MEMORANDUM

CH2M HILL

TO:	Marilyn Leitz/Port of Portland
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FROM:	David Collins/CH2M HILL Michelle Girts/CH2M HILL
DATE:	May 2, 1995
SUBJECT:	Results of Smith and Bybee Lake Water Level Management Analysis
PROJECT:	OPW40024.A0.02

Following is a description of the approach to a water level management plan for Smith and Bybee Lakes.

Background

Smith and Bybee Lakes are shallow, interconnected lakes which drain approximately 1600 acres. The lakes discharge into the east end of the North Slough via a control structure located at the southeastern end of Bybee Lake. The structure is fitted with a flap gate that prohibits North Slough water from entering Bybee Lake. The North Slough is approximately 1 mile long and enters the Lower Columbia Slough approximately 1-1/2 miles from the mouth of the Lower Columbia Slough. The Lower Columbia Slough enters the Willamette River at a point approximately 1/2 mile upstream of where the Willamette enters the Columbia. The Columbia River, Willamette River, and Columbia Slough are all tidally influenced in this area.

Scope

The Port of Portland requested CH2M HILL to estimate the flow augmentation required to maintain seasonally historic lake water surface elevations and maximum hydraulic detention times. The desired maximum detention times were 14 days for the May 15th to November 15th period and 60 days for the remaining months of the year.

General Approach

Historic Water Surface Elevations

An assumption was made that historically Smith and Bybee water surface elevations were closely tied to Columbia River water levels. The nearest gage on the Columbia is maintained by the US Corps of Engineers at Vancouver. The median water surface elevation for each month of the year was assumed to be the desired monthly water level for the lakes. It was thought that water surface elevations (WSE) since 1989 would be lower because river operations were changed to meet salmon recovery efforts.

6 8 acre-ft/day needed to maintain flow augmentation

The relationship of North Slough water levels to Columbia River water levels was determined because North Slough water levels influence the Smith and Bybee Lakes control structure. Water level data for the North Slough, Columbia River and Willamette River were plotted and compared. Figure 1 shows that the three water levels are approximately the same. Figure 2 is a plot of Columbia River and Willamette River flows for the period of record of the Willamette. These water levels are also very similar. Table 1 is a summary of water level data. This summary shows the following:

- Median water surface elevations for the Columbia and Willamette River are very similar.
- Water surface elevations since 1987 are lower than previous years.
- Removing 1990-1995 Columbia River data from the analysis has little effect on the monthly median water surface.

Based on a review of these data, it was assumed that median monthly North Slough water elevations were the same as those in the Columbia River. North Slough median water surface elevations were based on Columbia River data from 1972 - 1989.

Since a water level difference is required for water to flow out of Bybee Lake, it is necessary to maintain water levels in Smith and Bybee Lakes that are higher than the median monthly Columbia River levels. The modeling approach kept lake levels as close as possible to median monthly Columbia River levels while maintaining maximum mean detention times. Tidal fluctuations were not modeled.

Table 1
Summary of Water Surface Elevations

Month	Columbia 72 - 95			Columbia 72 - 89			Willamette 87-94		Columbia 87-94		Count
	Ave	Median	Count	Ave	Median	Count	Ave	Median	Ave	Median	
January	8.5	8.0	651	8.9	8.3	527	6.7	6.5	6.7	6.7	110
February	8.5	7.9	587	8.7	7.9	476	6.4	6.1	6.6	6.3	93
March	8.5	7.9	651	8.8	8.1	527	6.9	6.5	7.0	6.6	120
April	8.3	7.8	612	8.5	8.3	510	7.4	7.2	7.5	7.4	118
May	9.8	9.5	614	9.9	9.6	527	8.6	8.6	8.8	8.7	102
June	9.7	9.2	597	9.8	9.3	510	8.8	8.3	9.0	8.3	79
July	6.5	5.9	616	6.5	5.9	527	5.3	5.1	5.4	5.2	115
August	5.1	4.9	615	5.1	4.9	527	4.2	4.2	4.6	4.5	108
September	4.7	4.7	599	4.8	4.8	510	4.5	4.5	4.4	4.3	78
October	4.9	4.8	641	5.0	4.9	558	4.5	4.5	4.5	4.5	119
November	6.3	6.0	628	6.5	6.2	540	5.3	4.9	5.3	5.0	148
December	8.3	7.7	649	8.5	7.9	558	6.3	6.4	6.4	6.4	140

Mean Detention Time

The time that an average drop of water spends in the lake is called the mean detention time. The mean detention time is calculated by dividing the volume of the lake by non-evaporative outflows. Evaporation was not considered in the calculation of mean detention time.

Water Balance Model

A water balance approach was used to model the lakes. The volume of water in the lakes at any time can be estimated from the water surface elevations using the elevation-storage relationship. Water entering the lake system (via precipitation or pumping from the Willamette River) is added to this volume. Water leaving the lakes by evaporation or via the lake outlet structure is subtracted. The new water surface elevation in the lakes can then be determined from the new volume of water in the lakes. Lake water surface elevations are calculated on a daily basis.

Water Balance Components

Lake Bathymetry

The Elevation-Volume relationship and Elevation-Surface Area relationships were obtained from prior Portland State University studies.

Precipitation

Average monthly values of precipitation at Portland International Airport (for the years 1948-1993) were converted into average daily depth of precipitation. The full depth of precipitation that fell on lake surface was added to the lake. It was assumed that 30% of the rainfall depth on the remaining area of the basin would end up in the lake as runoff or groundwater infiltration. No additional contribution from groundwater was assumed. The 30% figure was determined from calibrated stormwater models for the Portland area.

Evaporation

Lake evaporation is calculated from monthly data of pan evaporation taken at the North Willamette Experimental Station. The value of the monthly evaporation was taken as 70% of the pan evaporation. Daily evaporation was computed based on the monthly data and the water surface area in the lakes.

Flow Control Structure

The outflow from Bybee Lake to the North Columbia Slough was assumed to occur only through the flow control structure. This structure, shown in a model schematic in Figure 3, incorporates a low flow grated inlet with a channel gate and a high flow grated inlet with an overflow weir. The high and low flow streams join in a 54-inch corrugated metal pipe (CMP) and flow out to the North Slough through a 60-inch CMP. A tide/flap gate has been installed on the downstream end of the 60-inch CMP to prevent backflow from the North Slough into Bybee Lake.

The original design of the structure was intended to primarily release high flows over the weir while the low flow channel gate was to be used for draining the lake when needed (according to conversations with the designer, Don Oakley). The high flow weir is set to an elevation of 8.4 feet. Water surface elevation data indicates that for about half of the year, the historical water levels are below this weir elevation. Under these conditions, the low flow channel would be the only source of outflow from Bybee Lake. The low flow gated inlet and canal gate cause a significant amount of head loss. This was determined from hydraulic equations, model simulation and from conversations with Scott Wells at Portland State University.

Flow across the control structure can only occur when the water surface elevation in Bybee Lake is greater than the WSE within the North Slough. However, the North Slough is subject to tidal, daily and monthly water level fluctuations from as low as 5.0 feet to as high as 10.0 feet. The historical levels of Bybee Lake vary from 5.0 feet to 13.0 feet. Therefore, there are many times when the head difference between Bybee Lake and the North Slough is not sufficient to push flows through the structure.

Simulation of the Flow Control Structure

The hydraulics of the flow control structure under the varying water surface elevations can be fairly complex. Although simplifying assumptions can be made, the assumptions cannot dismiss or minimize the effects of head loss through the grated inlets, the control structures (canal gate and overflow weir), the CMP conduits and the flap gate. Because the entire structure is driven by the difference in WSE between the lake and the slough, any significant energy or head losses required to push a given flow rate through the structure must be accounted for in the simulation.

It was decided to use XP-SWMM to quickly simulate the control structure performance for a variety of upstream and downstream water surface elevation conditions. The schematic of the model is shown in Figure 3. A series of "steady-state" simulations were performed to determine the resulting flow rate across the control structure given a specific WSE in Bybee Lake and in the North Slough. The WSE in Bybee Lake was varied from 6.0 feet to 13.0 feet while the WSE in the North Slough was varied from 5.0 feet to 10.0 feet. This array of WSE settings and flow capacity results were used in the water balance model to determine outflow from Bybee Lake under specific WSE conditions.

Model Output

The water balance model simulates the flow through and storage in Smith and Bybee Lakes for a theoretical average year where water levels at the end of the year match water levels at the beginning of the year. Model simulation steps are as follows:

1. Model calculations begin with a starting water surface elevation and associated lake water volume.
2. Daily water inputs and losses are then summed to obtain the water surface elevation and lake water volume at the end of each 24-hour period.
3. The model calculates the daily change in water volume in the lakes and the detention time.
4. These steps are performed for each day of the year. The initial (start-of-year) lake level is varied iteratively unitl the end-of-year level is the same as start-of-year.

Results

The model results are presented in Figures 4 through 7.

Control Gates Open, No Flow Augmentation

Figure 4 shows the effects of opening the canal gates and allowing only precipitation, evaporation, and outflow to influence lake levels. The January 1 water level was varied until the difference between January 1 and December 31 water levels was equal to zero. This represents an equilibrium condition during several years of average conditions.

Opening the structure control gates will cause lake water levels to approach Columbia River median water surface elevations for the majority of the year. During the months of Janurary through June, Columbia River Levels are at or above lake levels. Little or no outflow occurs during these periods resulting in very long average detention times. During July the water level of the Columbia River decreases, allowing water to flow out of the lakes and into the North Slough. As the lake levels drop below six feet the flows approach zero. At this point the lake level is near the bottom of the low flow inlet to the flow control structure and a significant amount of lake bottom is exposed. Some sections of the lake are likely isolated from other sections. Columbia River levels rise faster than lake levels during the fall resulting in very low lake outflows for the remainder of the year.

Control Gates Closed, No Flow Augmentation

Figure 5 shows the equilibrium condition created by closing the structure control gates and allowing only precipitation and evaporation to influence lake levels. This is the closest condition to existing that was modeled. Lake levels range from 9 feet to 11 feet. Lake water has essentially infinite detention time.

Detention Time Minimized using Flow Augmentation and Opening Control Gates

Figure 6 demonstrates the effects of flow augmentation and opening the structure with a goal of minimizing detention times. This is a balance between: a) having enough head difference to cause water to flow out of the structure and b) keeping the volume of water in the lake as low as possible so as to reduce the amount of water that must be exchanged. In this scenario flow augmentation was increased to a rate the flow control structure could efficiently pass. Note that lake levels are from 2 to 3-1/2 feet higher than Columbia River levels. Figure 7 shows the detention times resulting from this scenario. Note that detention time increases as the difference between lake and Columba River water levels decreases.

Summary

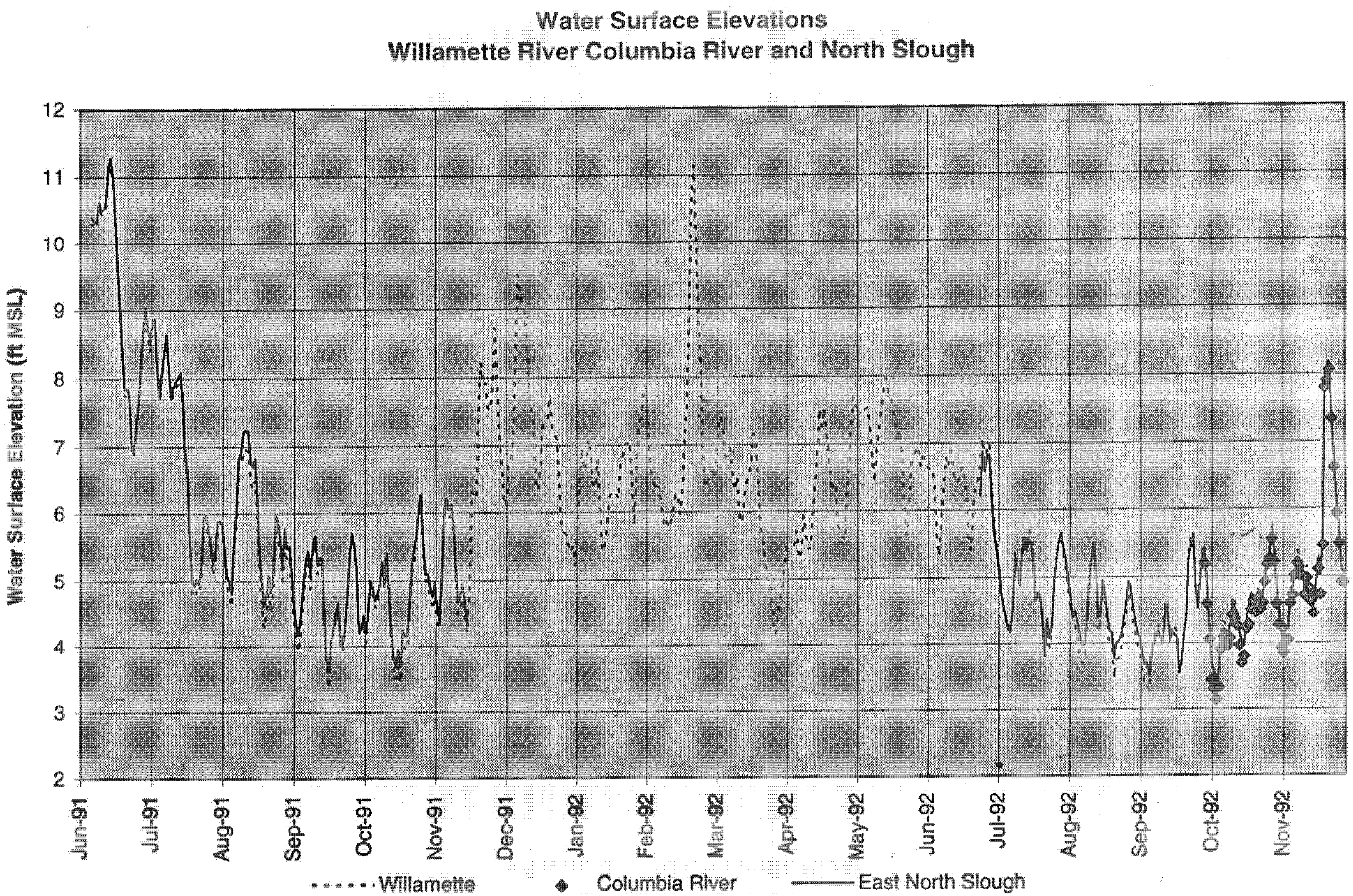
- Typical water levels for the Willamette River, North Slough, and Columbia River and were found to be essentially the same.

- Operating Smith and Bybee Lakes at median monthly Columbia River levels would result low outflows and high detention times.

- Opening the flow control structure without flow augmentation will lower lake levels without significantly decreasing detention times during the majority of the year.

- Using flow augmentation and the control structure to raise lake levels, detention times of 70 to 165 days are attainable.

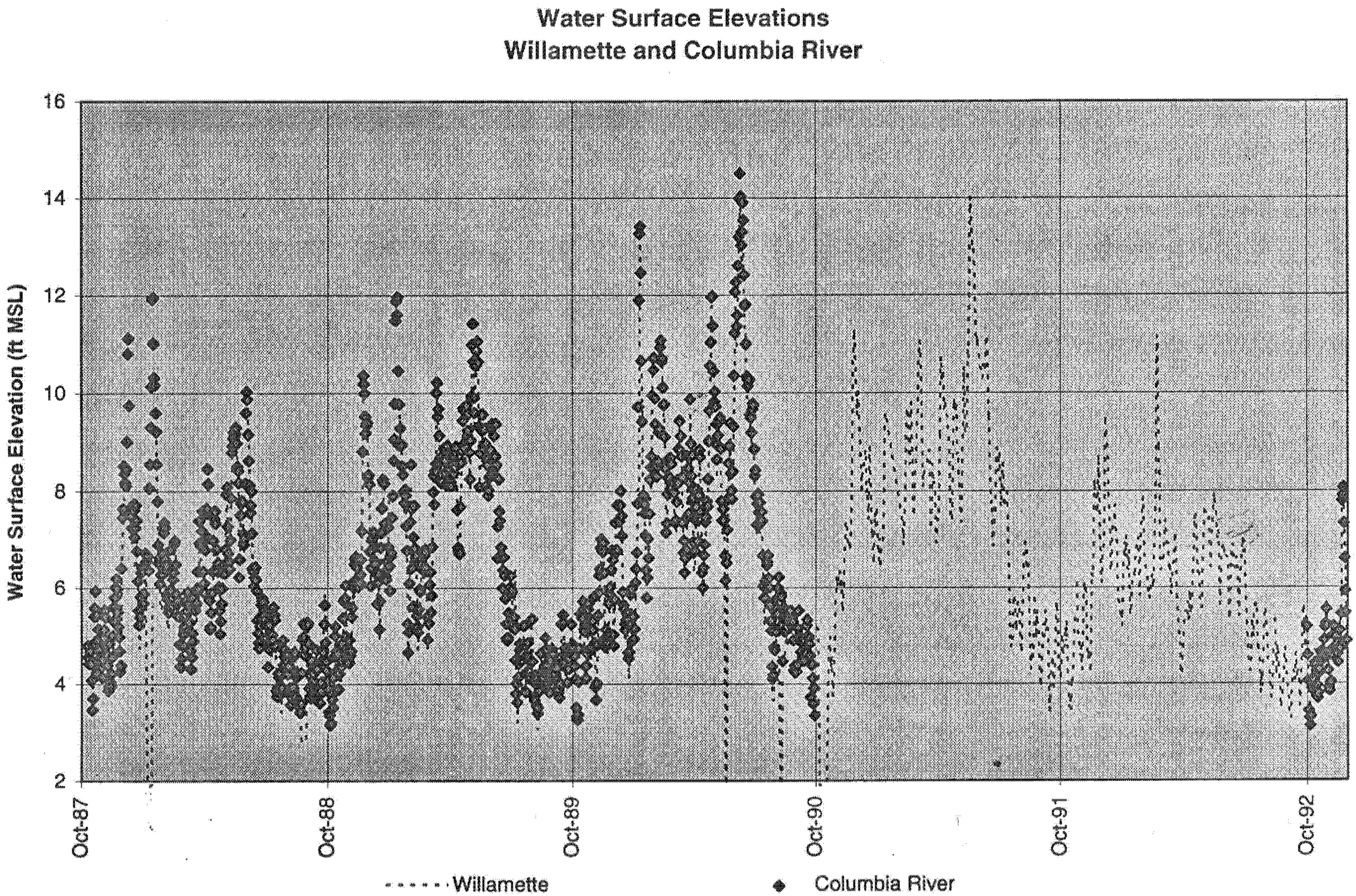
FIGURE 1



Sources
Willamette River -- Earthinfo
Columbia River -- Corps of Engineers
East North Slough -- Portland State University

3GAGES.XLS

FIGURE 2



Sources
Willamette River -- Earthinfo
Columbia River -- Corps of Engineers

3GAGES.XLS

Figure 3
Bybee Lake Flow Control Structure: XP-SWMM Model Schematic

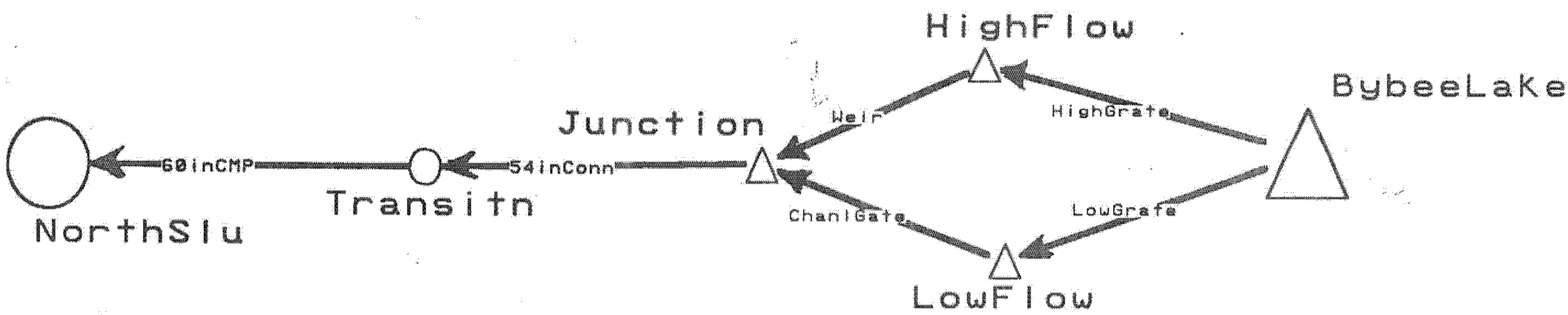


FIGURE 4

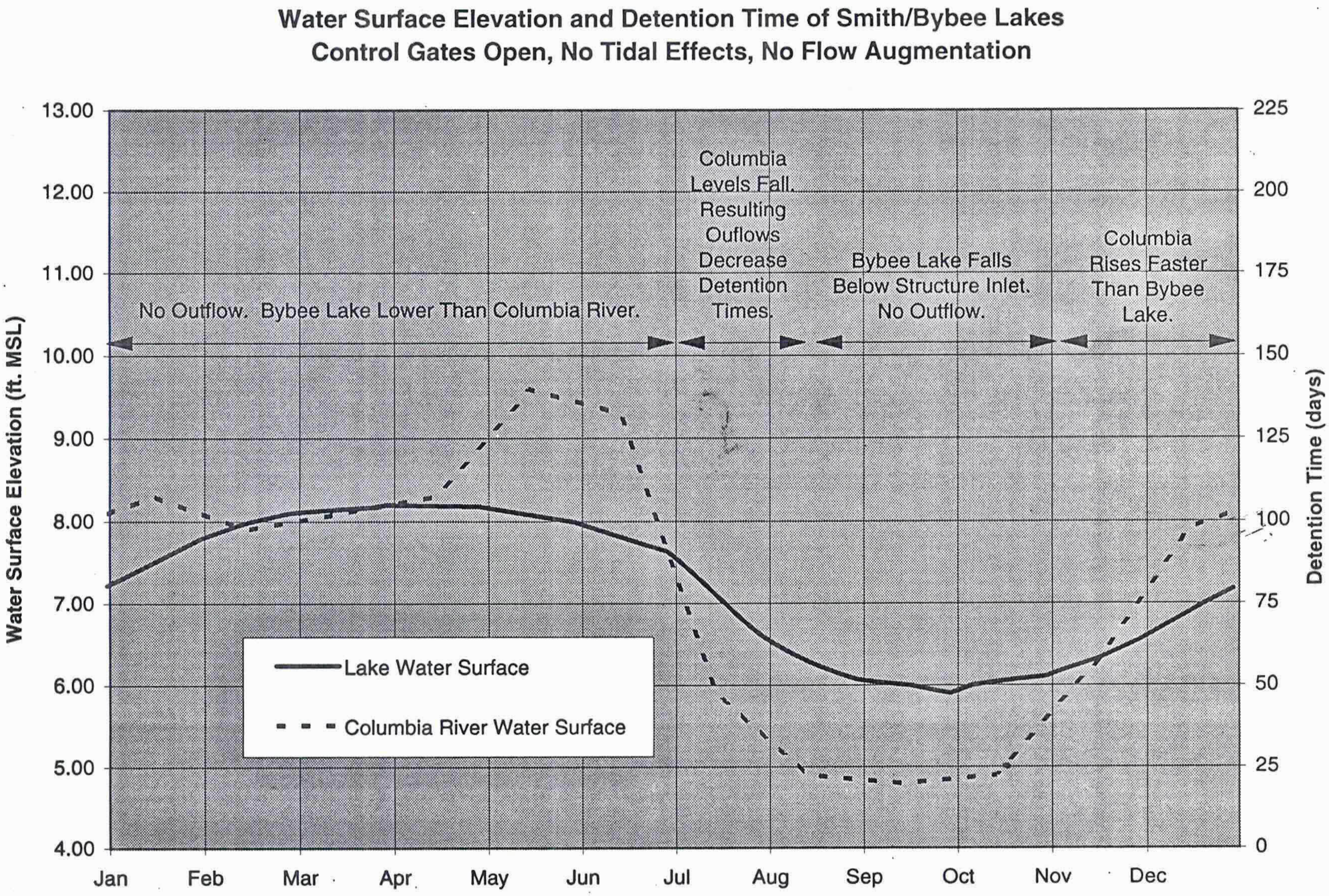
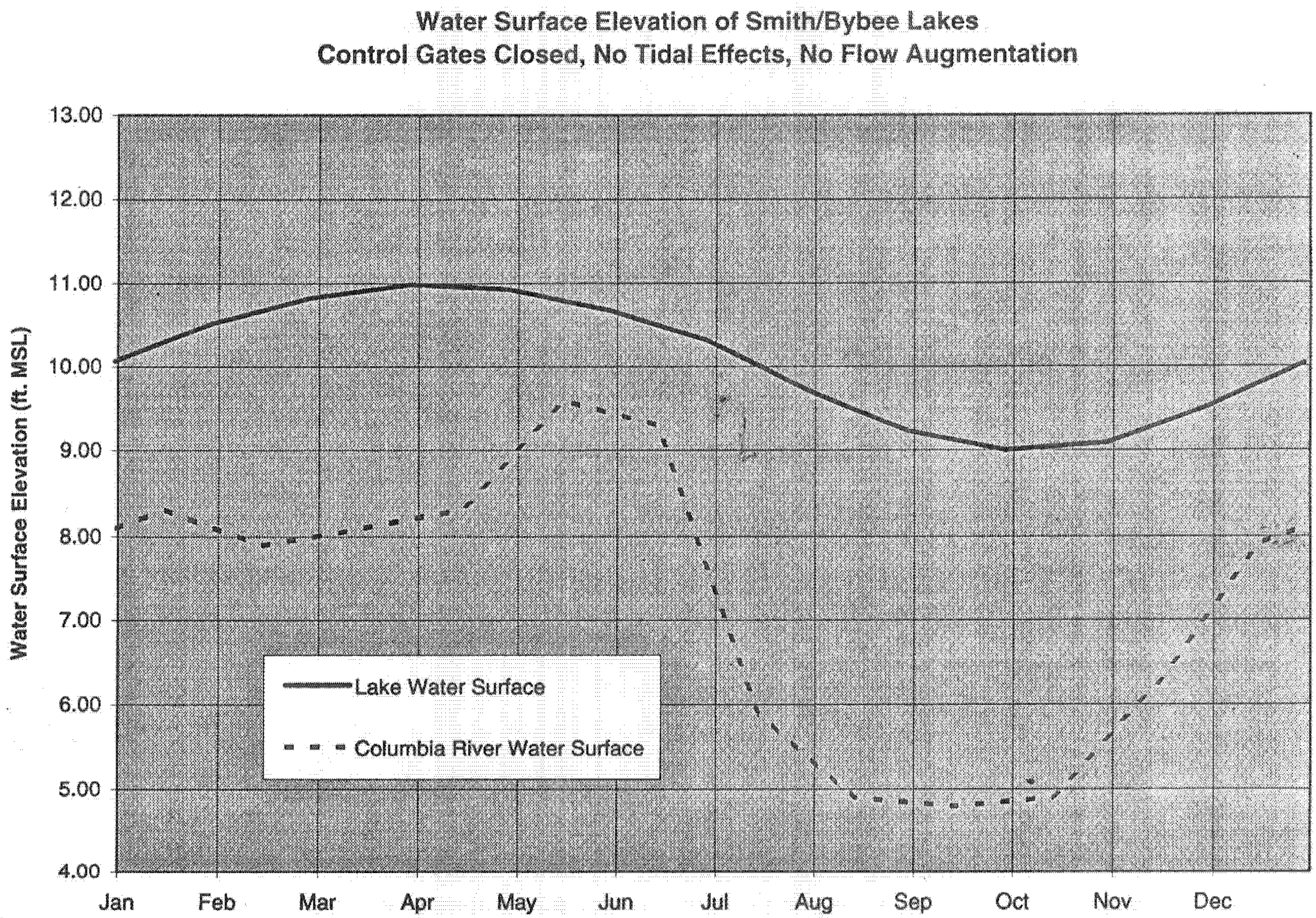

Water Surface Elevation and Detention Time of Smith/Bybee Lakes
Control Gates Open, No Tidal Effects, No Flow Augmentation
Water Surface Elevation (ft. MSL)
Detention Time (days)
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
225
200
175
150
125
100
75
50
25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
No Outflow. Bybee Lake Lower Than Columbia River.
Columbia Levels Fall. Resulting Ouflows Decrease Detention Times.
Bybee Lake Falls Below Structure Inlet. No Outflow.
Columbia Rises Faster Than Bybee Lake.
Lake Water Surface
Columbia River Water Surface

FIGURE 5



Water Surface Elevation of Smith/Bybee Lakes
Control Gates Closed, No Tidal Effects, No Flow Augmentation
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
Water Surface Elevation (ft. MSL)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lake Water Surface
Columbia River Water Surface

FIGURE 6

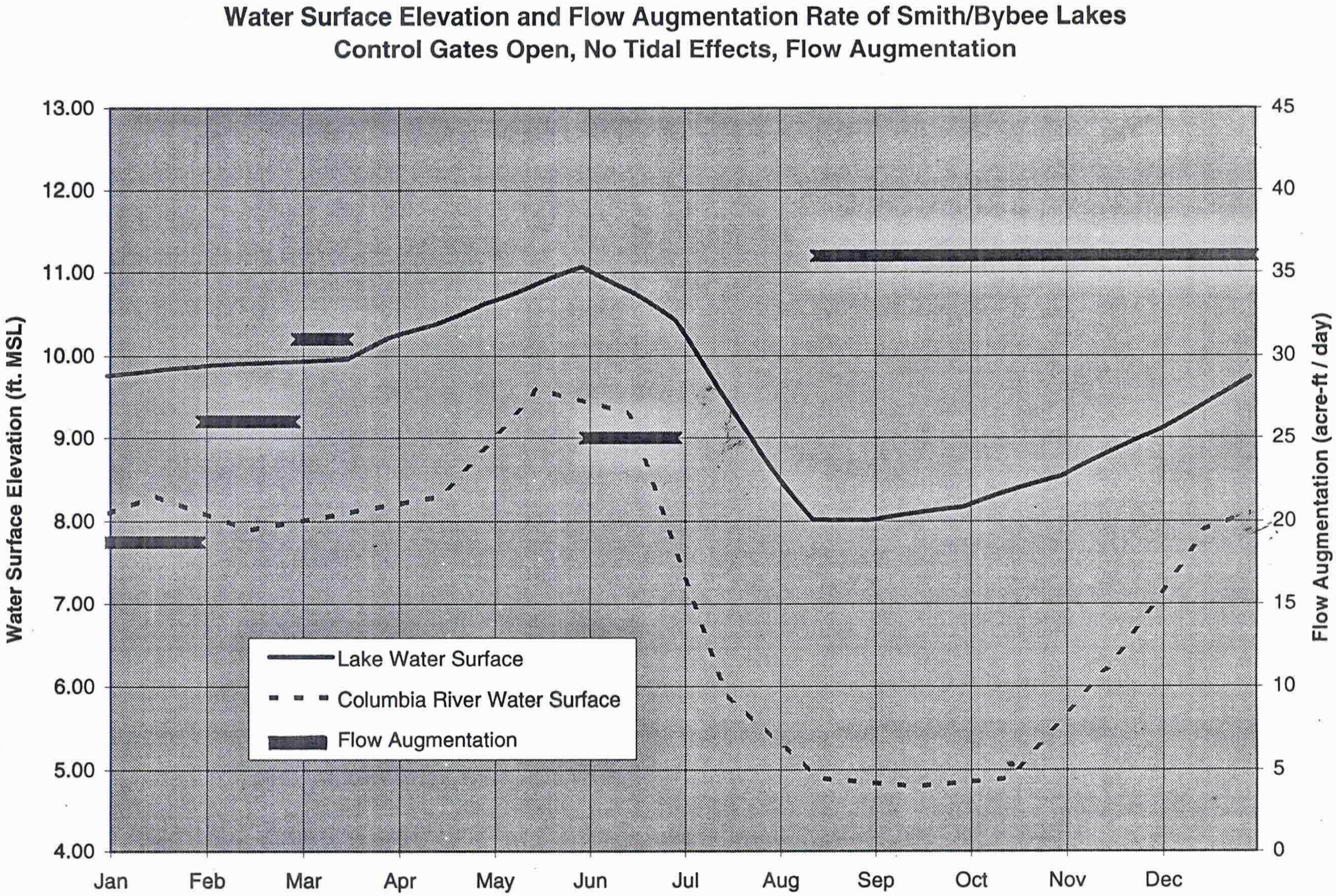
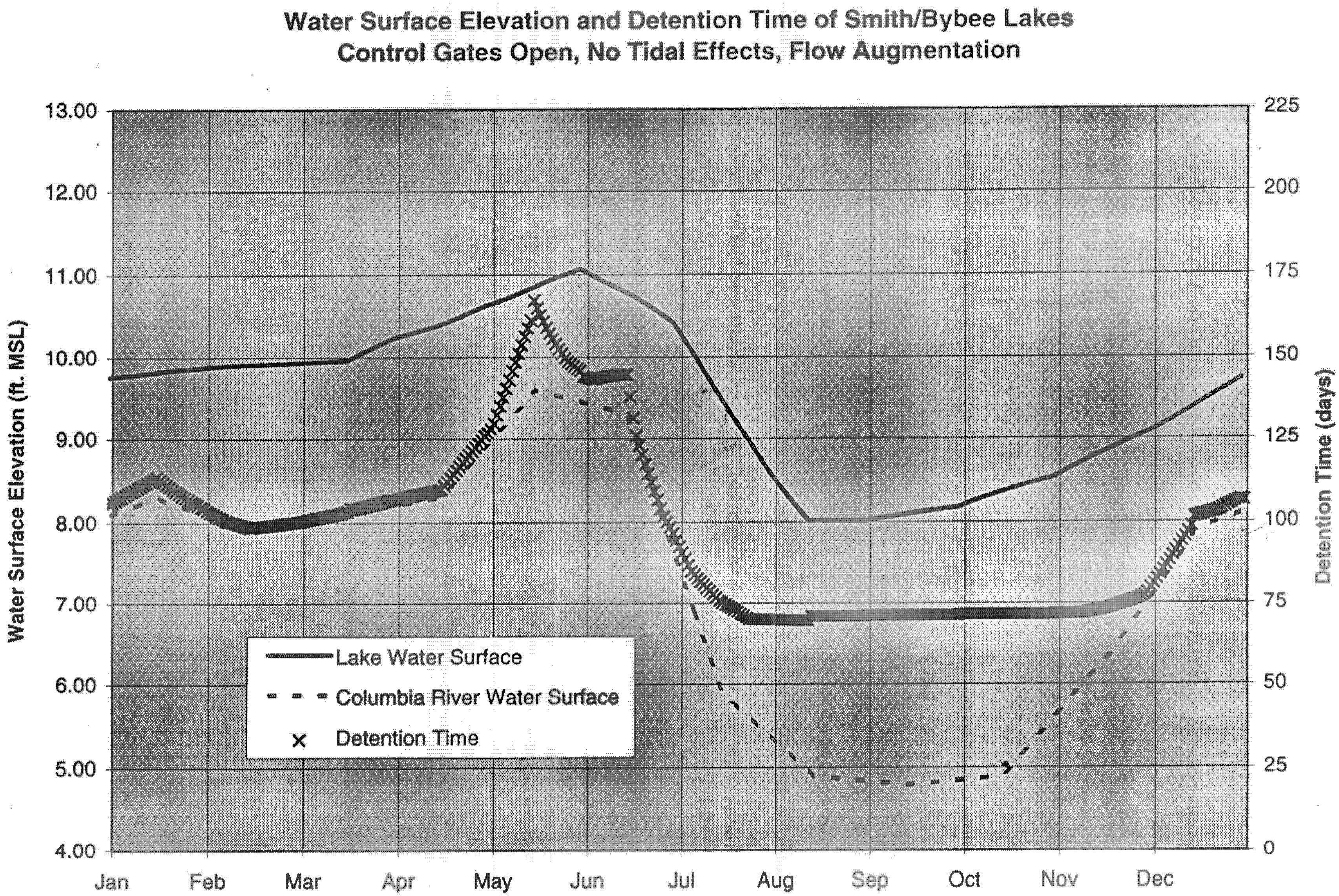

Water Surface Elevation and Flow Augmentation Rate of Smith/Bybee Lakes
Control Gates Open, No Tidal Effects, Flow Augmentation
Water Surface Elevation (ft. MSL)
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
Flow Augmentation (acre-ft / day)
45
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lake Water Surface
Columbia River Water Surface
Flow Augmentation

FIGURE 7


Water Surface Elevation and Detention Time of Smith/Bybee Lakes
Control Gates Open, No Tidal Effects, Flow Augmentation
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
Water Surface Elevation (ft. MSL)
225
200
175
150
125
100
75
50
25
0
Detention Time (days)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lake Water Surface
Columbia River Water Surface
Detention Time