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Memorandum

HYDRAULICS BRANCH
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Memorandum
TO : Chief, Hydraulics Branch

Denver, Colorado
DATE: April 10, 1975

FROM : Robert L. George

SUBJECT: Simulation Results for Multilevel Outlet Modification, Flaming Gorge Dam

PAP

The temperature simulation model developed by WRE (Water Resources Engineers) and later modified by the Corps of Engineers was applied to Flaming Gorge Reservoir to determine the effect of the proposed multilevel penstock intakes, hereinafter referred to as outlets. Data required for the simulation were daily streamflow and temperature, solar radiation, windspeed, and wet- and dry-bulb air temperatures. The various coefficients used to attain the best simulation of the measured temperature profiles were critical stability of E_c=1.75 x 10^{-5}, diffusion coefficient of D = 2.5 x 10^{-2} and evaporation coefficient of E_v = 1.59 x 10^{-9}.

The elevations of the shutter gate withdrawal outlets were obtained from Drawing No. 591-D-1396. Table 1 lists the outlets and their elevations at the center of each shutter gate.

Table 1
Elevations of Outlets at Flaming Gorge Dam

Outlet	Elevation	
1	5850	(Existing outlets)
2	5933	
3	5962	
4	5993	

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Attached are figures 1 to 3 which compare the measured temperature profiles at the dam with the profiles obtained from the simulations. The only periods that do not have good agreement between the measured and simulated profiles are at the end of May and June. The measured profiles exhibited abrupt changes in temperature which were not duplicated by the model but compare favorably at other depths and times. The steep gradients were probably transient temperature changes caused by the unusually warm air temperatures near the end of these months. The air temperature near the end of May was nearly 20° F above the rest of the month and the air temperature at the end of June was nearly 10° F above the remainder of the month.

The results of the temperature and outflow simulation are shown on figures 4 and 5. Figure 4 shows the objective temperature compared to the simulated temperature for multiple outlets is quite close to the objective temperature after the first of May. Prior to May, the temperature of the entire reservoir is below the objective temperature. The verification mode used the existing outlet exclusively and a much lower release temperature resulted.

The outflow shown in figure 5 indicates that most of the water released will be drawn from the upper outlet (#4). Outlet #3 is only used during a few periods to meet the objective temperature. The withdrawal layer in the reservoir under these conditions is usually confined to the upper 100 feet. This may result in a layer of warmer water near the surface moving through the reservoir from the inflow streams to the outlets without much mixing with the lower depths of the reservoir.

Several things could result from this condition: lower dissolved oxygen and higher suspended solids in the lower levels, upward shift of the thermocline, increased surface temperatures, and consequently increased evaporation losses. However, the shift of the thermocline and increased cumulative evaporation obtained by comparing the results of the two simulations were less than 3 feet and 0.02 foot, respectively. These changes are so small they are insignificant.

The decreased oxygen concentration in the lower levels may result because water of relatively high concentration is withdrawn from the surface and not mixed (diffused) with the fluid from the lower layers as is now done by withdrawal from the existing outlets.

Oxygen concentration and temperature of the water released through the multilevel outlets increase and the concentration of suspended solids is likely to decrease, thus creating more favorable conditions downstream. However, there may be a net decrease in the water quality of the lower portion of the reservoir. Higher concentrations of dissolved or suspended materials may result from the withdrawals from these upper layers.

One limitation of the model is that it must be operated either in the verification mode, where outlet releases are specified in amount and location, or in the prediction mode, where releases are specified in amount only. Consequently, the case where water is withdrawn from the lowest unmodified outlet and the higher modified outlets cannot be simulated directly. However, a weighted average release temperature was determined and is shown on figure 4, assuming that one-third of the flow was released through the lowest outlet.

Several practical aspects should be considered:

1. Two of the three intakes will be modified and withdrawal will normally occur at or near the reservoir surface unless all three turbines are required for power generation. Consequently, the temperatures shown on figure 4 in the prediction mode are valid. When all three turbines are required, with equal flow through each, the weighted average temperature of figure 4 will be obtained.

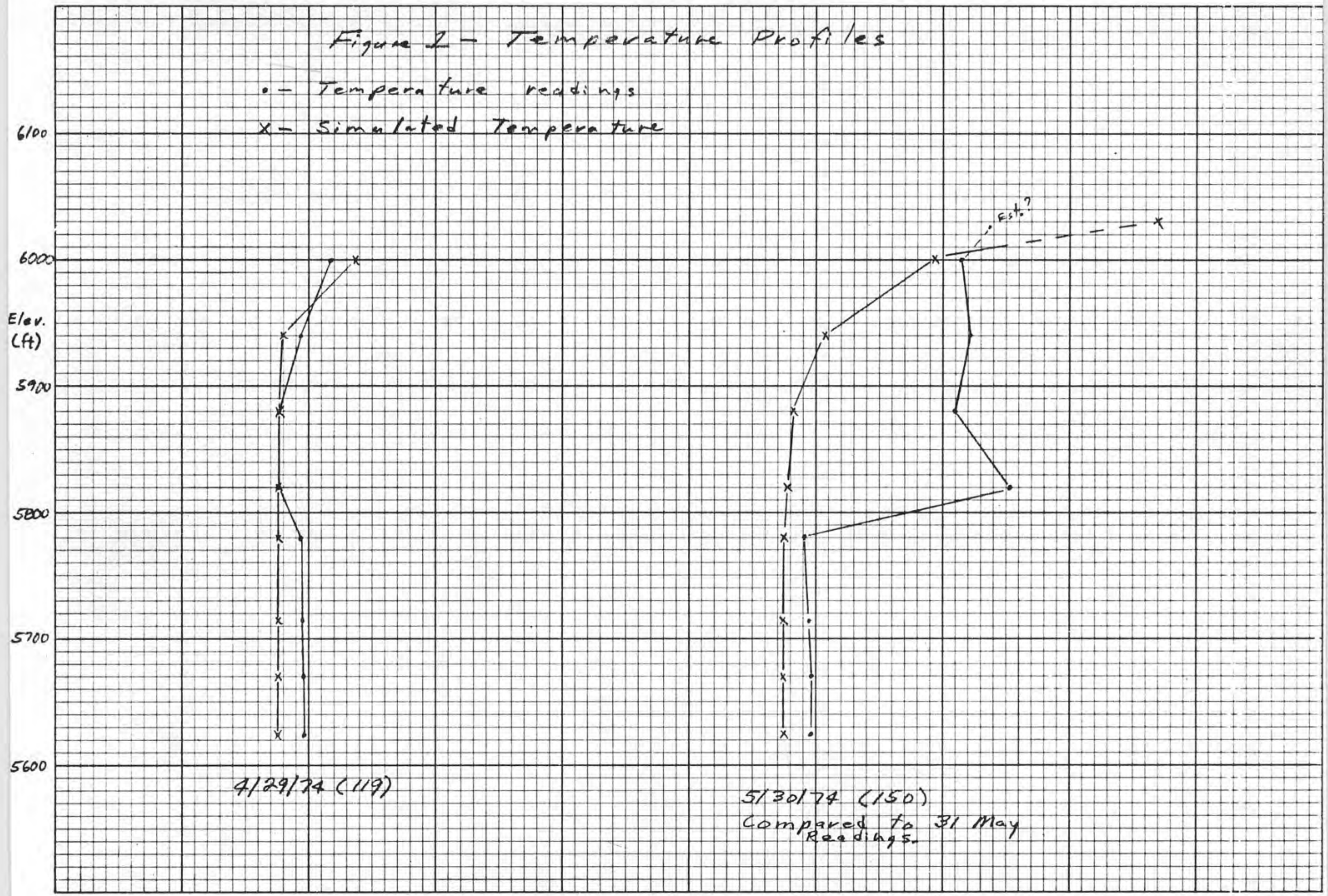
2. Only the upper set of shutter gates and the existing outlet will be used under normal operation, unless the water level becomes lower than about 5990. Then, the next highest shutter gates will need to open.

3. Withdrawals from the existing outlet are likely to be at lower temperature and dissolved oxygen levels with a possibility of higher suspended solids concentration than waters taken from the surface.

Robert L. George

Attachments

Figure 2 – Temperature Profiles



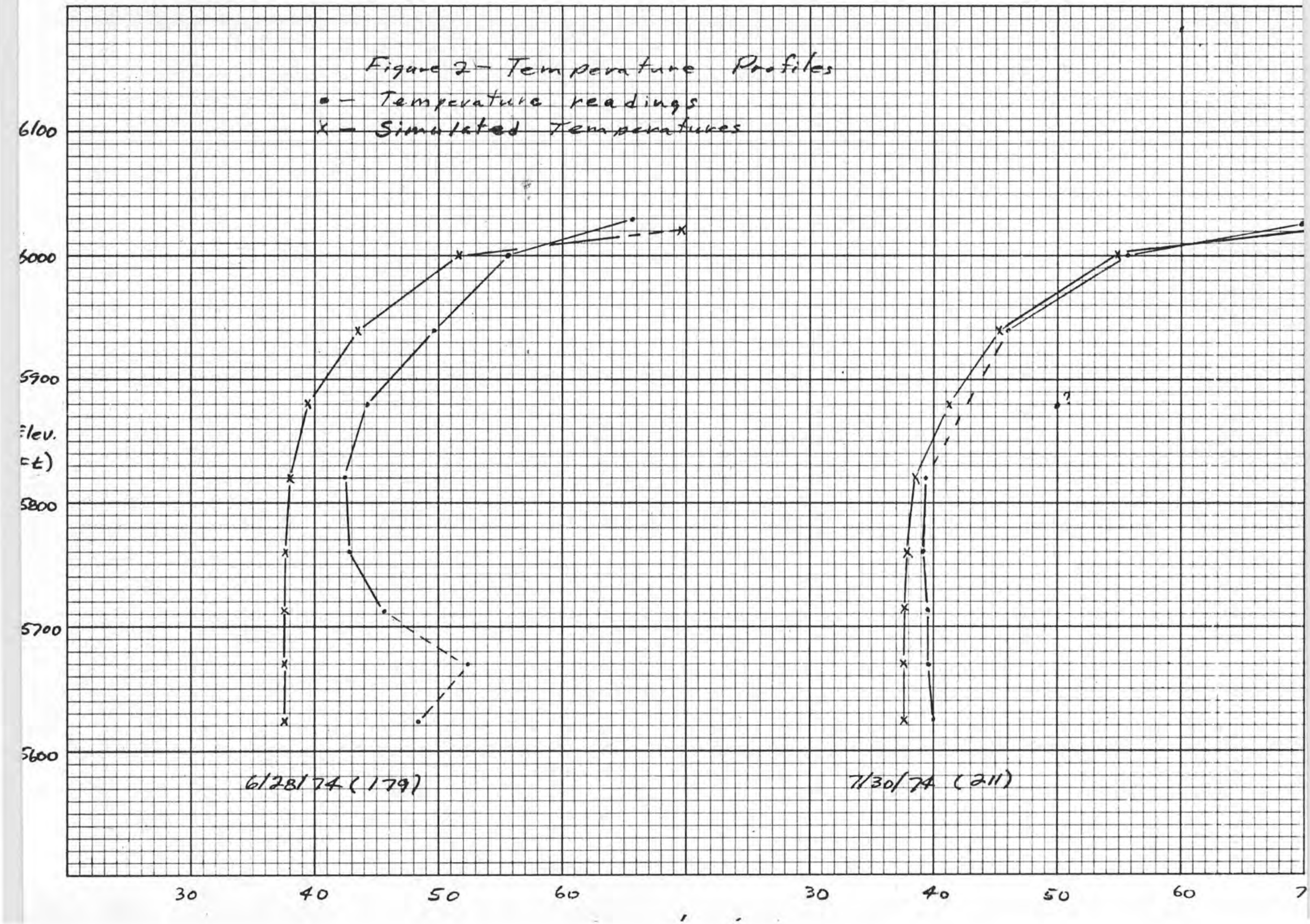


Figure 2 - Temperature Profiles
• - Temperature readings
x - Simulated Temperatures
6100
6000
5900
Elev.
(ft)
5800
5700
5600
6/28/74 (179)
7/30/74 (211)
?
30
40
50
60
30
40
50
60
7

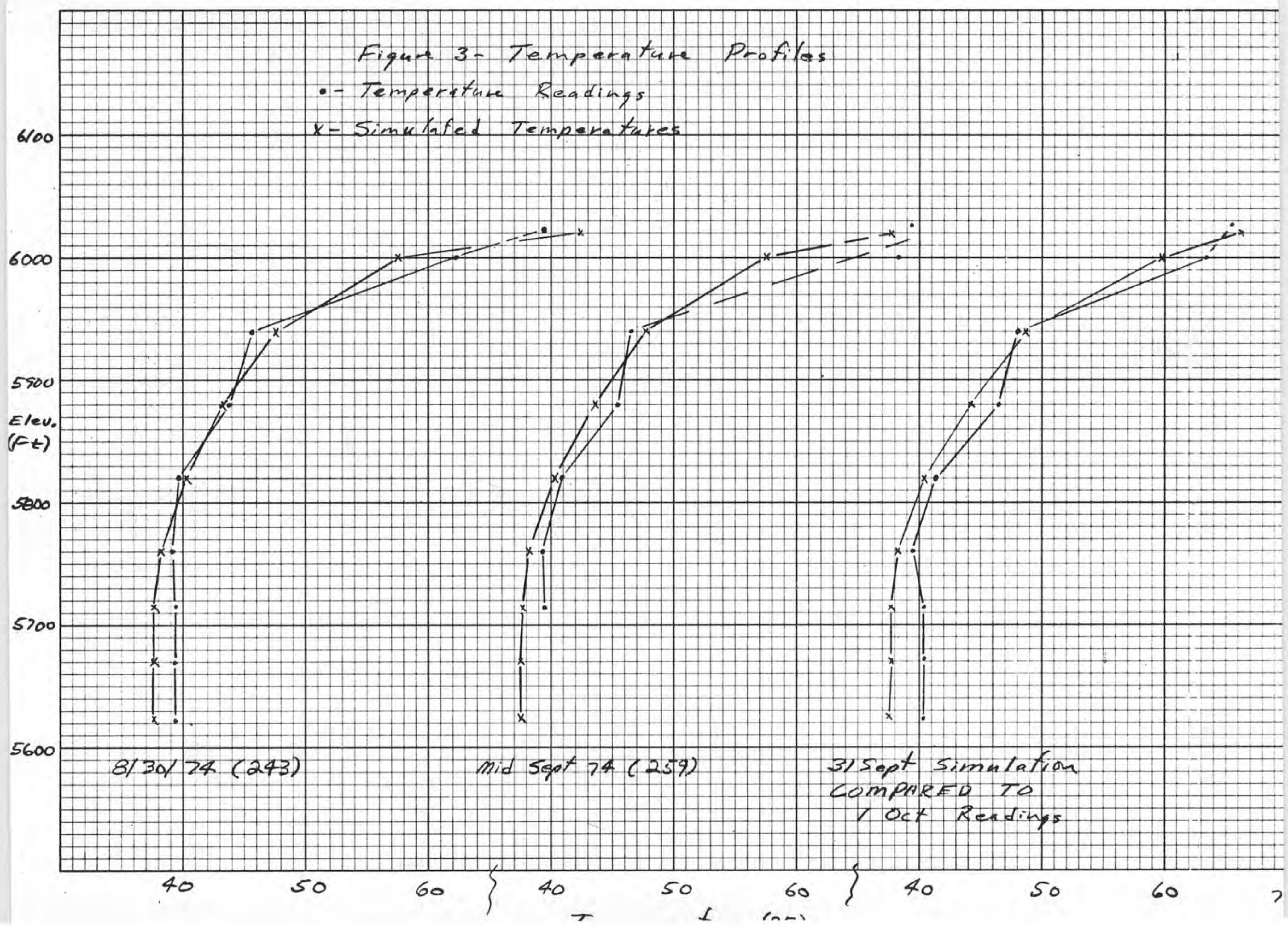


Figure 3- Temperature Profiles
•- Temperature Readings
x- Simulated Temperatures
6100
6000
5900
Elev. (Ft)
5800
5700
5600
8/30/74 (243)
Mid Sept 74 (259)
31 Sept Simulation
COMPARED TO
1 Oct Readings
40
50
60
40
50
60
40
50
60

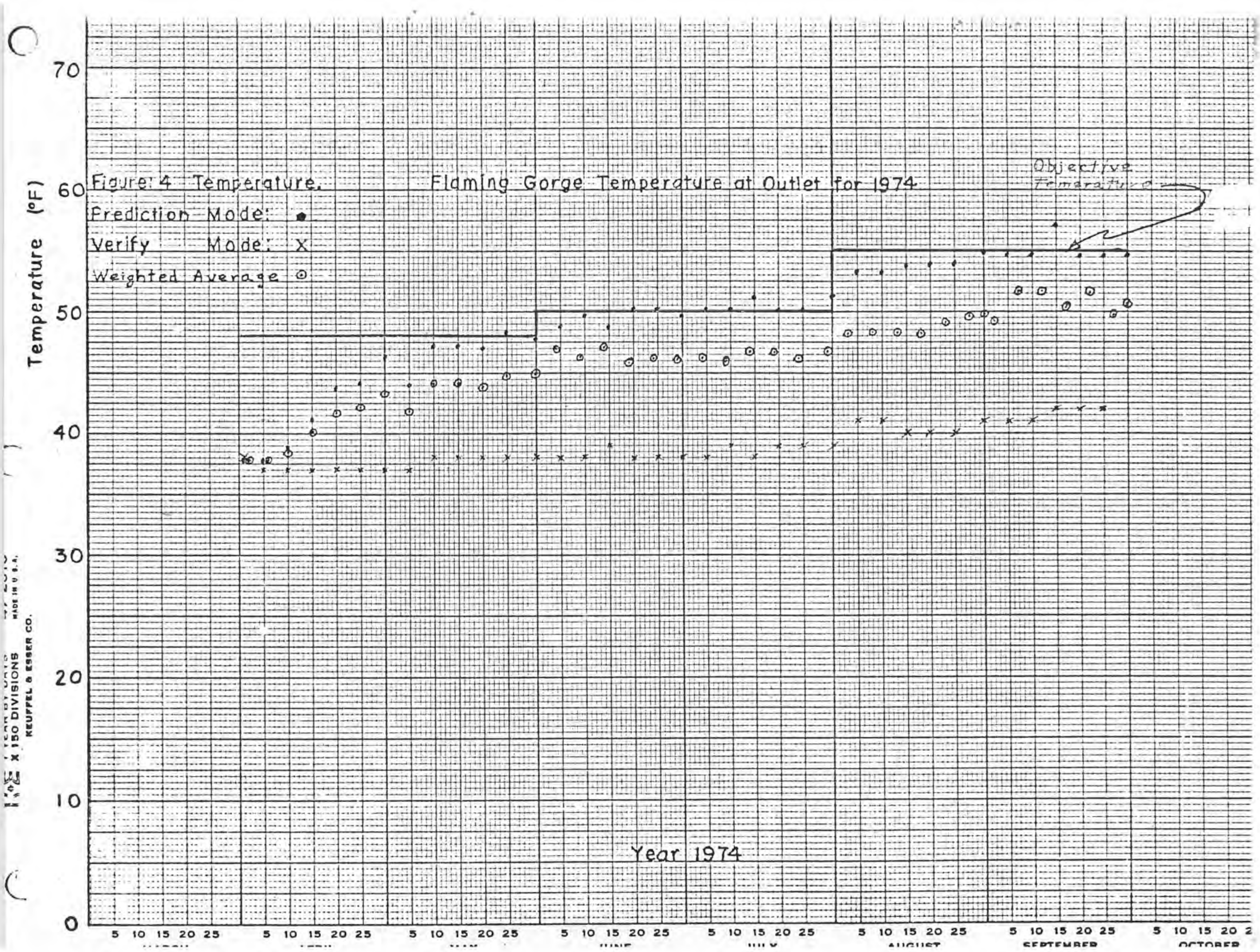


Figure: 4 Temperature.
Flaming Gorge Temperature at Outlet for 1974
Prediction Mode: •
Verify Mode: X
Weighted Average ⊙
Objective Temperature
Temperature (°F)
0
10
20
30
40
50
60
70
Year 1974
5 10 15 20 25
AUGUST
SEPTEMBER
OCTOBER
X 150 DIVISIONS
KEUFFEL & ESSER CO.
MADE IN U.S.A.

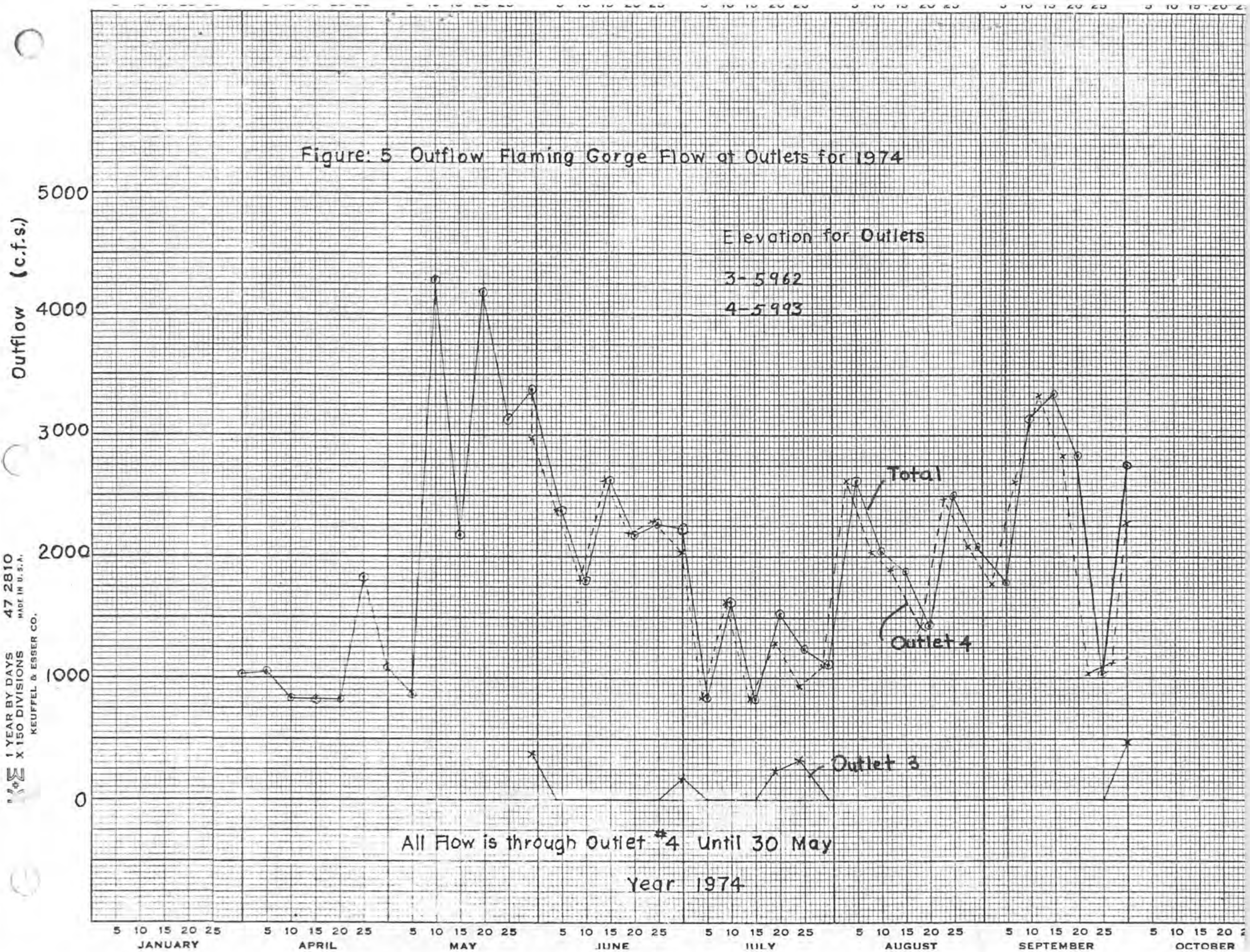


Figure: 5 Outflow Flaming Gorge Flow at Outlets for 1974
Outflow (c.f.s.)
5000
4000
3000
2000
1000
0
Elevation for Outlets
3-5962
4-5993
Total
Outlet 4
Outlet 3
All Flow is through Outlet #4 Until 30 May
Year 1974
JANUARY
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
1 YEAR BY DAYS X 150 DIVISIONS
KEUFFEL & ESSER CO.
47 2810
MADE IN U.S.A.