Siemens Digital Industries Software

Town Water Supply design and optimization by Simcenter Flomaster

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Introduction

Reliable and efficient supply of town water is an essential necessity for the brand new Brisbane West Wellcamp Airport and its surrounding business park. Static and dynamic hydraulic modeling of the area's town water supply system will assist in optimizing critical plant components and result in lower life cycle costs and more reliable system operation.

Kehoe Myers Engineering Consultants provides consulting engineering services since 1990 to clients throughout Australia and specialises in civil, structural, hydraulic and infrastructure engineering. As the primary civil engineering consultants for Brisbane West Wellcamp Airport, Kehoe Myers has performed design work in record time for earthworks, access roads, business park and stormwater drainage, sewer services and town water supply infrastructure, this resulting in a significant contribution to the success of this project.

JS Pump and Fluid System Consultants, specialists in hydraulic design and modeling of complex fluid networks and advanced control systems, are providing flow assurance services for a range of industries. With more than 25 years of experience with Simcenter Flomaster™ software, JS Pump and Fluid System Consultants are now focusing on the hydraulic design and optimization of complex water supply systems.

The challenge

The safe storage and reliable distribution of water of sufficient volume and quality is the ultimate objective of every town water supply system design.

The Brisbane West Wellcamp Airport area is located in hilly terrain with an elevation range of some 90m, this creating a challenging pressure distribution envelope when complying with town water supply design guidelines. The challenge is further exacerbated by water flow from the deeper supply network being limited to 60L/s while the maximum town water system demand is 163L/s.

Hydraulic modelling of complex water supply networks is traditionally carried out in steady state mode. However, dynamic simulations are able to predict a time based system response which may prove important. For example, time-lags resulting from filling and draining of site storages may have a significant impact on the overall system capacity and thus require careful consideration.

The Brisbane West Wellcamp Airport

Brisbane West Wellcamp Airport is the first international airport built in Australia in the last 50 years. The site is approximately 839ha in area and the approximate natural fall of the land is in a north westerly direction. Site levels range from about RL 520m to RL 430m. The site is predominantly bound by the Westbrook Creek to the west and a quarry lease to the east. It is constrained to the north by the Toowoomba Cecil Plains Road and to the south by the proposed Toowoomba Bypass.

Wellcamp Business Park (WBP) comprises of industrial zoned allotments of varying sizes, distributed around the airport as shown in figure 1. In the current development, the main access to the airport is provided via an intersection with Toowoomba Cecil Plains Road.

Figure 1: Locality map.

Wellcamp Airport lies adjacent to Westbrook Creek and to the west of WBP. The airport will consist of runways, taxiways, hangars, fuel storage terminal and storage buildings, and associated roads and car parks.

The ultimate site development will consist of an airport and mainly industrial uses in the WBP area. The WBP comprises around 250 lots ranging in size from 0.2ha to around 30ha and in total contains about 540ha of developable land.

The Town Water Supply System

The source of water for the Wellcamp Town Water Supply System will be the local town water network owned and operated by Toowoomba Reginal Council (TRC). The Wellcamp Town Water Supply System will provide water take-off points shared between two adjacent allotments with fire hydrants provided at the service branches. The town water supply system will follow the road easements within the Wellcamp precinct and will form ring mains were possible to enable continuous supply to customers in the event of component outages.

The current town water supply system comprises a single water main connecting the TRC trunk main at Toowoomba Cecil Plains Road with the airport terminal located some 4.2km downstream. Transitioning the site to its ultimate development is an ongoing process and expected to be complete by about 2030. The ultimate site development will incorporate site water storages and backup supply options to achieve maximum flexibility and reliability in town water supply.

Bottom-up type water demand projections were based on actual lot size, including an allowance for batters, estimated as a factor of 0.95. Individual water usage rates for adjacent lots were further grouped together in order to reduce the total number of offtakes and therefore making the hydraulic model more manageable. The potential error in hydraulic calculations when moderately grouping water usage rates is considered to be insignificant.

Water demand factors were selected in accordance with the DEWS planning guidelines:

- Average day demand to peak day demand: Factor 1.7
- Peak day demand to peak hour demand: Factor 1.9

For the ultimate development of WBP and Wellcamp Airport, the following water usage rates were projected:

- Average day demand: 41.3L/s
- Peak day demand: 70.2L/s
- Peak hour demand: 133.4L/s

Water demand for firefighting of 30L/s is in addition to above demand figures and applies for a nominal duration of four hours.

The hydraulic design objectives

The following key hydraulic design objectives for this hydraulic system design were identified:

- Design the town water supply system to enable gravity water supply where possible
- Ensure site water storages are of sufficient capacity to manage a firefighting event when coinciding with peak day and peak hour demand
- Provide sufficient redundancy in water storage to enable any water supply source to be taken out of service for an extended period of time
- Ensure pressure distribution is maintained within the acceptable pressure envelope
- Incorporate existing water infrastructure of the current development in the design of the ultimate development
- Provide ring main connections where possible and minimize dead end supply branches
- Ensure the hydraulic system design meets all relevant codes and guidelines

The hydraulic system design

In the current development a DN150 water supply main made of PVC connects the incoming valve and pressure reduction station with the airport terminal located some 4.4km downstream. The current development will soon be enhanced by the provision of a site water storage reservoir, designed to enable full firefighting capacity independent from the TRC supply. The reservoir will hold 1200kL of water and will be called main reservoir to be backed up by the existing DN150 water supply main.

The current development is expected to transition to the ultimate development in distinct stages. The exact progression of this transition is unknown at this stage. It is assumed that sufficient site water storage and backup supply will be provided to satisfy the water supply code requirements at any intermediate stage in the development.

In the ultimate development, a total of 30.7km of water supply pipelines were arranged in ring main arrangements where possible to serve customers at WBP and Wellcamp Airport. Two independent water storage reservoirs will provide a fully redundant water supply and will form the predominant source of system pressure and flow for WBP and Wellcamp Airport. The second reservoir called zone 6 reservoir of 1200kL capacity will be located at a higher level than the Main Reservoir and will supply the elevated parts of the eastern development. It will also provide full back up to the main reservoir.

Network supply to the main reservoir is via a DN200 branch line connected to the incoming TRC trunk main. Because of the higher elevation of zone 6 reservoir, two transfer pumps are required to provide the necessary lift which the TRC trunk main may not able to achieve at times of high system demand.

In the event of the main reservoir being out of service and with the feed from the two transfer pumps, zone 6 reservoir will be able to maintain sufficient water supply to the ultimate development.

In the event of zone 6 reservoir being out of service, the transfer pumps will enable the main reservoir to also service the elevated eastern part of the ultimate development.

The hydraulic model development

The advanced graphics functionality of Simcenter Flomaster software enables the creation of a hydraulic model which closely resembles the site master plan. This helps the viewer to find his way around in the model and enables the easy identification of critical system components and nodes.

A hydraulic model comprising the ultimate development was created first to achieve the right proportions in the overall model design. Components were then populated with specific input data files and performance graphs as required. The ultimate development contains some 280 active hydraulic components. A current development model was also prepared by cutting down the ultimate development model. Specific sub-models were created to enable the case specific script for each modeling scenario.

Hydraulic performance of system components, where not available from manufacturers, was based on work by British Hydraulic Research Group lead by D.S. Miller and published as Internal Flow Systems (third edition), which forms an integral part of the Simcenter Flomaster database.

An absolute surface roughness of 0.003mm is recommended by major PCV pipe suppliers for clean pipes. A surface roughness of 0.03mm was selected to cover for pipe ageing and fittings losses such as for bends not included in the hydraulic model. The selected surface roughness covers for eight 900 bends installed in a length of 1000m of pipeline, this in addition to the pipe friction head loss.

The hydraulic model for the ultimate development is shown in figure 2 below.

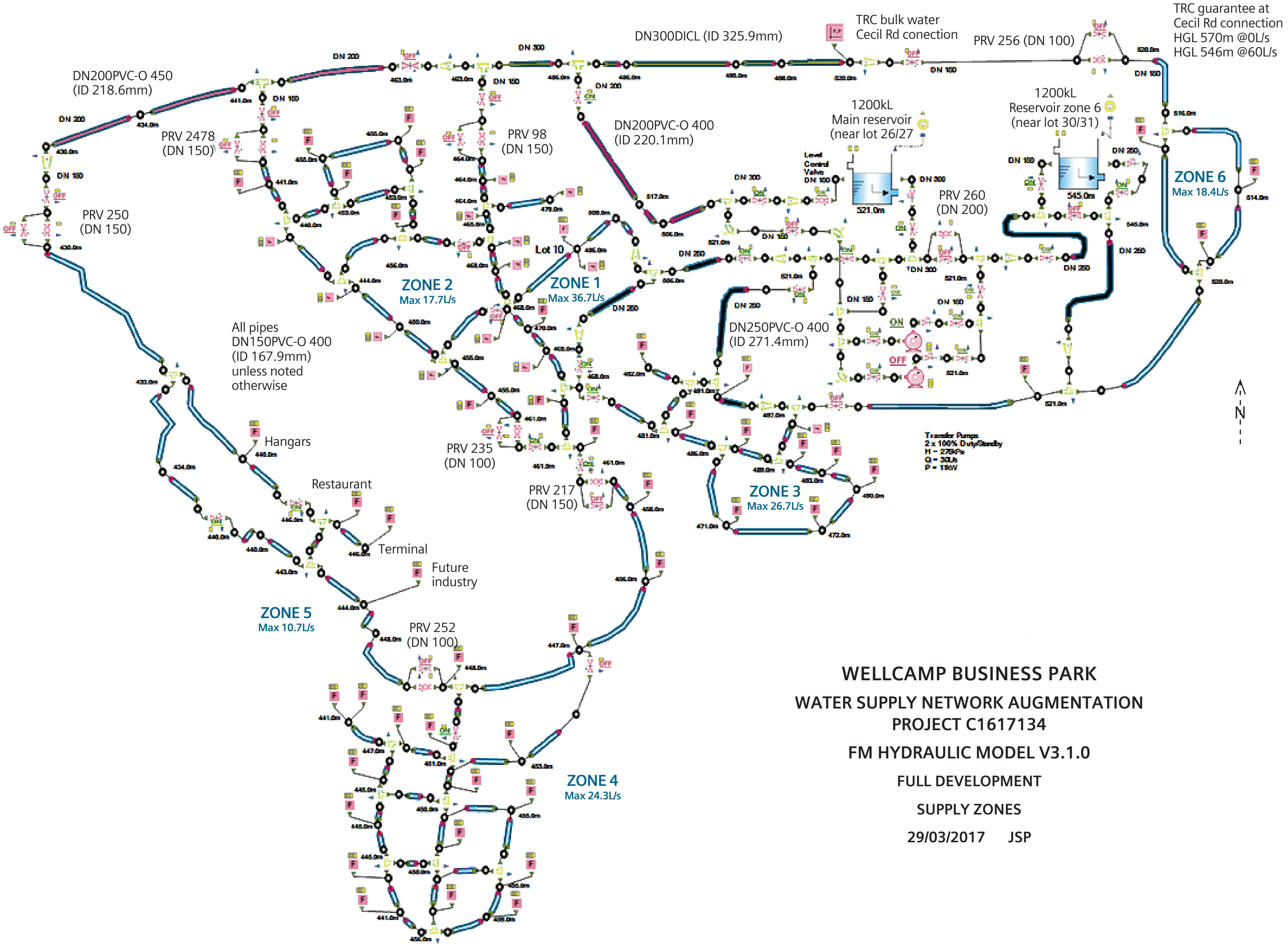

Figure 2: Hydraulic model – ultimate development.

Steady state simulations

The pressure flow distribution simulations

Hydraulic modeling work to establish the flow and pressure distribution in the town water supply system was mainly performed by steady state simulations.

The variation in elevation and subsequent high pressures in lower laying areas required the town water supply system to be divided into six separate supply zones. Zones in lower laying areas were protected by pressure reduction valves (PRV) in order to maintain pressure within acceptable limits. Also, backup supply points from the TRC trunk main were also protected by PRVs. A total of eight PRVs have been installed in the design for the ultimate development.

Following the optimization of PRV location and set pressure, each supply zone was tested for a firefighting event with the other zones operating at peak hour flow. In a conservative approach, the location of the fire was assumed to be at the most disadvantaged location in the zone, such as the highest elevation, thus resulting in the lowest supply pressure.

For further dynamic modeling, the PRVs were automated to maintain downstream pressure at varying flow rates.

The firefighting simulations

Transient simulations were required to model fire pump start up and shut down. The purpose of such dynamic modelling was to confirm that pump supply pressure would not result in loss of pump suction due to excessive cavitation. Fire pump modeling requires short time steps of about 0.1s in order to follow the transient operation of components, the simulation running for 250 seconds.

The fire pump was equipped with suction valve, discharge piping and variable speed controller. The suction valve was actuated to enable the simulation of a realistic pump start up.

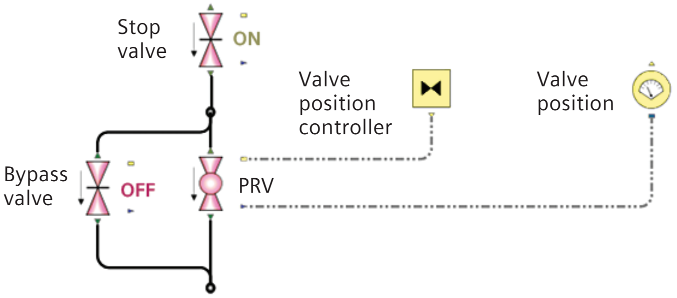

Figure 3: Typical pressure reduction valve (PRV) arrangement.

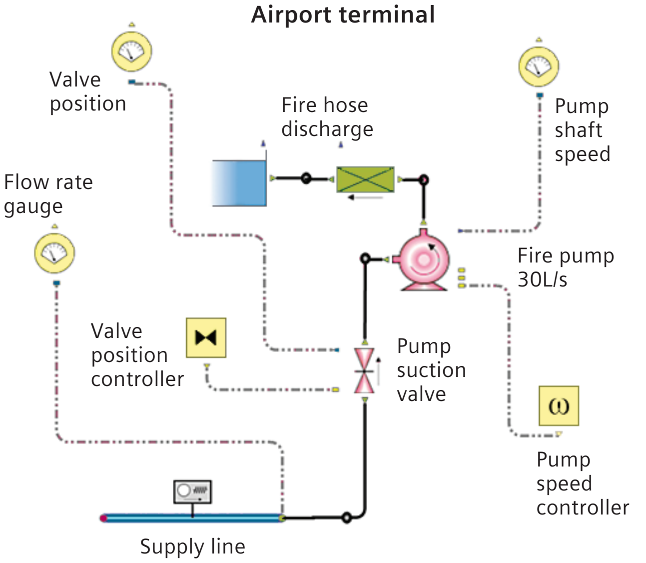

Figure 4: Typical fire pump arrangement.

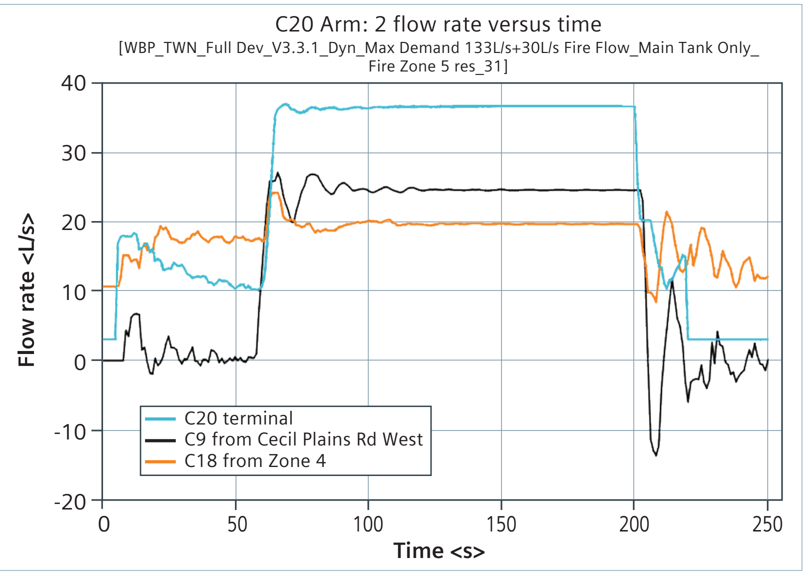

Figure 5: Flow rates in fire pump area.

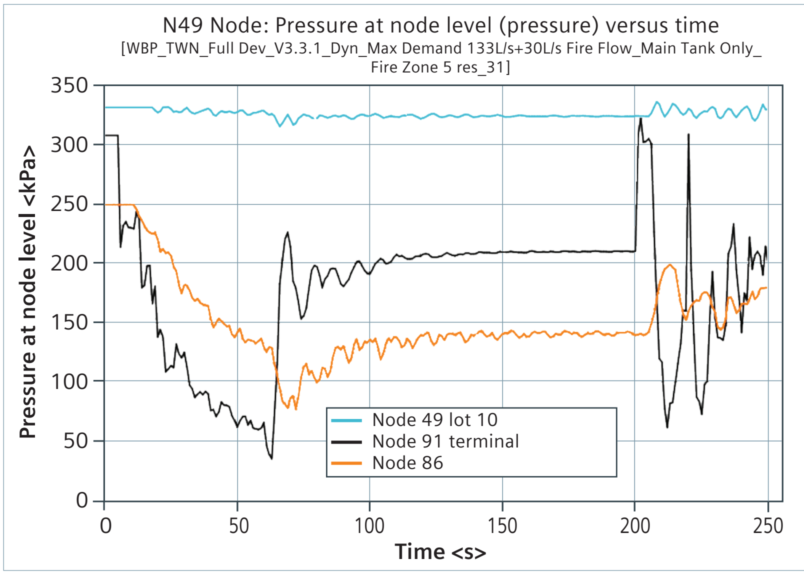

Figure 6: System pressure response.

The simulation of a fire pump start up and stop event is shown in figure 5. The graph illustrates the dynamic flow rates from different flow paths (C9 and C18) and how they affect the fire pump flow rate (C20).

Shown in figure 6 is the dynamic pressure response at critical locations in the deeper town water supply system (node 49 and node 86) and at the fire pump suction (node 91). It confirms that down surge on pump start up is contained within acceptable limits.

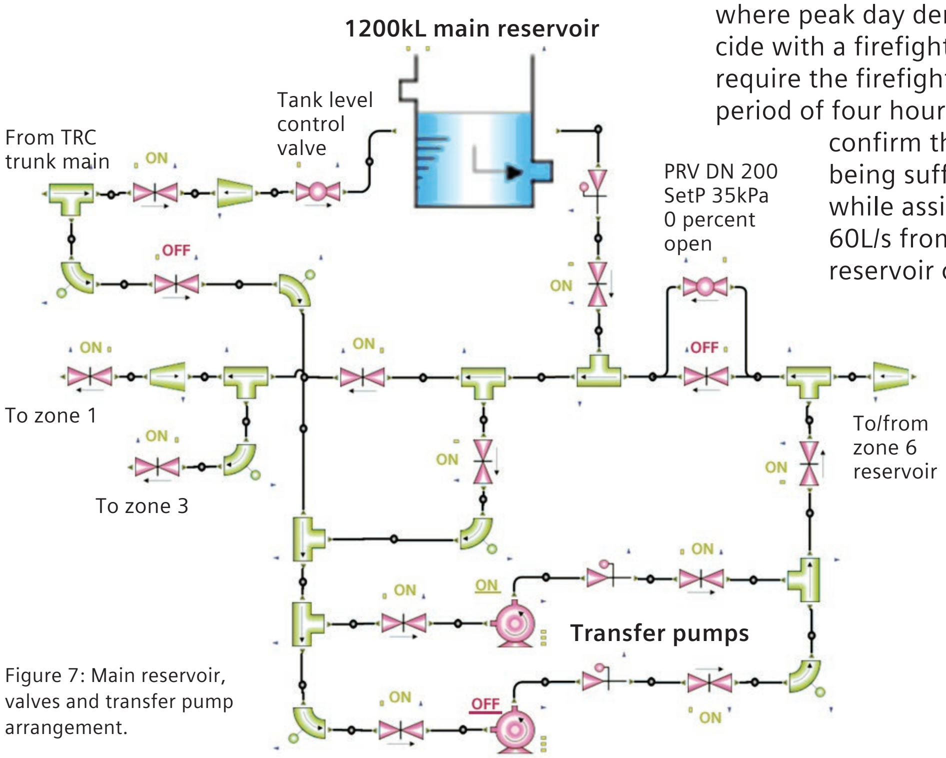

Figure 7: Main reservoir, valves and transfer pump arrangement.

The storage tank capacity simulations

Transient simulations were required to model reservoir level behaviour under extreme draw-down scenarios. The largest time step possible to result in a stable simulation was selected in order to keep result files small and to achieve short simulation run times. Reservoir level modelling allows for a time step of up to 10s and has to run for a period of two days (173,000s) to provide the desired result graphs.

The simulations assume the worst draw-down scenario where peak day demand and peak hour demand coincide with a firefighting event. The design guidelines require the firefighting event to run for a nominal period of four hours. The purpose of the simulation is to confirm the capacity of the main reservoir being sufficient to manage this extreme event, while assisted by the supplement supply of 60L/s from the TRC trunk main and zone 6 reservoir out of service.

The main reservoir, valve and transfer pump arrangement in figure 7 shows the piping arrangement around the main reservoir.

The model was set up for time based draw-offs in each zone operating at peak day and peak hour demand. In addition, a firefighting event was initiated in zone 5. After working hours the zonal draw-offs were reduced to 50 percent of the average day demand. Supply from the TRC trunk main replenishing the main reservoir was controlled by a level control valve, its maximum flow rate limited to 60L/s.

The result graph (figure 8), shows outflow from the main reservoir and inflow from the TRC trunk main. The firefighting event occurs during peak day and peak hour demand on the first day only while peak day and peak hour demand also occur on the second day.

The useful level range of the main reservoir extends from 0.3m to 5.3m. When the level reaches 5.3m, the inlet control valve matches inflow with outflow and thus keeps the level steady. Following rapid draw down during the firefighting event, the level recovers sufficiently fast after working hours with enough storage capacity available for another firefighting event on the next day if required (figure 9).

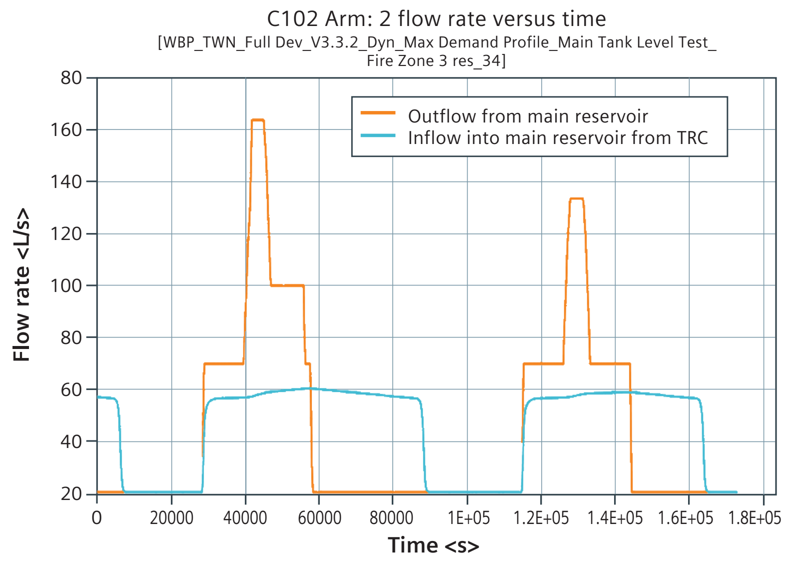

Figure 8: Main reservoir inflow and outflow over two-day period.

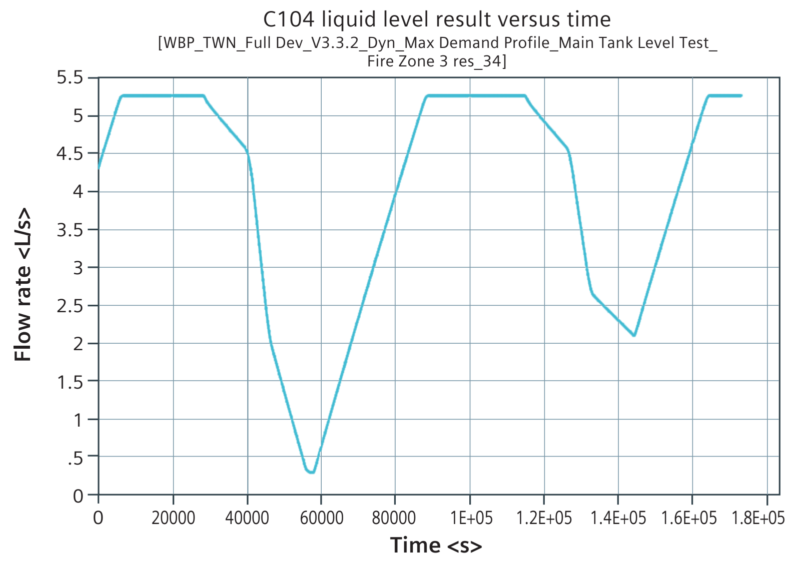

Figure 9: Main reservoir water level response over two-day period.

The key outcomes

The advanced Simcenter Flomaster software has enabled the complete hydraulic design of the Wellcamp Town Water Supply System and has confirmed its operational capabilities by static and dynamic model simulations.

Pipe material PVC DN150 was utilized for most pipelines. However, in some high flow areas this diameter was found to cause significant head loss and had to be increased by one or two pipe sizes.

Modeling results confirm that under low and high flow demand scenarios (except for firefighting events) the pressure distribution throughout the town water supply system is maintained with the acceptable limit from 250kPa to 600kPa.

In the current development, a firefighting incident in the airport area (zone 5) requires the resetting of the incoming PRV from 500 kPa to 650kPa in order to provide sufficient supply pressure. Following completion of firefighting event, the PRV has to be reset to 500kPa as otherwise the pressure would be excessive in lower parts of the system.

In the full development, responding to a firefighting incident in a particular zone may require the temporary opening of alternative flow passages in order to maintain a minimum system pressure of at least 250kPa.

Dynamic modeling of fire pump operation has confirmed sufficient supply pressure being available to avoid loss of prime when the system is operating at maximum flow demand.

Dynamic modeling of reservoir levels for a period of 48 hours when operating under extreme water demand has confirmed that water levels are being maintained above low reservoir levels while being supplemented from the TRC trunk main at 60L/s.

It has been concluded that all design objectives of this project have successfully been achieved.

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