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Water and Environment Support in the ENI Southern Neighbourhood region

N-W-1-EG1

STRENGTHEN THE WATER UTILITIES CAPACITIES TO MANAGE/REDUCE NRW AND DETECT LEAKAGE

T3 & T4 - Hydraulic Model and Zone Design Report

29 October 2022

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v.1	*WES N-W-EG1 T3 NA Report*	*Paolo RUFINI*	*Suzan TAHA*

WATER AND ENVIRONMENTAL SUPPORT
IN THE ENI SOUTHERN NEIGHBOURHOOD REGION

The "Water and Environment Support (WES) in the ENI Neighbourhood South Region" project is a regional technical support project funded by the European Neighbourhood Instrument (ENI South). WES aims to protect the natural resources in the Mediterranean context and to improve the management of scarce water resources in the region. WES mainly aims to solve the problems linked to the pollution prevention and the rational use of water.

WES builds on previous similar regional projects funded by the European Union (Horizon 2020 CB/MEP, SWIM SM, SWIM-H2020 SM) and strives to create a supportive environment and increase capacity all stakeholders in the partner countries (PCs).

The WES Project Countries are Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Libya, Palestine, Syria and Tunisia. However, in order to ensure the coherence and effectiveness of EU funding or to promote regional cooperation, the eligibility of specific actions can be extended to neighbouring countries in the Southern Neighbourhood region.

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ABBREVIATIONS

AOD	Above Ordnance Datum, used to specify heights above mean sea level
AOI	Area of Interest
AWWC	Asyut Water and Wastewater Company
CARL	Current Annual Real Losses
DB	Database
DMA	District Metering Area
DMZ	District Metering Zone
DN	Diamètre Nominal (Nominal Diameter)
EPSG	European Petroleum Survey Group. It is a public registry of geodetic datum, spatial reference systems, Earth ellipsoids, coordinate transformations and related units of measurements.
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
HCWW	Holding Company for Water and Wastewater
HP	Horsepower
ILI	Infrastructure Leakage Index
IWA	International Water Association
kVA	kilovolt-Ampere
Kw	Kilowatt
lps	litre per second
m	metre
m^3*/day*	cubic metre per day
m^3*/hour*	cubic metre per hour
m^3*/year*	cubic metre per year
MLD	Million Litres per day
mm	millimetre
NOS	Normal Operating Status
NRW	Non-revenue Water
POI	Point of Interest
PRV	Pressure Reducing Valve
PS	Pump Station
SMS	Short Message Service
TP	Treatment Plant

UARL	Unavoidable Annual Real Losses
WDS	Water Distribution System
WGS	World Geodetic System
WKID	Well-Known ID
WSS	Water Supply System
WTP	Water Treatment Plant
WTS	Water Transmission System

1 EXECUTIVE SUMMARY

This report comprises the third deliverable within the framework of the second task of WES activity in Egypt (WES-N-W-EG-1) titled "*Strengthen the water utilities capacities to manage/reduce NRW and detect leakage*". *Task 3: Calibration of the Hydraulic Model for the network* and *Task 4: Preliminary division and design of the network system into distribution zones (DZ) and design of the zones* of the said activity provide for: (1) organizing and importing water supply network facilities data and demand data into the hydraulic model software,; (2) supporting AWWC in carrying out field activities to monitor flow and pressure and analysing these data to adapt the hydraulic model to the field results; (3) the preliminary design of DMAs, assessing their NRW rate and finally indicating interventions to be implemented in the near future.

The AWWC Reduction of Water Losses and Hydraulic Analysis department uses WaterCAD as a hydraulic modelling software. AWWC has already developed a schematic of the overall network, importing data from the GIS. The existing schematic and the customer database were checked in order to evaluate whether they could have been used for this analysis. A separate hydraulic model was therefore developed in order to use the monitored data of flow and pressure collected during the activity. DMAs were developed with the developed model indicating both the type and size of flowmeters to be installed and where to install valves to be closed for the DMA implementation. In the end, a KPI has been adopted to rank the DMA in order to prioritize the near future activities.

2 INTRODUCTION

The total domestic water use in Egypt is estimated at about 5.5 billion m³ per year or 8% of total water use. This corresponds to an average of about 200 litres per capita per day (l/c/d). Water use varies considerably between different localities in Egypt. For example, the installed drinking water supply capacity ranges from 70 l/c/d in Upper Egypt to 330 l/c/d in Cairo. Water consumption in Alexandria is about 300 l/c/d. Furthermore, actual domestic water use is lower because of network losses. For example, in 2011, the water transmission and distribution losses amounted to 31% of the produced amount of water. This is estimated to be partially due to pipe leakage and partially due to unaccounted-for water calculated by subtracting the amount of water sold from the amount of water produced.

As a result, Egypt has asked the WES Project to implement a national activity entitled "[Strengthen the water utilities capacities to manage/reduce NRW and detect leakage]".

3 SCOPE OF WORK

The overall objective of this activity is "to assist a selected water utility to target the reduction of Non-Revenue Water (NRW) and to continue its efforts to improve NRW management".

The specific objectives are to:

- Investigate the situation of non-revenue water management in a pilot city served by Asyut Drinking Water and Sewerage Company and prepare its network, as part of a rational planning aimed to NRW reduction, to the next stage of implementation of distribution zones/sectors and their subsequent division into District Metered Areas (DMAs).
- Implement and calibrate a hydraulic model for the network of the pilot city as a tool to provide valid support to move into the design stage and establishment of DMAs
- Introduce internationally recognised best practices for improving NRW (including the design of Distribution Zones and the use of GIS to enable analysis of the geographical distribution of leakage).
- Build the capacity of the utility staff involved in the pilot area on the implementation of best practices for the management of non-revenue water through on-the-job training and direct involvement in the implementation of the tasks with the support of non-key experts (field data analysis, water balancing, model calibration, and fixing anomalies between the results of the model calculations and the field data).
- Develop a manual documenting the proposed procedures for reducing NRW in Asyut city water network.

4 TARGET GROUP

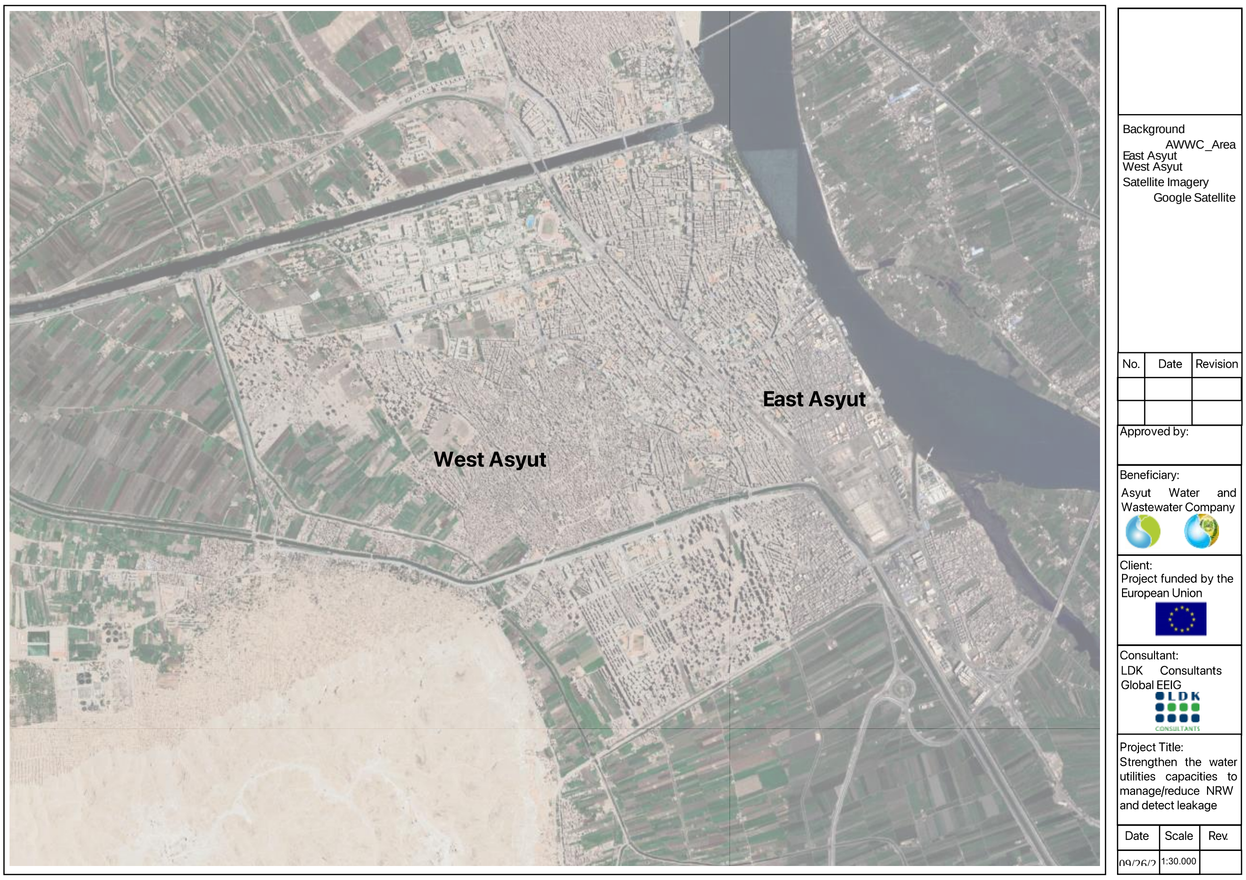
The main partners and beneficiaries of the project are:

Partner (Main Beneficiary)	Name of Institution: Asyut Water and Wastewater Company Contact person's First Name: Marwa Contact person's Last Name: Ahmed Title and position: Loss Department Manager Email: measurements@ascww.com.eg Mobile: +201 272 669 558
Other beneficiaries	Name of Institution: Holding Company for water and wastewater (HCWW) Contact person's First Name: Tarek Contact person's Last Name: Nada Title and position: Head of Planning and Design Sector Email: Tarek.Nada@hcww.com.eg Mobile: +201 282 333 341 Name of Institution: Ministry of Water Resources and Irrigation Contact person's First Name: Walid Contact person's Last Name: Hakiki Title and position: WES Focal Point & Head of Central Department for Water Resources and Uses - Planning Sector Email: walidhakiki@yahoo.com Mobile: +2 01223409805

5 DESCRIPTION OF THE STUDY AREA

The activity was implemented for the Asyut city water network; an extended water supply system of more than 250 km and multiple water sources served by the Asyut Drinking Water and Sewerage company. Asyut city is customarily divided into two sub-zones: West Asyut (AlGharb) and East Asyut (AlSharq); the two zones constitute the study area of this project.

Figure 1: Zones of Asyut city



6 TASKS, RESULTS & DELIVERABLES

In accordance with the Terms of Reference, this intervention is divided into five (5) tasks according to the brief description of the tasks and the corresponding results and deliverables summarized in the following **Error! Reference source not found.**:

Table 1: Tasks and Deliverables

Tasks	Results	Deliverables
Task 1: Inception Phase	1. The various stakeholders concerned are identified and involved, where appropriate, in the study; 2. Initial data assessment (Background, Network, Infrastructure, Customers) is performed 3. The plan of actions necessary to carry out the activity is agreed with the partners during a one-day inception workshop. 4. The requirements and necessary resources from the stakeholders are agreed upon. 5. The scope of work and job profiles of the GIS and non-revenue partner teams members are agreed upon 6. The partner teams for GIS and non-revenue water are established	T1.1: Inception report. The report includes the results/outcomes of the Inception Workshop and the preliminary list of the main stakeholders involved in the activity
Task 2: Verification of GIS Maps and Customers Database (DB)	1. A diagnosis of existing Customers DB and network and infrastructures maps and data of the water utility assets in the study area as well as a review of possible gaps is performed: 2. Option 1: An action plan necessary to reach an updated state for water networks and installations and for the customers' database is proposed for implementation by the partner (with the support of the project). 3. Option2: A list for the necessary and relevant data/information to collect and an action plan to collect such data and for the preparation of digital maps of the network for implementation by the partner (with the support of the project). 4. A GIS DB Conceptual and Logical Data Model is prepared and t 5. The structure of the GIS database of the water supply network and facilities is implemented and the customers' database link to the GIS database is designed. (if any)	T2: GIS Database DB and Customers' DB Report reflecting the results of the workshop on GIS DB and Hydraulic Modelling

Tasks	Results	Deliverables
	6. Available water supply network and facilities' validated data are uploaded in the GIS DB	
Task 3: Calibration of the Hydraulic Model for the network	1. Water supply Network and facilities data are organized and imported into the Hydraulic Model tool for hydraulic calculation 2. Population and Demand data, together with the data available in the customers database, are combined to prepare the demand allocation necessary to perform the hydraulic calculation 3. Flow (Q) and Pressure (P) monitoring sites are selected 4. Q-P monitoring fieldwork is performed by the local staff with support and supervision of the project team experts 5. Analysis of the Q-P monitored data is performed and reflected in the hydraulic calculation to adapt the model results to the field work results	T3: Schematic Model and Hydraulic Model Report reflecting the results of the workshop on GIS DB and Hydraulic Modelling
Task 4: Preliminary division and design of the network system into distribution zones (DZ) and design the zones	1. The Distribution Zones (DZs) are preliminarily designed and the set of activities necessary to make the Zones controlled and isolated is developed. 2. The DZs are established and their tightness is checked with the support of the local expert and the supervision of the international expert. Actions to ensure their complete insulation are proposed 3. The Q & P monitoring sites for the Distributing Zones are identified and the Zones' inlet flow and pressure is monitored with the support of the local expert and the supervision of the project experts. 4. The NRW reference rate of each distribution zone is assessed (apparent and actual losses) by calculation of the water balance, with recommendations for the maximum rate of physical losses that can realistically be achieved. 5. Based on the results of the NRW assessment, a set of interventions to reduce NRW is identified and a priority list is proposed indicating those interventions which can be implemented immediately, while being cost effective and providing a rapid return on investment	T4: Hydraulic Model and Zone Design Report reflecting the results of the workshop on GIS DB and Hydraulic Modelling

Tasks	Results	Deliverables
Task 5: Elaboration of procedures to reduce NRW and prepare the synthesis report	1. A set of procedures aimed to reduce NRW is prepared giving special attention to: a. Data collection and GIS DB implementation, upload and maintenance b. Understanding of Hydraulic calculation as a tool to improve the performance of the water supply network c. Procedures for the operation and maintenance of the DZs d. Calculation of the water balance and analysis of results e. Guidance on how to divide the Distribution zones further into District Metered Areas (DMAs) 2. The results and recommendations of the activity are presented to the beneficiaries (in a one-day workshop) and are validated, and problems and potential solutions are discussed. 3. A dialogue between the different stakeholders is established (during the one-day workshop) and a set of actions is selected for which the country commits to implement during the WES project. 4. The Egyptian peers for the regional "Peer to Peer" exchange on Non-Revenue Water are identified and the set of topics of interest proposed.	T5.1: NRW reduction procedure reflecting the results of the workshop on GIS DB and Hydraulic Modelling T5.2: The report on the “GIS DB and Hydraulic Modelling” workshop according to WES guidelines. T5.3: Synthesis report

This report is the “T3 & T4: Hydraulic Model and Zone Design Report” and reflects the activities carried out in Task 3 and Task 4 of this project.

7 DATA COLLECTION

7.1 WATER DISTRIBUTION NETWORK

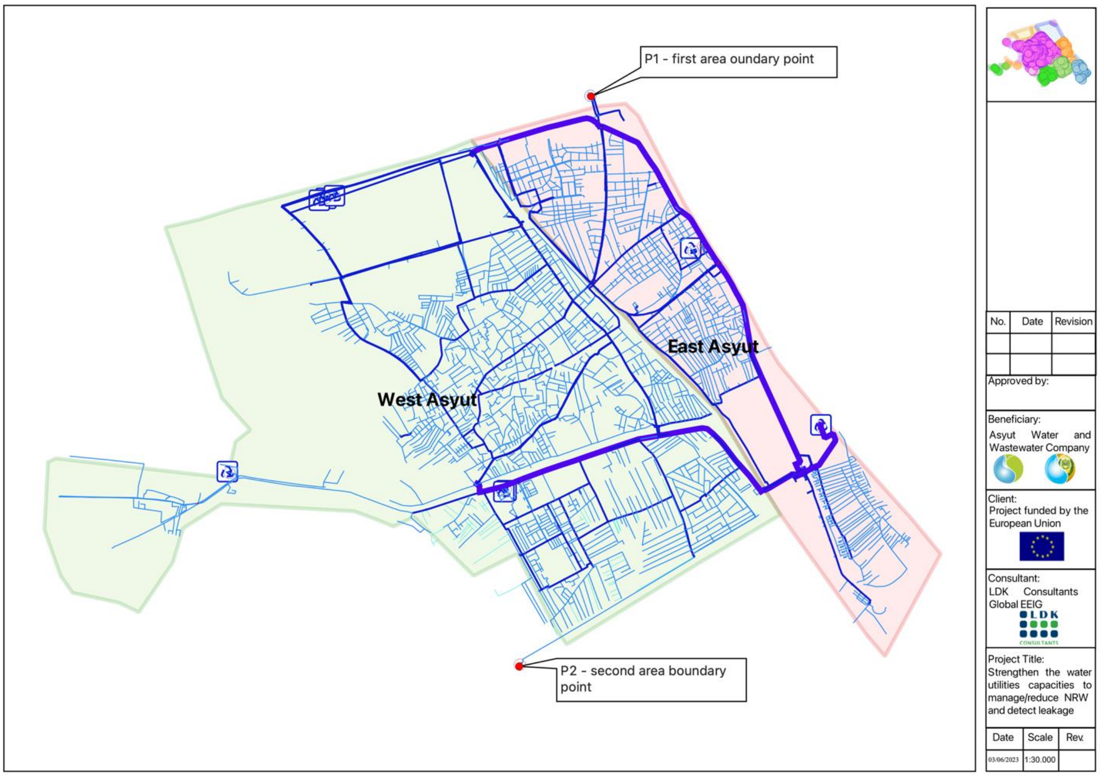
Asyut Water and Wastewater Company (AWWC) staff provided the following information about the network and the infrastructures of the Water Supply System (WSS) in Asyut.

There are 6 WTPs in the area that supply customers, five of which are in operation and equipped with flowmeters (in some cases permanent flowmeters, in other situations AWWC staff installed portable ones). The WTP considered in this analysis are:

1. Al Nazla WTP (in operation and flow-monitored)
2. Czech WTP (not in operation)
3. German WTP (also called Czech Artesian Well) (in operation and flow-monitored)
4. University Compact (in operation and flow-monitored)
5. Madabygh Compact (in operation and flow-monitored)
6. Forty Compact (in operation and flow-monitored)

The city area has two boundary points with the outbounds: the first area boundary point is between the city area and Walidieh and it is in the north-east part of Asyut; there is one lift station (P1) pumping the inlet flow into the city area. The second area boundary point is the outlet point between the city area and the Durunka area in the southern part of the city; a lift station (P2) also marks the boundary point. Two tanks support the peak supply of the area.

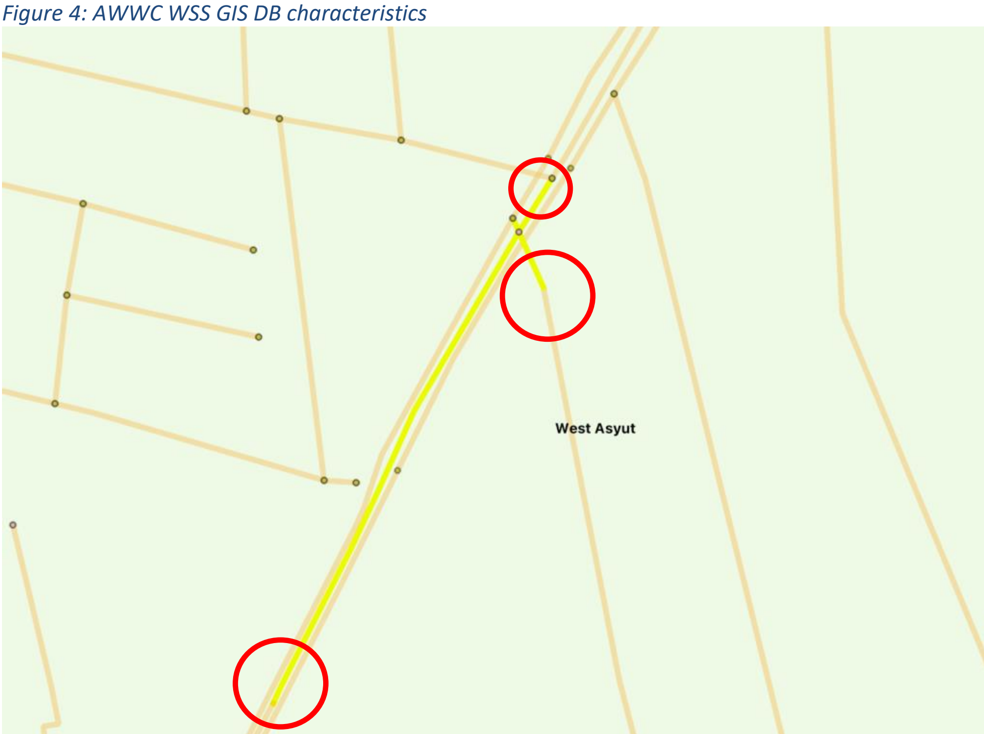
Figure 2: AWWC Water Supply System Boundary Points



Along with the data of the infrastructures, AWWC also has water supply network data (nodes positions and elevations, routes DN and materials of the pipelines) from the GIS that AWWC developed. Unfortunately, the WES team could not use the GIS data provided due to numerous errors (isolated nodes, lack of connectivity and missing data). Figure 3 shows some of the unconnected nodes and Figure 4 shows one of the cases where a lack of connectivity (the nodes do not break the pipe and, at the same time, where one pipe ends there is no node at that location) was noticed.

Figure 3: AWWC WSS GIS DB

Figure 4: AWWC WSS GIS DB characteristics



Afterwards, AWWC provided the network developed in Water GEMS (the one used for hydraulic calculations); Currently (at least until March 2022) the AWWC's water supply network GIS data are different from those used for HM calculations and the network layouts in the two databases have slightly different routes.

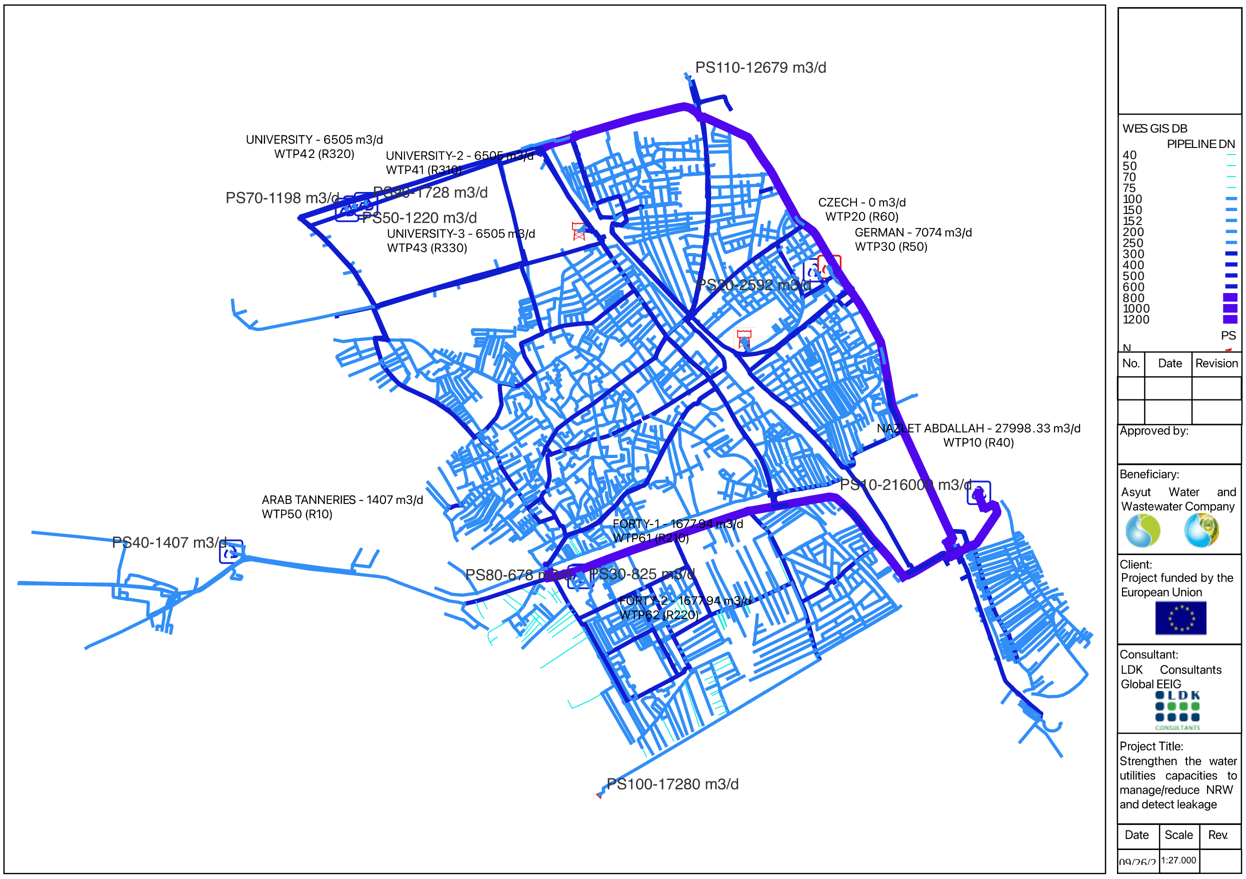
The WES team always emphasized to the AWWC staff the importance of maintaining the same origin of the GIS and HM data. This is a task that the WES team strongly recommends to the AWWC staff.

In the end, the WES team has exported the HM data to the WES WSS GIS DB – developed by the WES team in Task 2 of this project - to ease export to EPANET needed to perform calculations for zoning the city area.

Therefore, in this project, the WSS GIS DB network and the modelled network database are consistent and have the same source.

Next Figure 5 shows the transmission and distribution WSS of Asyut city uploaded into the WES WSS GIS DB. This is the basis adopted to perform the hydraulic calculations.

Figure 5: WES WSS GIS DB



Next Table 2 gives a summary view of the pipe length of Asyut WSS organised by DN and material.

Table 2: WES GIS DB pipe length by DN and material

DN	Length by DN (km)	Length by material (km)						
		AC	DI	GRP	HDPE	STEEL	UPVC	
40	2,47	-	0,72	-	-	-	1,75	2,47
50	0,13	0,02	0,11	-	-	-	-	0,13
70	3,49	-	1,32	-	0,08	-	2,09	3,49
75	0,31	-	0,26	-	-	-	0,06	0,31
100	56,73	1,35	21,25	0,35	1,43	0,49	31,87	56,73
150	109,41	0,44	57,27	0,68	3,87	0,01	47,15	109,41
152	0,42	-	0,09	0,04	-	0,21	0,08	0,42
200	41,21	1,15	21,44	0,58	3,55	0,19	14,29	41,21
250	9,16	1,05	1,37	0,52	0,24	0,44	5,54	9,16
300	33,29	1,80	26,16	1,35	0,79	1,00	2,20	33,29
400	12,19	1,12	5,76	2,44	0,94	0,12	1,80	12,19
500	12,23	-	3,92	5,19	-	1,49	1,64	12,23
600	1,63	-	0,30	0,02	-	1,31	-	1,63
800	5,93	0,02	0,58	4,35	-	-	0,97	5,93
1000	1,40	-	0,00	1,03	-	0,37	-	1,40
1200	0,64	-	-	0,64	-	-	-	0,64
	290,65							

7.2 MONITORING POINTS

A list of sites where monitoring points – both flowmeters and pressure gauges - were installed was provided by AWCC (see Table 3 below).

Table 3: AWWC Flow and pressure monitoring points

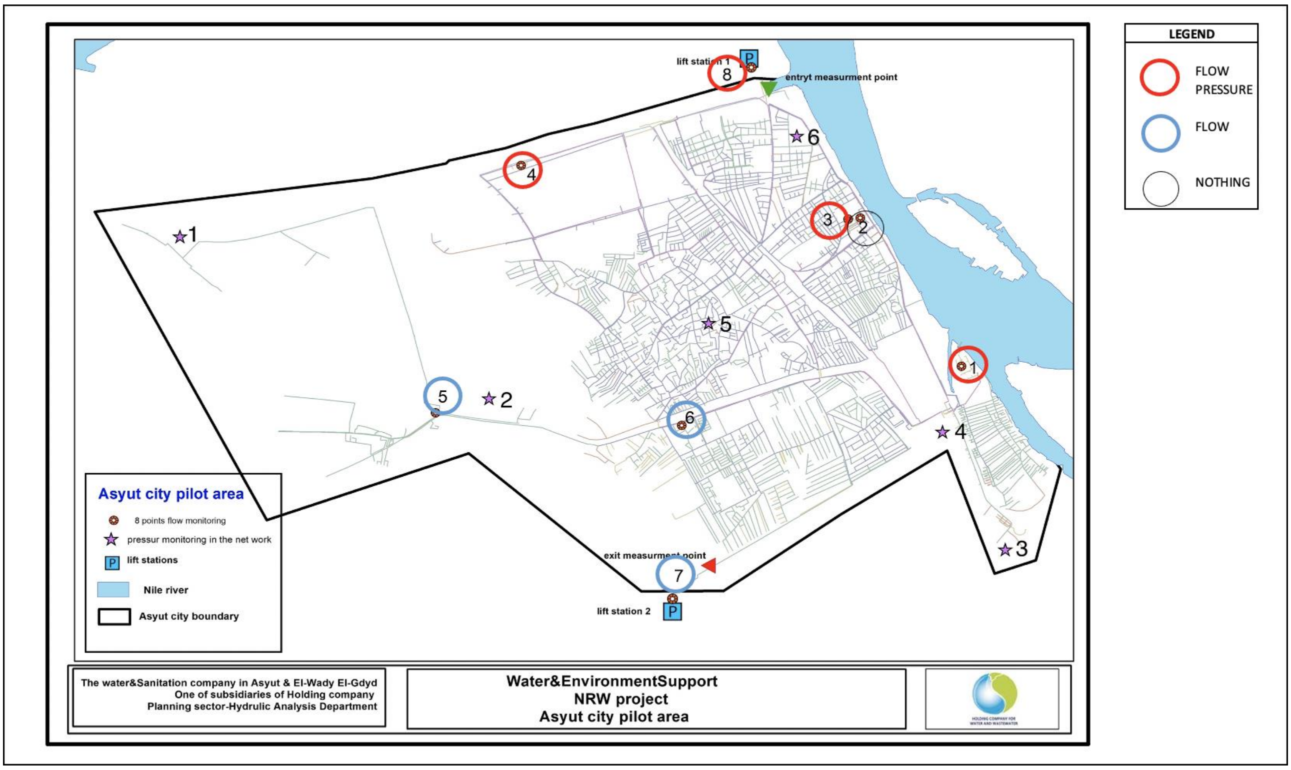
Flow and Pressure Monitoring Points Details				
Water Source Name	**No.[1]**	**Flowmeter Type**	**Flowmeter situation**	**Pressure gauge situation**
Nazlet Abdallah WTP	1	Ultrasonic	Installed Digital recording	Installed Digital recording
Czech WTP	2	Not in operation		
German WTP Czech Artesian Wells	3	Ultrasonic	Installed Digital recording	Installed Digital recording
University Compact	4	Turbine	Installed Manual data download	Installed Manual data download
Arab Tanneries Compact	5	Turbine	Installed Manual data download	Installed Manual data download
Forty Compact	6	Turbine	Installed Manual data download	Installed Manual data download
Lift Station 2	7	Ultrasonic Portable	To be installed Digital recording	-
Lift Station 1	8	Ultrasonic Portable	To be installed Digital recording	-
Pressure Gauges spread around the water network		Pressure Gauge	-	To be installed Digital recording

During the monitoring campaign it was not possible to monitor the pressure at sites except where there were flowmeter installations; therefore, pressure data are only available where the flow was also monitored.

[1] The number refers to the plant presented in **Error! Reference source not found.**

Regarding flow monitoring, it was possible to monitor the flow at all points with the only exception of site n. 2 (Czech WTP) but this is not a problem because we were told that this WTP is not in operation.

Figure 6: AWWC flow and pressure monitoring point map

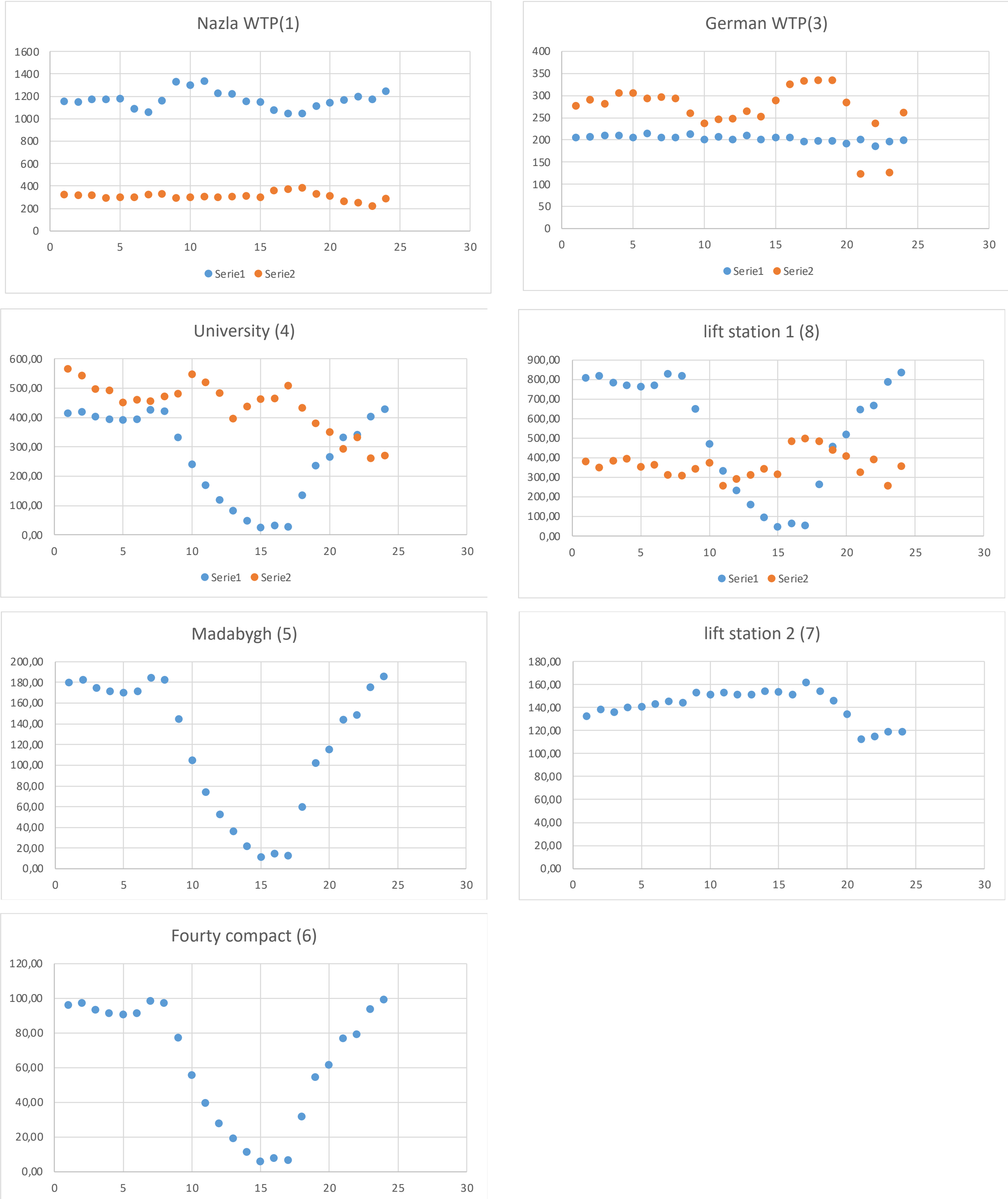


The following figures show the flow and pressure patterns we got by combining the information of the monitoring points; data were taken from the monitoring sets from August 11th to August 20th; unfortunately, it was not possible to get a full set of monitoring data for the same period at all points. Therefore, it was decided to combine the data and get a kind of synthetic daily pattern which is shown in the next figures. The corresponding data are available in the excel file whose link will be shared with the AWWC team.

Next figures show both flow (series 1) and pressure (series 2) patterns; the pressure values of the patterns where flow data are also available have been multiplied by a factor (100) to facilitate the reading and combined analysis of flow and pressure data.

The last three patterns show the flow data taken at points no. 5 (Arab Tanneries), no. 6 (Forty compact) and 7 (lift station n. 2), for which no pressure data are available.

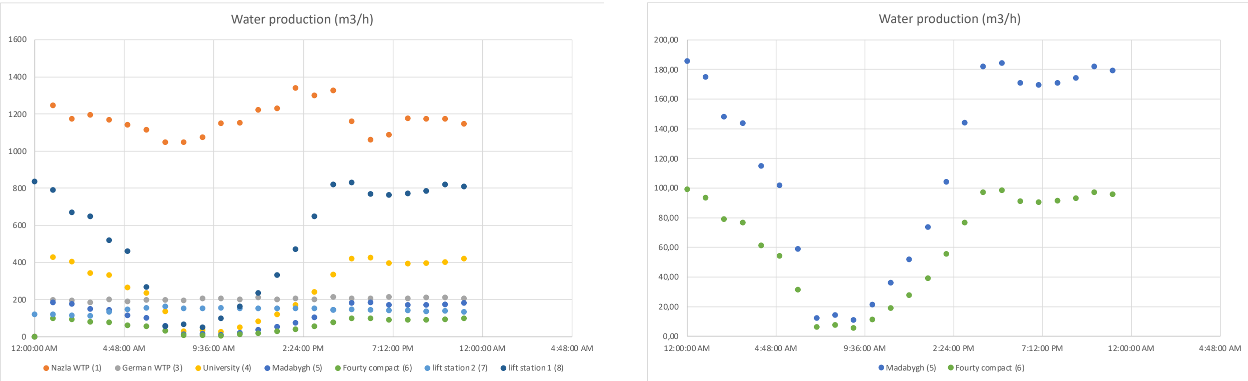
Figure 7: AWWC monitored data (Q and P)



As expected, Nazlet Abdallah WTP (site no. 1) is the largest water production plant for Asyut city. Flow and pressure data seem to be in harmony (pressure increases when flow drops down) and no special comments can be made. Flow ranges from 1048 m^3/h at 7:00am to 1339 m^3/hour at 1:00pm.

Flow patterns of sites no. 4, 5 and 8 (the second largest plant supplying Asyut) have a similar shape with the only exception of the German WTP (site no. 3).

Figure 8: AWWC monitored data



Site no. 3 (German WTP) shows a few anomalies; the pressure pattern shows a couple of anomalies at night whose cause could be interesting to detect. The specific analysis of the flow pattern (site no. 3) shows fluctuations that should also be analysed. It can be also noticed that there does not seem to be correspondence between pressure and flow data.

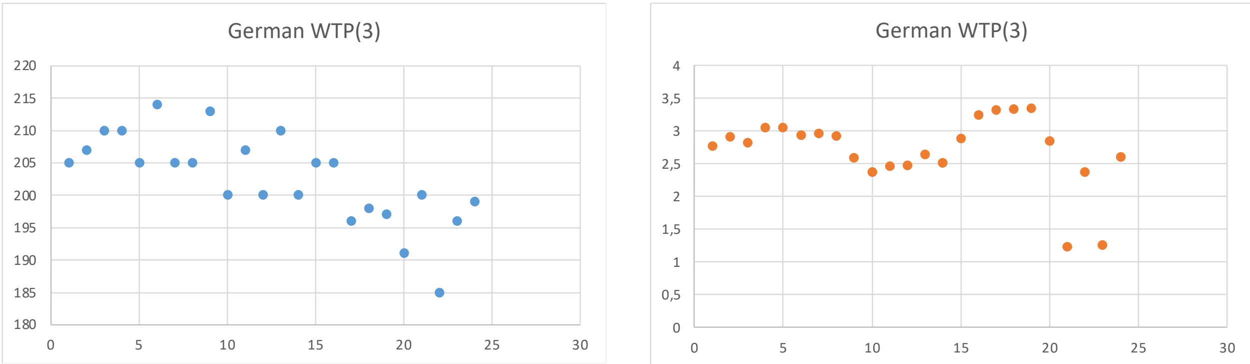


Figure 9: AWWC monitored data (German WTP)

The same consideration about pressure can be made for sites no. 4 and 8; in both cases the pressure patterns do not seem to harmonise with the flow patterns. A possible explanation is that some operation on the pumps was carried out during the monitoring period. This point needs to be clarified. The flow pattern of the site no. 7 is different, but it is expected; the reason is that it represents the flow out of the zone; the monitored flow is downstream of the pump station which is a kind of the hydraulic discontinuity.

Table 4: Asyut city water inlet and outlet

Asyut ID	ID	Name 1	Name 2	Q (m3/day) WTP	compact 1	compact 2	Total	P (bar)	Q (lps)
1	WTP10	Nazlet Abdallah	Nazlet Abdallah	27.998,33			27.998,33		324,05
2	WTP20	Altishikia	Czech				0,00		-
3	WTP30	Almania	Germany	7.074,00			7.074,00		81,88
4	WTP40	Jamiea	University	6.505,00			6.505,00		75,29
5	WTP50	Arab el Madabigh	Arab Tannery	1.407,00			1.407,00		16,28
6	WTP60	Arbaeyn	Forty		825,91	852,03	1.677,94		19,42
7	WTP70	Al Sadria PS (**)	Lift Station 1	11.923,08			11.923,08		138,00
8	WTP80	Railway PS (*)	Lift Station 2	-3.244,11			-3.244,11	-	37,55
							53.341,24		**617,38**

(*) this is the outflow from the WSS
(**) this is the inlet point to the WSS

7.3 CUSTOMER DATABASE

Initially, AWWC engineers provided the information and type of analysis they carried out on their customer database. As said, the pilot area is divided into two zones named AlSharq and AlGharb.

AWWC divides the customers of the DB in three categories:

- **Not connected**: they are AWWC customers, but they are not connected to the Water Supply network; for that they are not part of demand allocation, which considers only the customers directly connected to the WS network.
- **Connected with meters**: this category has three sub-categories: "metered with consumption", "metered without consumption" and "closed". The second category customers don't use water of the WS network (perhaps they are closed villas or apartments without dwellers); they can be considered like the "not connected category". The third category – with very low or zero consumption – is charged of a consumption of 30 m^3/month but they don't use this amount of water. For them we can apply the definition of "zero customers" and apply the average consumption determined with the data of the customers of the first sub-category.
- **Connected without meters**: this category is also a part of the users of the WS network.

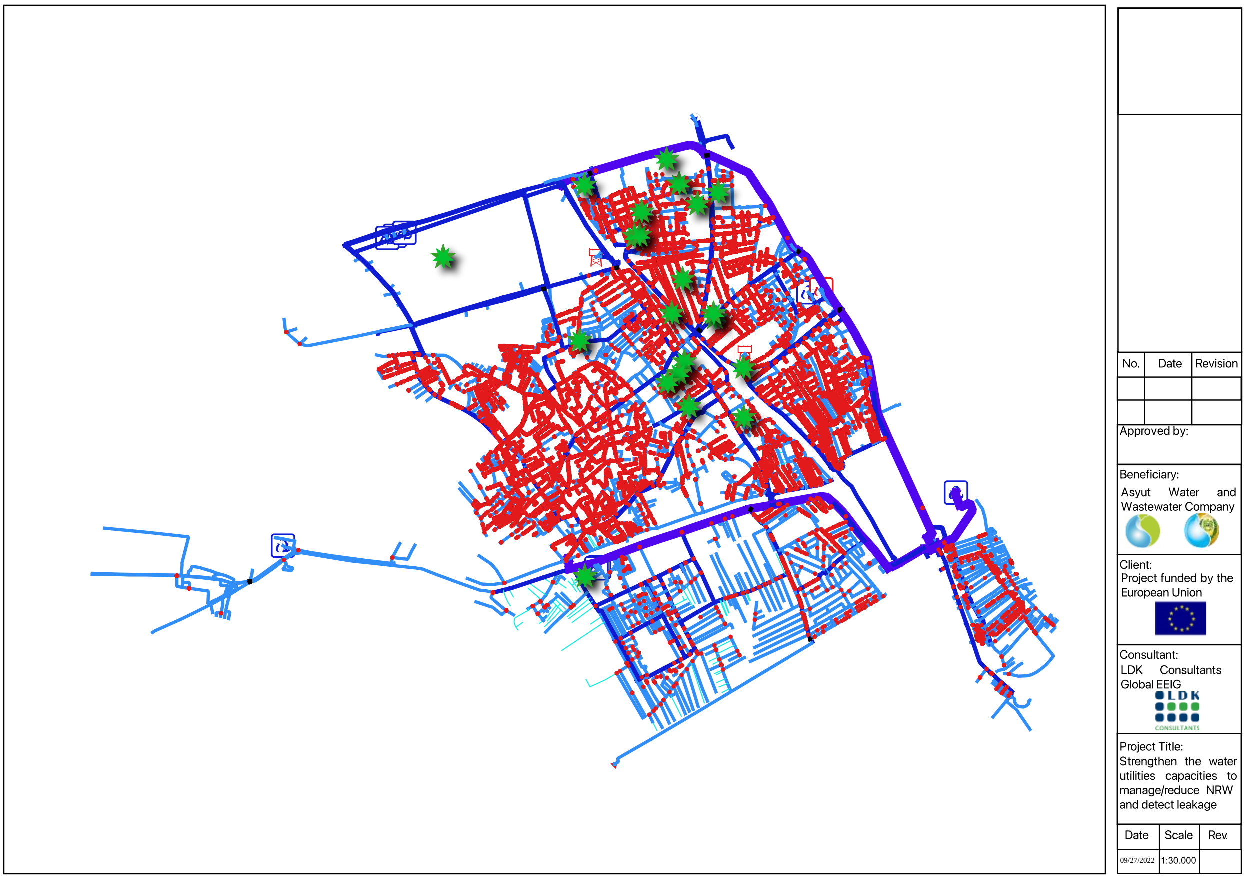
Table 5: AWWC Customers summary data

Zone	Not connected	Connected with meter: metered	closed	working	Total	Connected without meter	Total
West Zone	6144	29591	7548	6532	43671	3753	53568
East Zone	4761	21487	2631	9433	33551	219	38531
Total	**10905**	51078	10179	15965	**77222**	**3972**	**92099**

Therefore, the demand allocation will consider the metered consumption of 51078 customers whose consumption will be used to determine the average demand that will be applied to (15965+3972) = 19937. Total number of customers for the model is (51078 + 19937) = 71015.

AWWC also provided a meter (consumer) database with an incomplete geographical position of the meters where many areas, despite having the network, had no users; in particular, in the southwest and southeast areas. The green stars in the map show the positions of the twenty large consumers AWWC had identified; the northern area with apparently no meters is the University area which is one of the large consumers of the WS network. The next figure shows the WS network pipes and the AWWC meters (red points are standard consumers and green stars are large consumers).

Figure 10: map of AWWC meters and large consumers location



8 NETWORK ANALYSIS

8.1 MODEL CONSTRUCTION

After creating the WES WSS GIS DB, the WS network was exported into EPANET. Some simplifications were adopted such as pipes with the smallest diameters (DN40 and some below DN100) were ignored and not exported into EPANET. The next figure shows in red the pipes that were disregarded, they are basically the end pipes of the network with small diameters; the Table 6 shows the length of the modelled pipe organised by DN. The practice of simplifying the network to be modelled by excluding smaller diameters is common and does not affect the accuracy of the calculation. The only caution is to include in the network to be modelled those diameters that, although small, are intermediate to larger diameters and should not be removed so as not to damage the continuity of the water system.

Figure 11: WES modelled WSS network

Table 6: WES modelled network pipe length by DN and material

	Modelled WS Network Length by DN and Material						
DN	AC	DI	GRP	HDPE	STEEL	UPVC	Total L (km)
40	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-
75	-	-	-	-	-	-	-
100	-	2,58	-	0,00	-	1,42	4,01
150	0,44	57,12	0,68	3,87	0,01	47,07	109,20
152	-	0,03	-	-	0,18	0,06	0,28
200	1,15	21,27	0,57	3,55	0,19	14,29	41,03
250	1,05	1,37	0,52	0,24	0,44	5,54	9,15
300	1,80	26,10	1,35	0,79	1,00	2,20	33,24
400	1,12	5,76	2,44	0,94	0,12	1,80	12,19
500	-	3,81	5,19	-	1,41	1,64	12,04
600	-	0,30	0,02	-	1,31	-	1,63
800	0,02	0,58	4,35	-	-	0,97	5,93
1000	-	0,00	1,03	-	0,37	-	1,40
1200	-	-	0,64	-	-	-	0,64
							230,73

A few comments can be made are about the need to simplify the network used for hydraulic calculations. Very often it is not necessary to export the overall network; GIS can help select what can be exported and what can be disregarded, depending on the purpose of the calculations. Of course, also the nodes will need to be processed accordingly. Furthermore, the WES team noticed that the WSS network provided by AWWC has pipes whose length is less than 5 (five) centimetres as shown in the next table; this is of course an absurdity because there are no such small water network components. it should be noted again that when digitizing a water supply network, it is important to consider that the digitized network is a "real network" and not a drawing, so it must follow all the characteristics of a real network.

Table 7: AWWC WSS GIS DB pipe length anomalies

PIPE_V3 — Elementi Totali: 6158, Filtrati: 6158, Selezionati: 2

	ID	P_ID	P_HCWW	P_WTS	P_WDS	P_DMZ	P_DMA	P_CNT	P_FRM	P_FLAG	P_TYPE	P_LEN	P_MAT	P_DN	P_IND
1	3929	P39290	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02825554...		250	
2	3858	P38580	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02828001...	VC	200	
3	3974	P39740	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02830021...		300	
4	3897	P38970	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02831769...		300	
5	3899	P38990	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,028317701...		300	
6	3941	P39410	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,0283254911	VC	250	
7	3939	P39390	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02832990...	VC	250	
8	3842	P38420	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02834248...		300	
9	3903	P39030	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02835245...		100	
10	3931	P39310	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,02838108...		250	
11	4493	P44930	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,03134663...		150	
12	3812	P38120	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,03234606...		300	
13	3938	P39380	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,03245205...		400	
14	2215	P22150	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,03496878...		400	
15	3954	P39540	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,03556092...		200	
16	4452	P44520	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,036299115...		200	
17	3942	P39420	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,03645072...		100	
18	3860	P38600	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	[illegible]	UPVC	200	
19	4408	P44080	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,038777130...	DI	300	
20	3824	P38240	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,03933148...	DI	300	
21	3918	P39180	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,040184281...	UPVC	200	
22	3900	P39000	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,04034481...	DI	300	
23	3836	P38360	ASYUT	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0,04040599...	DI	300	

Mostra Tutti gli Elementi

8.2 WATER PRODUCTION

AWWC provided position, inflows and outflows of the boundary points of the WSS. See the next figure and table.

The AWWC staff also provided the corresponding monitored data for each water plant that feeds the WSS; these data are shown in Table 8 below.

Figure 12: AWWC Q and P monitoring points

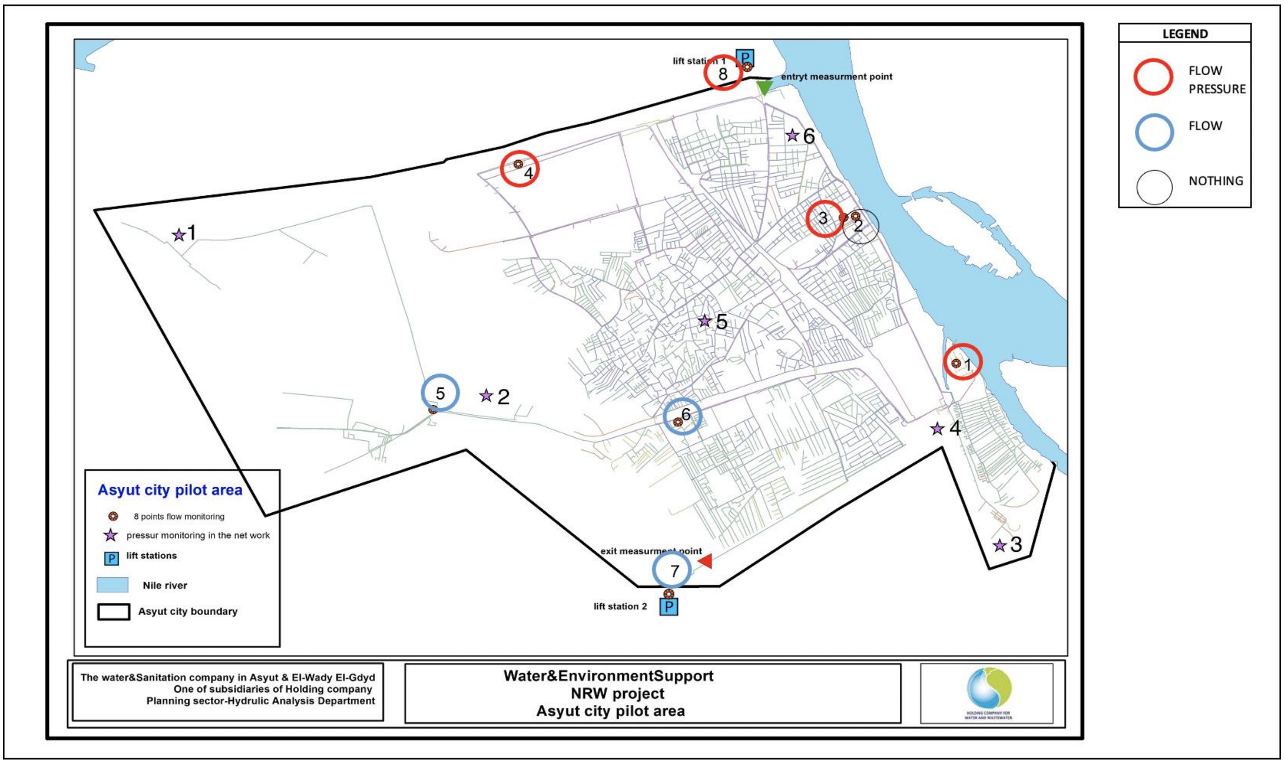


Table 8: Water production in the modelled zone

Asyut ID	ID	Name 1	Name 2	Q (m3/day) WTP	compact 1	compact 2	Total	P (bar)	Q (lps)
1	WTP10	Nazlet Abdallah	Nazlet Abdallah	27.998,33			27.998,33		324,05
2	WTP20	Altishikia	Czech				0,00		-
3	WTP30	Almania	Germany	7.074,00			7.074,00		81,88
4	WTP40	Jamiea	University	6.505,00			6.505,00		75,29
5	WTP50	Arab el Madabigh	Arab Tannery	1.407,00			1.407,00		16,28
6	WTP60	Arbaeyn	Forty		825,91	852,03	1.677,94		19,42
7	WTP70	Al Sadria PS (**)	Lift Station 1	11.923,08			11.923,08		138,00
8	WTP80	Railway PS (*)	Lift Station 2	-3.244,11			-3.244,11		- 37,55
							53.341,24		**617,38**

(*) this is the outflow from the WSS
(**) this is the inlet point to the WSS

Both flows (inlets and outlets) were imported into the hydraulic model and used to determine the domestic and commercial components.

The assumption is that the WSS must be balanced, which means that all that gets in must get out.

The next table provides a synthesis of what has been applied to determine the components of demand (domestic commercial and large consumers).

The overall inflow-outflow is known, the component of large consumers is known, and the component of leaks has been estimated based on the length of the network (see example in Annex 1); therefore, by subtracting these components from the overall inflow-outflow the domestic and commercial demand can be calculated and an individual consumption determined.

Table 9: Demand allocation adopted parameters

	Q (lps)	
leakage	217,99	35,3%
large consumers	61,502	10,0%
domestic + commercial	337,886	54,7%
	617,38	**100,0%**
number of meters	92099	
domestic + commercial	0,00366873	lps/meter
	316,98	l/c/d

8.3 DEMAND ALLOCATION

The standard approach to allocating demand to a hydraulic model requires the following information to be available:

1. Realistic number of customers connected to the WS network
2. Realistic consumption of the customers is better if applied by categories of consumption i.e. domestic/non-domestic
3. The realistic geographical position of the customers so that demand allocation of the model will consider – together with the demand of the customers - also their position.
4. Identification of a set of so-called “large consumers” who will be treated individually, both for what concerns their position and their demand.

The number of customers is determined by the database provided by AWWC (see the corresponding chapter in the data collection paragraph).

About the consumption of the customers, two options are available:

Option 1. The consumption data from the customers' database shall be considered reliable and therefore used to determine the average consumption to be applied to the “zero customers” group. In this case, the customer database consumption to be adopted shall be that corresponding to the period in which the flow monitoring was carried out, i.e. it shall include the month of August 2021.

Option 2. The consumption data from the customer database is considered for any reasons NOT reliable, so the individual demand (the one to be applied to each customer) will be determined using the inflow and outflow as determined by the field monitoring.

Option 2 is the safest option for model calibration because it refers to data monitored in the field. This is the one to be adopted if no reliable consumer data are available.

Regarding the geographical position of the customers, AWWC carried out, under the guidance of WES, a field activity whose scope was to apply to each customer a geographical character that allows the positioning of the customers and the allocation of their demand to the nearest network node. Unfortunately, this activity was not completed in time with only 85% of the customers being geo-located while 15% do not have this attribute.

The geographical location of the customers consists of the attribution of a street code to the customer; therefore, we don't know the real position of the customers, but we know how many customers are connected to a street with a identified ID. In addition, AWWC has a graph of the road network, therefore a reasonably good geographical positioning of the customers (at least in terms of roads) is possible.

Unfortunately, some **discrepancies were found that require to be fixed;** particularly some roads have an exaggerated high number of customers (most probably they were allocated to the road by area and not by individual road) and many roads have no customers. It has been decided to **improve the allocation of customers to roads and this is a work that AWWC should pursue.**

About large consumers, a standard and wise approach is to identify a group consisting of the first largest consumers. Of course, the final decision is based on data from the customer database. It is advisable to keep this group not too big – not exceeding 20 as an indication - and to consider only the real large consumers.

In summary:

- The number of customers has been determined from the customers' database as indicated above.
- The individual consumption to be applied to each customer has been determined by dividing the total inflow of the zone by the number of customers. The total inflow of the area needs to be "cleaned" from the estimated real losses amount and from the large customer demand (which will be taken from the customer database) before being applied to determine the individual consumption of customers.
- The "real losses" component has been determined using the total length of the WS network (from where the length of the transmission and primary distribution mains should be deducted. See Annex 1 for an example of the procedure for estimating real losses per km and calculating leaks). Due to the age and size of the network, it is proposed to use 0,75 lps/km as a unit of real losses per km applied to this length. This value was therefore adopted for the case of this project.
- GIS tools have been used to allocate the "real losses" component to the network nodes to be modelled.
- GIS tools have also been used to allocate demand to the nodes of the network to be modelled.
- The members of the large consumer group will be treated individually. Consumption will be captured from the customers' database and geolocation positioned from the information collected from the field.

8.3.1 PER CAPITA CONSUMPTION

Three categories, as agreed, were used for demand allocation:

- domestic and commercial,
- large consumers and
- leaks.

8.3.2 DOMESTIC AND COMMERCIAL

To allocate domestic and commercial demand, the following procedure was applied:

1. Asyut is divided into two zones [east (AlSharq) and west (AlGharb)] and AWWC knows the number of meters (regardless of their positions) for each zone. See the next figure.

Figure 13: Asyut city zones

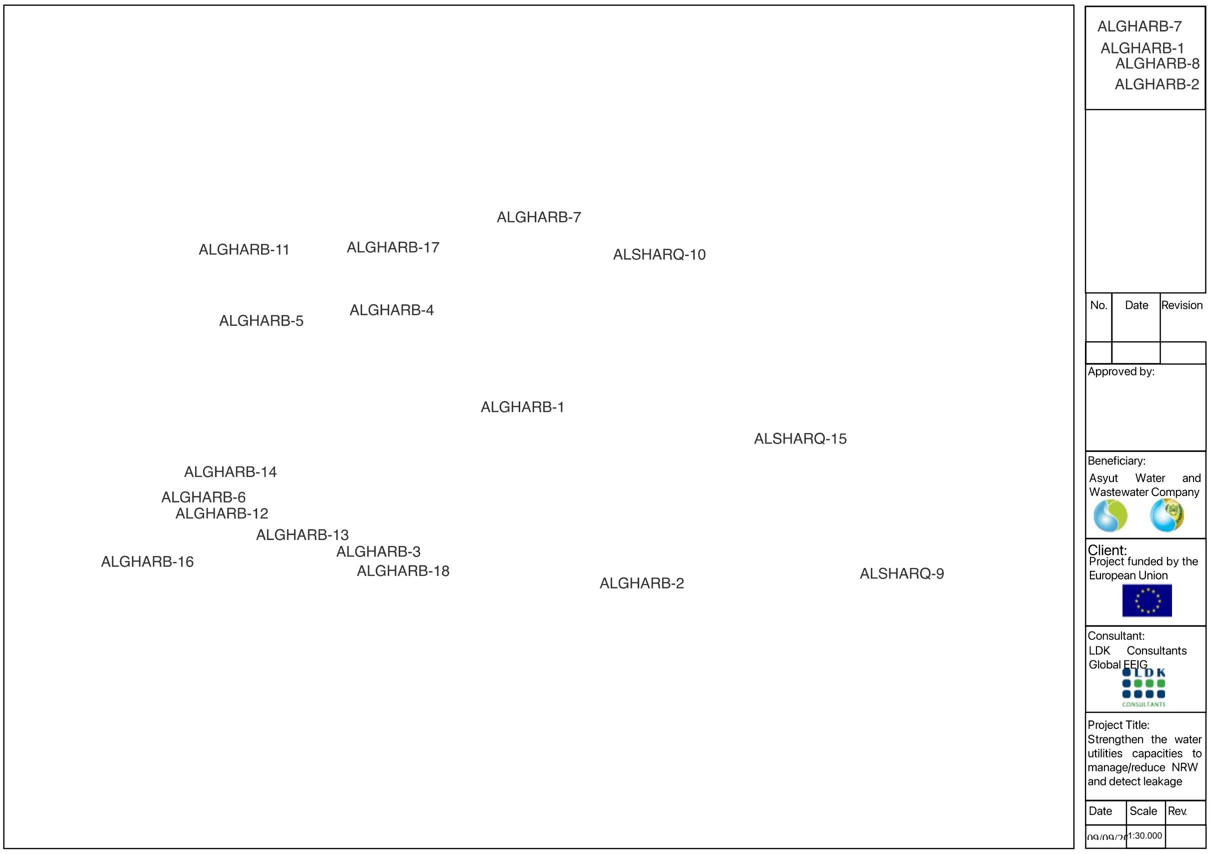
2. For each zone, the urban areas (where most meters are) were separated from the rural areas and an ID has been applied to each urban area. Seventeen (17) urban areas for both zones were identified.
3. The number of meters for each urban area was determined by using the average density of the zone (total number of meters divided by the total area of the zone) multiplied by the area of each urban area. These meters were then allocated to the demand nodes of the WSS network in the urban area.
4. Table 10 shows the meters/node parameter adopted for each sub-area. Sub-areas Al Gharb-6 incorporates the areas of Al Gharb-12 and Al Gharb-14 because in such sub-areas there were no demand nodes. The sub-area Al Gharb-13 incorporates the sub-area Al Gharb-8 because in such sub-area there were no demand nodes.

Table 10: meters allocated to the nodes of the network

URBAN AREA ID	NODES Y-Y	meters	meters/node	Notes
ALGHARB-1	865	25.440,14	29,41	
ALGHARB-2	425	15.820,54	37,22	
ALGHARB-3	2	163,96	81,98	
ALGHARB-4	7	453,07	64,72	
ALGHARB-5	4	946,31	236,58	
ALGHARB-6	4	328,02	82,00	incorporates ALGHARB-12 and ALGHARB-14 meters because there are no demand nodes in the network
ALGHARB-7	9	1.676,92	186,32	
ALGHARB-8		-		
ALSHARQ-9	234	9.297,15	39,73	
ALSHARQ-10	681	21.804,95	32,02	
ALGHARB-11	3	579,58	193,19	
ALGHARB-12		-		
ALGHARB-13	5	649,24	129,85	incorporates ALGHARB-8 meters because there are no demand nodes in the network
ALGHARB-14		-		
ALSHARQ-15	107	7.428,90	69,43	
ALGHARB-16	19	2.453,98	129,16	
ALGHARB-17	10	4.956,99	495,70	
ALGHARB-18	3	99,24	33,08	

NODES Y-Y It is a node of the network and a demand node (EPA_FLG = Y, EPA_BDMD = Y)
NODES Y-N it is a node of the network but it is not a demand node (EPA_FLG = Y, EPA_BDMD = N)
NODES N-N it is not a node of the network and it is not a demand node (EPA_FLG = N, EPA_BDMD = N)

Figure 14: Asyut city urban areas



8.3.3 LARGE CONSUMERS

AWWC provided the positions and consumption of twenty-one large consumers.

OBJECTID	C_UNIT	c_m3_d	URB_A_ID	N_ID	LC_ID	C_LPS
1	572	19,07	ALGHARB-1	N30380	LC1	0,221
2	500	16,67	ALGHARB-1	N17780	LC2	0,193
3	547	18,23	ALGHARB-1	N28530	LC3	0,211
4	500	16,67	ALGHARB-1	N30070	LC4	0,193
5	834	27,80	ALGHARB-1	N31630	LC5	0,322
6	956	31,87	ALSHARQ-10	N5990	LC6	0,369
7	1750	58,33	ALSHARQ-10	N31460	LC7	0,675
8	2456	81,87	ALSHARQ-10	N22330	LC8	0,948
9	500	16,67	ALSHARQ-10	N2310	LC9	0,193
10	1200	40,00	ALSHARQ-10	N2110	LC10	0,463
11	1000	33,33	ALSHARQ-10	N29460	LC11	0,386
12	500	16,67	ALSHARQ-10	N14730	LC12	0,193
13	3488	116,27	ALSHARQ-10	N8370	LC13	1,346
14	557	18,57	ALSHARQ-10	N21380	LC14	0,215
15	2130	71,00	ALSHARQ-10	N29350	LC15	0,822
16	500	16,67	ALSHARQ-10	N24770	LC16	0,193
17	2000	66,67	ALSHARQ-10	N30220	LC17	0,772
18	1329	44,30	ALGHARB-1	N5170	LC18	0,513
19	500	16,67	ALGHARB-2	N25750	LC19	0,193
20	520	17,33	ALGHARB-1	N21960	LC20	0,201
21	137070	1.142,25	ALGHARB-17	N21710	LC21-1	13,22
22		1.142,25	ALGHARB-17	N18290	LC21-2	13,22
23		1.142,25	ALGHARB-17	N20140	LC21-3	13,22
24		1.142,25	ALGHARB-17	N30920	LC21-4	13,22
						61,502

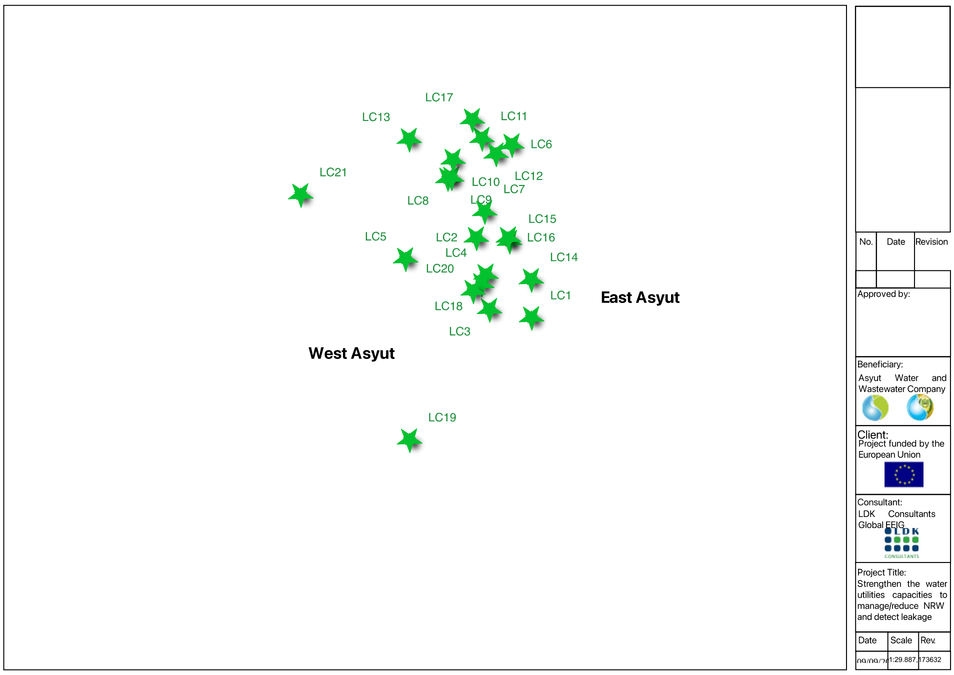
Table 11: large consumers' demand to be allocated

Where:

Abbreviations:	
C-UNIT:	monthly consumption of the large consumer (cmm)
c-m3-d:	daily consumption of the large consumer (cmd)
URB-A-ID	ID of the urban area used for demand allocation
N_ID	ID of the node of
LCD_ID:	ID of the large consumer
C_LPS	consumption of the large consumer (lps)

Their consumption was manually allocated to the nearest node of the WSS network. See the next figure.

Figure 15: large consumers locations map



8.3.4 LEAKS

Leaks were calculated by applying a coefficient (0,75 lps/km) to the overall extension of the network. The corresponding demand has been applied to the end node of the pipes (see the leak allocation procedure notes distributed to the AWWC team for more information and recapped in Annex 1 to show an example of the procedure for estimating real losses per km and calculating leaks).

9 CALIBRATION

The model developed as described was calibrated by assigning the monitored water inflow and outflow to the corresponding points in the water network and checking the pressure distribution in the network.

The results of the calculations are shown in the following figures, which respectively show the demand allocated to the network nodes (Figure 16), the pressure distribution at the nodes (Figure 17), the flow distribution (Figure 18) and the velocity distribution (Figure 19) in the pipes over the WS network.

Figure 16: modelled allocated demand map

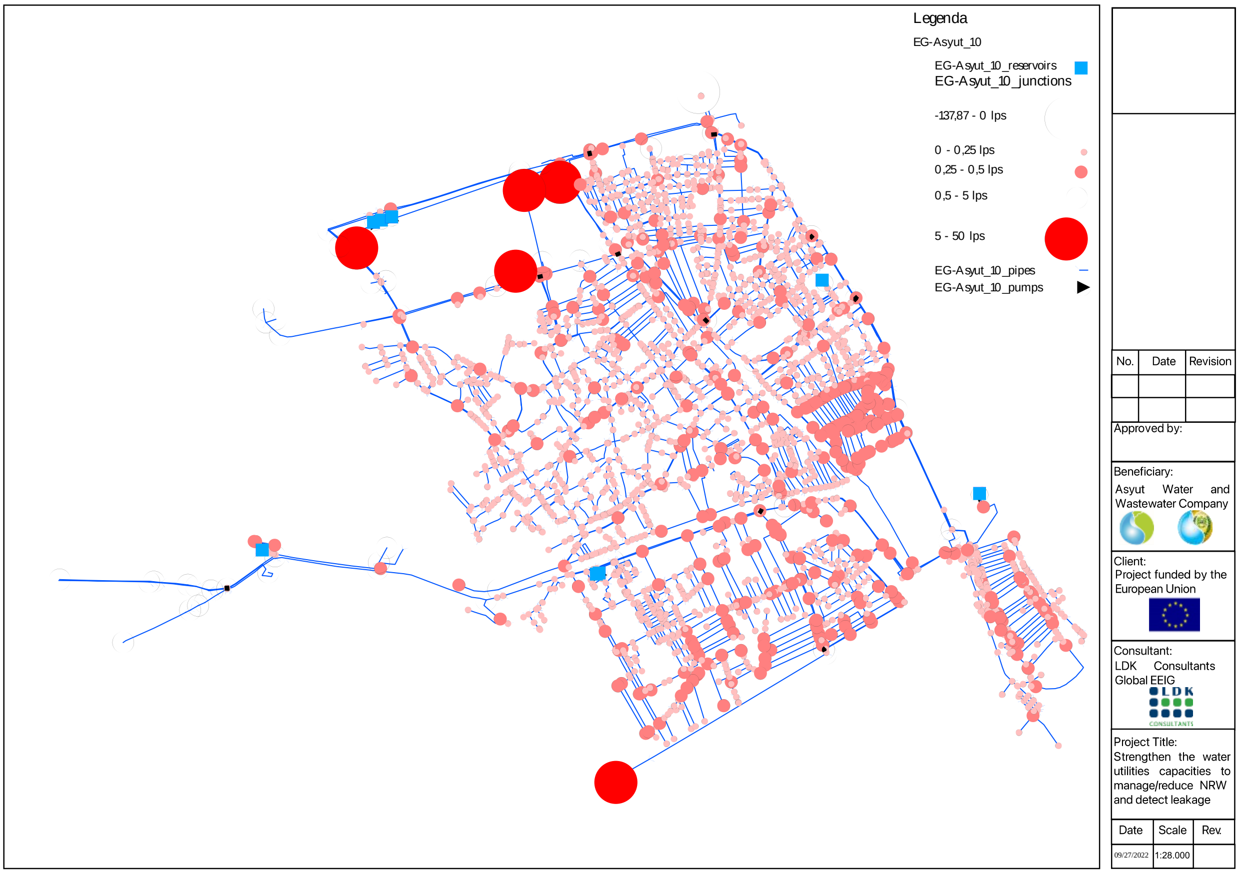


Figure 17: modelled pressure (P) map

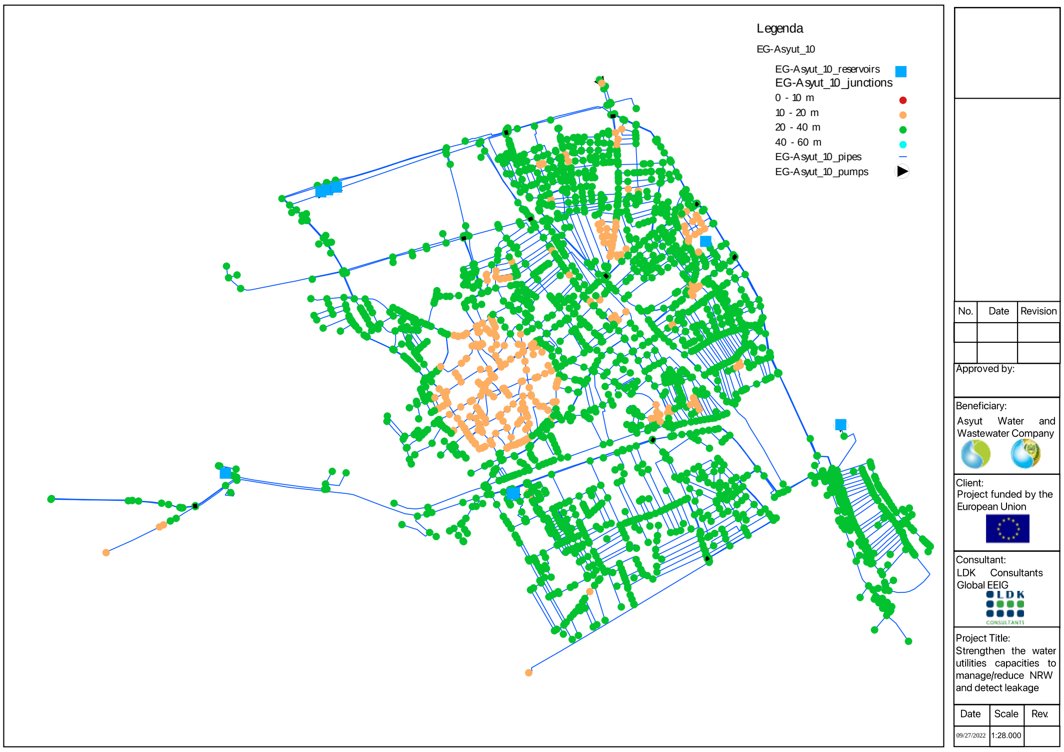


Figure 18: modelled flow (Q) map

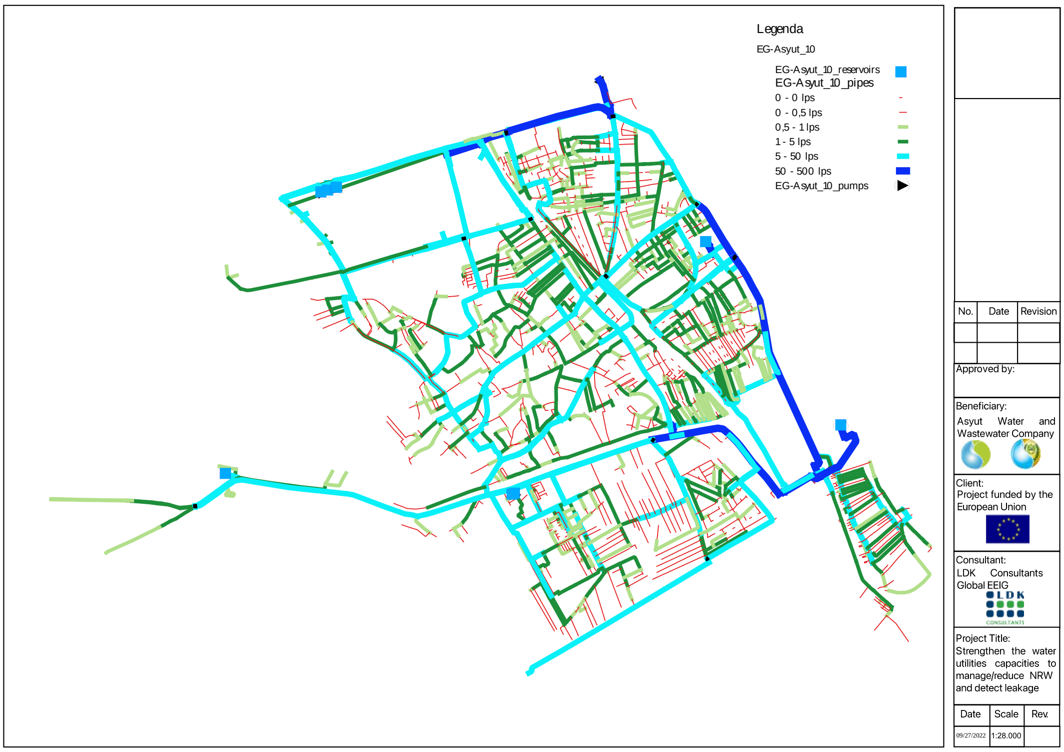


Figure 19: modelled velocity (V) map

The calculation shows that there are no pressure problems in the network (given the assigned head of 30 m for all pumps). There are only some areas to consider where pressures are between 10 and 20 m, somewhat lower than good practice. These areas should be taken under control because they could be areas where trouble can come.

A warning to consider carefully comes from the velocity distribution resulting from the calculations. They show a large area with low velocities (less than 0,5 m/s) distributed throughout the water supply system.

Annex 1 provides the output generated by EPANET which includes all the information on the modelled network.

10 RESULT OF PREDICTIVE WORK

DMA planning and design are the processes of:

i. Dividing the distribution system into sectors, typically containing a defined number of service connections.
ii. Defining what to do when the main pipe crosses the sector boundary, i.e. install a meter or close a valve so that any flow at the boundary crossing, either into the sector or out into another sector, is continuously monitored;
iii. Determining the demand of the sector and, by taking flow-rate measurements and knowing the number of connections, deriving the night flow (minimum flow), which will be used in a future phase of sector implementation.

10.1 DMA DESIGN

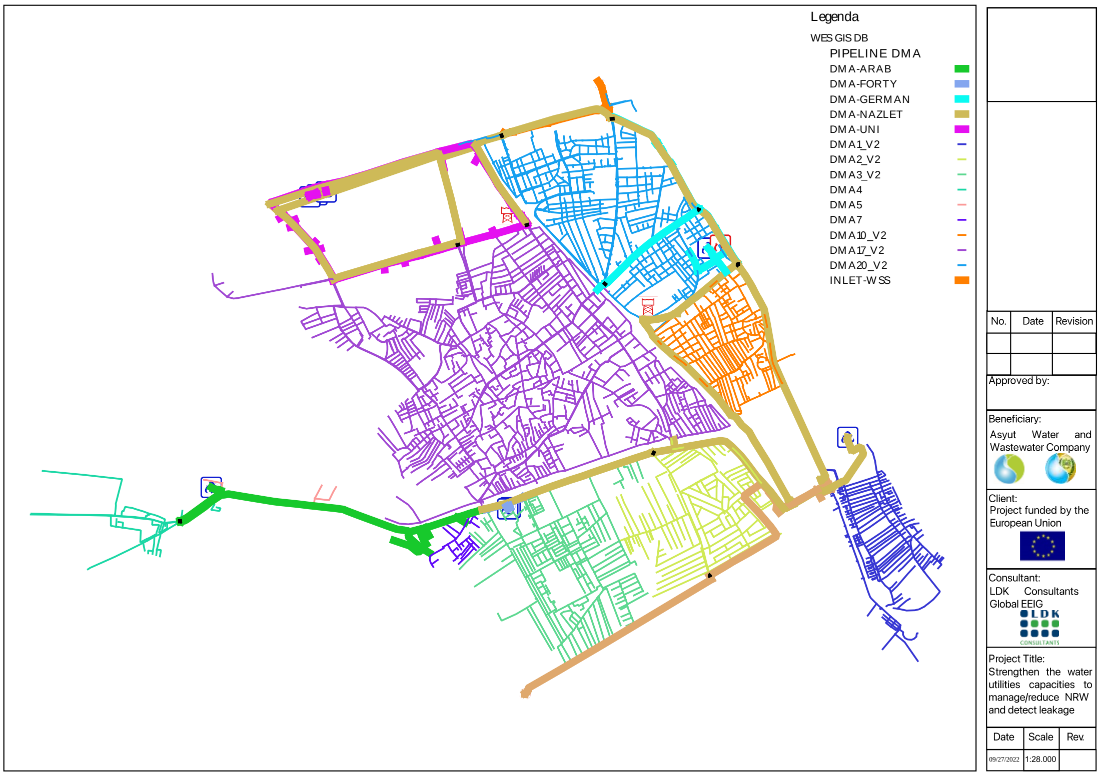
The network layout and allocated demand developed using data provided by AWWC, and the flow distribution resulting from the calculations were used to select the initial proposal for the overall network zoning and the corresponding identification of the locations of flowmeters to be installed and valves to be closed.

The map in Figure 20 shows in different colours the proposed DMAs and the transmission mains associated with the water sources (WTPs and inlet points) in the network. Branches of distribution pipelines are very often connected to these transmission main pipelines and the control of these areas requires specific flowmeters.

It is worth noting that some sections of transmission mains exiting WTPS have been controlled by flowmeters to achieve overall control of the Water Supply System; these sections have been called DMA, although strictly speaking, they are not. The list of these sections includes DMA-ARAB, DMA-FORTY DMA-GERMAN, DMA-NAZLET, DMA-UNI and INLET-WSS.

DMAs were named according to a numerical sequence; in some cases, the suffix “V2” indicates a second version of the proposed DMA.

Figure 20:designed DMAs map



The following figures show the characteristics of the WSS network (Pressure P, flow Q and velocity V) resulting from closing the boundary valves identified as necessary to create the DMAs. These were modelled in the proposed network schematic by closing the corresponding pipes in order to direct the flow according to the new configuration of the WSS.

In general, there does not seem to be much change in respect of the scenario with no DMAs; one can see a larger part where pressures are less than 20 metres and a lightly different distribution of flow along the system.

Velocities are still low everywhere; obviously, this is a point that needs to be further investigated both by checking and improving the input data used for the calculation and by carrying out new monitoring campaigns in the field.

The positive conclusion is that the proposed changes do not seem to significantly alter the operation of the network; in fact, for us, it is more important to compare the differences between the two configurations after the changes than the individual results of each configuration.

Figure 21: DMA implementation - modelled pressure (P) map

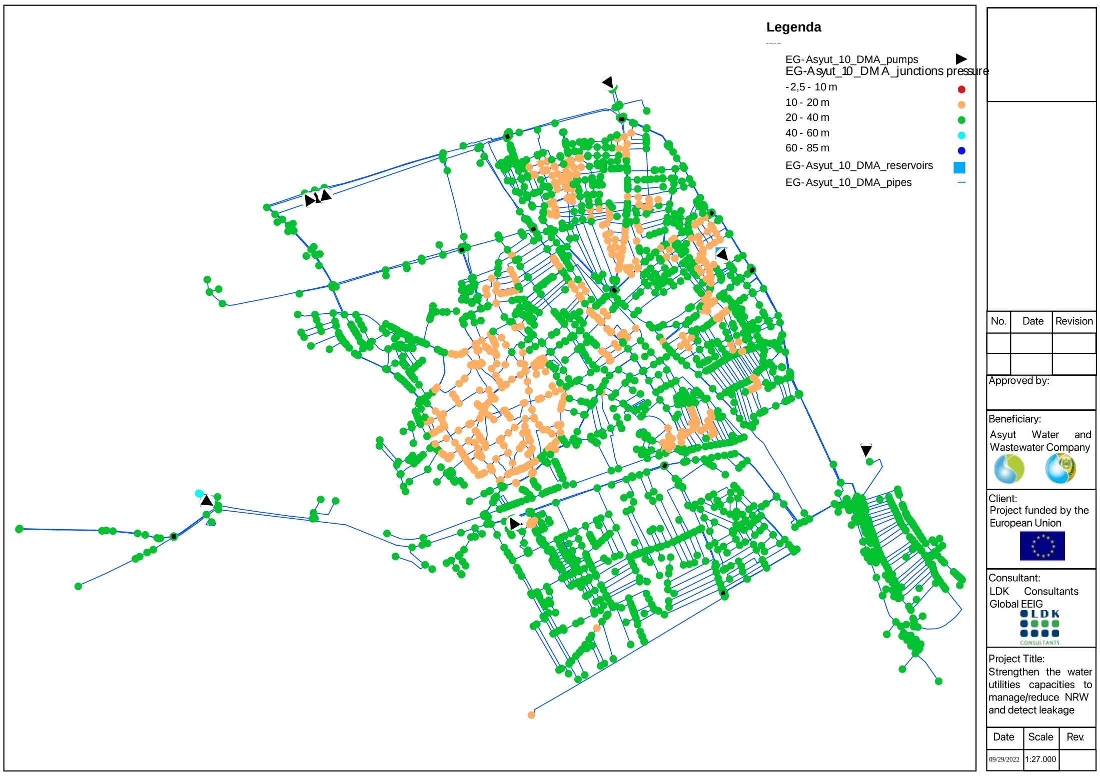


Figure 22: DMA implementation – modelled flow (Q) map)

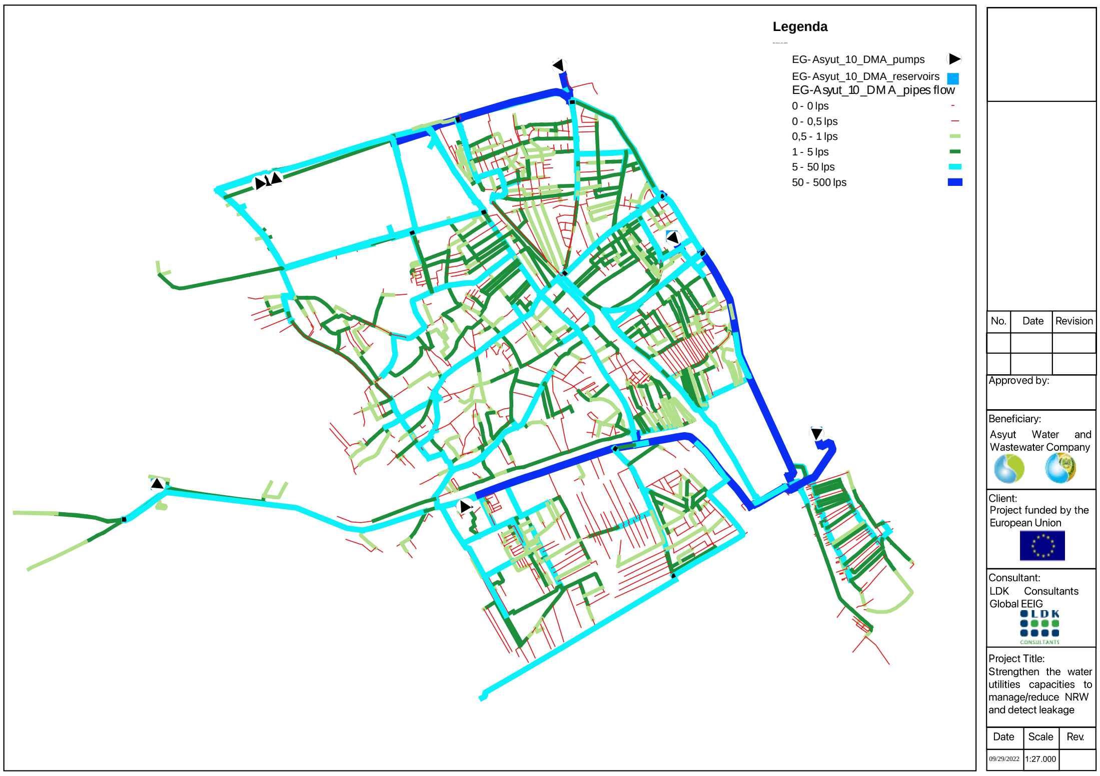
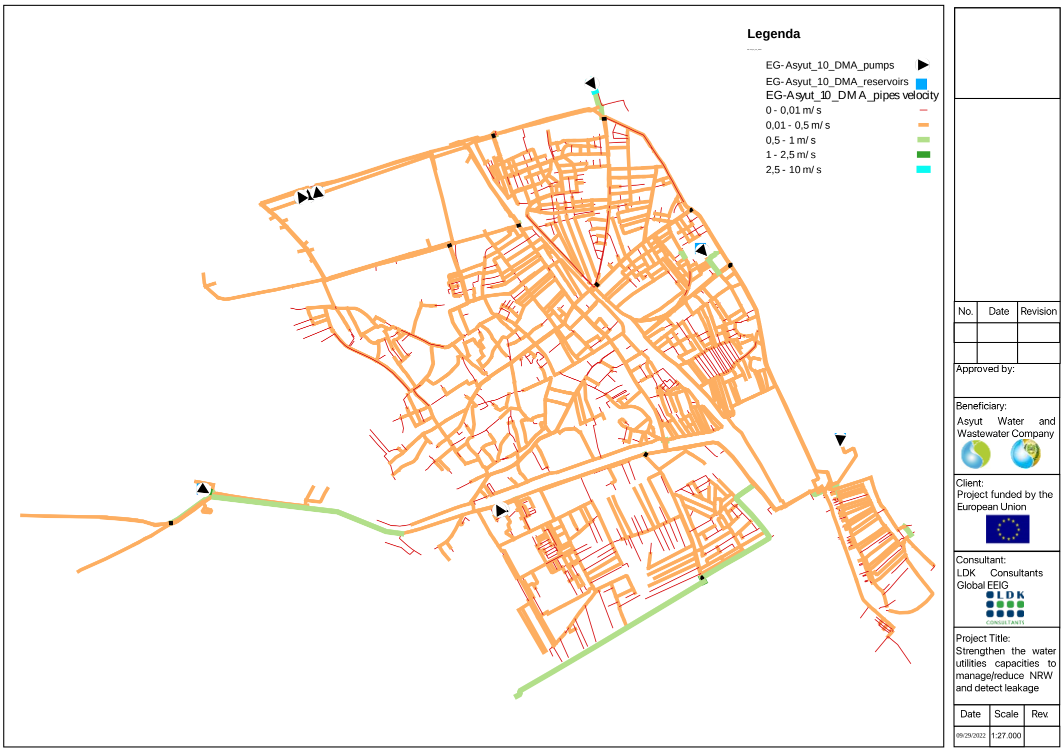


Figure 23: DMA implementation - modelled velocity (V) map



Annex 3 provides the output generated by EPANET which includes all the information on the modelled network simulating the DMA implementation.

10.2 SELECTION OF DMA FLOWMETERS AND MONITORING POINTS

This chapter shows the criteria adopted for sizing and selecting both flowmeters and boundary valves. A Q_{min} equal to 35% of the calculated flow (Q) and a Q_{max} equal to 1,5 of the calculated were adopted for sizing the flowmeters.

The boundary valves were dimensioned by adopting the DN class of the pipe. This is a standard approach in order not to cause unnecessary head-losses.

For each DMA, the map(s) with the locations of flowmeters and valves to be closed (CV) are presented, together with two tables showing the main characteristics of each installation and the DN determined for flowmeters and valves.

10.2.1 DMA1

Figure 24: DMA1 boundary points

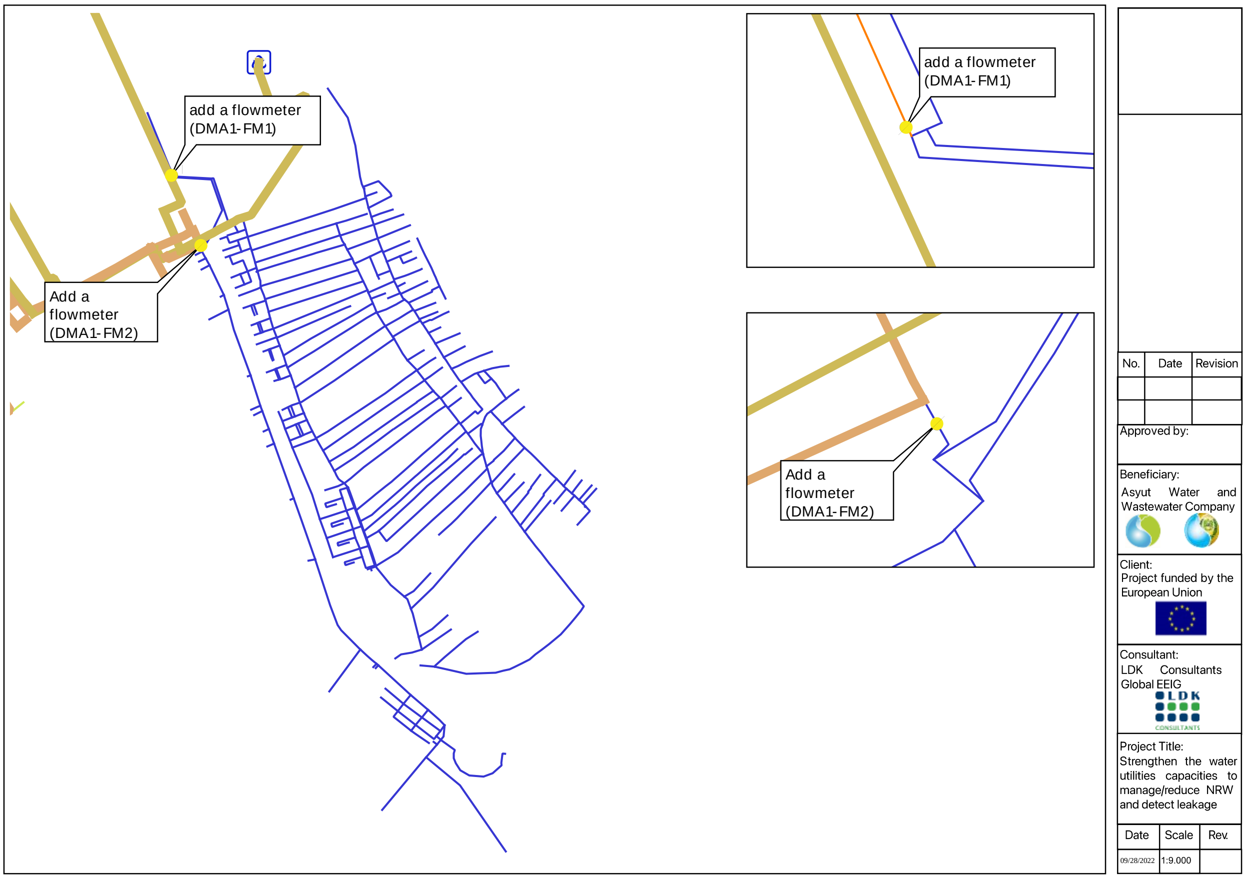


Table 12: DMA1 flowmeters sizing

DMA1	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	300 DI	400 DI						
Q (lps)	11,66	36,90						
Q_{max} (lps)	17,49	55,35						
Q_{min} (lps)	3,49	11,07						
FM DN	100	125						

Table 13: DMA1 valves sizing

DMA1	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN								
Valve DN								

10.2.2 DMA2

Figure 25: DMA 2 boundary points

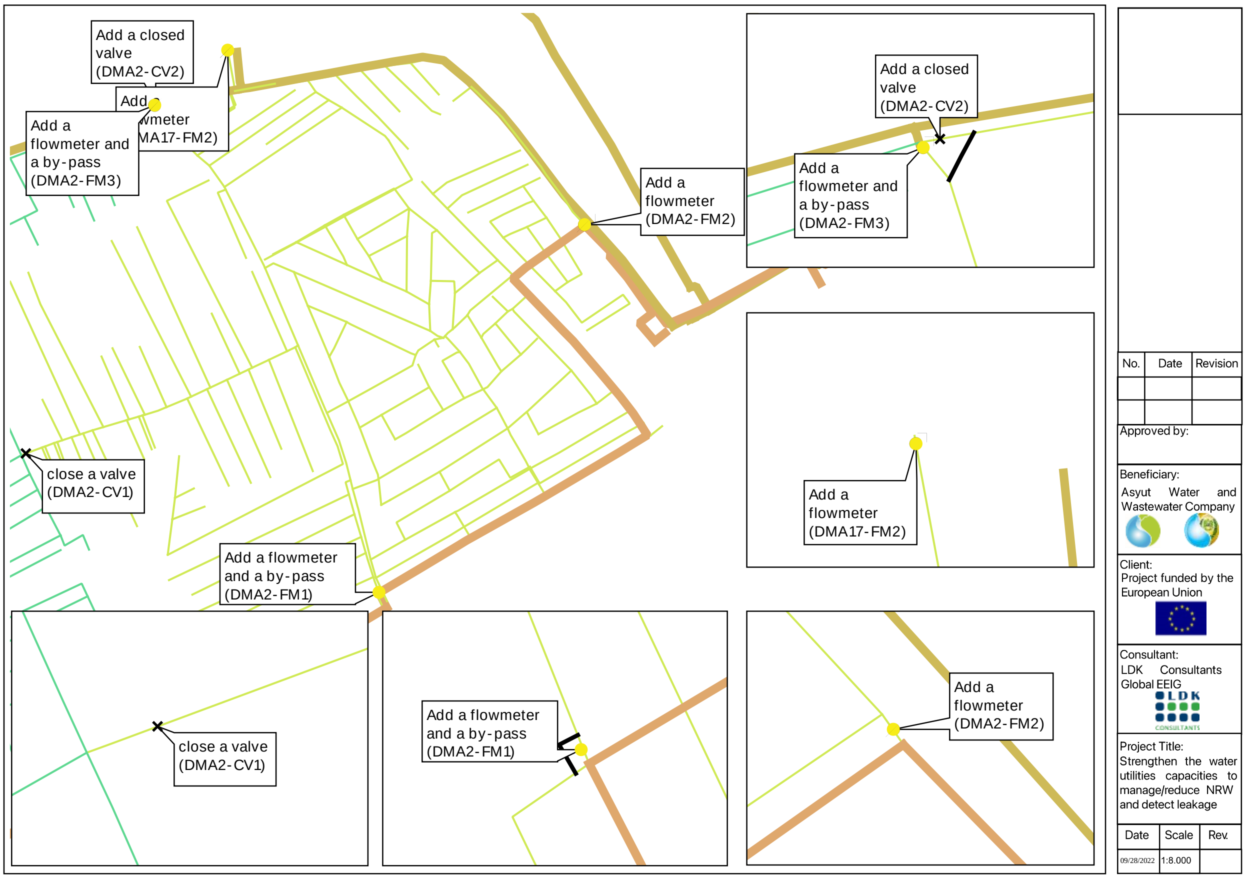


Table 14: DMA 2 flowmeters sizing

DMA2	FM1	FM2	FM3	17-FM2	FM5	FM6	FM7	FM8
Pipe DN	200 UPVC	400 DI	300 UPVC	300 GRP				
Q (lps)	3,35	26,82	32,96	28,84				
Q_{max} (lps)	5,02	40,23	49,44	43,26				
Q_{min} (lps)	1,00	8,05	9,89	8,65				
FM DN	40	125	125	125				

Table 15: DMA 2 valves sizing

DMA2	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN	300 DI	150 DI						
Valve DN	300	150						

10.2.3 DMA3

Figure 26: DMA 3 boundary points

Table 16: DMA 3 flowmeter sizing

DMA3	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	400 DI	400 DI	300 DI					
Q (lps)	10,47	14,65	29,73					
Q_{max} (lps)	15,71	21,97	44,59					
Q_{min} (lps)	3,14	4,39	8,9265					
FM DN		100	125					

Table 17: DMA3 valves sizing

DMA3	2-CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN	300 DI							
Valve DN	300							

10.2.4 DMA4

Figure 27: DMA4 boundary points

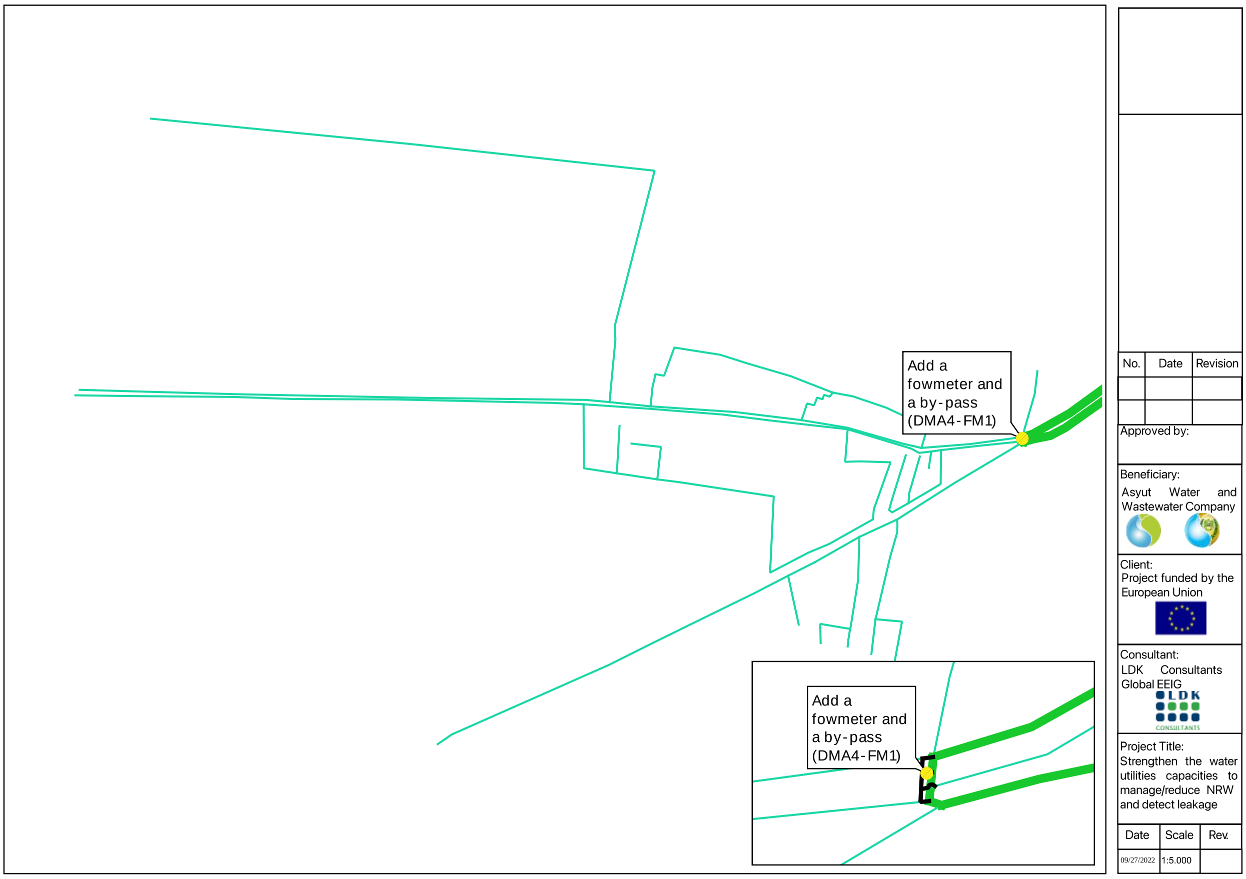


Table 18: DMA 4 flowmeter sizing

DMA4	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	250 HDPE							
Q (lps)	8,23							
Q_{max} (lps)	12,34							
Q_{min} (lps)	2,47							
FM DN	65							

Table 19: DMA4 valves sizing

DMA4	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN								
Valve DN								

10.2.5 DMA5

Figure 28: DMA 5 boundary points

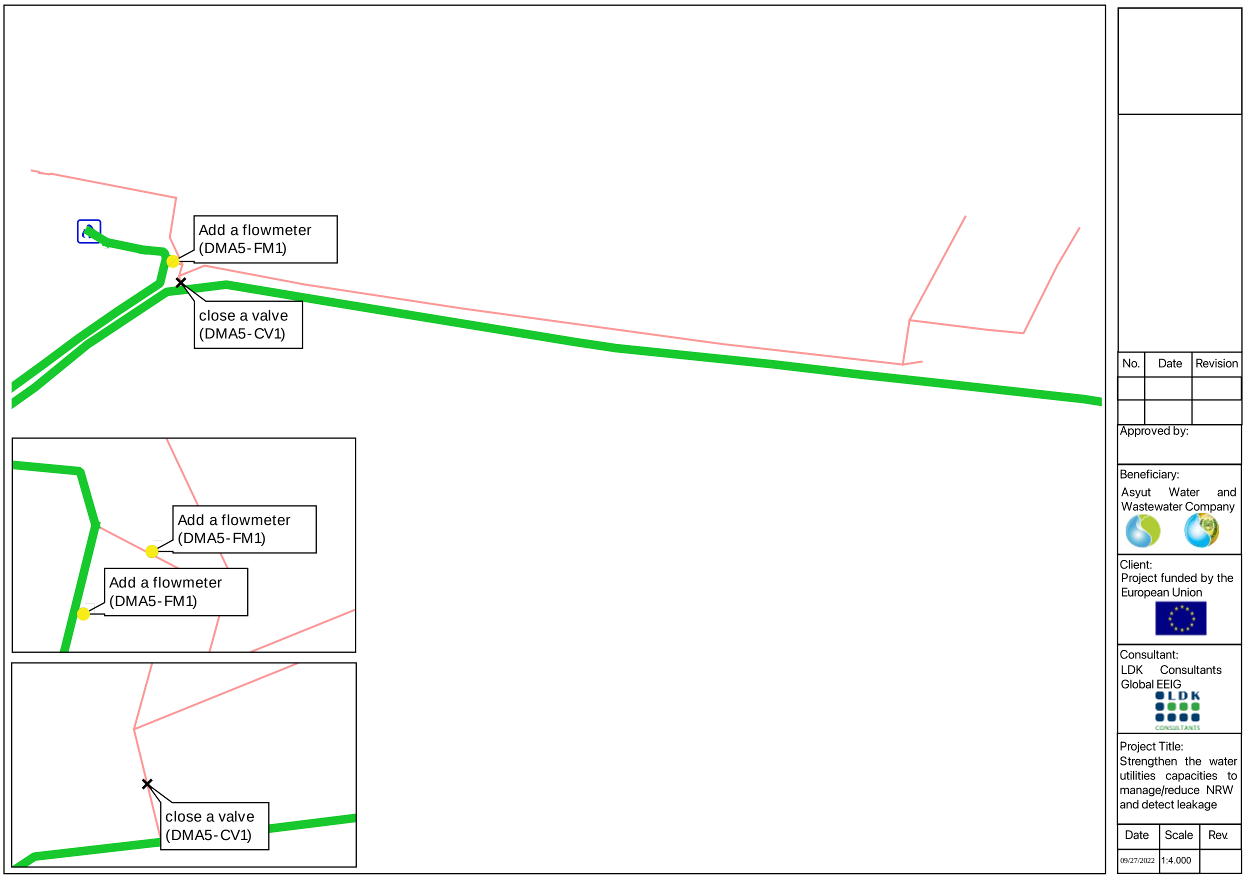


Table 20: DMA 5 flowmeter sizing

DMA5	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	200 UPVC							
Q (lps)	5,14							
Q_{max} (lps)	7,71							
Q_{min} (lps)	1,54							
FM DN	50							

Table 21: DMA 5 valves sizing

DMA5	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN	200 UPVC							
Valve DN	200							

10.2.6 DMA6

Figure 29: DMA 6 boundary points

Table 22: DMA 6 flowmeter sizing

DMA6	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	150 AC							
Q (lps)	0,97							
Q_{max} (lps)	1,45							
Q_{min} (lps)	0,29							
FM DN	25							

Table 23: DMA 6 valves sizing

DMA6	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN								
Valve DN								

10.2.7 DMA7

Figure 30: DMA 7 boundary points

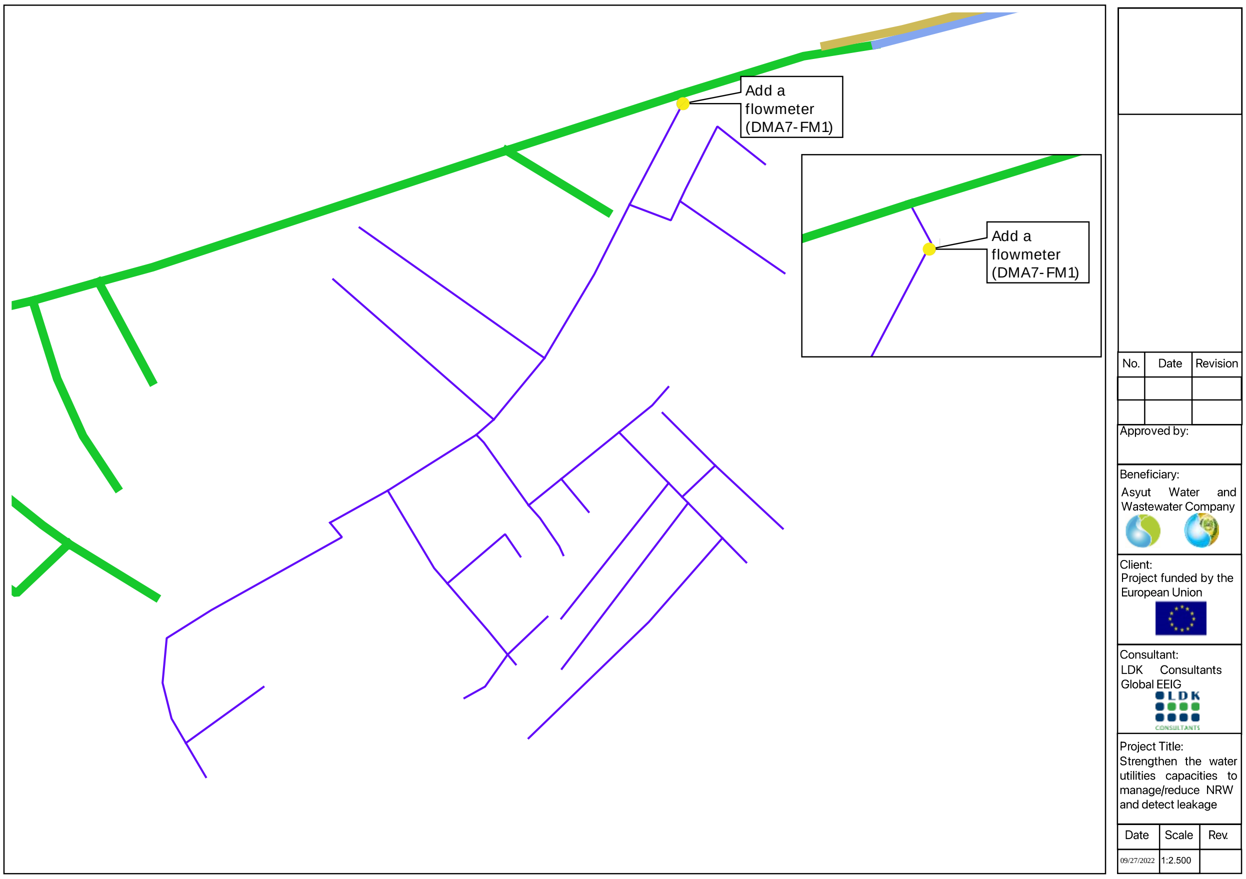


Table 24: DMA 7 flowmeter sizing

DMA7	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	200 DI							
Q (lps)	2,58							
Q_{max} (lps)	3,87							
Q_{min} (lps)	0,77							
FM DN	40							

Table 25: DMA 7 valves sizing

DMA7	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN								
Valve DN								

10.2.8 DMA10

Figure 31: DMA 10 boundary points

Table 26: DMA 10 flowmeter sizing

DMA10	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	300 DI	300 DI	300 DI	300 DI				
Q (lps)	29,55	16,26	13,81	12,41				
Q_{max} (lps)	44,32	24,39	20,72	18,61				
Q_{min} (lps)	8,86	4,88	4,14	3,72				
FM DN	125	100	80	80				

Table 27: DMA 10 valves sizing

DMA10	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN	300 GRP	250 DI						
Valve DN	300	250						

10.2.9 DMA17

Figure 32: DMA 17 boundary points

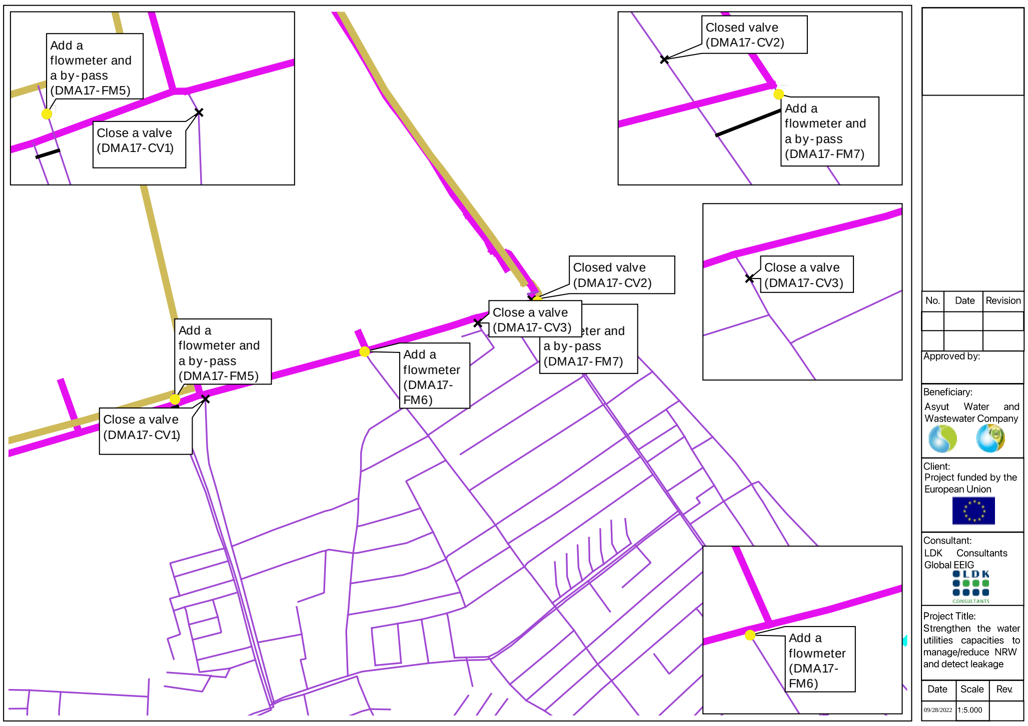


Figure 33: DMA 17 boundary points, part 1

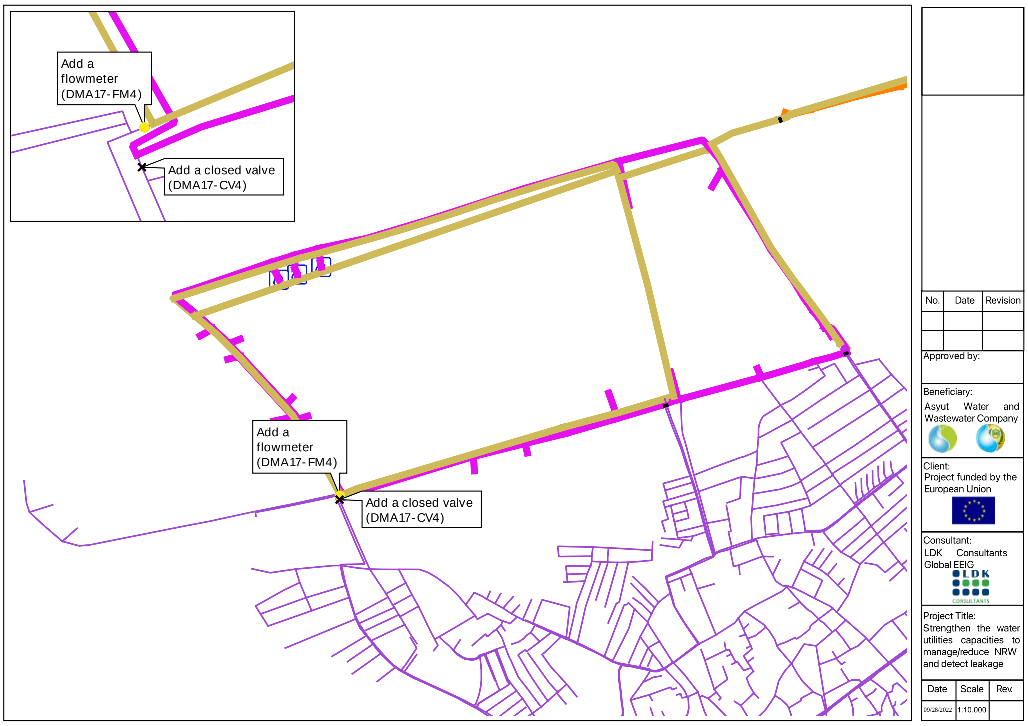


Figure 34: DMA 17 boundary points, part 2

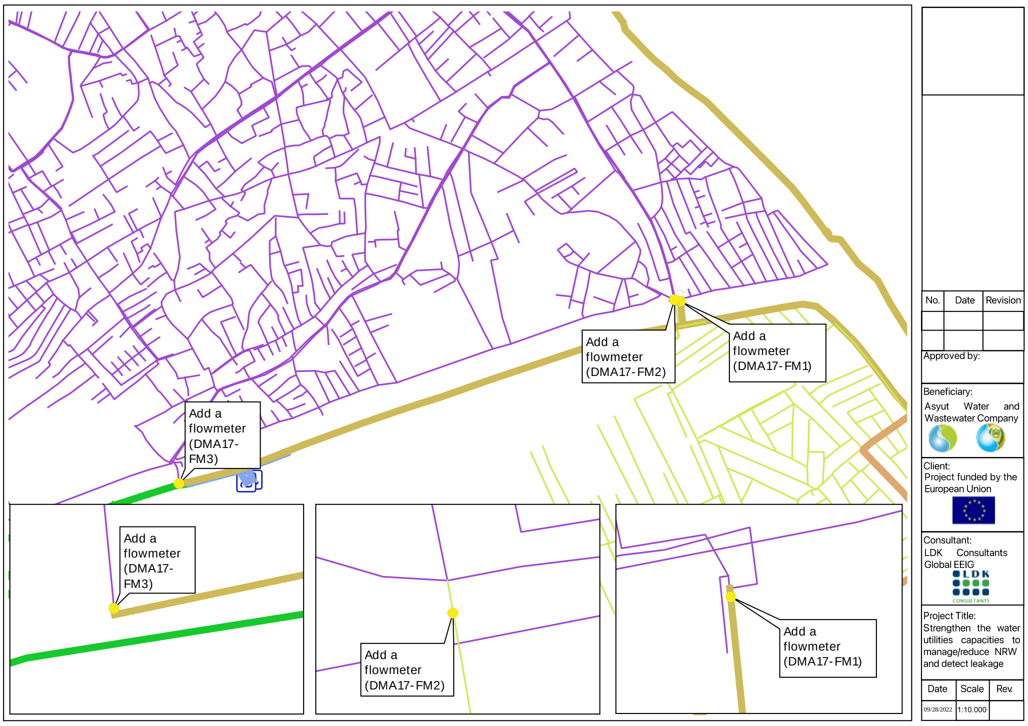


Figure 35: DMA 17 boundary points, part 3

Table 28: DMA 17 flowmeter sizing

DMA17	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	500 STEEL	300 GRP	800 GRP	400 GRP	400 GRP	200 DI	300 DI	500 DI
Q (lps)	85,54	28,84	43,46	17,18	8,74	1,99	1,74	39,82
Q_{max} (lps)	128,31	43,26	65,19	25,77	13,11	2,98	2,61	59,73
Q_{min} (lps)	25,66	8,65	13,04	5,15	2,62	0,60	0,52	11,95
FM DN	200	125	150	100	65	32	32	150

Table 29: DMA 17 valves sizing

DMA17	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN	200 DI	500 DI	100 UPVC	300 DI				
Valve DN	200	400	100	300				

10.2.10 DMA20

Figure 36: DMA 20 boundary points, part 1

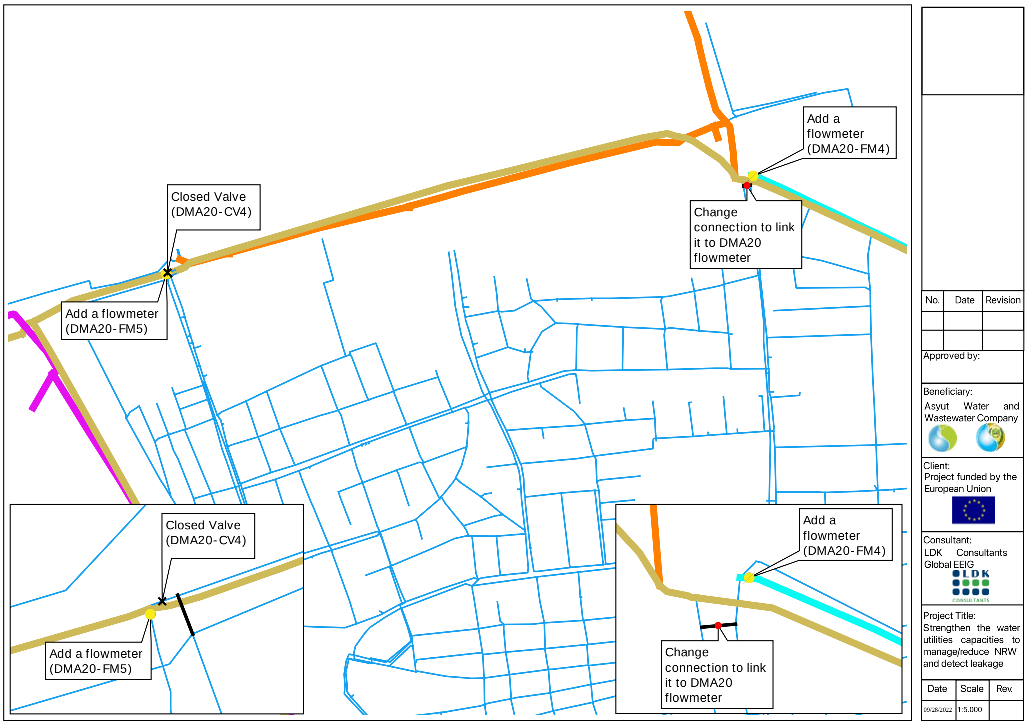


Figure 37: DMA 20 boundary points, part 2

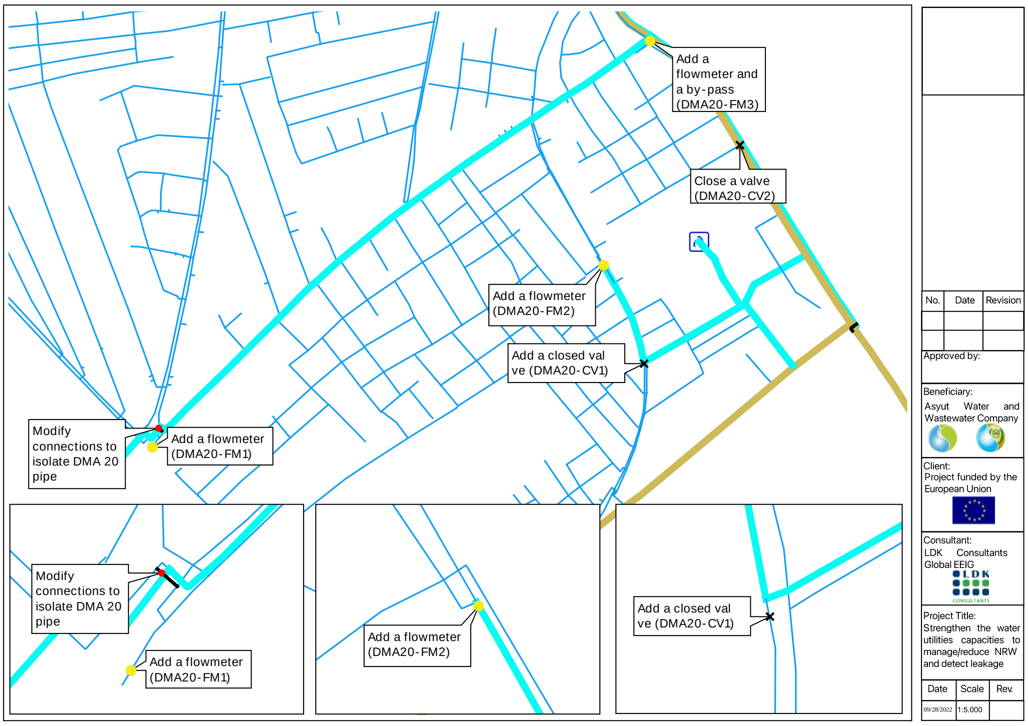


Figure 38: DMA 20 boundary points, paert 3

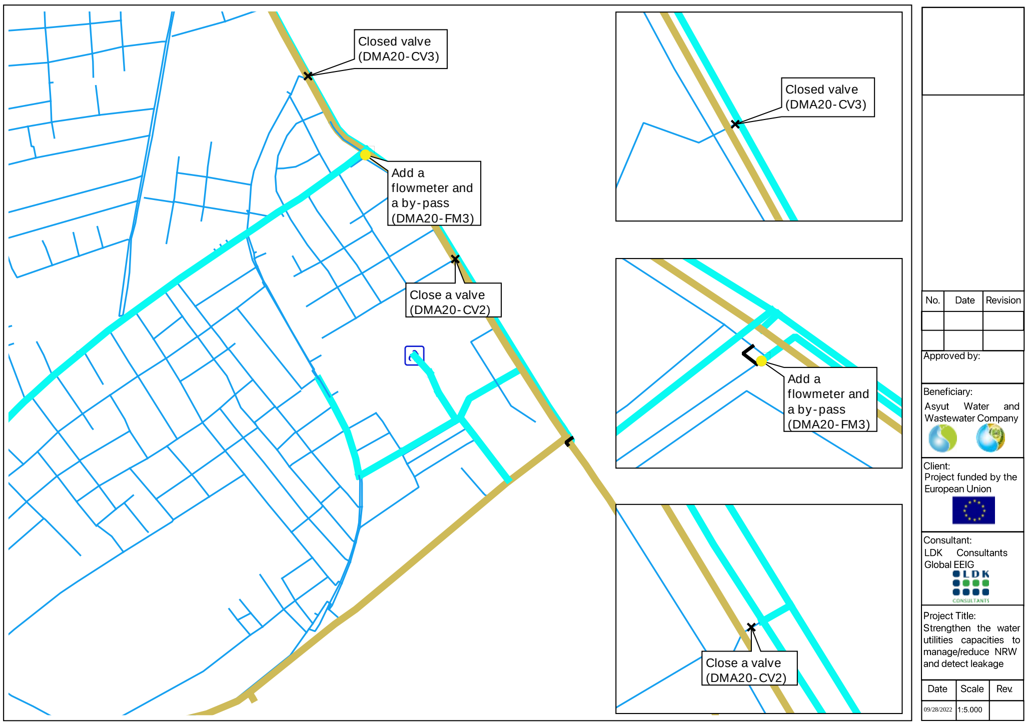


Table 30: DMA 20 flowmeter sizing

DMA20	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8
Pipe DN	300 DI	400 DI	300 DI	400 DI	500 DI			
Q (lps)	1,13	46,20	6,49	14,55	26,03			
Q_{max} (lps)	1,69	69,30	9,73	21,82	39,04			
Q_{min} (lps)	0,34	13,86	1,95	4,36	7,81			
FM DN	40	150	65	100	125			

Table 31: DMA 20 valves sizing

DMA20	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8
Pipe DN	200 DI	200 GRP	200 GRP	250 STEEL				
Valve DN	200	200	200	200				

Nowadays good accuracy can also be achieved by using either electromagnetic insertion flowmeter or an ultrasonic flowmeter. This solution can be adopted when there is a huge difference between the diameter of the flowmeter and the DN of the pipe.

10.3 WATER BALANCE CALCULATIONS FOR DMAS

The available data do not allow the IWA water balance to be prepared with the required accuracy as (i) the demand data is only an estimate based on the volume transiting in the system and the number of nodes in each urban area, (ii) the amount of water lost is also a pure estimate based on the length of the network in the area and an estimated coefficient with no reference to the real situation, (iii) no information on pressure is available from the field.

To provide an indication of what to do in the immediate future, an exercise was carried out to compare the estimated volume entering into the WSS (domestic + commercial demand, large consumers demand and leakage) with the estimated amount of water lost, DMA by DMA. This is only a theoretical exercise but, in our opinion, it gives some indication of where to start NRW reduction activities and can be seen as the first step in the procedure that should be followed in the near future.

Next Table 32 shows the result of the exercise and indicates a possible ranking of the DMAs from which NRW activities could start. The performance indicator (KPI) adopted is defined by the ratio between the amount of water lost (in lps) and the total length of the network (in km) in each DMA.

Table 32: DMA to watch out for according to KPI (lps/km)

DMA	Total Demand (lps)	Leak (lps)	Pipe length (km)	KPI	Rank
DMA1	55,97	17,87	19,36	0,923	2
DMA2	38,56	15,53	23,61	0,658	8
DMA3	57,04	20,50	29,58	0,693	7
DMA4	4,60	1,76	6,38	0,276	13
DMA5	1,28	0,32	1,29	0,251	14
DMA6	1,04	0,63	0,52	1,221	1
DMA7	19,20	1,67	2,12	0,787	6
DMA10	64,92	20,22	23,95	0,844	4
DMA17	217,84	80,34	101,34	0,793	5
DMA20	140,68	42,75	46,64	0,917	3
DMA-ARAB	3,36	1,70	2,73	0,622	10
DMA-FORTY	1,07	0,33	1,21	0,276	12
DMA-GERMA	4,80	1,79	3,61	0,496	11
DMA-NAZLET	7,03	2,85	16,52	0,173	16
DMA-UNI	10,08	3,68	5,74	0,641	9
INFLOW	0,74	0,22	1,10	0,198	15
OUTFLOW	1,71	0,61	3,87	0,157	17
	629,91	**212,77**	**289,58**		

11 RECOMMENDATIONS

At the conclusion of the hydraulic analysis, it is possible to list a few recommendations which require AWWC's attention, and which must be implemented in the immediate future in order to give continuity to the activities initiated with this project. They are:

- In our opinion, it is mandatory to have an up to date AWWC WSS GIS DB that provides information to all other AWWC departments; this means that a link between the AWWC GIS department and the other departments must be activated/enabled. Furthermore, the network of the GIS department must be a real network and not just a drawing, so the network in the GIS DB must not have isolated nodes, illogical connections or any types of errors, which is not relevant if one looks at the WSS network on a map - as a drawing - but is a serious problem if one looks at the WSS network as a tool to help make decisions. Every effort must be made to achieve this result. The aim is for the GIS department to provide the up-to-date and correct network data and schematics to all other departments which, in turn, periodically feed the GIS department with all the changes that have occurred in the meantime. This is the priority activity to perform.
- AWWC staff already started collecting the locations of customers in the field; around 80% of the total number of customers have been geo-localised. AWWC should finish this activity and the GIS department should add this database to those they already manage. The commercial department will periodically provide information on the actual (not the billed) consumption of each customer.
- Pressure monitoring points should be installed along the WSS system and flow monitoring activities should be continued using the same portable ultrasonic flowmeter used during this project. It is also recommended that permanent installations be built to monitor both flows and pressures.
- Special attention must be paid to all pumping stations, both in water treatment plants and along the WSS network. The head and flow rates of the pumps strongly influence the behaviour of the WSS and the more accurate the information, the better. It is therefore advisable to carry out specific field activities to collect data on the flows and the head of all pumps at all pumping stations and use the data to revise the model calculations. This is also a task that must be started before any other (in addition to checking the network layout).
- Some DMAs are easy to implement because they are simply connected to the main network and therefore there are few flowmeters and valves to install; the DMAs to start with are DMA1, DMA4, DMA5 DMA6 and DMA7. It is highly recommended to start by installing flowmeters and closing boundary valves from these areas. Before purchasing the equipment, a flow monitoring campaign must be carried out in each selected DMA to confirm the data provided by the calculations and the sizing of the flowmeters carried out as part of this project. The ultrasonic flowmeters already available at the AWWC are sufficient in number to start this activity.
- The geolocation of customers must start from these DMAs, so that all DMAs in this first group have the complete set of data needed for the water balance or the calculation.
- The leakage detection field campaign should also start from the indicated DMAs. They are small networks and the result that can be got can be easily combined and used with the other information.

- DMA17 and DMA20 are very complicated areas with many flowmeters and boundary valves. At this stage of the study, with the accuracy achieved in many data (network schematics, customers and flows in the network), it is not advisable to start any activities.

12 CONCLUSIONS

The general objectives of the project are to:

- Investigate the situation of non-revenue water management in a pilot city served by Asyut Drinking Water and Sewerage Company and prepare its network, as part of a rational planning aimed to NRW reduction, to the next stage of implementation of distribution zones/sectors and their subsequent division into District Metered Areas (DMAs).
- Implement and calibrate a hydraulic model for the network of the pilot city as a tool to provide valid support to move into the design stage and establishment of DMAs
- Introduce internationally recognised best practices for improving NRW (including the design of Distribution Zones and the use of GIS to enable analysis of the geographical distribution of leakage).
- Build the capacity of the utility staff involved in the pilot area on the implementation of best practices for the management of non-revenue water through on-the-job training and direct involvement in the implementation of the tasks with the support of non-key experts (field data analysis, water balancing, model calibration, and fixing anomalies between the results of the model calculations and the field data).
- Develop a manual documenting the proposed procedures for reducing NRW in Asyut city water network.

This report refers to the implementation of a hydraulic model and the preliminary phases of the design and implementation of DMAs in Asyut by using international best practices with particular attention to the use of GIS tools in the DMA design and implementation.

The hydraulic model and the WSS GIS DB have been developed using EPANET 2.0 and QGIS respectively. This is not a limitation because what has been done with the adopted software can be repeated with any other tool i.e., ArcMap as a GIS tool and WaterCAD as a hydraulic modelling tool.

The specific objectives of this activity were:

- To calibrate a hydraulic model using the flow and pressure data provided by AWWC staff
- To divide the network into permanent sectors (DMA)
- To define the type of interventions required for dividing the network into permanent controlled areas.

This has been accomplished by performing a network analysis, consisting of estimating the flows in those mains crossing district boundaries and providing indications for flowmeters and boundary valves to be operated/installed.

The result of all these tasks permitted the design of the DMA, the list of all the required equipment and the indication of the activities required to continue the activities from the reached point.

Major works were undertaken during the task and the results were the following:

- The calibrated model was adopted as a starting point to develop the required network analysis.
- Demand allocation has been developed based on the actual number of customers allocated to the nodes on the basis of the density of meters by area.
- DMA boundaries were identified and valves requiring to be closed were selected; the impact of such operations was simulated with the hydraulic model developed and it was found that they do not appreciably affect the general behaviour of the water system.
- DMA Inlet bulk flowmeters were designed by selecting the optimal number, site and size.
- A list of recommendations to start/complete the implementation of each DMA was prepared, which includes the construction of connections between pipes to minimize the number of flowmeters in the DMAs.

Annex 1 –Example of estimation of leakages

Leakage could represent a significant proportion of the "demand" of a water supply system and the way in which this is accounted for needs to be considered; normally it is adequate to allocate leakage to nodes based on the length of pipelines i.e., the total leakage will be assigned to the nodes in proportion to the length of pipelines converging in each node (half of the length of each converging pipe in each end node).

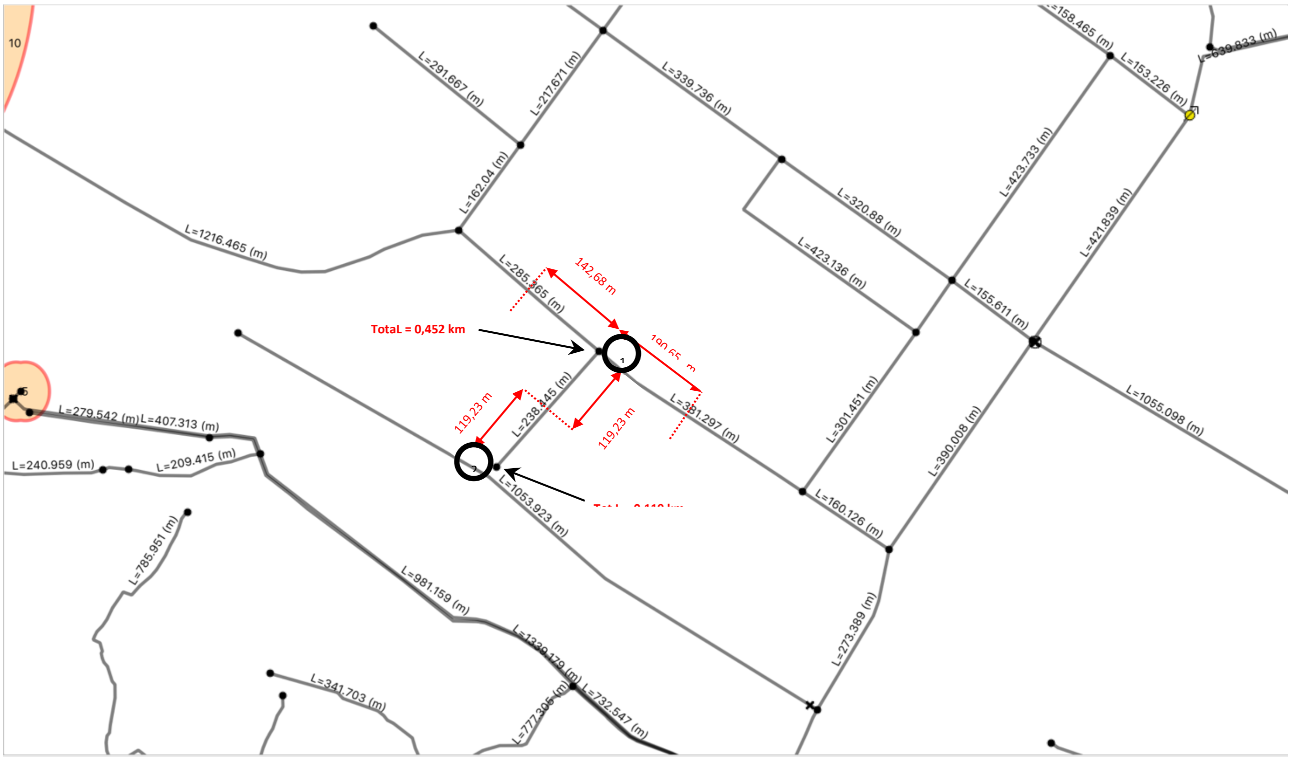
Quantitatively, leakages can be expressed as a value of litres per second per length of mains and distribution pipes (km); based on the existing literature and experience, the coefficients that can be adopted are listed in below.

Table 33: Real losses technical performance indicators

Description	Real Losses Performance Coefficient (l/s/km)
New pipes	0,25
Existing pipes	1,0

Error! Reference source not found. shows an example: the three sections of pipes converging in node 1 have a total length of 0,452 km (142,68 m + 190,65 m + 119,23 m) and the only section of pipe converging in node 2 has a length of 0,119 km.

Figure 39: Real losses allocation to nodes



Let's say that 142,68m (about 0,143 km) and 190,65m (about 0,191 km) are the lengths of "existing" pipes, while 119,23m (about 0,119 km) is the length of a "new " pipe. Therefore, the leak demand associated with node 1 is:

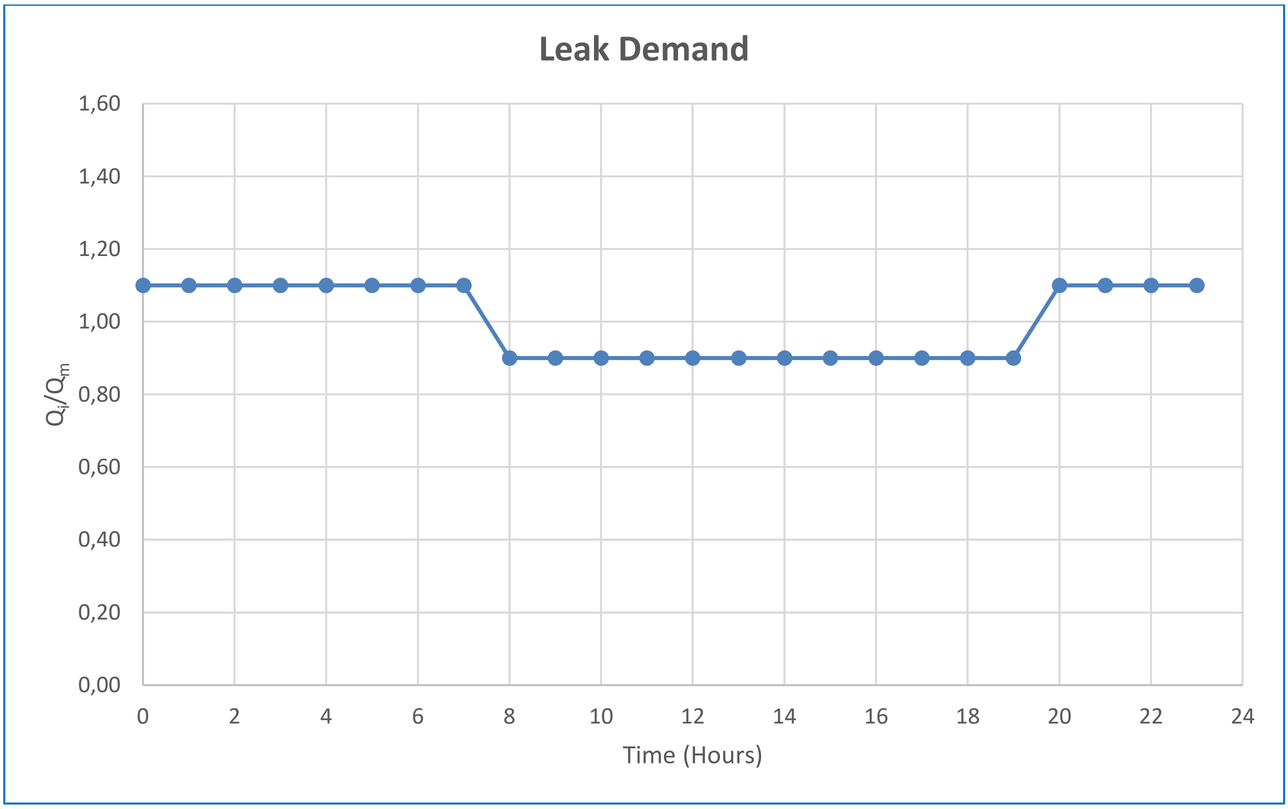
$$\frac{1\ [l/s/km] \times 0{,}143\ [km]\ + 1\ [l/s/km] \times 0{,}191\ [km]\ +\ 0{,}25\ [l/s/km] \times 0{,}119\ [km]}{0{,}143\ [km] + 0{,}191\ [km] + 0{,}119\ [km]}$$
$$= 0{,}364\ l/s$$

and the leak demand associated with node 2 is:

$$0{,}25\ [l/s/km] \times 0{,}119\ [km] = 0.02975 l/s.$$

It can be assumed that the leak daily pattern has reduced levels of leakage during periods of lower pressures, which correspond to periods of higher demand during the day.

Figure 40: NRW demand daily pattern



GIS tools can greatly facilitate the calculation of the length of pipes to be assigned to each node.

Annex 2 – Data and results of the modelled network

Annex 3 – Data and Results of the modelled network for DMA design