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Optimization of a Booster Pump Location within the Reykjaveita Hot Water Distribution System in NE Iceland using a Network Model

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ABSTRACT

Norðurorka, a regional utility company in NE Iceland, owns and operates the Reykjaveita hot water distribution system which supplies hot water to homes and businesses in the rural area of Fnjóskadalur valley and in the small fishing village of Grenivík. The hot water transmission main extends 50 km from the Reykir low temperature geothermal field in Fnjóskadalur valley, 200 m a.s.l., down to the fishing village of Grenivík in the Eyjafjörður fjord. Since the distribution network was taken into operation in 2006, the demand for hot water has increased as new consumers have been added to the network, including individual homes as well as larger consumers such as the local swimming pool in Grenivík and a fish drying processing plant. Because of this increased demand, the distribution system reaches its maximum capacity during peak demand periods, leading to insufficient pressure in homes at the highest elevations in Grenivík at the end of the distribution main.

Norðurorka commissioned Vatnaskil Consulting Engineers to set up a network model of the Reykjaveita distribution system with the aim of locating weak points on the distribution line and modelling the effect of future scenarios of increased demand both in Fnjóskadalur valley and in Grenivík. The network model was constructed and based on an existing network database of the distribution system. The model was calibrated using annual average consumer demand and pressure measurements taken along the distribution main over a week-long period.

The initial calibration of the model and review of the pressure measurements revealed the need for a booster pump station along the distribution main as a mitigation measure to supply a sufficient amount of hot water to current consumers during peak hours, reduce pressure fluctuations along the distribution main and account for expected increased demand in the near future. To find the optimal location for the booster station along the distribution main, the calibrated network model was then used to test different locations with respect to different future scenarios of increased demand both in Fnjóskadalur valley and the village of Grenivík.

1. INTRODUCTION

Norðurorka, a regional utility company in NE Iceland, owns and operates the Reykjaveita hot water distribution system which supplies hot water to homes and businesses in the rural area of Fnjóskadalur valley and in the small fishing village of Grenivík. The hot water transmission main extends 50 km from the Reykir low temperature geothermal field in Fnjóskadalur valley, 200 m a.s.l., down to the fishing village of Grenivík in the Eyjafjörður fjord. An overview of the distribution system is shown on Figure 1. The transmission main consists of 150 mm diameter steel pipe for roughly the first 12 km, from P1 to P3. The remaining length of the transmission main, from P3 to P12, consist of 125 mm diameter steel pipe. The distribution system is split into two pressure zones by a pressure reducing valve located at the lower bridge over the Fnjóská river where pressure is reduced to 6 Bar. Since the distribution network was taken into operation in 2006, the demand for hot water has increased as new consumers have been added to the network, including individual homes as well as larger consumers such as the local swimming pool in Grenivík and a fish drying processing plant. Because of this increased demand, the distribution system reaches its maximum capacity during peak demand periods, leading to insufficient pressure in homes at the highest elevations in Grenivík.

Norðurorka commissioned Vatnaskil Consulting Engineers to set up a network model of the Reykjaveita distribution system with the aim of locating weak points on the distribution line and modelling the effects of future scenarios of increased demand both in Fnjóskadalur valley and in Grenivík.

2. THE NETWORK MODEL

The distribution network was modelled using EPA's EPANET network modelling software. Norðurorka has an extensive GIS database which contains various information on their distribution networks such as elevations at junctions, pipe diameters and pipe material. The GIS database provided the basis of the modelling process and reduced the modelling effort dramatically. Additionally, information on the distribution system usage was provided by Norðurorka. Norðurorka monitors well head and discharge at the well site at the Reykir geothermal field and registers measurements at regular intervals (within hourly values). As for consumer usage over the distribution network, only annual usage data are available. In Iceland, a gauge is installed at every household which measures the volume of geothermal water usage. These gauges are visited annually by the utility companies to record the usage of each household. As seasonal variations in geothermal water usage are highly variable, a mean annual discharge was defined for each user.

2.1 Calibration Data

In order to validate the model, pressure measurements were carried out before the modelling process began. Because of a limited number of pressure gauges available, the measurement period was split into two phases. In the first phase pressure in the distribution main was measured at intervals from the Reykir geothermal field down to the lower bridge of the Fnjóská river where a pressure reducing valve is located which reduces pressure of the distribution main to 6 Bar. The locations are shown in Figure 1. For the first phase, pressure measurements were recorded over a week-long period in late September 2018. The second phase of measurements were taken along the distribution main from the lower bridge of the Fnjóská river to the end of the distribution main at the small village of Grenivík. For the second phase, pressure measurements were recorded over a week-long period in the beginning of November 2018. For both phases the total demand in the system was recorded at Reykir geothermal field (P1).

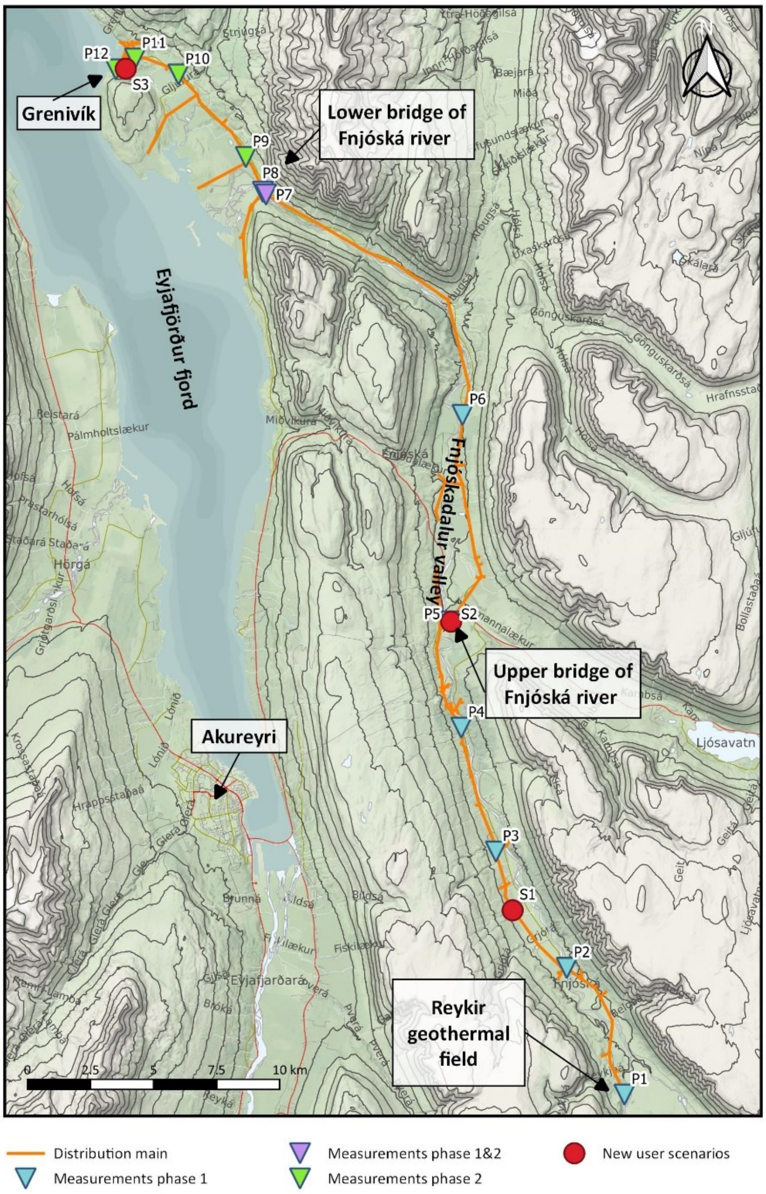

Figure 1: Overview of the Reykjaveita hot water distribution system and location of pressure gauges.

2.2 Model Calibration

The network model was calibrated with regards to two main parameters, pipe roughness and consumer demand. The larger diameter sections of the pipeline consist mostly of insulated steel pipe, while the smaller diameter sections consist of both steel and PEX pipe. Inner diameters of the pipes in the system range from 20 mm to 150 mm. Headloss was calculated using the Darcy-Weishbach formula with a roughness of 0.01 mm for the steel pipes and 0.0005 mm for the PEX pipes. The mean annual hot water usage for 2017 was used as a basis for the consumer demand defined in the model.

In Figure 2, calculated and measured pressure for the first phase of measurements are shown at locations P1 to P8. The comparison between measured and calculated pressures vary between gauging stations, with some of the stations having better fit than others. The calibration mainly involved dividing the demand between consumers on the distribution main. With no information on how the demand varied between individual consumers from the annual mean over the calibration period, the fluctuations in demand were scaled and divided between zones on the distribution main with most of the high demand tops being defined as demand at the local swimming pool at Grenivík village, as the pipe to the swimming pool was the only pipe able to carry the amount of flow that was present in the measurements. In general, the response in the model calculations is fairly good compared to the measurements. Further improvements on the model performance were not feasible as it would require more detailed real-time information on the demand of individual consumers during a measurement phase.

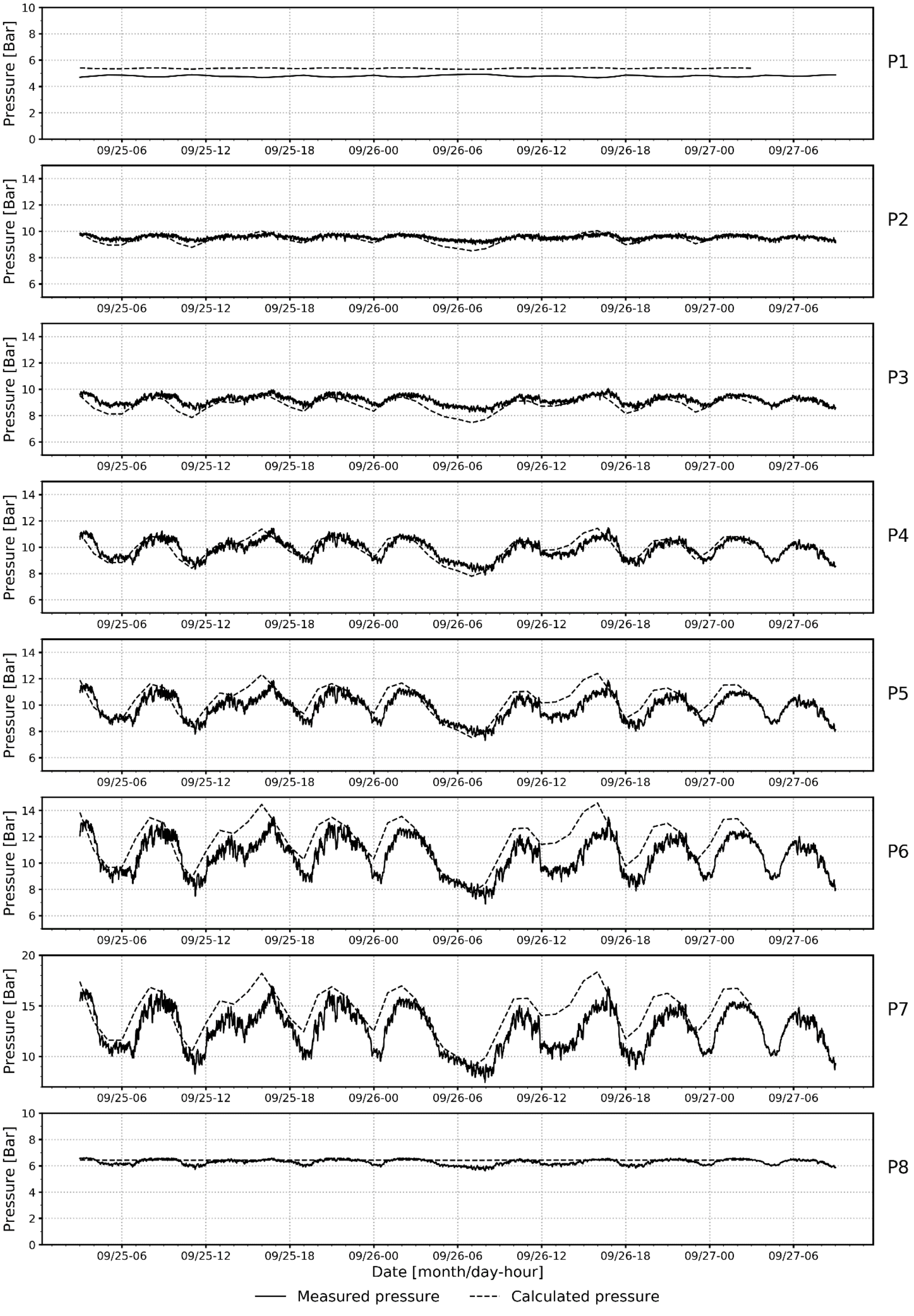

Figure 2: Calculated and measured pressure at locations P1 to P8 for the first phase of measurements.

In Figure 3, calculated and measured pressure for the second phase of measurements are shown in comparison at locations P7 to P12. As with the calibration of the first phase (Figure 2), the measurements and calculations are in good comparison at most locations. The measurements at location P7, just above the pressure reducing valve, appear to be of a quite different character compared to other locations. Further calibration would require more detailed real-time information on the demand of individual consumers during a measurement phase.

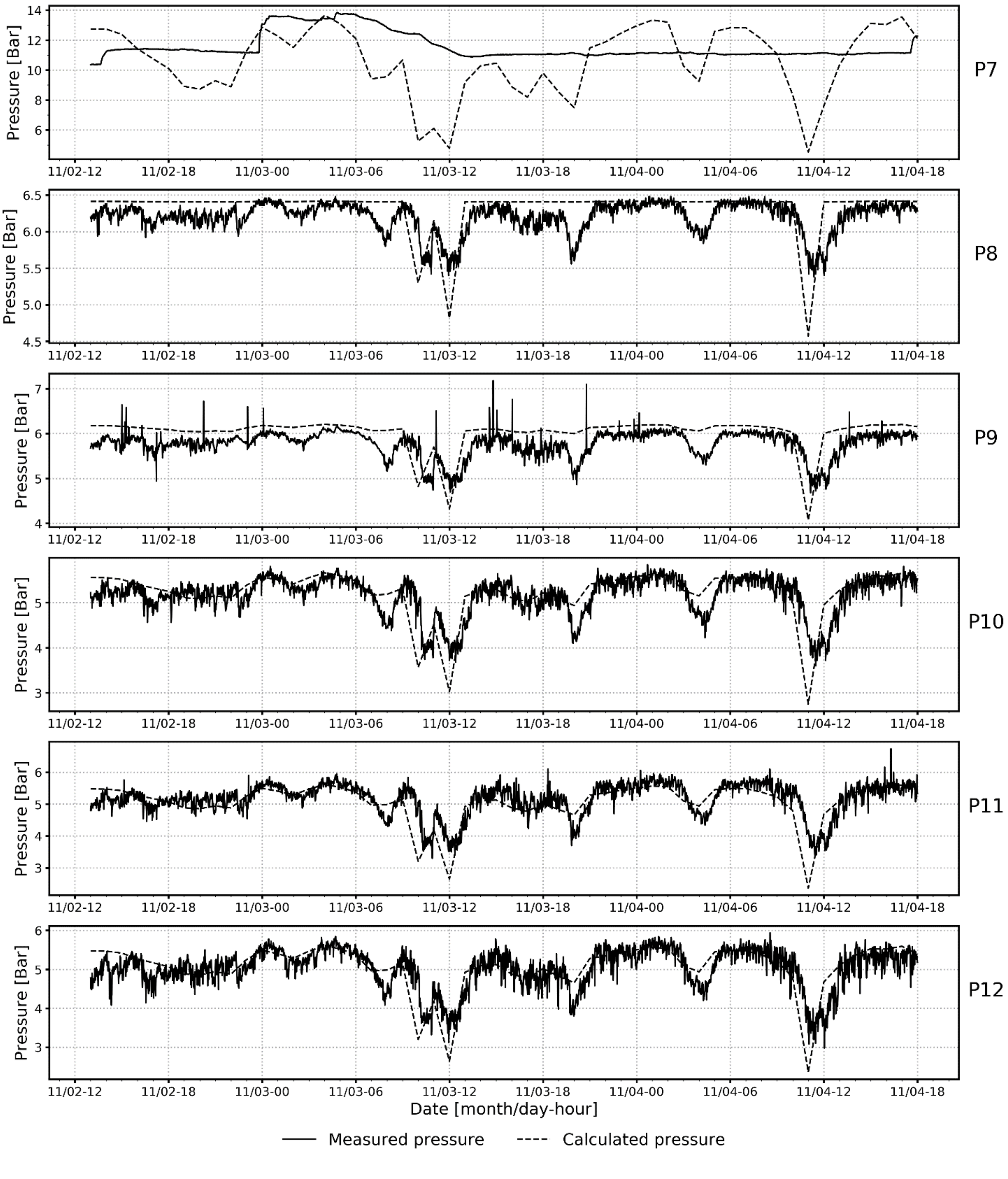

Figure 3: Calculated and measured pressure at locations P7 to P12 for the second phase of measurements.

3. NEW BOOZTER PUMP STATION

The results of the pressure measurements showed that during peak demand the transmission main was barely providing sufficient pressure at the pressure reducing valve, as pressure just upstream of the valve would drop below 6 Bar. Pressure at the highest locations in the village of Grenivík were also known to be insufficient. To compensate for the increased head loss during peak demand in the transmission main, Norðurorka commissioned Vatnaskil to utilize the existing network model to optimize the location of the new boozter pump station.

In order to find the optimum location for a pumping station, future scenarios of hot water demand were laid out. For the initial case, hot water demand was increased annually by 2.1% over 20 years for the existing users on the transmission main. A 2.1% annual increase is in accordance with the annual increase in the demand since the transmission main was constructed. To account for hours of peak demand, a case with 23% increase to the annual mean was included. In Table 1, the average and peak demand in the Reykjaveita hot water distribution system is shown. In addition to the future scenario, a new air separator being constructed in the summer of 2019 was added to the network which provides additional head to the system at the Reykir geothermal field.

Table 1: Average and peak demand in the Reykjaveita hot water distribution system calculated forward 20 years

Year	Average demand [L/s]	Peak demand [L/s]
0	14.9	18.3
5	16.5	20.3
10	18.3	22.5
15	20.3	25.0
20	22.5	27.7

In Figure 4, head loss and discharge in the distribution main is shown in accordance with an increase in demand for the scenarios in Table 1. On the upper most part of the figure, hydraulic head and land elevation are shown. The modelling results show that in seven years the pressure above the pressure reducing valve will go below 6 Bar. It is evident that reduced diameter pipe just downstream of location P3 causes a significant pressure drop in the network. If looking toward the next ten years of increased demand, a new boozter pump downstream of measurement station P6 would be optimal. The peak demand shows on the other hand quite a different story, where a new boozter pump would be needed much further upstream, around measuring station P4. The peak demand scenarios are quite extreme with regards to the area over which an increase is expected, as the distribution network supplies farms along the distribution main and further increase in demand at most locations is not very likely.

In Figure 5, the effect of a new boozter pump around location P4 is shown for the same scenarios as shown in Figure 4. The boozter pump station is set up with the same type of pumps as in the pumping station at the Reykir geothermal field, two parallel Grunfoss CR64-2 pumps which can increase the pressure head between 5 to 6 Bar. The pressure reducing valve is still active in this scenario. With the boozter pump station, sufficient pressures at Grenivík fishing village can be provided for the average demand for the next 10 years. During peak demand, however, the new boozter pump station only provides sufficient pressure at Grenivík village for the next 3 years. But as mentioned before, the peak demand scenarios are considered unlikely.

To take a more realistic approach to the future demand in the distribution network, three new scenarios where simulated, consisting of new developments with demand up to 3 L/s at three different locations along the distribution main, S1, S2 and S3 (shown in Figure 1). The demand at other locations along the distribution main consisted of the mean demand of 2017. The results of the three scenarios are shown in Figure 6. The distribution main will not provide sufficient pressure for new developments in Grenivík village, scenario S3, for more than 1 L/s. For new development scenarios S1 and S2, the distribution main will suffice up to 3 l/s or more demand. In Figure 7, the effect of a new boozter pump station around location P4 is also shown for scenario S3. The boozter pump at location P4 will provide sufficient pressures for up to 2 L/s increased demand in Grenivík village. To provide sufficient pressure of increased demand up to 3 L/s, larger pumps would be required with pressure head in the range of 70 to 80 m. Another approach to solve the problem would be to add a second boozter pump station downstream of location P6. This would, however, only be necessary when demand below station P6 would exceed 10 L/s. In Figure 8, the effect of an additional boozter pump station below station P6 is shown. It is apparent that a second boozter pump station would only be necessary if demand below station P6 exceeds 10 L/s. The head loss from the pressure reducing valve to Grenivík village is significant when demand in Grenivík village exceeds 7 L/s, which could be counteracted by limiting the effect of the pressure reducing valve.

4. CONCLUSION

The Reykjaveita hot water distribution network is a relatively long network where significant head loss can be expected with increased demand. The distribution has reached its capacity during hours of peak demand resulting in insufficient deliverability to costumers in Grenivík village. The need for a new boozter pump station is apparent, and according to modelling results it should be located in the upper most part of the distribution network. A secondary boozter pump in the lower part of the network is only needed if demand downstream of station P6 exceeds 10 L/s. The network model has shown its capabilities in optimizing the location of a new pumping station and could by used for further development within the distribution network. The use of standardized percentile of annual increase in demand can be questioned as an adequate method when working with rural networks where increased demand is more likely to be associated with new development with significant demand at specific locations.

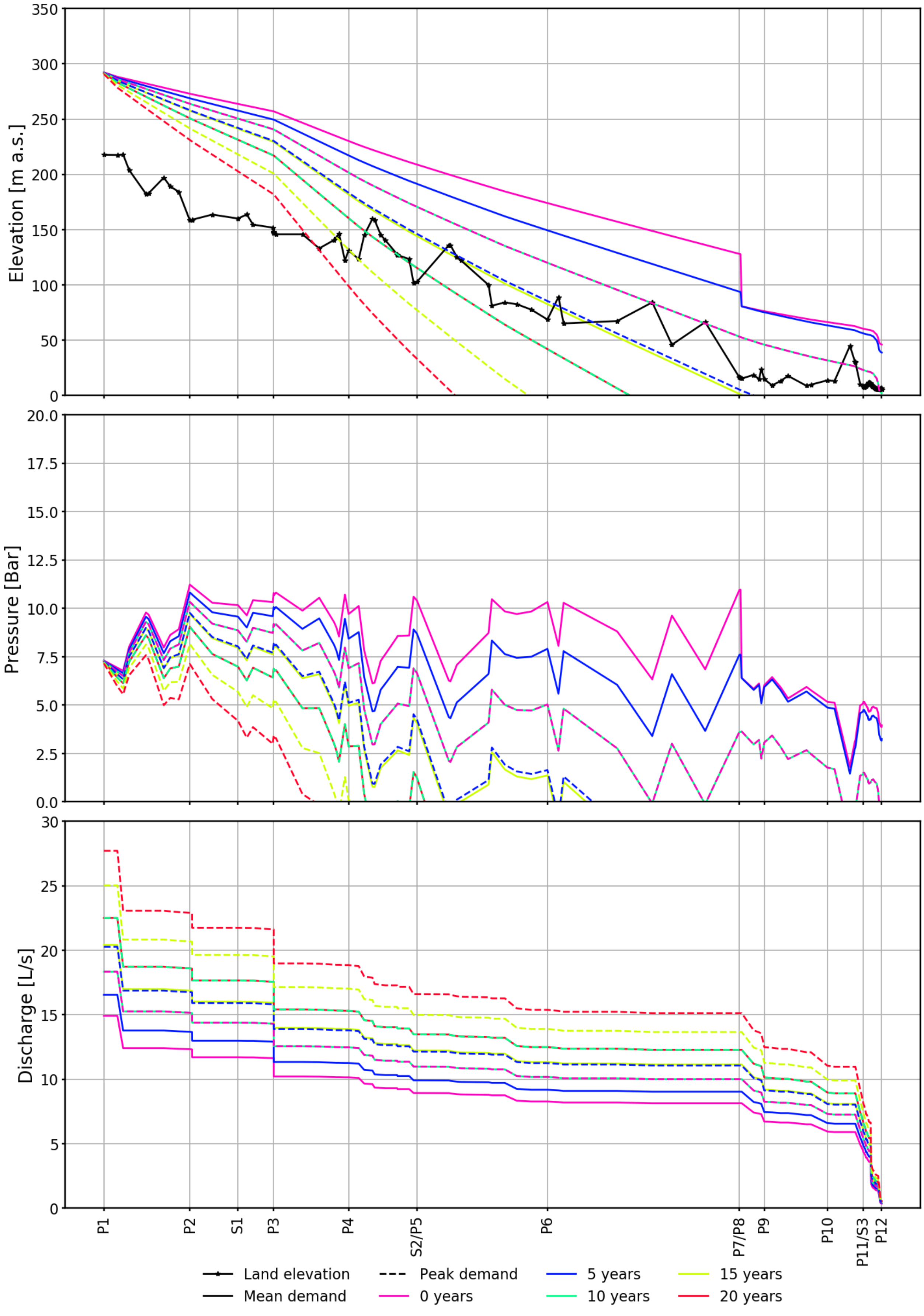

Figure 4: Hydraulic head, pressure and discharge along the Reykjaveita hot water main. Scenarios for 2.1% annual increase of hot water demand and 23% increase during peak demand.

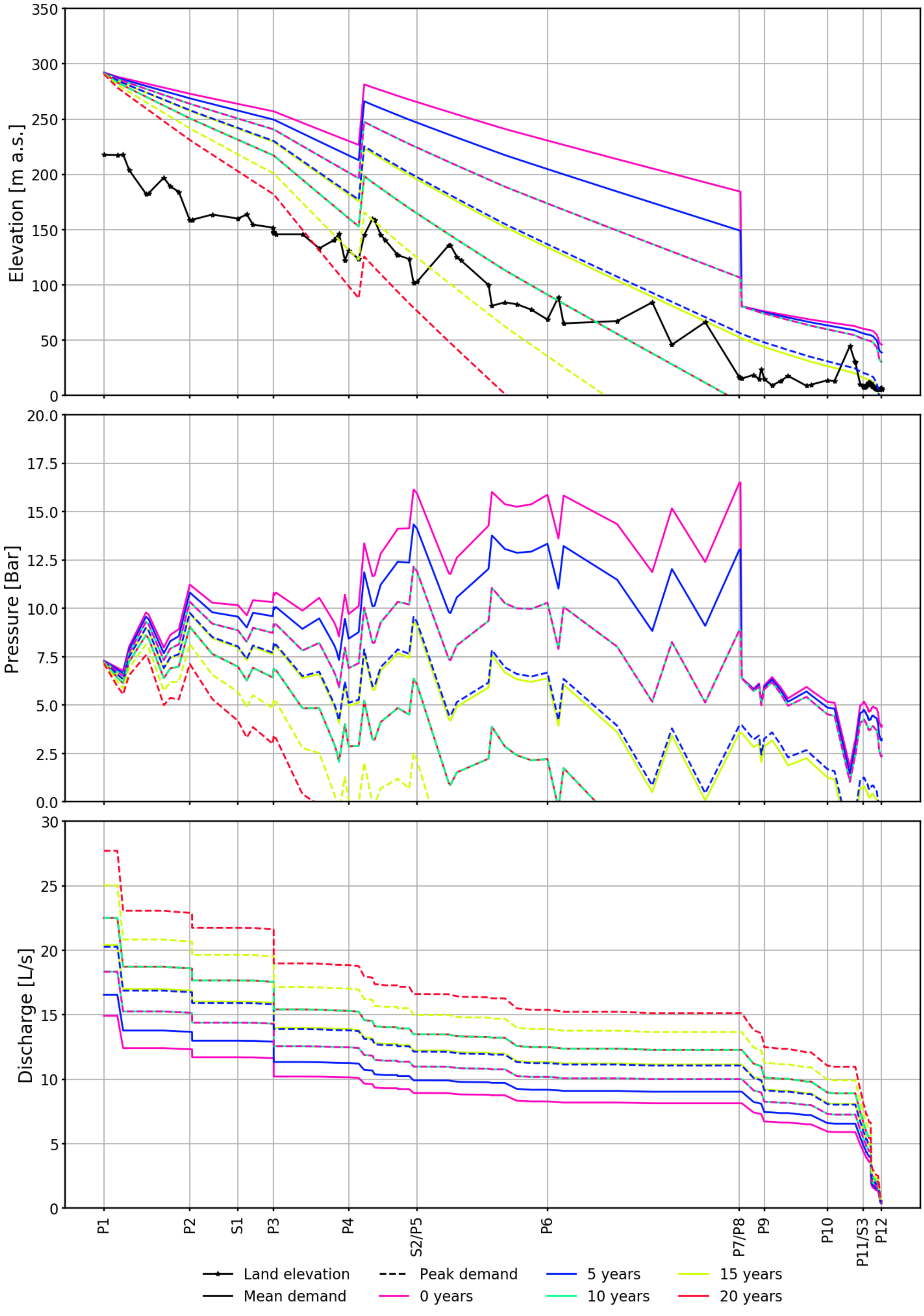

Figure 5: Boozter pump station located downstream of station P4. Hydraulic head, pressure and discharge along the Reykjaveita hot water main. Scenarios for 2.1% annual increase of hot water demand and 23% increase during peak demand.

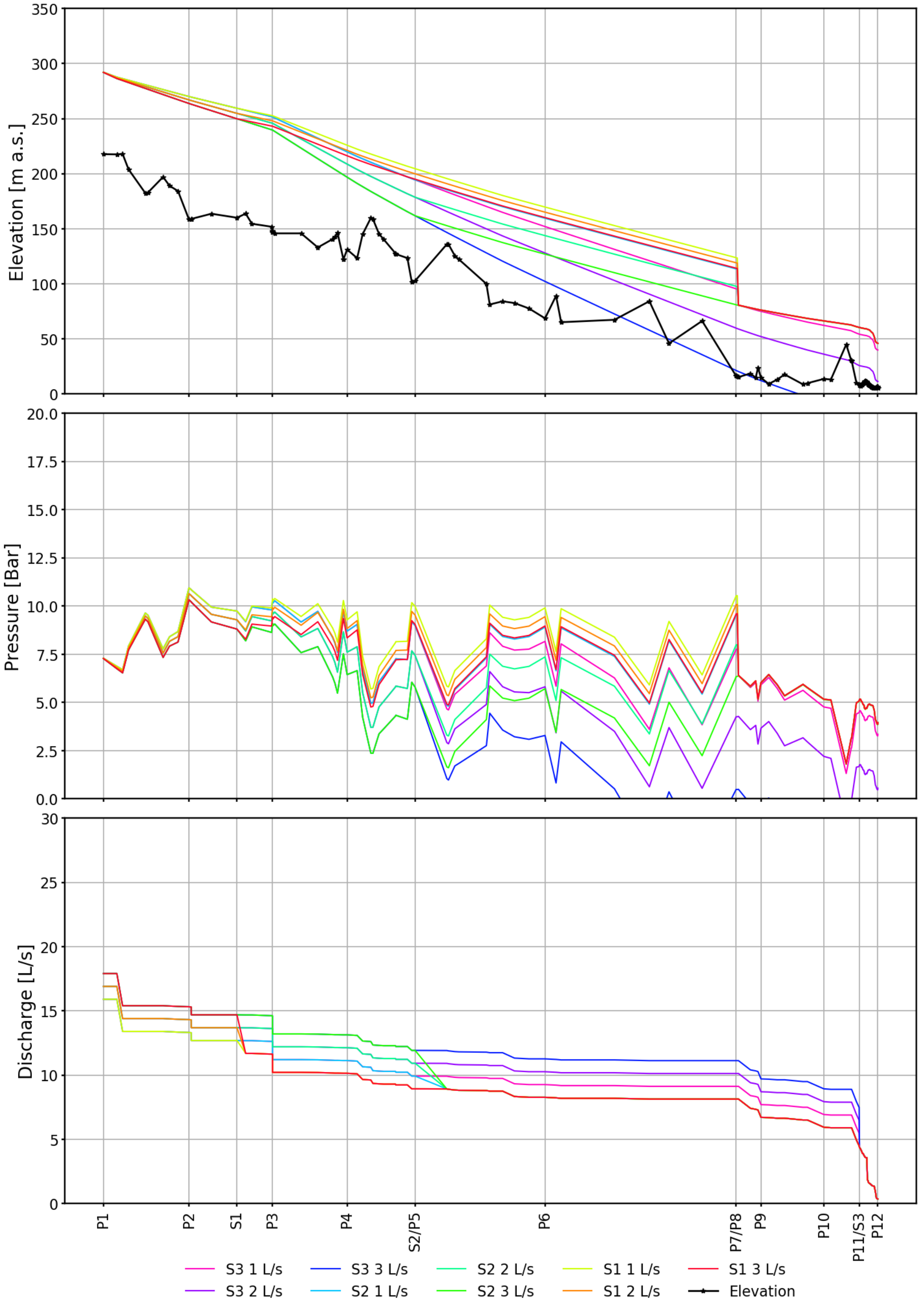

Figure 6: Hydraulic head, pressure and discharge along the Reykjaveita hot water main. Scenarios for new developments, S1, S2 and S3.

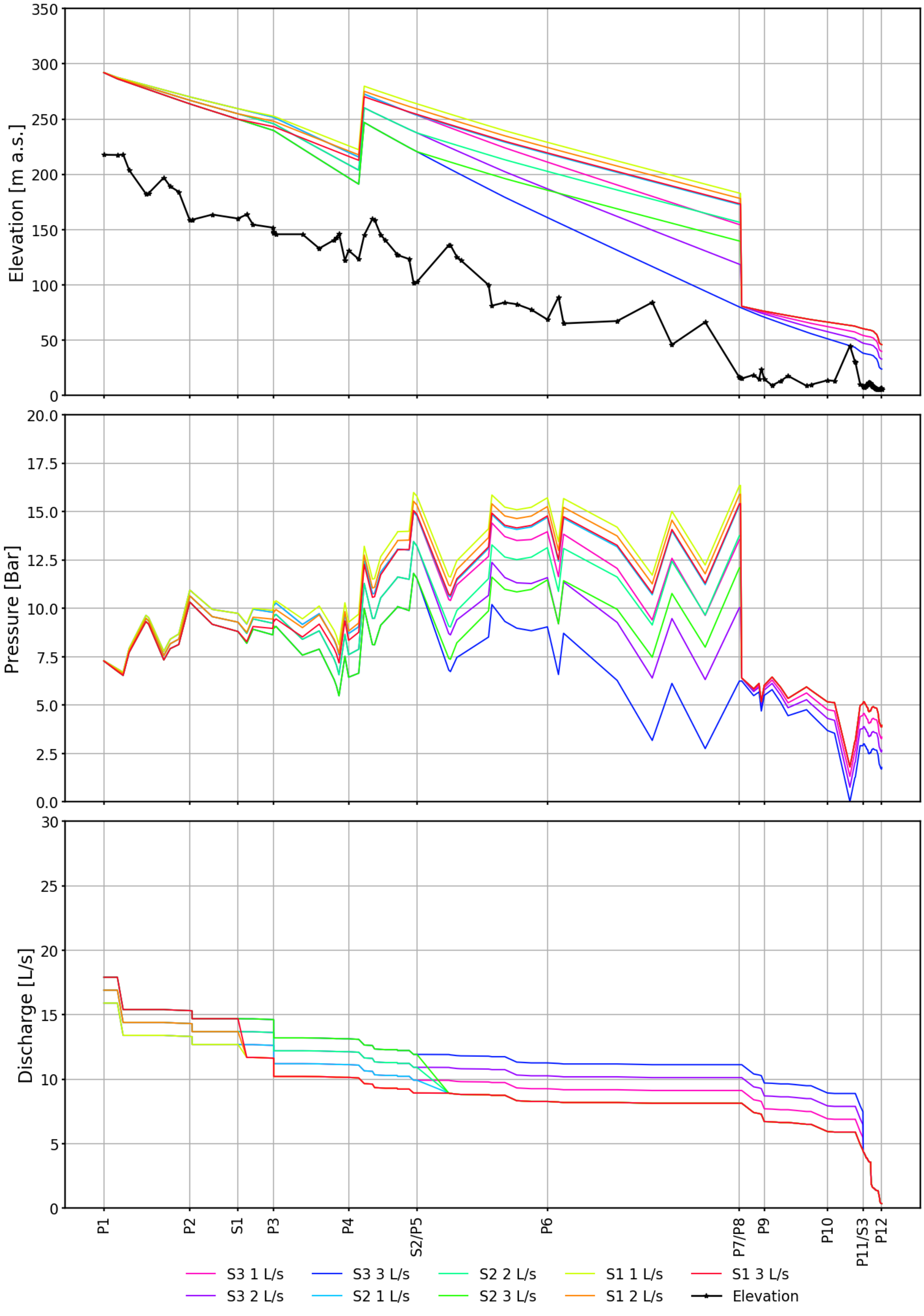

Figure 7: Boozter pump station located downstream of station P4. Hydraulic head, pressure and discharge along the Reykjaveita hot water main. Scenarios for new developments, S1, S2 and S3.

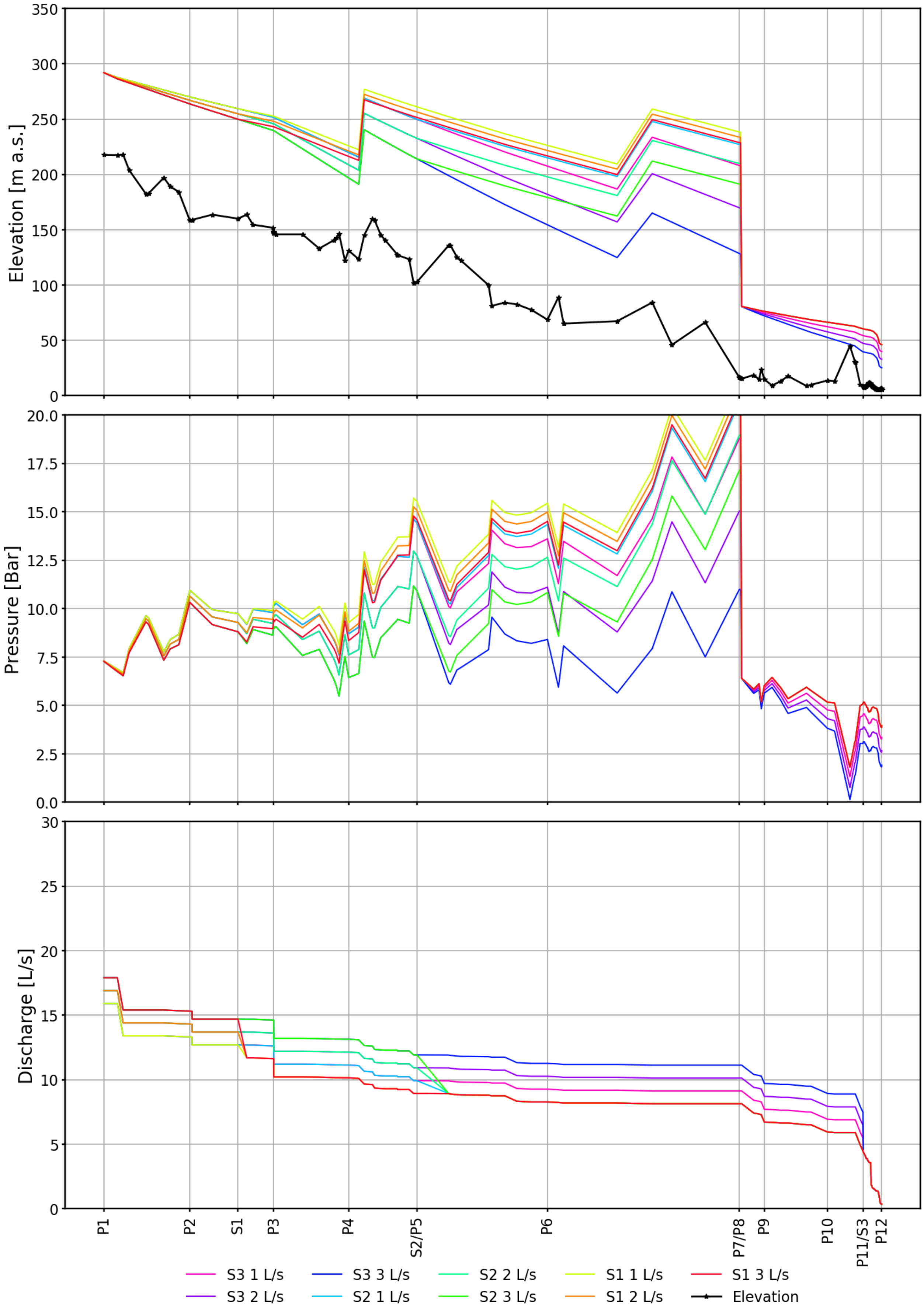

Figure 8: Boozter pump stations located downstream of stations P4 and P6. Hydraulic head, pressure and discharge along the Reykjaveita hot water main. Scenarios for new developments, S1, S2 and S3.