy Grass
Plantago major	Plaintain
Polystichum munitum	Sword Fern
Populus balsamifera	Cottonwood
Pseudotsuga menziesii	Douglas Fir
Pteridium aquilinum	Bracken Fern
Rhus sp.	Sumac
Rubus discolor	Himalyan Blackberry
Rubus spectabilis	Salmonberry
Rubus parviflorus	Thimbleberry
Rubus ursibus	Everygreen Blackberry
Rumex crispus	Curly Dock
Salix spp.	Willow
Scirpus microcarpus	Small-fruited Bulrush
Solanum dulcemara	Bittersweet Nightshade
Symphoricarpos albus	Snowberry
Taraxacum officinale	Dandelion
Thuja plicata	Western Red Cedar
Tolmiea menziesii	Piggy-back Plant
Typha latifolia	Cattail
Urtica dioica	Stinging Nettle
Veronica americana	American Brooklime

Table C-2

CAPITOL LAKE

TOLERANCE OF EXISTING FRESHWATER VEGETATION TO SALINITY AND WATER LEVEL FLUCTUATIONS

Species	Community	Tolerance to Water Level Fluctuations	Tolerance to Salinity
lady fern (*Athyrium felix-femina*)	PEM, PSS	can tolerate saturation year round	salt sensitive
scouring-rush (*Equisetum hyemale*)	PEM	N/A	N/A
fescue (*Festuca* spp.)	PEM, UPL	N/A	moderately salt sensitive
yellow flag (*Iris pseudacorus*)	PEM	very tolerant to inundation and saturation	very salt sensitive: freshwater species
soft rush (*Juncus effusus*)	PEM	thrives in wet areas; can tolerate drier areas where few competitors exist	intolerant: freshwater species
skunk cabbage (*Lysichitum americanum*)	PEM, PFO	requires soil inundation or saturation	very salt sensitive: freshwater species
water parsley (*Oenanthe sarmentosa*)	PEM, PFO	requires soil saturation or inundation year round or at least inundation during the growing season	moderately salt tolerant
reed canarygrass (*Phalaris arundinacea*)	PEM, PSS, UPL	requires soil saturation during the growing season but does not tolerate extended inundation until it is well established	moderately salt tolerant (reproduction decreases with an increase in salinity)
curly dock (*Rumex crispus*)	PEM, PSS, UPL	N/A	moderately salt tolerant: adaptable from fresh to high salt content
pig-a-back (*Tolmeia menziesii*)	PEM, PFO	N/A	N/A
common cattail (*Typha latifolia*)	PEM	requires 1 to >24" of standing water	salt sensitive
stinging nettle (*Urtica dioica*)	PEM, PFO	N/A	N/A
American brooklime (*Veronica americana*)	PEM	N/A	N/A
vine maple (*Acer circinatum*)	PSS, PFO, UPL	can withstand flooding for most of one growing season	N/A
salmonberry (*Rubus spectabilis*)	PSS, PFO, UPL	N/A	sensitive: low salt tolerance

Table C-2, continued

Species	Community	Tolerance to Water Level Fluctuations	Tolerance to Salinity
willow (*Salix* spp.)	PSS, PFO	very tolerant to flooding for >2 growing seasons	moderately salt tolerant
red alder (*Alnus rubra*)	PSS, PFO, UPL	Very tolerant: withstands flooding or saturation for >2 growing seasons	sensitive: low tolerance to intolerant Does occur in tidally influenced fresh water.
birch (*Betula* spp.)	PFO, PSS, UPL	tolerant: can withstand flooding for most of one growing season	intolerant: freshwater species
beaked hazelnut (*Corylus cornuta*)	UPL, PSS, PFO	N/A	N/A
black cottonwood (*Populus trichocarpa*)	PFO, PSS, UPL	tolerant to flooding for most of one growing season	N/A
western red cedar (*Thuja plicata*)	PFO, PSS, UPL	very tolerant to flooding for >2 growing seasons	N/A
orchard grass (*Dactylis glomerata*)	UPL, PEM	N/A	moderately salt sensitive
bedstraw (*Galium* spp.)	UPL, PFO, PEM	N/A	very salt sensitive
Indian plum (*Oemelaria cerasiformis*)	UPL, PSS, PFO	N/A	N/A
Douglas fir (*Pseudotsuga menziesii*)	UPL	can tolerate moist soils but not inundation	N/A

Notes:

Salinity Tolerances (from Hutchinson)

Very sensitive	0-0.5ppt
Sensitive	0.5-5ppt
Moderately sensitive	5-10ppt
Moderately tolerant	10-15ppt
Tolerant	15-20ppt
Very tolerant	>20 ppt

PEM = palustrine emergent wetland
PSS = palustrine scrub/shrub wetland
PFO = palustrine forested wetland
UPL = upland

- hardwoods are generally more tolerant to inundation than conifers
- flooding during the growing season of coniferous and deciduous trees is critical, while flooding has little effect during the dormant season
- N/A = information not available

Source: Jones & Stokes Associates, Inc.

Table C-3
Animals Observed at Capitol Lake

The following animals, or recent signs of their presence, were observed in the Capitol Lake area on a field trip conducted 29 October 1975 by Charles Lindberg and Christopher Dlugokenski.

<u>Mammals</u>

Deer	*Odocoileus* sp.
Muskrat	*Ondatra zibethica*
Striped skunk	*Mephitis mephitis*
Raccoon	*Procyon lotor*
Voles	*Microtus* sp., *Clethrionomys* sp.
Mink	*Mustela vison*
Mountain beaver	*Aplodontia rufa*
River otter	*Lutra canadensis*
Deer mouse	*Peromyscus maniculatus*
Bushytail woodrat	*Neotoma cinerea*
Pacific mole	*Scapanus orarius*
Bat	*Myotis sp.*

<u>Amphibians</u>

Frogs
Turtles
Lizards

<u>Benthic Animals</u>

Crayfish
Snails

<u>Fish</u>

Salmon
Steelhead
Cutthroat trout

These populations were compiled from the lists of the Black Hills Audubon Society, and are concerned with the area of the lake between the I-5 bridge and Tumwater Falls.

Winter Residents	Permanent Residents
Common loon***	Great blue heron***
Horned grebe*	Green heron***
Eared grebe*	Mallard*
Western grebe*	Sharp-shinned hawk**
Pied-billed grebe*	Cooper's hawk***
Double-crested cormorant*	Red-tailed hawk
American bittern	California quail
Gadwall*	Ring-necked pheasant*
Pintail*	Killdeer***
Green-winged teal*	Glaucous-winged gull*

Winter Residents

American widgeon*
Northern shoveler
Ring-necked duck*
Canvasback**
Greater scaup***
Lesser scaup*
Common goldeneye***
Barrows goldeneye***
Bufflehead*
Ruddy duck*
Hooded merganser*
Common merganser***
Red-breasted merganser*
American coot*
Common snipe*
Spotted sandpiper
Least sandpiper
Dunlin***
Western sandpiper
California gull
Ring-billed gull*
Mew gull
Bonaparte's gull*
Winter wren***
Varied thrush***
Golden = -crowned kinglet
Ruby-crowned kinglet***
Northern shrike
Evening grosbeak***
Golden-crowned sparrow***
Fox sparrow***

Permanent Residents

Belted kingfisher*
Common flicker**
Pileated woodpecker***
Yelow-bellied sapsucker
Hairy woodpecker*
Downy woodpecker
Steeler's jay***
Common crow*
Black-capped chickadee
Chestnut-backed chickadee*
Common bushtit***
Red-breasted nuthatch***
Brown creeper
Dipper***
Bewick's wren*
Long-billed marsh wren*
American robin***
Cedar waxwing
Starling***
Hutton's vireo***
Yellow-rumped warbler*
House sparrow***
Red-winged blackbird***
Brewers blackbird***
Purple finch***
House finch*
Pine siskin*
American goldfinch
Rufous-sided towhee***
Dark-eyed junco*
Song sparrow*

* Indicates birds observed 29 October 1975. Charles Lindberg, Christopher Dlugokenski, and Douglas Canning, researchers.
** Indicates species that are unusual for the area.
*** Indicates species seen since 20 October 1975.
NOTE: Bald eagle observed 21 April 1976.

Spring and Summer Residents

Turkey vulture
Band-tailed pigeon**
Common nighthawk
Rufous hummingbird***
Violet-green swallow***
Tree swallow
Rough-winged swallow
Barn swallow***
Cliff swallow***
Solitary vireo***
Red-eyed vireo
Warbling vireo
Swainson's thrush
Orange-crowned warbler***
Yellow warbler
Black-throated gray warbler
Yellowthroat***
Wilson's warbler
Brown-headed cowbird
Western tanager
Black-headed grosbeak
Savanah sparrow
White-crowned sparrow***

Breeding Birds and Potential Breeders

- Green heron
- Blue grouse*
- Ruffed grouse*
- California quail
- American coot
- Killdeer
- Screech owl
- Great horned owl
- Saw-whet owl*
- Rufous hummingbird
- Belted kingfisher
- Common flicker
- Pileated woodpecker
- Yellow-belled sapsucker
- Hairy woodpecker
- Downy woodpecker
- American robin
- Varied thrush
- Swainson's thrush
- Golden-crowned kinglet
- Ruby-crowned kinglet
- Cedar waxwing
- Starling
- Hutton's vireo
- Solitary vireo
- Red-eyed vireo
- Warbling vireo
- Orange-crowned warbler
- Yellow warbler
- Yellow-rumped warbler
- Yellowthroat
- Wilson's warbler
- Violet-green swallow
- Tree swallow
- Rough-winged swallow
- Barn swallow
- Cliff swallow
- Steller's jay
- Common crow
- Chestnut-backed chickadee
- White-breasted nuthatch
- Red-breasted nuthatch
- Brown creeper
- Dipper*
- House wren
- Winter wren
- Bewick's wren
- Long-billed marsh wren
- House sparrow
- Red-winged blackbird
- Brewer's balckbird
- Western tanager
- Black-headed grosbeak
- Evening grosbeak
- Purple finch
- House finch
- Pine siskin
- Rufous-sided towhee
- Dark-eyed junco
- Savannah sparrow
- White-crowned sparrow
- Song sparrow

<u>Appendix D</u>

LAKE QUALITY DATA

Table D-1
Historical Capitol Lake Fecal Coliform Levels in the Swimming Beach Area

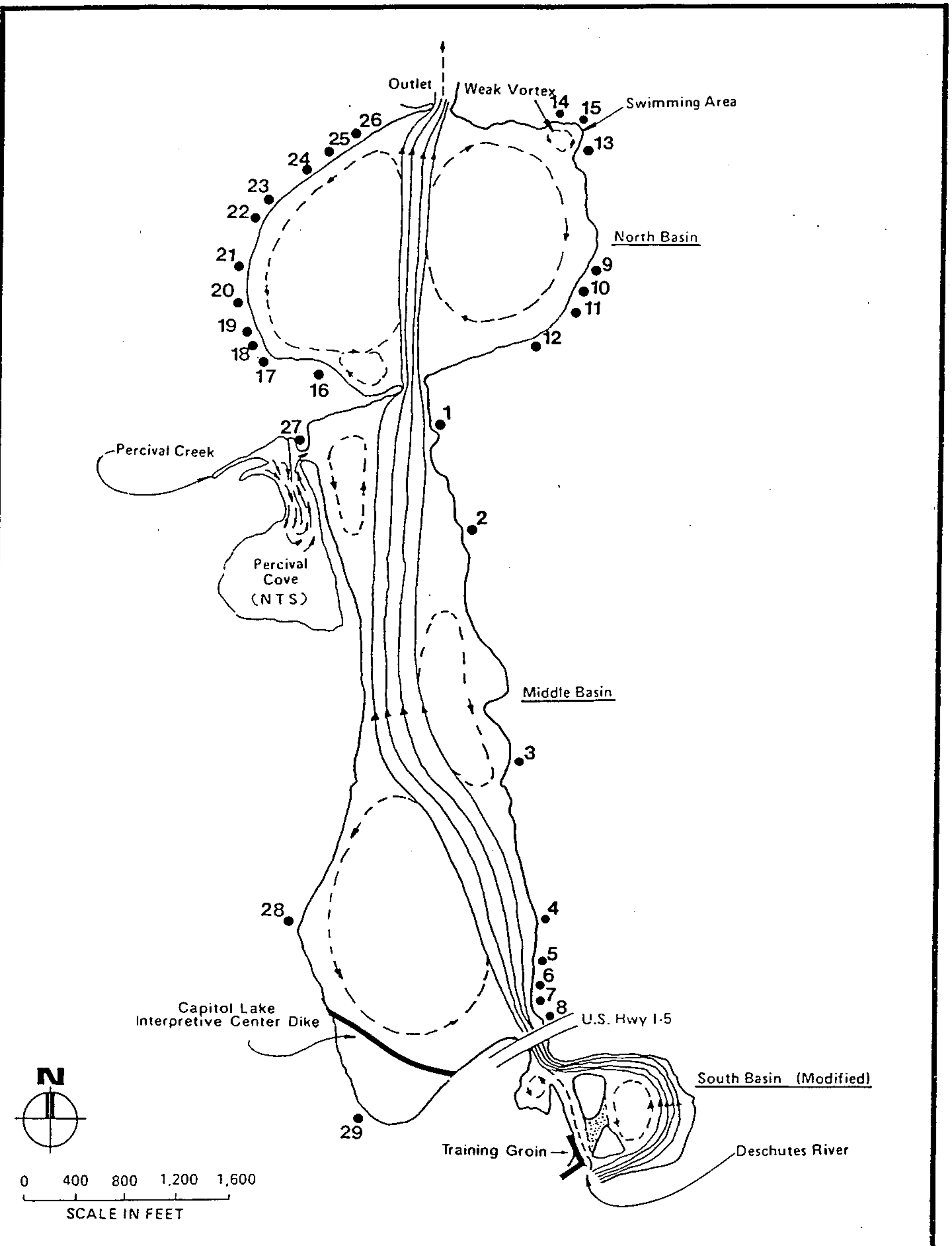
Year	Month	Fecal Col. (#/100 ml)
75	7	150
75	8	23
75	8	4
76	3	23
76	3	16
76	3	23
76	3	23
76	3	75
76	3	23
76	3	16
76	3	23
76	3	43
76	3	43
76	3	43
76	4	23
76	4	23
76	4	240
76	4	23
76	4	43
76	4	4
76	5	23
76	5	15
76	6	4
76	6	4
76	6	15
76	6	9
76	7	< 3
76	7	4
76	7	> 240
76	7	> 240
76	8	23
76	8	43
76	8	< 3
76	8	23
76	8	< 3
76	8	9
76	8	23
76	8	4
76	8	4
76	8	9

Year	Month	Fecal Col. (#/100 ml)
79	7	23
79	7	23
79	7	9
79	7	15
79	7	9
79	7	23
79	8	43
79	8	< 23
82	6	23
82	7	43
82	7	43
82	8	9
82	8	4
83	6	4
83	6	< 3
83	7	52
83	7	25
83	7	41
83	7	31
84	6	23
84	6	5
84	7	11
84	7	40
84	7	8
84	8	145
84	8	8
84	8	30
84	8	286
84	8	175

Source: Thurston County Health Department

Table D-2
Capitol Lake
Recent Lake and Outfall Bacterial Concentrations
July 2 - July 6, 1990

	Station Description	Basin	Fecal Coliform (# 100ml)	Comments
LAKE				
1	N. end of concrete bulkhead	North	140	Swim Area
2	In swim area	North	70	#1-4
3	By rock breakwater	North	20	
4	Swim area, south end by dock	North	0	
5	Marathon Park	North	30	Marathon Park
6	Marathon Park	North	10	#5-6
7	Center of north basin	North	10	Middle of Lake
8	Center of north basin	North	10	#7-8
9	Under RR trestle	North	10	Railroad Trestle
10	Under RR trestle	North	10	#9-10
	Geometric Mean = 21.2			
OUTFALL				
1	Steam plant	Middle	2,450	
2	CM pipe	Middle	10	
3	Spring/seep	Middle	300	
4	Small stream	Middle	40	
5	Small stream	Middle	240	
6	Small stream	Middle	2,050	
7	Small stream	Middle	20	
8	Small stream	Middle	145	
9	6" pipe near artesian	North	5	
10	Spring	North	0	
11	Artesian Well	North	0	
12	?	North	115	
13	12" storm drain	North	130	
14	3.5" pipe in swim beach area	North	0	
15	3.5" pipe in swim beach area	North	0	
16	Marathon Park	North	25	
17	18" CGM	North	20	Samples
18	24" CGM	North	40	affected
19	Drain	North	480	by storm
20	Drain	North	375	runoff
21	Drain by shuttle stop	North	90	#17-26
22	8" pipe	North	>160,000	
23	18" culvert	North	0	
24	Drain	North	2,625	
25	Drain	North	6,450	
26	Drain	North	0	
27	Percival Creek	Middle	40	
28	Courthouse Creek	Middle	55	
29	Drain at Interpretive Center	Middle	0	



Source: Orsborn (1976)

Sampling Stations at Approximate Location Only

ENTRANCO ENGINEERS, INC.

Figure D-1

SHORELINE SAMPLING STATIONS