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Software Used for the Design and Computation of Hydraulic Water Supply Networks: Overview

Przegląd programów wykorzystywanych do projektowania i obliczeń hydraulicznych sieci wodociągowych

The aim of this paper is to present the potential of computer software for designing and computation of hydraulic water supply systems. The paper presents applications available in the Polish market, such as: Stanet, Woda, Wodociągowiec, Wavin-NET and Epanet. The paper presents the functionalities of each application: the method of construction of the water supply network, limitations to the size of the network, options of inputting such data as e.g. water distributions and the type of generated output data. It was shown which applications allow for hydraulic calculations of both radial and annular networks, and which can be used only for radial networks. Attention was also drawn to the option of automatic generation of longitudinal profiles of designed networks.

Keywords: **water supply system, computer-aided design of water supply networks, hydraulic modelling**

Introduction

Nowadays, it is difficult to imagine managing water supply infrastructure without the use of modern IT systems. They allow for automation of most of the activities that need to be performed in order to facilitate and optimize the operation of water supply system. Hydraulic modelling, which offers a digital representation of network operation, is also increasingly used. With this type of modelling, it is possible to observe the phenomena occurring in the network and to determine the effect of various factors on the network operation. The process of designing new water supply lines is also often supported by dedicated software.

At present, at the design stage, it is necessary to perform the hydraulic calculation of water supply systems, which usually play the role of fire protection networks at the same time. According to the Ordinance [1], the fire-fighting water supply system should ensure the efficiency of not less than 5 dm^3/s and the pressure in the external fire hydrant not less than 0.1 MPa for at least 2 hours. Furthermore, the efficiency of the water supply system may not be lower than the total amount of

water required for the following purposes: fire protection, household water supply (limited to 15%), industrial water supplied (limited to the necessary operation of technological equipment). When designing branches from the annular network, the diameter of the pipe should be based on hydraulic computations. The design documentation should demonstrate that the minimum operating pressure in the network will be sufficient for the proper operation of the hydrants.

There are many programs available in the market to support the work of designers of water supply networks, but not all of them are characterized by full functionality, e.g. they do not feature hydraulic calculation of both branched and peripheral networks. Individual applications differ in the number of operations performed (the size of the network may be limited), the form of presentation of the results and archiving data, opportunities for automated generation of longitudinal profiles, possible modules, compatibility with digital maps and calculation algorithms.

However, they also share many common features. For example, water supply network most often consists of nodes and sections, with nodes representing branches and connections of the sections, and final points of water collection from the network and initial points of water intake, whereas sections are the connections between two adjacent nodes by means of a pipe with constant diameter and roughness. Connections may also include other elements such as local resistances (elbows, tees, reducers, gate valves), a pump or pump assembly with a preset flow characteristic, a reducer with a constant preset pressure loss, a device with known rated parameters (pressure loss and flow rate), but not all applications allow such elements to be input. Water distribution can be presented as focused (in nodes) and dispersed (along the length of sections).

1. Stages in computation of water supply networks

The works connected with the design and hydraulic computation of water supply networks can be divided into several phases:

1. Preliminary determination of assumptions for the design, including: supply conditions of the designed network, determination of the routes for the water supply system, determination of the demand for water for social, economic, fire-fighting and industrial and other purposes at present and in the future, choice of materials used for the construction of the network.
2. Entry of input data into the program: it is important to ensure compatibility with the .dwg/.dxf files used in digital maps.
3. Preliminary computations, including correction of input data, simulations for different scenarios (e.g. variable water demand, network operation under fire-fighting flow conditions, etc.).
4. The final stage is to develop the results of the computations and to adopt a final design solution for which the network will operate optimally.

The choice of the software for hydraulic calculations is not an easy decision. Different criteria that have an effect on using the software should be taken into

account. These include, for example, the method of entering and configuration of the data. Due to the widespread use of digital maps, it is desirable for the software to feature the option of automatic generation of water supply networks based on such maps, with the possibility of manual adjustment.

2. Characterization of certain applications for the design and calculation of water supply networks

Nowadays, many pieces of software are available to perform hydraulic calculations of water supply networks. Due to the large number of applications available in the market, the study presents only the functionalities of selected applications. The choice of the software was mainly dictated by price availability of the application: free software and the software at a price affordable for people running small businesses. The applications with very extensive functionalities, whose main objective isthe real-time hydraulic modelling of wide-area water supply networks, but which is complicated in use and very expensive were excluded e.g.: InfoWater, WaterCAD or MIKE URBAN. Academic software such as ISYDYW (Cracow University of Technology), NET (Warsaw University of Technology) or SYMWOD (Wrocław University of Science and Technology) were also not described due to their limited availability for designers.

All applications described below have the option to visualize basic network parameters such as water flow rate and pressure. They also have many other common features, including:

- creation of a water supply network as a system of ducts - sections, connected with each other in nodes,
- possibility of editing and deleting individual elements,
- representation of the network with raster or vector images,
- hydraulic calculation of the network for steady state,
- visualization of network operation data, e.g. water flow rates.

Some of the applications also feature computation for subsequent time steps (for variable water demand) and monitoring of water age or concentration of selected substances during water flow through the network, for example chlorine. A useful feature from the designer's point of view is also the option of automatic generation of longitudinal profiles of the designed water supply network.

2.1. STANET

The STANET application is an integrated piece of software developed by the German company Fischer-Uhrig Engineering. It is available in German, English and Polish language versions, with the first version launched in 1980 and since then the application has been constantly improved [2]. It is offered in several price versions, depending on the expected size of the analysed network. STANET is used for the analysis of networks supplying and providing and transferring various types of media, such as:

- gas networks,
- water supply networks or other liquid media,
- heating and steam networks,
- electrical networks,
- sewer systems [3, 4].

The computations can be conducted for both radial and annular networks, with virtually unlimited size of the analysed network. The application allows for presentation of the network in both steady and dynamic modes. Network data are mostly downloaded from external systems (GIS) using special interfaces (ODBC, Shape, text). STANET also offers tools for verification and automated correction of errors that occur during manual data input and errors present in models. Networks can also be automatically loaded from drawing software (for example, as .dxf files). Missing elements can be entered manually. Furthermore, maps in the form of raster or vector files can be used as a background.

In the case of water supply networks, the analysis and computations include, among other things:

- simulation of network operation for variable water distribution,
- optimization of pipe diameters for the required hydraulic conditions,
- optimization of hydrants and fittings arrangement,
- any definition of hydraulic parameters,
- automated verification and possible correction of network topology,
- automated creation of subnetworks,
- computation of additional parameters, for example heat loss,
- water quality analysis,
- taking into account water for fire-fighting purposes (capacity and pressure in the hydrants, conditions for maintaining the set pressure for the hydrants, etc.).

The following functionalities used during design and editing impact on flexibility of creating networks:

– selective display of the results by sorting, grouping and filtering,
– presentation of the background in the form of raster files (for example TIFF, BMP, etc.) or vector files (AutoCad-DXF format),
– assigning attributes (e.g. colours, types and line thickness) to any parameter,
– widely understood opportunities for modification of network configuration,
– possibility of assigning an individual water demand pattern to each customer,
– individual definition of graphic elements by the user,
– use of layers to manage network elements,
– options of saving and fast loading of the most frequently used network settings (by creating scenarios),
– presentation of results in the form of diagrams (for example: longitudinal network profiles, time profiles),
– displaying technical data in a network window, next to an element or in the form of a list,
– cutting and pasting subnetworks (Copy&Paste).

An example of a water supply network designed using STANET software is illustrated in Figure 1.

Despite numerous functions and extended modules, the application is easy to use and transparent. STANET can also be used as a system of information about the existing water supply network and enables the analysis of elements that are at the design stage or planned to be removed from the use. It is possible to export graphic files and calculation data to other applications (e.g. AutoCad or Excel).

Fig. 1. Diagram of a water supply network in the STANET application [3]

2.2. WODA

WODA is an application intended for designers of water supply networks and for services responsible for the proper functioning of existing water supply systems. The application was developed by UKTN Usługi Komputerowe with its registered office in Gliwice, Poland. The application performs hydraulic computation of the steady state of water supply networks, both radial and annular, e.g.:

- it calculates volume flow rates for water in all sections of the network,
- it determines the pressures in all network nodes,
- it enables the choice of pipe diameters for preset hydraulic conditions [5].

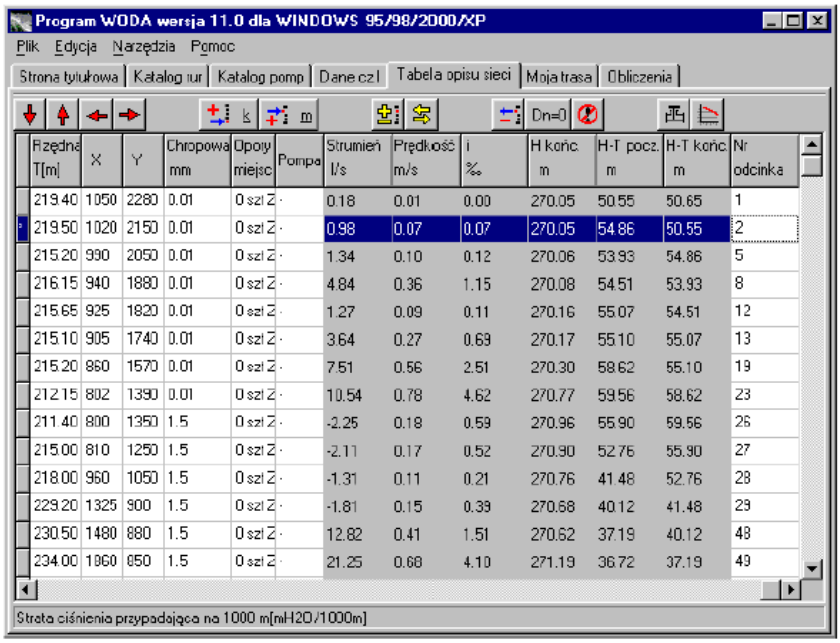
It is possible to perform computations for subsequent time steps, but this requires a set of new input data. However, the application stores in memory only three simulations, and the comparison is made in the form of pressure line diagrams [6]. In addition to the selection of diameters, the application allows the designers to check the operation of the network in various conditions. The application can help water service employees solve a number of problems, for example:

- location of bottleneck sites and those with too low water flow rates,
- analysis of the impact of the investments on network operation (e.g. connecting new customers),
- choice of optimal parameters for operation of pumps at variable water demand (peak load, night hours).

An example description of a water supply network in a tabular form is presented in Figure 2. The software allows for simulation of the operation of the following devices:

- a pump or pump assembly with a preset flow characteristic,
- reducer with constant preset pressure loss,
- regulation valve with set Kv coefficient,
- a device with known rated parameters (pressure loss and flow rate).

It is also possible to take into account local resistance (e.g. elbows, tees, reducers, gate valves). The application allows for introducing distribution both as concentrated (in nodes) and distributed (in sections). The number of sections and nodes is basically unlimited, but with large networks, the computation speed may be lower.



Rzędna T[m]	X	Y	Chropowa mm	Opory miejsc	Pompa	Strumień l/s	Prędkość m/s	i ‰	H końc. m	H-T pocz. m	H-T końc. m	Nr odcinka
219.40	1050	2280	0.01	0 szt Z		0.18	0.01	0.00	270.05	50.55	50.65	1
219.50	1020	2150	0.01	0 szt Z		0.98	0.07	0.07	270.05	54.86	50.55	2
215.20	990	2050	0.01	0 szt Z		1.34	0.10	0.12	270.06	53.93	54.86	5
216.15	940	1880	0.01	0 szt Z		4.84	0.36	1.15	270.08	54.51	53.93	8
215.65	925	1820	0.01	0 szt Z		1.27	0.09	0.11	270.16	55.07	54.51	12
215.10	905	1740	0.01	0 szt Z		3.64	0.27	0.69	270.17	55.10	55.07	13
215.20	860	1570	0.01	0 szt Z		7.51	0.56	2.51	270.30	58.62	55.10	19
212.15	802	1390	0.01	0 szt Z		10.54	0.78	4.62	270.77	59.56	58.62	23
211.40	800	1350	1.5	0 szt Z		-2.25	0.18	0.59	270.96	55.90	59.56	26
215.00	810	1250	1.5	0 szt Z		-2.11	0.17	0.52	270.90	52.76	55.90	27
218.00	960	1050	1.5	0 szt Z		-1.31	0.11	0.21	270.76	41.48	52.76	28
229.20	1325	900	1.5	0 szt Z		-1.81	0.15	0.39	270.68	40.12	41.48	29
230.50	1480	880	1.5	0 szt Z		12.82	0.41	1.51	270.62	37.19	40.12	48
234.00	1960	850	1.5	0 szt Z		21.25	0.68	4.10	271.19	36.72	37.19	49

Fig. 2. A window with description of the network in the WODA application [6]

Sectional and nodal distributions can be taken into account in two ways: for each customer connected to a given section or node, their offtake (using a special editor of connections) can be input, or the sum of offtakes for a given section or node should be entered without specifying the connected customers. The application requires the user to create a catalogue of pipes used. The diameters are chosen

according to the criterion of pressure loss or water flow rate. The application allows for testing various scenarios, e.g. network operation with fire fighting system started, with selected lines closed, or in case of failure (free flow of water through the damage).

The application generates three basic forms of results displayed on the screen or in the form of a printout:

- a table containing a set of data and results (including flow rates, speeds, pressure loss in sections and pressure in nodes),
- map of pressure distribution in the network, water velocity and flow intensity (the values of the above mentioned parameters are marked on the map with different colours) - Figure 3.
- a set of pressure line diagrams covering the entire network.

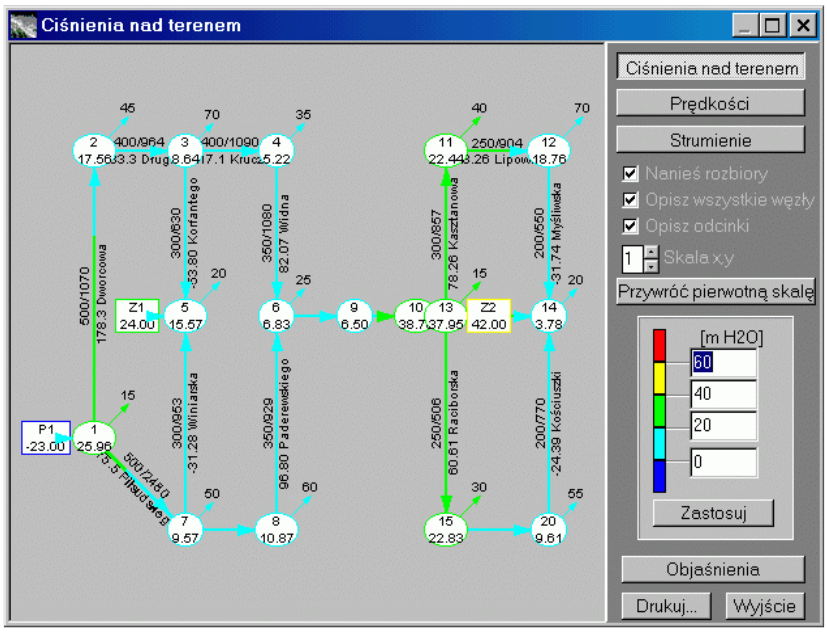


Fig. 3. Distribution of water pressure in the network, velocity and flow in the WODA application [6]

The application can be used for e.g. analysis of the water supply network in order to optimize the operation of the existing network and the connection of other customers, choice of diameters of new pipes, simulation of the operation of the water supply system for various variants of water demand.

Limitations of the application include impossibility of loading maps in the form of vector files. Furthermore, in order to prepare longitudinal profiles based on the calculated water supply networks, it is necessary to use another application, Profil Koordynator. The WODA application does not feature export of calculation results or drawings in the form of files that can be edited in other applications (e.g. Excel or graphic programs).

2.3. WODOCIĄGOWIEC

GAMRAT was one of the first companies in Poland to develop computer software supporting the design of water supply and sewage systems based on plastic pipes. Currently, Gamrat offers a package of three programs for designers [7]:

- "Kanalizator-CAD Gamrat 7.0" for supporting the design of gravitational sewer systems,
- "Wodociągowiec-CAD Gamrat 4.0" for supporting the design of water distribution networks,
- "Profiler-CAD Gamrat 4.0" for supporting the drawing of longitudinal network profiles.

All applications are free and can be downloaded from the company's website.

The application dedicated to water supply networks allows for computing only radial networks. The program allows for the use a terrain map as a background, performs hydraulic computations, and automatically generates longitudinal profiles. Compared to previous versions, the new application features the option of compatibility with digital maps. Wodociągowiec offers opportunities for designing a network on loaded maps of the area. In addition to scanned maps, users can also load increasingly popular digital maps. Using the maps, the designer has two new functionalities that were added to the current version of the application. They allow for automatic reading of terrain ordinates from the map and the ability to import sections of the network. With the first function, when entering individual sections of the water supply network on the digital map, the user does not have to manually enter the existing ordinates of the terrain as the application reads them from the map and enters them automatically. In the case of the second function, if the user has loaded a digital map with a network, they do not have to redraw it. After indicating individual sections, the program will automatically apply them on the map background. For users who prefer using scanned maps, a "bitmap gluer" has also been developed. This is a very helpful functionality for creating a map from smaller scanned parts (e.g. A2 format map composed of scanned A4 fragments) [8].

After loading the terrain map, the user enters the individual sections of the network and determines the boundary conditions for the hydraulic calculations (Fig. 4). It is also advisable to introduce sites of collisions with underground utilities. This is done by simply clicking on the collision sites and entering their basic data. The application performs hydraulic calculations and checks if the pipeline on the calculated depth does not interfere with the underground utilities and selects the diameters from the loaded series of pipe types. The designer has all types of pipes offered by GAMRAT SA at his or her disposal. It is also possible to input fixtures and fittings. All network elements will be included in an automatically generated list of materials. The calculation of excavation cubic capacity by means of the application is also very helpful feature in the case of preparation of the bill of quantities.

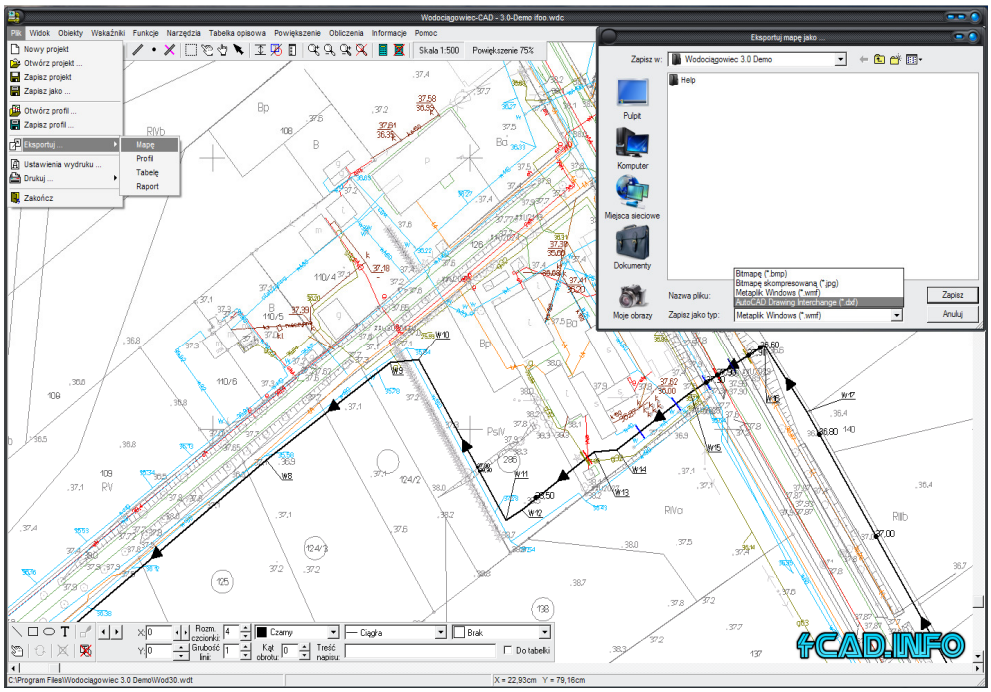


Fig. 4. A map of water supply network in Wodociagowiec-CAD GAMRAT application [9]

The results of the hydraulic computations are contained in the table. The designer can check the individual sections and make corrections, if necessary. Each entered network section is fully editable and can be modified at any stage of project development. Drawings of longitudinal profiles are made automatically: it is enough to indicate any sequence of network sections (Fig. 5). The program allows for choosing the settings of vertical and horizontal scales and the comparison level. There is also a graphical editor that enables the user to draw and enter captions both on profiles and on the network map.

Profiler-CAD is an application that complements and extends the functionality of the Wodociągowiec application. It is used to create longitudinal profiles based on the input numerical parameters and to edit profiles generated by other applications. Its very useful function is “gluing”, i.e. joining several longitudinal profiles into one drawing. All drawings created in the package programs, apart from printing options, can also be exported to files with such extensions as .jpg, .bmp, .wmf, and .dxf. Dxf files are used for data exchange between CAD software, so it is possible to open and further edit drawings in any CAD applications (AutoCAD, MegaCAD, Microstation, IntelliCAD). The .dxf files are also used for loading digital maps into programs. This allows users to import maps created in any CAD program.

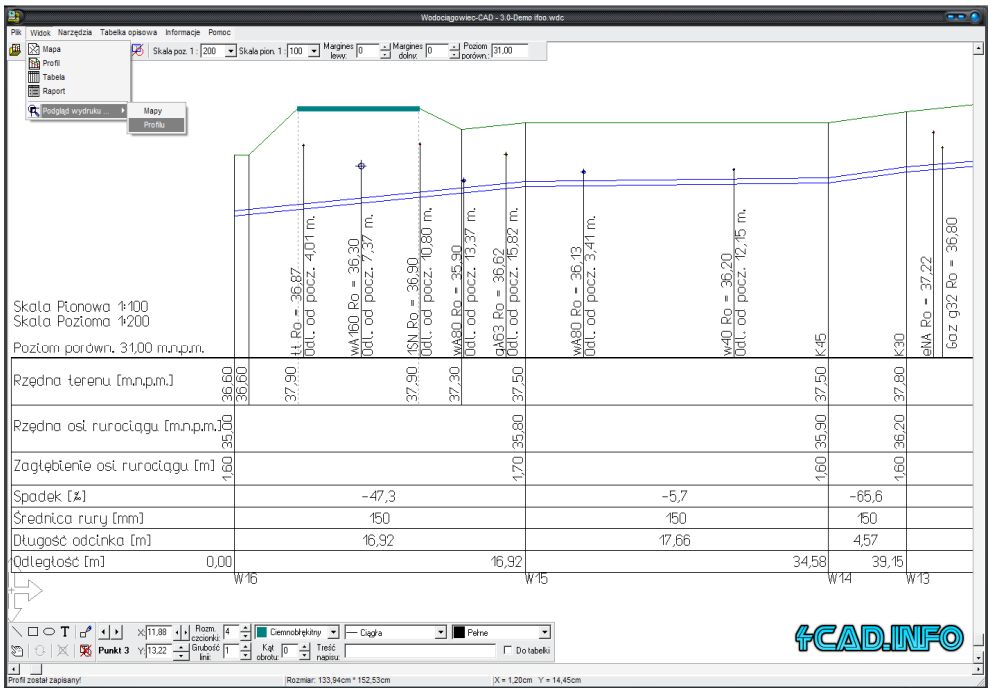


Fig. 5. Longitudinal profile of the water supply network in the Wodociągowiec-CAD Gamrat 4.0 application [9]

2.4. WAVIN-NET

Wavin-NET is the software developed by InstalSoft - Oprogramowanie Inżynierskie in cooperation with WAVIN Polska S.A. It is used for designing radial water supply networks, supplied from one source. The application performs hydraulic computations only for a steady state, for a specific water requirements at a specific instant. It is impossible to include different recipients in the nodes and the values of distributions can only be entered as clustered.

The program enables the choice of pipe diameters for specific water demand values. Partial or complete introduction of planned or existing dimensions is also possible. In this case, the program optimizes the diameters of the missing sections and computes the network parameters. The application allows users to determine the required pressure at the place of supply and the automatic creation of longitudinal profiles of water supply networks. The background maps can be loaded from files (e.g. in .dwg/.dxf format, see Fig. 6) or as a scan (.jpg, .bmp). The program also recognizes other graphic file formats, such as: .tiff, .pgn, .rle and .pcx. The profile files are integrated into the map file and allow users to automatically add the changes they introduced. It is also possible to create profiles without drawing a situational plan and making calculations. The application also features catalogues of water pipes (Fig. 7) [10].

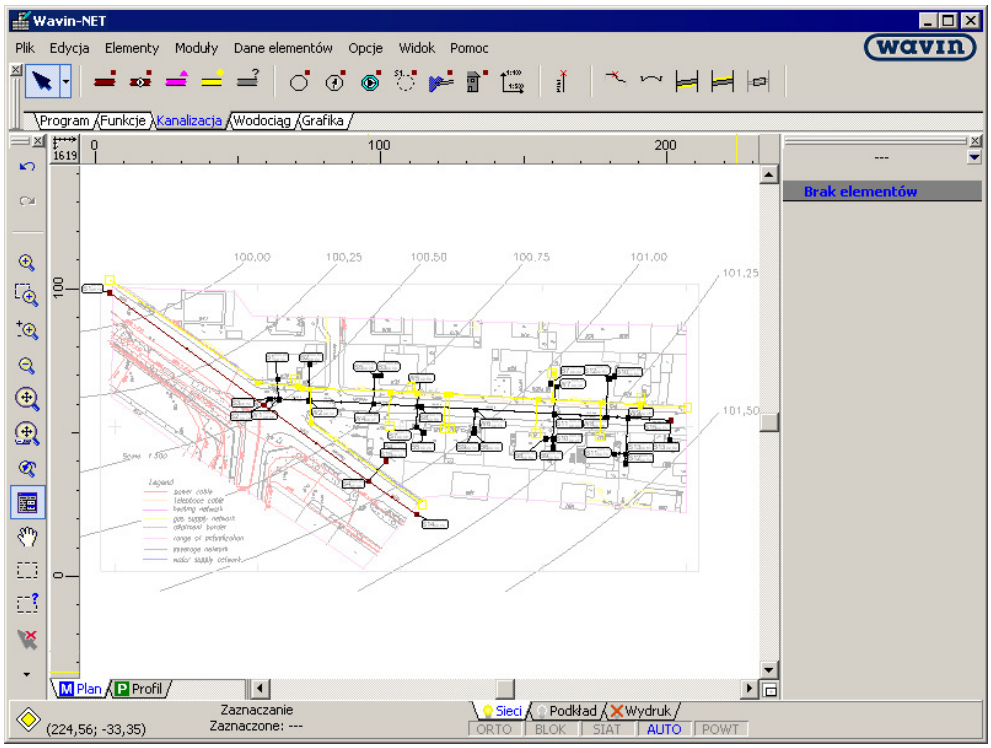


Fig. 6. A map of water supply network in the WAVIN-NET application [10]

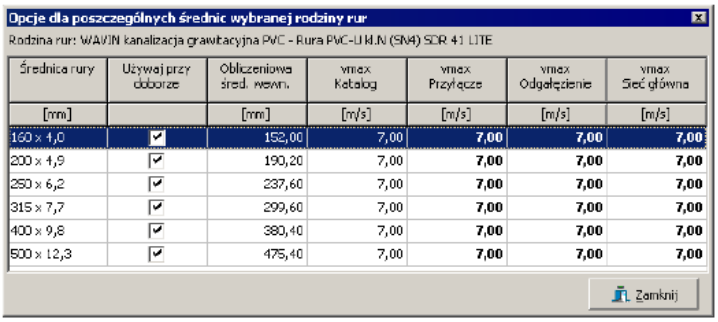


Fig. 7. Table showing the catalogue of water pipes in the WAVIN-NET application [11]

2.5. EPANET

EPANET [12-14] is one of the pieces of software which are most frequently used for hydraulic modelling of water supply networks. The application was developed by the U.S. Environmental Protection Agency, is free of charge, and can be downloaded from the manufacturer's website www.epa.gov/water-research/epanet. It is also available in Polish version, EPANET 2 PL (Fig. 8).

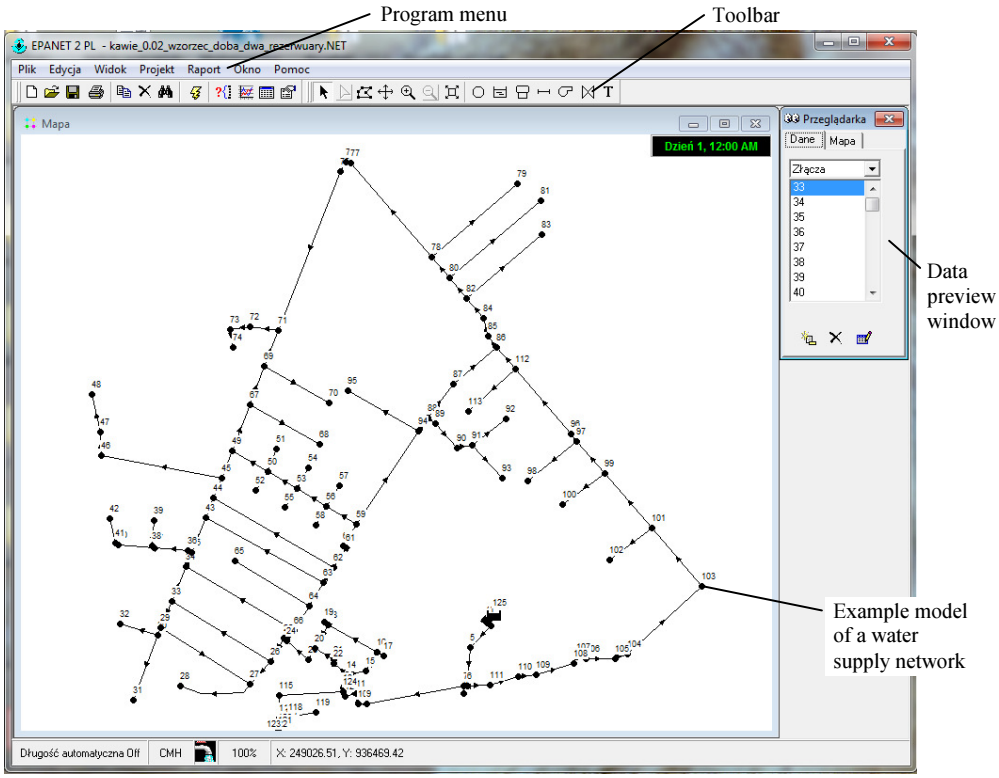


Fig. 8. The interface of the EPANET 2.0 application

The application offers options to perform hydraulic simulations in pressure networks (monitoring the flow of water in water pipes, pressure changes in selected nodes, visualization of emptying and filling water supply tanks). It is possible to create both static and dynamic models. The application enables using different water supply sources and many categories of water distribution in the nodes. It also allows users to assess the condition of the pipes, develop an optimal schedule for their cleaning or modernization, and helps optimise the operation of the pumps. The obtained calculation results are presented in the form of colour maps, tables, layers and diagrams.

In addition to hydraulic modelling, EPANET is also capable of water quality analysis:

- modelling changes in the concentration of chemical substances in the network during water flow (for example, concentration of disinfection by-products or residual chlorine),
- modelling the age of water throughout the network,
- tracking the percentage distribution of liquid from one to other nodes,
- modelling of chemical reactions occurring both in the bulk flow and at the pipe walls,
- limiting the course of chemical reactions (increase and decrease in concentration of substances) to given concentration limits,

- the use of global coefficients of reaction speed,
- dependence of the wall reaction speed coefficient on the roughness of thepipe.

The Epanet software environment is user-friendly and easy to use. From the designer's point of view, however, the application has certain limitations. It is impossible to load the network in a vector form. The only option to automate the work is to enter it as a .txt file (giving the coordinates of subsequent nodes). The application also does not allow users to draw longitudinal profiles of the water supply networks. The automatically generated profiles are very schematic and it is impossible to export them to files read by graphic programs (in editable form).

Conclusions

The use of computer software for the design and computation of hydraulic water supply systems is not only a convenience, but also a necessity today. The computations allow for the determination of the levels of flow rates in pipes, values of pressures in nodes and temporary variability of the states of network facilities at given operating conditions, for example when fire-fighting flows are started.

Based on the analysis, Table 1 presents the most important features of the discussed applications.

Table 1. **Basic functionalities of the presented applications**

Functionality \ Software	STANET	WODA	Wodociągowiec	Wavin-NET	EPANET
Calculations in dynamic mode	YES	NO[1]	NO	NO	YES
Calculation of annular networks	YES	YES	NO	NO	YES
Diffused distributions	NO	YES	NO	NO	NO
Assigning different categories of distribution to nodes	YES	YES	NO	NO	YES
Connections as elements with specified characteristics (e.g. pumps, valves, reducers, etc.)	YES	YES	NO	NO	YES
Loading digital maps	YES	NO	YES	YES	NO[2]
Automatic generation of longitudinal profiles	YES[3]	NO[4]	YES	YES	NO
Export of calculation results and drawings (editable form)	YES	NO	YES[5]	YES[5]	NO
Reduction of network size	NO[6]	NO	NO	NO	NO
Price in PLN (net)	10,750[7]	2,500	free	800	free

[1] three subsequent simulations stored in memory
[2] network route can be input in the form of the text file
[3] the necessity of correcting the drawing in a graphic application
[4] compatible with Profil Koordynator
[5] only for drawings
[6] only for the most expensive version of the software (price approx. 65,000 PLN)
[7] version price for networks limited to 1,000 nodes

All described applications allow for hydraulic calculations of water supply systems, but not all of them have full functionality from the designer's point of view. STANET seems to be an optimal choice as the application allows users to calculate both radial and annular networks powered from multiple sources, and also offers the possibility to draw longitudinal profiles. However, its price, even for the simplest version (Table 1), is much higher than the price of other applications. The Woda and Epanet software also allows for calculation of peripheral networks, but the number of available options is smaller. Both applications are deprived of the options to create longitudinal profiles based on the designed network, but in the case of the first application, it is compatible with another application, Profil Koordynator, intended for the creation of such profiles.

Furthermore, Wodciągowiec and Wavin-NET applications allow users to calculate only radial networks, but on the other hand, they have an extensive functionality enabling users to draw water supply profiles, which is important from the standpoint of the designer's work. The first application is also free and easily available, and can be used especially by beginner designers. It helps users define preferences concerning the desired functionalities before buying more expensive commercial programs with greater range of available options.

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References

[1] Rozporządzenie Ministra Spraw Wewnętrznych i Administracji w sprawie przeciwpożarowego zaopatrzenia w wodę i dróg pożarowych z dn. 24.07. 2009 r., Dz.U. 124, poz. 1030.

[2] http://www.stafu.de/en/home.html.

[3] Kogut K., Using artificial neural networks in pressure decomposition modelling in distribution gas networks, Gospodarka Surowcami Mineralnymi 2008, 24, 3, 157-166.

[4] Cieślik T., Kogut K., Prognozowanie pracy sieci gazowej za pomocą sztucznych sieci neuronowych, Nafta-Gaz 2016, 6, 443-450.

[5] http://www.uktn.com/woda.html.

[6] Niderlińska T., Opis programu WODA, materiały firmowe, niepublikowane.

[7] http://www.informatykawbudownictwie.pl/aktualnosci/komputerowe-wspomaganie-projekto wania-sieci-wodociagowych-i-kanalizacyjnych/.

[8] Programy komputerowe wspomagające projektowanie sieci wodociągowych i kanalizacyjnych firmy GAMRAT S.A., Inżynieria Bezwykopowa 2009, I-II, 62-63.

[9] http://4cad.info/aplikacja/921.

[10] http://www.instalsoft.com/pl.

[11] https://www.wavin.com/pl-pl/Wsparcie-projektowe/Systemy-infrastrukturalne.

[12] Zimoch I., Łobos E., Application of the Theil statistics to the calibration of a dynamic water supply model, Environment Protection Engineering 2010, 36, 4, 105-115.

[13] Kępa U., Stańczyk-Mazanek E., A hydraulic model as useful tool in the operation of a water-pipe network, Polish Journal of Environmental Studies 2014, 23, 3, 995-1001.

[14] Iglesias-Rey P.L., Martinez-Solano F.J., Ribelles-Aquilar J.V., Extending EPANET capabilities with Add-In Tools, Procedia Engineering 2017, 186, 626-634.

Streszczenie

Celem artykułu jest przedstawienie możliwości wybranych programów do projektowania i obliczania hydraulicznego sieci wodociągowych. Przedstawiono aplikacje dostępne na polskim rynku, takie jak: Stanet, Woda, Wodociągowiec, Wavin-NET oraz Epanet. W artykule zawarto charakterystyki poszczególnych aplikacji: omówiono sposób budowy sieci wodociągowej, ograniczenia w wielkości analizowanej sieci, możliwości wprowadzania danych, takich jak np. rozbiory wody oraz rodzaj generowanych danych wynikowych. Podkreślono, które z programów umożliwiają obliczenia hydrauliczne zarówno sieci promienistych, jak i pierścieniowych, a które mogą być zastosowane tylko dla sieci promienistych. Zwrócono również uwagę na możliwość automatycznego generowania profili podłużnych projektowanych sieci.

Słowa kluczowe: **system zaopatrzenia w wodę, komputerowe wspomaganie projektowania sieci wodociągowych, modelowanie hydrauliczne**