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UPDATING THE PIPE NETWORKS LAYOUT PLAN USING MODERN DETECTION EQUIPMENT

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Abstract. Water and wastewater networks are made of pipes conveying drinking water or wastewater to and from consumers. Water-sewage agencies, especially those managing old networks, face an important issue consisting of accurately locating the pipe routes. Furthermore, the lack of data to detail the pipes’ structural characteristics prevents their optimal management. Unlike relatively new networks, whose constructive and functional parameters are found in GIS monitoring models, this information is missing in the case of old networks. In order to increase the operational efficiency of the water-sewage network, one of the measures to be adopted consists of using modern pipeline detection methods and equipment. Currently, a range of modern equipment is used to collect field data needed to update GIS models. The case study elaborates on the use of georadars for subsurface networks detection.

Keywords: georadar; water and wastewater networks; GIS; monitoring.

1. Introduction

Water and wastewater networks are complex systems made up of all the pipelines, fittings, measuring devices and side structures which convey water to consumers (adduction pipes, main, secondary and service pipes) as well as all the pipelines, plumbing and structures which convey wastewater from consumers to wastewater treatment plants.

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One of the issues affecting the performance of water-sewage companies is the lack of complete databases which should include information on all operated systems, regardless of their age. On this line, there is a discrepancy between the data available for relatively new and old systems in current GIS models. Often, for networks with high service life, real field data could not be identified. The lack of adequate post-execution documentation, either incomplete or degraded, has led to a situation where operators relied on tracing these networks according to an approximate route for which only part of the attributes that define such a system (diameter, depth of cover, fittings, water supply source, etc.) were specified.

In order to align the performance of water supply and sanitation systems to European standards it is required to update existing GIS models and populate databases with missing information. Reaching these goals can be achieved by using modern equipment and technologies that allow remote monitoring without interfering with the structural or hydraulic integrity, in order to identify all the elements characterising a water and wastewater system.

2. Material and Research Method

Pipeline networks are placed in various locations: rural areas, urban areas, under street structure, sidewalks or green areas. In some cases, the change in the ownership regime has led to the situation where pipelines or distribution network components are located on private property. The pipe network's large spatial distribution involves difficult to monitor routes when crossing unpopulated areas, hills and valleys, watercourses and obstacles such as railways, roads, etc.

Current GIS models are incomplete with regard to the exact route and water supply system pipeline characteristics in some sectors, as a result of some aspects such as (Chirica, 2017):

– the long service life of some pipeline sections whose execution documentation has deteriorated over time and which have not been intervened upon since they were built, making it impossible to know precisely the pipeline's characteristic parameters;

– the operator not being allowed to further investigate the condition of the operated structures due to land ownership regime changes together with pipeline networks passing under private domains;

– emergency field alterations that have not been further reported and completed in the GIS model;

– the existence of unauthorized works that have not been recorded in the operators' databases (extensions, connections, by-passes);

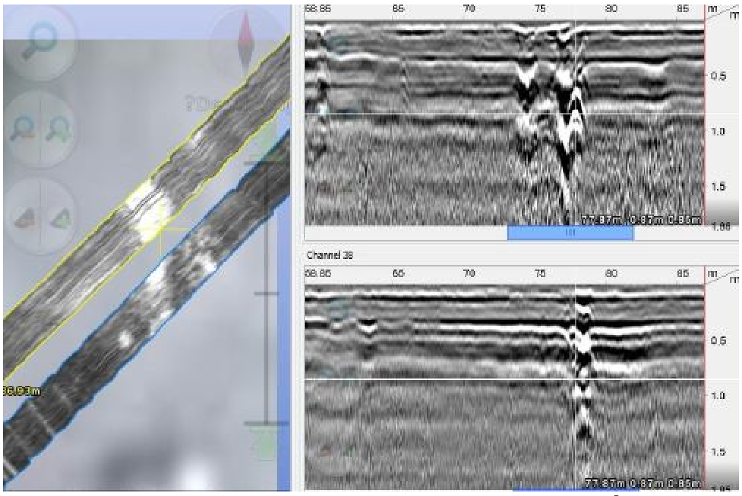
– structural changes due to events such as earthquakes, landslides, pipe integrity damage, etc.

In such situations it is necessary to use modern equipment and technologies for analysis and detection of the components that are part of the water supply networks. Identifying and tracking these components over time using ground penetrating radars (georadars), drones, or satellite detection allows the existing GIS models to be upgraded.

The ground penetrating radar has been used lately due to its immediate and high quality results. The georadar is a modern detection equipment used to investigate buried pipe networks from above the ground (Chirica, 2017). The data obtained from the field surface scan is processed with the help of special software and the results are analysed by experienced operators. The equipment (Fig. 1) uses electromagnetic radio waves to investigate underground elements. The technology has been adapted to locate water losses in buried pipes and investigate the condition of underground networks. Leaks are identified due to the differences in the density of the land in which the pipelines are incorporated and its water content (Themistocleous *et al.*, 2013).

The penetration power of the system depends on the length of the radiation wave and the electrical permissiveness of the terrain. The use of this technology requires knowledge of the properties of the field to be investigated, especially its conductivity. Terrains characterised by high conductivity, such as those composed of very fine particles or with high water content (Fig. 2), can provide misleading results (Postăvaru, 2015). Georadar acquired field data is entered in the pipeline network map as well as in the GIS monitoring system.

Fig. 1 – The equipment uses electromagnetic radio waves to investigate.



a *b*

Fig. 2 – Water loss detection using the ground penetrating radar:
a – detection equipment; *b* – charts with the results of field investigations (Postăvaru, 2016).

U.A.V. (unmanned aerial vehicle) technology has been used in recent years by water-sewage companies to monitor operated networks (Chirica, 2017). Among the main applications of U.A.V. the following are listed: land surface monitoring, soil erosion identification, water loss detection or overground structures inspection (Sadovnychiy, 2017). Ramalli *et al*. (2016), establish the usage of detection techniques and procedures based on photogrammetry, spectrometry and thermal monitoring used for pipe network investigation. Photogrammetry uses images to analyse objects in terms of their shape and position. The three-dimensional characterisation obtained from the primary data processing provides information on the monitored system (diameters, lengths, position of fittings, etc.).

Spectrometry is especially used to monitor pipelines in order to identify possible water losses. The procedure consists of periodically passing over the pipeline route and acquiring georeferenced images. Subsequent data processing indicates water loss. The use of thermal cameras facilitates the location of the damaged area by identifying the temperature difference between the water leaving the pipe and the embedding environment.

Water loss detection and pipeline networks monitoring using satellite technology is based on the identification of the spectral water footprint (Chirica, 2017). Satellites mounted sensors identify water losses from distribution and supply pipes.

The raw data obtained with this system is overlaid on top of the operator's GIS application and then processed by an algorithm. The main advantage of this technology is the ability to obtain information on the entire system with a single-use. Satellite detection covers large areas (thousand km^2)

and indicates the location of the losses in a 6.0 meter diameter area. The system can be used for all types of materials, diameters and types of land (Schumi, 2017).

3. Results and Discussions

The regional operator SC APAVITAL SA started the process of GIS implementation in 1998, by digitising existing plans on physical support. The digitised plans were the basis for NetSET's development in 2001, which operated until 2015, when the ArcGIS platform was introduced. Over time, the information entered into the GIS database has been updated. The attributes attached in the initial phase are constantly modified to reflect the situation on the ground. The most common operations consist of (Chirica, 2017):

– tracing and introducing parameters for new or extended networks;

– cancellation of decommissioned pipe sections;

– change of properties and attributes on sections or entire pipes: material, diameter, supply source, available pressure, connections, etc;

– adding new fields such as network interventions (damages, repairs, replacement of fittings, monitoring points, etc.);

– making intervention sheets describing the procedures from the operational activity (description of failures, remediation time, equipment used, extraordinary situations encountered, detection method used, remediation technology, etc.).

At the time of the plans' digitisation in 1998, the available archive did not cover the entire pipe network from the inventory. In the case of pipes with high service life, no location plans, vertical or horizontal sections or other technical documentation could be found in the archive to extract the information required to populate the GIS database. In these situations, the pipe routes were traced according to an approximate path and the network was described using attributes correlated with the information available for the adjacent sectors.

Timişeşti – Iaşi supply pipe I (Fig. 2) was put into service in 1911 and it conveys water from Timişeşti old collecting drain to Păcurari area tanks in Iaşi. The pipeline's service life of more than 100 years led to a series of negative events in the operational process. Water losses resulting from frequent damages due to the advanced age of the pipe are amplified by the long duration of their repair. Pipeline repair times have increased exponentially as intervention teams manage to locate damaged pipe sectors on the ground only after extensive field excavations.

Timişeşti – Iaşi supply pipe I route (Fig. 3) is characterised by the presence of some special constructions: Soci area Moldova River undercrossing, Siret River overcrossing in Rotunda, pressure breaking chambers, localities supply by-passes etc. These constructions' complexity require careful monitoring of the structural and hydraulic features' behaviour over time by integrating these components into the GIS model.

Currently, the Timişeşti – Iaşi supply pipe I model contains an array of potable water supply pipes characteristics, such as (Figs. 4 and 5.): valve homes, hydraulic features, special structures, sanitary protection area, etc. The networks' junctions (nodes) consist of: water tanks, potable and raw water pumping stations, chlorination stations, groundwater catchment areas, etc.

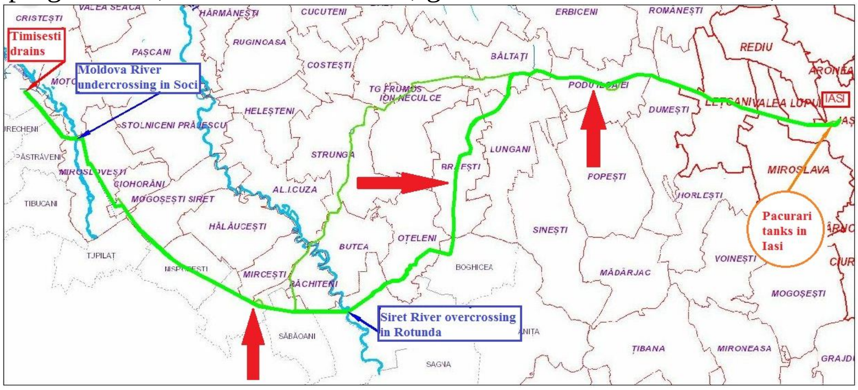


Fig. 3 – Timişeşti – Iaşi supply pipe I location layout.

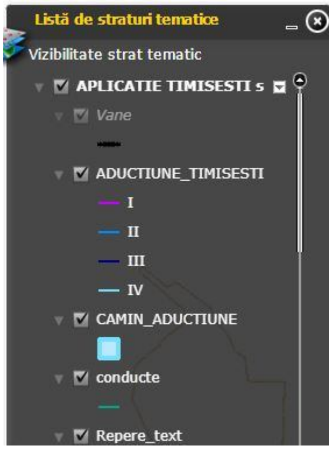


Fig. 4 – Timişeşti – Iaşi supply pipe I characteristic layers defined in ArcGIS model.

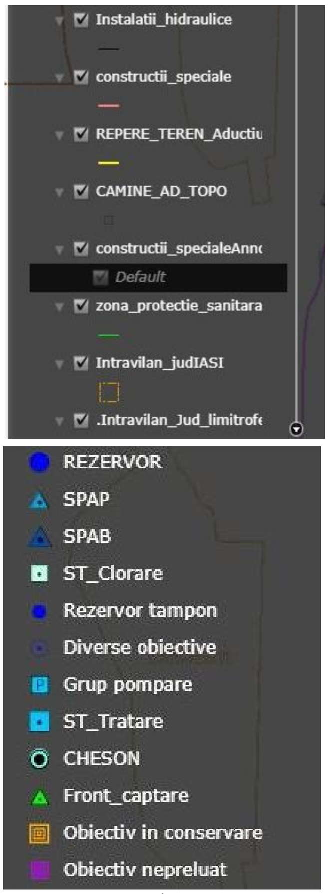


Fig. 5 – Iaşi County water supply system nodes.

Expanding existing data sets in the GIS model requires investigation into the structure of the water supply system to accurately identify the missing features of the currently available model. Table 1 presents the main parameters which define the Timişeşti – Iaşi supply pipe I structures (the undercrossing, overcrossing and pipeline) and the equipment that can be used to acquire the necessary data.

Table 1
Timişeşti – Iaşi Supply Pipe I Specific Parameters Identification and Monitoring

Analysed structures	Specific attributes	Georadar	U.A.V.	Satellite detection
Moldova River undercrossing	River bank erosion phenomena		x	
	Pipe cover depth		x	
	Valve chambers structural damage		x	
	Damage and water loss		x	
Siret River overcrossing	Overcrossing structures displacement		x	
	Scouring phenomena		x	
	Damage and water loss		x	x
Timişeşti – Iaşi adduction pipe I	Route	x		
	Diameter	x		
	Fittings density	x		
	Connections density	x		
	Vertical/horizontal movement	x	x	
	Water loss	x	x	x
	Execution material	x		
	Pipe cover depth	x		x
	Embedding environment stratification	x		
	Ground moisture content	x	x	
	Landslides		x	
	Extreme hydrological phenomena		x	

The most frequent problems of the Timişeşti – Iaşi supply pipe I operational procedures occur at the pipeline's structure. The density and magnitude of the factors defining the structure of the pipeline network require a special approach (Luca *et al.*, 2015). Table 1 data analysis shows that the georadar is the most appropriate equipment for investigating buried pipe networks. The information provided is the basis for the longitudinal and transverse sections of the pipeline, which are used when performing network interventions (repairs, investigations, sections or fittings replacements).

Water supply systems operational procedures require accurate data regarding pipe cover depth, diameters, execution materials and possible vertical or horizontal displacement. These factors have an impact on the hydraulic characteristics of the system (pressures, flow regime, velocity, flow rate). Moreover, the structural degradations that may occur determine the quality and quantity parameters of the water conveyed to the consumers. The data obtained by using ground penetrating radars allows the identification of these aspects and offers a high degree of safety during the operational process.

4. Conclusions

1. One of the problems facing the current water supply systems is the lack of complete GIS models to show the real state of the operated networks.

2. Old pipe networks are a risk factor in the water supply system management, given the lack of real actual data for them.

3. Modern technologies, such as the ground penetrating radar (georadar), U.A.V. or satellite detection allow the investigation and analysis of water supply systems through non-invasive procedures.

4. The structural complexity of the pipe network shows that the use of the georadar is the optimal solution for monitoring and acquiring data in order to update the existing GIS models.

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ACTUALIZAREA PLANULUI REȚELELOR DE CONDUCTE UTILIZÂND ECHIPAMENT MODERN DE DETECTARE

(Rezumat)

Rețelele de apă şi de canalizare sunt realizate din conducte care transportă apă potabilă sau ape uzate către şi de la consumatori. Agențiile de canalizare, în special cele care administrează rețele vechi, au o problemă importantă, constând în localizarea precisă a traseelor conductelor. Mai mult, lipsa de date pentru a detalia caracteristicile structurale ale conductei previne gestionarea lor optimă. Spre deosebire de rețele relativ noi, ale căror parametri constructivi şi funcționali se găsesc în modelele de monitorizare GIS, aceste informații lipsesc în cazul vechilor rețele. În scopul creşterii eficienței operaționale a rețelei de canalizare, una dintre măsurile ce urmează a fi adoptate constă în utilizarea metodelor moderne de detectare a conductelor şi a echipamentelor. În prezent, o gamă de echipamente moderne este folosită pentru a colecta date de teren necesare actualizării modelelor GIS. Studiul de caz elaborează utilizarea georadelor pentru detectarea rețelelor subterane.