File S1

A.1. Hydraulic Modeling

Modeling hydraulic systems is a valuable tool for evaluating the behavior of water distribution systems. It involves creating a mathematical or computational representation of the physical and operational characteristics of a system, aimed at identifying and solving problems, as well as providing information for decision-making. Through laws of mass, energy and kinetic reactions conservation, it is possible to create hydraulic and water quality simulation models. However, for the model to be effective as a management and planning tool, it must be calibrated, adjusting its physical, hydraulic and load characteristics, so that its results are realistic and consistent with field observations [1–5].

The hydraulic modeling of the water distribution system that served as a support for the research was carried out using the QGIS, EPANET and QGISRed [6] software. The model allowed georeferencing the system and performing static and dynamic simulations of the hydraulic behavior of the water distribution network. Finally, it was possible to acquire designed parameters (pressure, velocity, flow, length and diameter) in each pipeline of the network. These results were obtained following seven steps presented in Figure A1.

1. Data Acquisition: Collect information about the system's characteristics, including the network layout, pipe dimensions and types, pumps, valves, reservoirs, etc.

2. Network Model: Import and organize geographical data into the QGIS software, including creating hydraulic element layers and defining attributes for each element.

3. Parameter Assignment: Import the network model and use the EPANET software for hydraulic modeling, define operational conditions and parameters such as roughness, demand, water level height in reservoirs, etc. and simulate the system's operation.

4. Calibration: Compare the results obtained with real data and make adjustments to the model, repeated processes until it corresponds adequately with the system's reality.

5. Integration: Use the QGISRed plugin to integrate the calibrated hydraulic model in EPANET with QGIS to visualize the simulation results in GIS.

6. Result Analysis: Interpret the simulation results to evaluate the model's performance and identify areas for improvement

7. Documentation: Record the modeling process, the results obtained and the conclusions so that the model can be reviewed and updated in the future.

Figure A1. Steps for building, simulating, validating and recording the hydraulic model.

A.1.1. Data Acquisition

All necessary primary data have been obtained through cooperative efforts between the system operator and the agency responsible for the improvement actions conducted in the distribution network. This collection includes the technical registry of the water distribution system, operational data and technical information of the works and maintenance conducted in the system. Initially, all this data were processed so that they could be used in this research.

The technical registry was updated, considering the works and maintenance services conducted during the period. These data have been georeferenced and the connectivity problems of the network and the level curves were corrected using the AutoCAD 2021® software, data represented in Figure A2.

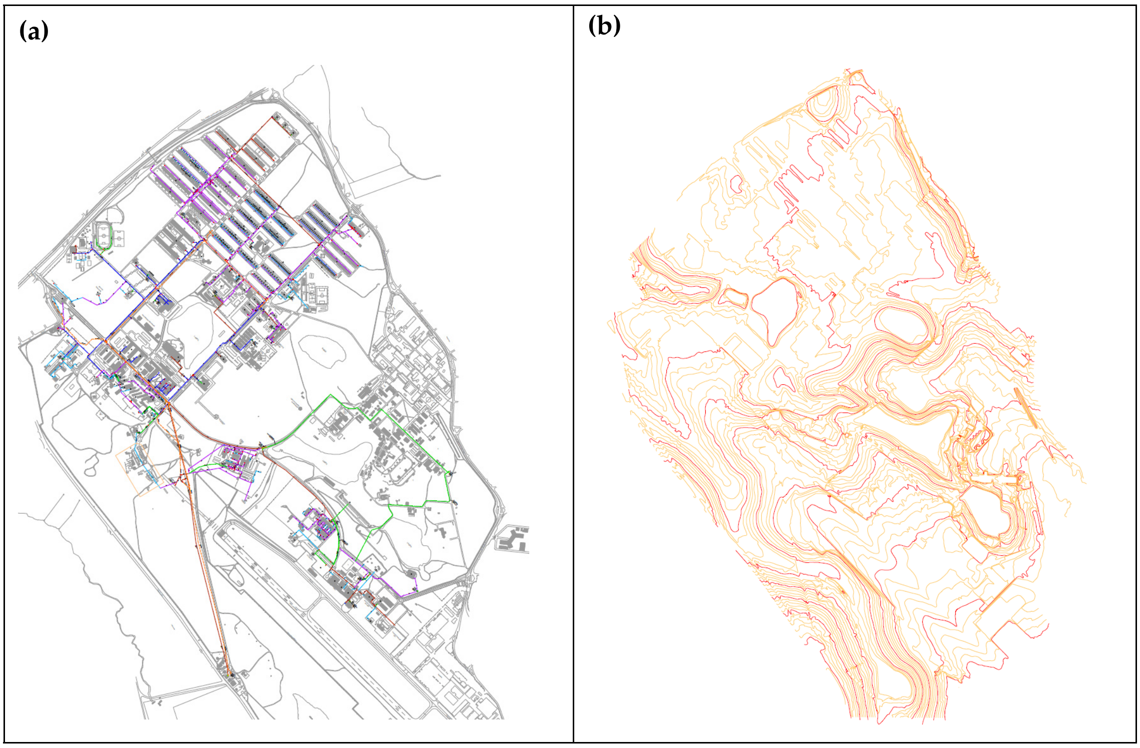

Figure A2. CAD files: (a) Updated and georeferenced technical registry; (b) Level curves

The operational data and technical information of various elements of the system, such as reservoirs, valves, pumps, consumption and monitoring points (pressure and flow) were consolidated into a single workbook using Excel 365® software. Some of this information is presented below. It should be noted that undisclosed data are available from the corresponding authors upon reasonable request.

Table A1. Information on the storage subsystem of the case study

Cod.	Type	Shape	Dimensions		Altitude (m)		Water Level (m)		
			V (m^3)	Ø (m)	Base	Input	Initial	Min	Max
R1	RNV	Round	150	2.71	596.88	625.98	28.50	3.00	29.00
R2	RNV	Rectangular	48	4.04	598.03	613.63	15.00	11.75	15.50
R3	RNV	Round	60	4.37	598.33	617.93	19.00	15.50	19.50
R4	RNV	Round	47	2.19	598.68	613.28	14.00	2.00	14.50
R5	RNV	Round	40	2.45	600.58	611.18	10.00	2.00	10.50
R6	RNV	Round	66	2.29	600.70	620.30	19.00	3.50	19.50
R7	RNV	Round	40	2.45	600.91	611.51	10.00	2.00	10.50
R8	RNV	Round	40	2.45	602.37	612.97	10.00	2.00	10.50
R9	RNV	Round	10	1.30	603.01	612.61	9.00	2.00	9.50
R10	RNV	Round	20	2.74	606.21	622.51	15.00	12.81	16.20

R11	RNV	Round	242	3.60	629.36	674.78	44.00	21.57	45.32
R12	RNV	Rectangular	31	1.85	620.56	635.16	14.40	3.00	14.50
R13	RNV	Round	10	1.26	626.04	635.14	8.00	1.00	9.00
R14	RNV	Round	10	1.16	626.60	638.20	11.00	2.00	11.50
R15	RNV	Round	54	2.76	626.94	626.94	26.00	18.00	27.00
R16	RNV	Rectangular	54	10.31	606.22	607.07	0.64	0.10	0.75
R17	RNF	Rectangular	2525	-	634.00	-	3.00	1.00	3.50

Some simplifications were necessary to create the hydraulic model due to the lack of some operational data related to micrometers and the level monitoring of reservoirs in low areas. In this simplification, the secondary networks were disregarded and the number of reservoirs was reduced. In this case, the consumption of these customers was considered at the NODE (a graphic element used to represent the junction of various system components, such as pipes, valves, and pumps). It represents the water entry into the variable-level reservoir (RNV) that was removed from the model. The node replaces many consumers, representing, therefore, a region supplied by the same distribution network. The base consumption value assigned at the NODE was informed by the system operator and adjusted based on the volume recorded by the respective region's flow meter, as detailed in Table A2 and represented in Figure A3.

Table A2. Base consumption assigned in the water distribution system of the case study.

Client	Consumption (L/s)		Flow Meter	Node
	Measured	Corrected		
1	0.0231	0.054	MM3	N-127
2	0.0058	0.013	MM3	N-127
3	0.0208	0.048	MM3	N-225
4	0.0098	0.023	MM3	N-81
5	0.0006	0.001	MM3	N-81
6	0.0017	0.004	MM3	N-81
7	0.0093	0.021	MM3	N-81
	0.0819	0.19	MM3	N-81
9	0.0017	0.004	MM3	N-81
10	0.776	1.801	MM3	N-466
11	0.0017	0.004	MM3	N-289
12	0.0009	0.002	MM3	N-289
13	0.0035	0.008	MM3	N-36
	0.1667	0.387	MM3	N-36
15	0.0075	0.017	MM3	N-357
	0.1667	0.387	MM3	N-357
17	0.239	0.555	MM3	N-318
18	0.0116	0.027	MM3	N-250
19	0.2188	0.508	MM3	N-250
20	0.0087	0.02	MM3	N-250
21	0.0289	0.067	MM3	N-250
22	0.0388	0.09	MM3	N-89
23	0.0405	0.094	MM3	N-69
24	0.0775	0.18	MM3	N-350
25	0.0168	0.039	MM3	N-125
26	0.0556	0.129	MM3	N-57

	0.0434	0.101	MM3	N-57
28	0.1053	0.244	MM3	N-4
29	0.031	0.072	MM3	N-4
30	0.0101	0.023	MM3	N-4
31	0.0058	0.013	MM3	N-4
32	0.0428	0.099	MM3	N-84
33	0.7205	1.672	MM3	N-84
34	0.3232	0.323	MM3	N-85
35	0.0156	0.036	MM3	N-353
36	0.0289	0.067	MM3	N-211
37	0.0023	0.005	MM3	N-5
	0.0486	0.113	MM3	N-5
39	0.3029	0.303	MM3	N-83
40	0.317	0.317	MM3	N-82
41	0.4803	1.115	MM3	N-10 + N-255
	0.1372	0.318	MM3	N-100
	0.4109	0.953	MM3	N-99
	0.1105	0.256	MM3	N-131
	0.0683	0.158	MM3	N-131
46	0.0087	0.02	MM3	N-16
47	0.0248	0.025	MM3	N-337
48	0.0006	0.001	MM3	N-79
49	0.0006	0.001	MM3	N-79
50	0.0017	0.004	MM3	N-79
51	0.0515	0.12	MM3	N-328
52	0.0828	0.192	MM3	N-110
	0.8825	2.048	MM3	N-110
54	1.0747	2.494	MM3	N-67 N-283 N-281
57	0.0642	0.149	MM3	N-264
58	0.0069	0.016	MM3	N-104
59	0.0064	0.015	MM3	N-128
60	0.0156	0.036	MM3	N-349
61	0.0718	0.167	MM3	N-194
62	0.0243	0.056	MM3	N-212
63	0.0046	0.011	MM3	N-43
64	0.0058	0.013	MM3	N-41
65	0.0035	0.008	MM3	N-37
66	0.0023	0.005	MM3	N-29
67	0.0087	0.02	MM3	N-31
68	0.0093	0.021	MM3	N-311
69	0.0064	0.015	MM3	N-215
70	0.0046	0.011	MM3	N-231
71	0.0046	0.011	MM3	N-335
72	0.0359	0.083	MM3	N-221
	0.3125	0.725	MM3	N-221
74	0.0046	0.011	MM3	N-144

75	0.0069	0.016	MM3	N-227
76	0.07	0.162	MM3	N-180
	0.026	0.06	MM3	N-180
78	0.0208	0.048	MM3	N-209
79	0.0122	0.028	MM3	N-76
80	0	0	MM3	N-338
81	0.0116	0.027	MM3	N-342
82	0	0	MM3	N-187
83	0.2865	0.665	MM3	N-366
84	0.2951	0.685	MM3	N-363
85	0.2604	0.604	MM3	N-368
86	0.3125	0.725	MM3	N-385
87	0.2778	0.645	MM3	N-391
88	0.2778	0.645	MM3	N-392
89	0.2951	0.685	MM3	N-382
90	0.2951	0.685	MM3	N-380
91	0.2951	0.685	MM3	N-381
92	0.0833	0.193	MM3	N-157
93	0.0058	0.013	MM3	N-356
94	0.2865	0.665	MM3	N-367
95	0.2691	0.624	MM3	N-360
96	0.2778	0.645	MM3	N-362
97	0.2778	0.645	MM3	N-364
98	0.2083	0.483	MM3	N-365
99	0.2083	0.483	MM3	N-369
100	0.2083	0.483	MM3	N-370
101	0.2083	0.483	MM3	N-372
102	0.1997	0.463	MM3	N-371
103	0.1389	0.322	MM3	N-387
104	0.1649	0.383	MM3	N-377
105	0.0521	0.121	MM3	N-390
106	0.1215	0.282	MM3	N-374
107	0.1215	0.282	MM3	N-388
108	0.1215	0.282	MM3	N-375
109	0.0955	0.222	MM3	N-389
110	0.1476	0.342	MM3	N-373
111	0.2083	0.483	MM3	N-378
112	0.1128	0.262	MM3	N-379
113	0.2604	0.604	MM3	N-386
114	0.0955	0.222	MM3	N-376
115	0.1042	0.242	MM3	N-383
116	0.1042	0.242	MM3	N-384
117	0.2083	0.483	MM3	N-169
118	0.2083	0.483	MM3	N-166
119	0.2083	0.483	MM3	N-158
120	0.1424	0.33	MM3	N-292
121	0.1136	0.114	MM3	N-429
122	0.0058	0.013	MM3	N-306

123	0.0359	0.273	MM5	N-1
124	0.0231	0.176	MM5	N-80
125	0.0174	0.132	MM5	N-359
126	0.0156	0.119	MM5	N-189
127	0.0029	0.022	MM5	N-168
	0.0014	0.011	MM5	N-168
129	0.0023	0.018	MM5	N-252
130	0.0023	0.018	MM5	N-161
131	0.0689	0.524	MM5	N-305
132	0.0122	0.092	MM5	N-324
133	0.0637	0.484	MM5	N-179
134	0.0255	0.194	MM5	N-204
135	0.0046	0.035	MM5	N-358
136	0.0056	0.006	MM5	N-330
137	0.012	0.012	MM5	N-330
138	0.0029	0.022	MM5	N-109
139	0.0058	0.044	MM5	N-463
140	0.0116	0.088	MM5	N-243
141	1.2153	1.278	MM2	N-462
142	0.1713	1.167	MM2 - MM4	N-132

Figure A3. Location of the consumption attributed to the various consumers.

The distribution network in this case study has monitoring technology through an operational control center (CCO) that receives network information (flow and/or pressure) through a telemetry system (Vectorasys) with communication via cell signal (GPRS), indicated locations in Figure A4.

Figure A4. Location of the monitoring points in the system, flow (F) and pressure (P) parameters.

The results of this monitoring, after data processing, refer to the hourly average values of the month of August 2021 (working days of the month with the highest consumption), that is, observed real results, flow and pressure parameters, represented in Table A3.

Table A3. Control points of the system and respective observed flow (F) and pressure (P) values

Hour	MM1		MM2		MM3	MM4	MM5		MM6		P_A	P_R
	F [L/s]	P [mwc]	F [L/s]	P [mwc]	F [L/s]	F [L/s]	F [L/s]	P [mwc]	F [L/s]	P [mwc]	P [mwc]	P [mwc]
00:00	34.768	20.01	1.904	13.42	30.458	0.000	1.230	43.20	0.303	12.88	23.90	14.44
00:15	35.056	20.03	1.870	13.72	30.454	0.000	1.200	43.00	0.144	13.37	23.76	14.48
00:30	34.167	19.94	1.900	13.64	30.630	0.000	1.194	43.04	0.114	13.44	23.39	14.69
00:45	35.722	19.83	1.919	13.92	31.194	0.000	1.178	43.08	0.125	13.82	23.77	14.57
01:00	37.556	19.80	1.944	14.21	30.833	0.000	1.183	42.97	0.078	13.71	23.21	14.71
01:15	37.111	19.80	1.959	13.87	30.167	3.963	1.178	43.18	0.019	13.84	23.71	14.56
01:30	36.444	19.77	5.000	12.89	29.704	4.111	1.172	42.38	0.022	13.26	23.65	14.70

01:45	36.222	19.78	5.352	12.59	29.046	4.037	1.183	42.73	0.172	13.92	23.35	14.74
02:00	36.000	19.70	5.378	12.56	29.704	4.074	1.172	42.64	0.014	13.91	23.54	14.66
02:15	36.222	19.67	5.352	12.61	29.056	4.037	1.178	42.72	0.014	14.10	23.38	14.76
02:30	35.889	19.65	5.352	12.70	29.426	4.074	1.172	42.73	0.006	13.92	23.40	14.72
02:45	35.889	19.63	5.344	12.63	29.324	4.037	1.183	42.90	0.006	13.52	23.38	14.98
03:00	36.389	19.55	5.341	12.45	29.037	4.037	1.183	42.96	0.011	14.01	23.37	14.84
03:15	36.333	19.55	5.304	12.59	29.787	4.074	1.172	42.98	0.086	14.05	23.50	14.79
03:30	35.778	19.56	5.337	12.73	29.676	4.037	1.167	42.92	0.022	14.14	23.41	14.94
03:45	35.611	19.55	5.341	12.81	28.818	4.037	1.178	42.99	0.022	14.15	23.36	14.93
04:00	35.611	19.49	5.326	12.54	28.519	4.037	1.172	43.17	0.022	14.19	23.42	14.89
04:15	35.500	19.50	5.311	12.35	28.431	4.037	1.200	43.09	0.008	14.22	23.37	14.98
04:30	35.278	19.44	5.330	13.24	28.454	4.037	1.172	43.02	0.008	14.19	23.62	14.78
04:45	35.389	19.42	5.319	12.72	29.184	4.037	1.178	43.20	0.006	14.17	23.35	14.73
05:00	35.667	19.38	5.293	12.38	29.361	4.037	1.178	43.25	0.006	14.11	23.62	14.83
05:15	35.778	19.35	5.193	12.03	29.509	4.000	1.167	43.27	0.006	18.07	23.40	19.47
05:30	36.444	19.26	5.196	11.83	29.421	4.074	1.183	43.35	0.008	18.00	23.44	20.02
05:45	36.611	19.26	5.174	11.92	29.880	4.037	1.172	43.10	0.008	18.59	23.47	20.08
06:00	36.333	19.24	5.178	11.86	30.091	4.037	1.167	43.14	0.011	17.71	23.42	20.04
06:15	37.000	19.10	5.159	11.90	30.481	4.037	1.172	43.11	0.083	18.52	23.50	19.82
06:30	38.000	19.02	5.156	11.82	31.315	4.037	1.189	43.23	0.086	18.03	23.28	19.31
06:45	39.000	19.01	5.159	11.64	32.306	4.000	1.300	43.08	0.086	17.13	23.33	19.33
07:00	39.278	18.95	5.122	11.59	33.157	4.111	1.285	42.95	0.086	17.67	23.39	19.46
07:15	40.778	18.95	5.070	11.25	34.009	4.000	1.781	43.17	0.022	16.81	22.97	19.25
07:30	41.278	18.92	5.026	11.09	34.944	4.111	1.963	43.03	0.142	18.00	23.26	18.90
07:45	41.500	18.82	5.015	11.22	35.685	4.037	1.489	43.17	0.189	16.66	23.04	19.56
08:00	42.111	18.96	5.052	11.20	35.343	4.074	1.511	43.20	0.222	17.09	22.79	19.68
08:15	42.500	18.84	5.059	11.44	35.731	4.037	1.507	43.07	0.100	16.82	22.80	19.66
08:30	42.556	18.95	5.044	11.24	36.259	4.074	2.353	42.96	0.106	16.80	22.38	19.65
08:45	42.944	18.96	5.030	11.30	37.139	4.037	2.706	42.94	0.072	16.75	22.65	19.60
09:00	43.333	18.95	5.044	11.30	37.333	4.074	2.856	42.85	0.067	16.59	21.30	20.07
09:15	42.778	19.12	5.044	11.05	36.977	4.037	2.889	42.67	0.175	16.48	22.55	19.23
09:30	42.611	18.97	5.041	11.12	37.204	4.074	2.989	42.79	0.189	16.96	22.15	20.03
09:45	44.611	18.83	5.026	11.16	38.093	4.074	2.814	42.80	0.161	16.98	22.09	19.99
10:00	46.000	18.88	5.022	11.30	38.611	4.111	2.953	42.77	0.222	17.05	22.02	20.12
10:15	46.278	18.92	5.004	10.86	38.778	4.000	3.617	42.83	0.125	16.76	21.99	20.30
10:30	45.222	18.93	4.974	11.02	38.565	4.074	4.078	42.86	0.131	16.99	21.88	20.32
10:45	44.722	19.05	4.996	11.15	39.278	4.111	4.215	42.89	0.219	17.07	21.85	20.17
11:00	44.778	19.02	5.007	11.01	39.343	4.037	4.185	42.96	0.242	16.54	22.08	19.44
11:15	46.056	19.04	5.044	11.29	39.815	4.074	4.174	42.88	0.333	16.64	22.03	19.52
11:30	46.444	19.01	5.052	11.33	39.889	4.074	4.156	42.85	0.197	16.81	22.12	19.64
11:45	46.278	19.23	5.074	11.17	39.880	4.111	4.119	43.03	0.219	16.55	22.32	19.62
12:00	45.500	19.20	5.056	11.45	39.231	4.074	4.552	43.22	0.192	16.54	22.23	19.68
12:15	42.333	19.31	5.078	11.38	39.741	4.037	4.567	42.91	0.175	16.68	21.89	20.19
12:30	43.556	19.29	5.063	11.28	40.139	4.111	4.500	42.71	0.069	17.31	22.23	20.05
12:45	43.778	19.37	5.052	11.26	40.472	4.037	4.426	42.67	0.056	18.38	22.36	19.87
13:00	43.833	19.33	5.041	11.33	40.065	4.074	4.333	43.07	0.044	17.80	21.89	19.85
13:15	42.500	19.46	5.063	11.26	39.546	4.037	4.096	43.20	0.092	17.96	22.11	19.72

13:30	41.389	19.79	5.074	11.36	39.657	4.111	3.848	43.26	0.200	17.88	22.19	19.95
13:45	41.444	19.75	5.081	11.50	39.389	4.000	3.844	43.32	0.150	17.97	21.75	20.64
14:00	41.944	19.52	5.081	11.53	39.889	4.074	3.915	43.37	0.061	18.21	21.52	20.60
14:15	42.167	19.65	5.096	11.64	39.926	4.074	4.189	43.32	0.081	18.83	21.87	20.74
14:30	42.500	19.74	5.115	11.56	39.444	4.037	4.315	43.59	0.078	18.98	21.87	20.49
14:45	42.167	19.78	5.130	11.63	37.556	4.074	4.263	43.60	0.083	18.07	21.88	20.13
15:00	41.222	20.02	5.144	11.69	37.556	4.074	4.263	43.82	0.153	19.12	22.13	20.59
15:15	40.944	20.01	5.178	11.87	37.694	4.037	4.033	44.24	0.153	18.47	21.83	20.79
15:30	41.722	20.09	5.174	12.03	37.935	4.074	3.881	43.90	0.281	18.73	22.13	21.25
15:45	41.278	20.05	5.185	11.81	38.315	4.074	3.837	43.86	0.369	19.07	21.96	21.02
16:00	40.611	20.30	5.185	12.04	38.185	4.037	3.956	44.11	0.072	19.18	22.03	21.21
16:15	40.444	20.17	5.204	11.89	37.583	4.074	4.522	44.17	0.025	20.07	22.14	21.61
16:30	41.444	20.29	5.230	12.18	37.769	4.037	4.578	44.03	0.058	19.72	22.81	20.07
16:45	40.667	20.19	5.219	11.97	36.676	4.074	4.489	44.10	0.169	19.62	22.58	20.51
17:00	40.111	20.35	5.233	11.95	35.833	4.037	4.250	44.05	0.275	19.78	22.92	20.66
17:15	36.056	20.40	5.196	11.98	36.250	4.111	3.639	44.03	0.042	19.35	22.91	20.47
17:30	40.389	20.48	5.222	12.08	36.935	4.037	2.363	44.14	0.047	19.72	22.46	20.21
17:45	40.722	20.23	5.241	12.27	37.231	4.037	1.537	44.01	0.167	20.28	22.84	20.27
18:00	41.778	20.18	5.244	12.26	37.056	4.074	1.317	44.19	0.186	18.73	22.65	20.43
18:15	41.333	20.37	5.263	12.44	37.167	4.000	1.306	44.19	0.183	19.44	22.93	20.11
18:30	40.667	20.33	5.263	12.40	37.288	4.000	1.259	44.06	0.256	19.74	22.87	20.11
18:45	39.722	20.43	5.259	12.51	36.148	4.111	1.244	44.16	0.153	20.33	20.91	20.15
19:00	39.611	20.40	5.263	12.28	37.056	4.000	1.256	44.09	0.083	19.51	19.95	20.09
19:15	39.500	20.40	5.237	12.21	37.306	4.037	1.270	43.81	0.183	19.72	21.22	20.19
19:30	39.278	20.40	5.248	12.38	36.824	4.074	1.178	43.82	0.050	19.53	21.21	20.39
19:45	39.167	20.39	5.267	12.31	36.278	4.000	1.152	43.93	0.050	18.54	20.99	20.24
20:00	40.056	20.35	5.263	12.29	36.287	4.074	1.300	43.79	0.050	18.98	21.55	20.24
20:15	39.944	20.21	5.252	12.34	36.130	4.037	1.272	43.83	0.253	18.05	21.28	20.16
20:30	40.222	20.23	5.252	12.34	36.102	4.037	1.256	43.73	0.147	17.90	21.27	20.28
20:45	39.944	20.21	5.244	12.26	35.731	4.037	1.256	44.04	0.119	17.50	20.81	20.30
21:00	39.389	20.24	5.252	12.27	35.454	4.037	1.239	43.76	0.175	17.44	21.21	20.40
21:15	39.389	20.14	5.226	12.16	35.370	4.037	1.456	43.79	0.067	17.88	21.61	20.35
21:30	38.778	20.27	5.215	12.16	35.398	4.037	1.472	43.84	0.044	17.78	21.35	20.35
21:45	38.222	20.19	5.215	12.26	35.241	4.037	1.372	44.05	0.067	18.22	21.67	20.14
22:00	37.722	20.20	5.241	12.22	34.935	4.074	1.283	43.69	0.164	18.61	21.70	20.49
22:15	37.611	20.07	2.141	13.30	34.565	0.000	1.239	43.71	0.100	18.15	21.13	15.54
22:30	37.111	20.08	1.863	13.30	34.460	0.000	1.228	43.71	0.067	16.47	21.69	14.61
22:45	36.611	20.16	1.874	13.36	33.120	0.000	1.239	43.66	0.111	14.24	21.50	14.34
23:00	35.556	20.18	1.567	13.60	33.630	0.000	1.278	43.66	0.172	13.42	20.82	14.71
23:15	32.333	20.25	1.467	14.00	32.742	0.000	1.272	43.53	0.125	13.16	21.48	14.69
23:30	32.111	20.38	1.456	14.22	31.165	0.000	1.272	43.47	0.175	13.22	21.96	14.71
23:45	31.500	20.26	1.433	14.21	30.437	0.000	1.256	43.29	0.119	13.23	20.73	14.70
00:00	34.77	20.01	1.90	13.42	30.46	0.00	1.23	43.20	0.30	12.88	23.90	14.44
Avg.	**39.58**	**19.68**	**4.71**	**12.14**	**34.89**	**3.55**	**2.27**	**43.35**	**0.11**	**16.90**	**22.42**	**18.54**

The results from Table A3 were used to define the consumption characteristics of the region, the hourly flow coefficient of variation (k2), which generally represent the shape and quantitative distribution of the flows to be applied at each node identified in Tab. A2, these consumption patterns are represented in Figure A5.

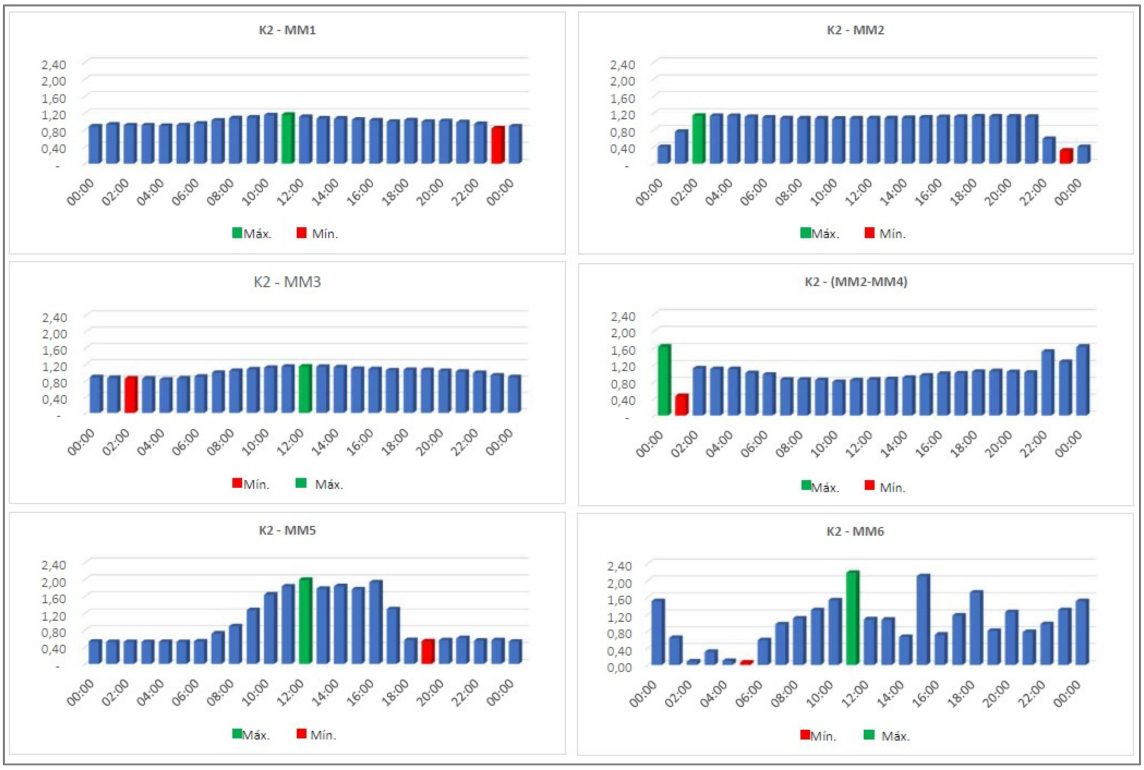

Figure A5. Consumption Pattern - Hourly flow coefficient (k2)

A.1.2. Network Model

The data and information produced previously were imported and organized in QGIS, including the creation of hydraulic element layers and the definition of attributes for each element of the distribution system (pipes, reservoirs, valves, pumps, etc.). In addition, a digital elevation model (DEM) was produced from the "elevation contours" vector layer in order to extract the elevation data of the nodes in the network model. With these layers produced and the use of the QGISRed plugin, the network model, represented in Figure A6, could be exported (INP file) for hydraulic modeling in EPANET.

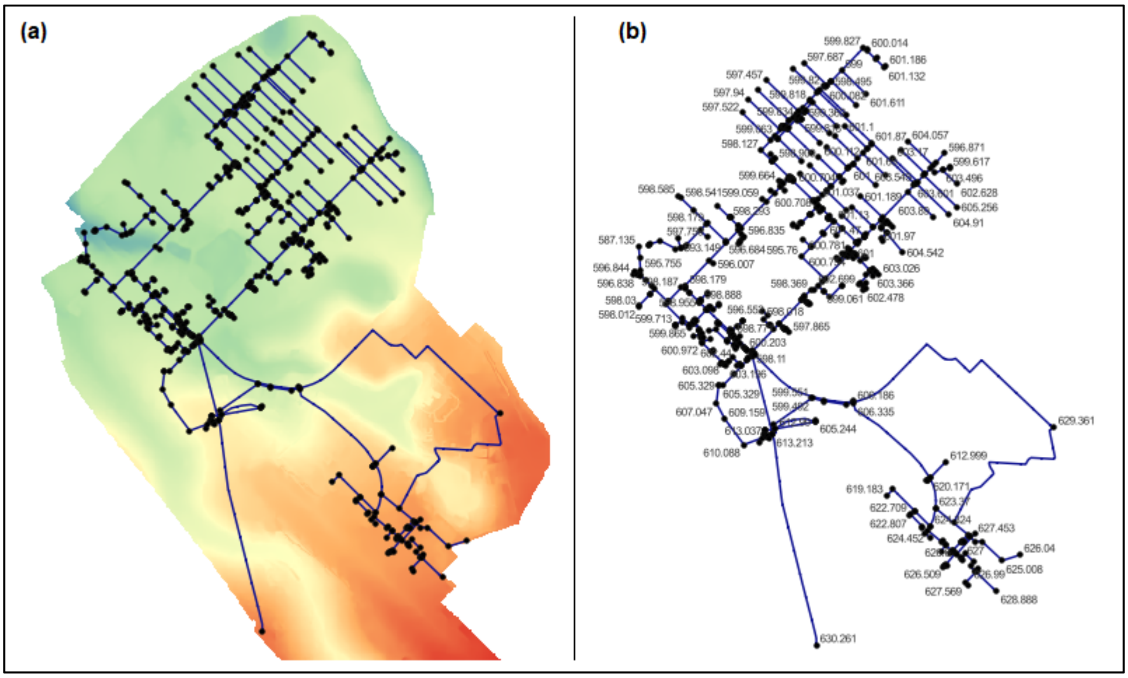

Figure A6. Building the Network Model: (a) Tracing and DEM; (b) Network Model

A.1.3. Parameter Assignment

The produced network model (INP file) was imported into EPANET, where hydraulic, mechanical and operational parameters were assigned to each element of the network. It allowed to represent the water distribution system and to perform hydraulic simulations, as presented in Table A4.

Table A4. Assignment of parameters for hydraulic model simulation

Component	[1]Parameters
Pipe	Length (m)
	Diameter (mm)
	Hazen-Williams Roughness Coefficient (C)
Node	Altitude (m)
	Consumption (L/s)
Variable Level Reservoir (RNV)	Altitude (m)
	Initial water level (m)
	Minimum water level (m)
	Maximum water level (m)
	Reservoir diameter (m)
Fixed Level Reservoir (RNF)	Water Level
Valve	Initial and final nodes (Id)
	Diameter (m)
	Valve control parameter (F, P...)
	State (Open / Closed / Active)
	Type
Pump	Pump Curve

A.1.4. Calibration

The calibration of the hydraulic model was conducted adjusting the value of the roughness coefficient and demand at the nodes. In addition, it was necessary to insert and edit the controls on the valves to represent the operational characteristics of the system until they were in accordance with the reality of the system. This step was essential to adjust the parameters of the model in a way that minimizes deviations between observed and simulated values.

The results of the hydraulic model calibration, observed "versus" simulated results (flow and pressure parameters), were summarized in Tables A5, A6, and in Figure A7, which reflects a 24-hour period with a 15-minute interval between each value.

Table A5. Statistical Treatment of Calibration Results for Flow

Location	Segment	N° Obs.	Daily Average Flow (L/s)		Mean Error (L/s)	Sd (L/s)
			Observed	Simulated		
MM1	T-395	96	39.58	39.63	1.68	1.949
MM2	T-477	96	4.71	4.72	0.073	0.091
MM3	T-441	96	34.89	34.9	0.437	0.577
MM4	T-468	96	3.55	3.54	0.024	0.03
MM5	T-449	96	2.27	2.23	0.094	0.21
MM6	T-453	96	0.11	0.11	0.041	0.053
Network		**576**	**14,19**	**14.19**	**0.392**	**0.835**

Table A6. Statistical Treatment of Calibration Results for Pressure

Location	Node	N° Obs.	Daily Average Pressure (m.w.c)		Mean Error (m.w.c)	Sd (m.w.c)
			Observed	Simulated		
MM1	N-393	96	19.68	19.54	0.508	0.587
MM2	N-465	96	12.14	12.44	0.471	0.59
MM5	N-464	96	43.35	43.45	1.345	1.564
MM6	N-429	96	16.90	17.39	1.078	1.408
PR	N-251	93	18.60	18.50	0.61	0.86
PA	N-302	96	22.42	21.59	0.944	1.066
Network		**573**	**22,20**	**22.17**	**0.827**	**1.081**

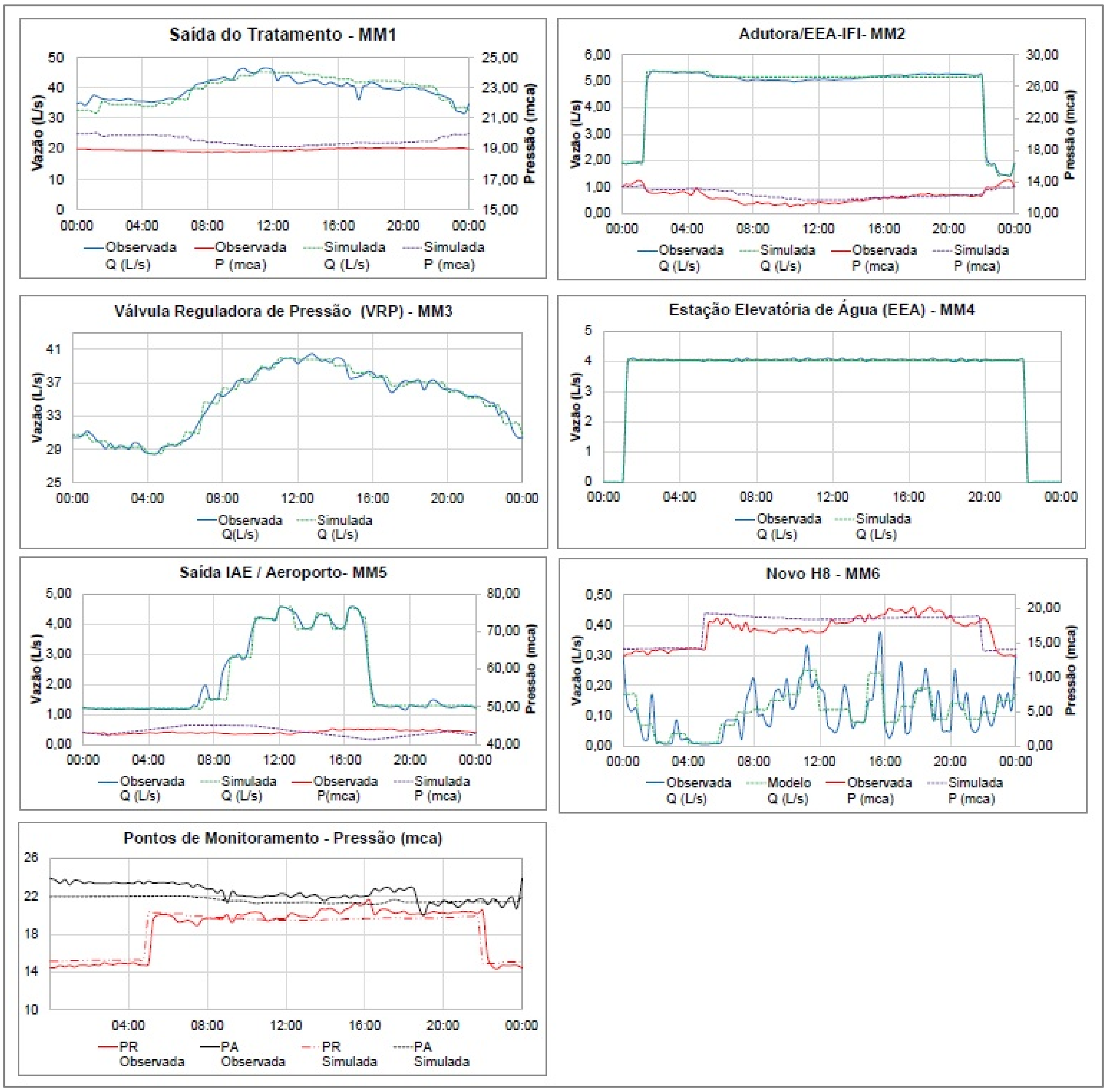

Figure A7. Calibration Results of the Hydraulic Model, Flow and Pressure Parameters.

A.1.5. Integration

The QGISRed plugin was employed to integrate the calibrated hydraulic model in EPANET with the QGIS software. It made it possible to take advantage of its functionalities and promote communication between both programs through the conversion of .INP files. This way, it is possible to visualize and examine the results of the hydraulic simulation in the GIS. By combining hydraulic and mechanical information with other relevant data such as water quality and pipeline replacement cost, a database could be established for the application of the risk assessment model proposed in the research.

A dynamic simulation of the integrated hydraulic model, followed by a simple field calculation in the attribute table of the respective vector layer, was performed to determine the minimum and maximum value of the hydraulic parameters in each pipeline segment. As an example of the use of the tools, the integrated hydraulic model to QGIS with the simulated flow and pressure results at 12 pm were presented in Figure A8.

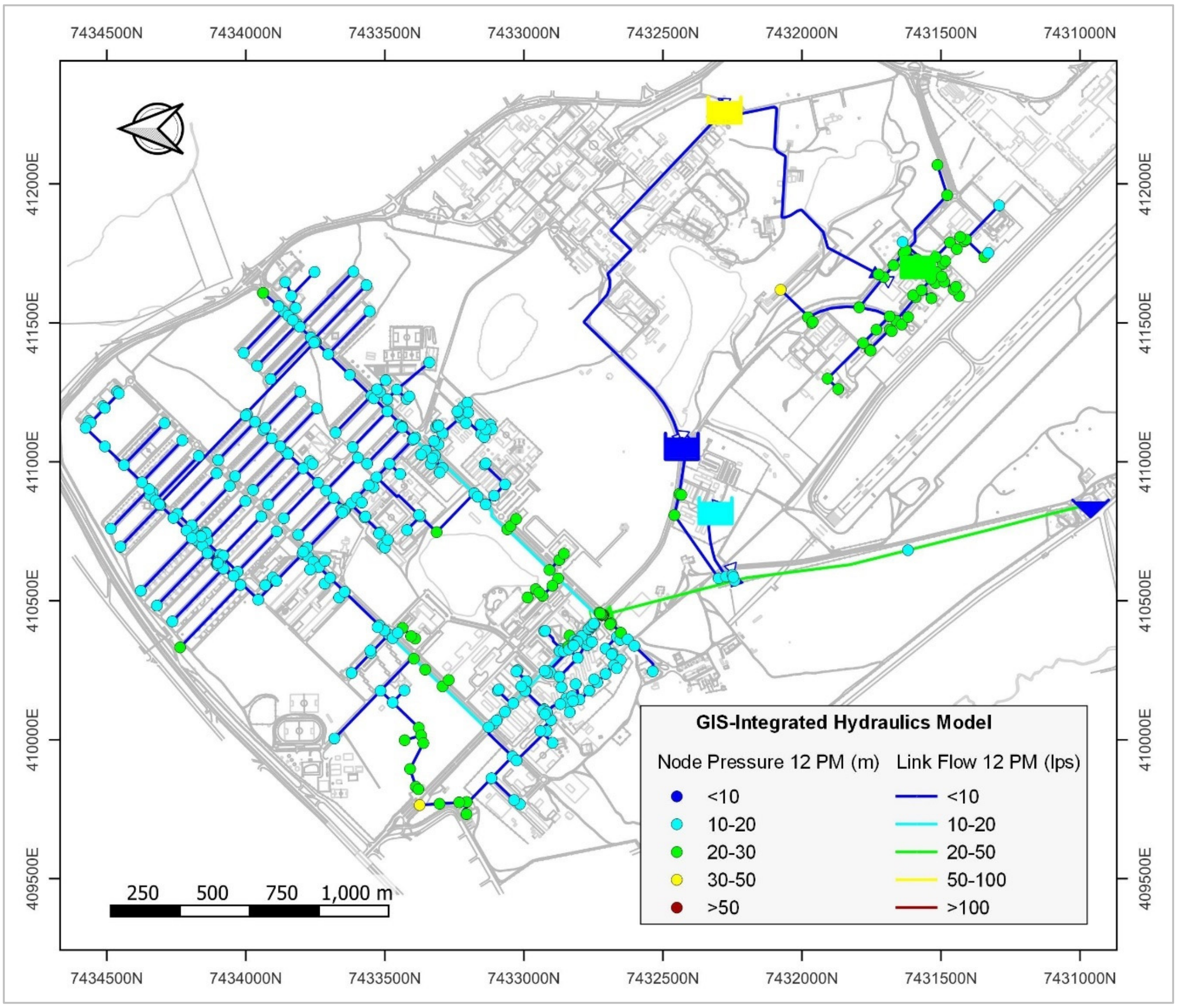

Figure A8. Example of the Hydraulic Model Integrated with QGIS, Pressure and Flow Results at 12 PM.

A.1.6. Analysis of Results

There is no universally accepted maximum deviation for the validation of the results of hydraulic modeling. The required accuracy depends on various factors, including the objective of the model, the complexity of the system, the quality and availability of the data. In general, the acceptable deviation varies between 5% and 20%, but can be lower or higher depending on the specific circumstances. For example, for the design, management or control of water quality in the system, a maximum deviation of 5% is recommended. On the other hand, for the study of the state variables of the network, such as pressure, flow and velocity, a deviation of 10% is allowed [7].

In this context, it can be stated through the analysis of the calibration results of the hydraulic model that its performance is adequate for the study's objective, obtaining the design parameters in the distribution network, as they showed a deviation of less than 10%. However, the simplification of the model limited the obtaining of hydraulic parameters in all the pipes of the distribution network, a reduction of 23% of the total extension. Therefore, as points of improvement, it is recommended the expansion of the meter park (micro-metering), the monitoring of the reservoir levels and the systematic recording of data (flow, pressure and reservoir levels), using, for example, the SCADA supervisory system, allowing the updating and optimization of the hydraulic model of this case study.

A.1.7. Documentation

In this document, Appendix A, there is a record of the modeling process, the results obtained, and the conclusions so that the model can be reviewed and updated in the future. It should be noted that the hydraulic model in digital format is available from the corresponding authors upon reasonable request.

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