

PERFORMANCE ASSESSMENT OF THE WASTEWATER SYSTEM OF PÓVOA DA GALEGA

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ABSTRACT

Due to the increasing complexity of the wastewater drainage systems in Portugal and the increased importance given to its optimization, it is acknowledged the importance of mathematical modelling, by the managing companies, as an evaluation tool for these systems.

This dissertation, made in partnership with SimTejo, aims to deliver a performance analysis to all the wastewater system of Póvoa da Galega, including the drainage system and the Wastewater Treatment Plant (W.W.T.P.) of Póvoa da Galega.

Therefore, to perform this analysis, a model was built using Bentley SewerGEMS in which was simulated the entire network, with all its components characterized. This model aimed to analyse not only the behaviour of the current system to various rainfall events, but also its behaviour with the introduction of some modifications designed to improve the drainage system.

Result analysis was focused on the compliance with the legislative standards to dry weather, and for the wet weather alternatives the verification of the discharged volumes into receiving waters, as well as the discharged volumes at the W.W.T.P. of Póvoa da Galega.

At the same time, it was made a performance analysis to the W.W.T.P., to the current situation and for a future scenario, where the pumping station was improved. Some modifications to the treatment scheme were also suggested, in order to improve the plant's hydraulic behaviour and functionality.

With this study, it is possible to conclude that the drainage system will perform on a higher level, compared to the current situation, with the modifications of the third scenario. On the other hand, the W.W.T.P. will show improved behaviour with the introduction of a new pre-treatment phase and the construction of a second line to the secondary treatment phase.

Key words: Combined sewer systems, mathematical modelling, SewerGEMS, wastewater, wastewater treatment plant.

1 INTRODUCTION

1.1 PRELIMINARY REMARKS

On today's society, it is increasingly important and defying the management and optimization of the wastewater infrastructures, and assure the compliance of the legislative standards.

Ferreira (2006), Amorim (2008) and Vaz (2011), refer that the usage of structural solutions associated to mathematical modelling and real time control, aiming the optimization of the systems performance, is a tool more and more powerful, collecting a bigger number of followers.

Therefore, according with Ferraz (2013), the utilization of mathematical models of integrated systems of wastewater drainage it's increasingly important, whether it is on the design phase, operation phase, maintenance and rehabilitation, aiming the assessment of those systems.

These infrastructures imply a major investment, and many times these systems operate with a several number of deficiencies, due to design errors and to untidy exploitation, according to IGAOT (2004).

1.2 METHODOLOGY

The aim of this study is to analyse the general performance of the wastewater system of Póvoa da Galega, verifying the drainage system and the wastewater treatment plant (W.W.T.P.).

To assess the drainage system, it was built a mathematical model, simulating dry weather conditions, as well as wet weather conditions to four rainfall events, occurred between October and November of 2013.

Hence, four scenarios where analysed, one for the current configuration of the drainage system and three encompassing the introduction of weirs and the deactivation of some pumping stations.

It was intended to analyse the system inputs, the weirs behaviour, the inputs to the W.W.T.P., as well as the compliance of the legislative standards. The model was calibrated with the measured tributaries volumes to the WTPP.

Lastly, W.W.T.P. was assessed intending to ascertain its main deficiencies, hydraulically and functionally. There were considered three scenarios all using the current configuration of the plant. The first one aimed to analyse the plant to the current flow input, the second considering the maximum flow of the current pumping station nº3 and the third considering the maximum flow of the future pumping station nº3.

2 GENERAL CHARACTERIZATION OF PÓVOA DA GALEGA WASTEWATER SYSTEM

2.1 DRAINAGE SYSTEM

Póvoa da Galega wastewater system is located on the Milharado and Venda do Pinheiro parishes, municipality of Mafra, Lisbon district. Its drainage system has 10.7 km of interceptors and seven pumping stations. Characteristics of the interceptors and pumping stations are given in the **Error! Not a valid bookmark self-reference.** and Table 2 , respectively.

Table 1 – Characteristics of the interceptors

Location	Design flow (l/s)	Diameter (mm)
Roussada interceptor	5,5	200
Asseiceira I interceptor	5,1	200
Asseiceira II interceptor	8,9	200
Asseiceira III interceptor	14,7	200
Casais da Serra interceptor	3,8	200
Vale de S.Giãõ I interceptor	4,6	200
Vale de S.Giãõ II interceptor	6,8	200
Vale de S.Giãõ III interceptor	10,1	200
Casais de Pedregulho interceptor	2,5	200
Charneca collector	5,4	200

Table 2 - Pumping stations characteristics

Pumping station	Location	Provenance	Design flow (l/s)
EE1	Right side of Roussada's brook	Asseiceira Grande interceptor	13,0
EE2	Right side of Vale de São Giãõ's brook	EE1 and Casais da Serra interceptor	20,0
EE3	Upstream of the W.W.T.P.	EE2 and Casal do Pedregulho interceptor	30,0
EE4	Asseiceira Grande interceptor	Venda do Pinheiro	4,5
EE5	Roussada interceptor	-	4,5
EE6	Charneca collector	Other collectors	4,5
EE7	Casal do Pedregulho interceptor	-	4,5

Figure 1 shows the current configuration of the drainage network. The system on its current configuration has several shortcomings, like structural deformations, cracks and some sediment deposition. These shortcomings were mainly observed on Asseiceira's and Vale de São Giãõ's interceptors.

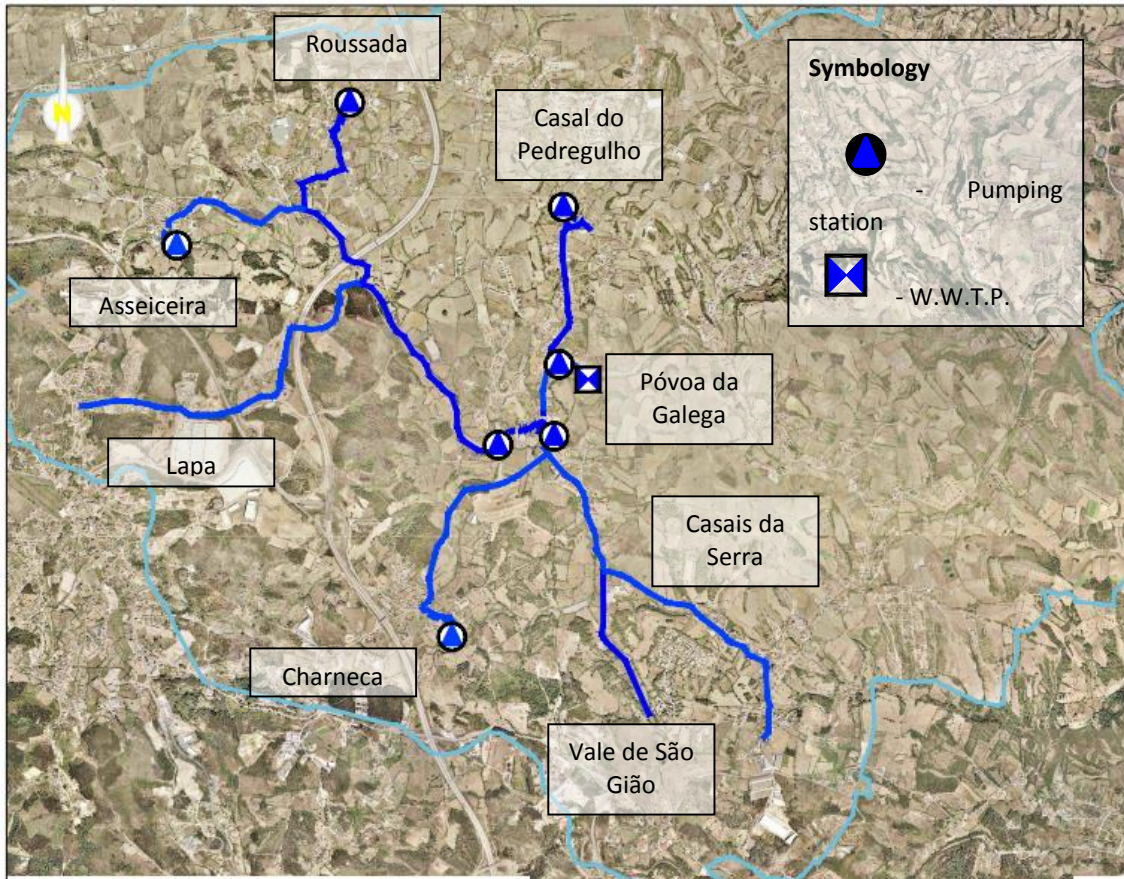


Figure 1 - Drainage network of Póvoa da Galega

2.2 WASTEWATER TREATMENT PLANT

The W.W.T.P. (Figure 2) has the following treatment scheme:

- Pre-treatment – grit removal, mechanical and manual.
- Primary treatment – sedimentation on settling tank.
- Secondary treatment – attached growth with trickling filter and a secondary settling tank.
- Tertiary treatment – sand filtration and ultraviolet disinfection.

This plant presents as its main shortcomings the non-existence of a scourer and a sand trap, which consequently decreases the settling tank and the trickling filter efficiencies. Adding to this, the plant does not possess a good and well-designed coagulation and flocculation phase, required to increase the settling tank efficiency.



Figure 2 - Póvoa da Galega's Wastewater Treatment Plant (SimTejo, 2009)

3 DESIGNED MODIFICATIONS TO THE DRAINAGE SYSTEM

In order to improve the hydraulic behaviour of the wastewater system there were advocated several modifications to the system, exhibited on Table 3.

Table 3 - Designed modifications to the drainage system

Groups of Modifications	Modifications
I	Construction of Casais da Serra, Lapa, Póvoa-1, Póvoa-2, Póvoa-3 and Roussada's weirs.
II	Construction of the Montachique's weir, rehabilitation of Vale de São Gião's interceptor and construction of the Montachique's interceptor.
III	Rehabilitation of Asseiceira interceptor.
IV	Rehabilitation and magnification of Póvoa da Galega's interceptor.
V	Construction of the new pumping stations and deactivation of the pumping stations nº1, 2 and 3.

These modifications were designed with the intent of increasing the predominance of flow by gravity over pumped flow, improve the general capacity of some interceptors and also reduce the volume, due to rainfall events, collected by the W.W.T.P.

On this study, the assessment focused on groups I, IV and V. The weir designed for the Lapa collector was not studied.

4 PERFORMANCE ASSESSMENT OF THE DRAINAGE SYSTEM

4.1 MATHEMATICAL MODEL

In order to assess the Póvoa da Galega's drainage system, a Bentley SewerGEMS model was used. This software provides an integrated analysis of the system, allowing the creation of numerous scenarios and alternatives, whether they're physical or climatic.

The model was built through the insertion of several components, such as:

- Conduits.
- Manholes.
- Catchments
- Pressure pipes.
- Weirs.
- Pumps.
- Wet wells.
- Outfalls.

Drainage system assessment was focused on four major scenarios, each one providing one different configuration to the system. Scenario one focused on the current configuration and scenario two presented the addition of the weirs to scenario one. Whereas scenario three focused on the deactivation of the pumping stations 1 and 3, scenario four had the deactivation of units 2 and 3. All these scenarios were studied to five climatic alternatives, one to dry weather and the other four with different rainfall events occurred between October and November of 2013.

4.2 RESULTS

4.2.1 DRY WEATHER

To study dry weather conditions, three criteria were analysed:

- $0,3\% < \text{slope} < 15\%$,only analysed on scenario 1.
- $0,6 \text{ m/s} < \text{velocity} < 3 \text{ m/s}$.
- $\text{Rise/depth} \leq 0,5$.

Most of the conduits complied with the slope standard, being Asseiceira's interceptor the one that presents a larger number of irregularities. There were also detected some conduits with a 0 or negative slope, indicating some soil consolidation throughout the network.

In dry weather condition all the scenarios have showed good system behaviour, despite some problems with the minimum velocity (Table 4). Maximum velocity was complied in all scenarios.

Table 4 - Minimum velocity irregularities for dry weather conditions

Scenario	Conduits that complied the minimum velocity	Total conduits
1	52	234
2	28	244
3	38	254
4	32	255

The rise/depth condition was not complied in all conduits, mainly on Asseiceira's interceptor, with irregularities on 31 of its 74 conduits.

4.2.2 WET WEATHER

To assess the system in wet weather conditions, there were verified the total affluent volumes at the system (Table 5) and the affluent volume at the W.W.T.P. (Table 6), comparing the values for each scenario and analysing the impact of each modification on the total volume that the plant receives.

Table 5 - Total affluent volume to the system for each rainfall event

	Volume (m ³)			
	19/10/2013	24/10/2013	05/11/2013	08/11/2013
Total	6902,8	24587,6	27,3	2399,7

Table 6 - Total affluent volume to the W.W.T.P.

Rainfall event	Volume (m ³)			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	1020,72	1003,47	1085,86	1375,74
2	2361,41	2342,53	2969,18	3532,56
3	505,80	506,38	507,29	509,31
4	914,23	904,17	958,62	1044,84

There were also analysed two legislative standards for wet weather conditions:

- $0,9 \text{ m/s} \leq \text{velocity} \leq 5 \text{ m/s}$.
- Rise/depth ≤ 1 .

Analysing Table 6, it is possible to conclude that the insertion of weirs leads to a reduction of affluent volume to the W.T.T.P., providing also a better routing for the stormwater to the receiving environment. On the other hand, scenario 3 has a lower affluent volume to the plant, in comparison with scenario 4. With less affluent flow, the plant will have lower operation costs.

The minimum velocity was enhanced in scenarios 2, 3 and 4, compared with scenario 1, the current system configuration. The maximum velocity criteria were violated in all scenarios, but that just occurred to one conduit in scenarios 1 and 2, and in two conduits in scenarios 3 and 4.

During some simulation steps, it was verified the occurrence of overflows in all scenarios, mainly on Casais da Serra's interceptor and on Asseiceira's interceptor, as shown in Figure 3 and Figure 4. Once the studied modifications did not include improvements on these interceptors, the problems were similar in every scenario, being aggravated in the events with higher precipitation.

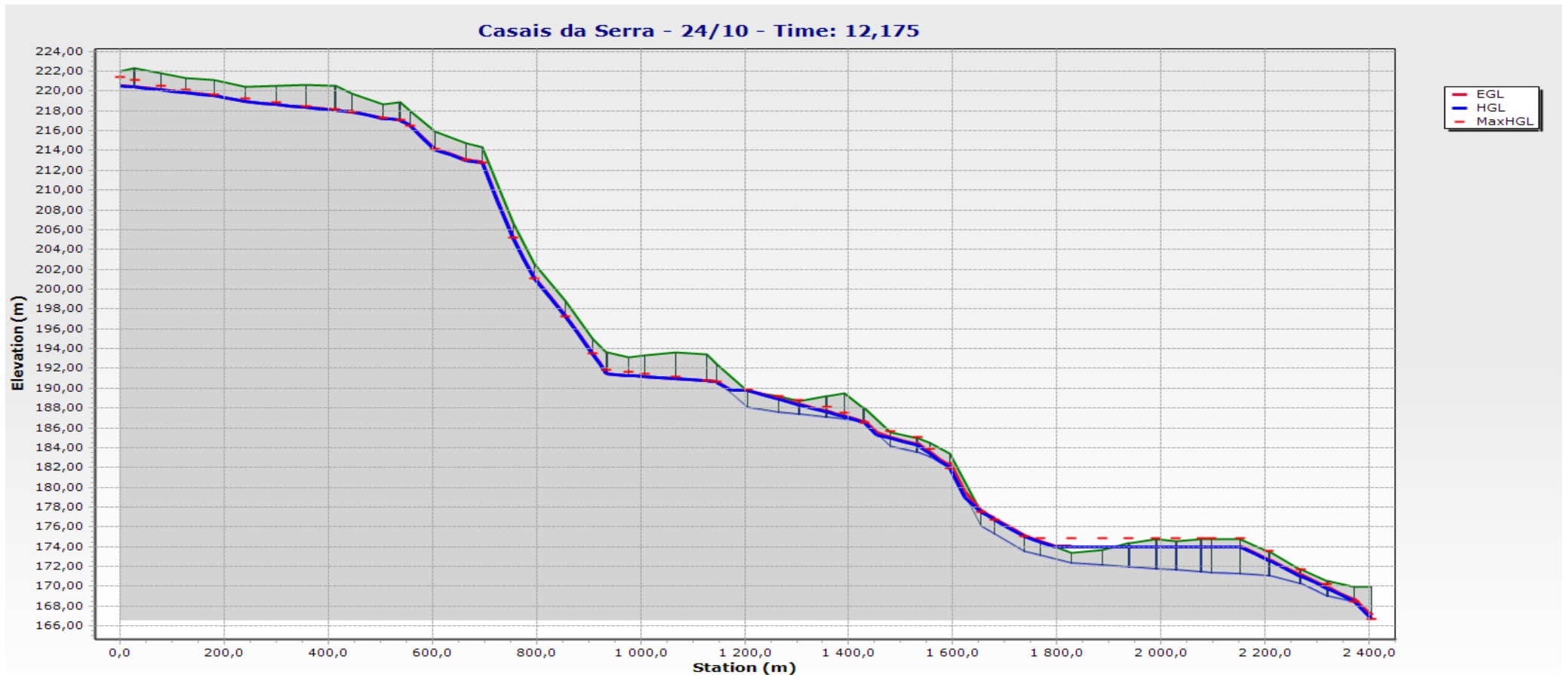


Figure 3 – Profile of the Casais da Serra interceptor for scenario 2

Asseiceira - 24/10 - Time: 12,175

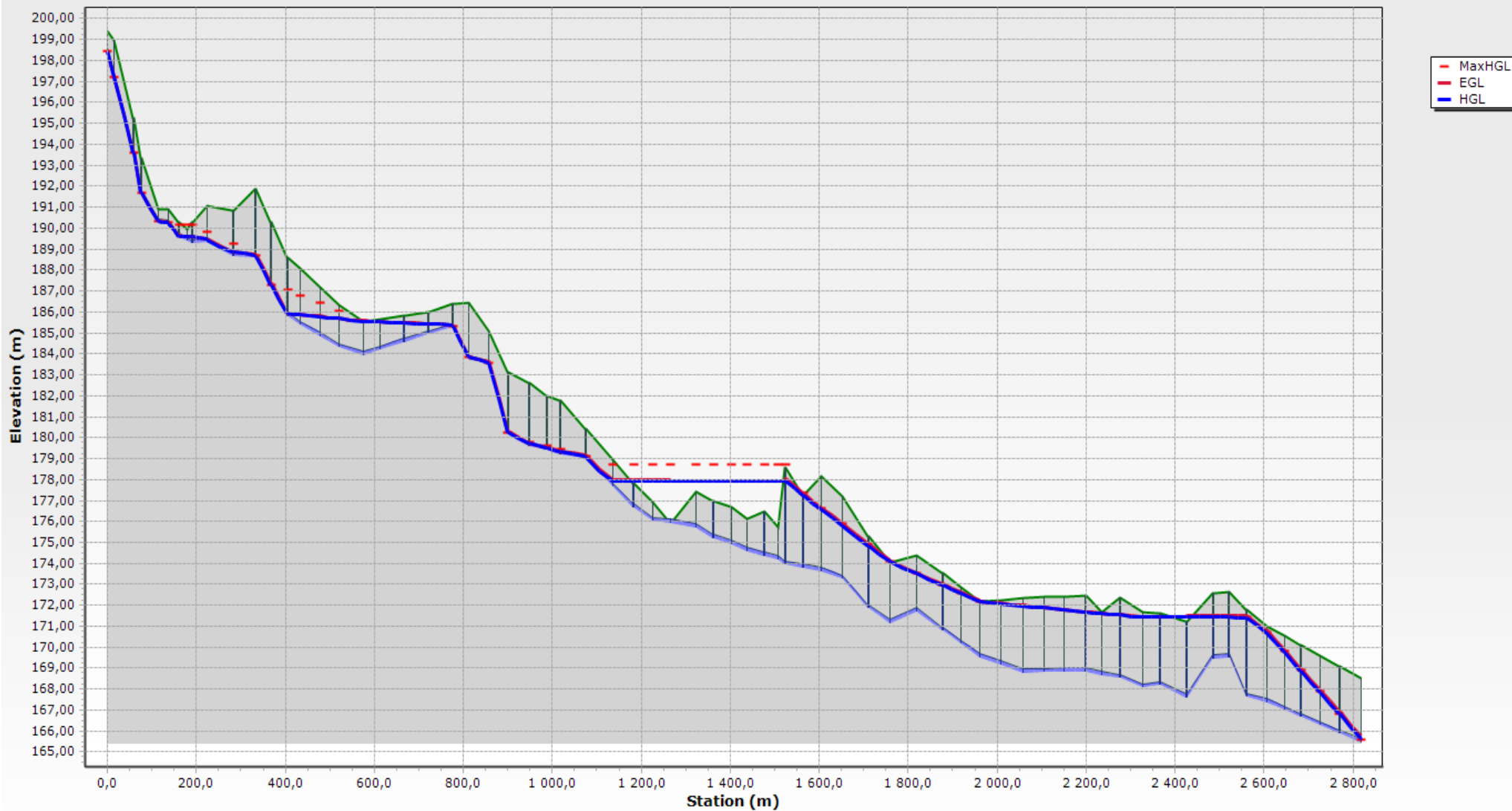


Figure 4 – Profile of the Asseiceira's interceptor for scenario 3

5 PERFORMANCE ASSESSMENT OF THE WASTEWATER TREATMENT PLANT

5.1 PERFORMANCE ASSESSMENT

In order to assess the W.W.T.P., three scenarios were analysed. Whereas the first one studied to the current situation, with the design flow given in Table 7, the second one studied the plant to the maximum design flow of the pumping station n^o3,

Table 8. Lastly, the plant was assessed to the maximum design flow of the new pumping station, given in Table 9.

Table 7 – Design flow for the first scenario

Population (inhab)	Per capita average daily flow (l/inhab.day)	Average flow (m ³ /day)	Peaking factor (-)	Peak flow (m ³ /dia)	Peak flow (l/s)	Design flow (m ³ /dia)
7766	120	745,54	2,4	1998,67	23,13	745,54

Table 8 - Design flow for the second scenario

Average flow (m ³ /day)	Peak flow (m ³ /day)	Peak flow (l/s)	Design flow (m ³ /day)
996,92	2592,00	30,00	996,92

Table 9 - Design flow for the third scenario

Average flow (l/s)	Peak flow (m ³ /day)	Peak flow (l/s)	Design flow (m ³ /day)
21,08	4553,28	52,70	1821,31

Assessment of all the plant components was made using hydraulic criteria provided by Tchobanoglous et al.. (2003), for the primary and secondary phases, and Cairns et al.. (2006) for the U.V. disinfection. These criteria are presented on Table 10 and Table 11.

Table 10 - Hydraulic criteria (Tchobanoglous et al., 2003)

Parameter		Primary settling tank		Secondary settling tank		Trickling filter		Sand filter		UASB reactor	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Hydraulic loading (m ³ /(m ² /h))	Average	2,08	1,25	1,17	0,67	1,67	0,42	14,40	4,80	-	-
	Peak			2,67	1,67						
Detention time (h)		2,08	1,25	8,00	4,00	-	-	-	-	60,00	
BOD removal efficiency (%)		-	-	-	-	90,00	50,00	-	-	-	-
Organic Loading (kg BOD/(m ³ /h))		-	-	-	-	0,10	0,02	-	-	-	-
Depth (m)		4,30		6,00	3,50	-	-	-	-	5,00	3,00

Table 11 - Lethal dose for each microorganism (Cairns et al., 2006)

Microorganism	Lethal dose (mJ/cm ²)
E-coli	7,0
<i>Pseudomonas aeruginosa</i>	7,6
<i>Legionella pneumophila</i>	9,6
<i>Cryptosporidium</i>	16,0
Giardia	20,0

The functioning conditions for all the equipment, in each scenario, are given from Table 12 to Table 17.

Table 12 - Performance assessment of the primary settling tank

Parameter	Scenario one		Scenario two		Scenario three	
	Average	Peak	Average	Peak	Average	Peak
Volume (m ³)	72,69					
Area (m ²)	38,49					
Depth (m)	2,62					
Hydraulic loading (m ³ /(m ² /h))	0,81	2,16	1,08	2,81	1,97	4,93
Detention time (h)	2,34	0,87	1,75	0,67	0,96	0,38

Table 13 - Performance assessment of the secondary settling tank

Parameter	Scenario one		Scenario two		Scenario three	
	Average	Peak	Average	Peak	Average	Peak
Volume (m ³)	157,84					
Area (m ²)	60,48					
Depth (m)	2,61					
Hydraulic loading (m ³ /(m ² /h))	0,51	1,38	0,69	1,79	1,25	3,14
Detention time (h)	5,08	1,90	3,80	1,46	2,08	0,83

Table 14 - Performance assessment of the trickling filter

Parameter	Scenario one		Scenario two		Scenario three	
	Average	Peak	Average	Peak	Average	Peak
Volume (m ³)	451,00					
Area (m ²)	225,50					
Depth (m)	2,00					
Affluent BOD (mg/L)	116,95		156,39		243,29	
CBO5 Efluente (mg/L)	14,81		19,81		36,19	
Efficiency (%)	0,87		0,87		0,85	
Organic loading (kg CBO ₅ /(m ³ /h))	0,02		0,03		0,04	
Hydraulic loading (m ³ /(m ² /h))	0,14	0,37	0,18	0,48	0,34	0,84

Table 15 - Performance assessment of the sand filters

Parameter	Scenario one		Scenario two		Scenario three	
	Average	Peak	Average	Peak	Average	Peak
Diameter (m)	3,00					
Area (m ²)	7,10					
Number of filters (-)	3,00					
Hydraulic loading (m ³ /(m ² /h))	1,46	3,91	1,95	5,07	3,56	8,91

Table 16 - Performance assessment of the UASB reactor

Parameter	Scenario one		Scenario two		Scenario three	
	Average	Peak	Average	Peak	Average	Peak
Volume (m ³)	802,70					
Area (m ²)	1015,55					
Depth (m)	5,40					
Detention time (h)	123,58		92,42		50,33	

Table 17 - Performance assessment of the U.V. disinfection

Microorganism	Design dosage (mJ) (
E-coli	12,0
<i>Pseudomonas aeruginosa</i>	22,0
<i>Legionella pneumophila</i>	38,0
<i>Cryptosporidium</i>	40,0
Giardia	40,0

Analysing this results, it is possible to conclude that the plant will present a good behaviour in scenarios one and two, struggling on scenario three, mainly on the secondary settling tank and on the UASB reactor.

Hence, in order to improve the plant behaviour for the future scenario, some modifications are suggested:

- Construction of a new pre-treatment phase, with a scourer and a sand trap.
- Construction of a new rapid mixing phase, in order to improve the flocculation and coagulation, enhancing as well the functional behaviour of the secondary settling tank.
- Increase of the primary settling tank depth, enhancing the detention time.
- Construction of another secondary settling tank, with the same area as the current one, and increase of the current one's depth, reducing simultaneously the hydraulic loading and detention time.
- Deactivation of the UASB reactor.
- Construction of a sludge thickener and dehydrator.
- Construction of a chemical stabilization phase, with the addition of whitewash.

6 CONCLUSIONS

The mathematical model used to assess the drainage system, was only correctly calibrated with a *per capita* daily flow of 80 l/inhab/day instead of the usual 120. This led to conclude that the system probably has several leaks throughout the length of its interceptors or that the pumping stations are working below their design flow. The user rate values can also present too high values for this location.

In all scenarios, the system showed a good behaviour in dry weather conditions, despite of some problems with minimum velocity criteria for conduits. With wet weather conditions, scenarios 3 and 4 presented the best behaviour, notwithstanding of some overflow occurred mainly on Asseiceira's interceptor. These two scenarios reduced significantly the received volume at the W.W.T.P., enhancing as well the conduits rise on some interceptors such as Casais da Serra and Roussada. In spite of having very similar hydraulic behaviour, scenario 3 has a lower general cost than scenario 4, about 34 thousand € less, presenting the better cost/benefit relation.

The W.W.T.P. performance assessment led to the conclusion that the plant will endure, with the current configuration, the solicitations of scenarios one and two, but it will struggle in scenario three. Therefore some modifications were suggested, to the liquid and sludge phase, in order to improve the plant's general behaviour.

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