ALASKA POWER AUTHORITY RESPONSE TO AGENCY COMMENTS ON LICENSE APPLICATION; REFERENCE TO COMMENT(S): I.346, I.542, I.552

SUSITNA HYDROELECTRIC PROJECT

RIVER STAGE FLUCTUATION RESULTING FROM ALTERNATIVE OPERATIONS

WATANA DEVELOPMENT

Report by

Harza-Ebasco Susitna Joint Venture

Prepared for

Alaska Power Authority

Final Report
January 1984

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LIST OF EXHIBITS

1.0 SUMMARY

River stage fluctuations due to alternative operations of the Watana development were estimated for the Susitna River from the Devil Canyon damsite to the Sunshine gage station. The estimation was made by routing two discharge patterns assumed to represent near extreme summer and winter power peaking operations for Watana. Results of the routing are given in Tables 3 and 4. The ranges of river stage fluctuation upstream of the confluence with Chulitna River are 0.9 to 1.9 feet for summer operation, depending on location, and 1.6 to 4.2 feet, for winter operation, depending on location. From the confluence with the Chulitna River to Sunshine gage, the corresponding fluctuations are reduced to 0.1 to 0.5 foot for summer operation and to about 1.4 feet for winter operation. The discharge and stage hydrographs at 9 selected locations along the river are shown on Exhibits 6 through 23.

2.0 INTRODUCTION

Operation of the Watana development requires adjustments of release from the reservior for energy production according to load requirements. There could be considerable fluctuation of reservior releases within short time intervals if the development is operated to meet consumption requirements. A brief study was made in late November 1983 to evaluate attenuation of discharge and river stage fluctuations in the reach between Devil Canyon to Talkeetna upstream of the confluence with the Chulitna River. This study extends the analysis to the Sunshine gage located about 14 miles downstream of the confluence.

3.0 METHODOLOGY

To estimate river stage fluctuation due to alternative operation of Watana, the dynamic wave routing model (DAMBRK) developed by Dr. D. L. Fread of National Weather Service (1) was used to route the reservior release for energy production from Watana Dam to Sunshine.

The model is based on the Saint-Venant unsteady flow equations. The Saint-Venant unsteady flow equations consist of a conservation of mass equation, i.e.,

$$\frac{\partial Q}{\partial x} + \frac{\partial (A+A_o)}{\partial t} - q = 0$$

and a conservation of momentum equation, i.e.,

$$\frac{\partial Q}{\partial t} + \frac{\partial (Q^2/A)}{\partial x} + gA(\frac{\partial h}{\partial x} + S_f + S_e) = 0$$

where Q is the discharge, A is the active cross-sectional area of flow, A_o is the inactive (off-channel storage) cross-sectional area, x is the longitudinal distance along the channel (valley), t is the time, q is the lateral inflow or outflow per linear distance along the channel (inflow is positive and outflow is negative in sign), g is the acceleration due to gravity, S_f is the friction slope, S_e is the expansion-contraction slope, and h is the water depth.

In order to solve the unsteady flow equations, the initial conditions of the flow at all cross sections must be known.

The initial flow at each cross section is computed to be:

$$Q_1 = Q_{i-1} + q_{i-1}\Delta x \quad i = 2, 3, \text{---}N$$

where Q_1 is the known discharge (assumed to be steady) at the upstream end, and $q_i\Delta x$ is any lateral inflow from tributaries existing between the cross sections spaced at intervals of Δx along the reach.

The water surface elevations associated with the initial flows are internally determined by solving the following equation:

$$\frac{\partial}{\partial x} (Q^2/A) + gA \left(\frac{\partial h}{\partial x} + S_f\right) = 0$$

where Q is the flow (assumed to be steady), A is the active cross-sectional area of flow, x is the longitudinal distance along the channel, h is the water depth, g is the acceleration due to the gravity, and S_f is the friction slope.

In addition to the initial condition, boundary conditions at the upstream and downstream sections of the reach must be specified. At the upstream boundary, the reservoir release pattern provides the necessary boundary condition. The downstream boundary condition may be, and was, specified by the stage-discharge rating curve for the downstream end of the reach.

4.0 BASIC DATA

Two release patterns assumed to represent near extreme summer and winter power peaking operations for Watana were used in the analysis, assuming no downstream project (Devil Canyon dam) and open water flow conditions. These release patterns are shown in Table 1.

The drainage area downstream from Watana also contributes runoff to the Susitna River. This runoff, termed herein as "intervening flow," was estimated based on the drainage area ratio using natural streamflow at Gold Creek. The streamflows selected are those typical of summer (represented by August) and winter (represented by December) in an average year. Table 2 shows the estimated intervening flows for each sub-reach of the river between Watana and Sunshine.

Exhibits 1 through 5 show various sub-reaches of the river and the locations of cross sections used in the analysis. The cross section data used in the analysis were used in the Instream Hydraulics Study (2).

5.0 ROUTING AND RESULTS

Attenuation of discharge and river stage by the reach between Watana and Devil Canyon is insignificant because of the steep slope of the river and the narrow canyon confining the river. Therefore, the routing was carried out for the reach between Devil Canyon and the Sunshine gage, with the reach divided into two sub-reaches as described below:

1. Devil Canyon damsite to Talkeetna upstream of the confluence with the Chulitna River (52 miles).

   Cross-section data at the 63 locations shown on Exhibits 1 through 4 were used. The values of Manning's "n" used in the analysis were those obtained from the Instream Hydraulics Study (2). The reservoir release patterns provided the upstream boundary conditions. At the downstream boundary, the stage-discharge rating curve at cross section 3 just upstream of the confluence with the Chulitna River was used to define the boundary condition. The rating curve was obtained from the Instream Hydraulics Study (2).

Exhibits 6 through 17 show the routed discharge and stage hydrographs at six locations along the sub-reach. Table 3 summarizes the daily stage fluctuations at each of the six locations for each discharge pattern.

2. Downstream of the confluence with the Chulitna River to the Sunshine gage (14 miles).

Cross-section data at the 11 locations shown on Exhibit 5 were used. The cross-section data and channel roughness were also obtained from the Instream Hydraulics Study (2). The routed hydrographs at cross section 3 in the first sub-reach were used to define the upstream boundary condition. The downstream boundary condition was defined by the stage-discharge rating curve at the Sunshine gage.

Exhibits 18 through 23 show the routed discharge and stage hydrographs at three locations along the sub-reach. Table 4 summarizes the daily stage fluctuations at each of the three locations for each discharge pattern.

The result of the dynamic flow routing as presented in Tables 3 and 4 indicate that attenuation of the discharge and stage fluctuations by the channel storage downstream from the project is relatively small for the sub-reach upstream of the confluence with the Chulitna River. Thus considerable fluctuations remain in that sub-reach. However, the fluctuations are significantly smaller for the sub-reach downstream from the confluence with the Chulitna River to the Sunshine gage. The fluctuations downstream from Sunshine would be even smaller because of the wider channel and additional intervening flows.

REFERENCES

NO.	TITLE
1	Fread, D.L., "The NWS DAM-BREAK Flood Forecasting Model" National Weather Service, NOAA, January, 1982.
2	Harza-Ebasco Susitna Joint Venture Instream Hydraulic Study, "Lower Susitna River, Water Survace Profiles and Discharge Rating Curves," Preliminary Report, October 1983.

TABLE 1

Near Extreme Power Peaking Operation

Hourly Release Pattern for One Day (cfs)

TIME (hr.)	SUMMER OPERATION Watana 2185 (1)	WINTER OPERATION Watana 2185 (2)
1	8,602	6,090
2	8,062	5,360
3	7,561	4,710
4	7,407	4,345
5	7,291	5,035
6	7,561	7,265
7	8,718	9,500
8	11,978	11,285
9	11,843	12,890
10	12,171	13,195
11	12,884	13,155
12	13,019	13,095
13	12,826	12,990
14	12,634	12,890
15	12,634	13,135
16	12,691	14,050
17	12,846	14,050
18	12,961	14,050
19	12,441	14,050
20	12,036	13,745
21	11,843	12,665
22	12,036	11,285
23	12,961	9,380
24	9,895	7,045

TABLE 2

Estimated Intervening Flows

Reach	During Summer Operation (August) (cfs)	During Winter Operation (December) (cfs)
Between Watana - x-sect. 68 (Represented at x-sect. 68)	1,600	110
Between x-sect. 68-50 (Represented at x-sect. 58)	700	80
Between x-sect. 50-24 (Represented at x-sect. 35)	300	40
Between x-sect. 24-3 (Represented at x-sect. 11)	500	60
Between x-sect. 3-2 (Represented at x-sect. 22)	22,200	1,460
Between x-sect. 2-0.001 (Represented at x-sect. 1.1)	9,270	840

TABLE 3

Range of River Stage Fluctuation (ft)

Devil Canyon Damsite to the Confluence with Chulitna River

Location	River Mile from Mouth (mi)	Watana 2185	
		SUMMER OPERATION	WINTER OPERATION[2/]
x-sect. 68	150.2	1.9	4.2
x-sect. 55	141.6	0.9	2.1
x-sect. 44	136.4	1.5	3.0
x-sect. 30	127.5	0.7	1.6
x-sect. 18	113.0	1.1	2.4
x-sect. 3	98.6	1.6	3.1

2/ Assuming open water condition.

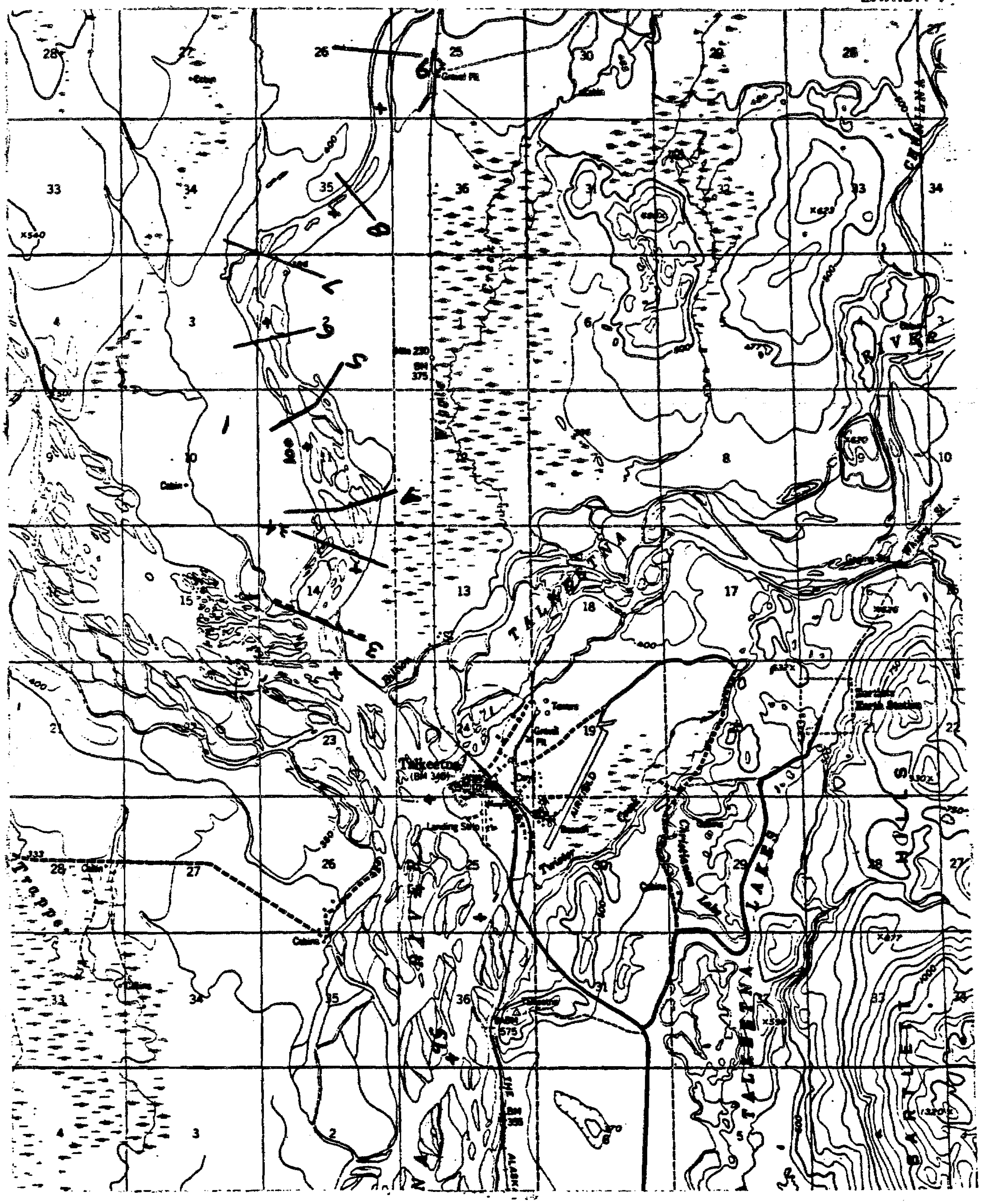
TABLE 4

Range of River Stage Fluctuation (ft)

Confluence with Chulitna River to Sunshine Station

Location	River Mile from Mouth (mi)	Watana 2185	
		SUMMER OPERATION	WINTER OPERATION[2/]
x-sect. 1	97.02	0.1	1.4
x-sect. 0.3	94.23	0.2	1.4
Sunshine gage station	83.9	0.5	1.4

[2/] Assuming open water condition.



LEGEND

——— River Cross Section

====== River Cross Section For Which Discharge and Stage Hydrographs are Prepared

RIVER CROSS SECTIONS USED IN DYNAMIC FLOOD ROUTING

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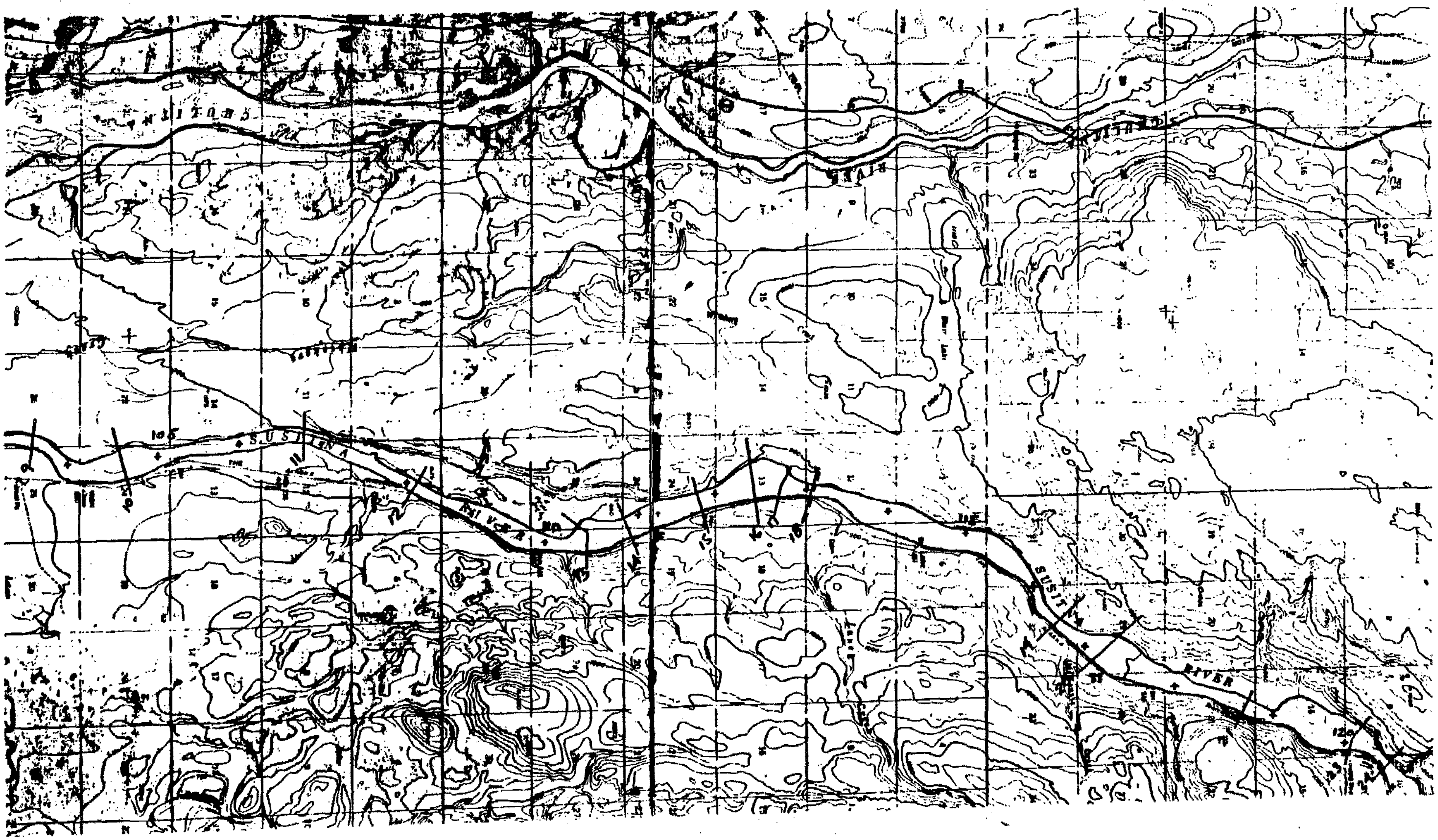
EXHIBIT 2



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—— River Cross Section

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RIVER CROSS SECTIONS USED IN DYNAMIC FLOOD ROUTING

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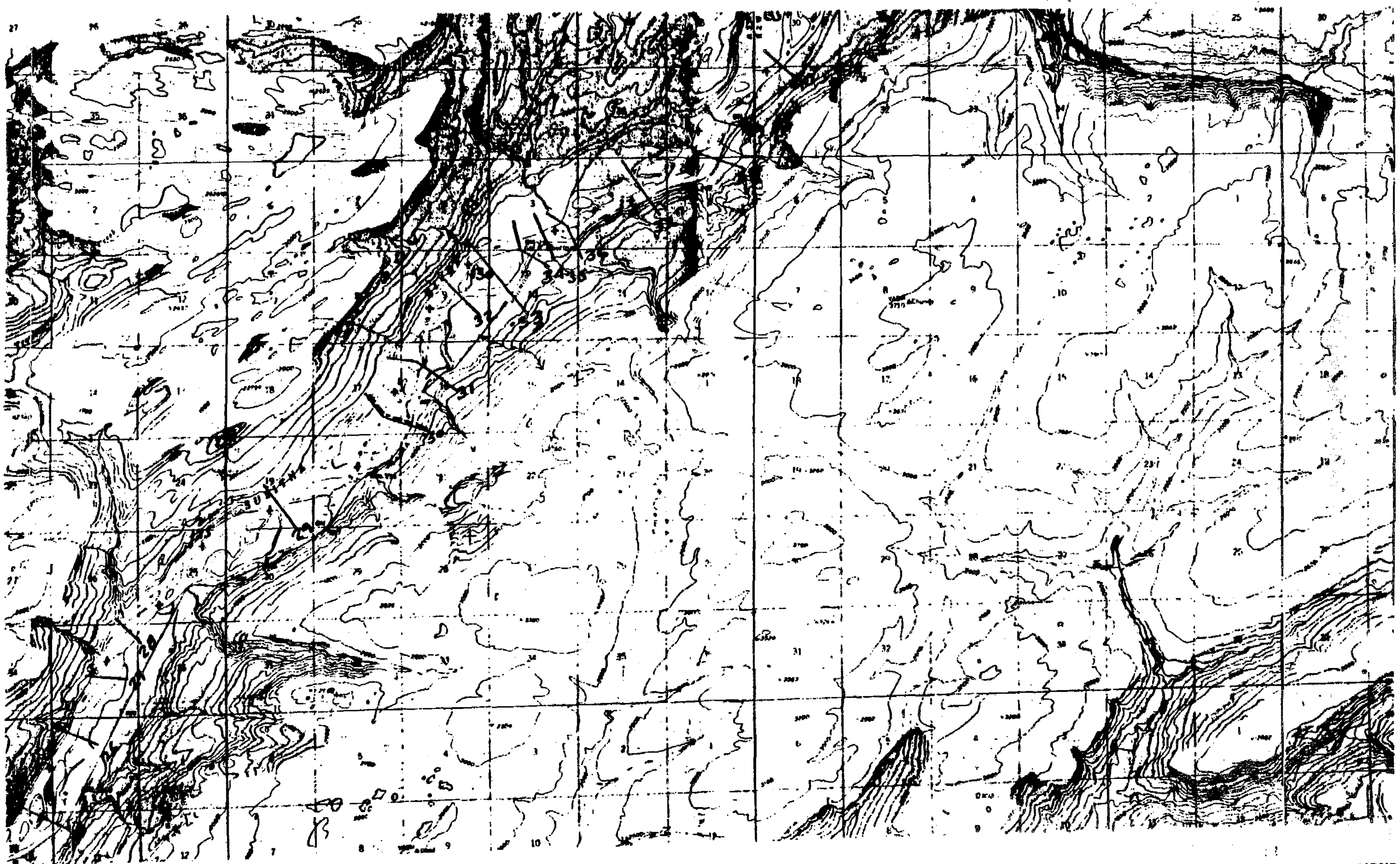

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═══ River Cross Section For Which Discharge and Stage Hydrographs are Prepared

RIVER CROSS SECTIONS USED IN DYNAMIC FLOOD ROUTING

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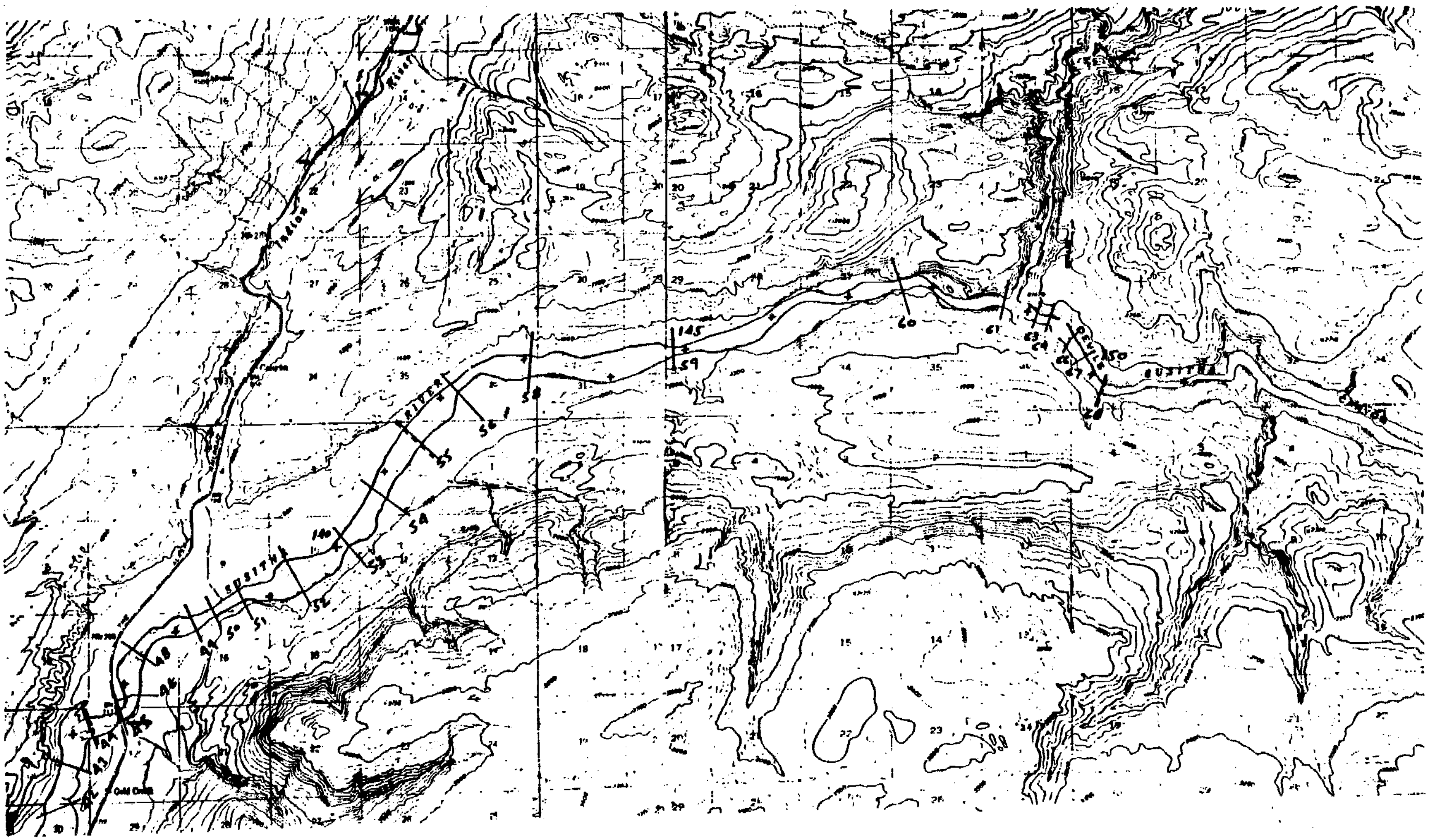
EXHIBIT 3

EXHIBIT 4



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====== River Cross Section For Which Discharge and Stage Hydrographs are Prepared

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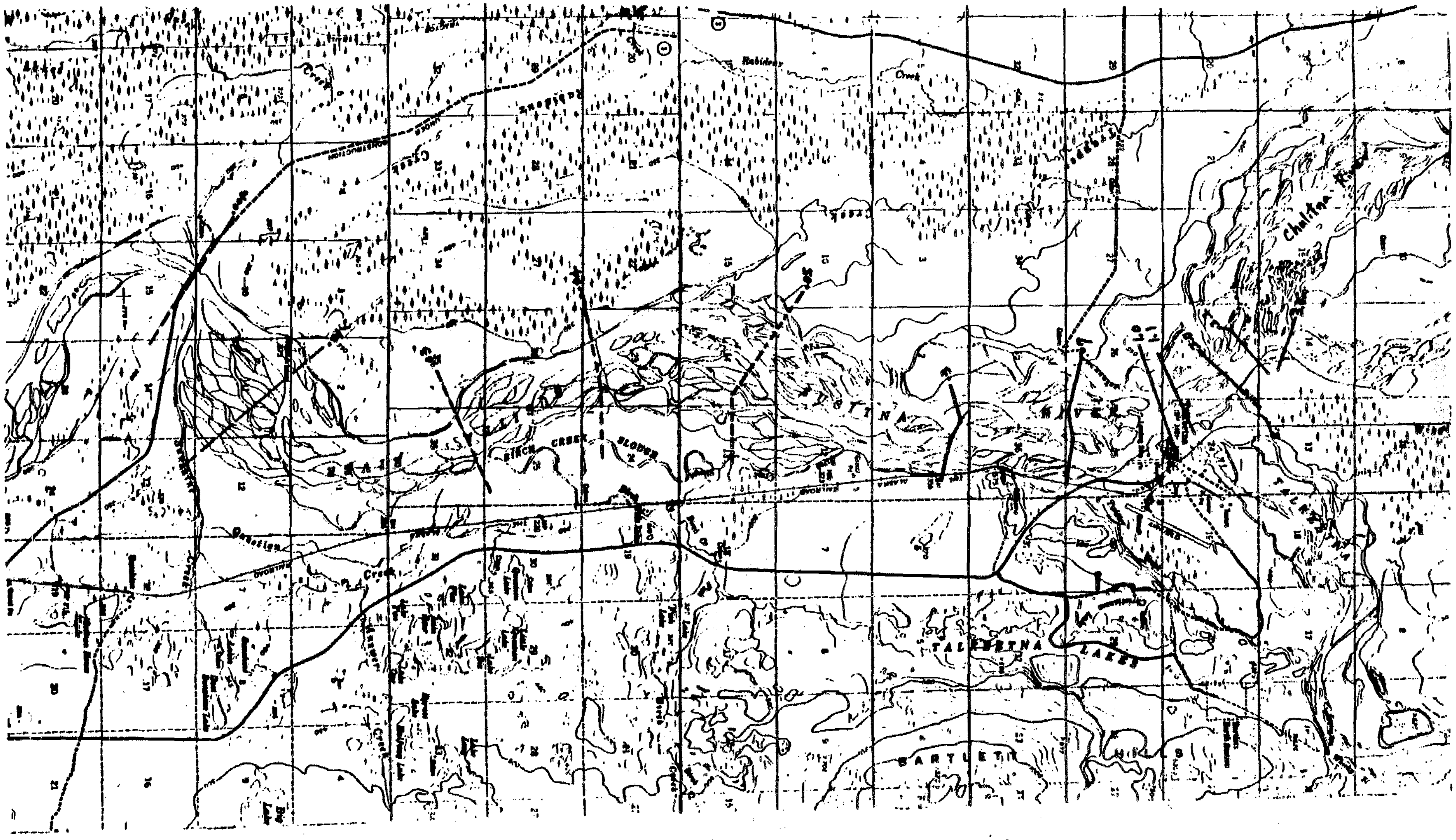
RIVER CROSS SECTIONS USED IN DYNAMIC FLOOD ROUTING

EXHIBIT 5



LEGEND

——— River Cross Section

– – – Cross Section Taken From Topographic Map

RIVER CROSS SECTIONS USED IN DYNAMIC FLOOD ROUTING

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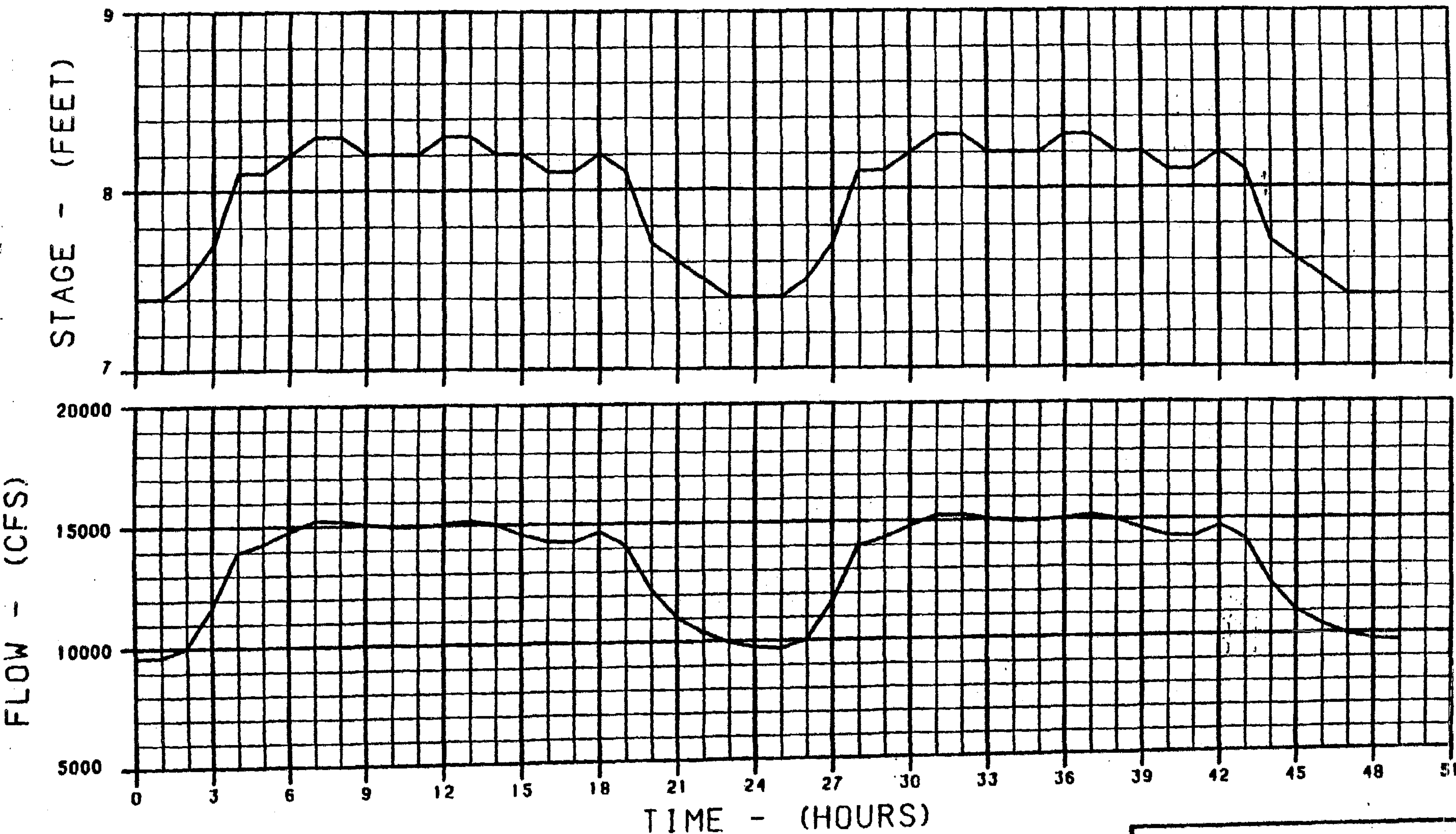

NOTES:
1. SUMMER SIMULATION
2. SECTION NUMBER 55.0
3. STAGE DATUM ELEVATION AT 735.30 FT. MSL

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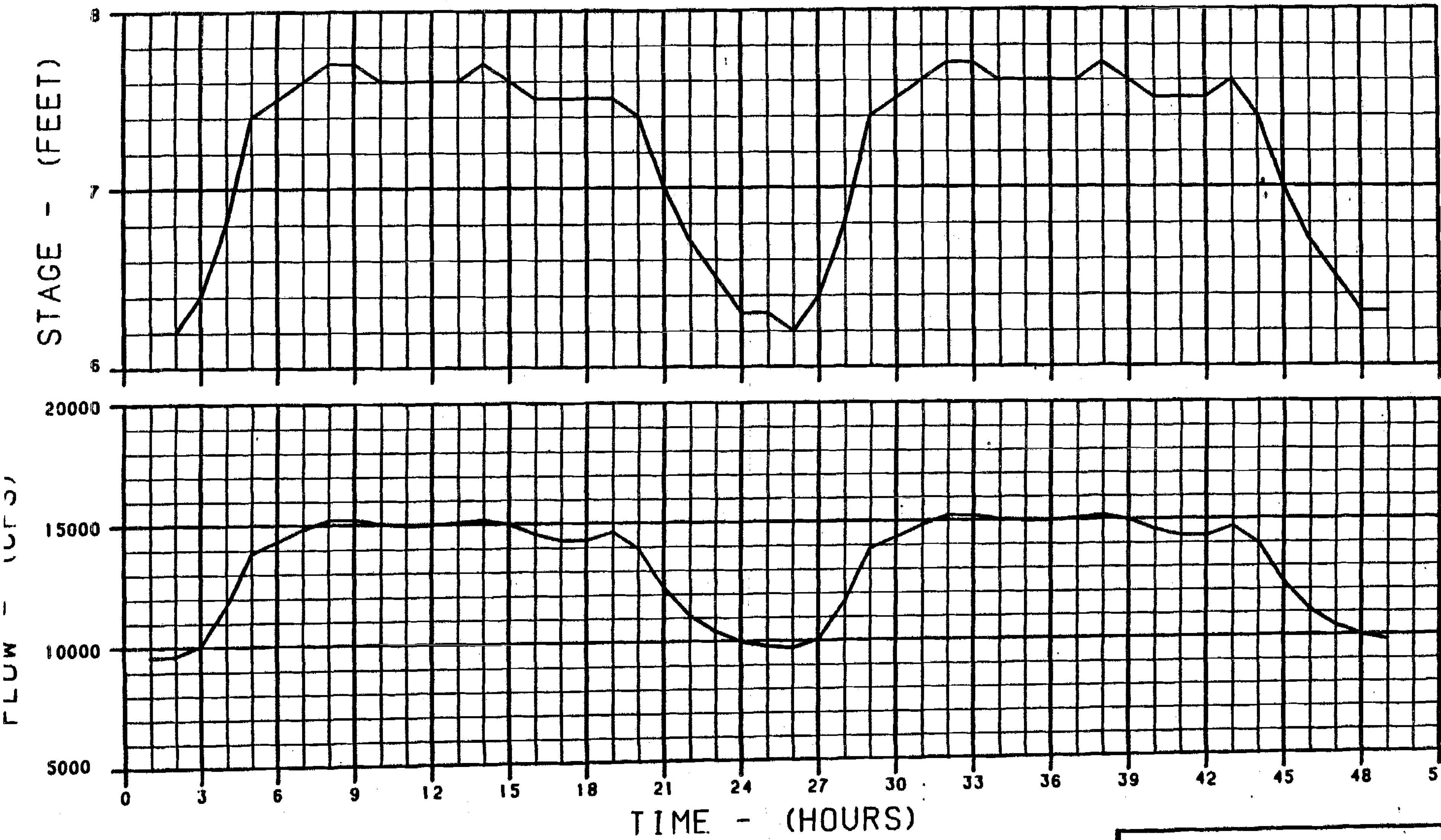
EXHIBIT 7



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3. STAGE DATUM ELEVATION AT 675.00 FT. MSL

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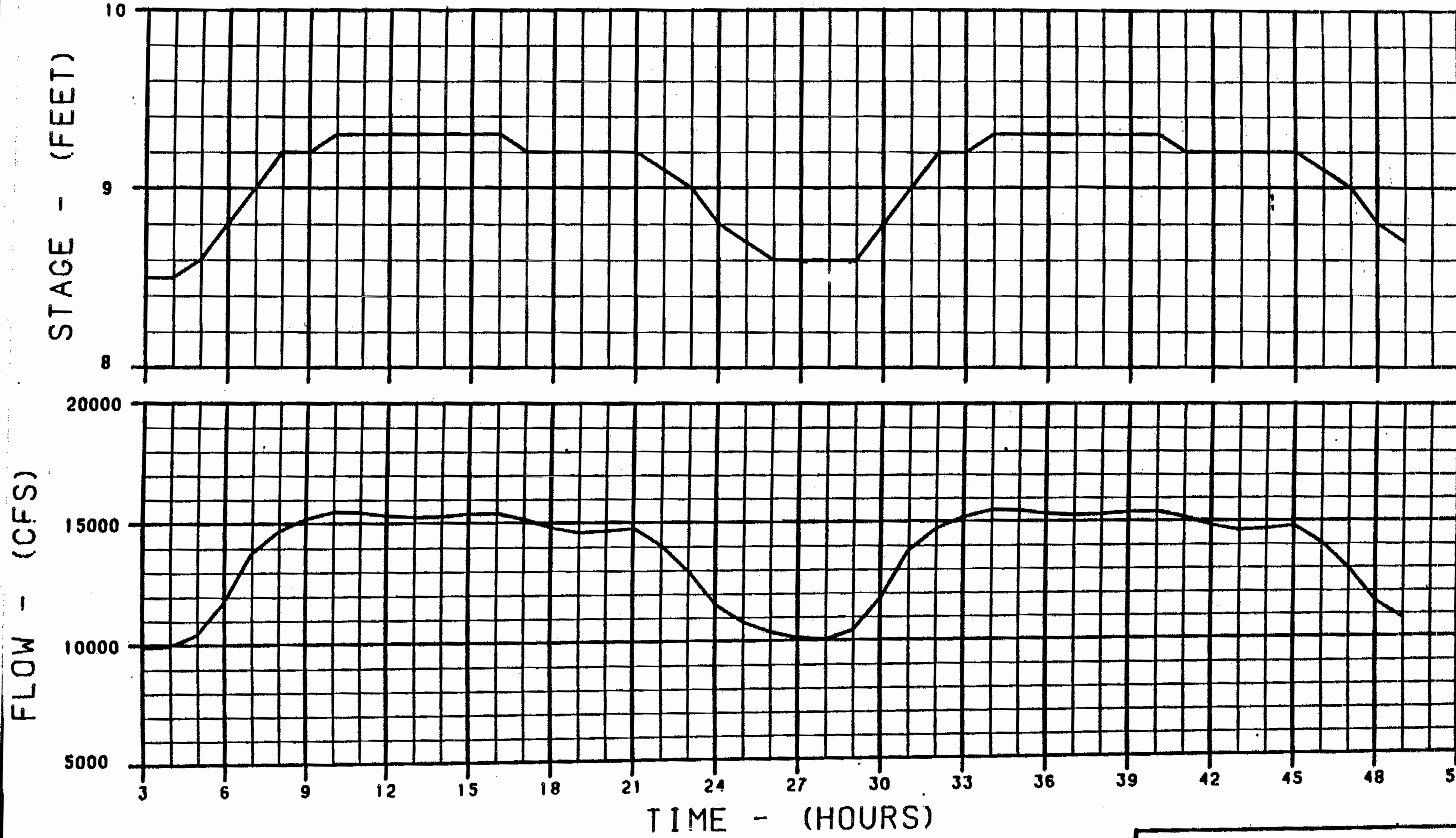
EXHIBIT 8

EXHIBIT 9



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2. SECTION NUMBER 30.0
3. STAGE DATUM ELEVATION AT 578.40 FT. MSL

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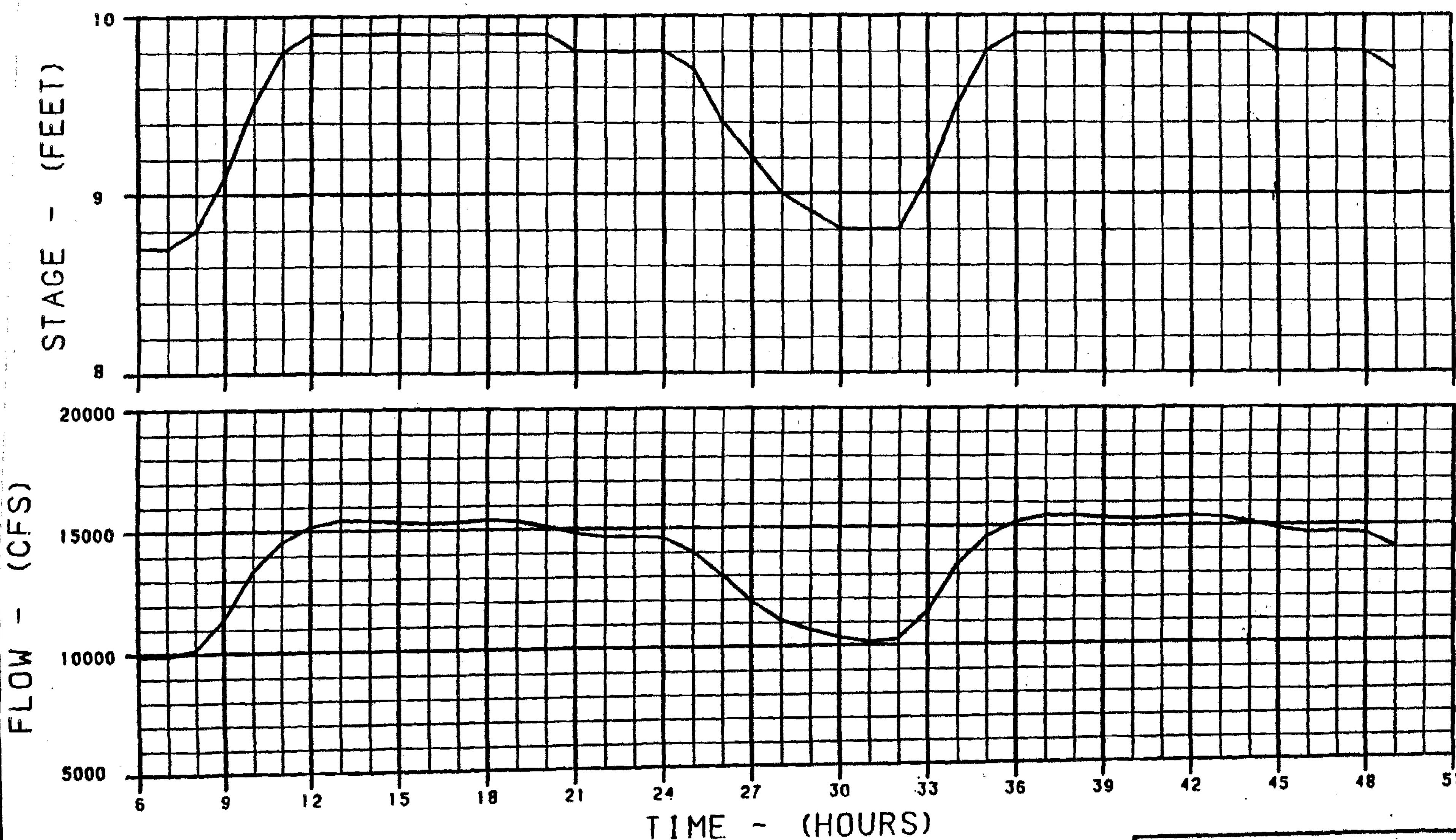

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2. SECTION NUMBER 18.0
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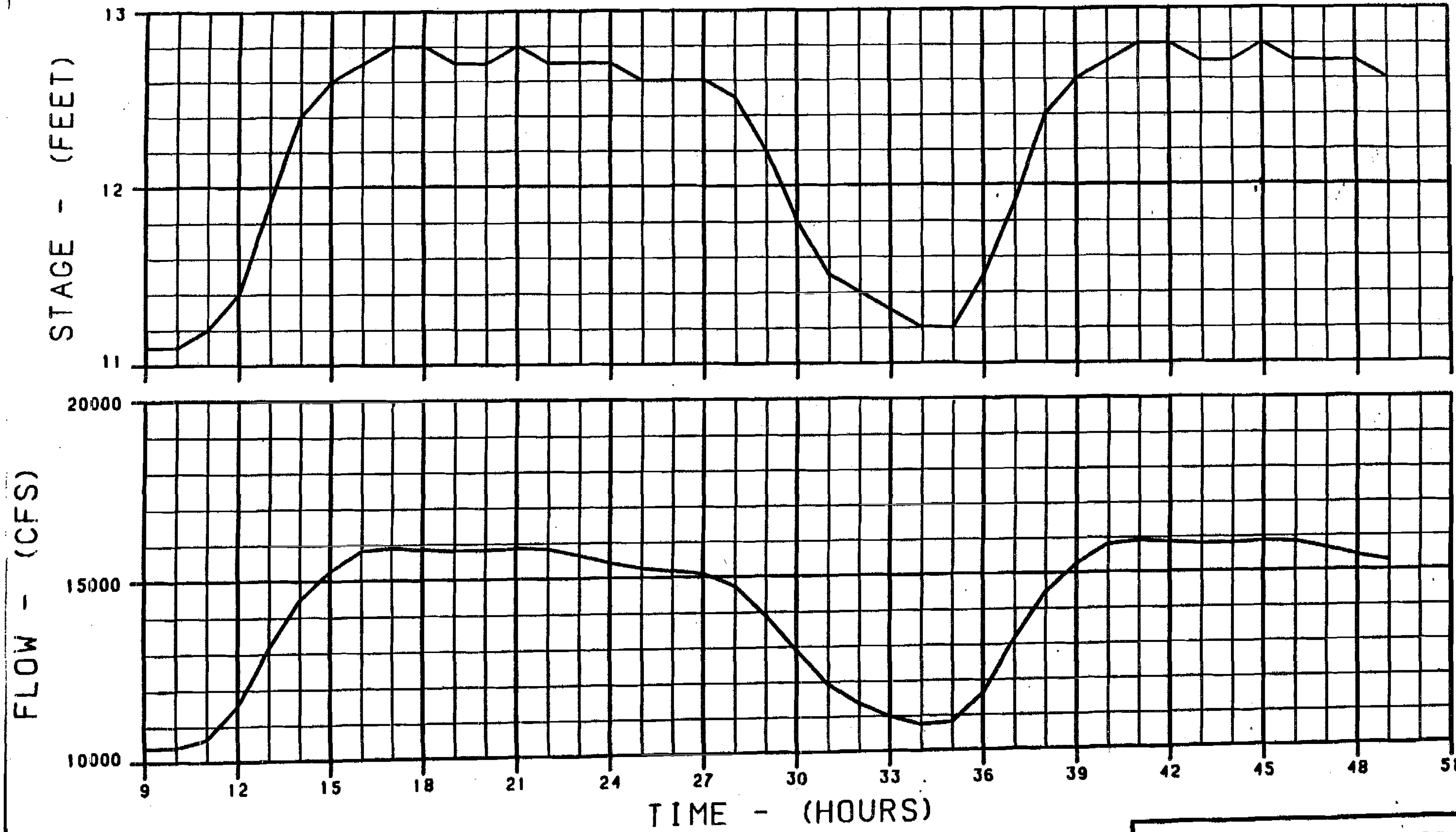
EXHIBIT 10



NOTES:
1. SUMMER SIMULATION
2. SECTION NUMBER 3.0
3. STAGE DATUM ELEVATION AT 332.70 FT. MSL

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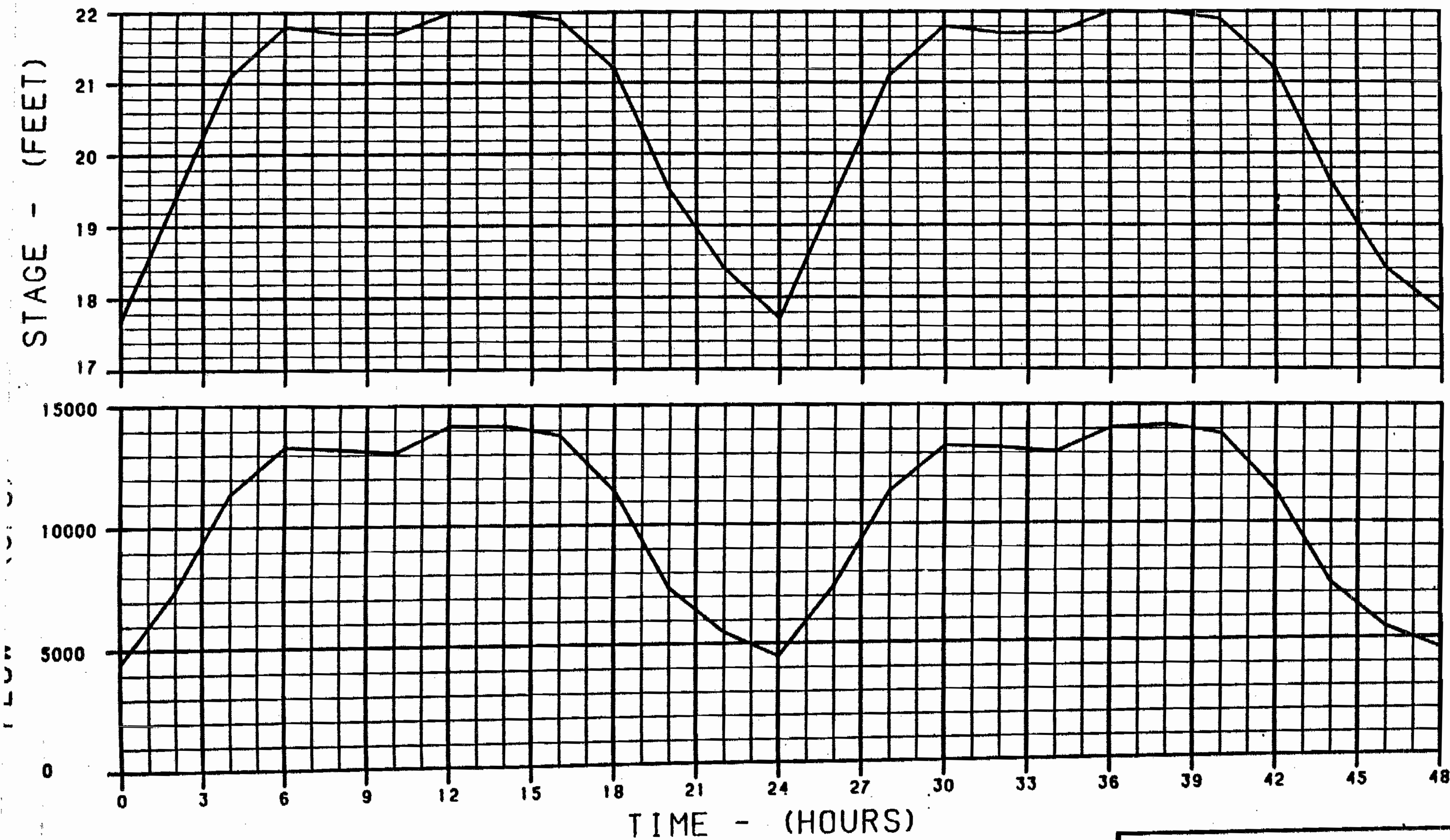
EXHIBIT 11

EXHIBIT 12



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2. SECTION NUMBER 68.0
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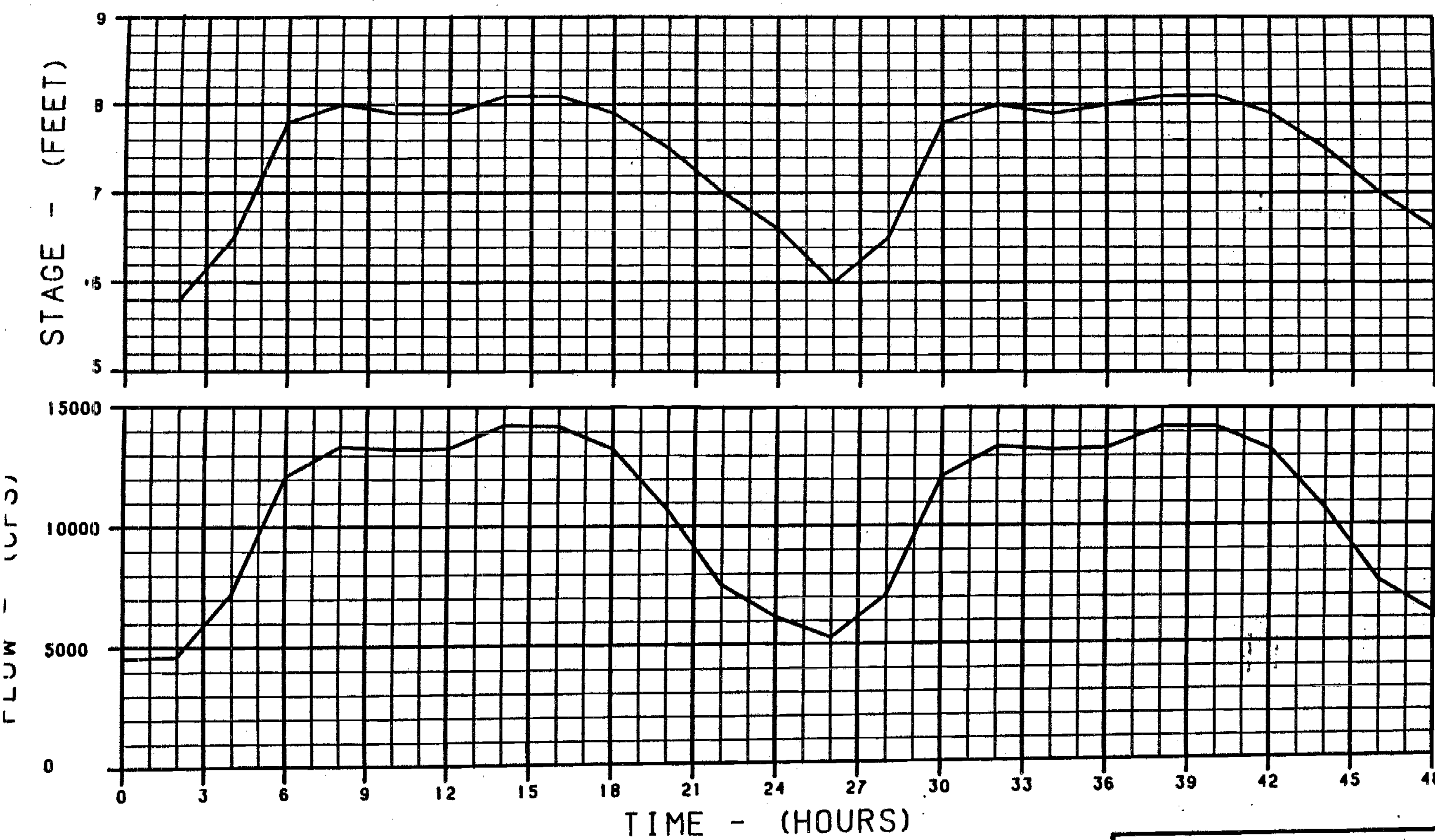

NOTES:
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2. SECTION NUMBER 55.0
3. STAGE DATUM ELEVATION AT 735.30 FT. MSL

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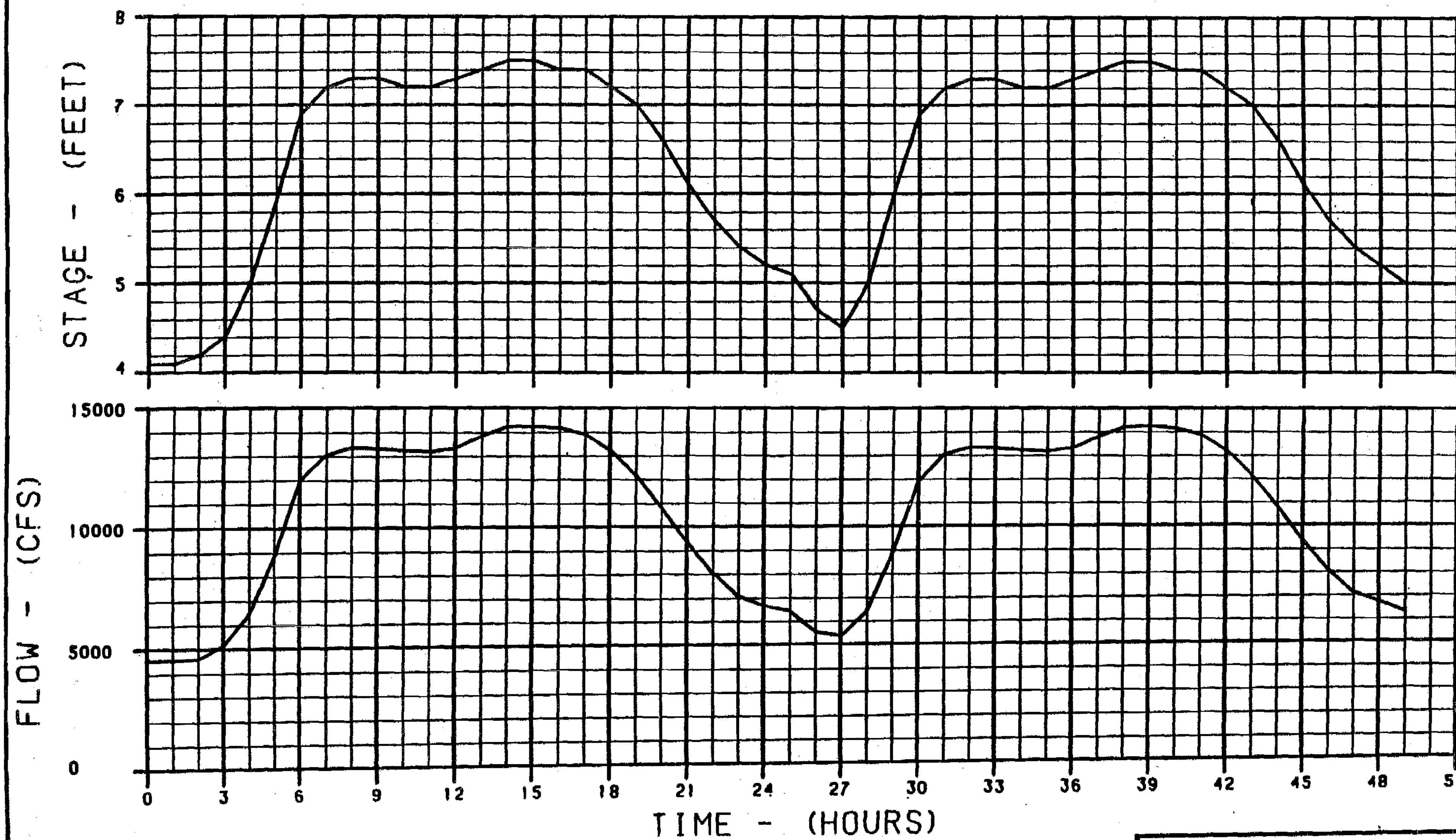

NOTES: 1. WINTER SIMULATION
2. SECTION NUMBER 44.0
3. STAGE DATUM ELEVATION AT 675.00 FT. MSL

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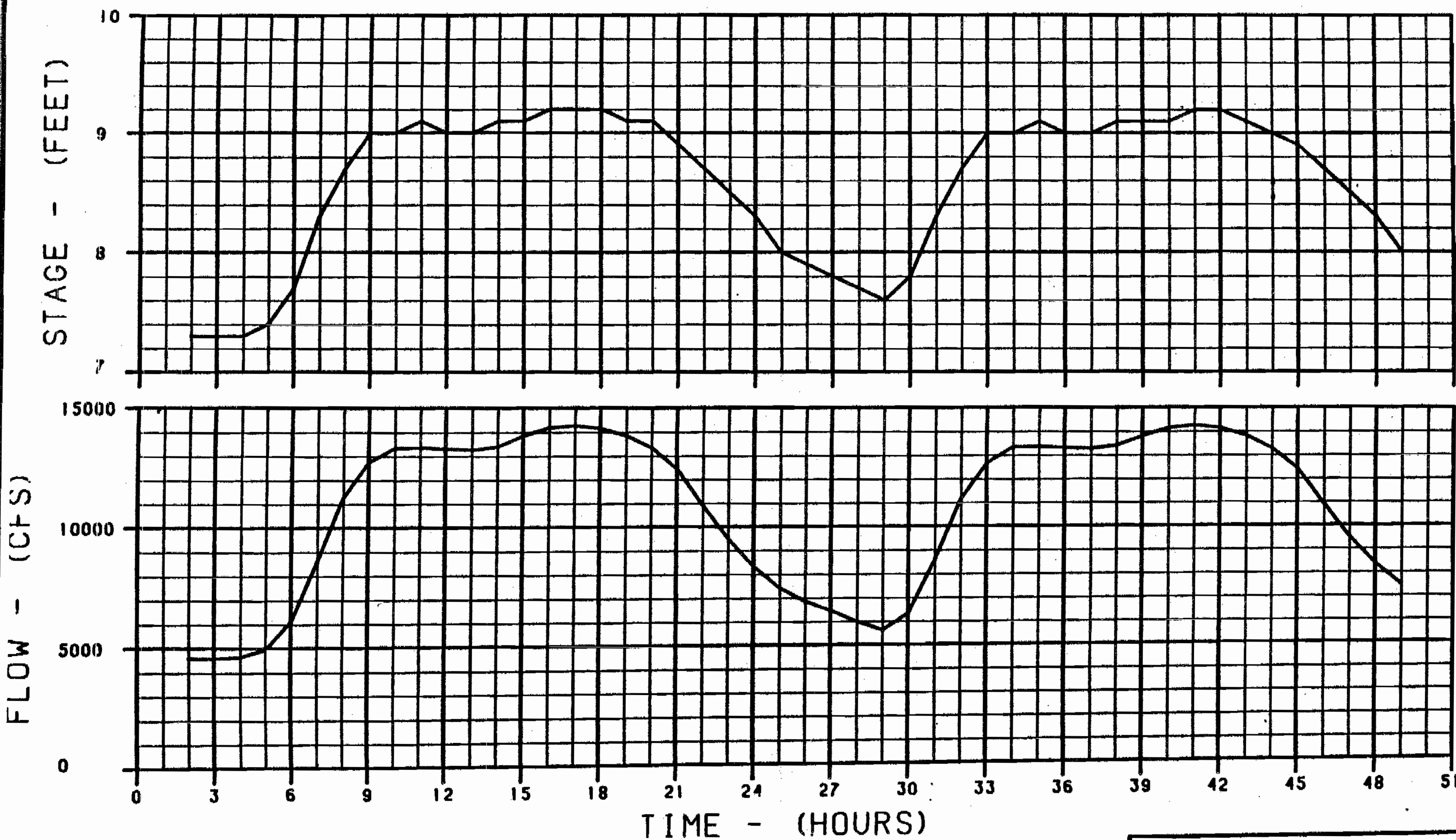

NOTES:
1. WINTER SIMULATION
2. SECTION NUMBER 30.0
3. STAGE DATUM ELEVATION AT 578.40 FT. MSL

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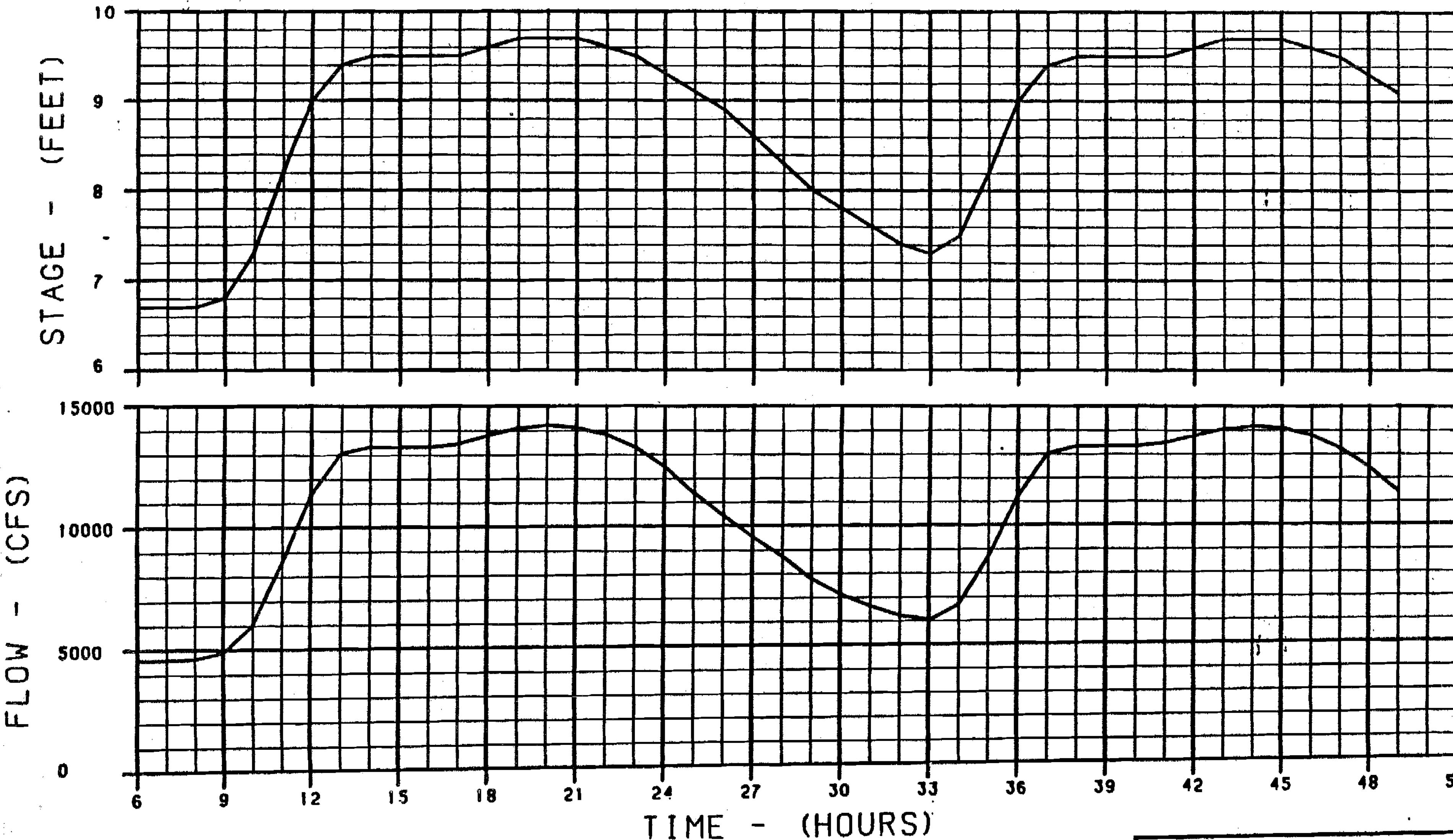
EXHIBIT 15



NOTES: 1. WINTER SIMULATION
2. SECTION NUMBER 18.0
3. STAGE DATUM ELEVATION AT 452.00 FT. MSL

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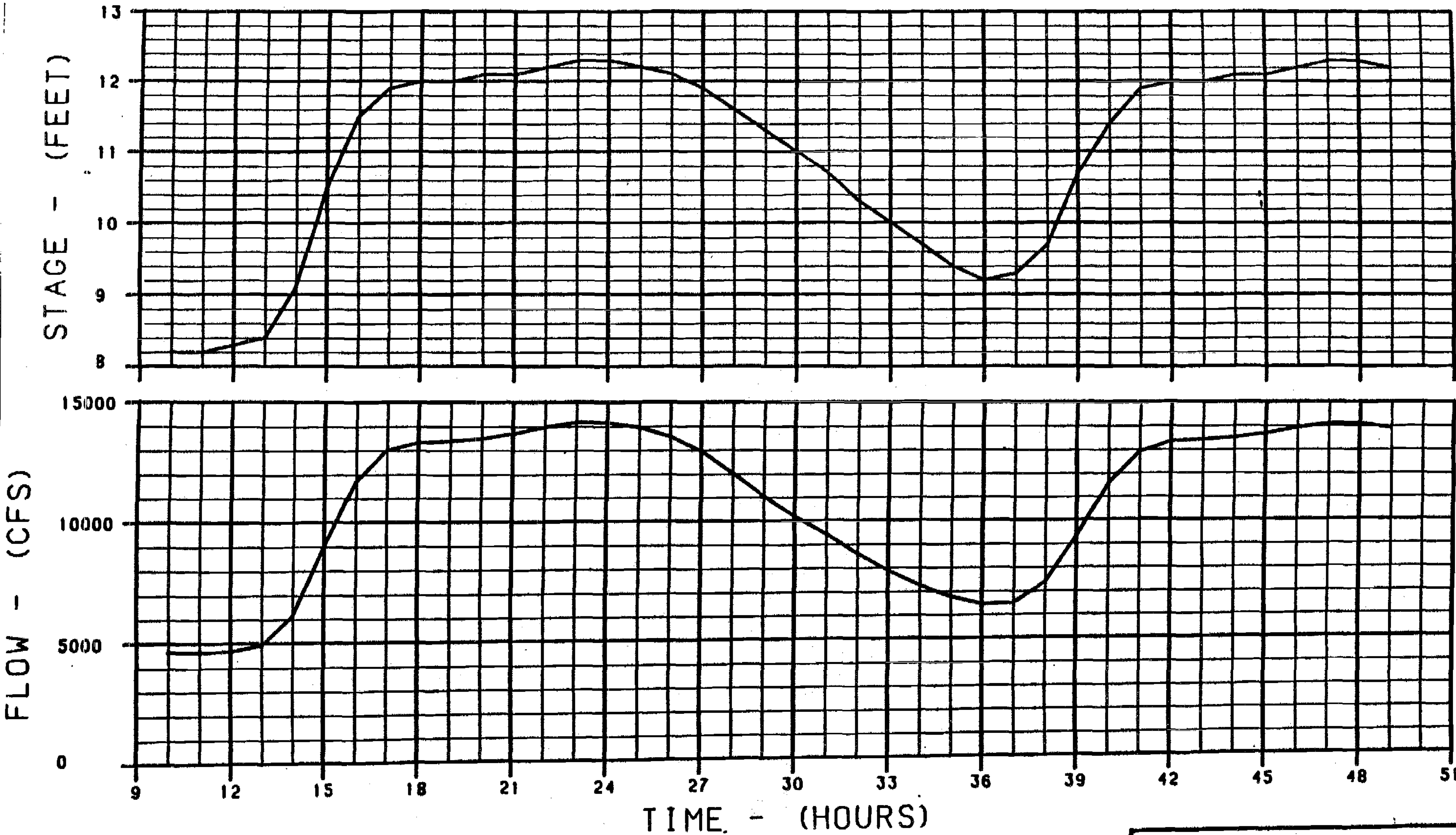

NOTES: 1. WINTER SIMULATION
2. SECTION NUMBER 3.0
3. STAGE DATUM ELEVATION AT 332.70 FT. MSL

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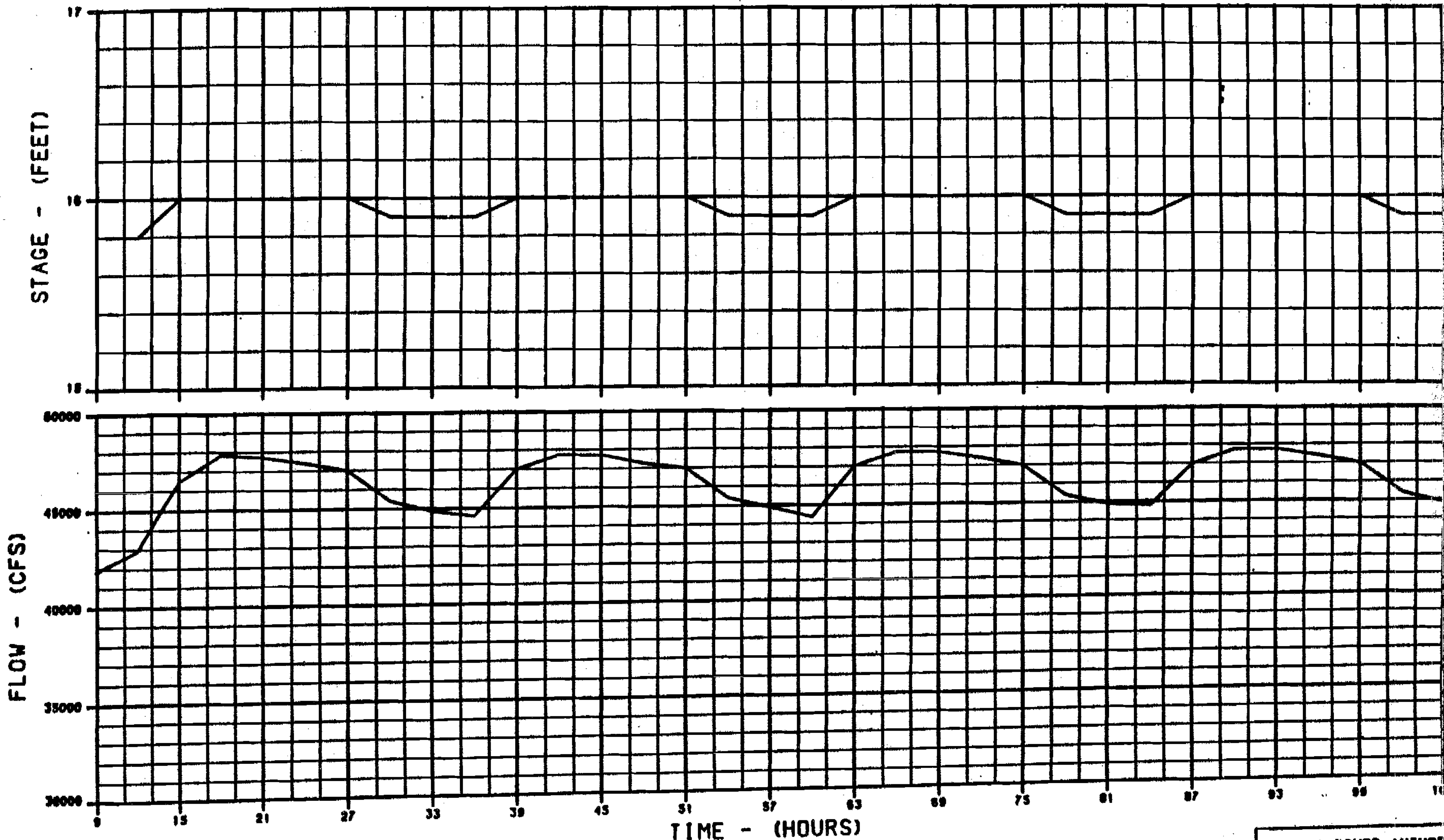

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2. SECTION NUMBER 1.0
3. STAGE DATUM ELEVATION AT 820.40 FT. MSL

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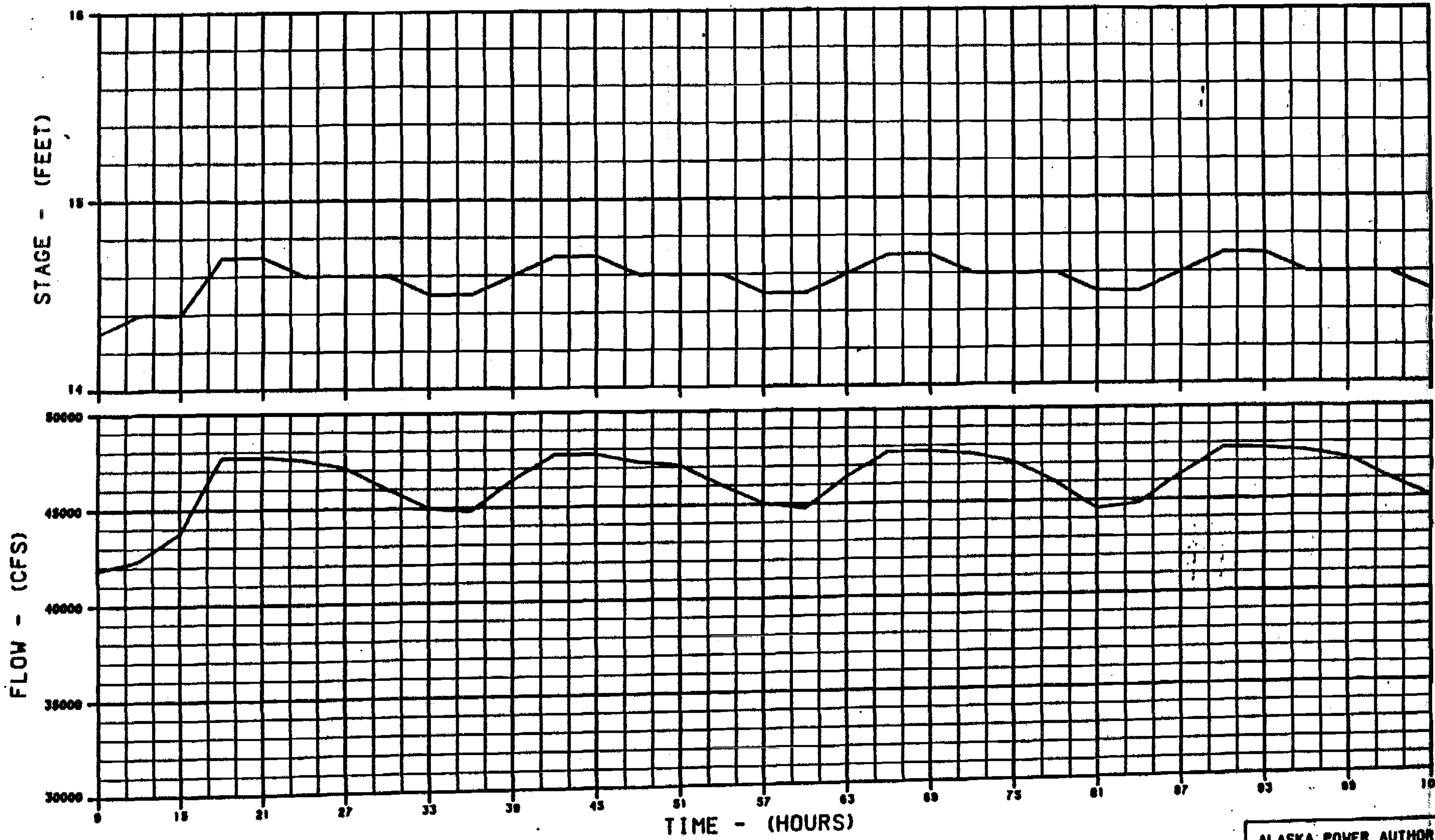
EXHIBIT 18

EXHIBIT 19



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1. SUMMER SIMULATION
2. SECTION NUMBER 0.3
3. STAGE DATUM ELEVATION AT 304.00 FT. MSL

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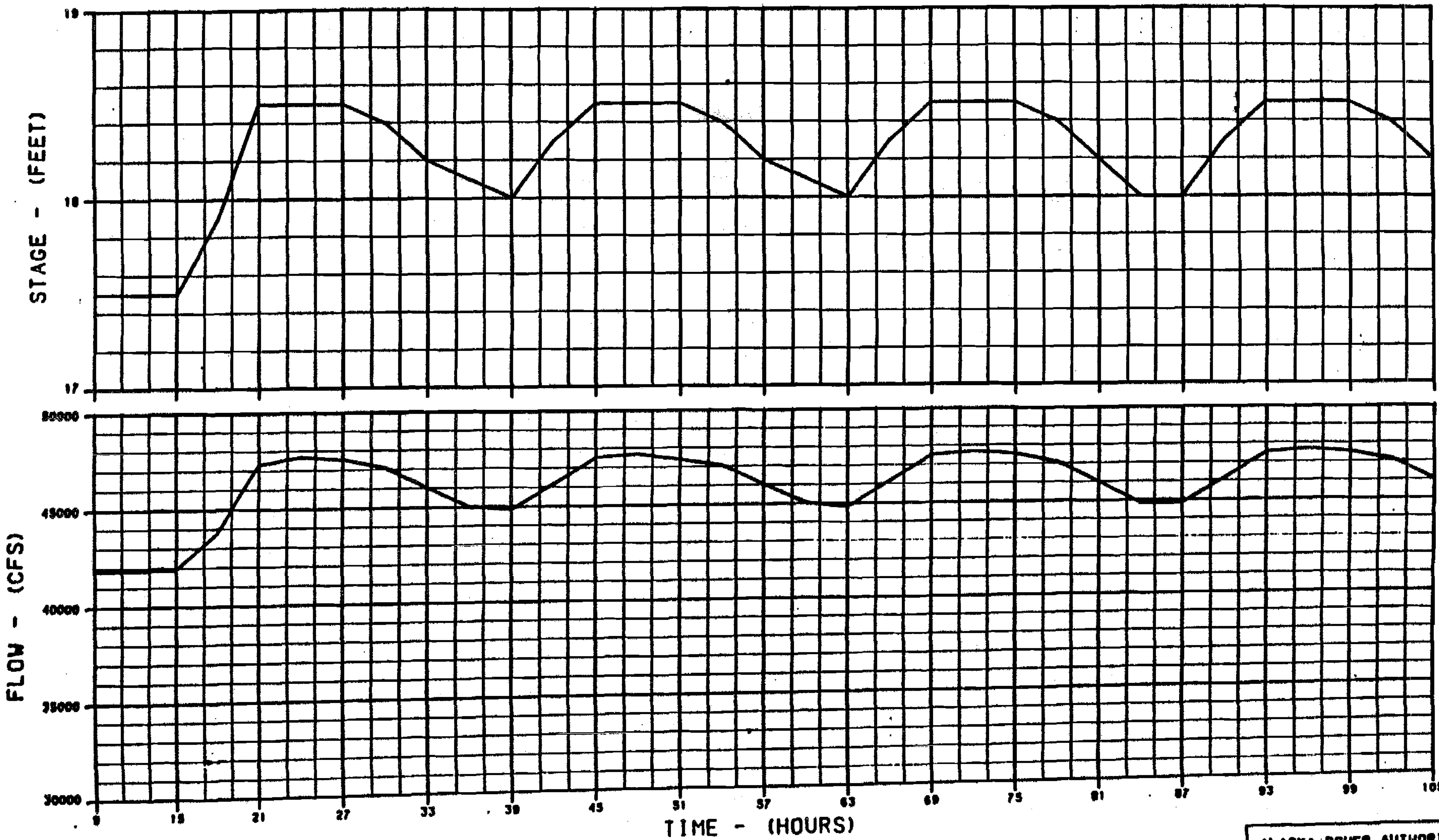

NOTES: 1. SUMMER SIMULATION
2. SECTION AT SUNSHINE GAGE STATION
3. STAGE DATUM ELEVATION AT 263.00 FT. MSL

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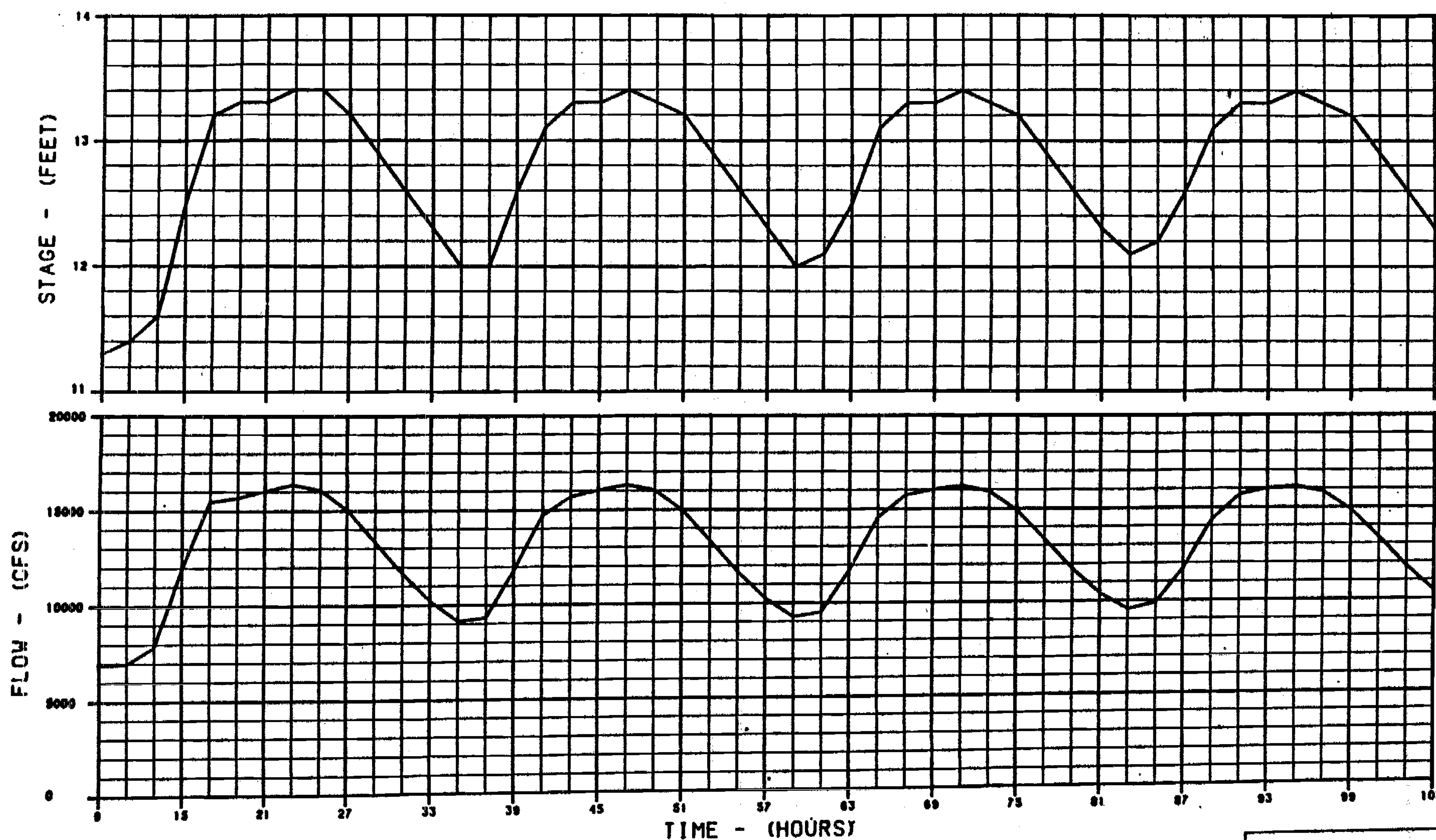
EXHIBIT 20

EXHIBIT 21



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1. WINTER SIMULATION
2. SECTION NUMBER 1.0
3. STAGE DATUM ELEVATION AT 320.40 FT. MSL

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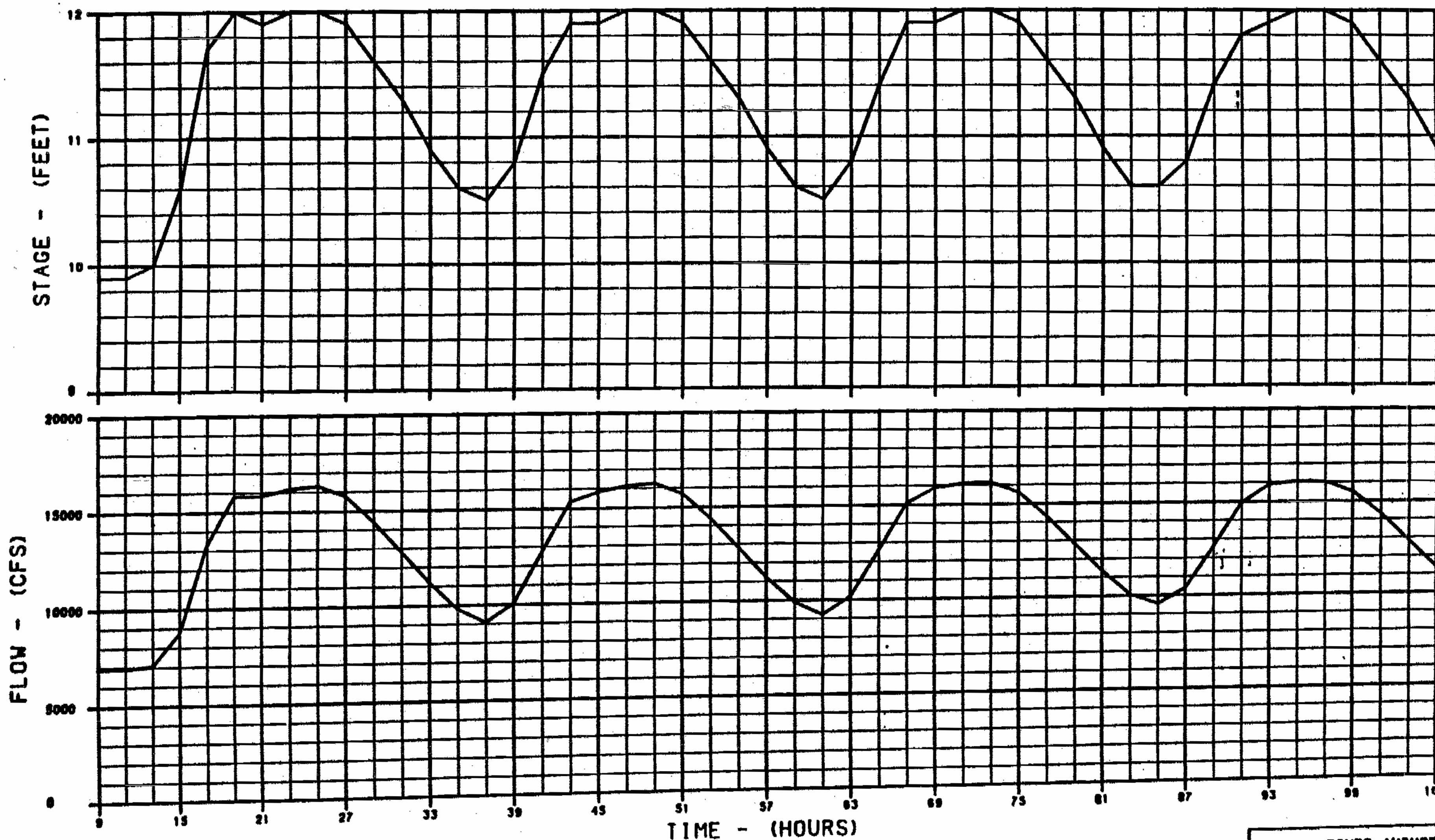

NOTES: 1. WINTER SIMULATION
2. SECTION NUMBER 0.3
3. STAGE DATUM ELEVATION AT 304.00 FT. MSL

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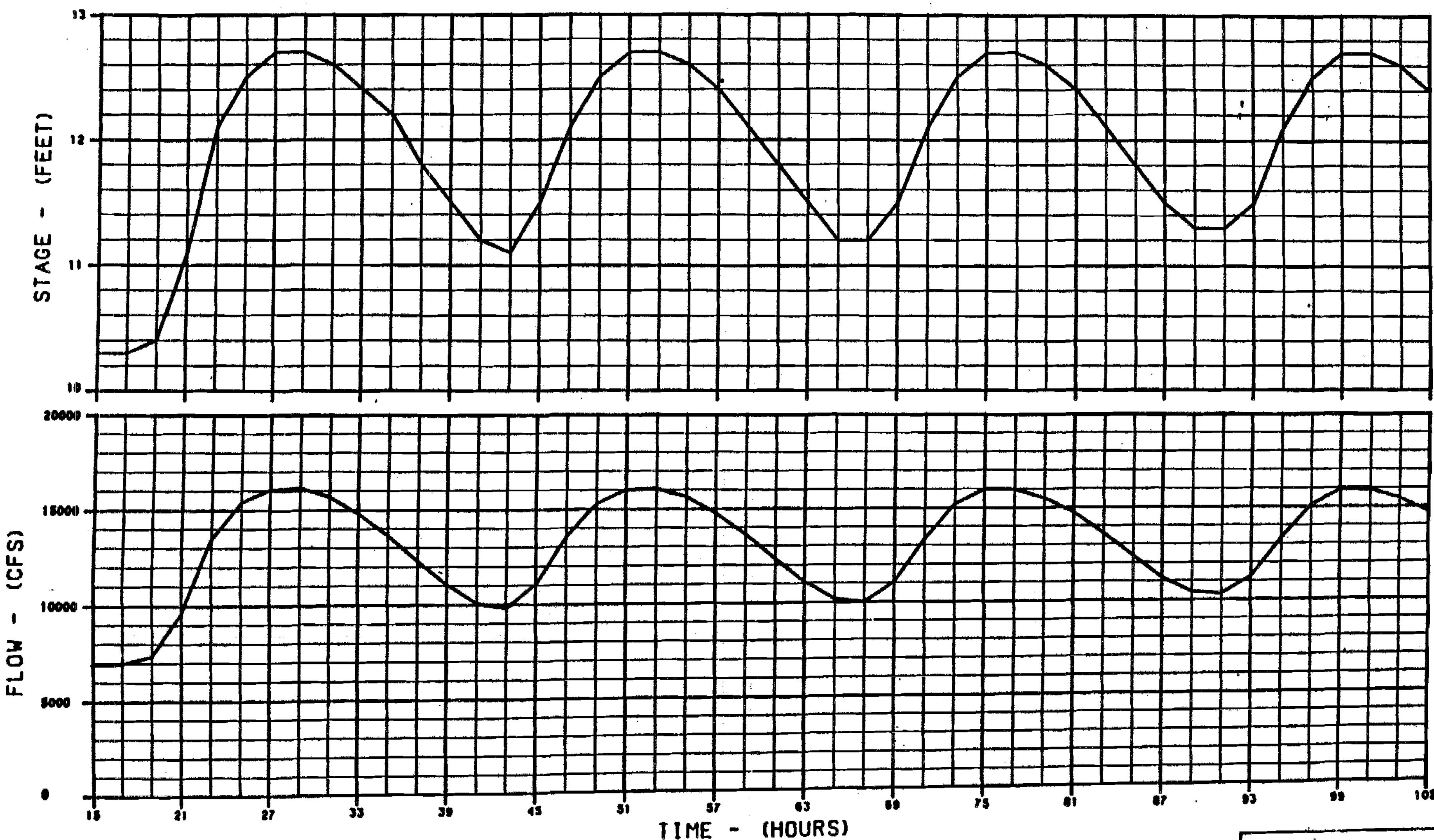
EXHIBIT 23



NOTES: 1. WINTER SIMULATION
2. SECTION AT SUNSHINE GAGE STATION
3. STAGE DATUM ELEVATION AT 263.00 FT. MSL

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