Example: Pump Operation with Node Depth Control

This example demonstrates how to model pump operation to regulate water depth in a pond within specified limits. The sewer network, shown in Figure 1, consists of six pipe sections with diameters ranging from 4.3 m (14.1 ft) to 4.8 m (15.7 ft). These pipes extend for 3.5 km (2.2 miles) and feature various elevation drops, ultimately discharging into a 125,000-cubic-meter (33.02-million-gallon) storage tank with a height of 5 m (16.4 ft). The complete ITM input for this example is available in the accompanying file: *ITM-SWMM Pump Operation.inp*.

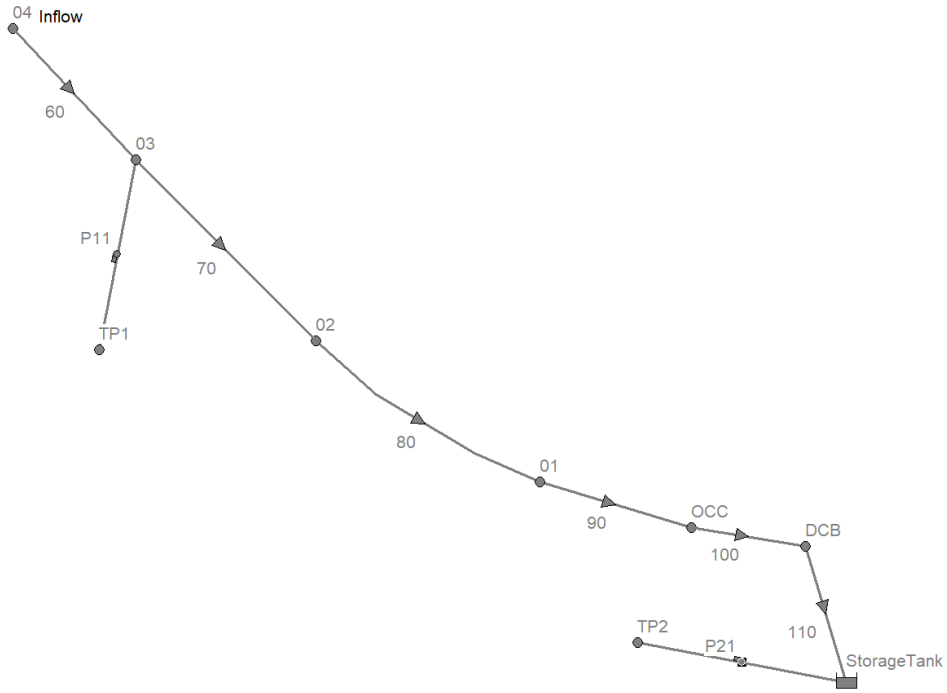

Figure 1. Layout of the Example Sewer System

We aim to implement pumps in Pond 03 and the Storage Tank, operating them according to a control strategy to achieve the following two objectives:

1. **Pond 03:** Limit the water depth to a maximum of approximately 6 m while minimizing the number of pumps installed.
2. **Storage Tank:** Determine the minimum number of pumps required to maintain the water depth between 4 and 5 m. The water depth must stay within this range.

The pumps installed in Pond 03 and the Storage Tank transfer water to Ponds TP1 and TP2, respectively. All pump systems in Pond 03 and the Storage Tank will operate according to the pump curve shown in Figure 2. A control curve must be determined for both pump systems to achieve the stated objectives.

The design inflow hydrograph is shown in Figure 3.

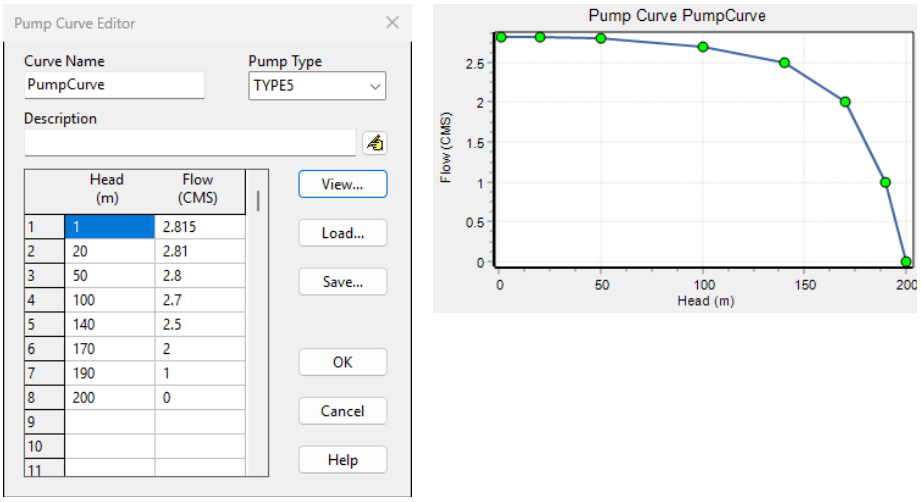

Figure 2. Pump curve representing the pumps in Pond 03 and the Storage Tank.

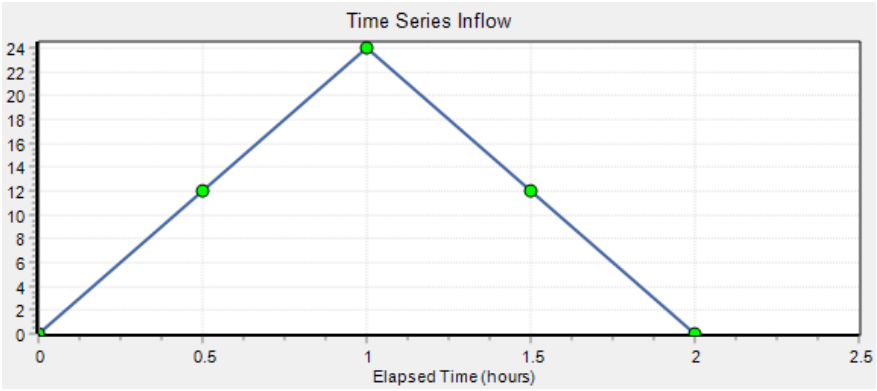

Figure 3. Design Inflow Hydrograph (Flow in cubic meters per second, cms).

If the pumps remain off in Pond 03 and the Storage Tank, the resulting time series of water depth and overflow at Nodes 03 and the Storage Tank will be shown in Figures 4 and 5, respectively.

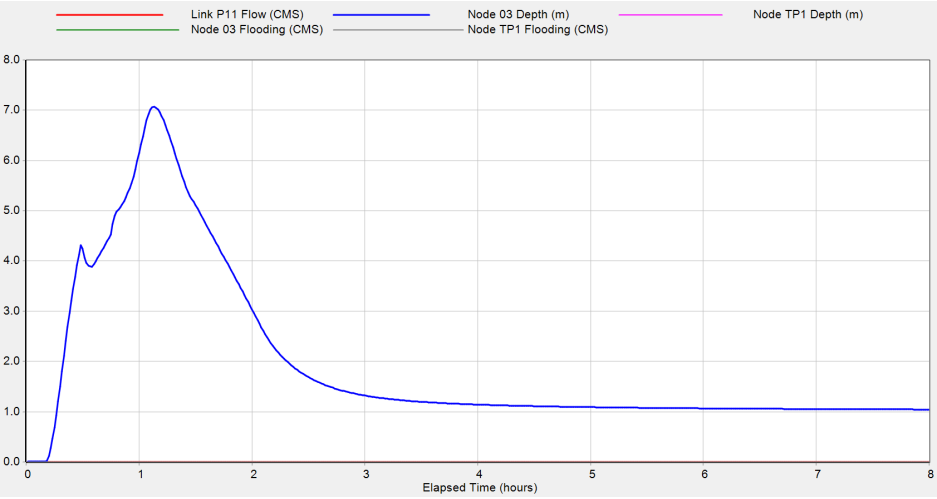

Figure 4. Simulation results for water depth and flooding at Nodes 03 and TP1 with pumps turned off.

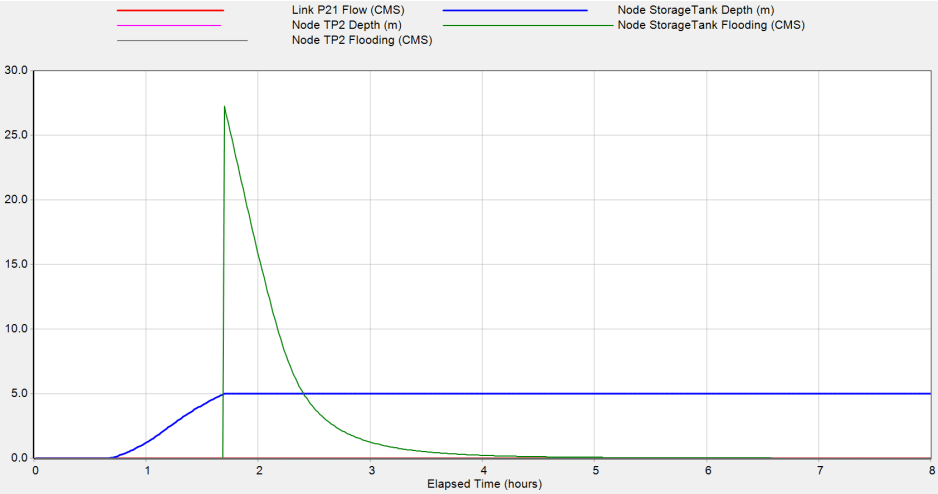

Figure 5. Simulation results for water depth and flooding at Nodes Storage Tank and TP2 with pumps turned off.

As shown in Figure 4, the threshold depth of 6 meters at Node 03 is exceeded. Similarly, Figure 5 demonstrates that once the water depth in the Storage Tank reaches its maximum of 5 meters, any subsequent inflow results in overflow.

In the next iteration, we will test the use of one pump at Node 03 and one at the Storage Tank. The maximum depth at Storage TP1 is initially set to 5 meters. If both pumps are fully turned on, the resulting water depths and flooding at Nodes 03 and the Storage Tank are shown in Figures 6 and 7, respectively.

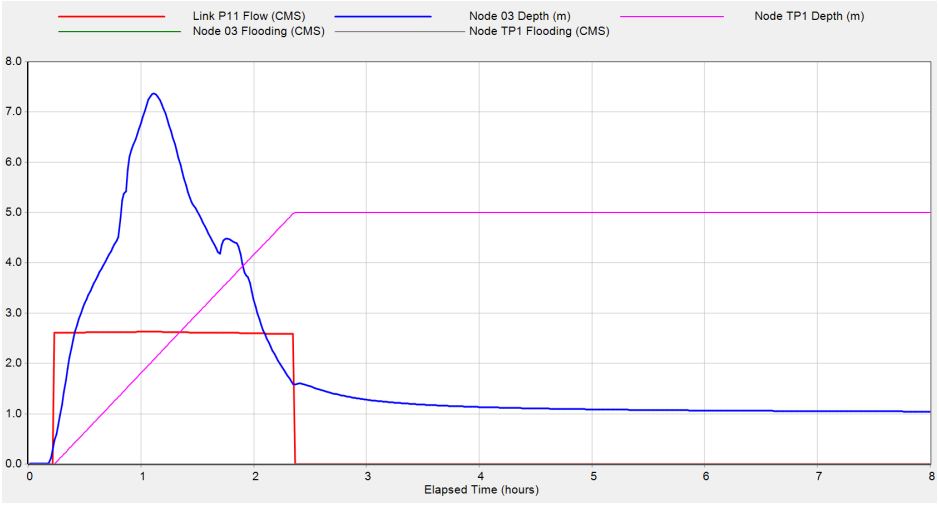

Figure 6. Simulation results for water depths and flooding at Nodes 03 and TP1 with one pump at Node 03 and one pump at the Storage Tank fully turned on.

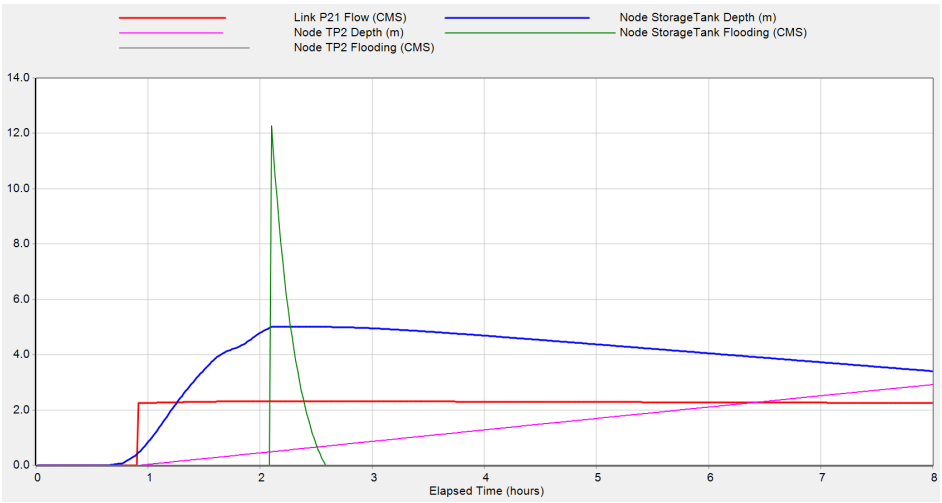

Figure 7. Simulation results for water depths and flooding at Nodes Storage Tank and TP2 with one pump at Node 03 and one pump at the Storage Tank fully turned on

As shown in Figure 6, when one pump at Node 03 and one pump at the Storage Tank are both turned on, the threshold water depth of 6 meters at Node 03 is still exceeded. Additionally, the water depth at the Storage Tank briefly surpasses the 5-meter threshold, causing overflow. The water depth at the Storage Tank then decreases as pumping continues throughout the simulation.

To meet the stated objectives, the number of pumps at Nodes 03 and the Storage Tank must be increased. Since pumping is not allowed once the discharge node is completely filled, the maximum depth at Node TP1 was raised to 15 meters for further simulations. With a maximum water depth of 15 meters at Node TP1, using four pumps at Node 03 and five pumps at the Storage Tank, both turned on, the resulting water depths and flooding at Nodes 03 and the Storage Tank will be shown in Figures 8 and 9, respectively.

Commented [AL1]: Question for Dr. Rossman: As shown in Figure 6, pumping at Node 03 stops when Storage TP1 reaches its maximum depth of 5 meters. Is there a way to keep the pumps at Node 03 running and allow overflow at Node TP1?

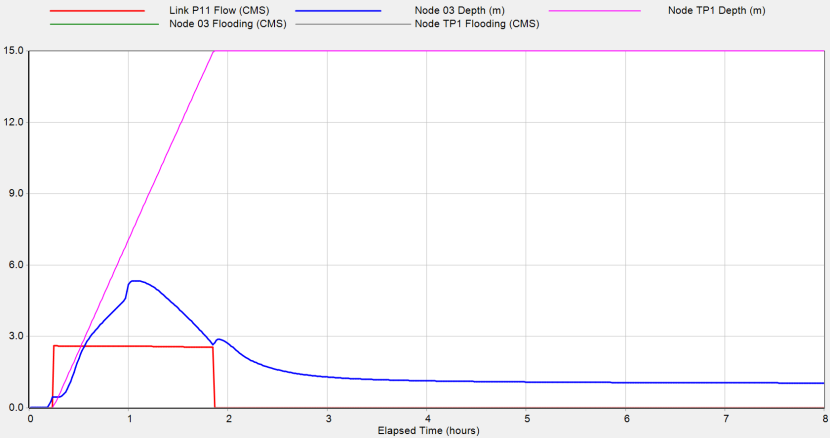

Figure 8. Simulation results for water depths and flooding at Nodes 03 and TP1 with four pumps at Node 03 and five pumps at the Storage Tank fully turned on.

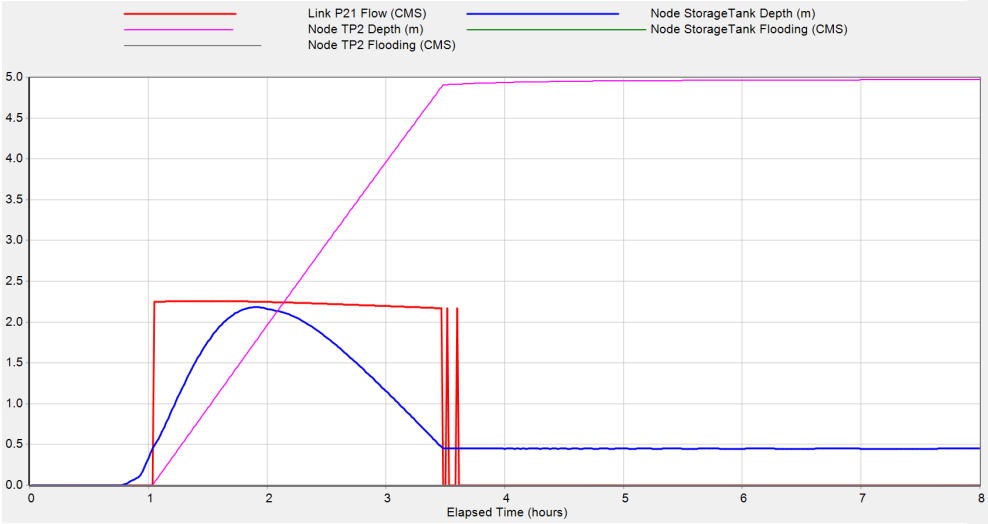

Figure 9. Simulation results for water depths and flooding at Nodes Storage Tank and TP2 with four pumps at Node 03 and five pumps at the Storage Tank fully turned on.

As shown in Figure 8, the water depth at Node 03 is below the threshold limit. However, for the pumps to operate only when the threshold is exceeded, a control curve must be specified. Similarly, as seen in Figure 9, the water depth at the Storage Tank is below the 4-5m range, and the water level is not maintained as the pump runs continuously throughout the simulation. To achieve the stated objectives, a control curve must also be specified for the Storage Tank.

The control curves for the pumps at Node 03 and the Storage Tank, derived through iteration, are shown in Figures 10 and 11, respectively. The Controller Value in the control curves represents the water depth at the nodes (e.g., Storage Tank), while the Control Setting corresponds to the nominal speed setting (0 indicates the pump is off, and 1 indicates the pump is on).

Please note that the previous two options—pump always off or always on—can be implemented by setting the pump's Control Method to NONE and its Initial Setting to 0 or 1, respectively.

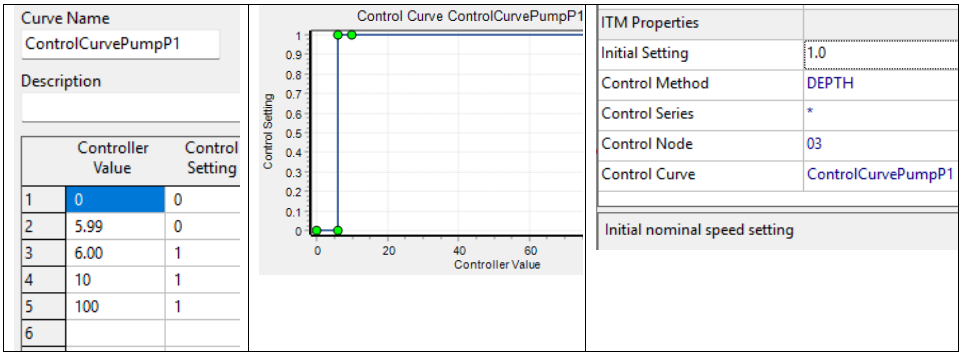

Figure 10. Defining the Control Curve for All Pumps at Node 03

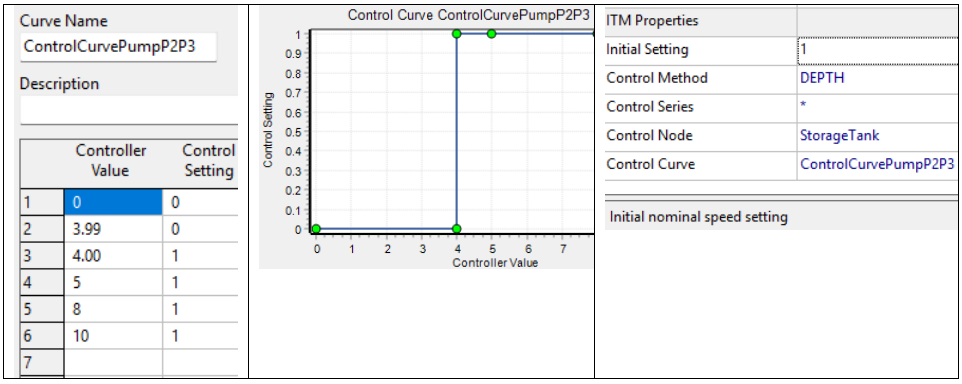

Figure 11. Defining the Control Curve for All Pumps at Node Storage Tank

As shown in Figure 12, when using four pumps at Node 03 and five pumps at the Storage Tank, operated according to the control curves mentioned above, the water level at Node 03 does not exceed 6 meters, and the pumps operate only when the water level exceeds the 6-meter threshold. Similarly, as shown in Figure 13, the water depth at the Storage Tank is maintained between 4 and 5 meters without overflow. The pumps at the Storage Tank operate only when the water level exceeds 4 meters and are turned off when the water level drops below 4 meters.

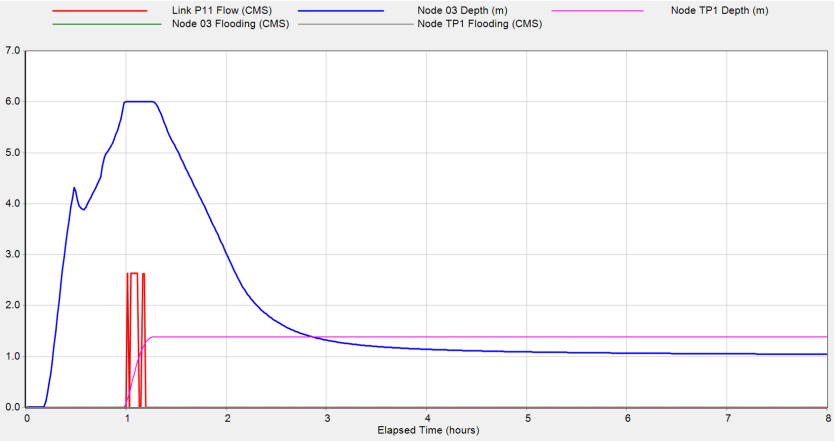

Figure 12. Simulation results for water depths and flooding at Nodes 03 and TP1 with four pumps at Node 03 and five pumps at the Storage Tank, operated according to the control curve "ControlCurvePumpP1."

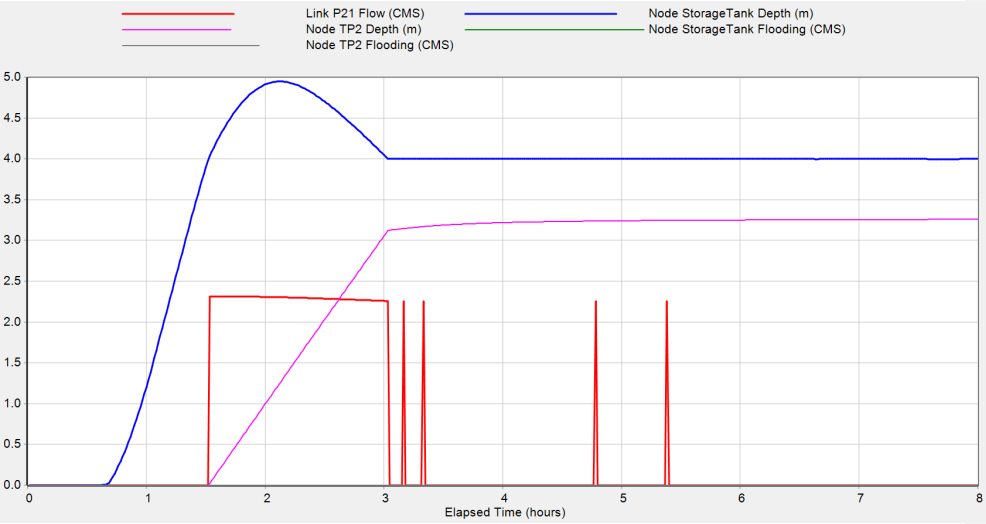

Figure 13. Simulation results for water depths and flooding at Nodes Storage Tank and TP2 with four pumps at Node 03 and five pumps at the Storage Tank, operated according to the control curve "ControlCurvePumpP2P3."