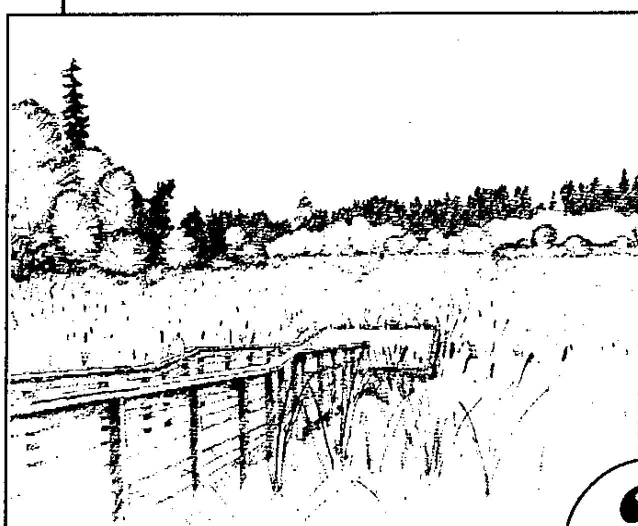
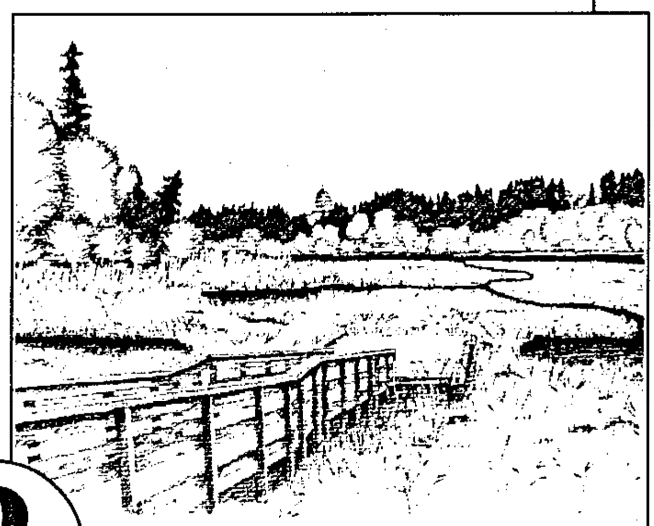
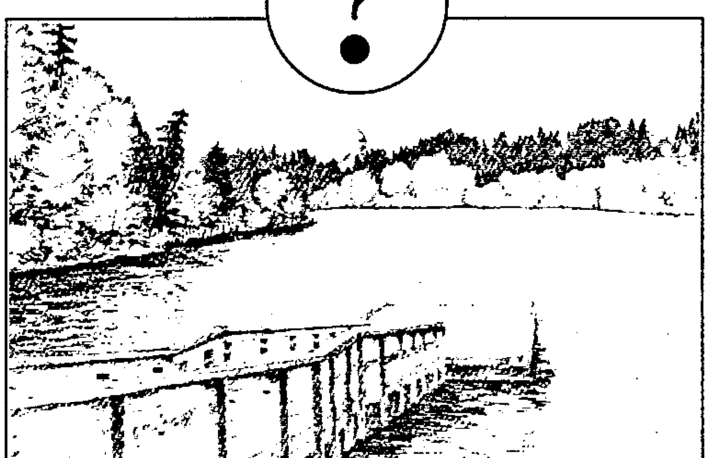
Capitol Lake

Adaptive Management Plan 1999 to 2001

Phase One - Task 2 Flood Analysis







August 2000

Phase One - Task 2
Flood Analysis

Capitol Lake Adaptive Management Plan
1999 to 2001

Olympia, Washington

Prepared For
Washington State Department of General Administration

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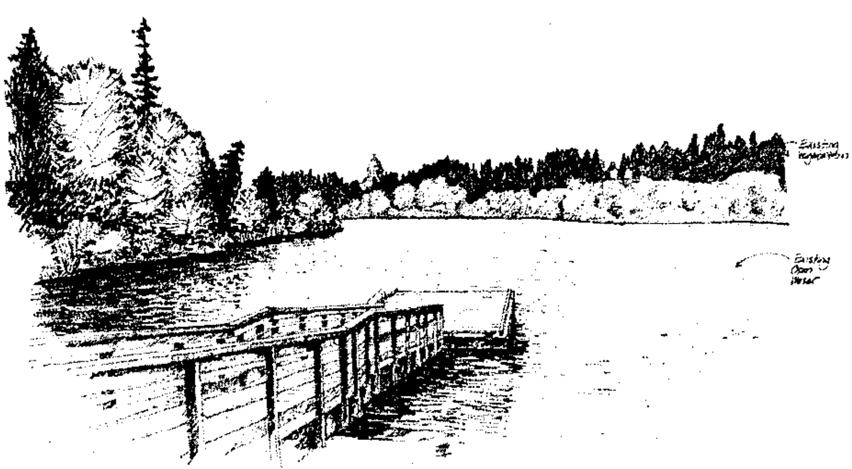
August 24, 2000

Summary

The Capitol Lake Adaptive Management Plan (CLAMP) outlined several technical studies to provide information for future management decisions concerning Capitol Lake. One study was a flood analysis to determine the impacts of the current management system and the impacts of selected proposed management scenarios. The key question is: Does the flooding of the Capitol Lake basin pose risk to surrounding structures or shoreline uses?

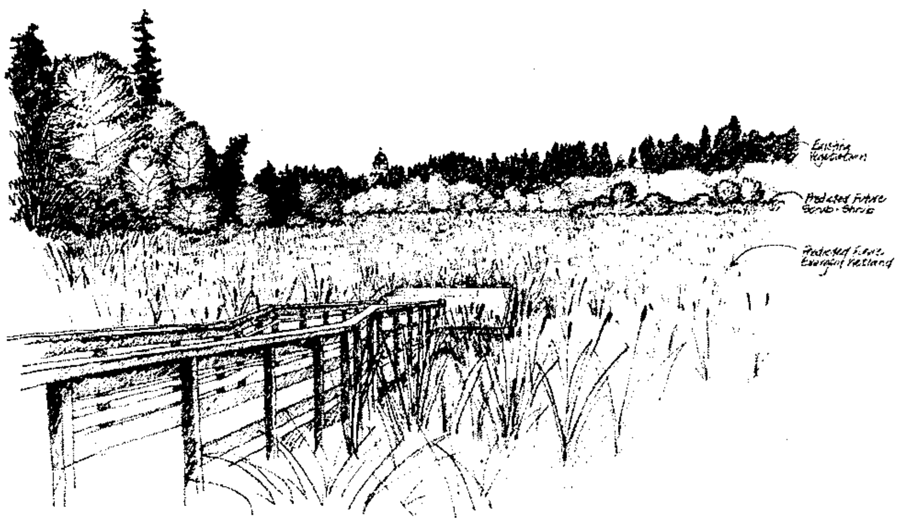
The quantitative analysis documented in this report includes the use of hydrologic and hydraulic analyses to predict river flows and tide heights, the depth of water during floods, and the location of flooding. Deschutes River flood flows were updated based on previous work done for the hydraulic scour analysis (**Entranco 2000**). Three selective alternatives, as presented in the 1998 Capitol Lake Adaptive Management Plan (CLAMP) Draft Environmental Impact Statement (DEIS), were studied in the flooding analysis. These selected alternatives include: 1) Lake Alternative, 2) Lake/River Wetland Without Trap Alternative, and 3) Estuary Alternative. Both the Lake/River Wetland Without Trap Alternative and the Estuary Alternative were evaluated for a young and mature system condition. The Estuary Alternative assumed removal of the 5th Avenue Dam and creation of a 500-foot-wide estuary opening.

This analysis identifies flooding impacts to key areas around Capitol Lake. **Table S-1** provides a summary of flood elevations compared to benchmark elevations noted in the CLAMP. These impacts are summarized below:



Lake Alternative – Capitol Lake as it is currently would cause significant flooding in downtown Olympia during a 100-year flow. It was estimated that the elevation of the floodwater would reach 12.7 mean sea level (MSL) in the vicinity of the North Basin. Heritage Park and the area adjacent to the Arc of

Statehood would have approximately 2 to 3 feet of flooding. There would also be varied amounts of flooding in the entire area west of Capitol Way and north of 7th Avenue. It is possible that there would be minor flooding, approximately 1 foot, north of 4th Avenue on the peninsula jutting into Lower Budd Inlet. Toward the southern end of the North Basin, Marathon Park would be flooded, including the parking lot, as well as into the intersection of Deschutes Parkway southwest of the park. The South Basin would also experience flooding in small areas of the Tumwater Historical Park.



Lake/River Wetland Without Trap Alternative – This alternative would cause flooding comparable to that of the Lake Alternative during a 100-year flow. The predicted floodwater elevation is also 12.7 MSL. In addition to the flooding described above in the Lake Alternative, the Heritage Park wetland mitigation site (Middle Basin) and wetlands in the South Basin would be submerged under approximately 5 to 6 feet of water.

Table S-1
Summary and Comparison of Selected CLAMP Alternatives Relative to Flood Elevations and Local Landmarks

CLAMP Alternative/ Flood Event	Lake Elevation -feet - MSL	Historical Events & Local Landmarks
Lake Alternative: 500-year flood	16.0	Tumwater Historical Park – Children's Play Area
	14.9	BSNF
Lake/River Wetland Without Trap Alternative: 100-year flood	12.6 / 12.8	North Basin / South Basin
	12.7	North of 5th Ave.
Lake Alternative: 100-year flood	12.6 / 12.7	North Basin/South Basin
	12.4	4th and Columbia
Lake Alternative: 50-year flood	11.9 / 12.0	
	12.0	Tumwater Historical Park – Shoreline Walk
	11.9	Capitol Way and 4th Ave. intersection
Lake Alternative: 25-year flood	11.3 / 11.4	North Basin / South Basin
	11.00	Center of Intersection 5th Ave. & Water St.
	10.9	Water Street and 5th
	10.67	Top of Tide Gates
	10.60[a] 10.9 updated[b]	100-Year High Tide in Lower Budd Inlet
	(10.47)[c]	Record High Tide, December 15, 1977
	10.2	Columbia and Legion
	(10.07)[c]	Previous Record High Tide January 18, 1914
	10.00	Heritage Park Arc of Statehood/ Tumwater Historical Park – Boat Ramp Parking Lot/7th and Columbia
	9.79	Heritage Park Bulkhead
Mature Estuary Alternative: 100-year flood[d]	9.6 / 9.9	North Basin/South Basin
	9.5	Average High Higher Tide (used in modeling)[d]
	9.20-9.50	Sidewalks in Vicinity of 7th Ave. & Columbia St.
	8.88	Street Gutter at 7th Ave. & Columbia St.
	7.13	South Catch basin at Sandbag Lot
	6.45	Normal Summer Lake Level (Mar 16–Oct 14)
	(5.77)[c]	Mean High Tide
	5.50	Fish Ladder Operational
	5.43	Normal Winter Lake Level (Oct 15 – Mar 15)
	4.50	Pre-Winter Storm Drawdown
	-7.07	Tide Gate Sill (Bottom of Dam)

a. FEMA, *Flood Insurance Rate Study; City of Olympia, Washington.* (1981)
b. Flooding with the Estuary Alternative (500-foot opening) is primarily influenced by tidal elevations. The updated 100-year high tide in Lower Budd Inlet is estimated at 10.9 feet (MSL). Therefore, the 100-year flood (tide-based) would be this elevation, at a minimum.
c. (xx) elevations converted using 7.73 feet difference between MSL and MLLW.
d. Updated flood events are based on updated Deschutes River Flow recurrence and arithmetic mean of higher high tide elevation record from Seattle Station 9447130, NOAA: water years 1951 to 1973 and 1977 to 1999. 3.1 feet were added to the Seattle tide elevation to obtain the tide elevation for Lower Budd Inlet.

Estuary Alternative – The predicted water surface elevation for the estuary alternative is approximately 9.6 feet MSL in the North Basin. This would not cause any flooding in the downtown area or in Heritage Park. Developed estuary wetlands would be submerged under approximately 2 feet of water. This prediction, as well as the others presented, is based on the average-annual maximum tide elevation, when routing flood flows through the lake. It is important to note that estuary flood levels, with a 500-foot opening, will more closely follow extreme tides rather than flood flows. As such, the 100-year flood level, as affected by a 100-year high tide, would at a minimum, be expected to be 10.9 feet MSL for the open estuary.

5th Avenue Dam Operation During Floods – Flood analysis was performed to evaluate the mitigation effectiveness of dam operations during flood events. The mitigation effectiveness is variable, depending on river flow and tide heights. Under the conservative tide conditions of an average high higher tide (9.5 feet - MSL), the dam operations appear to provide flood control benefit for the more frequent floods (1, 2, 5, and possibly 10-year floods). Larger floods would tend to overwhelm the system with water and preclude mitigation benefits.

A briefing was provided by Entranco to the CLAMP Steering Committee on May 4, 2000 concerning both the Task 3 Hydraulic Scour Analysis and the Task 2 Flood Analysis. Several questions were asked, including a request for further map resolution for the extent of flooding. Answers to questions and two additional flood maps are provided at the end of this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

Entranco, Inc. was contracted by the Washington State Department of General Administration (DGA) to provide technical analyses for implementing the Capitol Lake Adaptive Management Plan – 1999 to 2001 (CLAMP). One task essential to plan implementation is flood analysis (Task 2 in the CLAMP). The purpose of the analysis is to predict the flood impacts to areas adjacent to Capitol Lake resulting from flood flows and selected CLAMP alternatives.

This study is an expansion of work performed during Task 3, the hydraulic scour analysis. Updated flood flows and hydrologic and hydraulic models prepared for the hydraulic scour analysis were used as a starting point to prepare the flood analysis. Flooding analysis involves altering the existing model as necessary to match the selected CLAMP alternatives.

Physical Description

In 1951, Capitol Lake was created by installing a dam at 5th Avenue. The dam created a freshwater reflecting pool for the State Capitol Building in an area that was previously an estuary between the Deschutes River and Lower Budd Inlet. Two radial gates were also constructed to help regulate flow and lake level.

Capitol Lake is physically separated into three distinct basins: North, Middle, and South (**figure 1**). Each basin was formed as a result of downstream structures that restrict or regulate the water flow. The Interstate 5 (I-5) Bridge, the Burlington Northern Santa Fe (BNSF) railroad bridge, and the 5th Avenue Dam function as downstream controls to the South Basin, Middle Basin, and North Basin respectively.

The City of Olympia surrounds the North Basin of Capitol Lake. Much of downtown Olympia is located on fill from the dredging of Lower Budd Inlet; most of the area is at low elevations. Prior to construction of the Heritage Park Arc of Statehood, Water and Columbia streets experienced chronic flooding problems. Due to its elevation, the Arc of Statehood reduces this street flooding during smaller floods. During higher floods, some of the landmarks of concern include: Heritage Park to the east, Downtown Olympia to the east, Marathon Park located at the southwest corner of the north basin, and the Deschutes Parkway located to the west of the North Basin.

The Middle Basin is bordered by the BNSF Railroad Bridge to the north and the I-5 Bridge to the south. Deschutes Parkway is located along the west side of the basin. Bluffs rising approximately 100 feet to the Capitol Campus are located on the east. Flooding of the Middle Basin would be a concern as it affects Deschutes Parkway.

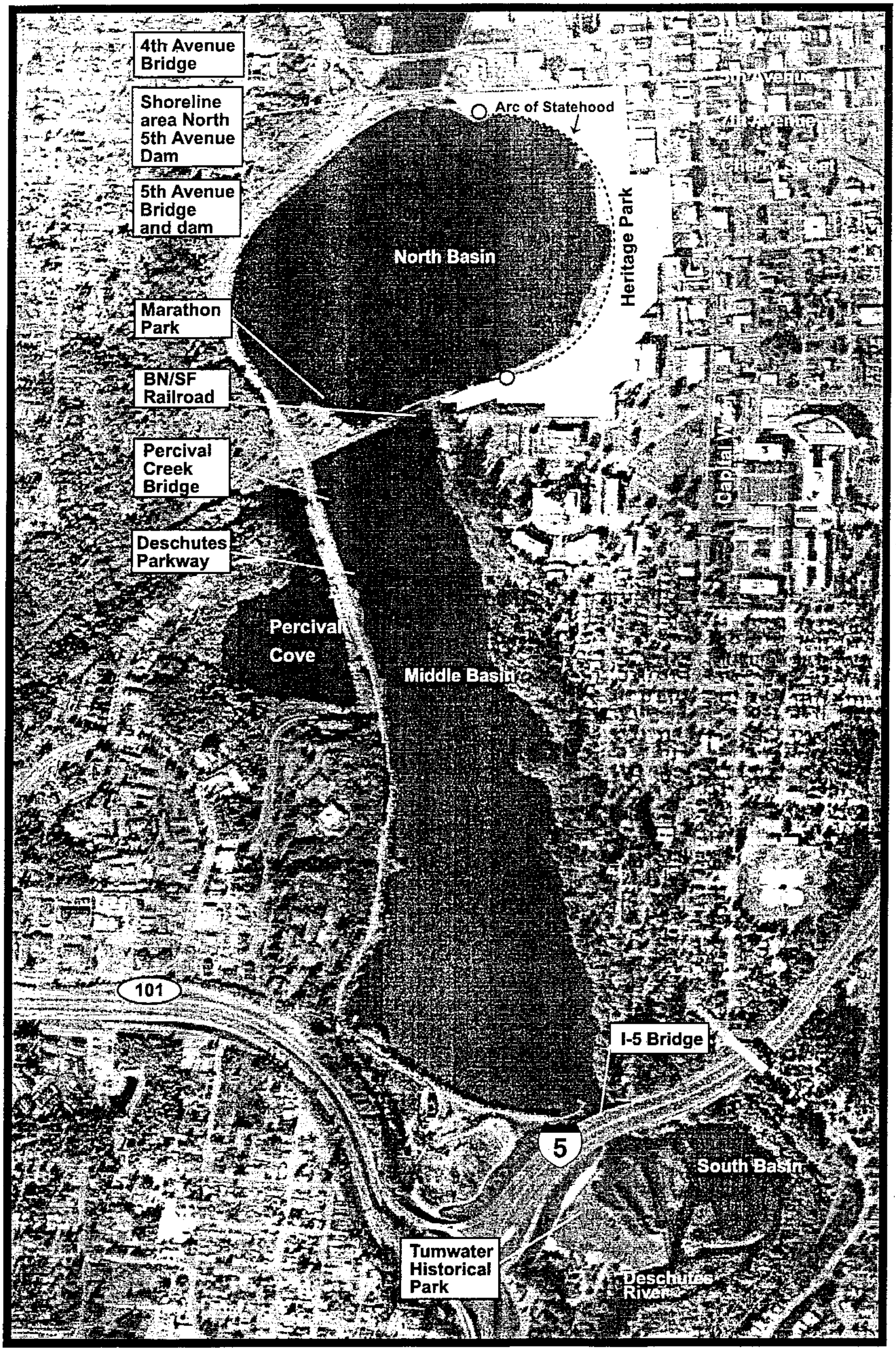


Figure 1

Capital Lake and Surrounding Area

The South Basin is bordered to the north by the I-5 Bridge. Directly upstream of the bridge on the west side of the basin is the Tumwater Historical Park. Flooding impacts to Tumwater Historical Park are a concern.

Previous Flood Analyses

Prior to this flood analysis, several flood analyses have been performed for Capitol Lake. A brief history of the previous flood models follows:

Flood Insurance Study (1981)

A Flood Insurance Study for the City of Olympia, Washington, Thurston County was published in 1981 by the Federal Emergency Agency (FEMA). The study included an analysis of flooding within Capitol Lake. The study pointed out that extreme high tides or river flows could cause high water conditions within the lake similar to what occurred when the lake was an estuary. The analysis of flood levels within the lake, however, was primarily based upon extreme tide elevations. The study conducted a statistical analysis of extreme tide elevations using the Seattle Tidal Station then transferred the predicted tide elevations to Olympia using the tide prediction tables. An observation of lake levels during an extreme tide elevation in 1977 led to the conclusion that the lake level is somewhat higher than the tide, but the difference is expected to be typically small. As a result, the Capitol Lake flood levels presented in the Flood Insurance Study are based upon predicted extreme tides with a relatively small adjustment added to reflect the differences measured during the extreme tide observed in 1977.

Wetland Development Feasibility Analysis on Capitol Lake (1990)

Entranco performed an updated flood study in 1990 as part of a Wetland Development Feasibility Analysis for Capitol Lake. The analysis considered the effects of high tides and Deschutes River flows using level-pool routing methods that integrated the effects of tidal phasing and tide gate operation. Flow data for the Deschutes River was obtained from a 1985 USGS report on Streamflow Statistics and Drainage Basin Characteristics for the Puget Sound Region, Washington. A representative tidal cycle was used with a maximum tide elevation of 11 feet MSL. The lake volume was based on an aerial survey taken by Walker & Associates in 1983 combined with north shore ground survey dated 1995.

Heritage Park Environmental Impact Statement (1996)

The Entranco study was updated in 1996 as part of the Heritage Park EIS. At that time, the model continued to use the USGS 1985 flow data, but assumed a new sedimentation level, and a new minimum lake elevation. The study also modified the tide and river phasing. In addition, a lake bathymetry survey was performed in 1991 (**Walker & Associates**). This survey basemap was used to calculate lake volume.

Approach

The flood study described in this memorandum builds on the work performed for the hydraulic scour analyses described in the Phase 1 – Task 3 Hydraulic Scour Analysis technical memorandum submitted to DGA in April 2000. The flood analysis uses a dynamic hydraulic model to route Deschutes River flood flows (hydrographs) through the individual lake basins, assuming selected CLAMP alternatives. This study included updated statistical analyses of Deschutes River flows and tide levels. To describe existing conditions, the Lake Alternative was analyzed for the 2-year, 25-year, 50-year, 100-year, and 500-year flood events. To provide a consistent basis for comparison, the 100-year flood was analyzed for all three alternatives. **Table 1** provides a summary of the modeling conducted for this study.

Table 1
Flood Modeling Conducted

	Lake	Lake/River Wetland Without Trap Alternative		Estuary Alternative (500-foot opening)	
Flood Type	**Alternative**	**Young**	**Mature**	**Young**	**Mature**
2 Year	X				
25 Year	X				
50 Year	X				
100 Year	X	X	X	X	X
500 Year	X				

X = modeling conducted ▩ = no modeling

Characterization of Lake Basins

The first major task was to understand the physical characteristics of the North, Middle, and South basins of Capitol Lake. This provided input to the hydraulic models used in the flood analysis. Over the past several years, surveys have been conducted during lake draw down to estimate the rate at which the lake is filling with sediment transported by the Deschutes River. Several topographic and bathymetric maps were reviewed and assessed for use in setting up the hydraulic model. Since no single map provided all the information needed, selected data from each of the following topographic maps were used for model set up:

- 1983 Capitol Lake topography by Walker & Associates, Inc.
  (provided specific bathymetric data around the dam)

- 1996 Capitol Lake topography by NIES Mapping Group, Inc.
  (most complete)

- 1999 Survey basemap for the 4th Avenue bridge design from David Goodyear Engineering Services (for Lower Budd Inlet bathymetry (provided data downstream of dam)

It should be noted that the limited topography information available does not represent the current topography of Capitol Lake. However, after examining the limited available resources, it was concluded that the information is appropriate for a planning-level analysis.

Each basin's volume was estimated based on aerial photographs, survey information, as well as the modified Capitol Lake level-pool flood model developed by Entranco in 1996. These physical characteristics and basin volumes were used as inputs to the hydraulic model XP-SWMM.

In addition, a GIS topography map of shoreline areas adjacent to Capitol Lake was provided by Thurston County Regional Planning to help determine the extent of flooding into areas surrounding Capitol Lake.

Flows

Statistical analyses were conducted to update predictions for extreme floods for the Deschutes River entering Capitol Lake. Previous flow estimates had been based upon an 18-year record extending from 1947 to 1964 obtained at the USGS gauging station 1208000 for the Deschutes River near Olympia. Since that time, additional flow data has been gathered resulting in an extended record that can help improve the predictions. The more recent flood flow data are available nearby for gauge station (1208010) referred to as the Deschutes River at E Street Bridge in Tumwater. Flow data at this station have been collected from 1990 through 1998. Combining both stations provided a 27-year flood record with the largest recorded flood being 10,700 cfs measured during the 1996 water year.

A Log-Pearson Type III analysis was conducted using the 27 peak-annual flows. The results of the analyses provided peak annual flow estimates corresponding to different return intervals (see **table 2**). Each flow rate corresponds to a specific return interval and represents the flow that is expected to be equaled or exceeded on the average of once during the return interval. For example, the 100-year flow rate is the flood that is expected to be equaled or exceeded, on the average, once every 100 years. The average annual flood is the average of the largest flow measured for each year.

Table 2
Updated Flood Flow Summary – Deschutes River near Capitol Lake

Peak-flow Recurrence (interval in years)	**Flow** (cfs)
Average Annual Flood	4,450
2 year	3,989
5 year	5,887
10 year	7,249
25 year	9,082
50 year	10,523
100 year	12,031
500 year	15,842

For this study, flows with return periods of 25 years, 50 years, 100 years and 500 years were studied for the Lake Alternative (existing conditions). The 25-year and 50-year flows are relatively high flows that often serve as acceptable bench marks for flood studies. The probability of the 100-year flow or the 500-year flow occurrences are much smaller, but should be considered due to the magnitude of flow. Additionally, the 100-year flow is also often used as a benchmark for many design considerations.

Tides

Lower Budd Inlet tide elevations were analyzed in a method similar to the Deschutes River flows. Historical information was collected from Seattle NOAA Station 9447130, for the water years 1951 to 1973 and again from 1977 to 1999. Seattle tide elevations were then increased by 3.1 to convert the elevations to conditions for Lower Budd Inlet. A Log-Pearson Type III analysis was then conducted to determine tide elevations corresponding to various return intervals. **Table 3** summarizes the results of the analyses.

Table 3
Predicted Tide Elevations (MSL) –
Lower Budd Inlet at Capitol Lake

Maximum Tide Elevations Recurrence (interval in years)	**Tide Elevations** (ft)
Average-annual maximum tide	9.5
2 year	9.6
5 year	10.1
10 year	10.3
25 year	10.6
50 year	10.7
100 year	10.9
500 year	11.1

The analysis of flood levels within Capitol Lake required critical assumptions regarding the interaction of extreme tide levels and extreme flows. Often, higher tides occur during storms as a result of lower barometric pressure or tidal surges. It is questionable, however, if a 100-year tide level can be expected to happen during the 100-year flood event. If the two events were independent, then the combined probability of the 100-year tide coinciding with the 100-year flood would be on the order of once every 10,000 years. But given the likelihood that higher tides could occur as a result of a storm event that is producing flood flows, it was decided to use a more typical maximum-annual tide level for the flood analysis. As a result, the average-annual maximum tide elevation, or approximately the 2-year tide was assumed when routing flood flows through the lake. This tide level of 9.5 feet MSL was used for modeling and is highlighted in **tables S-1** and **4**.

Hydraulic Model

The hydraulic model was developed to predict water surface elevations under different flows and lake management alternatives. The interaction between Deschutes River flows, lake volume, conveyance capacity at key locations, and tide fluctuations of Lower Budd Inlet are the key factors controlling lake levels. The XP-SWMM model was used to understand the interaction between these factors due to its capabilities to route a flood hydrograph through the lake while tidal elevations change.

The basic set-up of XP-SWMM starts by inputting the inflow hydrograph into the South Basin and routing the flow through the I-5 Bridge to the Middle Basin. The basic hydrograph shape used to characterize the inflow hydrograph is based upon an event recorded by Entranco during an earlier study (1984). After the flow is routed into the Middle Basin, inflow from Percival Creek is added and the combined flow is then routed through the BNSF railroad trestle and into the North Basin. From the North Basin, the flow passes through the 5th Avenue Dam to Lower Budd Inlet.

A tidal cycle ranging up to 9.5 feet in elevation was added to represent the tide effects during the storm flows. As a conservative measure, it was assumed that the timing of the peak flow would coincide with the maximum tide elevation.

Alternatives

The following alternatives were examined using the XP-SWMM model and the assumptions or approaches previously described.

Lake Alternative

This alternative was studied to show the effects of different return period flood flows with the system managed in the same way it is currently managed. It also provides a baseline to compare the other alternatives against.

In this alternative, the lake operates as a freshwater lake and the tide gates serve to keep saltwater from entering the lake. The gates also act to regulate the lake level in accordance with the current operation practice. The east gate is 24 feet wide and the west gate is 36 feet wide. The gates are operated such that the lake is usually maintained at approximately 6.45 MSL during summer months and 5.45 MSL during winter months. The lake can be drawn down slightly if a high flow is anticipated. Once the high Deschutes River flow enters the Capitol Lake basins, the tide gates are held fully open to facilitate drainage of the lake and minimize flooding. The USGS gauging station on the Deschutes River at Rainier (upstream of Capitol Lake) provides early flood warnings of 12 to 14 hours.

Lake/River Wetland Without Trap Alternative

In this alternative, the tide gates are retained to preserve a freshwater lake in the North Basin. The Middle and South basins do not undergo maintenance dredging and consequently fill with Deschutes River sediment. Expected maturity would occur in 50 to 85 years. As the sediment builds up, the Middle and South basins would evolve into freshwater wetlands.

The effect that this alternative would have on flooding is dependent upon the amount of sediment build-up in the Middle and South basins. It is assumed that during the first years of this alternative, the flood levels will mimic that of the existing condition since the Middle and South basins are not currently filled in with sediment. As the alternative nears maturity, the hydraulic results could vary from the existing conditions. It was assumed that at alternative maturity, the cross-section for the Deschutes River through the Middle and South basins would be approximately 100 feet wide with side slopes of 1:3. The adjacent riparian corridor (overbank floodplain) would reach an elevation of 7 feet MSL.

Estuary Alternative

The final alternative studied was returning Capitol Lake to an estuary. This alternative would allow tidal exchange throughout the basins. Dredging would not be performed and expected maturity would take 100 to 150 years.

The effect that this alternative would have on flooding is dependent upon the amount of sediment build-up in the three basins and the width of the estuary opening (500-foot opening versus removing tide gates and retaining the dam). The existing tide gate has a limited flow capacity and consequently causes backwater effects and impounds water in the lake during high-flow events. Significantly opening the channel by removing the 5th Avenue Dam could serve to lower flood elevations (see further discussion in Results section).

This alternative was evaluated as a young and mature estuary. For the mature estuary, it is assumed that an estuary/river channel exists with dimensions approximately 100 feet wide with 1:3 slopes. It is assumed that the adjacent estuary salt marsh (overbank floodplain) would reach an elevation of approximately 7 feet MSL.

Results

The following section presents the analysis results for the selected CLAMP Alternatives. **Table 4** presents a summary of the flooding elevation for the different alternatives. **Table 4** also includes some local landmarks or previous observations as points of reference for the predicted flood levels.

Table 4
Summary and Comparison of Selected CLAMP Alternatives Relative to Flood Elevations and Local Landmarks

CLAMP Alternative/ Flood Event	Lake Elevation -feet - MSL	Historical Events & Local Landmarks
Lake Alternative: 500-year flood	16.0	Tumwater Historical Park – Children's Play Area
	14.9	BSNF
Lake/River Wetland Without Trap Alternative: 100-year flood	12.6 / 12.8	North Basin / South Basin
	12.7	North of 5th Ave.
Lake Alternative: 100-year flood	12.6 / 12.7	North Basin/South Basin
	12.4	4th and Columbia
Lake Alternative: 50-year flood	11.9 / 12.0	
	12.0	Tumwater Historical Park – Shoreline Walk
	11.9	Capitol Way and 4th Ave. intersection
Lake Alternative: 25-year flood	11.3 / 11.4	North Basin / South Basin
	11.00	Center of Intersection 5th Ave. & Water St.
	10.9	Water Street and 5th
	10.67	Top of Tide Gates
	10.60[a] 10.9 updated[b]	100-Year High Tide in Lower Budd Inlet
	(10.47)[c]	Record High Tide, December 15, 1977
	10.2	Columbia and Legion
	(10.07)[c]	Previous Record High Tide January 18, 1914
	10.00	Heritage Park Arc of Statehood/ Tumwater Historical Park – Boat Ramp Parking Lot/7th and Columbia
	9.79	Heritage Park Bulkhead
Mature Estuary Alternative: 100-year flood[d]	9.6 / 9.9	North Basin/South Basin
	9.5	Average High Higher Tide (used in modeling)[d]
	9.20-9.50	Sidewalks in Vicinity of 7th Ave. & Columbia St.
	8.88	Street Gutter at 7th Ave. & Columbia St.
	7.13	South Catch basin at Sandbag Lot
	6.45	Normal Summer Lake Level (Mar 16–Oct 14)
	(5.77)[c]	Mean High Tide
	5.50	Fish Ladder Operational
	5.43	Normal Winter Lake Level (Oct 15 – Mar 15)
	4.50	Pre-Winter Storm Drawdown
	-7.07	Tide Gate Sill (Bottom of Dam)

a. FEMA, *Flood Insurance Rate Study; City of Olympia, Washington*. (1981)
b. Flooding with the Estuary Alternative (500-foot opening) is primarily influenced by tidal elevations. The updated 100-year high tide in Lower Budd Inlet is estimated at 10.9 feet (MSL). Therefore, the 100-year flood (tide-based) would be this elevation, at a minimum.
c. (xx) elevations converted using 7.73 feet difference between MSL and MLLW.
d. Updated flood events are based on updated Deschutes River Flow recurrence and arithmetic mean of higher high tide elevation record from Seattle Station 9447130, NOAA: water years 1951 to 1973 and 1977 to 1999. 3.1 feet were added to the Seattle tide elevation to obtain the tide elevation for Lower Budd Inlet.

Lake Alternative

Currently, Capitol Lake is managed as a freshwater lake. The tide gates at the 5th Avenue Dam maintain a constant lake elevation and prevent the entry of saltwater from Lower Budd Inlet into the lake. Dredging has occurred in the past and would need to occur at select intervals to maintain the current condition of the lake.

The 25-year flood analysis indicated flood elevations ranging from 11.3 feet MSL in the North Basin, to 11.4 feet MSL in the South Basin. These elevations would cause flooding of the overbank areas of the lake to the east including Heritage Park. In addition, the flooding could extend as far east as Cherry Street and north into Lower Budd Inlet. The Deschutes Parkway would not be flooded on the west side of the basin. Lower lying portions of Marathon Park would experience flooding, but not the parking lot. Small sections of Tumwater Historical Park would be flooded as well.

The 50-year flood produced flood levels ranging from 11.9 feet MSL in the North Basin to 12.0 feet MSL in the South Basin. The 50-year flood could possibly overtop part of 4th Avenue and create flooding north of the street. Flooding in other shoreline areas of the lake would be similar to that described for the 25-year flood.

During the 100-year flood, the water surface within the lake would range from 12.6 feet in the North Basin to 12.7 feet in the South Basin. Significant flooding of areas east of the North Basin is expected under these conditions as indicated on **figure 2**. Heritage Park would be submerged under 2 to 3 feet of water. The land north of 7th Avenue between the 5th Avenue Dam and Capitol Way would be under 1 to 2 feet of water and it is possible that flooding could extend north of 4th Avenue into Lower Budd Inlet. Marathon Park would be completely underwater, including the parking lot, and flooding would extend into the intersection of Deschutes Parkway southwest of the park. Tumwater Historical Park would also experience significant flooding.

The 500-year flood analysis indicated water surface elevations ranging from 14.9 feet MSL in the North Basin to 15 feet MSL in the South Basin. At this level, the effect of the tide elevation is minimal in comparison with the amount of river flow impounded. The flooding footprint is similar to that of a 100-year flow, but the depth of the submergence would increase by approximately 2 feet.

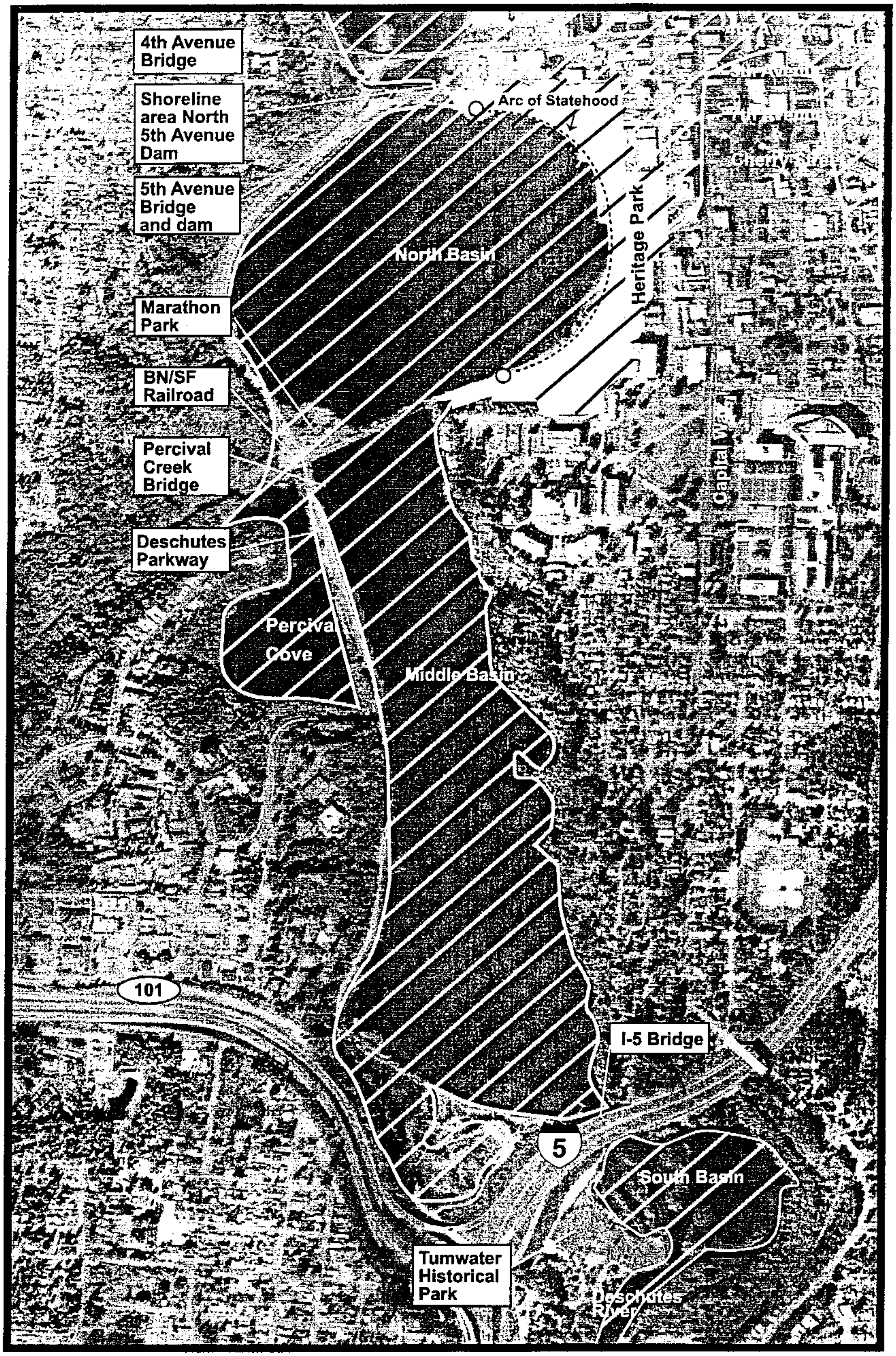


Figure 2

Lake Alternative, Approximate 100-Year Flood Extent

Lake/River Wetland Without Trap Alternative

This management alternative maintains the North Basin as a freshwater lake through the use of the existing tide gates, but ceases to provide further dredging of the Middle and South basins. The effects of this alternative will change over time as sediment is deposited within the lake. During the early stage of this alternative, the flooding conditions are expected to be the same as those presented under the Lake Alternative. At maturity, it is expected that the Middle and South basins will accumulate significant amounts of sediment with only a channel (assumed to be 100 feet wide) remaining to convey flow through the basins. It is also expected that wetland vegetation will become established in the floodplain areas that had previously been lake bottom.

The analysis of the mature system for the 100-year flow determined a water surface elevation ranging from 12.6 feet MSL in the North Basin to 12.8 feet MSL in the South Basin. These elevations are only slightly greater than predicted elevations under the Lake Alternative and are expected to produce similar flooding conditions (**figure** 3).

It is reasonable that the flood water surface elevations for this alternative are not significantly different from existing conditions. Flood storage volume, which is what is primarily affected by the accumulation of sediment in the Middle and South basins, plays a limited role in the water surface elevation of high flows. Storage volume plays a more significant role for the 2- to 10-year floods. The key factors affecting the flood elevation are the flow restriction points in the lake. In this situation, the main limiting factor is the capacity of the 5th Avenue Dam to drain the basins and the downstream head built up by the tide elevation at Lower Budd Inlet.

Estuary Alternative

The Estuary Alternative analysis is based on an estuary/river streambed elevation similar to what exists today. This alternative involves removing the 5th Avenue Dam and opening up the channel approximately 500 feet to allow water exchange between Lower Budd Inlet and Capitol Lake. Similar to the Lake/River Without Trap Alternative, two alternatives were examined.

The first case assumed a young estuary condition (e.g., little or no sediment accumulation had occurred in the basins). The estimated lake elevation for the young estuary for the 100-year flow ranged from 9.6 feet MSL in the North Basin to 9.7 feet MSL in the South Basin.

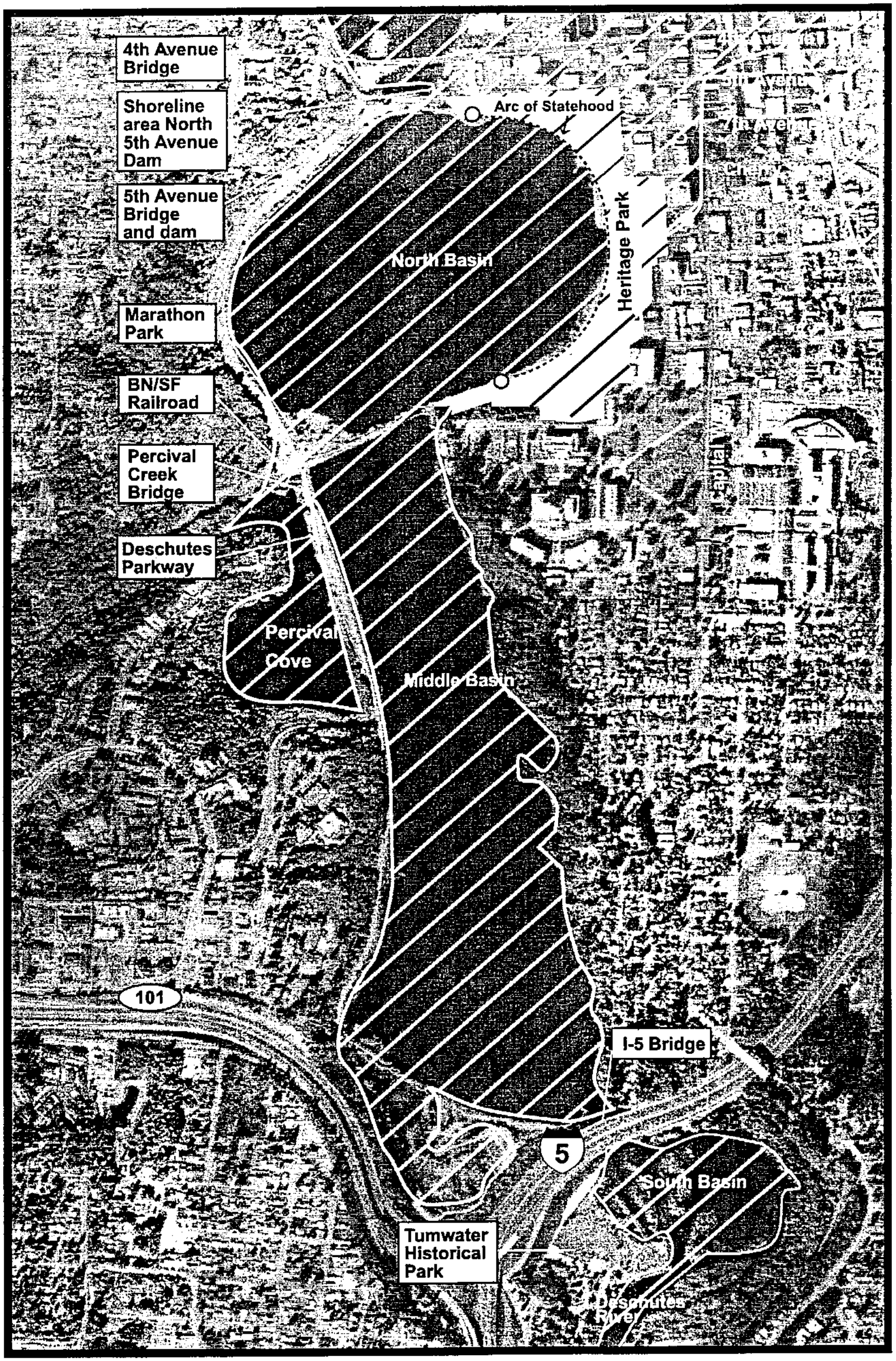


Figure 3

Lake/River Wetland Without Trap Alternative, Approximate 100-Year Flood Extent

Since dredging would not be performed within the basins, at maturity (in 100 to 150 years), estuary marsh plants would occur throughout the basin. It was assumed that sediment will accumulate to 7 feet MSL in all three basins and that a channel with a base width of 100 feet will remain. Under these conditions, the estimated lake water surface elevation at maturity of the estuary alternative for the 100-year flow ranged from 9.6 feet MSL in the North Basin to 9.9 feet MSL in the South Basin (**figure 4**).

Similar to the Lake/River Wetland Without Trap Alternative, the key factors affecting the flood elevations were the flow restriction points in the lake. In this situation, the removal of the dam, in effect, removed the flow restriction. Consequently, water is able to drain from the basins into Lower Budd Inlet to accommodate the inflow during the 100-year flow. As a result, flood levels corresponding to the 100-year Deschutes River flow are reduced by approximately 3 feet with the removal of the dam. In this case, most water is contained within the North Basin with the exception of potential flooding in the vicinity of 7th Avenue and Columbia Street. However, the Heritage Park Arc of Statehood should prevent this flooding. There will also be partial inundation of the Tumwater Historical Park.

It should be noted that extreme tides would produce flooding that is greater than that shown in **figure 4**. This prediction, as well as the others presented in the figures and tables, are based on the average-annual maximum tide elevation, when routing flood flows through the lake. It is important to note that estuary flood levels, with a 500-foot opening, will more closely follow extreme tides rather than flood flows. As such, the 100-year flood level, as affected by a 100-year high tide, would at a minimum, be expected to be 10.9 feet MSL for the open estuary.

5th Avenue Dam Operation During Floods

One of the key questions raised in the review of the draft flood analysis report is: "What is the flood control benefit of dam operations to create a preflood draw down of Capitol Lake?" To address this question, we spoke with Bob Wells of DGA (Bob assists Cliff Ikerd with dam operations) to get a clear indication of how the dam is operated during flood conditions. According to Bob, DGA uses computer controls to set a lower lake elevation whenever real-time river discharge at the Rainier gage exceeds 4,000 to 5,000 cubic feet per second. The lake then drains in advance of the peak river discharge, but the lake only drains when the tide is out, otherwise the dam gates are closed. The change in lake storage is typically in the range of 2 to 4 feet when high tide conditions prevail, but the lake may drain all the way to the sill elevation (-7.5 feet MSL) if extremely low tides occur.

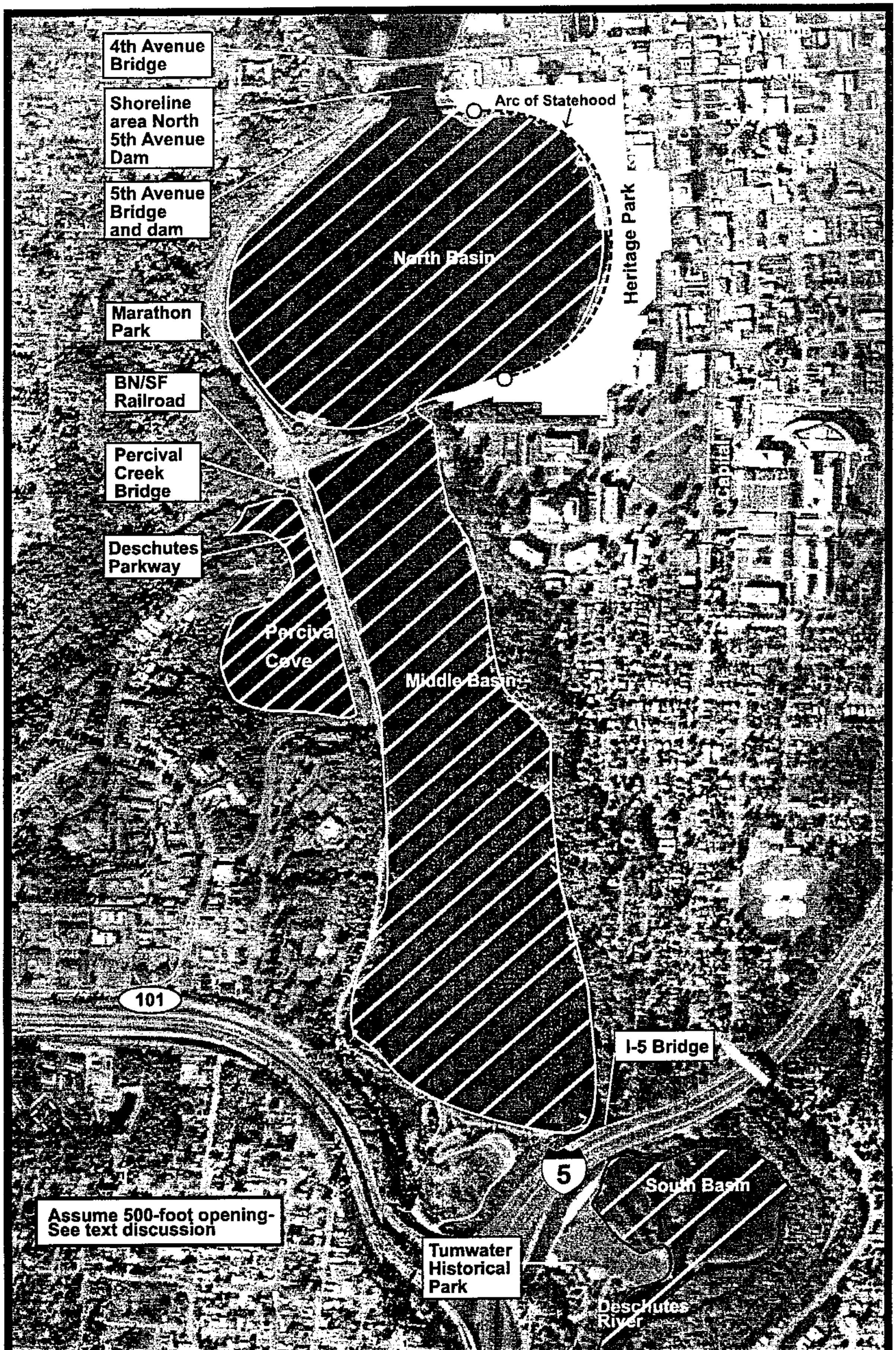


Figure 4

Estuary Alternative, Approximate 100-Year Flood Extent

To further evaluate this question, additional model runs were performed for the 1-year, 2-year, 5-year, and 10-year storms to determine what storm frequencies have flood elevations exceeding the 10.0 MSL elevation at the Arc of Statehood. These runs assumed average annual maximum tide elevations of 9.5 MSL and indicated that flood elevations would be below the Arc of Statehood for the 1-year and 2-year storms and above the Arc of Statehood for larger storms. For the 10-year storm, the flood elevations would be only 0.3 foot above the Arc of Statehood for the 9.5 MSL tide, but would probably be below this elevation under lower tide conditions. Thus, it appears that flood control benefits occur with preflood draw down management only for 1-year, 2-year, 5-year, and possibly 10-year floods. Larger floods would tend to overwhelm the system with water and preclude mitigation benefits.

Another key question raised in the review of the draft flood report is: "What about the potential for sea level rise in the Olympia area?" A preliminary assessment of sea level rise in the Olympia area (**Olympia 1993**), states that the sea level is rising at about one foot per century due to post-ice age warming of the oceans and land subsidence in Puget Sound. The report further suggests that if global warming occurs as predicted, sea level rise would accelerate to two to five feet per century. In the year 2100, the base flood is 14.3 ft (MSL) versus existing conditions of 10.3 ft (MSL) (Figure 5 - **Olympia 1993**). The sea level rise report concluded that the City would be vulnerable to sea level rise whether or not global warming occurs.

Flood predictions for this Capitol Lake flood analysis state that Capitol Lake flooding is significantly influenced by tide heights, particularly for the 500-foot-wide estuary opening. If the year 2100 sea rise predictions occur, the flood stage predictions, stated herein, could be 4 feet higher, using the data from the Olympia sea rise report (**Olympia 1993**).

Responses to Questions Asked in the May 4, 2000 CLAMP Steering Committee Briefing

A briefing was provided by Entranco to the CLAMP Steering Committee on May 4, 2000 concerning both the Task 3 - Hydraulic Scour Analysis (**Entranco 2000**) and this report, the Flood Analysis. Several questions were asked, including a request for further map resolution for the extent of flooding. The purpose of this memorandum is twofold: 1) to answer Steering Committee questions regarding the Capitol Lake Flood and Scour Analyses, and 2) to present two additional maps of flood extent, based on the model results and mapped by the Thurston Regional Planning GIS staff.

The following provides supplemental information and/or expanded discussion of the flooding and hydraulic analyses in response to comments received at the briefing to the Steering Committee on May 4, 2000.

Flood Modeling

Continuous Hydrologic Modeling

During the presentation, it was asked if continuous hydrologic modeling was used for the analyses; the answer is no.

We have frequently used continuous hydrologic modeling on other flooding analyses, using the Hydrologic Simulation Program-FORTRAN (HSPF) model. This type of approach can provide superior results over single-event based modeling and could be useful in better understanding the interaction between the timing of the tides and flood flows. However, applying continuous modeling to these analyses would have required considerably more work than was authorized, and there still could have been unresolved questions concerning interpretation of the results. One of the key questions is the timing between the flood hydrograph and the tide. With continuous modeling, we would be relying on the accuracy (time and magnitude) of the rainfall data (collected at Olympia) and the tide data (extrapolated from Seattle records). Furthermore, we typically need to extrapolate a "historical" hydrograph generated in the continuous simulation, to obtain a flood hydrograph of a more extreme event. This is because the available rainfall record is typically only 40 to 50 years in length and the 100-year or 500-year flood event is not included in the record. Flows for the extreme events (e.g., the 100-year flood) are obtained through statistical analyses of a shorter duration record such as the 27-year gauge record of the Deschutes River flood flows. Even if we had conducted continuous modeling of the Deschutes River/Capitol Lake system, we still would have had to "factor up" a simulated hydrograph to have the extreme floods to route through the lake. It is also worth noting that the SWMM EXTRAN model would still have been needed in the analyses as the HSPF model is not capable of performing the complex flow routing that includes variable tail water conditions and the possibility of flow moving in two directions.

The flood modeling that was used for the report relied upon a representative hydrograph of the Deschutes River routed through the lake basin under different management options. Statistical analyses were used to update the flood flows and obtain an instantaneous flow value corresponding to different return intervals. The inflow hydrograph was created by using a stormflow hydrograph for the Deschutes River measured by Entranco during earlier studies. That event was used to determine the shape of the hydrograph that was routed through the lake basin for the different alternatives examined. The hydrograph was factored upward or downward as needed such that the peak flow over the duration of the hydrograph equaled that determined by the statistical analyses.

In summary, the hydrologic analyses presented in the report are based upon a reasonable set of assumptions that are representative for the Deschutes River. It is questionable if a continuous hydrologic modeling approach would have given superior results given the limits of the data available to support the continuous modeling. Implications of critical data assumptions used for the analyses are expanded upon below.

Comparison with February 1996 Flood

A question was raised if the model developed for the flood analysis was compared to a recent flood such as the February 1996 event. The answer is that we have conducted additional work pertaining to this event, but could not obtain all the data we need for a complete comparison between simulated and observed flood levels.

We contacted the USGS to obtain flow information for that particular event to see if we could recreate the flood levels observed during that storm. We received 15-minute flow information with reference to a peak flow of 10,700 cfs, approximating a 50-year event based upon our updated statistical analysis. Unfortunately, the hydrograph provided by the USGS was truncated at the peak, indicating a maximum flow of only 7,600 cfs. Assuming the 10,700 cfs flow to be correct, we linearly extended the higher flows during the storm to attain a maximum flow of 10,700 cfs. We then compared the measured/"adjusted" hydrograph with the "typical" hydrograph we used for the flood analyses. **Figure 5** provides a comparison between the two hydrographs.

Figure 5 illustrates that the "generic" hydrograph that we used for the flood analyses has a larger volume than the estimated February 1996 event. We conducted a comparison between flooding results using both of the hydrographs shown in **figure 5**. It was found that if the February 1996 hydrograph is used, the maximum flood level predicted for 10,700 cfs would be about 0.2 feet lower than that obtained using the "generic" hydrograph used for the results presented in the report.

In summary, the February 1996 event had a lower volume than what we would have assumed for that event. However, the relatively larger volume appears to have a minor influence on the predicted flood level. We did not have enough reliable data (full hydrograph and corresponding tidal information) to conduct a calibration using the February 1996 event.

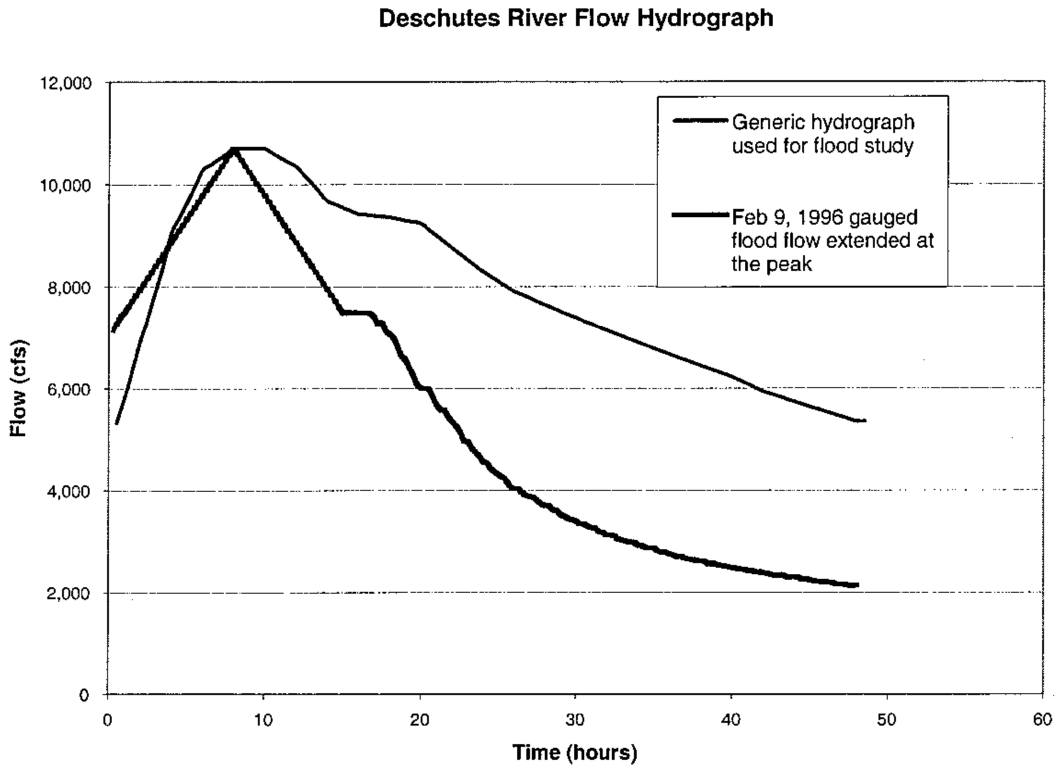


Figure 5
Deschutes River Flow Hydrograph

Interaction Between Tides and Peak Flows

There was a general discussion regarding the relationship between the flood flows and the tide levels. Our analysis assumed a moderately extreme high tide occurring at the time of the peak inflow to the lake from the Deschutes River. We used the "average-annual maximum tide", as calculated by taking the highest annual high tide for each of the years of record. This tide elevation is very nearly equivalent to the 2-year tide level. By using this tide level with extreme floods, we are assuming a combination of events that could be more infrequent than what we are reporting. If high tides and flood flows are independent, then the combination of the two would produce a combined probability that is equal to the product of the probability of each event. For example, a 2-year tide level occurring at the time of the 2-year flood flow would have a probability of occurring once every four years. Similarly, the 100-year flood occurring at the time of the 2-year tide would occur on the average of once every 200 years. As a result, from a regulatory standpoint, the 100-year flood level in Capitol Lake could be interpreted to be that reported for the 50-year flood or 11.9 feet.

The tide elevation assumed for the analyses has a significant effect on the predicted flood levels. For example, for the February 1996 event, it is estimated that a peak flow of 10,700 cfs would produce a lake level of up to 12 feet if it coincides with a tide of 9.5 feet. During one of the earlier studies by Entranco, it was noted that the tide that occurred during the February 1996 flood was 7.67 feet. Based upon our hydraulic analysis, 10,700 cfs occurring at a tide level of 7.67 feet would produce a lake flood level of 10.72 feet.

By comparison, the earlier Flood Insurance Study that current flood maps are based upon assumed that the lake level would be 0.4 feet above tide levels for all floods. Based upon the hydraulic analyses conducted for our study, this would equate to a flood flow of between 2,500 and 3,000 cfs for the 10-year to the 100-year floods.

In summary, we used a conservative assumption relating the approximate equivalent of the 2-year tide coinciding with extreme floods from the Deschutes River. Our analyses focused on the Deschutes River controlling flooding within the lake. The existing flood maps focused on the tide elevations in Budd Inlet.

Shoreline Erosion

Questions were raised concerning the expected velocities in the south basin as they relate to possible shoreline/bank erosion. **Table 5** provides average channel velocities (feet per second) in the vicinity of Tumwater Historical Park. The two management scenarios represented include the existing dam with the tide gates wide open (essentially the existing condition for extreme events) and the removal of the dam, creating an open channel estuary condition.

Table 5
Predicted Average Channel Velocities in the Vicinity of Tumwater Historical Park

	Average Channel Velocities (feet per second)	
Return Interval	**Open Gate Scenario**	**Open Channel Scenario**
25-year	3.06	3.17
100-year	2.54	3.14
500-year	2.85	3.15

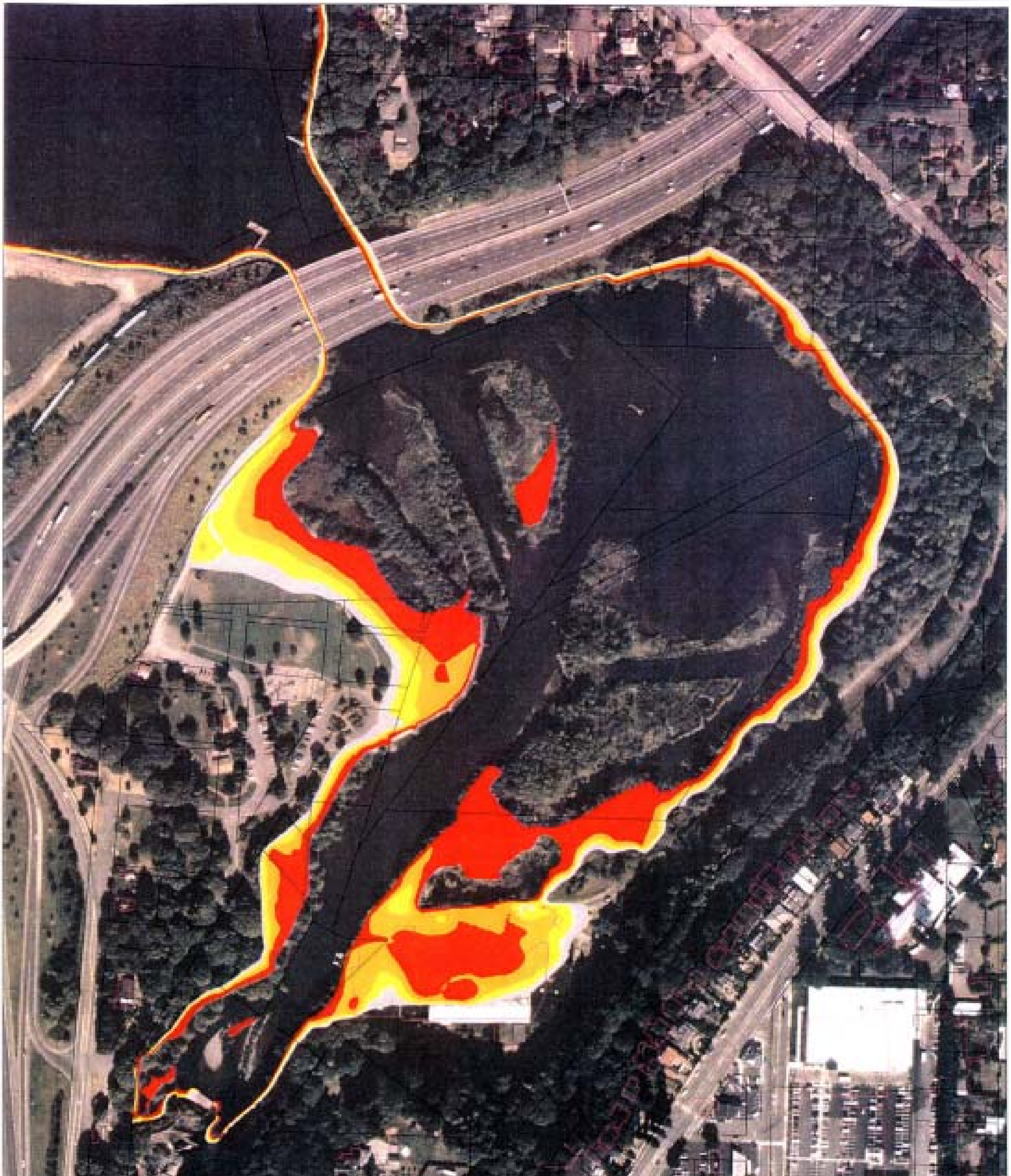
- 9-10 ft MSL : 1 and 2 year Floods
- 10-11 ft MSL : 5 and 10 year Floods
- 11-12 ft MSL : 25 and 50 year Floods
- 12-13 ft MSL : 100 year Flood

MSL - Mean Sea Level

Capitol Lake - North Basin - Lake Alternative

Mapped elevations are based upon 1999 and 2000 aerial topographic surveys with an accuracy of +/- one foot - from the City of Olympia

Figure 6



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12-13 ft MSL : 100 year Flood
MSL - Mean Sea Level

Capitol Lake - South Basin - Lake Alternative

Mapped elevations are based upon 1999 and 2000 aerial topographic surveys
with an accuracy of +/- one foot -- from the City of Olympia

Figure 7

Regional Planning

In summary, the open channel scenario produces slightly higher velocities, although the increase is probably not significant. In general, the velocities shown are considered moderate, but capable of creating erosion of finer material and/or localized scour at bends or changes of flow direction.

It is worth noting that these velocities are higher than those reported for the other shoreline areas in the Phase One – Task 3 Hydraulic Scour Analysis report (with a reported range of less than one to just over 2 feet per second). Velocities in the vicinity of Tumwater Historical Park are expected to be higher since the channel is confined in a smaller area along the park.

Estuary Scour

A question was raised regarding the expected scour resulting from large tidal exchanges during low flows in the Deschutes River. In response, we expanded our analysis to include a tide swing of 17 feet (ranging from a low tide elevation of –7.5 feet up to a high tide elevation of 11.0 feet MSL) during typical summer flows of 200 cfs in the Deschutes River. We then re-examined expected scour at the BNSF and I5 bridges for both the open gate and open channel management options.

Our findings for the open gate scenario indicate a total scour of 2.3 feet at the I5 bridge and 16.2 feet at the BNSF bridge. The results for the open channel scenario indicate similar results with a total scour depth of 16.4 feet at the BNSF bridge and 2.3 feet at the I5 bridge.

In summary, the amount of total scour expected by large tidal exchanges during low flows in the Deschutes River is lower than that predicted for extreme flood events in the Deschutes River. These scour totals, however, can be considered indicative of chronic scour expected to occur almost on a daily basis if the lake is converted to an estuary. Frequent scour will, over time, deepen the affected channel until equilibrium is reached where the water depth along with any residual material left armoring the lake bottom protects against any additional scour. There appeared to be little difference between the open gate and open channel scenarios in terms of expected total scour.

Flood Map Resolution

Comments were received pertaining to the accuracy of the flood mapping. Flood maps in the Final Report were based upon the topographic information provided by Thurston Regional Planning with a resolution of contour intervals every 2-feet. Some of the resolution of the maps was lost when the figures were prepared at the scale presented in the Final Report. In addition, general areas were mapped as being flooded. We did not have enough site-specific detail (e.g., structural floor elevations) to identify precisely the buildings that would be expected to be flooded. In addition, to prepare precise flood extent maps one would need more site-specific survey information. Additional comments were received concerning information about the movement of floodwaters through downtown Olympia. The work authorized under our agreement did not address detailed mapping or overland flow routes and patterns of water movement within the City. We did, however, incorporate several key elevations for the City of Olympia into our flood prediction table in the Final Report.

A meeting was held with DGA, Thurston Regional Planning Council (TRPC), and Entranco on May 31 to discuss closure on the flood analyses. A plan was developed with results reported below.

Entranco provided the TRPC with the flood elevations as shown in **table 6**.

Table 6
Flood Elevations for Different Flood Events

Lake Alternative[1]

Flood Event	Elevation
10 year Flood	10.7 feet MSL
5 year Flood	10.3 feet MSL
2 year Flood	9.9 feet MSL
1 year Flood	9.5 feet MSL

Note: See **table S-1** in the report to find elevations for 500-, 100-, 50-, and 25-year floods for the Lake Alternative.

1. All data provided in this table assumed a tide level of 9.5 feet MSL.

The City of Olympia provided TRPC with new topographic base maps of their jurisdiction to allow more detailed mapping of flood extent by TRPC. TRPC produced **figures 6** and **7** for the North and South Basins of Capitol Lake, respectively. It should be noted that the predicted flood elevations have been mapped on a topographic base with a contour interval of one foot. The accuracy of this mapping is typically plus or minus one foot, which is greater than some of the differences in elevations predicted for different flood events. Therefore, caution should be used when determining predicted flooding of specific structures based upon the maps. Detailed topographic information, such as structural floor elevations, would be needed, as mentioned above.

Possible Follow-up Work for CLAMP

Additional analyses that could be triggered under supplemental analyses include:

- Flood-routing through the City of Olympia.
- Further calibration of hydrologic/hydraulic model to historical events for which suitable data are available.
- Continuous modeling of the watershed to attempt to better define the relationship between high tides and flood flows from the Deschutes River. Note: this would likely require development and refinement of an extended precipitation and tide record.

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