INFORMATIONAL ROUTING

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Review of the San Juan-Chama controller - Control parameters

Messrs. W. M. Colvin and E. A. Serfozo, Electrical Branch, have installed in the Hydraulics Laboratory a demonstration model of a check gate controller similar to that installed and in operation on the San Juan-Chama Project.

GPO 832-606

I was requested by Mr. Colvin to determine the control parameters that are required to insure operational stability for any particular situation.

The basic criterion for any controlled system is to maintain continuity:

$$\Delta Q_{out} = \Delta Q_{in}$$

In simplified terms, ΔQ_{out} can be expressed as flow through the controlled check gate as follows:

$$\Delta Q_{out} = \Delta G * B * C_d \sqrt{2g(\Delta H)}$$

where:

ΔG = The change in the check gate opening
B = The gate width
C_d = The coefficient of discharge
ΔH = The head drop across the check gate

ΔQ_{in} can be expressed in terms of an elementary wave traveling downstream in a trapizoidal channel as follows:

$$\Delta Q_{in} = \Delta Y * T (V + C)$$

where:

ΔY = The change in the upstream depth
T = The top width of the water surface
V = The upstream channel velocity
C = The wave celerity equal to $\sqrt{g\frac{A}{t}}$ where A equals the crosssection area of the total flow.

The ratio of $\Delta Q_{out}/\Delta Q_{in}$ must be unity if stability is to be maintained and would be expressed as follows:

$$\frac{\Delta Q_{out}}{\Delta Q_{in}} = \frac{\Delta G}{\Delta Y}\left(\frac{B * C_d \sqrt{2g\Delta H}}{T\ (V + C)}\right) = 1$$

By transposing, the ratio of $\Delta G/\Delta Y$ can be found as:

$$\frac{\Delta G}{\Delta Y} = \frac{T\ (V + C)}{B * C_d \sqrt{2g\Delta H}}$$

The ratio of $\Delta G/\Delta Y$, by definition, is the GAIN for the controller and is the first main control parameter. The GAIN can be found as follows:

$$\text{GAIN} = \frac{T\ (V + C)}{B * C_d \sqrt{2g\Delta H}}$$

The latter equation shows that the GAIN of the controller is dependent upon the characteristics of the upstream channel and the width and flow (submerged or free-flow) through the controlling check gate. Once the GAIN is determined, the value of ΔY can be found by arbitrarily selecting a value for ΔG (usually 0.10 feet). ΔG can be expressed in terms of the operate time, Δt_o, of the gate motor hoist which has a displacement of $\Delta G = x * \Delta t_o$, where x is the rate of gate movement in feet per second. Solving for Δt_o gives:

$$\Delta t_o = \Delta G/x$$

From the GAIN the "offset" of the water level, which is the second control parameter, can also be determined. The "offset" is defined as:

$$\text{"Offset}_{(max)}\text{"} = G_{(max)}/\text{GAIN}$$

where $G_{(max)}$ is the maximum gate opening required to discharge the maximum desired flow.

The "offset$_{(max)}$" would have to be a value less than the difference in elevation between the maximum safe operating level or spill crest and the normal water surface operating level. An attempt to use an offset less than determined above would require the GAIN of the controller to be larger. This in turn would require the continuity ratio of $\Delta Q_{out}/\Delta Q_{in}$ to be larger than unity and could cause the system to overshoot excessively, and the chances for avoiding instability of control are greatly reduced.

It should be stressed that the above analysis can be used to determine approximate values of the control parameters, GAIN and "offset$_{(max)}$." The approximate method should provide a good idea as to the magnitude of the control parameters for any particular installation. Greater accuracy can be achieved through complete mathematical modeling and should be accomplished before selecting final values.

The "time lag of the system" which is the last main control parameter to be considered, is not discussed in this memorandum. It is assumed the water level sensor for the controller is adjacent to and upstream of the controlled check gate. The distance involved is short such that the timelag between the resulting wave perturbation caused by gate movements and its arrival at the sensor is less than 60 seconds. Substantially longer timelags would require filters or delay units, and reference should then be made to the final report "Automatic Downstream Control Systems for Irrigation Canals" by Michael J. Shand, University of California at Berkeley, HEL-8-4, dated August 1971.

Figure 1, attached, summarizes the operation of the San Juan-Chama controller laboratory installation. When the water level rises above the neutral zone, the controller is activated to the raise condition. Whenever ΔY is achieved, the gate hoist motor will operate for a period equal to Δt_o (previously determined) representing the arbitrarily selected value for ΔG. The summation of the ΔY's equals the total "offset" which is proportional to the discharge at the gate opening equal to the summation of the same number of ΔG's.

In Figure 1 (attached), Condition (1) can be considered as a rapid change in the upstream flow. The rest time, Δt_R, is the time interval between gate operations or the time it takes to achieve a change equal to ΔY. For Condition 1, the Δt_R is much smaller than for Condition (2) which represents a slower change in the upstream flow conditions.

The San Juan-Chama controller design has a leveling bar mechanism which resets ΔY back to null everytime ΔY is achieved. The ΔY can be adjusted to the value required as previously discussed. For a more complete description of the controller, reference is made to the travel report by Mr. Colvin dated November 1, 1971, to the San Juan-Chama Project.

The advantages of this design are that the rest time of the controller is proportional to the rate of change in the water surface level which is then proportional to the change in the upstream flow conditions. Even though the controller is ON or OFF, it is to be considered a proportional controller requiring an offset from the neutral zone. The design is a great improvement over controllers which have fixed rest times (such as the "Little Man") permitting greater flexibility of operation, and it should have greater application.

The main disadvantage is the "offset" requirement which could be larger than what can be tolerated for a maximum safe operating level for the desired maximum flow or be above the spill crest. In the case of the

San Juan-Chama controller, the offset is also required below the neutral zone because the gate will not be activated to lower until the water level reaches the lower limit of the neutral zone.

If the neutral zone could be floating as shown in Figure 2 (attached), the total water level change to produce a maximum gate opening for maximum flow and zero gate opening for zero flow would be reduced by about half.

It is recommended that, (1) further investigation to apply the floating neutral zone be made, and (2) the controller parameters be determined through complete mathematical modeling analysis.

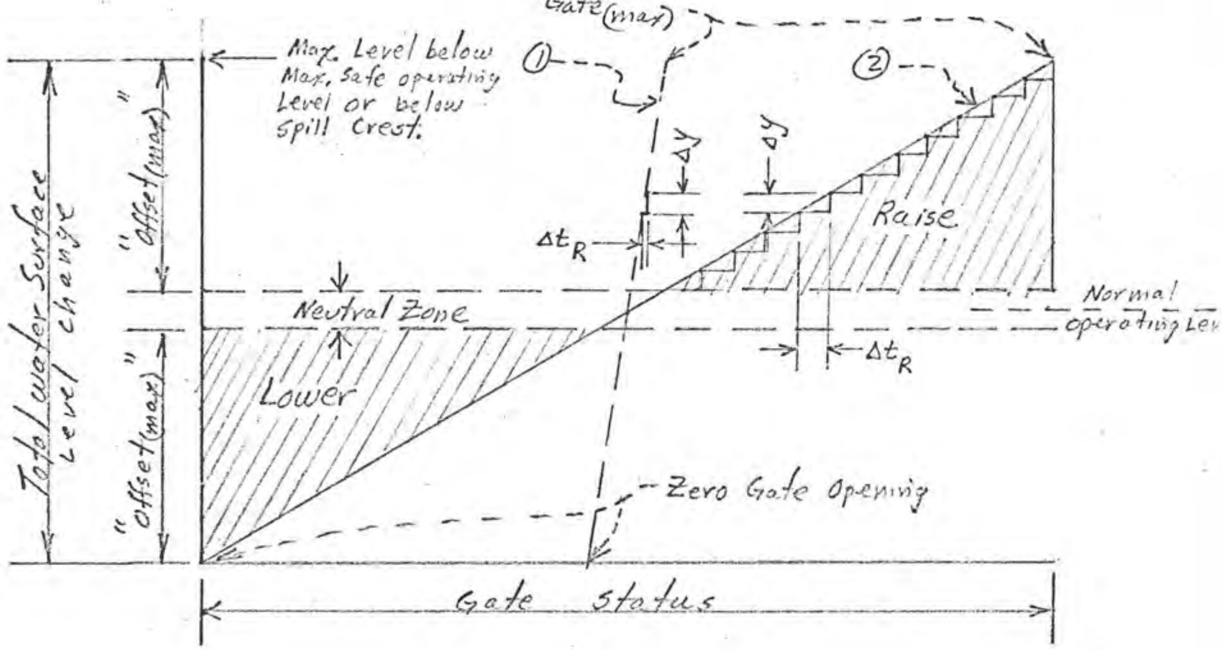
Clark P. Buyalski

Attachment

Copy to: 225 (Weide)
240 (Colvin)
1532 (Falvey)
1530

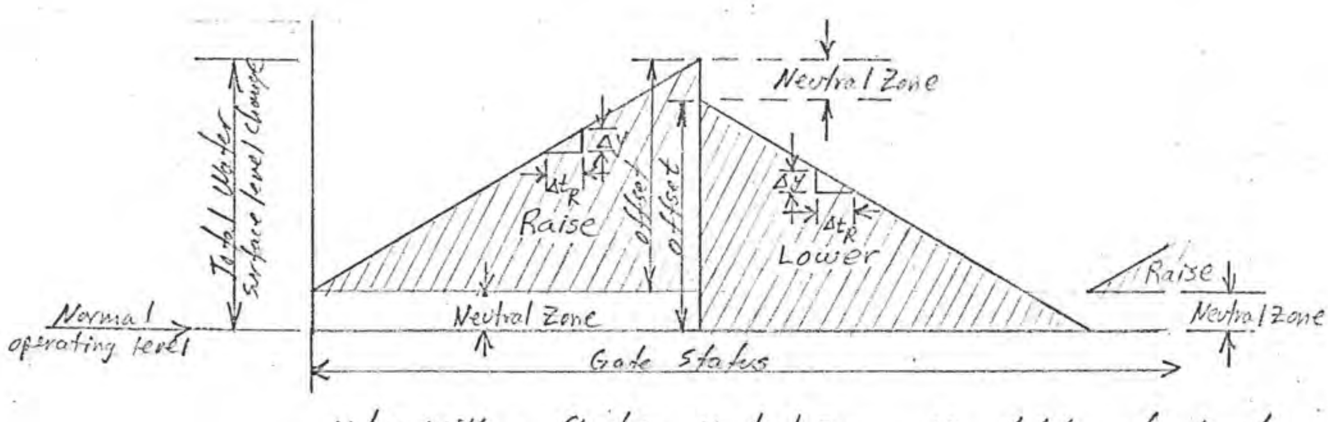
CPB 11/30/71 San Juan Chama Controller 1

Control Parameters



Notes: Condition ① represents a rapid change in the upstream flow conditions and condition ② represents a modera[te] change in the upstream flow

Figure 1



Note: With a floating Neutral Zone, the total water level change can be reduced considerably compared to that shown in Figure 1,

Figure 2