



TECHNICAL UNIVERSITY OF CIVIL ENGINEERING

Research report III

Numerical modelling and experimental validation of water losses in a distribution network in laboratory conditions

Doctoral student:

Asist. eng. ALDEA Alexandru

Ph.D. coordinators:

Prof. dr. eng. TATU Gabriel

Prof. dr. eng. ANTON Anton

1	UNELTE INFORMATICE.....	Error! Bookmark not defined.
1.1	WB-EasyCalc	4
1.2	CalcuLEAKator	5
1.3	AWWA Free Audit Software	6
1.4	Sigma	7
1.5	EurWB&PICalcs	8
2	MODELE HIDRAULICE.....	9
2.1	Județul BRĂILA	9
2.1.1	Localitatea Tufești	9
2.1.2	Localitatea Ianca.....	12
2.1.3	Localitatea Însurăței	13
2.1.4	Localitatea Făurei.....	17
2.1.5	Localitatea Viziru.....	18
2.2	Județul ILFOV	20
2.2.1	Localitatea Bragadiru	20
2.2.2	Localitatea Cornetu	Error! Bookmark not defined.
2.2.3	Localitatea Brănești.....	27
2.2.4	Localitatea Cernica	31
2.2.5	Localitatea Ciorogârla	35
2.2.6	Localitatea Domnești.....	39
2.2.7	Localitatea Dobroești.....	41
2.3	Județul DÂMBOVIȚA	45
2.3.1	Localitatea Titu.....	45

2.3.2	Localitatea Fieni	47
2.3.3	Localitatea Găești	49
2.3.4	Localitatea Moreni	52
2.3.5	Localitatea Pucioasa	55
2.3.6	Localitatea Târgoviște	59
3	CONCLUZII.....	Error! Bookmark not defined.
	Bibliografie	Error! Bookmark not defined.

Numerical modelling and experimental validation of losses in a distribution network in laboratory conditions

1 SOFTWARE TOOLS

Water balance and performance indicators calculation needs an intensified effort from the Water Operators because of the large quantity of information. This is the reason why, in most of the cases, this activity is performed with the help of the computer using different software applications more or less specialised. In the following I'll present three free software solutions for the calculation of the water balance and performance indicators.

1.1 WB-EasyCalc

WB-EasyCalc is a simple application for calculating water balance and performance indicators. The program in Excel format was created by Roland Liemberger and can be updated / downloaded from <http://www.liemberger.cc>.

The application is based on the IWA best practice manual and allows the step-by-step introduction of all the components needed to calculate the water balance. At the same time, the application allows the creation of simple "What If" scenarios, the evaluation of the cost of the distribution system as well as the global comparison with other water distribution systems in the world.

The application allows you to select the Romanian language as the working language, but if you want to change it, choose the tab *Change language* and enter the code for the new option.

WB-EasyCalc is a direct approach to the IWA calculation methodology, in the sense that it focuses on a "top-down" approach, for which it does not offer any facility for calculating or estimating physical losses. This application is recommended for quick and accurate calculations of water balance and performance indicators and is an excellent tool for beginners.

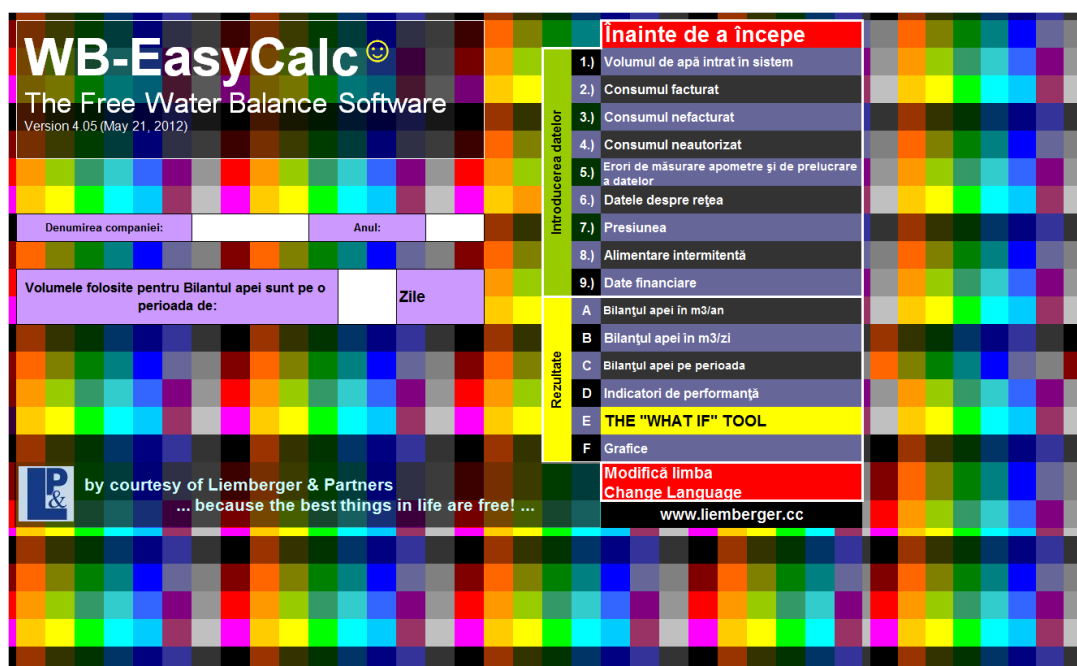


Figure 1-1 Start page of WB-EasyCalc

1.2 CalcuLEAKator

CalcuLEAKator este o aplicație destinată în special calculului balanței apei și a indicatorilor de performanță pentru DMA-uri, de asemenea în format *Excel*, creată de către Djevad Koldzo și poate fi descărcată de la adresa <http://www.waterloss.com.ba>. Programul este bilingv (suportă limbile engleză și bosniacă).

CalcuLEAKator is an application designed especially for calculating water balance and performance indicators for DMAs, also in Excel format, created by Djevad Koldzo and can be downloaded from <http://www.waterloss.com.ba>. The program is bilingual (supports English and Bosnian).

The application can manage up to 20 districts (DMAs) within a distribution network and allows the calculation of water balance and performance indicators both for the entire network and for each district.

The terminology used is based on the IWA best practice manual, but unlike WB-EasyCalc it adopts a “bottom-up” approach, in the sense that it allows the introduction of flow variation information for 24 hours.

CalcuLEAKator is for advanced users and involves the preparation of a consistent amount of information in advance. The program provides clear explanations of use (accessed with the Help button) and can be used together with two other applications: *ReCalcuLEAKator* and *LEAK REPORT - Water Leaks Database*).

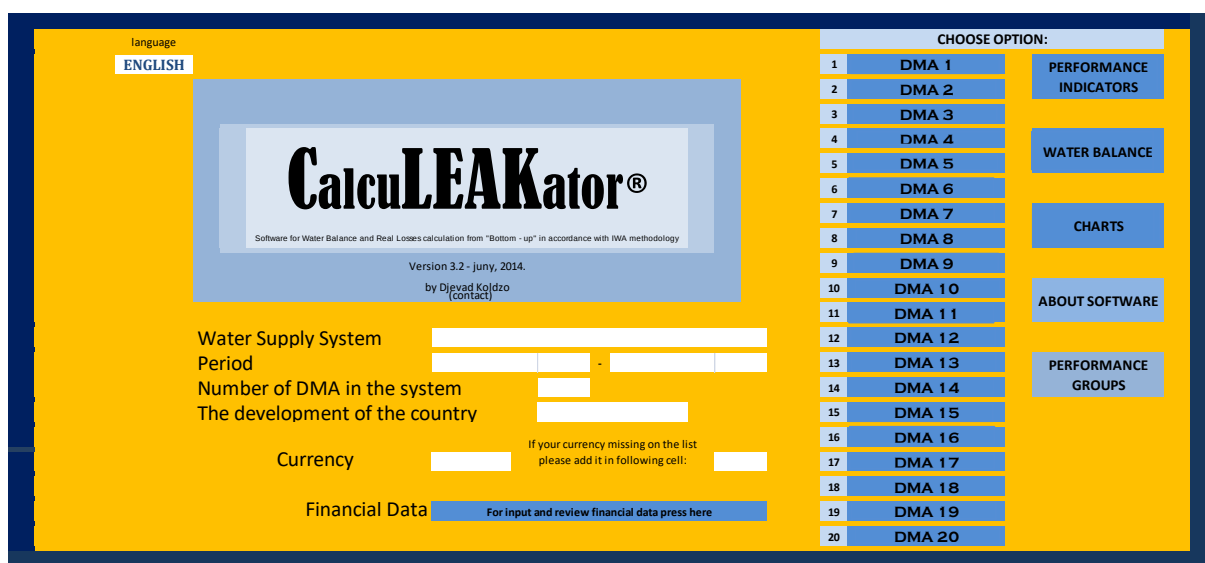


Figure 1-2 Start page of *CalcuLEAKator* application

1.3 AWWA Free Audit Software

Asociația Americană a Apei (AWWA) a dezvoltat o aplicație proprie în format *Excel* disponibilă pe pagina web www.awwa.org (necesită înregistrarea utilizatorului pentru a accesa resursele software).

The American Water Association (AWWA) has developed its own Excel application available on the website www.awwa.org (requires user registration to access software resources).

The program is based on the AWWA format for water balance (exported and imported water are separate components) and adopts a "top-down" approach. The current version allows you to choose your preferred unit of measurement for volume (megaliters or millions of gal.). The program also offers the opportunity to plan a water company-level loss management strategy based on an included assessment matrix. The calculated performance indicators are divided into two categories: financial and operational, and unused water can be expressed as volume or cost.

AWWA also provides an additional Excel program that aggregates information from multiple audit files, thus significantly facilitating multi-annual analysis for a particular water company.

AWWA Free Water Audit Software v5.0

American WaterWorks Association Copyright © 2014. All Rights Reserved.

This spreadsheet-based water audit tool is designed to help quantify and track water losses associated with water distribution systems and identify areas for improved efficiency and cost recovery. It provides a "top-down" summary water audit format, and is not meant to take the place of a full-scale, comprehensive water audit format.

Auditors are strongly encouraged to refer to the most current edition of AWWA M36 Manual for Water Audits
for detailed guidance on the water auditing process and targetting loss reduction levels

The spreadsheet contains several separate worksheets. Sheets can be accessed using the tabs towards the bottom of the screen, or by clicking the buttons below.

Please begin by providing the following information

Name of Contact Person:

Email Address:

Telephone | Ext.:

Name of City / Utility:

City/Town/Municipality:

State / Province:

Country:

Year:

Start Date:

End Date:

Audit Preparation Date:

Volume Reporting Units:

PWSID / Other ID:

The following guidance will help you complete the Audit

All audit data are entered on the [Reporting Worksheet](#)

Value can be entered by user

Value calculated based on input data

These cells contain recommended default values

Use of Option Pcnt: Value:

(Radio) Buttons: ☒ 0.25% ☐

Select the default percentage by choosing the option button on the left

To enter a value, choose this button and enter a value in the cell to the

The following worksheets are available by clicking the buttons below or selecting the tabs along the bottom of the page

<u>Instructions</u> The current sheet. Enter contact information and basic audit details (year, units etc)	<u>Reporting Worksheet</u> Enter the required data on this worksheet to calculate the water balance and data grading	<u>Comments</u> Enter comments to explain how values were calculated or to document data sources	<u>Performance Indicators</u> Review the performance indicators to evaluate the results of the audit	<u>Water Balance</u> The values entered in the Reporting Worksheet are used to populate the Water Balance	<u>Dashboard</u> A graphical summary of the water balance and Non-Revenue Water components
<u>Grading Matrix</u> Presents the possible grading options for each input component of the audit	<u>Service Connection Diagram</u> Diagrams depicting possible customer service connection line configurations	<u>Definitions</u> Use this sheet to understand the terms used in the audit process	<u>Loss Control Planning</u> Use this sheet to interpret the results of the audit validity score and performance indicators	<u>Example Audits</u> Reporting Worksheet and Performance Indicators examples are shown for two validated audits	<u>Acknowledgements</u> Acknowledgements for the AWWA Free Water Audit Software v5.0

If you have questions or comments regarding the software please contact us via email at: wlc@awwa.org

Figure 1-3 Start page of AWWA Free Audit Software

1.4 Sigma

Sigma is an executable application for the Windows platform dedicated exclusively to the calculation of performance indicators for a water supply system. The application allows the definition of performance indicators by the user and is not limited only to the study of water losses.

Among the special facilities offered are the ability to create dedicated charts for the values obtained and the ability to define target performance indicators. The application can be downloaded from the web page <http://www.sigmalite.com/novedades-en.php> and has recently been updated to version 3.

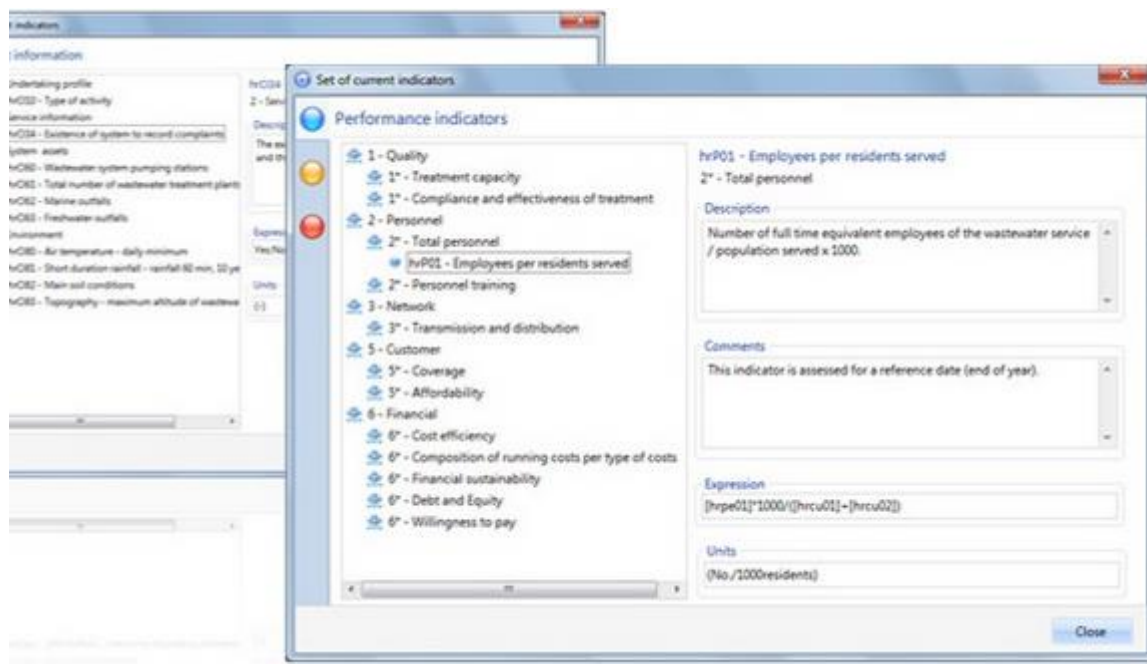


Figure 1-4 Definition / choice of performance indicators in Sigma 3

1.5 EurWB&PICalcs

EurWB & PICalcs is an Excel application created by Allan Lambert and can be accessed from the website <http://www.leakssuite.com/free-software/eurwbpicalcs/>.

This application introduces advanced concepts for the study of water losses and for the calculation of performance indicators and accordingly is recommended for experienced users in the field of water losses.

Slavonski Brod Grad	Whole System	transmission mains (km) =	200.0	+ Distribution mains =	800.0	km.	total mains length Lm km =	1,000.0
Underground service connections, main to first meter: Number Nc =		25,000	with average length =	10.0	metres/conn	Total conn length Lt km =	250.0	
Population =	100,000	number of Billed Properties Np =	30,743	Average pressure P =	50.0	metres.	Density of Conns/km of mains	25.0
Period of Water Balance from		01.01.2014	to	31.12.2014	365	days		
Enter data for your system in yellow cells. View the 'Comments', indicated by small red triangles in top right hand corner of some Cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	% pumped =	100%	Potable Water Input from UTILITY TREATMENT WORKS	6,861,955	m ³	18,800	m ³ /day	18.8
	% pumped =	100%	Potable Water IMPORTED to this system	658,330		1,804		1.8
	% pumped =	0%	SYSTEM INPUT VOLUME (Potable Water)	7,520,285		20,604		20.6
	% pumped =	0%	Potable Water EXPORTED from this system	0		0		0.0
	% pumped =	0%	Potable WATER SUPPLIED TO THIS SYSTEM	7,520,285		20,604		20.6
	Do most customers have storage tanks?	Residential No	Billed Metered Consumption (Residential)	3,179,269		8,710		8.7
		Non-Residential No	Billed Metered Consumption (Non-Residential)	780,396		2,138		2.1
			Billed Unmetered Consumption	0		0		0.0
			NON-REVENUE WATER NRW	3,560,620		9,755		9.8
	Unbilled Authorised Consumption	1.00%	of Billed Metered Consumption	39,597		108		0.1
WATER LOSSES				3,521,023		9,647		9.6
Unauthorised Consumption				39,597		108		0.1
Customer Metering	Residential	5.00%	of Billed Metered Residential Consumption	158,963		436		0.4
Inaccuracies	Non-Residential	5.00%	of Billed Metered Non-Residential Consumption	39,020		107		0.1
APPARENT LOSSES				237,580		651		0.7
CURRENT ANNUAL REAL LOSSES CARL (LEAKAGE)				3,283,443		8,996		9.0
UNAVOIDABLE ANNUAL REAL LOSSES (m ³ /year) = (6.57 x Lm + 0.256 x Nc + 9.13 x Lt) x P				762,625		2,089		2.1
INFRASTRUCTURE LEAKAGE INDEX ILI = CARL/UARL				4.31		Moderate		ILI for a Low Income Country

Figure 1-5 Typical water balance EurWB&PICalcs

2 HYDRAULIC MODELS

The next hydraulic models were produced between 2011 and 2015 for the distribution networks in the operation area of a various Regional Operators.

2.1 BRĂILA County

2.1.1 Tufești Locality

In this case, two hydraulic models were produced, one which simulates the network behaviour during the summer period and the other simulating the winter period behaviour. The differences resulting from the point of view of the network topology for the two cases were the following ones:

- The Tufești Reservoir has two functions depending on the model performed: for the summer period it holds the role of a physical reservoir as for the winter period it holds the role of a fictive reservoir which simulates the hydraulic conditions measured on the by-pass pipe of the Gropeni water transport main.
- The pump exists only in the model for the summer period, because for the winter time period this pump is not in function.

In order to proceed with the numerical simulation of the distribution network, the application used was the menu of *Hydra* and afterwards the *Compute*. The software automatically writes a file in the *Epanet* format and uses the *Epanet* libraries in order to perform the calculations of the hydraulic model.

Additionally, *Epanet* files in the *.net format were created for an easier use of the hydraulic model without the need of a *URBANO 8* license.

At the same time, the results are also presented in a table format and appended for the demand peak hours of the two produced models.

The simulation of the effect of variable speed for the pumping station was performed through the assignment of a pressure reducing valve (PRV type) in the 407 node, and the pressure was set to a 20 m value.

The summer time consumptions which resulted were two times larger than the ones in the autumn-winter months. In the conditions of non-existent measurements of the flow variation during the summer period, one more scenario was produced in *Epanet* in which at the demand peak hour the flow which transits the network is approx. 4 times larger than the medium flow (following the dialogue with the local representatives of the beneficiary the simulation tried to mimic the real situation in Tufești).

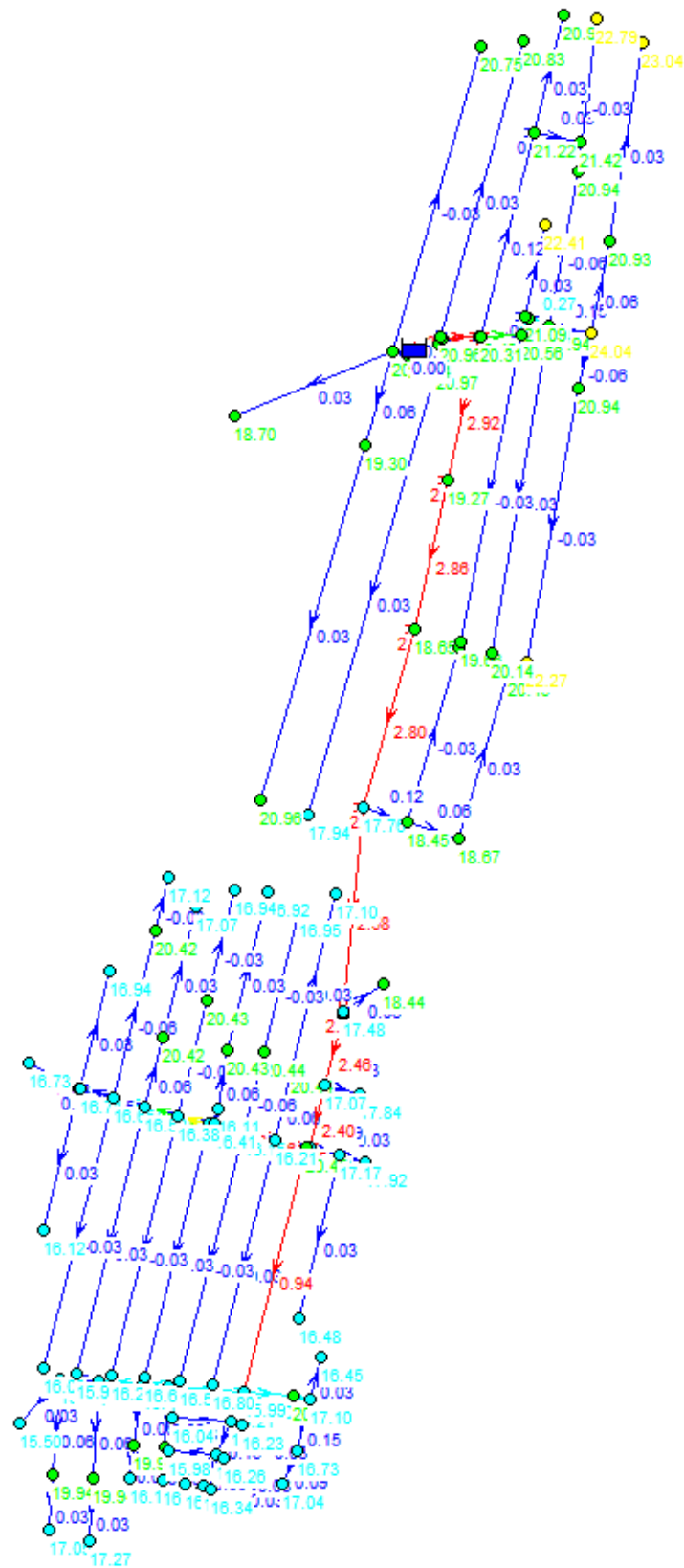


Figure 2-1 Results from the hydraulic model for the demand peak hour in the winter period.

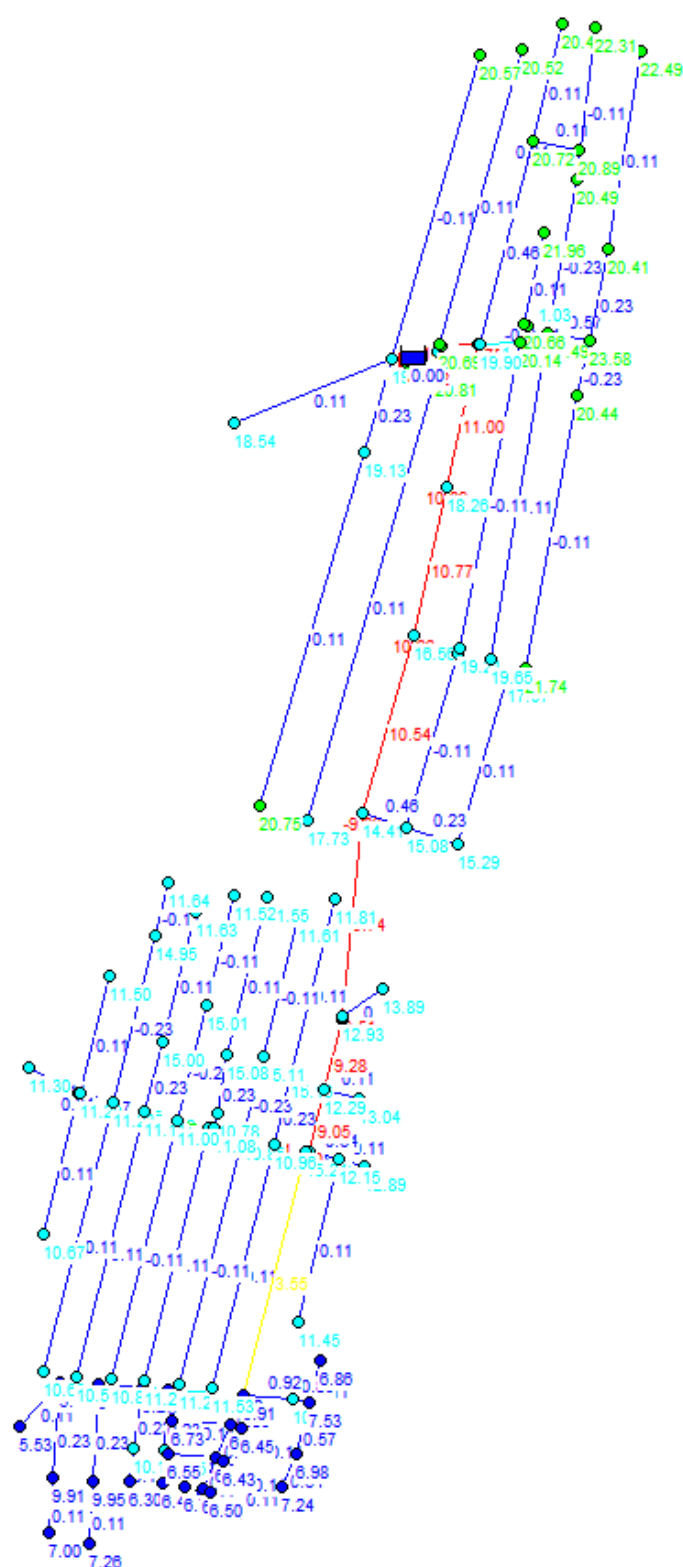


Figure 2-2 Results from the hydraulic model for the demand peak hour in the summer period.

After running the hydraulic models, the results were that in winter conditions the network can meet the necessary demand, but in summer conditions at the demand peak hour the pressure at the end of the network show values of approx. 6 mH₂O (the second alternative of the summer time model).

Regarding the pumping station, usually two pumps connected in parallel should be enough to meet the maximum demand in summer time. Nevertheless, analyzing the pump performance curve data, it could be observed that the pumping total head value is much larger than the network requirement (pump curve starts from a total head value of about 100 m). Thus another direct consequence is that the pump/pumps will operate at very low efficiency rating.

Even though is recommended to change the pumps with models which would better match the specificity of the Tufești distribution network, in order to solve the problem of low pressures at the end of the network it is proper to rise the pressure which must be maintained on pumps discharge in demand peak hours.

2.1.2 Ianca Locality

The hydraulic model produced in this case took into account only the distribution network belonging to the Ianca locality. The simulation of the hydraulic conditions at the network entrance was produced with the help of a constant level reservoir which ensures a pressure of approx. 35 mH₂O.

In the future it is recommended to also simulate the situation in which the other pertaining localities are also supplied with water, after the extension and rehabilitation works.

In order to produce the numerical simulation of the distribution network, the application used was the menu *Hydra* and afterwards the *Compute*. The software automatically writes a file in the *Epanet* format and uses the *Epanet* libraries in order to perform the hydraulic model calculation.

Further, *Epanet* files in the *.net format was also created for the easier use of the hydraulic model without the need of a *URBANO 8* license.

Moreover, in the appendices the results are also presented in a table format for the demand peak hours of the simulated model.

The simulation of the model was produced in the conditions in which the variation curve taken into account was considered to be the one obtained from the debit and pressure measurements.

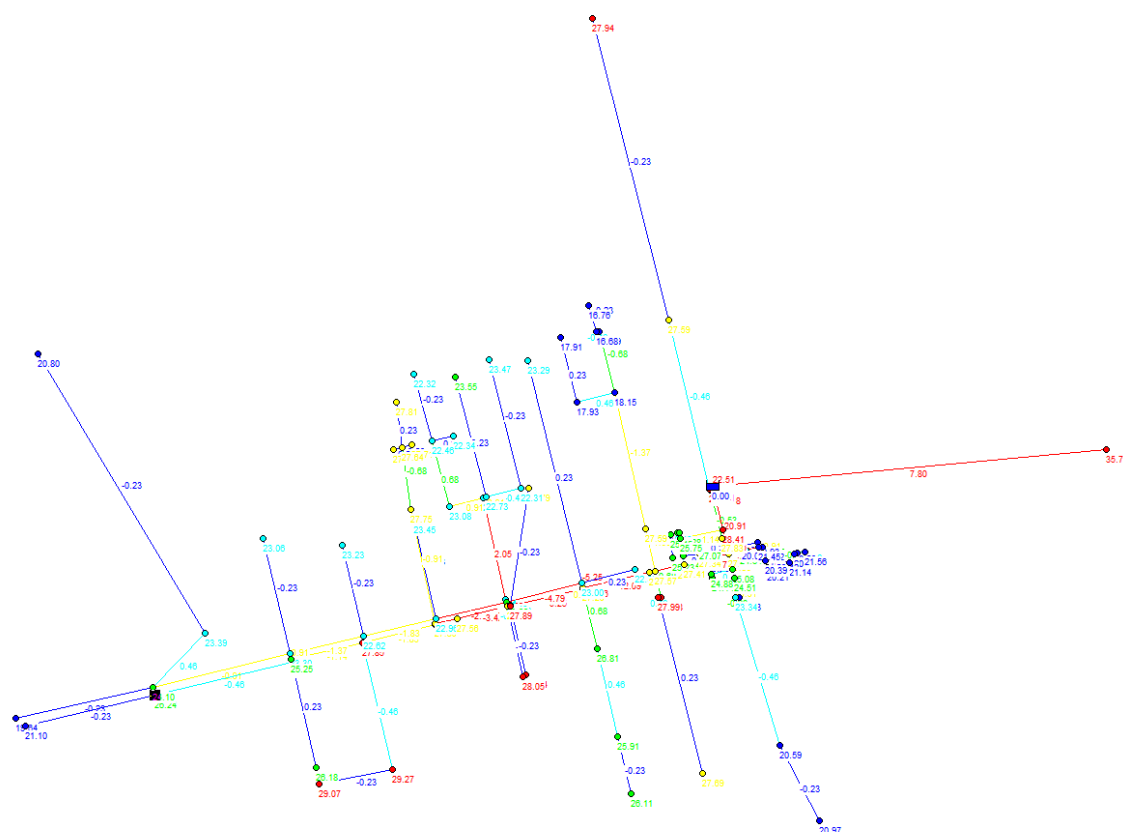


Figure 2-3 Results of the hydraulic model for the Ianca locality

Following the running of the hydraulic models turned out results showing that the existing distribution network can ensure the pressure needed in the network nodes, fact which was confirmed by the measurements carried out.

Nevertheless, the existing system presents an uninspired configuration of the water supply system, in the sense that the Ianca pumping station delivers water with only one pump for all the nearby localities.

As a result of the study carried out in the considered project, the water supply configuration is going to suffer major changes, thus it is recommended to update the hydraulic model so that it takes into account all of these aspects.

2.1.3 Însurăței locality

In this case two models were produced in the idea that only the distribution network belonging to the Însurăței locality was factored in the simulation of the consumption for the villages Mărul Roșu and Lacul Rezii in the node J138. The two working versions taken into account were the following:

- The distribution network presents a constriction on the discharge pipe of the Însurăței pumping station (DN65 instead of DN225), the existing situation at the moment of carrying out the pressure measurements at a **discharge pressure** of approx. 2.9 bar.

- The distribution network operates in a regular way (without the constriction on the discharge pipe of the pumping station), at a discharge pressure of approx. 3.4 bar.

For the purpose of numerical simulation of the distribution network, the menu *Hydra* followed by *Compute* were used. The application writes automatically a file in the *Epanet* format and uses the *Epanet* libraries in order to calculate the hydraulic model.

In addition, were created *Epanet* files in the *.net format for an easier use of the hydraulic model without the need of an *URBANO 8* license.

Therewith are the appended results which are also presented in a table format for the demand peak hours of the two modelled situations.

The simulation of the model was produced in the conditions in which the variation curve taken into account was considered to be the one obtained from the debit and pressure measurements.

The simulation of the discharge pressure observed on the ground was set by modifying the speed of the pump with the mention that at the present time the Însurăței pumping station works in manual operating conditions.

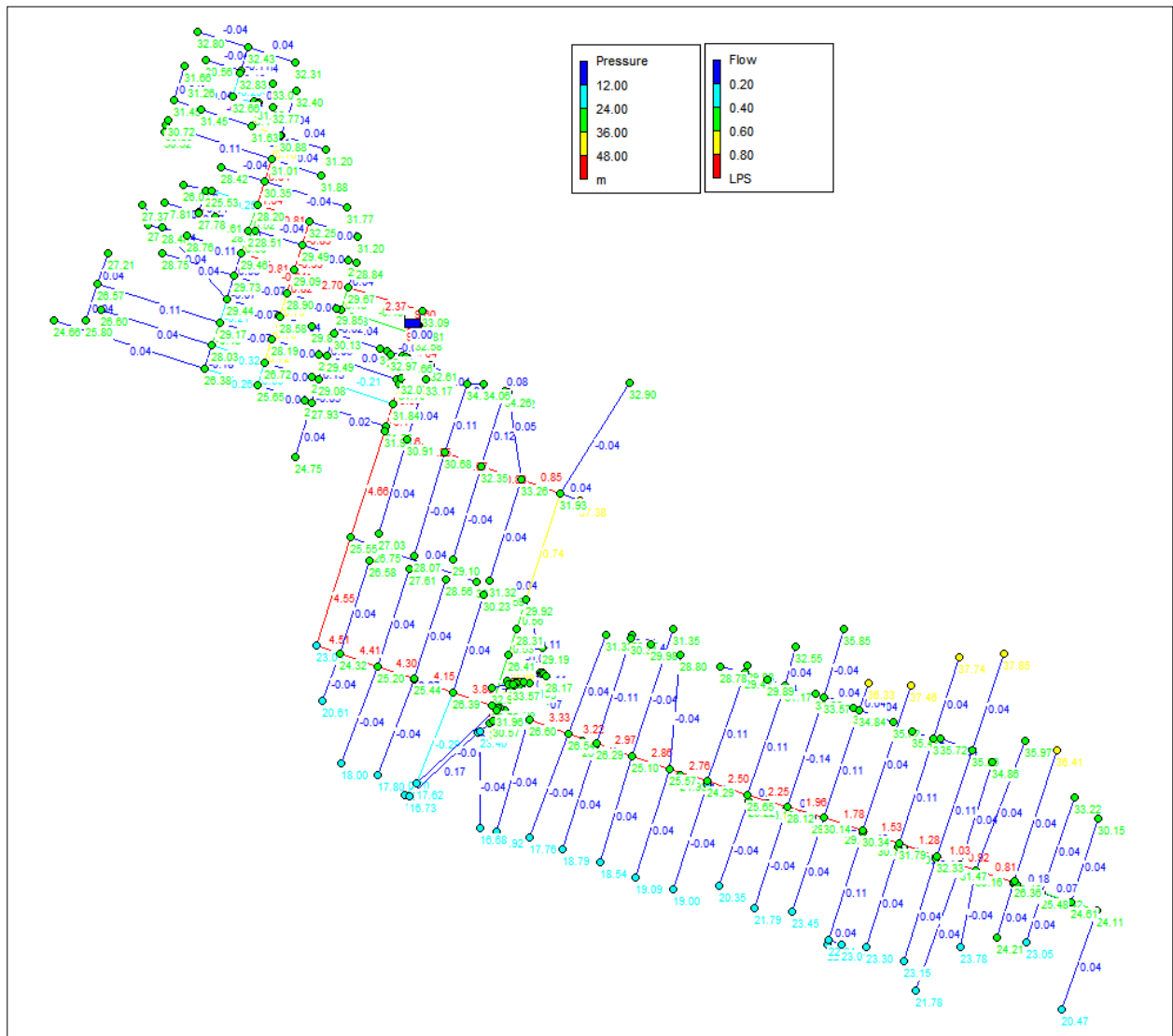


Figure 2-4 Results of the hydraulic model for the Însurăței locality (demand peak hour without the constriction)

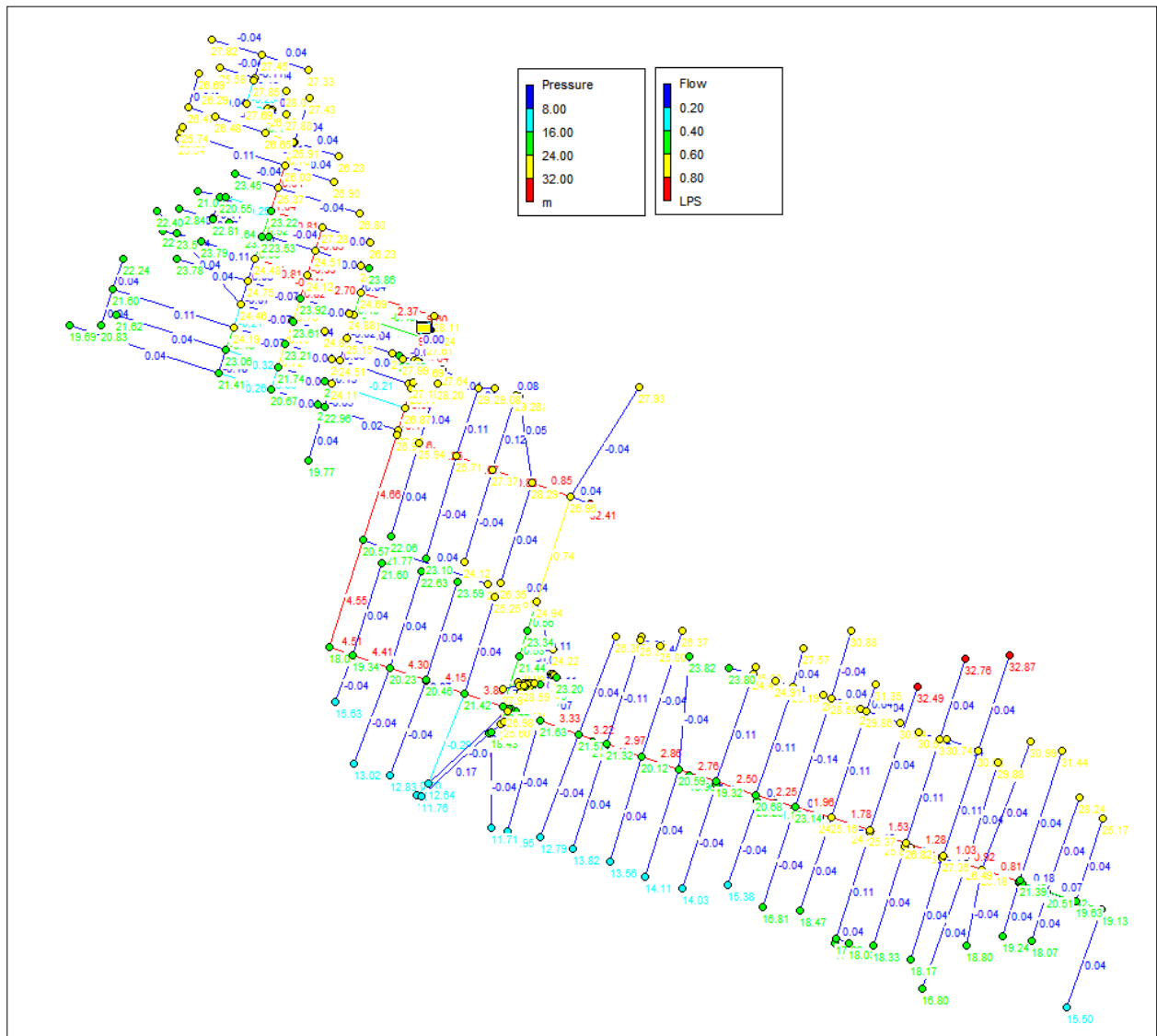


Figure 2-5 Results of the hydraulic model for the Însurăței locality (demand peak hour with the constriction on the discharge pipe)

After the running of the hydraulic models it turned out the results were showing that the existing distribution network can ensure the pressure needed in the network nodes, fact which was confirmed by the measurements carried out. It can be observed that the water supply in the winter period can be ensured with only one pump, but for the summer period it is estimated that there will be needed two pumps which will operate in parallel.

Head losses are relatively low, the differences in pressure being more likely the result of the differences in the geodetic elevation.

2.1.4 Făurei locality

The hydraulic model this time was created with the consideration of the distribution network only pertaining to the Făurei locality in the actual configuration (by-passing the water tower). The pumping station was simulated with a speed of 0.8 x rated speed in order to simulate a pressure of approx. 2.3 bar on the discharge (according to the measurements carried out on the ground).

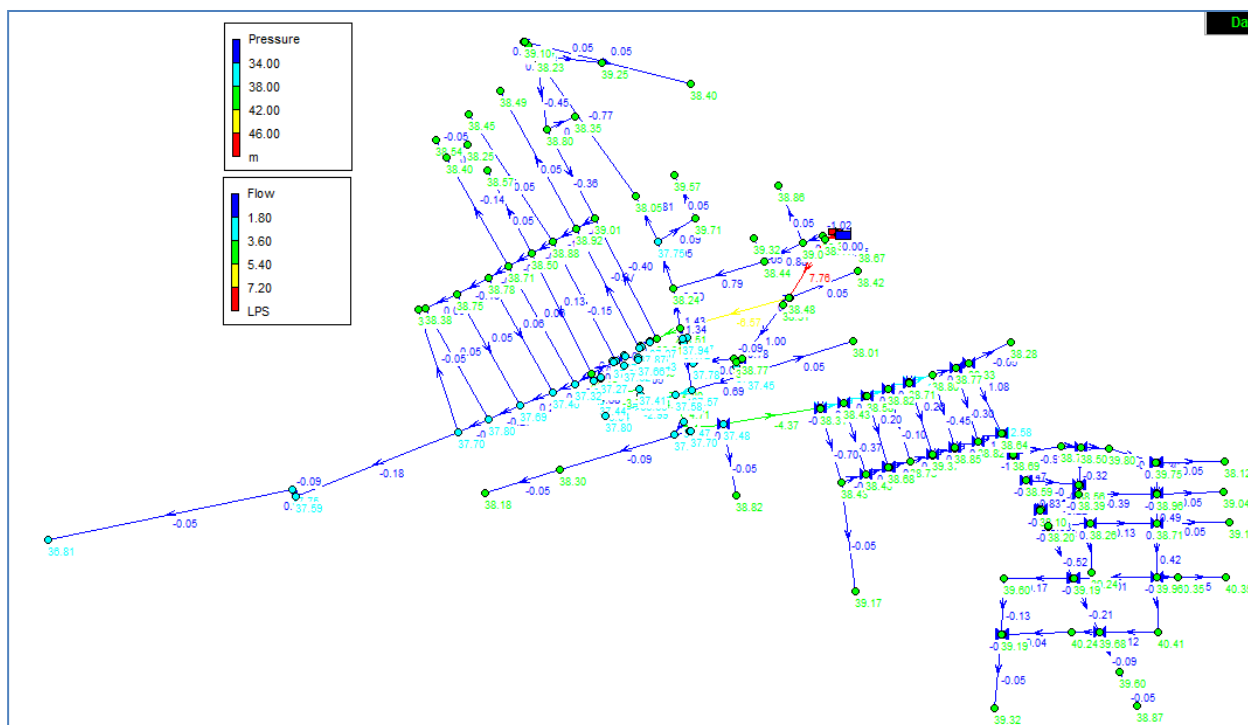
In order to produce the numerical simulation of the distribution network, the application used was the menu *Hydra* and afterwards the *Compute*. The software automatically writes a file in the *Epanet* format and uses the *Epanet* libraries to perform the hydraulic model calculation.

In addition, *Epanet* files in the *.net format were also created for an easier use of the hydraulic model without the need of a *URBANO 8* license.

Therewith, in the appendices the results are also presented in a table format for the demand peak hours of the modelled situation.

The simulation of the model was produced in the conditions in which the variation curve taken into account was considered to be the one obtained from the debit and pressure measurements.

The simulation of the discharge pressure observed on the ground was set by modifying the speed of the pump with the mention that at the present time the Făurei pumping station operates at a speed of 0.8 x rated speed.



Figură 2-6 Results of the hydraulic model for the Făurei locality (demand peak hour)

After running of the hydraulic models it resulted that the existing distribution network can ensure the pressure needed in the network nodes, fact which was confirmed by the measurements carried out. It can be observed that the water supply in the winter period can be ensured with only one pump, but for the summer period it is estimated that there will be needed two pumps which will operate in parallel.

Head losses are relatively low, the differences in pressure being more likely the result of the differences in the geodetic elevations.

2.1.5 Viziru locality Localitatea Viziru

The hydraulic model produced this time took into account only the distribution network belonging to the Viziru locality in the actual configuration (by-passing the water tower). The pumping station was simulated with a speed of 0.8 x rated speed in order to simulate a pressure of approx. 2.3 bar on the discharge (according to the measurements carried out on the ground).

In order to produce the numerical simulation of the distribution network, the application used was the menu *Hydra* and afterwards the *Compute*. The software automatically writes a file in the *Epanet* format and uses the *Epanet* libraries to perform the hydraulic model calculation.

In addition, *Epanet* files in the *.net format was also created for an easier use of the hydraulic model without the need of a *URBANO 8* license.

At the same time, in the appendices the results are also presented in a table format for the demand peak hours of the modelled situation.

The simulation of the model was produced in the conditions in which the variation curve taken into account was considered to be the one obtained from the debit and pressure measurements.

The simulation of the discharge pressure observed on the ground was performed by modifying the speed of the pump with the mention that at the present time the Făurei pumping station operates at a speed of 0.8 x rated speed.

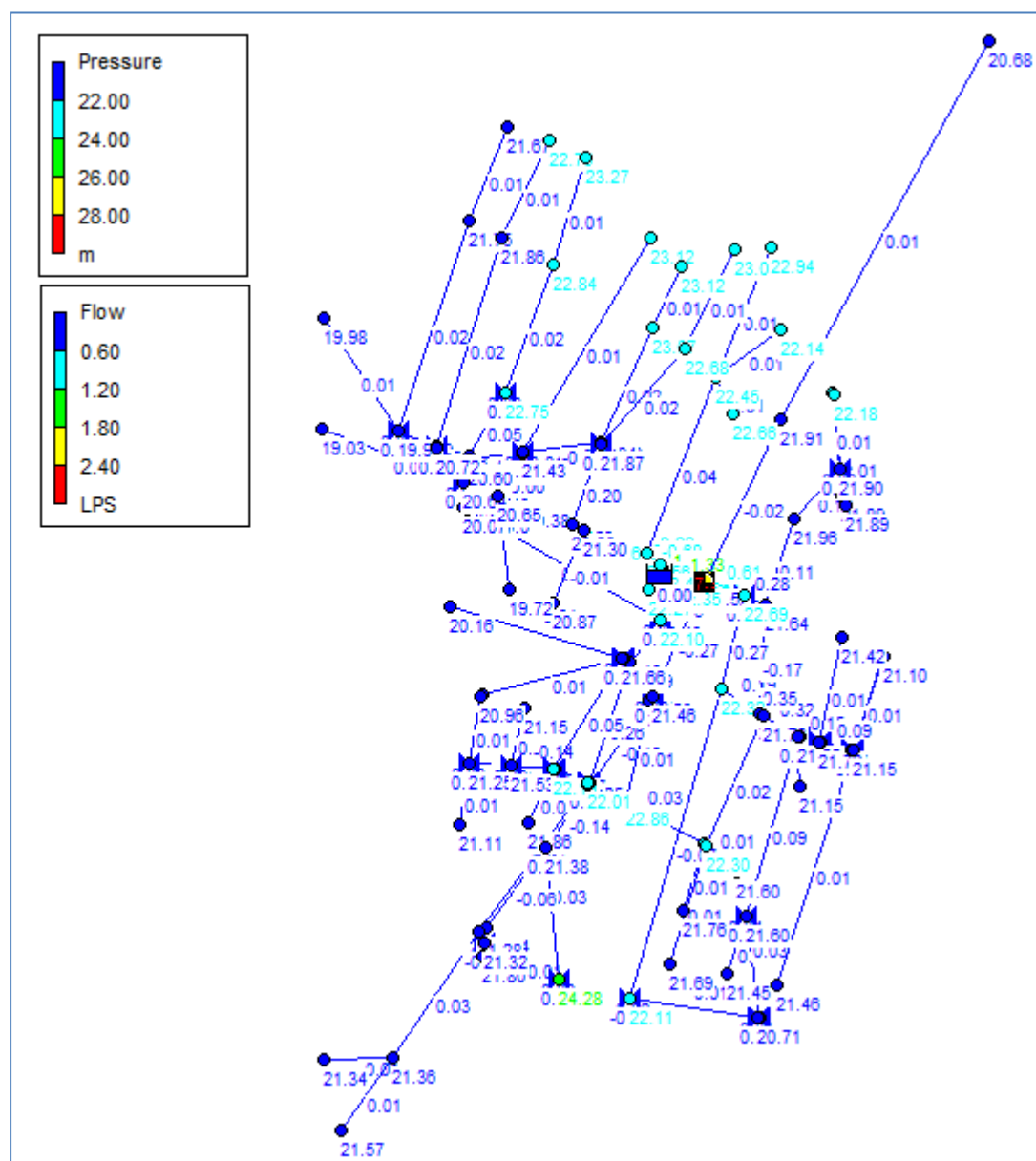


Figure 2-7 Results of the hydraulic model for the Viziru locality (demand peak hour)

After running of the hydraulic models it resulted that the existing distribution network can ensure the pressure needed in the network nodes, fact which was also confirmed by the measurements carried out. It can be observed that the water supply in the winter period can be ensured with only one pump, but for the summer period it is estimated that there will be needed two pumps which will operate in parallel.

Head losses are relatively low, the differences in pressure being more likely the result of the differences in the geodetic elevations.

2.2 ILFOV County

2.2.1 Bragadiru locality

The pipes used in the water distribution are from **PEID, PE 100, PN 6**. The water distribution network was placed as possible at the edge of the road, in the vicinity of the drain ditch or near the sidewalk, taking into account the placement of the other public networks (sewer, gas, electricity, telephony networks etc.) and with conformance to the SR 8591/1997.

Pipe laying depth for the water pipes was set to an average of 1.20 – 1.30 m.

For the individual households, the water service connections to the domestic consumer (adding up to 3 586 pcs.) were made from PEID, PN 6, PE 100 mm, De 32 mm pipes up to the property boundary, without providing a connection chamber.

To extinguish the fires, fire hydrants with a diameter of Dn 80 mm (311 pcs.) were provided on the network. They are located especially at the intersection of streets, as well as along them, at a maximum distance of 100 m from each other, in places easily accessible to the fire truck.

After filling with all the data from GIS, from measurements, and from technical documents or calculated mathematically, the hydraulic simulation of the model was run.

The simulation was performed in hydrodynamic regime, in order to highlight the behaviour in time of the network.

The simulation assumed that the pumps would work at a constant pressure by automatically adjusting the speed.

From the menus specific to the results of the modelling different parameters were chosen with which representative thematic maps were made:

- Demand, pressure or piezo metric head in each node;
- Flow, flow rate or head loss for each pipe

With any of the above, color-coded thematic maps can be made according to user-set parameters.

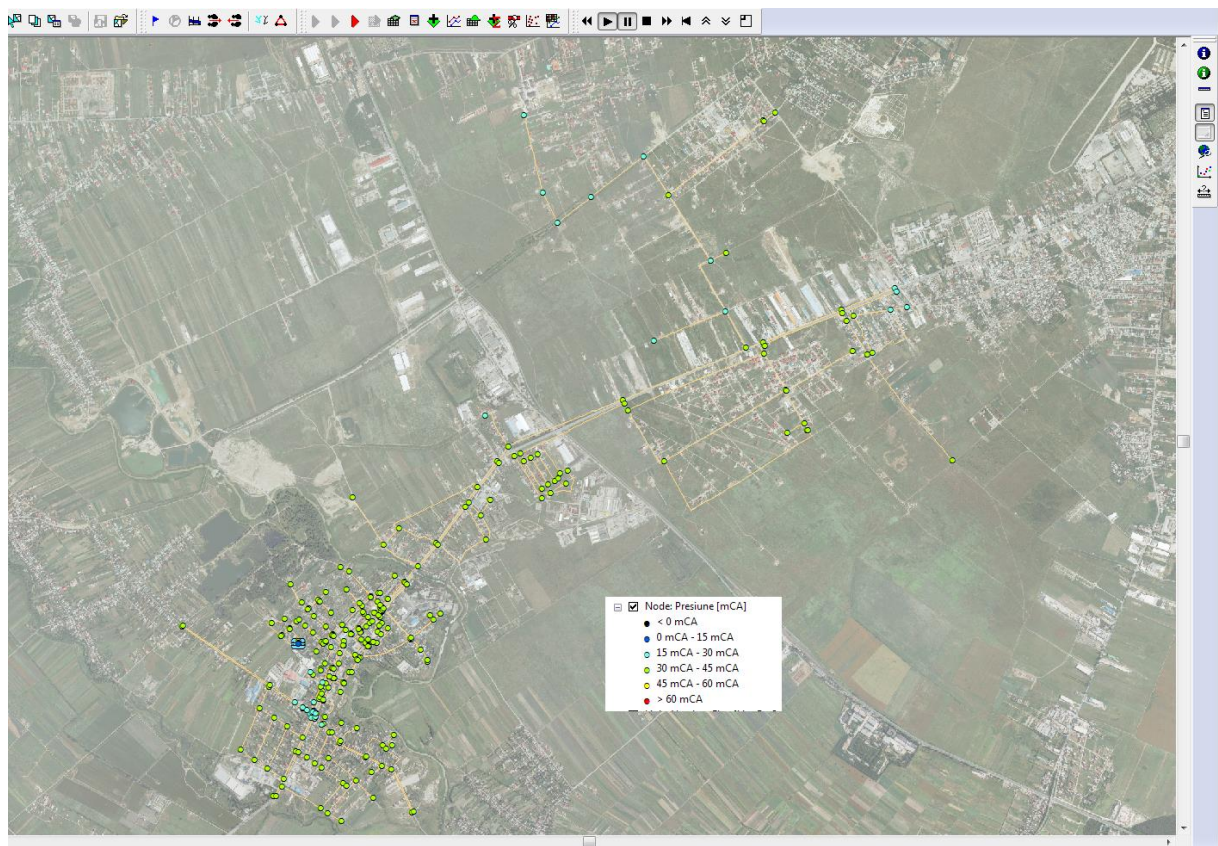


Figure 2-8 Pressures in the network nodes at demand peak hour

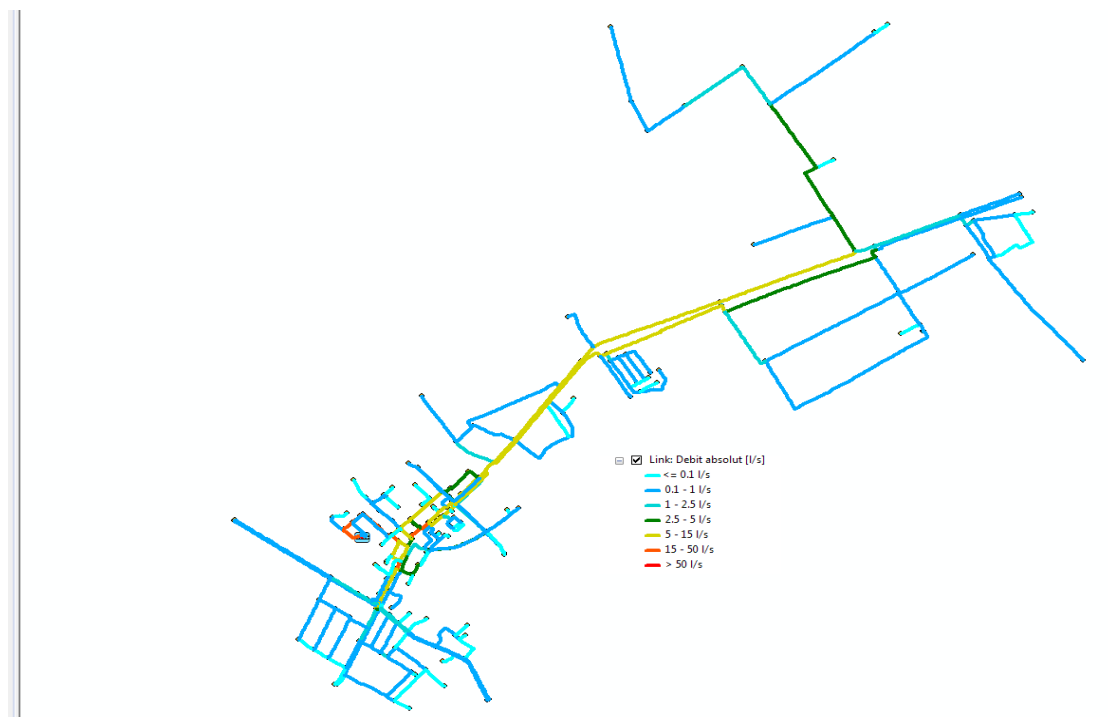


Figure 2-9 Flows transported at demand peak hour

The results obtained indicate the following:

- The average flow rate on water mains (diameters over 125mm) is 0.23 m/s, but low values are also recorded, below 0.01 m/s in the extremity areas.

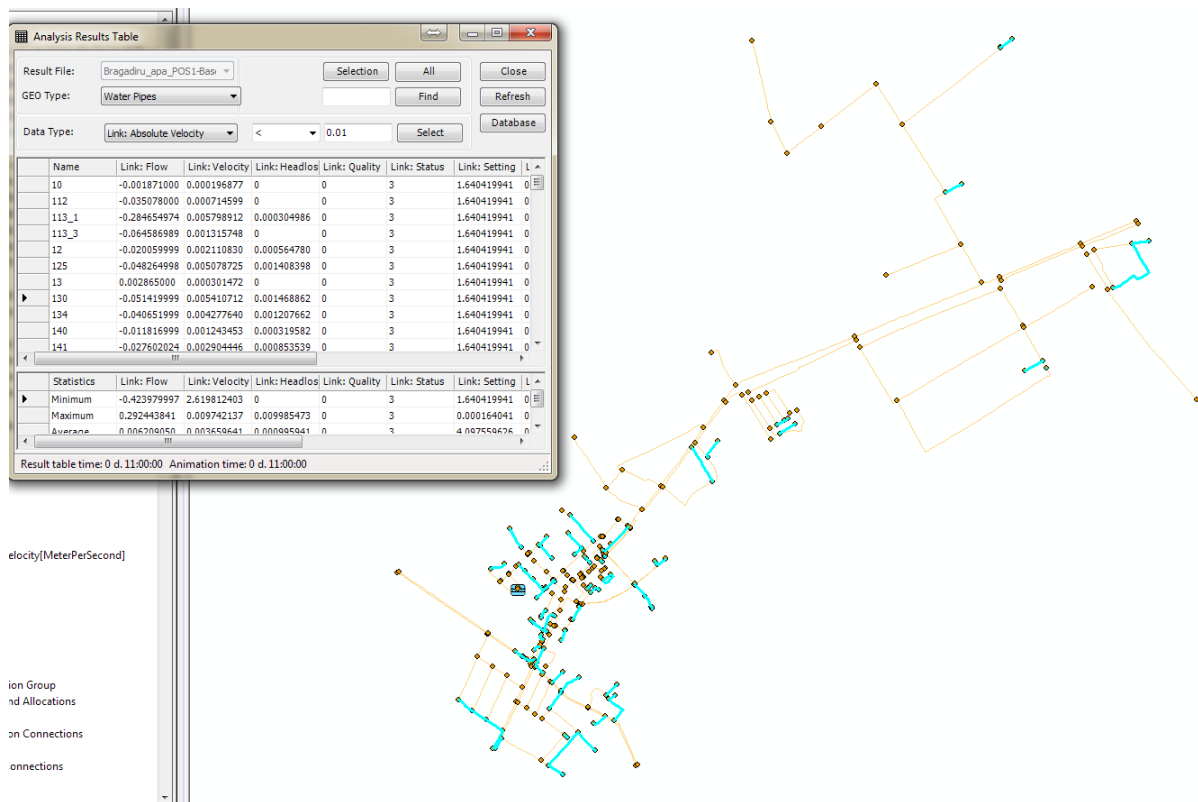


Figure 2-10 Highlighting pipes with flow rates below 0.01 m/s

- During periods of maximum consumption, the network pressure is ensured, this varying between 2.5 - 3.6 Bars. The most unfavourable point (near the Latin neighbourhood) is, incidentally, the furthest from the pumping group, but also for this point good pressures are ensured, between 2.5 and 2.8 Bar.
- It is necessary that once the network will go into operation and there will be a stable number of newly connected customers, to recalibrate the hydraulic model for the real, actual situation.

2.2.2 Cornetu locality

The pipes used in the water distribution are from **PEID, PE 100, PN 6**. The water distribution network was placed as possible at the edge of the road, in the vicinity of the drain ditch or near the sidewalk, taking into account the placement of the other public networks (sewer, gas, electricity, telephony networks etc.) and with conformance to the SR 8591/1997.

Pipe laying depth for the water pipes was set to an average of 1.20 – 1.30 m.

For the individual households, the water service connections to the domestic consumer (adding up to **1920** pcs.) were made from PEID, PN 6, PE 100 mm, Dn 25 mm pipes up to the property boundary, without providing a connection chamber.

To extinguish the fires, fire hydrants with a diameter of Dn 80 mm (20 pcs.) were provided on the network. They are located especially at the intersection of streets, as well as along them, at a maximum distance of 100 m from each other, in places easily accessible to the fire truck.

After filling with all the data from GIS, from measurements, and from technical documents or calculated mathematically, the hydraulic simulation of the model was run.

The simulation was performed in hydrodynamic regime, in order to highlight the behaviour in time of the network.

The simulation assumed that the pumps will work at a constant pressure by automatically adjusting the speed.

From the specific menus of the results, different parameters were chosen with which representative thematic maps were made:

- Demand, pressure or piezometric quota in each node;
- Flow, flow rate or load loss for each pipe

With any of these, color-coded thematic maps can be made according to user-set parameters.

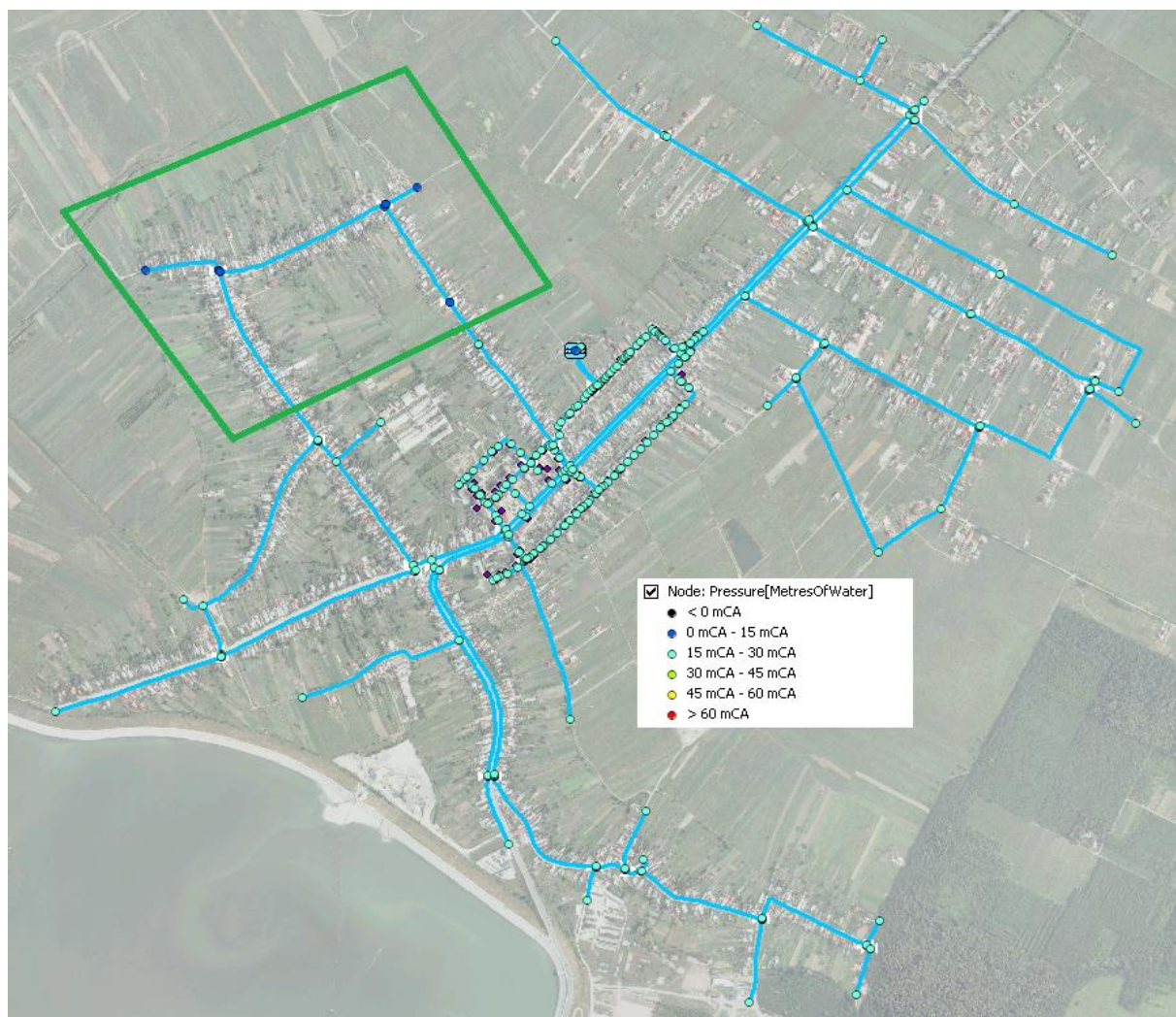


Figure 2-11 Pressures in the network nodes at maximum consumption time

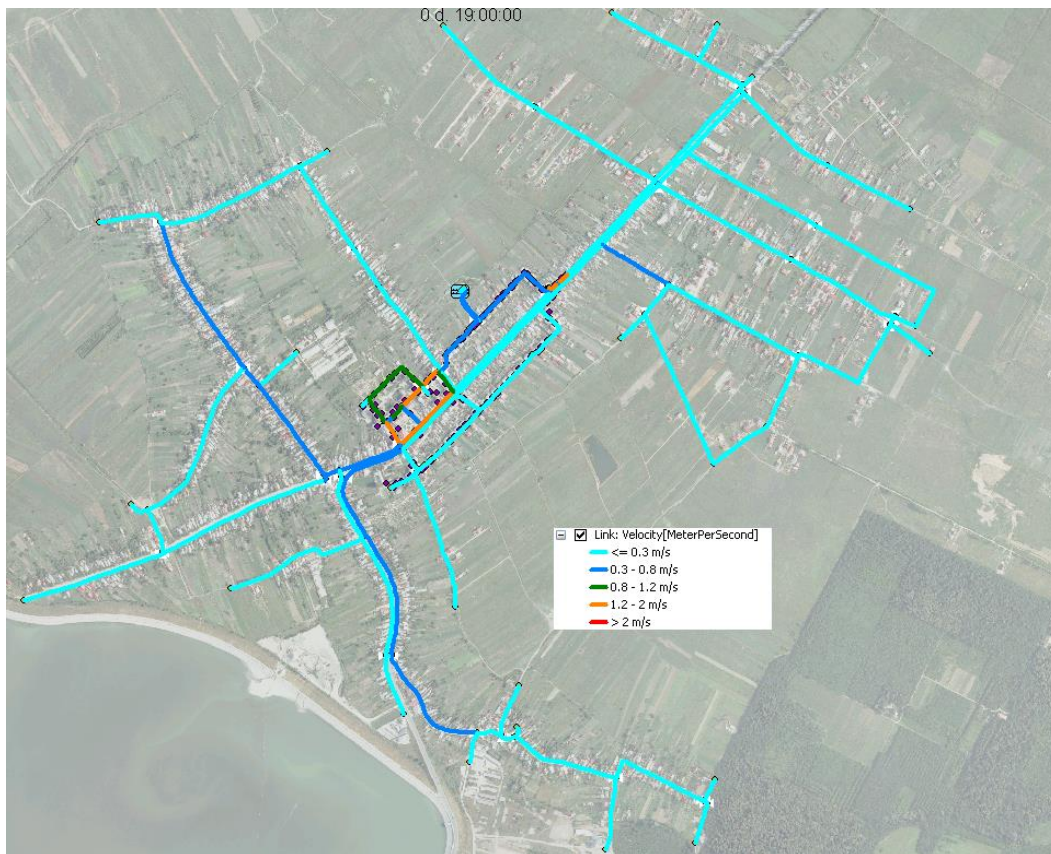


Figure 2-12 Highlighting the speeds on the pipes

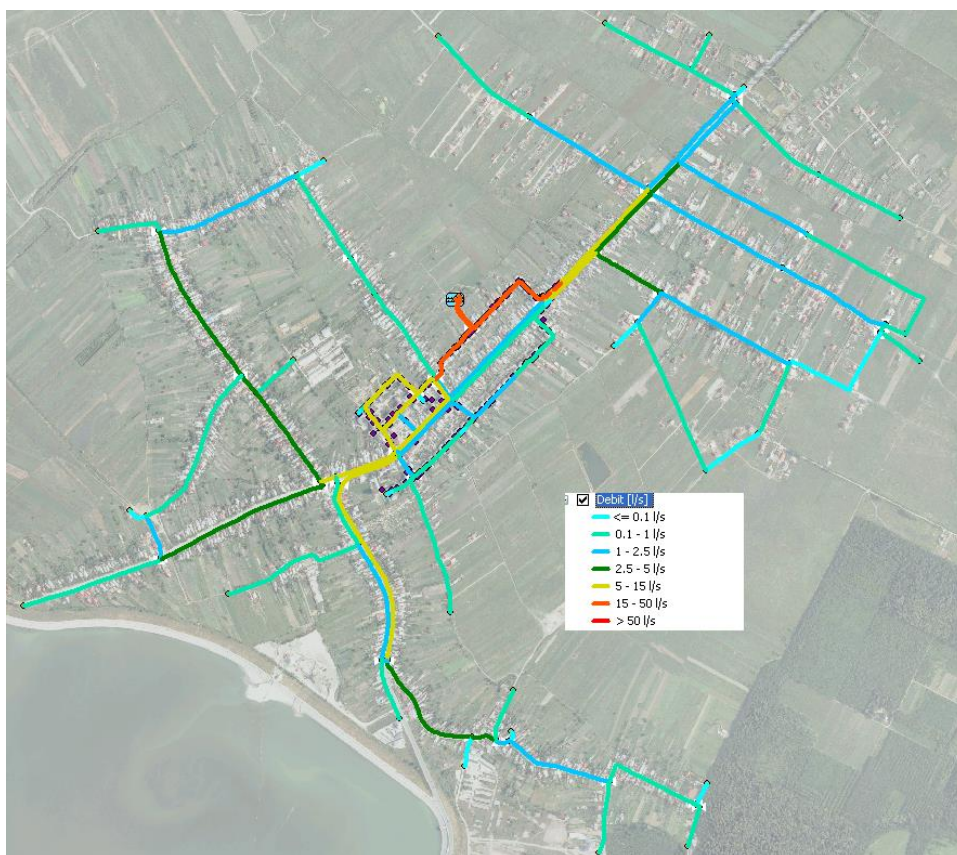


Figure 2-13 Highlighting flow rates on pipelines

Following the analysis of the results of the hydraulic model, the following conclusions can be drawn:

- Regarding the pressures, the values vary in the range of 1.5 - 3 Bars for most nodes of the network. There are also nodes in which the pressure drops slightly below the value of 1.5 Bar, but only in the hour of maximum consumption and only in the north-western area of the locality (Lalelelor Street).
- In terms of speeds, low speeds are observed for most sections of the network, but especially on the end areas or those far from the treatment plant.
- The average speed on arteries is 0.086 m / s, but there are also sections where it falls below 0.01 m / s.

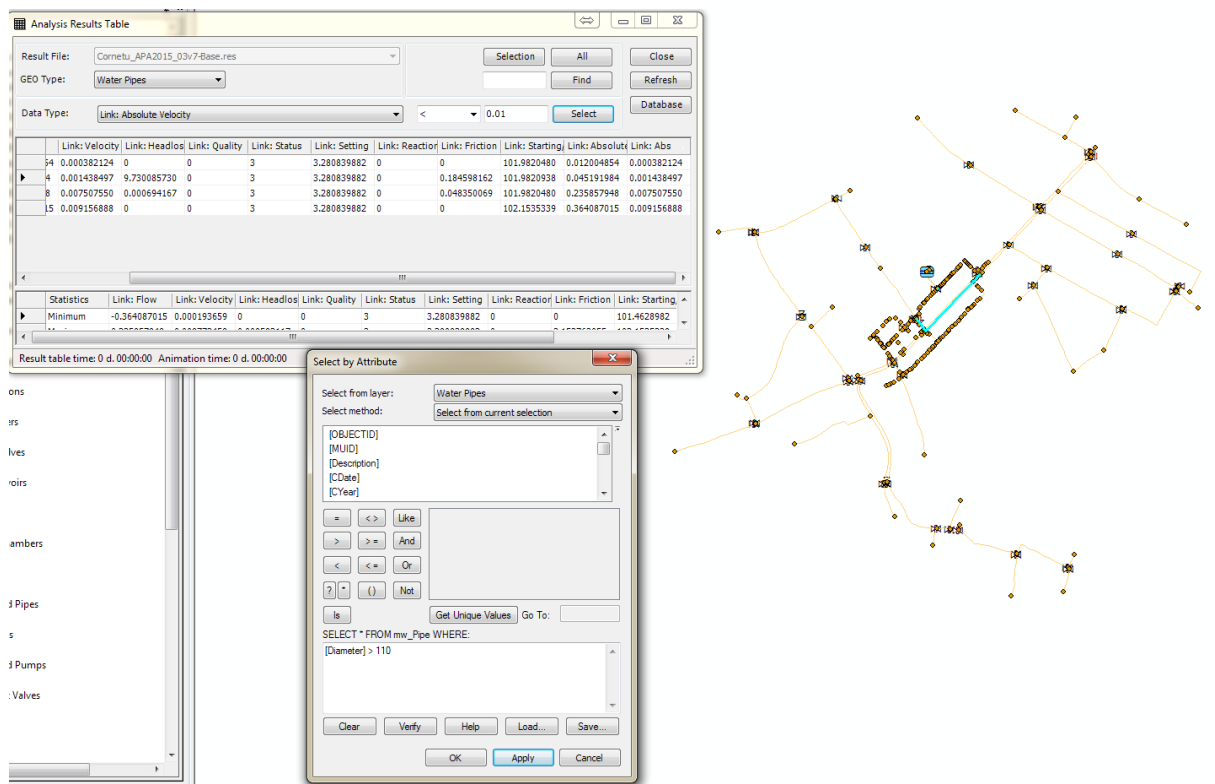


Figure 2-14 Highlighting pipes with speeds below 0.01 m / s

2.2.3 Brănești Locality

Conductele care s-au utilizat pentru proiectarea rețelei de distribuție sunt din **PEID, PE 100, PN 6**. Amplasarea rețelilor de distribuție a apei potabile s-a făcut pe marginea drumului, în vecinătatea santului drumului sau lângă trotuar, avându-se în vedere amplasarea celorlalte rețele edilitare existente (rețele de canalizare, gaze, electrice, telefonie, etc.) și respectând SR 8591/1997.

The pipes used for the design of the distribution network are made of PEID, PE 100, PN 6. The location of the drinking water distribution networks was made on the side of the road, in the vicinity of the road ditch or near the sidewalk, taking into account the location of the other networks. existing municipal networks (sewerage networks, gas, electricity, telephony, etc.) and respecting SR 8591/1997.

The laying depth of the water pipes on average was achieved at 1.20 - 1.30 m.

For individual dwellings, the connections to consumers (in total 2,086 pcs.) Were made of HDPE, PN 6, PE 100 mm, 25 mm and 40 mm pipes, up to the property limit, without the connection chimney being executed.

To extinguish the fires, fire hydrants with a diameter of 80 mm (62 pcs.) Were installed on the network. They were located especially at the intersection of the streets, as well as along them, in places easily accessible to the fire truck.

After completing all the data from GIS, from measurements, from technical documents or calculated mathematically, the hydraulic simulation of the model was run. Only one stationary hydraulic model was created.

The hydraulic models can be consulted with both the MIKE URBAN package and the Epanet program by importing files with the extension * .inp.

The simulation assumed that the pumps will work at a constant pressure by automatically adjusting the speed. The results obtained indicate the following:

- The average speed on arteries is 0.19 m / s at the sizing flow (which also includes household + technological needs as well as the occurrence of a fire)
- During periods of maximum consumption, the network pressure is ensured
- It is necessary that once the network goes into operation to re-calibrate the hydraulic model for the real situation

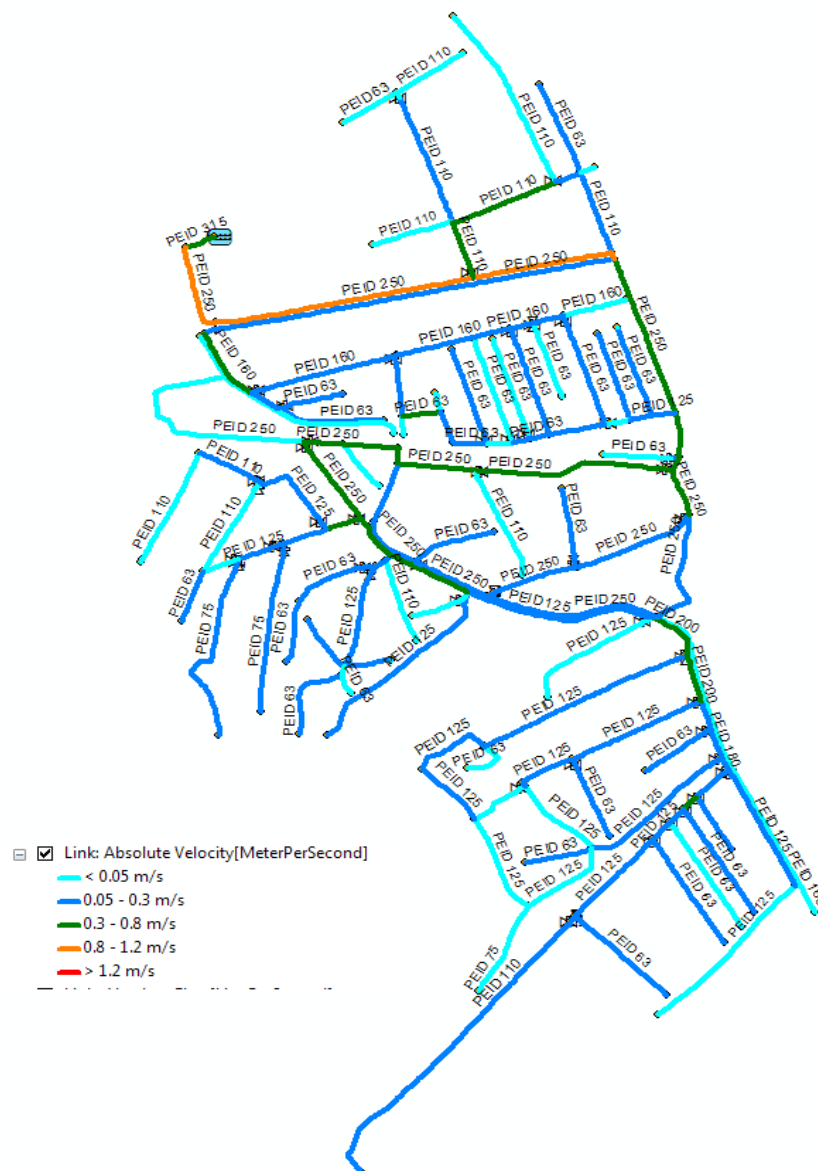


Figure 2-17 Highlighting the velocities on the pipes

2.2.4 Cernica locality

Conductele utilizate pentru proiectarea / executarea rețelei de distribuție sunt din **PEID, PE 100, PN 6**. Amplasarea rețelelor de distribuție a apei potabile s-a făcut pe cât posibil pe marginea drumului, în vecinătatea santului drumului sau lângă trotuar, avându-se în vedere amplasarea celorlalte rețele edilitare existente (rețele de canalizare, gaze, electrice, telefonie, etc.) și respectând SR 8591/1997.

The pipes used for the design / execution of the distribution network are made of PEID, PE 100, PN 6. The location of the drinking water distribution networks was made as much as possible on the roadside, near the road ditch or near the sidewalk, taking into account the location of the others. existing municipal networks (sewerage networks, gas, electricity, telephony, etc.) and respecting SR 8591/1997.

For individual dwellings, the connections to consumers (in total 837 pcs.) Were provided to be made from HDPE, PN 6, PE 100 mm, 32 mm pipes, up to the property limit, without providing the connection home.

To extinguish the fires, fire hydrants with a diameter of 80 mm (135 pcs.) Were provided on the network. They are located especially at the intersection of streets, as well as along them, at a maximum distance of 100 m from each other, in places easily accessible to the fire truck.

After completing all the data from GIS, from measurements, from technical documents or calculated mathematically, the hydraulic simulation of the model was run.

A single non-stationary hydraulic model was created to which a fire simulation was added. The reason for opting for this mode of work is that the fire analysis is complex and involves other running settings of the model than Extended Period Simulation.

The hydraulic models can be consulted with both the MIKE URBAN package and the Epanet program by importing files with the extension *.inp.

The simulation assumed that the pumps will work at a constant pressure by automatically adjusting the speed.

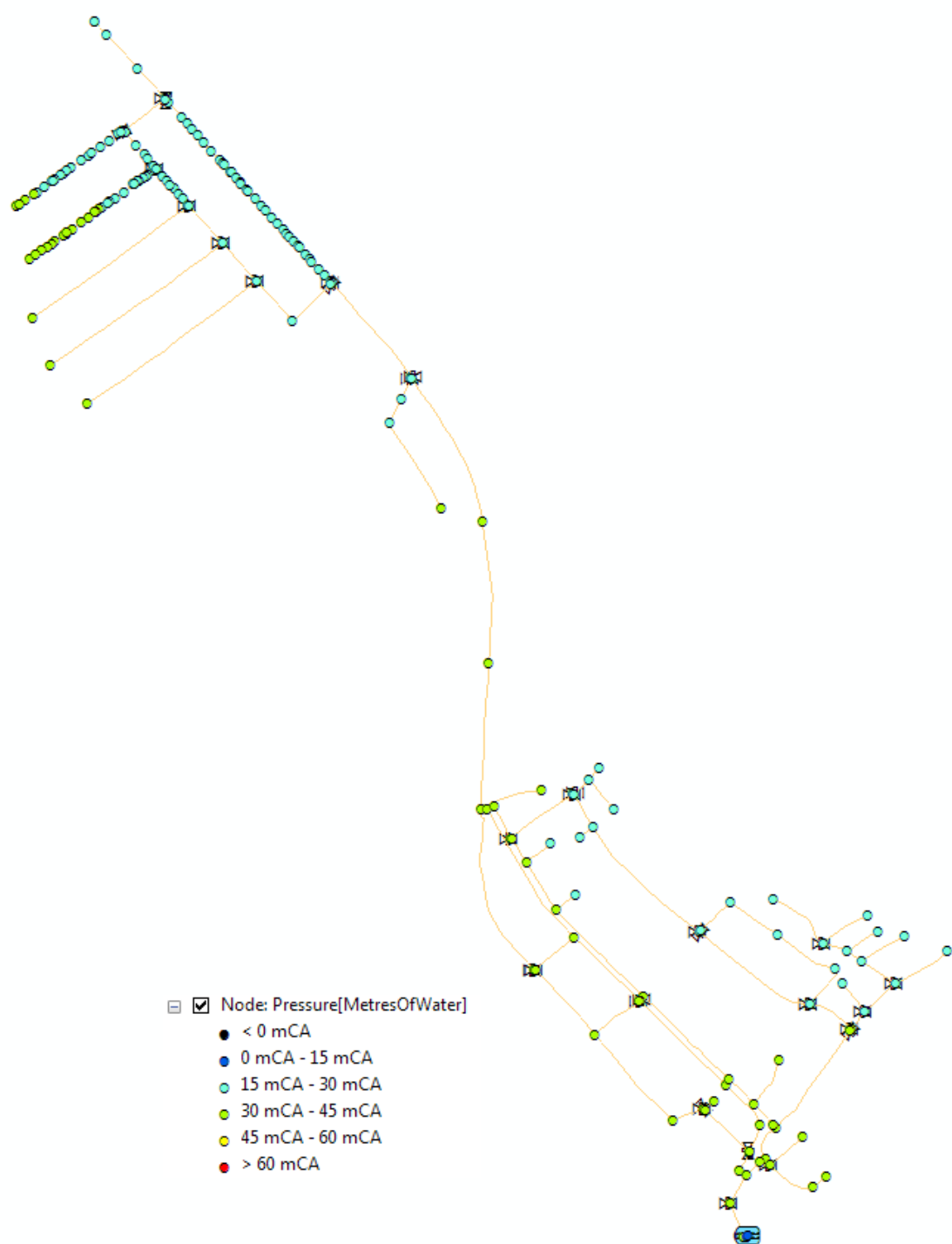


Figure 2-18 Pressures in the network nodes at maximum consumption time

0 d. 9:00:00

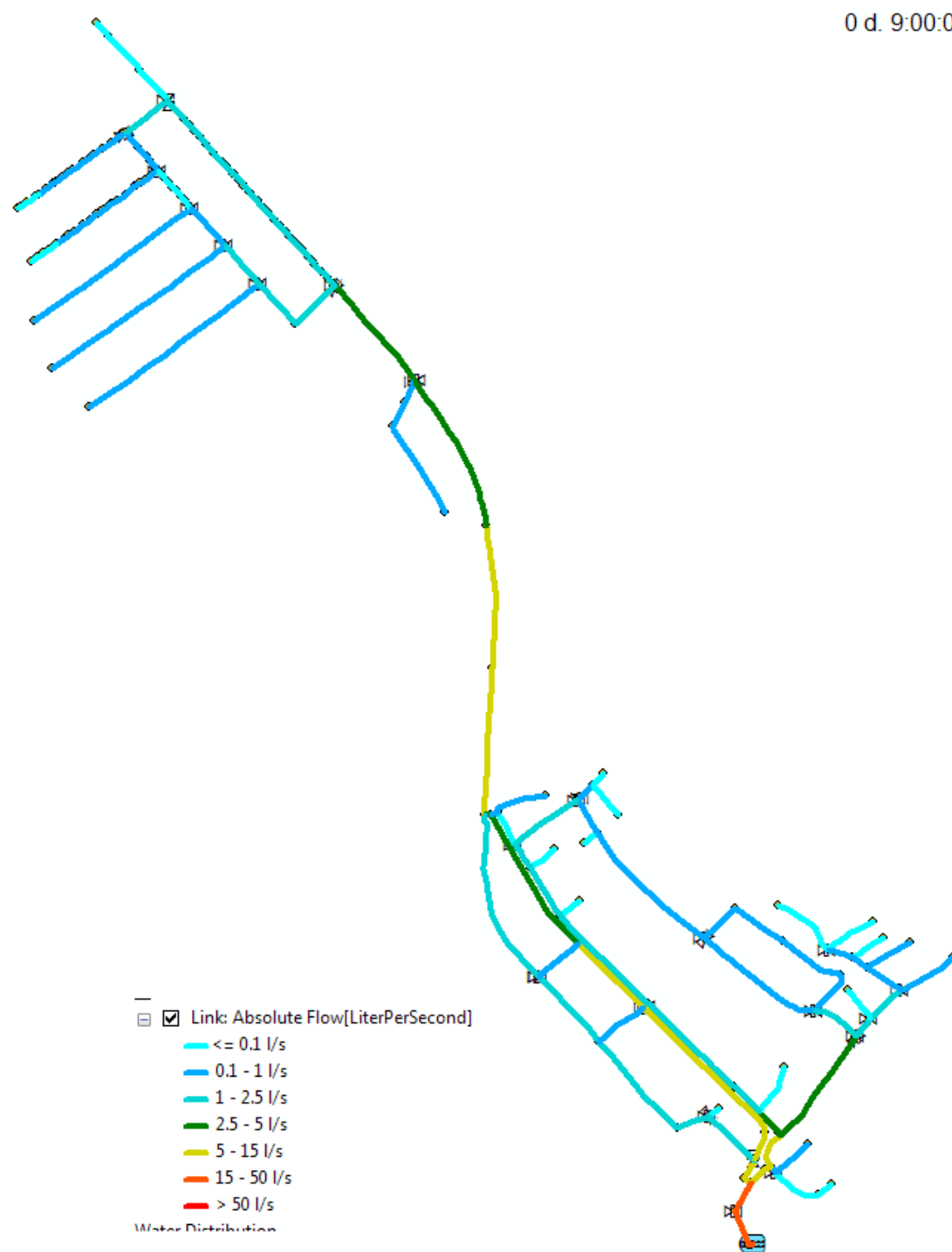


Figure 2-19 Highlighting flow rates on arteries

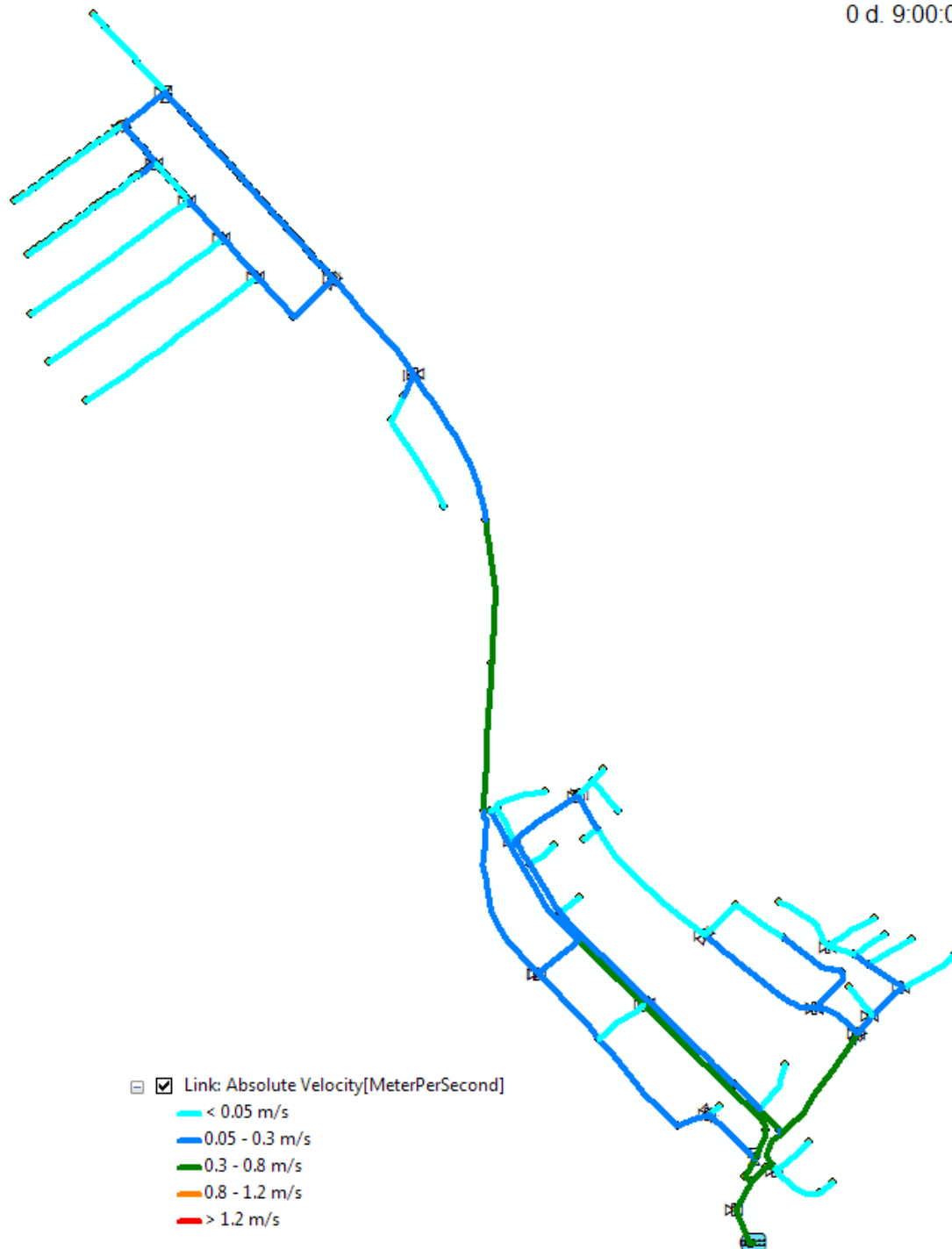


Figure 2-20 Highlighting velocities on pipes

The results obtained indicate the following:

- The speeds on the pipes are in the vast majority of cases very low (between 0.04 m / s and 0.4 m / s), which could lead to a high downtime of the water in the network.
- During periods of maximum consumption, the network pressure is ensured

- It is necessary that once the network goes into operation to re-calibrate the hydraulic model for the real situation
- Due to the very low speeds it results that the load losses are insignificant, and the variation of the pressures at the nodes per 24 h is very small. This is exemplified for the NOD16 node in the figure below:

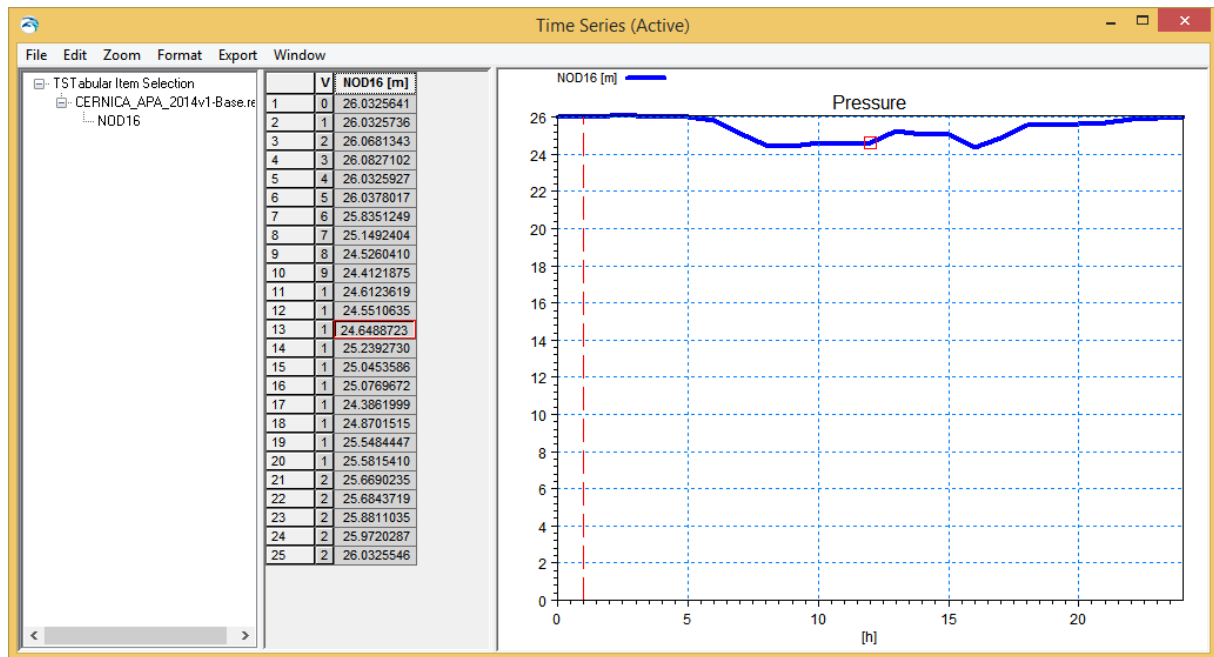


Figure 2-21 Pressure variation in the NOD16 node for 24 hours. Deviations of maximum 2 mCA are observed at maximum consumption hours

2.2.5 Ciorogârla Locality

The pipes used in the distribution network are made of SIDS, PE 100, PN 6. The location of the drinking water distribution networks was made as much as possible on the roadside, in the vicinity of the road ditch or near the sidewalk, taking into account the location of other existing municipal networks. (sewerage networks, gas, electricity, telephony, etc.) and respecting SR 8591/1997.

The laying depth of the water pipes on average was provided by 1.20 - 1.30 m.

For individual dwellings, the connections to consumers (in total 342 pcs.) Were provided to be made from HDPE, PN 6, PE 100 mm, Dn 25 mm pipes, up to the property limit, without providing the connection home.

After completing all the data in GIS, measurements, technical documents or calculated mathematically, the hydraulic simulation of the model was run.

The simulation was performed in hydrodynamic regime, in order to highlight the behavior in time of the network.

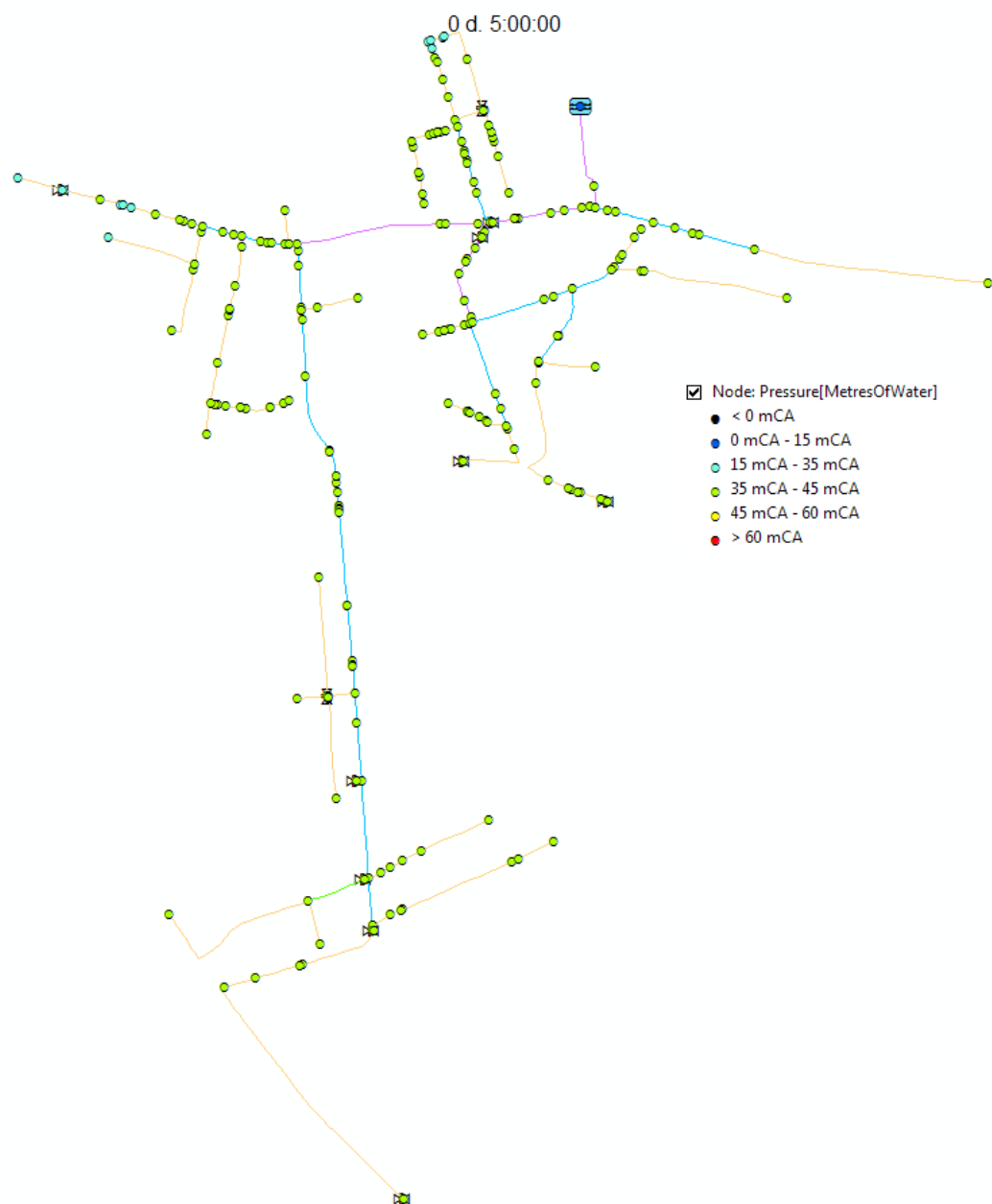


Figure 2-22 *Pressures in network nodes*

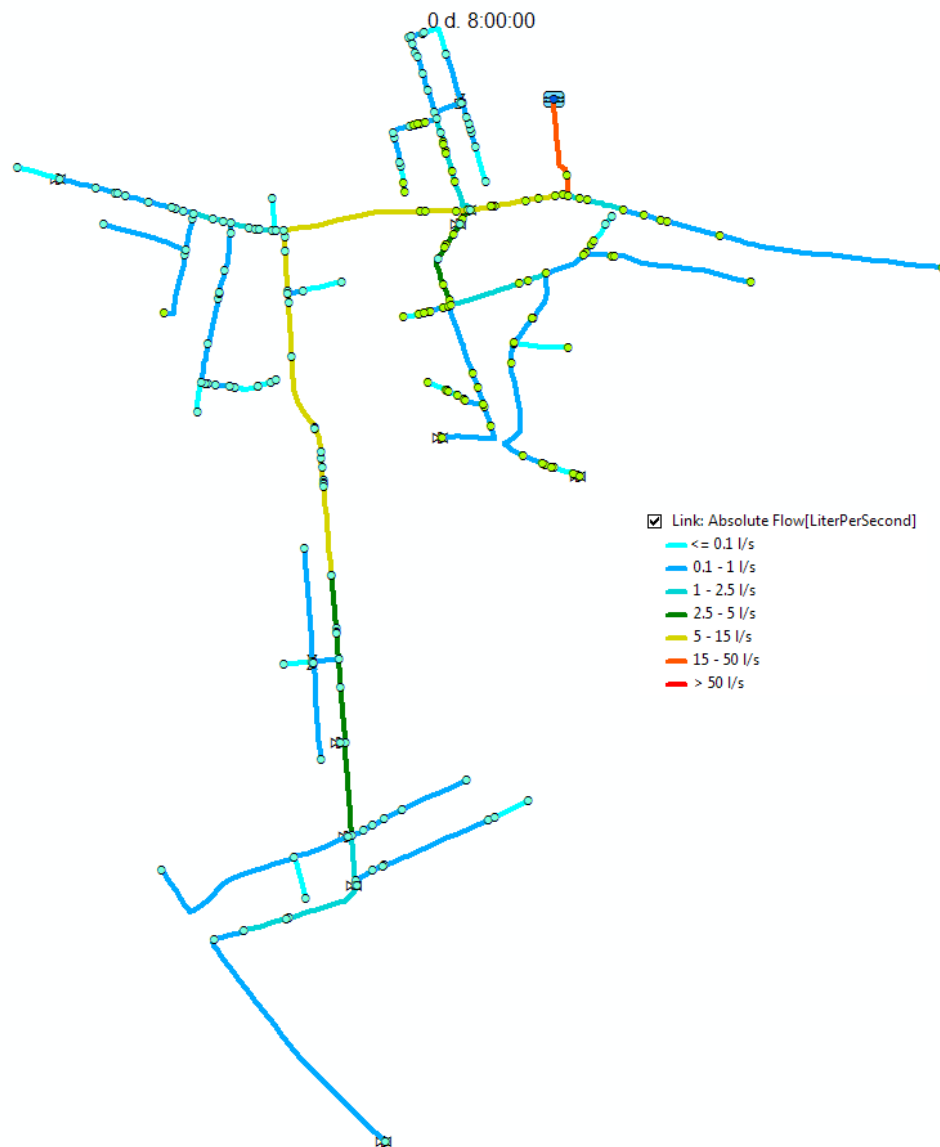


Figure 2-23 Highlighting flow rates on pipes

The results obtained indicate the following:

- The average speed on arteries (diameters over 110mm, inclusive) is 0.38 m / s, but at maximum hours it exceeds 0.7 m / s in most sections
- small values are also registered, below 0.01 m / s in the end areas
- During periods of maximum consumption, the network pressure is ensured, this varying in the range of 2.9 - 4.2 Bar.
- It is necessary that once the network will be operational and there will be a stable number of newly connected customers, to re-calibrate the hydraulic model for the real situation.

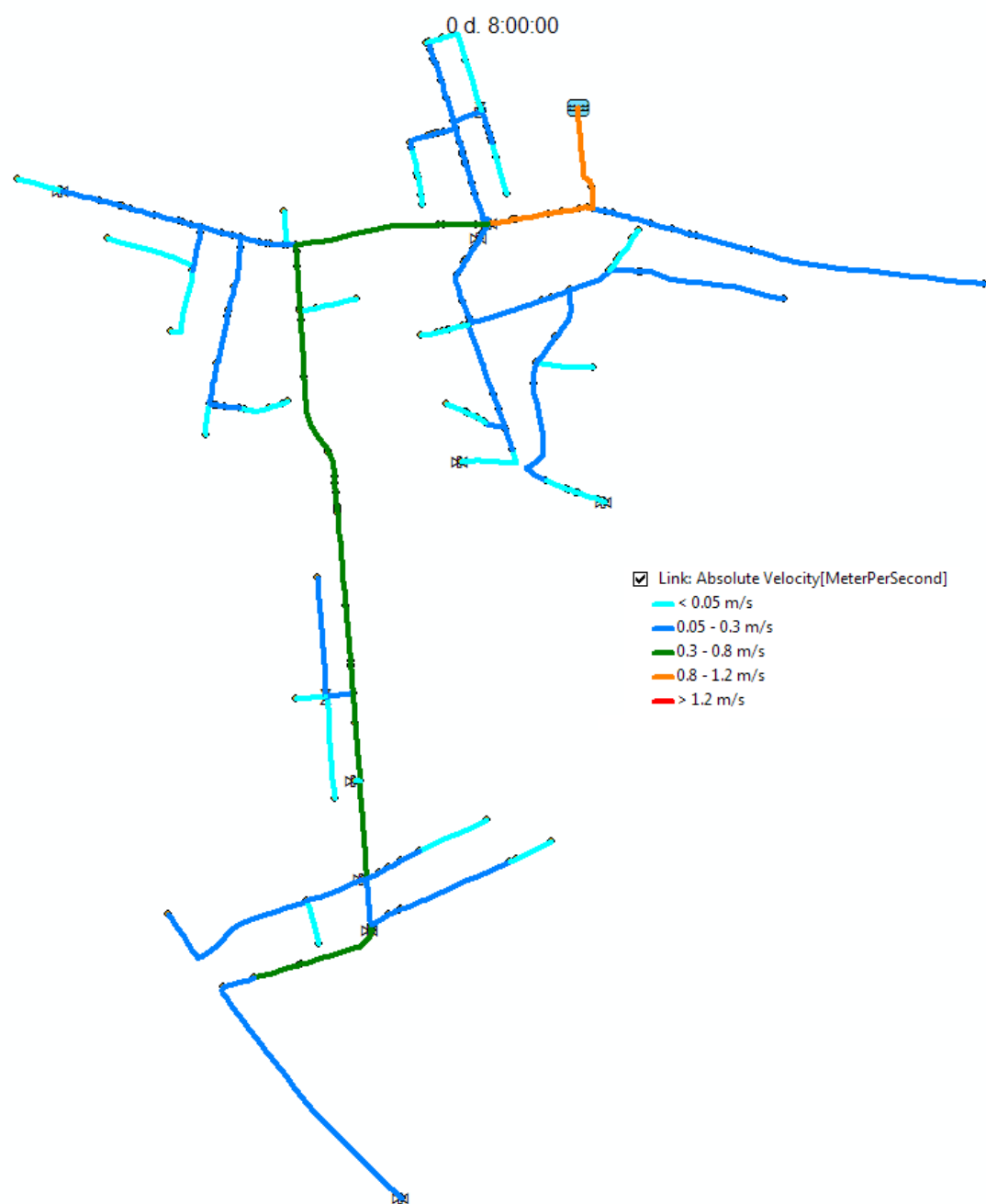


Figure 2-24 Highlighting velocities on pipes

2.2.6 Domnești Locality

The pipes used are made of HDPE, PE 100, PN 6. The location of the drinking water distribution networks was made as much as possible on the roadside, in the vicinity of the road ditch or near the sidewalk, taking into account the location of other existing municipal networks (sewerage networks, gas, electricity, telephony, etc.) and complying with SR 8591/1997.

The laying depth of the water pipes on average was provided by 1.20 - 1.30 m.

For individual dwellings, the connections to consumers (in total 2420 pcs.) Were provided to be made from HDPE pipes, PN 6, PE 100 mm, Dn 25 mm, up to the property limit, without providing the connection home.

To extinguish the fires, fire hydrants with a diameter of Dn 80 mm (15 pcs.) Were provided on the network. They are located especially at the intersection of streets, as well as along them, at a maximum distance of 100 m from each other, in places easily accessible to the fire truck.

After completing all the data from GIS, from measurements, from technical documents or calculated mathematically, the hydraulic simulation of the model was run. The simulation was performed in hydrodynamic regime, in order to highlight the behavior in time of the network.

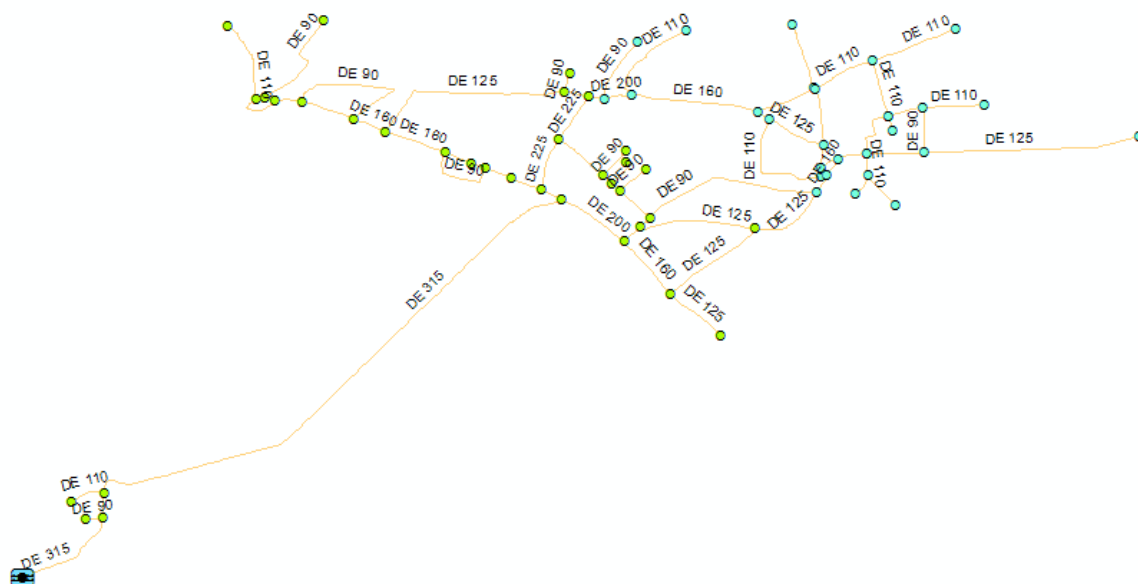


Figure 2-25 Pressures in network nodes



Figure 2-26 Flows transported at the time of maximum consumption

The results obtained indicate the following:

- The average speed on arteries (diameters over 125mm, inclusive) is 0.3 m / s
- small values are also registered, below 0.01 m / s in the end areas.
- During periods of maximum consumption, the network pressure is ensured, this varying in the range of 2.6 - 3.7 Bar.
- It is necessary that once the network will be operational and there will be a stable number of newly connected customers, to re-calibrate the hydraulic model for the real situation.

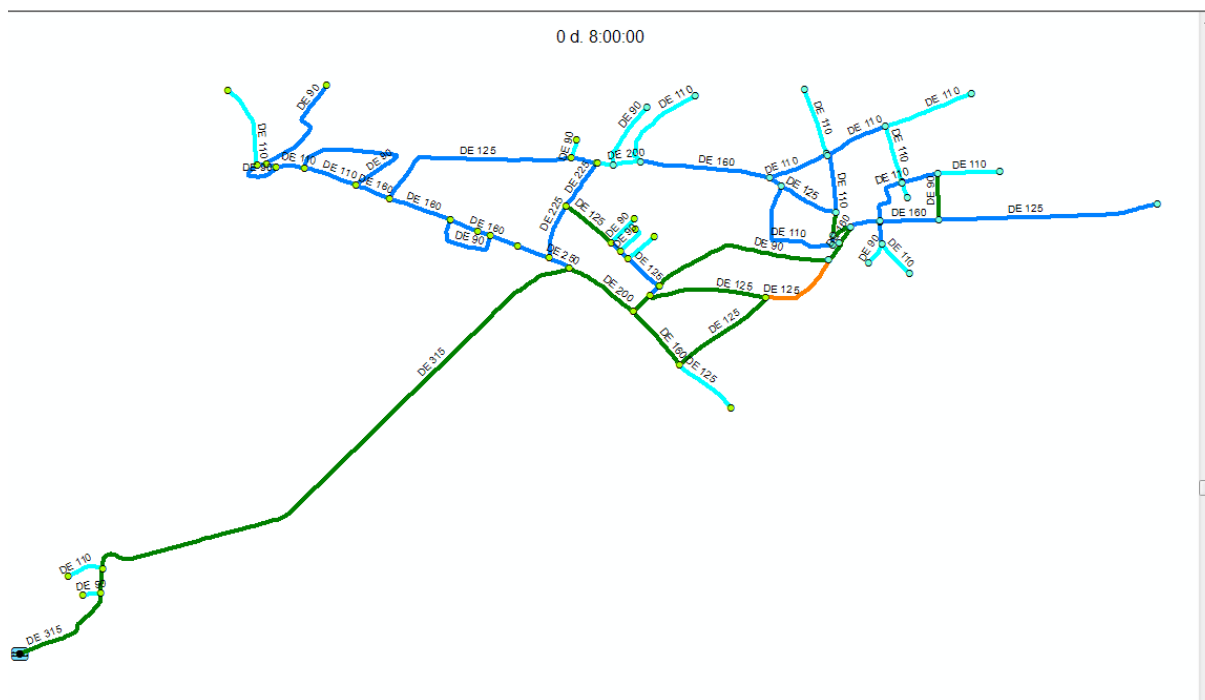


Figure 2-27 Network velocities at maximum consumption time

2.2.7 Dobroești Locality

The pipes used for the rehabilitation works are made of SIDS, PE 100, PN 10. The location of the drinking water distribution networks will be made as much as possible on the roadside, in the vicinity of the road ditch or near the sidewalk, taking into account the location of the other municipal networks. existing (sewerage networks, gas, electricity, telephony, etc.) and complying with SR 8591/1997.

For individual homes, connections to consumers (a total of 1,870 pcs.) Will be made of HDPE, PN 10, PE 100 32 mm pipes, up to the property limit, without providing the connection home.

To extinguish the fires, fire hydrants with a diameter of 80 mm (204 pcs) were provided on the network. They will be located especially at the intersection of the streets, as well as along them, at a maximum distance of 100 m from each other, in places easily accessible to the fire truck.

After completing all the data from GIS, from measurements, from technical documents or calculated mathematically, the hydraulic simulation of the model was run. The simulation was performed in stationary mode.

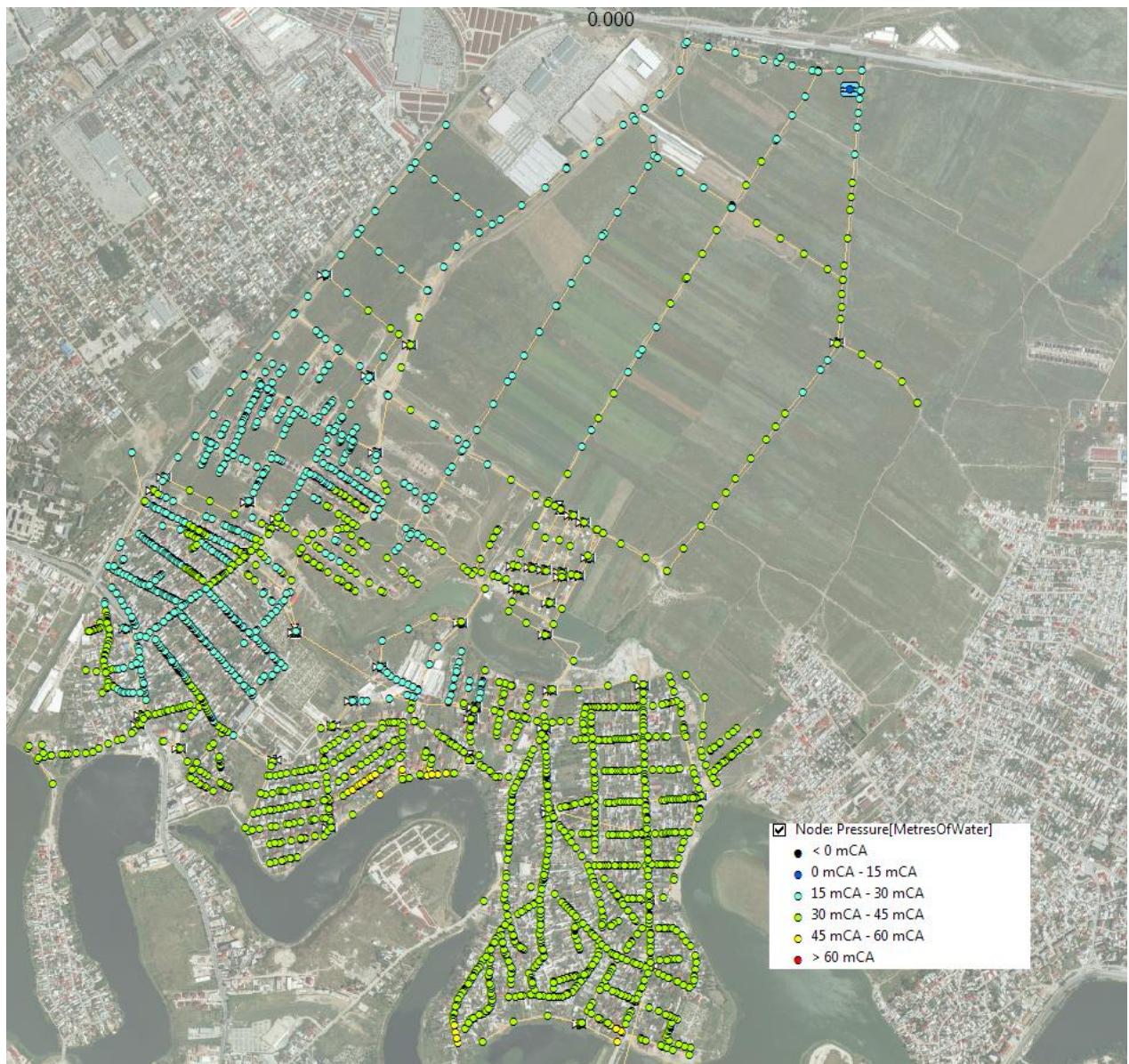


Figure 2-28 Pressures in network nodes

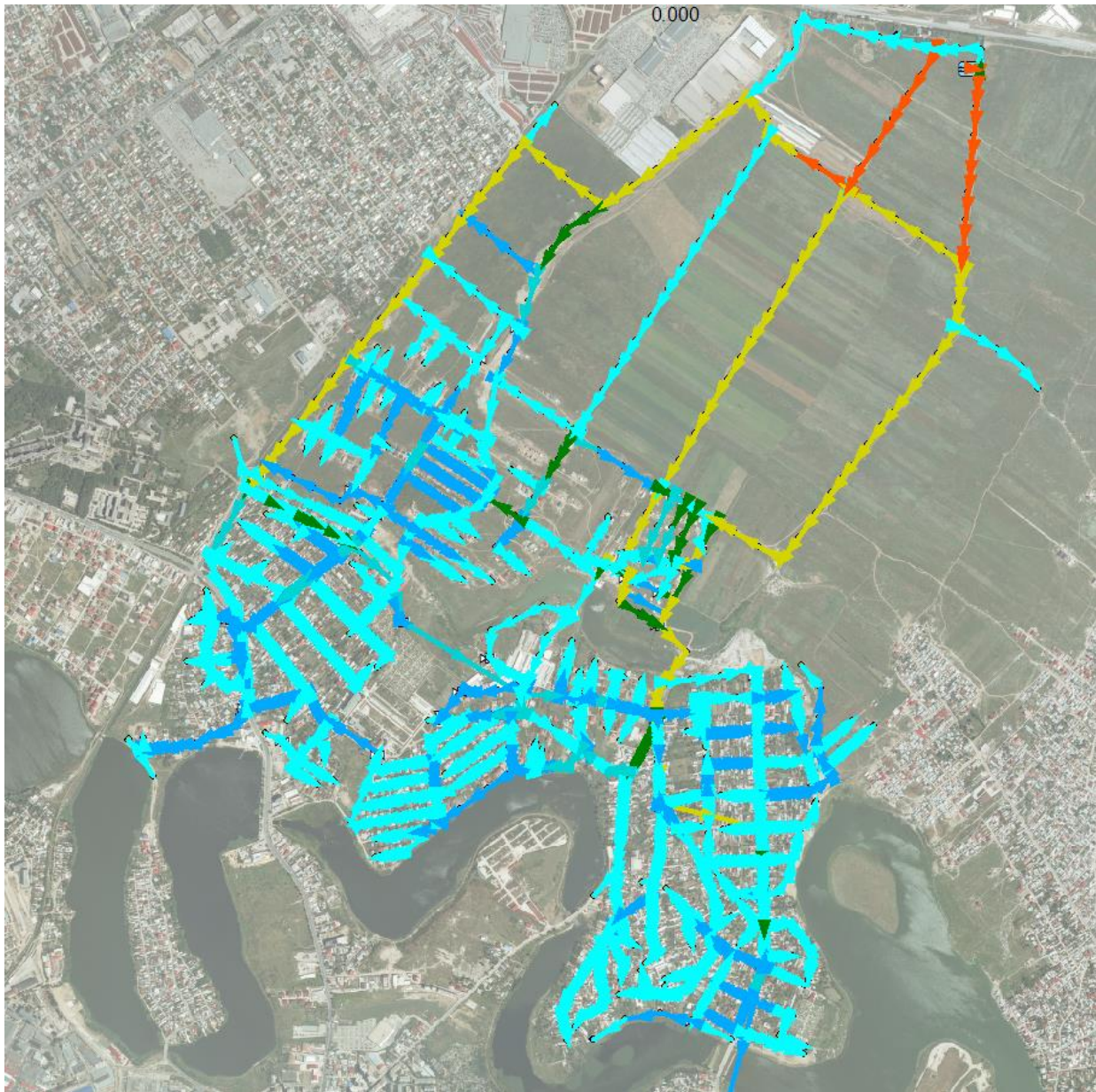


Figure 2-29 Flows transported at the time of maximum consumption

The results obtained indicate the following:

- The average speed on arteries (diameters over 125mm, inclusive) is 0.26 m / s
- small values are also registered, below 0.01 m / s in the end areas.
- During periods of maximum consumption, the network pressure is ensured, this varying in the range of 2.6 - 4.9 Bars.
- It is necessary that once the network will be operational and there will be a stable number of newly connected customers, to re-calibrate the hydraulic model for the real situation.

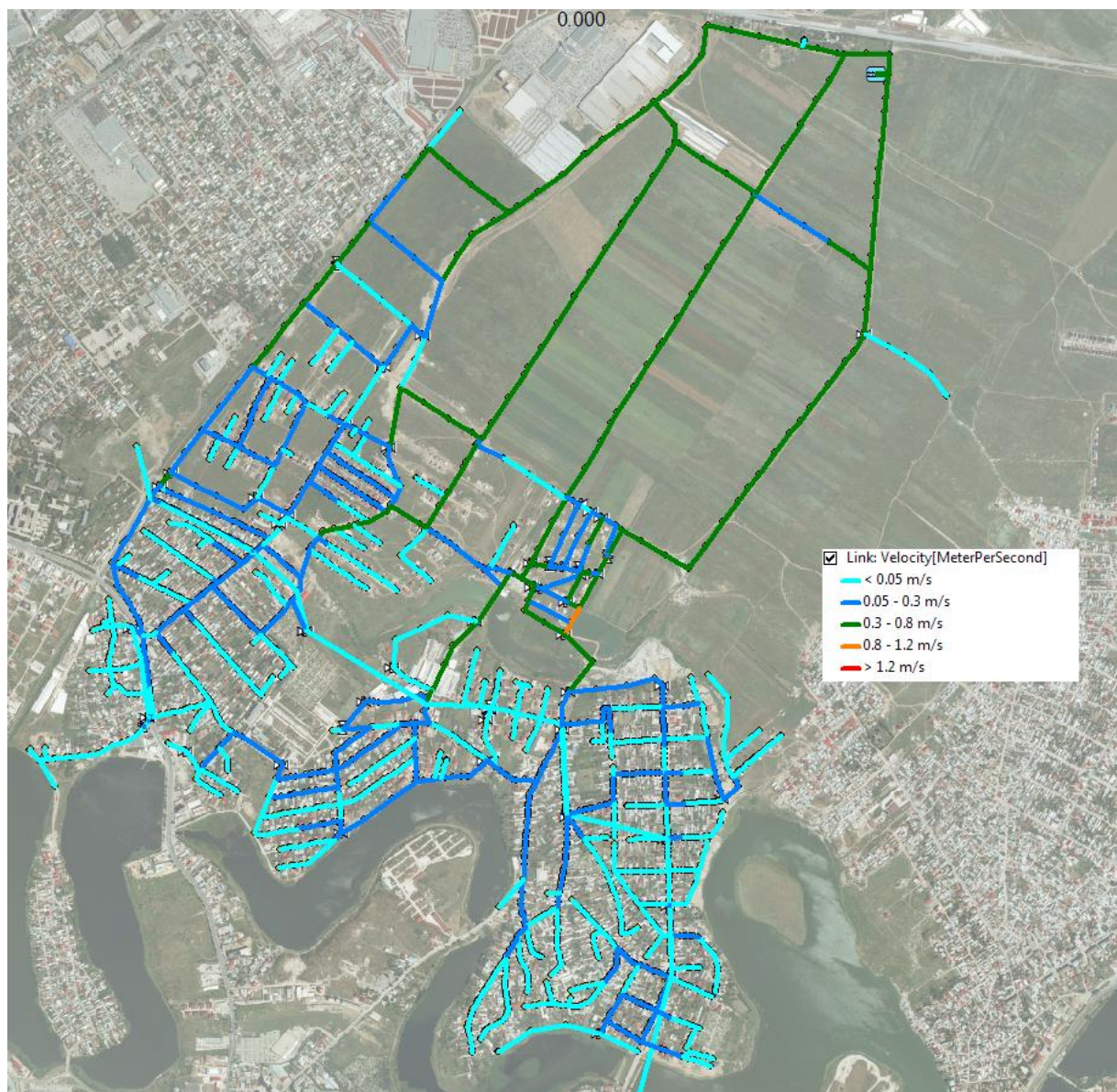


Figure 2-30 Network velocities at peak consumption hours

2.3 DÂMBOVIȚA County

2.3.1 Titu Locality

A hydraulic model was created in the idea that only the distribution network related to Titu + Plopu was taken into account. The pumping station was simulated with a single pump to which a PRV type valve was added to simulate the constant pressure of approx. 3 bar on the discharge (according to the measurements made in the field).

To perform the numerical simulation of the distribution network, the Hydra menu was used, and then Compute. The program automatically writes a file in Epanet format and uses the Epanet libraries to calculate the hydraulic model.

Additionally, Epanet files were created in *.net format for easier use of the hydraulic model without the need for an URBANO 9 license.

The simulation of the models was performed in the conditions in which the variation curve was considered that of the flow and pressure measurements for a period of 24 hours. Simulation of the distribution of chlorine in the network was performed for a period of 72 h, in the idea that the initial concentration of chlorine at the source is 0.35 mg / l.

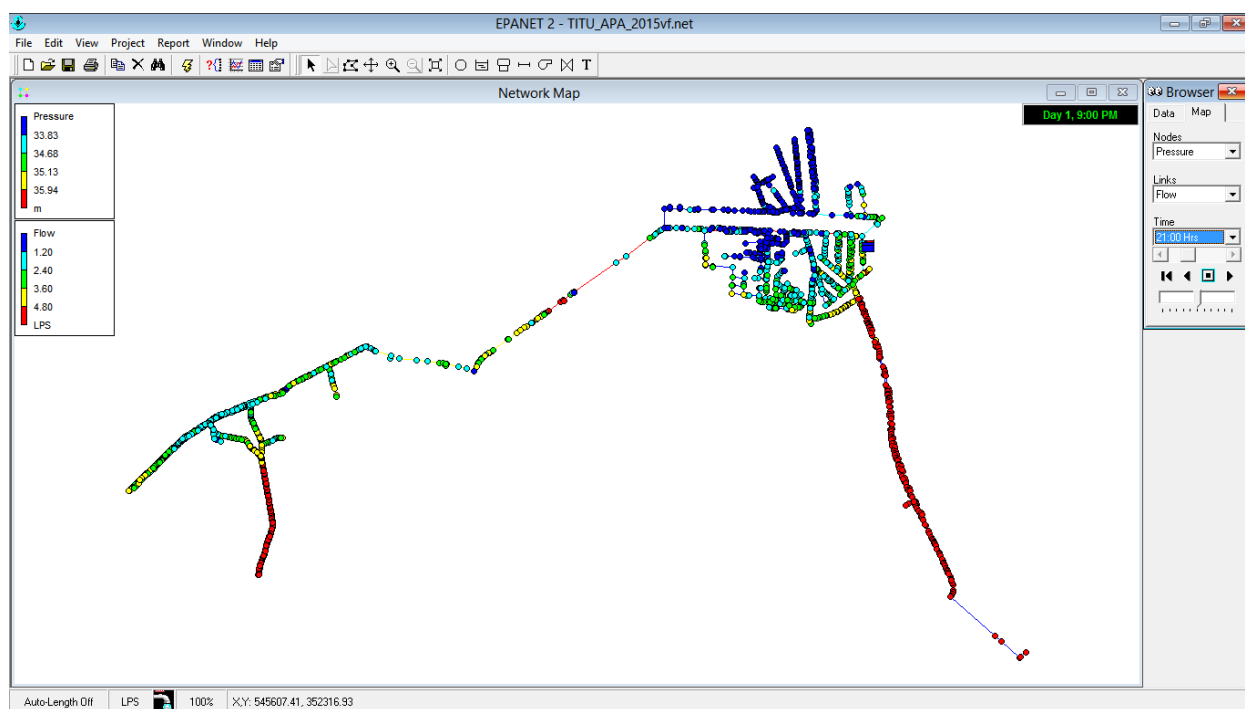


Figure 2-31 TITU distribution network in the EPANET program (21:00 - maximum consumption)

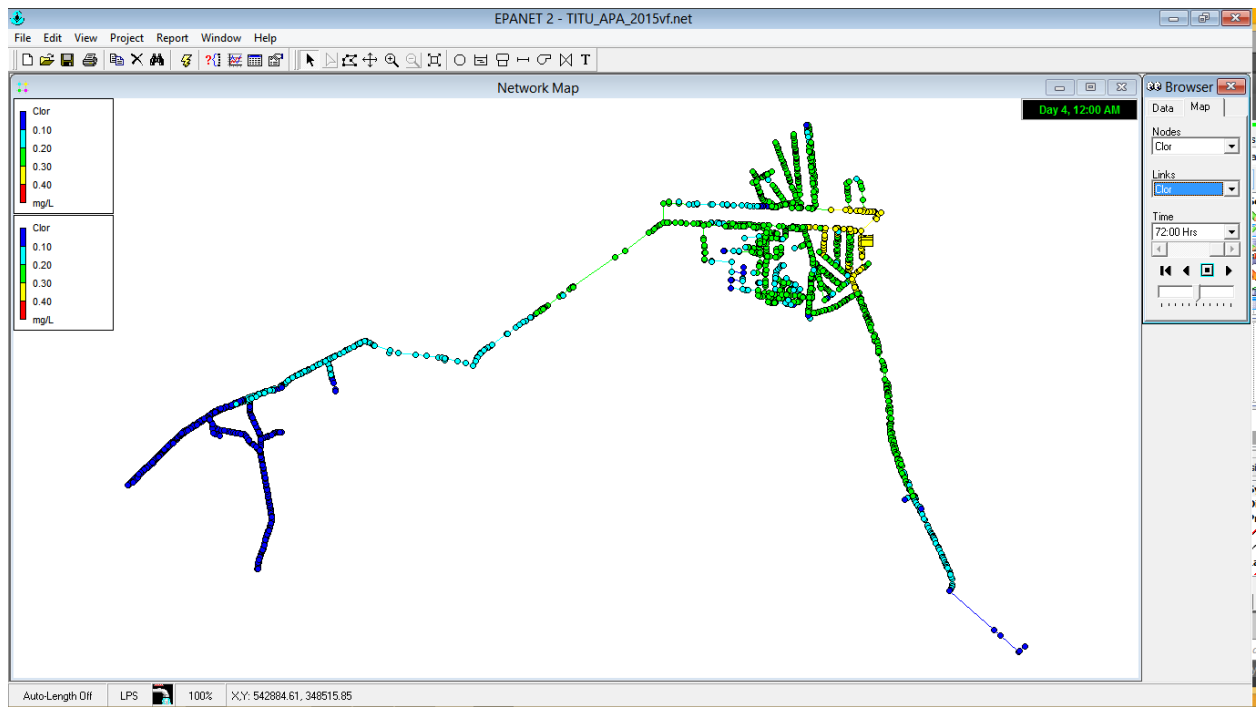


Figure 2-32 TITU distribution network in the EPANET program (chlorine concentration after 72 h)

The following observations were made following the hydraulic simulation:

- The supply area of Plopu has pressures of up to 3.9 bar, much too high for the needs of this distribution network
- Adjacent areas of the Titu distribution system have deficiencies in chlorine concentration (well below 0.2 mg / l)
- The results obtained are in accordance with the flow and pressure measurements carried out on this network

From the point of view of optimizing the operation of the distribution network, the following recommendations are made:

- Installation of pressure reducing veins at the entrance to the supply area of Plopu locality as well as at the entrance to the southern area of Titu locality
- In parallel, it is recommended to reduce the pressure at the outlet of the pumping station from 35 mCA to 30 mCA.

2.3.2 Fieni Locality

A hydraulic model was created in the idea that only the distribution network related to Fieni locality was taken into account. The pressure pumping stations in the distribution network were also simulated.

To perform the numerical simulation of the distribution network, the Hydra menu was used, and then Compute. The program automatically writes a file in Epanet format and uses the Epanet libraries to calculate the hydraulic model.

Additionally, Epanet files were created in *.net format for easier use of the hydraulic model without the need for an URBANO 9 license.

The simulation of the models was performed in the conditions in which the variation curve was considered that of the flow and pressure measurements for a period of 24 hours.

Simulation of the distribution of chlorine in the network was performed for a period of 72 h, in the idea that the initial concentration of chlorine at the source is 0.4 mg / l.

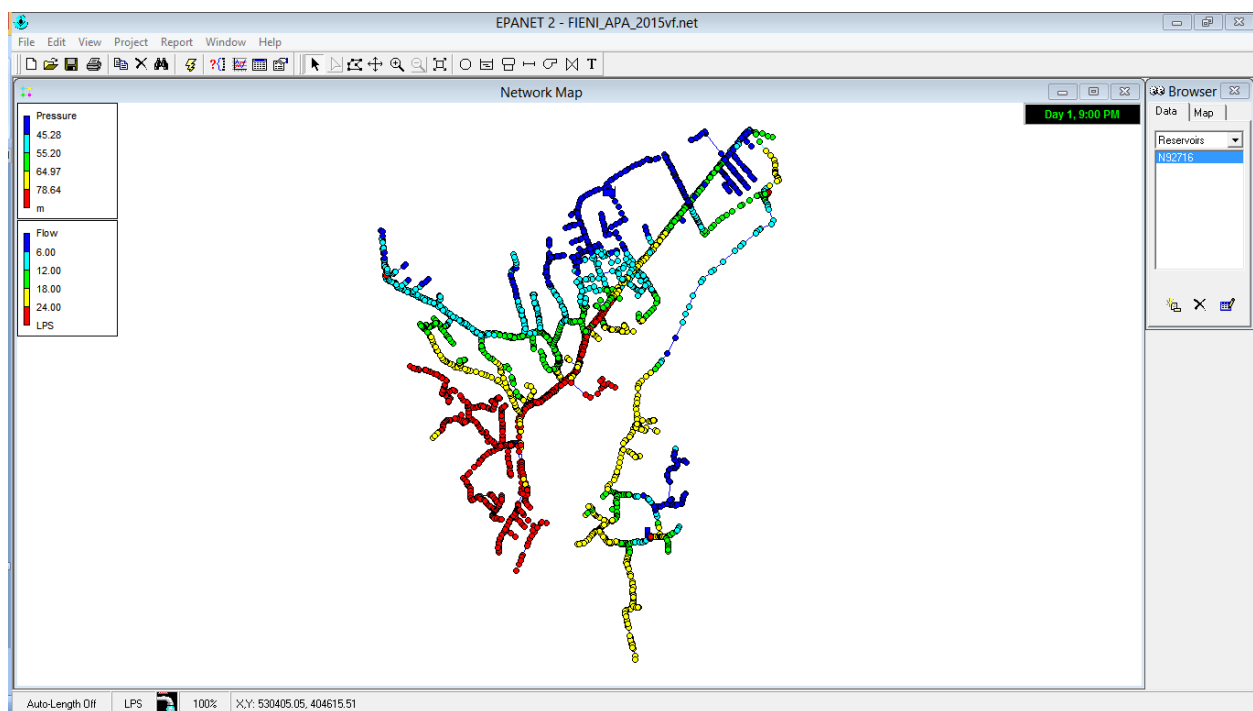


Figure 2-33 FIENI distribution network in the EPANET program (flow rates / pressures at maximum consumption time)

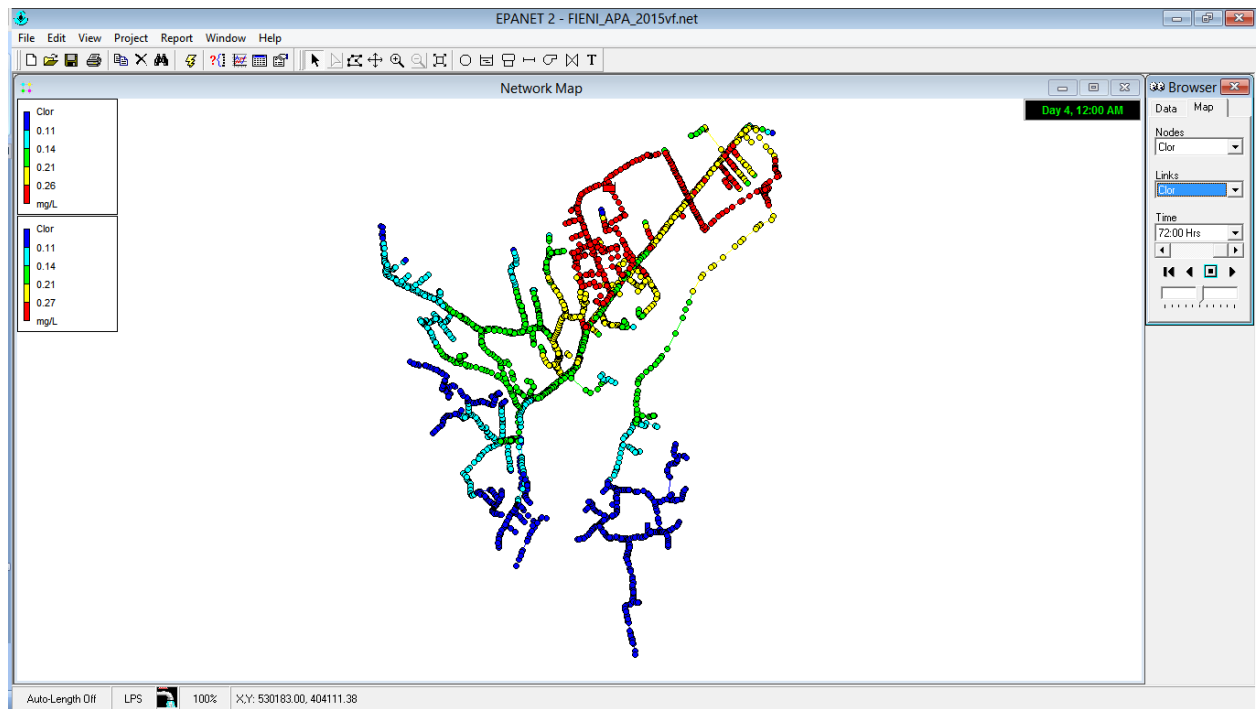


Figure 2-34 FIENI distribution network in the EPANET program (chlorine distribution after 72h)

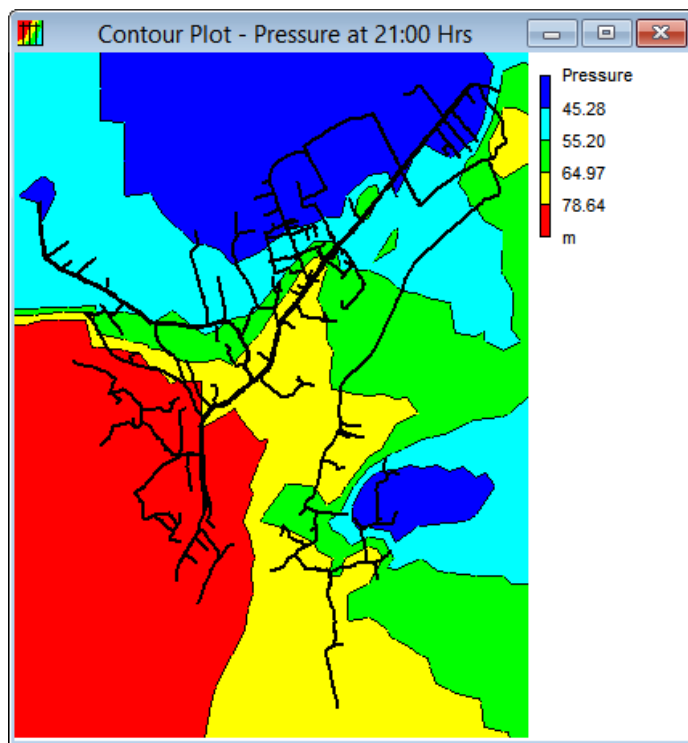


Figure 2-35 FIENI distribution network in the EPANET program (pressure distribution at maximum consumption time)

The variation of the network pressures is substantially influenced more by the differences in elevation than by the load losses, ensuring a minimum operating pressure of 20 mCA in the surrounding areas at the time of maximum consumption.

- The adjacent areas of the Fieni distribution system have deficiencies in terms of chlorine concentration (below 0.2 mg / l), especially in the western and southern areas
- The results obtained are in accordance with the flow and pressure measurements carried out on this network

From the point of view of optimizing the operation of the distribution network, the following recommendations are made:

- Zoning the distribution network for better pressure control
- Verification of chlorination solutions for areas with chlorine deficiencies

2.3.3 Găești Locality

A hydraulic model was created in the idea that only the distribution network related to Găești was taken into account. The pumping station was simulated with a single pump to which a PRV type valve was added to simulate the constant pressure of approx. 3.2 bar on the discharge (according to the measurements made in the field).

To perform the numerical simulation of the distribution network, the Hydra menu was used, and then Compute. The program automatically writes a file in Epanet format and uses the Epanet libraries to calculate the hydraulic model.

Additionally, Epanet files were created in * .net format for easier use of the hydraulic model without the need for an URBANO 9 license.

The simulation of the models was performed in the conditions in which the variation curve was considered that of the flow and pressure measurements for a period of 24 hours.

Simulation of the distribution of chlorine in the network was performed for a period of 72 h, in the idea that the initial concentration of chlorine at the source is 0.3 mg / l.

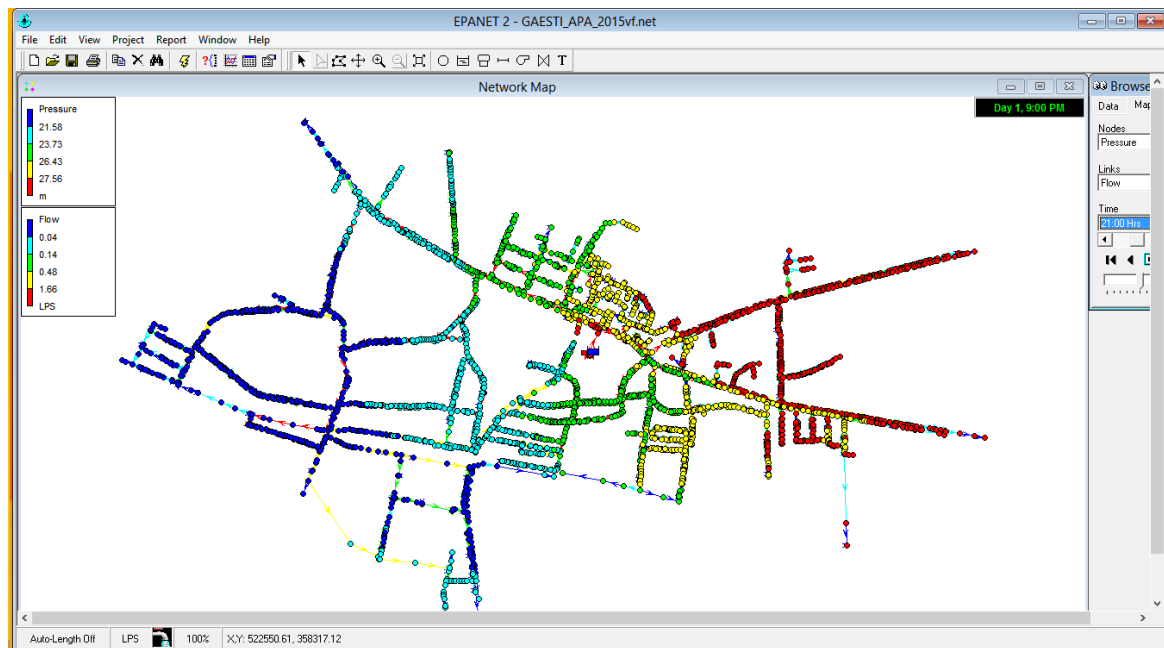


Figure 2-36 GAESTI distribution network in the EPANET program (flow rates and pressure at maximum consumption time)

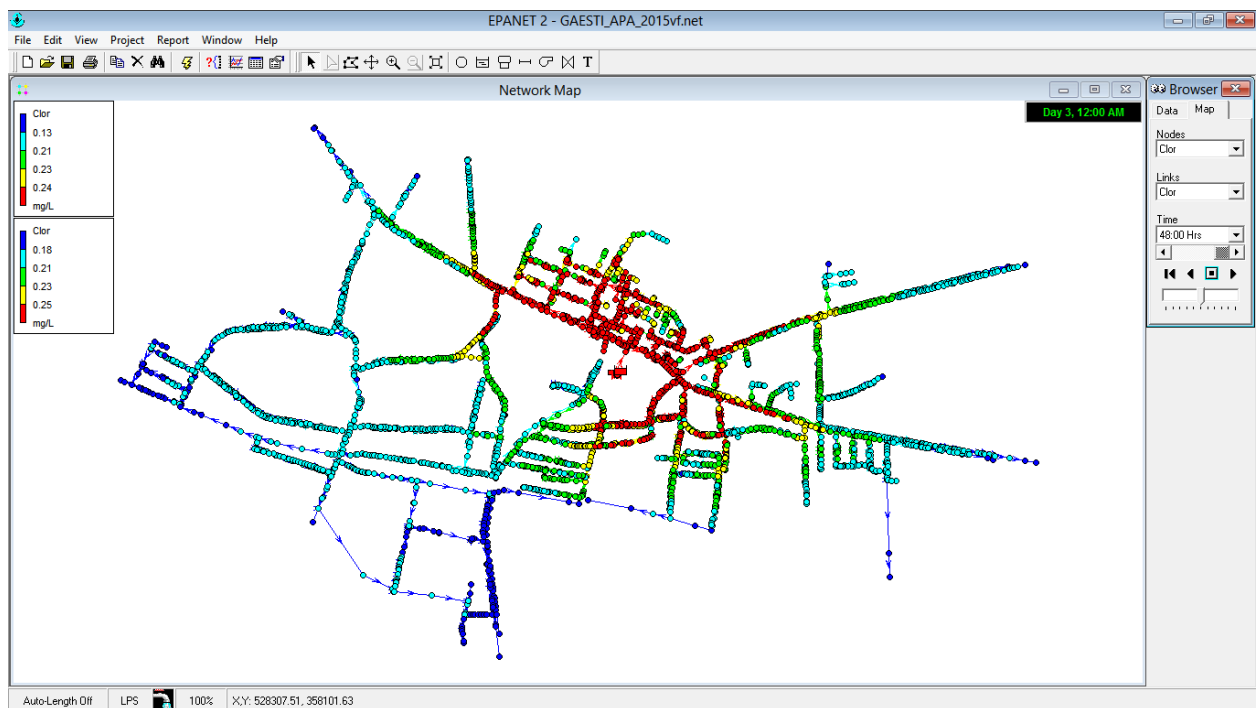


Figure 2-37 GAESTI distribution network in EPANET program (chlorine distribution after 48 hours)

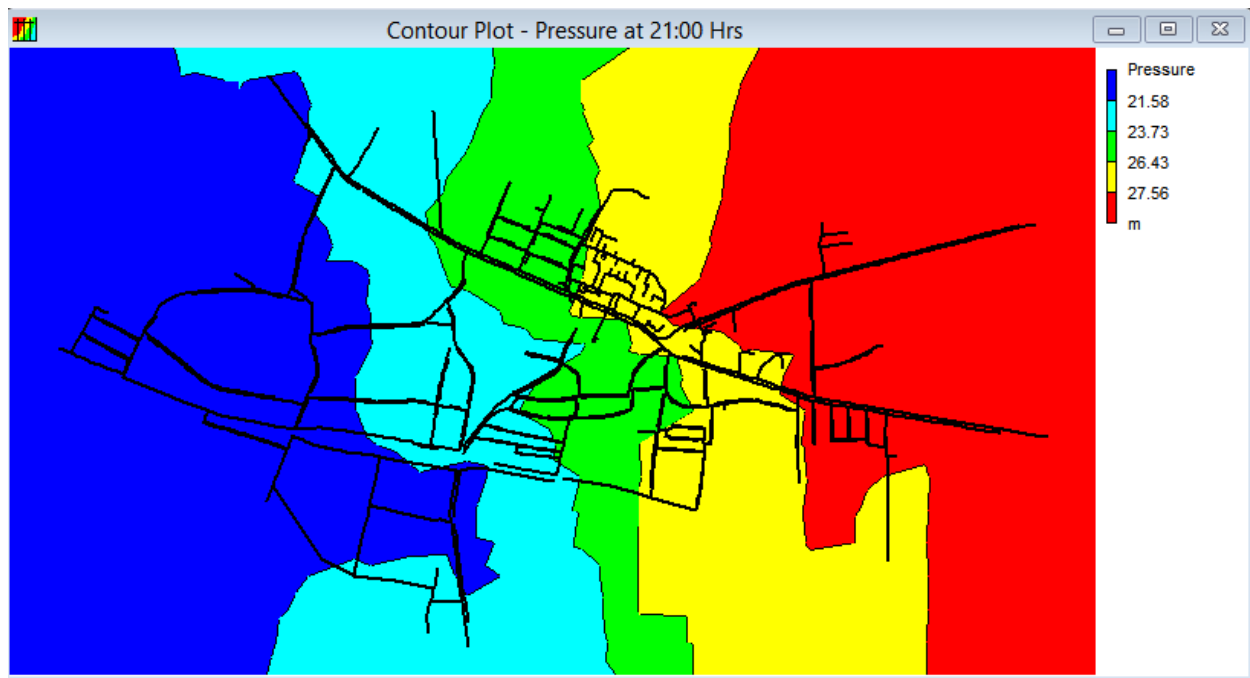


Figure 2-38 GAESTI distribution network in the EPANET program (pressure distribution at maximum consumption time)

The following observations were made following the hydraulic simulation:

- The variation of the network pressures is substantially influenced more by the differences in elevation than by the load losses, ensuring a minimum operating pressure of 20 mCA in the surrounding areas at the time of maximum consumption.
- The adjacent areas of the Găești distribution system have deficiencies in terms of chlorine concentration (below 0.2 mg / l), especially in the western and southern areas
- The results obtained are in accordance with the flow and pressure measurements carried out on this network
- The sewerage network presents an increased risk of flooding, especially in the central area

From the point of view of optimizing the operation of the distribution network, the following recommendations are made:

- Zoning the distribution network for better pressure control
- Verification of chlorination solutions for areas with chlorine deficiencies

2.3.4 Moreni Locality

A hydraulic model was created in the idea that only the distribution network related to Moreni was taken into account. The supply area served by the Plaiului tank was simulated by the supply pump and the corresponding tank.

To perform the numerical simulation of the distribution network, the Hydra menu was used, and then Compute. The program automatically writes a file in Epanet format and uses the Epanet libraries to calculate the hydraulic model.

Additionally, Epanet files were created in * .net format for easier use of the hydraulic model without the need for an URBANO 9 license.

The simulation of the models was performed in the conditions in which the variation curve was considered that of the flow and pressure measurements for a period of 24 hours.

Simulation of the distribution of chlorine in the network was performed for a period of 72 h, in the idea that the initial concentration of chlorine at the source is 0.35 mg / l.

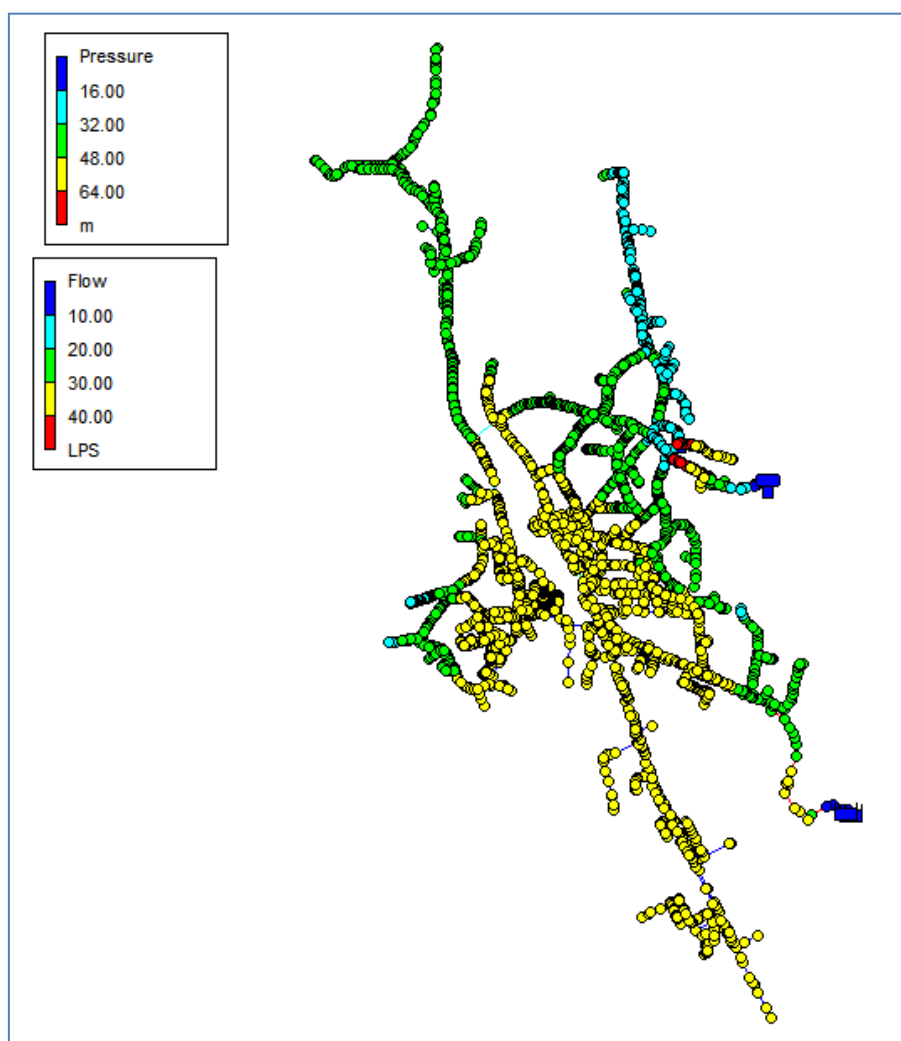


Figure 2-39 MORENI distribution network in the EPANET program (flow rates / pressures at maximum consumption time)

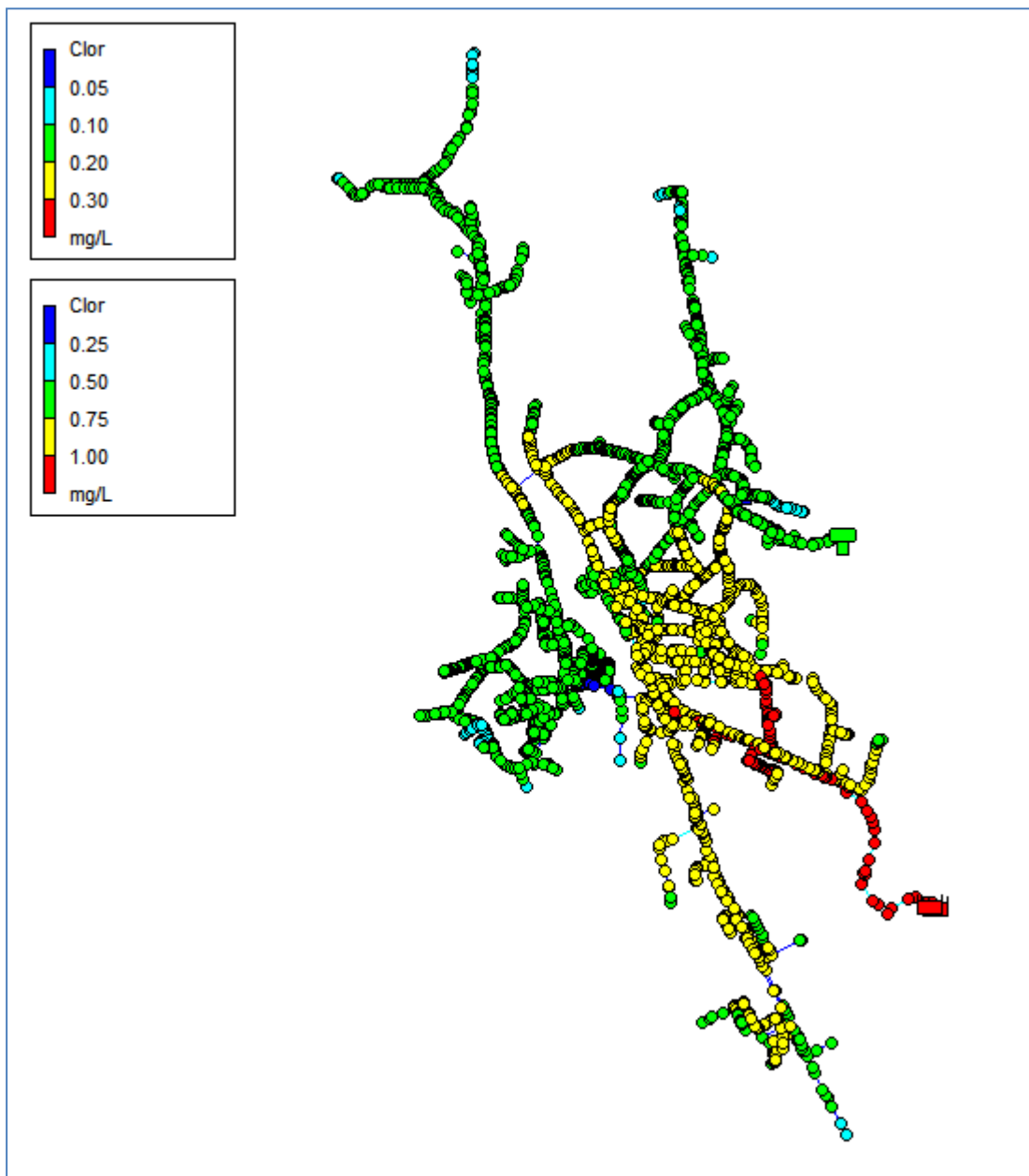


Figure 2-40 MORENI distribution network in EPANET program (chlorine distribution after 72h)

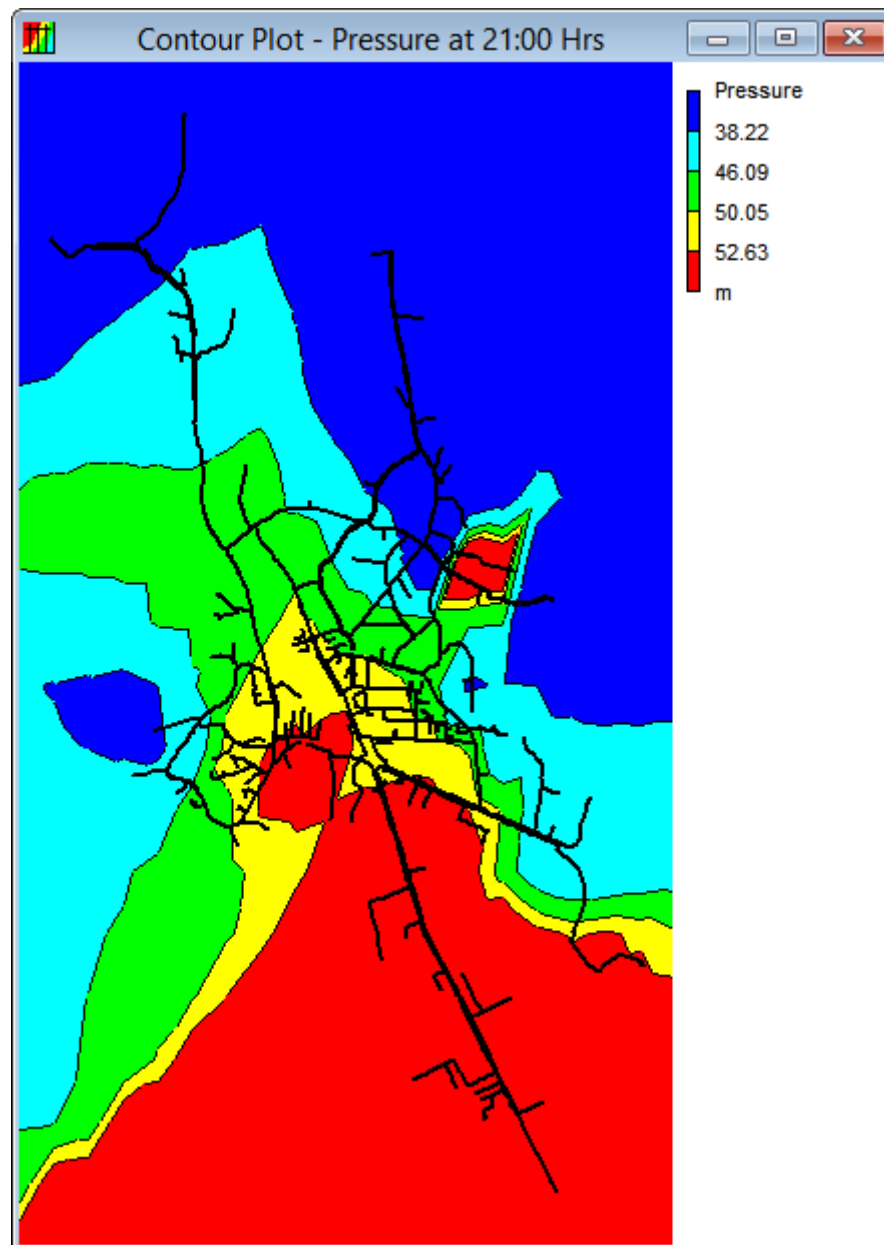


Figure 2-41 MORENI distribution network in the EPANET program (pressure distribution at maximum consumption time)

The following observations were made following the hydraulic simulation:

- The variation of the pressures in the network is substantially influenced more by the differences in elevation than by the load losses, ensuring an average service pressure of 40 mCA in the surrounding areas at the time of maximum consumption, very high pressure for the Moreni distribution network
- Adjacent areas of the Moreni distribution system have deficiencies in chlorine concentration (below 0.1 mg / l), especially in the southern area
- The results obtained are in accordance with the flow and pressure measurements performed on this network

From the point of view of optimizing the operation of the distribution network, the following recommendations are made:

- Zoning of the distribution network for a better control of the pressures and implicitly of the reduction of the losses
- Verification of chlorination solutions for areas with chlorine deficiencies

2.3.5 Pucioasa Locality

A hydraulic model was created in the idea that only the distribution network related to Pucioasa was taken into account. Pressure pumping stations in the distribution network were also simulated, and a series of PRV valves were added to the model to simulate the pressure conditions resulting from the measurements.

To perform the numerical simulation of the distribution network, the Hydra menu was used, and then Compute. The program automatically writes a file in Epanet format and uses the Epanet libraries to calculate the hydraulic model.

Additionally, Epanet files were created in * .net format for easier use of the hydraulic model without the need for an URBANO 9 license.

The simulation of the models was performed in the conditions in which the variation curve was considered that of the flow and pressure measurements for a period of 24 hours.

Simulation of the distribution of chlorine in the network was performed for a period of 72 h, in the idea that the initial concentration of chlorine at the source is 0.35 mg / l.

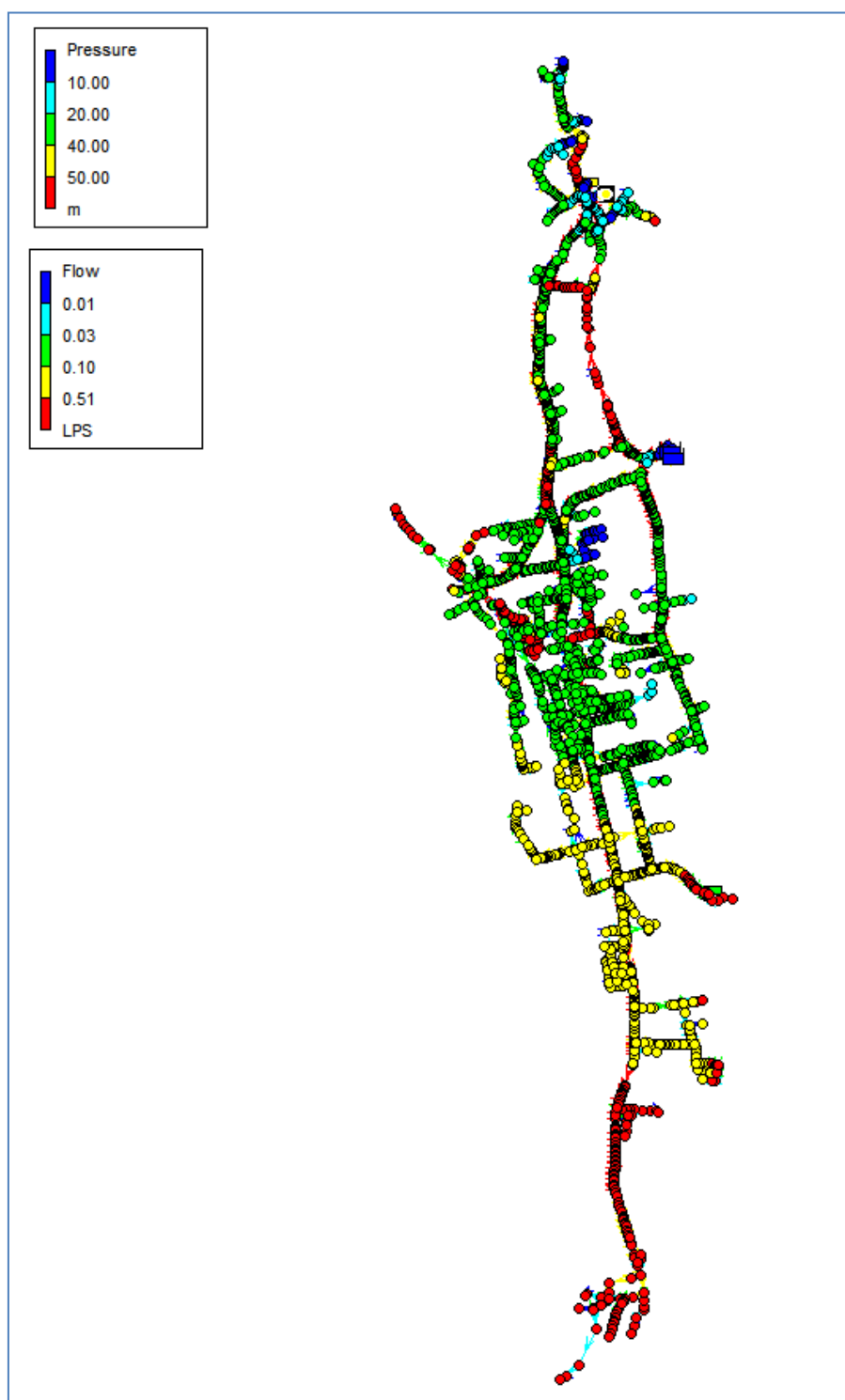


Figure 2-42 PUCIOASA distribution network in the EPANET program

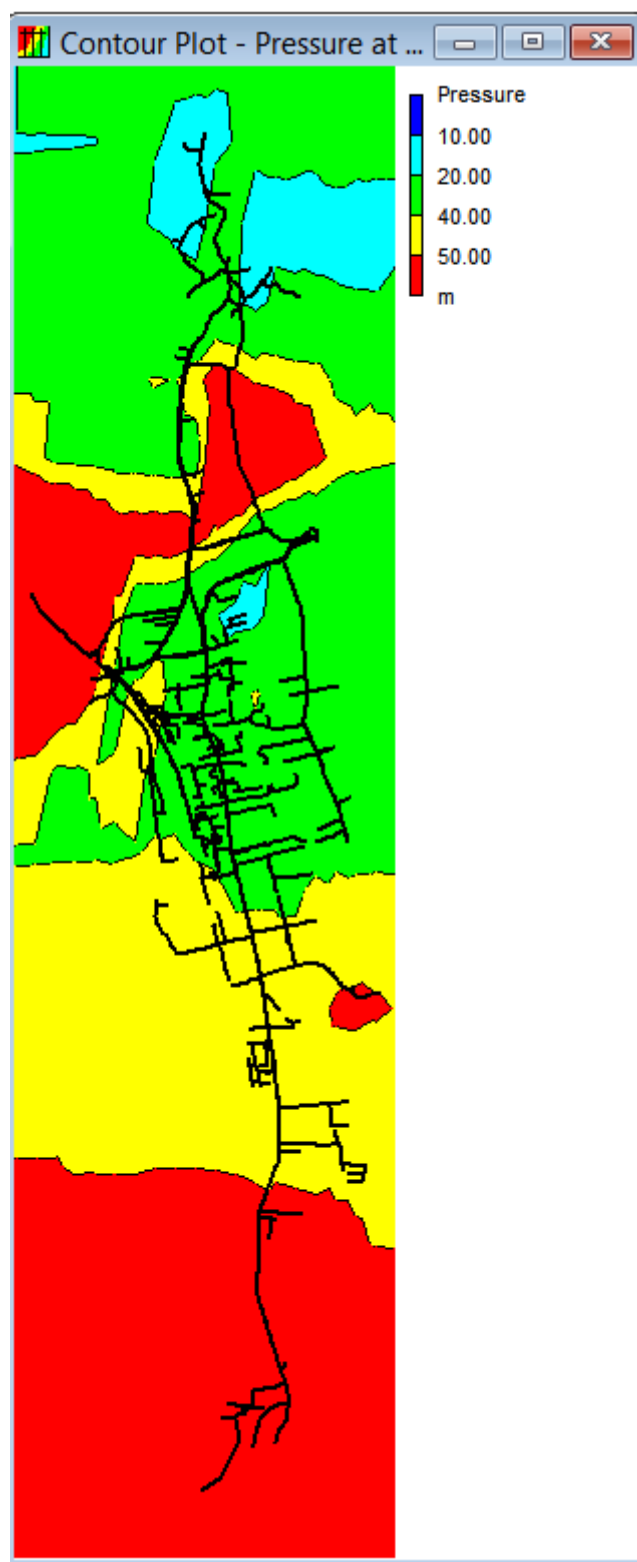


Figure 2-43 PUCIOASA distribution network in the EPANET program (pressure distribution at maximum consumption time)

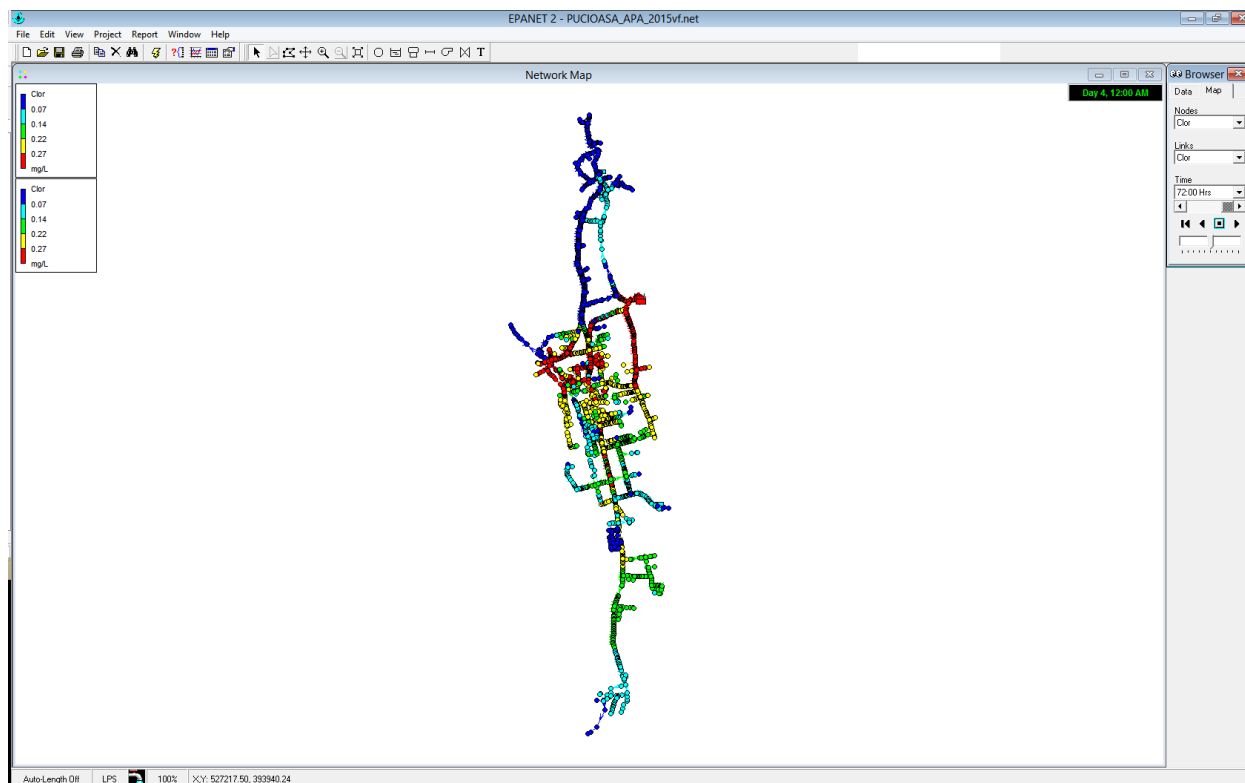


Figure 2-44 PUCIOASA distribution network in the EPANET program (chlorine distribution after 72h)

The following observations were made following the hydraulic simulation:

- The variation of the network pressures is substantially influenced more by the differences in elevation than by the load losses, resulting in overpressures in the southern area and deficient pressures in the northern area of the network
- Adjacent areas of the Pucioasa distribution system have deficiencies in chlorine concentration (below 0.07 mg / l), especially in the northern area
- The results obtained are in accordance with the flow and pressure measurements performed on this network
- The sewerage network presents an increased risk of flooding in the area of node N10075

From the point of view of optimizing the operation of the distribution network, the following recommendations are made:

- Zoning the distribution network for better pressure control, including the study of a solution involving pressure relief valves
- Verification of chlorination solutions for areas with chlorine deficiencies

2.3.6 Târgoviște Locality

A hydraulic model was created in the idea that only the distribution network related to Târgoviște was taken into account. The pumping stations for raising the pressure in the distribution network (approximately 30 hydrophore stations with the related networks were also simulated), and a series of PRV type valves were added to the model to simulate the pressure conditions resulting from the measurements.

To perform the numerical simulation of the distribution network, the Hydra menu was used, and then Compute. The program automatically writes a file in Epanet format and uses the Epanet libraries to calculate the hydraulic model.

Additionally, Epanet files were created in * .net format for easier use of the hydraulic model without the need for an URBANO 9 license.

The simulation of the models was performed in the conditions in which the variation curve was considered that of the flow and pressure measurements for a period of 24 hours.

Simulation of the distribution of chlorine in the network was performed for a period of 72 h, in the idea that the initial concentration of chlorine at the source is 0.5 mg / l.

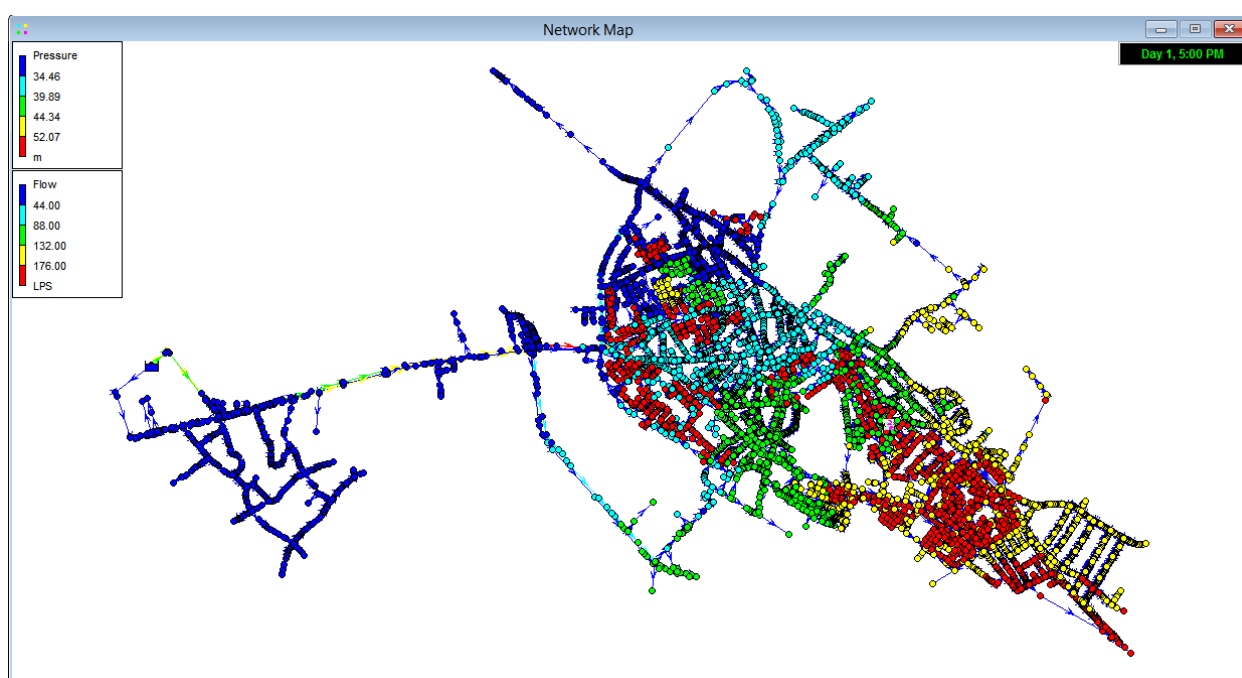


Figure 2-45 TÂRGOVIȘTE distribution network in the EPANET program (flow rates / pressures at maximum consumption time)

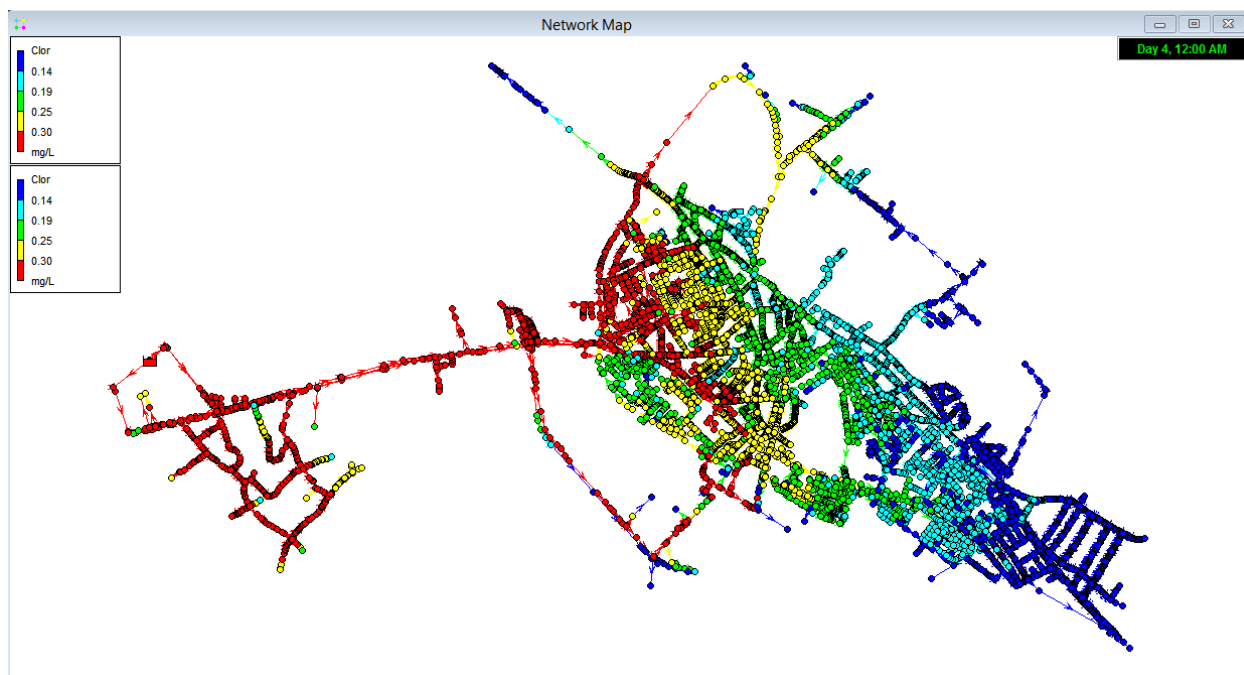


Figure 2-46 TÂRGOVIȘTE distribution network in the EPANET program (chlorine distribution after 72h)

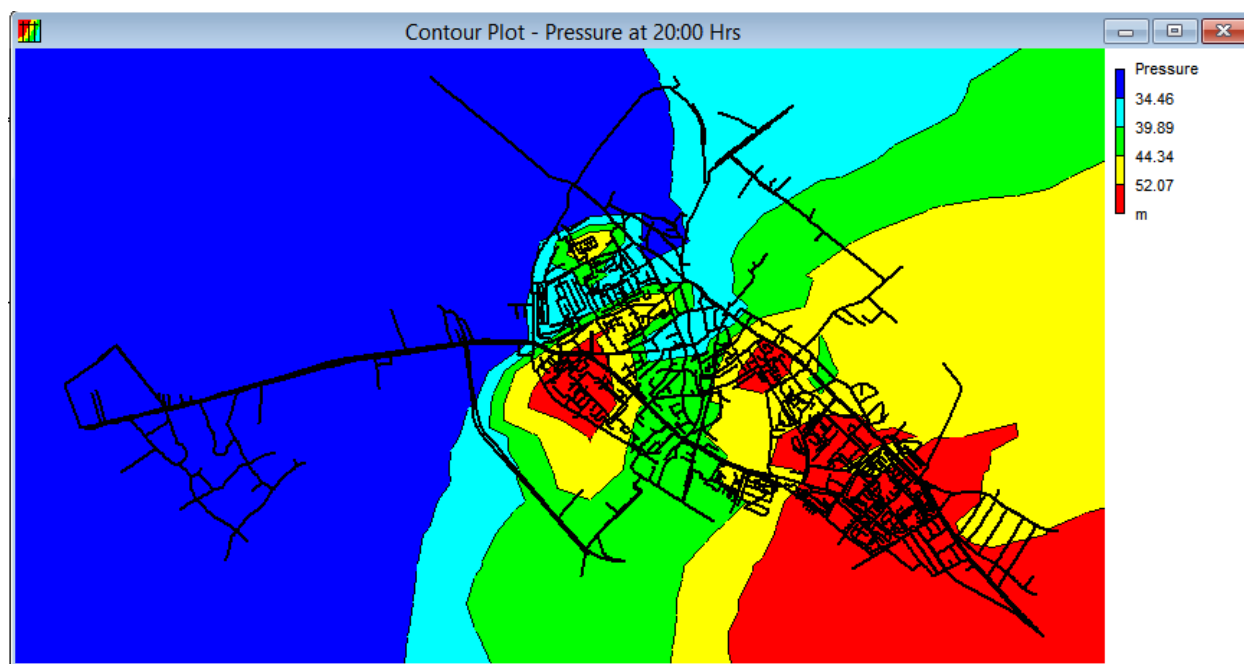


Figure 2-47 TÂRGOVIȘTE distribution network in the EPANET program (pressure distribution at maximum consumption time)

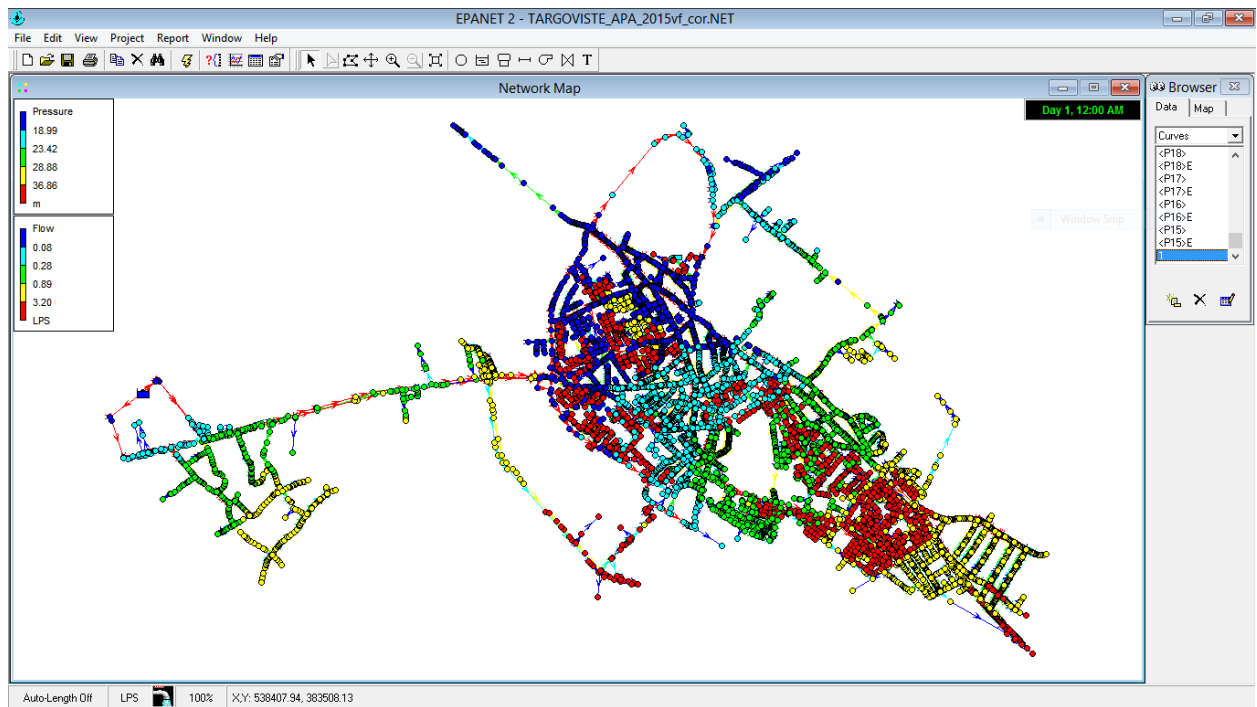


Figure 2-48 TÂRGOVIȘTE distribution network in the EPANET program (pressure distribution at maximum consumption time) - pressure relief valves

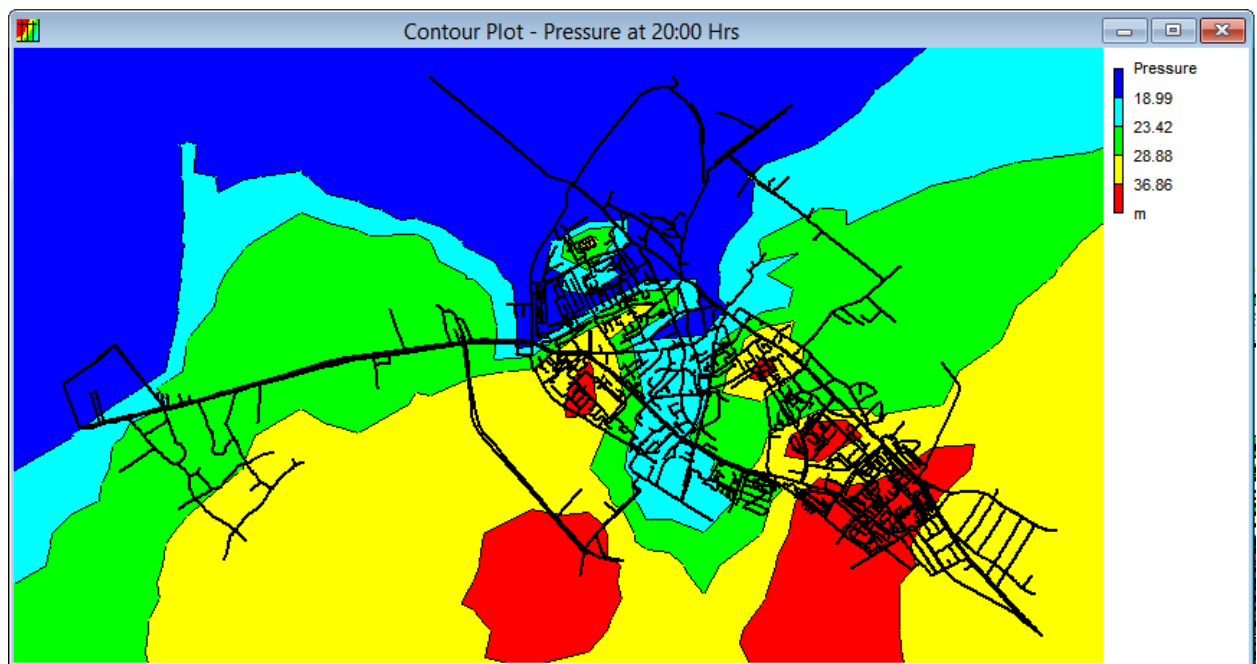


Figure 2-49 TÂRGOVIȘTE distribution network in the EPANET program (pressure distribution at maximum consumption time) - pressure relief valves

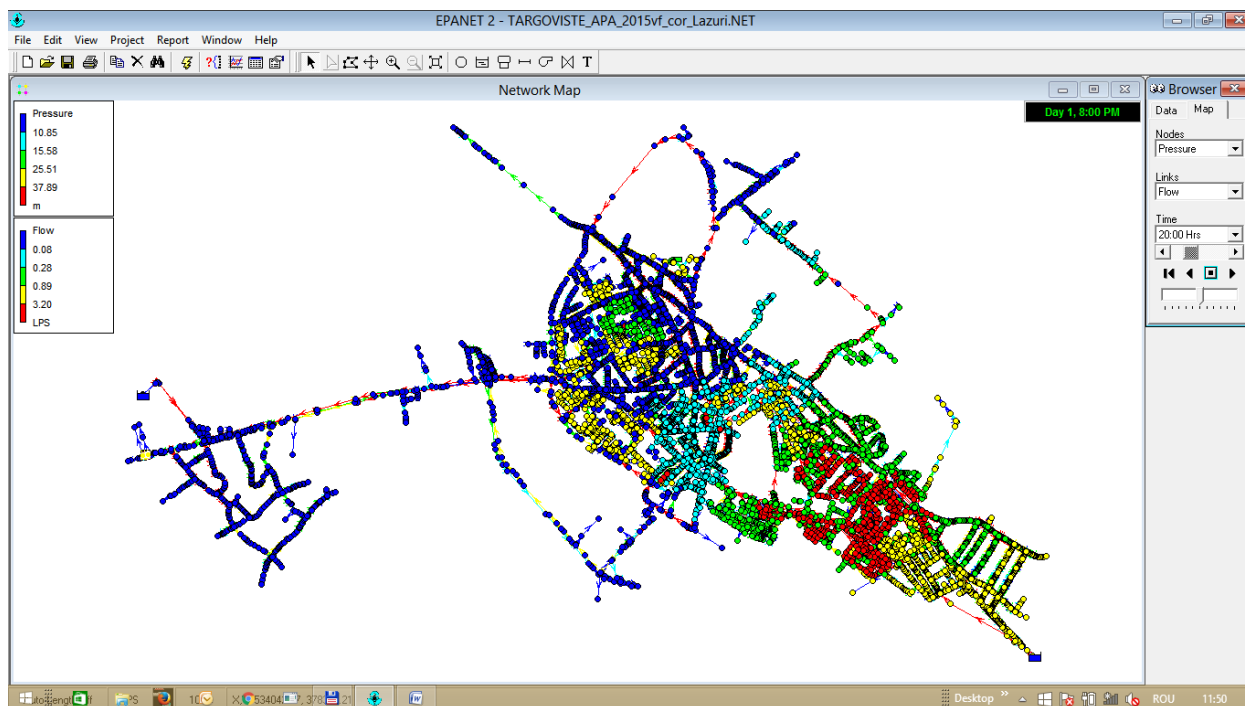


Figure 2-50 TÂRGOVIȘTE distribution network in the EPANET program (pressure distribution at maximum consumption time) - power supply from Lazuri source

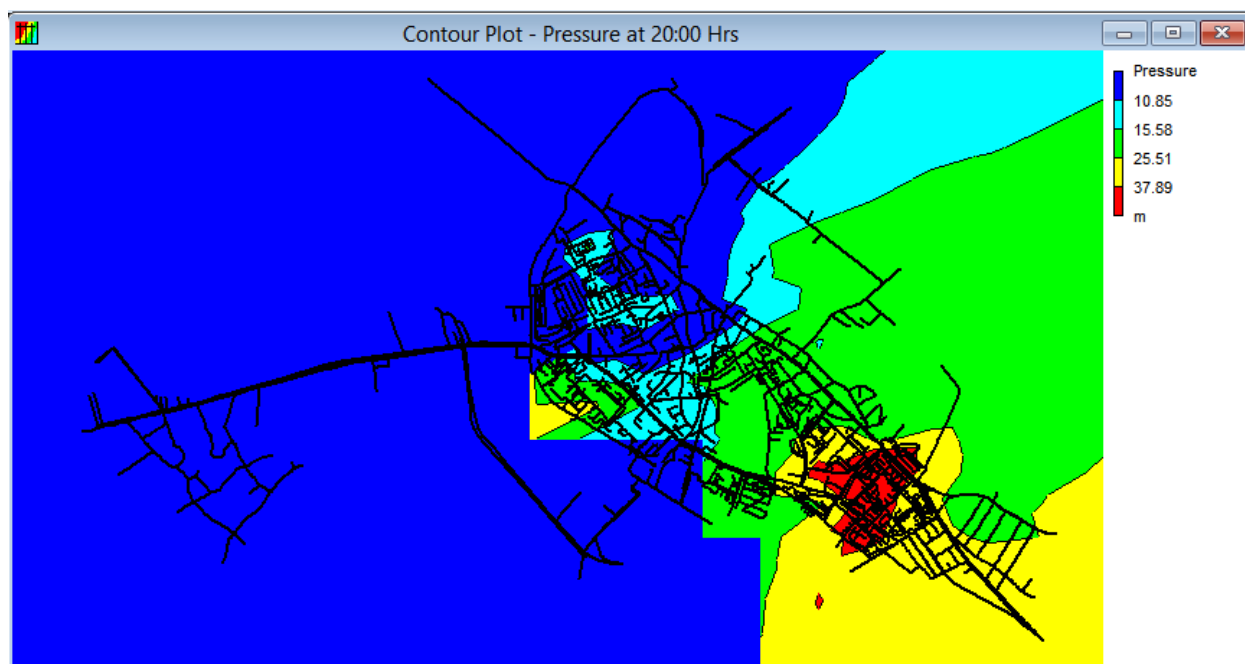


Figure 2-51 TÂRGOVIȘTE distribution network in the EPANET program (pressure distribution at maximum consumption time) - power supply from Lazuri source

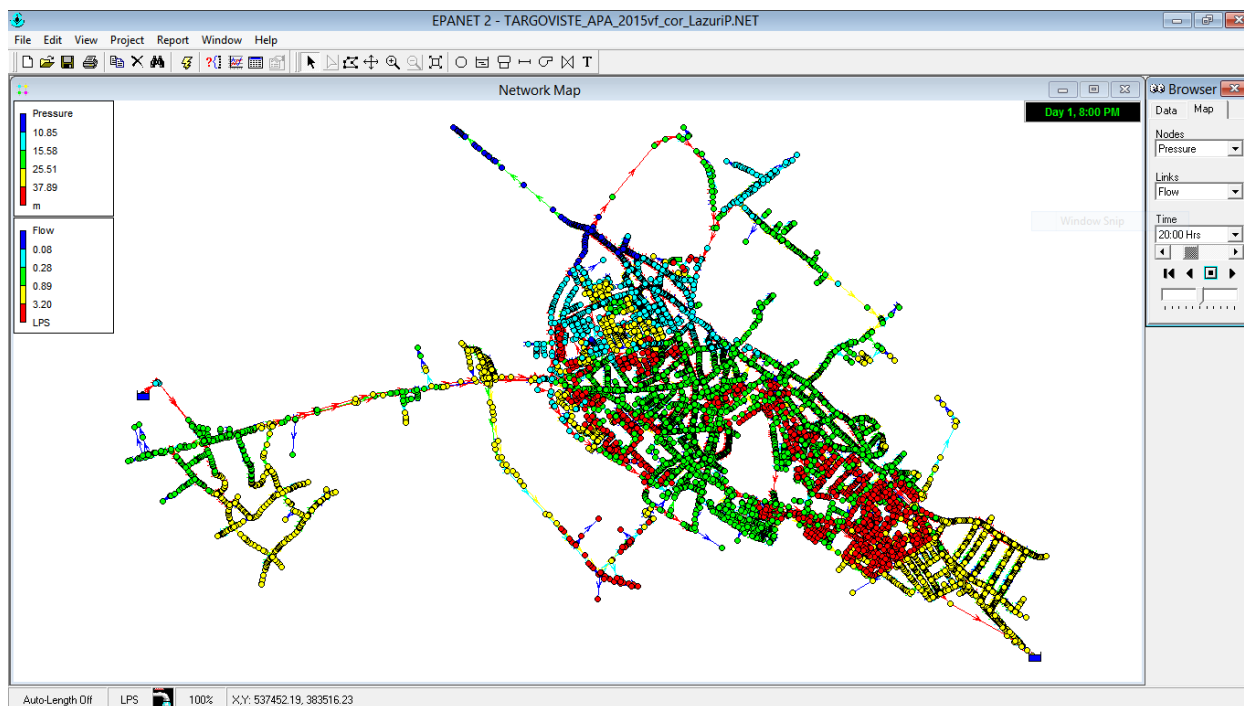


Figure 2-52 TÂRGOVIȘTE distribution network in the EPANET program (pressure distribution at maximum consumption time) - power supply from Lazuri and Priseaca source

The following observations were made following the hydraulic simulation:

- The variation of the network pressures is substantially influenced more by the differences in elevation than by the pressure losses, obviously the pressure being high in the areas fed by the hydrophore stations
- It is observed from the running of the hydraulic models that without the constriction of the valves the pressures in the distribution network exceed 5 bar in some areas (certain hydrophore stations can be abandoned)
- If the valves are strangled (situation in the field) there are major deficiencies in ensuring the service pressure in the north of the network
- Regardless of the water supply configuration, the southern area has relatively high pressures (approx. 3 bar) on the low-pressure network. For this reason, it is recommended that in the future to study the possibility of giving up hydrophore stations in this area.
- The bordering areas of the Târgoviște distribution system have deficiencies in terms of chlorine concentration (below 0.2 mg / l), especially in the southern and south-eastern area

- The results obtained are in accordance with the flow and pressure measurements performed on this network
 - The sewerage network presents an increased risk of flooding in the area of nodes N34843 and N38713.

From the point of view of optimizing the operation of the distribution network, the following recommendations are made:

- Zoning of the distribution network for better pressure control, in particular pressure control for each high-pressure network separately
- Verification of chlorination solutions for areas with chlorine deficiencies

3 CONCLUSIONS

The software tools currently available are dedicated to various practical and / or theoretical aspects in the field of water loss, and the decision to use a particular software tool must be based primarily on the real needs of the user. For this reason, a hierarchy of the analyzed software tools is irrelevant.

The hydraulic models presented for the 18 distribution networks lead to the following conclusions:

1. In the cases analyzed there are situations in which the pressures at nodes resulting from the simulation either exceed or are below the values of the required service pressures, which leads to the following implications:

- a. Distribution networks are not optimized in terms of pressure
- b. In case of excess average pressure, the ILI indicator is not recommended to be used as a target indicator if no pressure reduction actions are taken
- c. In case of insufficient average pressure, performance indicators (including ILI) are of little relevance because the effectiveness criteria are not met in the first place.

2. All hydraulic models indicate speeds on very low arteries (mostly around 0.2 - 0.3 m / s for peak consumption) regardless of their age, which inevitably leads to low chlorine concentrations especially in the surrounding areas of the network. This implies the appearance of an additional technological consumption due to the purge of the pipes and implicitly to the increase of the volume of water that does not bring income.

3. As the physical characteristics, variations and consumption volumes of the analyzed distribution networks are different, it is necessary to establish criteria for comparing them for a relevant analysis of performance indicators. The proposed comparison criteria are as follows:

- a. Connection density (connections / network length)
- b. The ratio between active and inactive connections
- c. The ratio between the length of the adductions and the length of the distribution network
- d. Annual profile of authorized consumption (only where data are available for several years)
- e. Per capita consumption

4. The proposed comparison criteria may also be used for the particular case of the multi-annual analysis for a given distribution network in the sense that the impact assessment for changes to the distribution network is desired.

Bibliography

1. **A. Aldea**, A. Anton – *Operational vs. Financial Performance Indicators in water loss assessment*, WaterLoss Management 2015, Bucharest, Romania
2. C. Toma, N. Tarău, S. Jiru, **A. Aldea** – *Decrease of the water loss step by step. A case study in Braila.*, WaterLoss Management 2015, Bucharest, Romania
3. A. Dascăr, B. Păiușan, F. Kiszely, **A. Aldea** – *Water loss reduction in the city of Deva by night-flow monitoring*, WaterLoss Management 2015, Bucharest, Romania
4. **A. Aldea**, N. Stoica, R. Tudor – *Re-assessing water losses in small distribution networks*, WaterLoss Management 2015, Bucharest, Romania
5. **A. Aldea** – *Key Mistakes for Establishing Water Loss Targets in Small Networks*, PI/Efficiency 2015, Cincinnati, OH, USA
6. **A. Aldea** – *Pierderi de apă - estimarea indicatorilor de performanță în rețele de mici dimensiuni*, International Conference ARA , 16th edition, EXPOA APA 2014, Bucharest, Romania
7. Iamandi C. & co. (2002) Hidraulica Instalatiilor vol. II, Editura Tehnica, Bucuresti
8. Luca B.A., Luca V.O., Hasegan L.V. (2008) Hidraulica speciala – Notiuni teoretice si aplicatii, Editura Printech, Bucuresti
9. Dimitriu B., Aldea A.. (2003) Monitorizarea nivelurilor de apă din rezervoare. Comanda la distanță a vanelor.. *ExpoAPA*, p. 206-216 ,2003, Brasov, Romania
10. Dimitriu B., Aldea A.. (2003) Automatizarea stațiilor de pompare pentru ape uzate, *ExpoAPA*, p. 240-245 .2003, Brasov, Romania
11. ***, Nivus OCM Pro – User Guide
12. Cioc D., Anton A., - *Rețele hidraulice: calcul, optimizare, siguranță*, 2001, Editura Orizonturi Universitare, Timișoara.
13. Iamandi C., Petrescu V., Damian R., Sandu L., Anton A., Degeratu M., - *Hidraulica Instalațiilor - Elemente de calcul și aplicații*.
14. Mănescu A., Sandu M., Ianculescu O., Alimentații cu apă, 1994, Editura Didactică și Pedagogică, București.
15. Mănescu A., - *Alimentații cu apă și canalizări*, 2009, Editura Conspress, Bucuresti.
16. Georgescu A.M., Georgescu S.C., - *Hidraulica rețelelor de conducte și mașini hidraulice*, 2007, Editura Printech, Bucuresti
17. Walski T., Chase D., Savici D., - *Water distribution modeling*, 2001, Haestad Press.
18. ESRI, “Building a Geodatabase”, USA, 2002

19. Data Invest, "Manual de Utilizare NetSET HYDRO", unpublished
20. B. Dimitriu, A.Aldea,"Monitorizarea presiunii si a debitului in retelele de distributie", Conferinta Internationala ARA editia a V-a, Brasov, Mai 2003
21. HAESTAD METHODS, "Advanced water distribution modeling and management"
22. Paul Ginther, "Use of GIS Growing in the Municipal Water, Wastewater Business"
23. Werner de Schaetzen and Paul F. Boulous, "Optimal Water Distribution System Management Using ESRI MapObjects Technology
24. H. Alegre, J.M. Baptista, E. Cabrera Jr. – Performance Indicators for Water Supply Services – 2nd edition, IWA Publishing, 2010
25. M. Farley, S. Trow – Losses in Water Distribution Network, IWA Publishing 2003