

# A new method of collecting water from an external hydrant in the event of large-scale power failures

Nowa metoda poboru wody z hydrantu zewnętrznego w przypadku wielkoobszarowych awarii zasilania

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The water supply system should be prepared to function both in normal conditions and in a crisis situation. A large-scale power failure may limit or completely stop the operation of water supply systems. For this reason, blackout is considered one of the greatest threats to the continuity of the supply of drinking water. The study assessed the preparation of a water supply company for water supply in a crisis situation based on conventional solutions. The idea of an original solution for drawing water from the water supply network during low pressure was presented. The developed water tap allows the use of water accumulated in water pipes by drawing it from external hydrants. The method of arranging draw-off points in the water supply network is presented. The accumulated amounts of water inside water pipes can provide significant support for the affected population during periods of lack of electricity supply, preventing the operation of water pumping stations. Obtaining treated water and distributing it among residents will reduce the health risks associated with the consumption of water of uncertain origin.

*Keywords: crisis situation; external hydrant; lack of water; water supply system*

Sieć wodociągowa powinna być przygotowana do funkcjonowania zarówno w warunkach normalnych, jak i w sytuacjach kryzysowych. Wielkoobszarowa awaria zasilania może spowodować ograniczenie lub całkowite wstrzymanie pracy systemów wodociągowych. Z tego powodu blackout jest uznawany za jedno z największych zagrożeń dla ciągłości dostawy wody przeznaczonej do spożycia. W pracy przeprowadzono ocenę przygotowania przedsiębiorstwa wodociągowego na dostawę wody w sytuacji kryzysowej w oparciu o rozwiązania konwencjonalne. Przedstawiono ideę autorskiego rozwiązania poboru wody z sieci wodociągowej w czasie obniżonego ciśnienia. Opracowana bateria czerpalna umożliwi wykorzystanie wody zakumulowanej w przewodach wodociągowych poprzez jej pobór z hydrantów zewnętrznych. Przedstawiono sposób rozmieszczenia punktów czerpalnych na sieci wodociągowej. Zgromadzone ilości wody wewnątrz przewodów, mogą stanowić znaczne wsparcie dla poszkodowanej ludności w okresach braku dostaw energii elektrycznej, uniemożliwiających pracę pompowni wodociągowych. Pozyskanie uzdatnionej wody i jej rozdysponowanie wśród mieszkańców pozwoli na ograniczenie ryzyka zdrowotnego związanego ze spożyciem wody o niepewnym pochodzeniu.

*Słowa kluczowe: sytuacja kryzysowa; hydrant zewnętrzny; brak wody; sieć wodociągowa*

## Introduction

The water supply system (WSS) is a priority in the city's integrated infrastructure, therefore it is classified as one of the critical infrastructure facilities [1]. The water supply process has a three-dimensional character, i.e. water is provided as a food product for city residents, it is a fire protection measure, and it is also a strategic product, key to the proper functioning of the state [32]. Water supply plays an important role in the development of all societies. Ensuring a guarantee of continuity of water supply is a key goal. The water supply should be secured, regardless of the external conditions. It is imperative that water

utilities are adequately prepared for the consequences of hazardous events, whether in the form of water contamination, failures in the water supply network, lack of energy supplies, or even war [24, 31]. In the case of small, regularly occurring operational failures, the course of action and minimization of the effects are well known to the operators of WSS. The situation is much more difficult when rare accidents occur, with serious consequences for consumers and the entire system. The unpredictable nature of these events significantly complicates analyzes in this area and often requires a non-standard approach [16, 20]. Reducing the risk of threats is possible thanks to the implementation of a risk

management strategy based on the Water Safety Plan [10, 22, 35, 36].

Widespread automation and dependence on information and communication technologies create new challenges in the field of security. There is an increase in the role and importance of cybersecurity, which is so important for the functioning of the entire critical infrastructure. Disabling IT systems generates indirect effects, i.e. shortages in water supply [28, 29]. It is not only cybercrime that threatens the continuity of WSS. The financial crisis, the electricity crisis, the political and migration situation and the war in Ukraine may reduce the sense of security. It is necessary to increase the efficiency of the

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system for detecting and responding to undesirable effects of occurring dangerous situations. An important aspect of crisis management is the cooperation of various services and institutions in order to quickly eliminate the effects and rebuild critical infrastructure resources. People react very negatively to a lack of water or food [9, 13]. In such situations, they may feel unsupported, which can cause frustration, stress and long-term effects on their sense of security and comfort. Therefore, efficient communication between the manager and the recipient is necessary, i.e. providing the necessary information about the situation. Ignorance or false information may lead to panic among the public, thus hampering the activities of the relevant services.

A large-scale power failure (power blackout) is understood as a failure of the energy system that may lead to the shutdown of all energy sources in a significant part of the energy system. Such a failure may cause problems in water supply systems, which is why a blackout is considered a source of threat to the continuity of drinking water supplies [11, 18]. Maintaining the WSS for a long period of time cannot be achieved without electricity. There is a need to constantly equip electrical devices with backup power sources in case of crisis situations. Strategic water supply facilities and emergency water sources should be equipped with permanent or portable power generators that will be able to operate in crisis situations. It is important to maintain an adequate supply of fuel or have an agreement with an external entity to provide it in a crisis situation. Appropriate protection is the use of double-circuit power supply of the water intake, water pumping stations and the Water Treatment Plant with electricity from two autonomous, independent power supply circuits, covering all elements of the power grid. The probability that supply to water facilities will be maintained is higher. Alternatively, other power options involving renewable energy sources can be used, including a small hydro power plant and a photovoltaic power [6, 15, 27]. A photovoltaic water pumping system can be used to draw water from a well or other reservoir [4, 19].

In the event of a blackout, the operation of water supply pumps stops, which results in a drop in pressure in the water supply network and, as a result, the water outflow pressure decreases [3, 30]. During this time, recipients consume a larger than usual amount of water in order to store it, which accelerates the pressure drop process. This makes water abstraction impossible in higher parts of the city. The water remaining in the water supply network flows by gravity to the lower parts of the water supply network. If it is not possible to supply water through the water supply

network, it is necessary to create access to alternative water sources in order to meet at least the minimum needs of recipients. The most frequently used solution is the use of underground reserve water sources and the use of vehicles for water distribution to specific parts of the city. A reserve source of water is bottled water and water packs. These known solutions are based on obtaining water from external, alternative sources and delivering it to recipients bypassing the water supply network. Alternative possibilities of obtaining drinking water that may be used during a crisis are being explored. The research concerns, among others: using rainwater for drinking water supply [34], desalination of the huge saline water bodies [23], water recovery from the ambient and indoor air [14] and opportunities for water reuse [33]. The selection of optimal alternative methods of drinking water supply is possible based on multi-criteria decision-making methods [8, 12]. In addition, it is possible to draw water accumulated in water pipes and use it to supply water to the population in situations where water consumption is limited or impossible [26]. None of the known solutions allows for the extraction of water accumulated in water pipes using an external hydrant, which is located in the lowest parts of the city due to the gravitational flow of water.

The aim of the work is to develop a new water tap that will enable the consumption of water accumulated in water pipes. It is possible to draw water by four people at the same time. Its use will enable the supply of water to the population, especially in situations of reduced pressure in the water supply network. This research also has several other important benefits, including reducing the health risks associated with consuming emergency water from unreliable sources. Water in the water supply network must meet the quality requirements for water for human consumption.

## Materials and Methods

### Study Area

The analysis covered a city located in south-eastern Poland with approximately 26,000 inhabitants. The city has one main source of water supply. The groundwater intake with the water treatment plant is located near the city's allotment gardens and recreational and sports gardens. The water intake consists of 10 deep wells. The abstracted water exceeds the permissible values for the quality of water intended for human consumption [5]. The exceedances concern the content of iron, manganese, ammonia and the color and turbidity of water. Contaminants are removed through a two-stage treatment process. The amount of water produced is sufficient to cov-

er current demand. The nominal production of the water treatment plant exceeds the maximum daily demand for drinking water.

Adaptation to the functioning of the WSS in a crisis situation was assessed on the basis of having measures to minimize the effects of crisis situations. During a crisis situation, water supply may be provided using:

- underground reserve water intakes,
- water collected in water storage tanks,
- bottled or bagged water,
- vehicles for water distribution based on own resources and cooperation agreements with external entities.

Water demand in a crisis situation should meet the basic needs of the population [2, 7, 21]:

- physiological water demand:  $q_p = 2.5 \text{ dm}^3/\text{person per day}$ ; i.e.  $Q_p = 65 \text{ m}^3/\text{city per day}$ ,
- minimum demand for drinking water:  $q_m = 7.5 \text{ dm}^3/\text{person per day}$  (human physiology and basic hygiene practices); i.e.  $Q_m = 195 \text{ m}^3/\text{city per day}$ ,
- necessary demand for drinking water:  $q_n = 15 \text{ dm}^3/\text{person per day}$  (human physiology, basic hygiene practices and basic cooking);  $Q_n = 390 \text{ m}^3/\text{city per day}$ .

There are several Abyssinian wells located in the city. The water quality in these wells is not monitored. The technical condition of these wells is unknown. For this reason, they cannot be treated as a source of water in a crisis situation. Treated water is collected in clean water tanks with a capacity of  $250 \text{ m}^3$  and  $1000 \text{ m}^3$ . Water can be collected into water tankers through a connector installed on each of them. The possibility of filling water tankers directly from the tanks is assessed positively. The volume of water in clean water tanks will meet the water demand in the first days of the emergency. The age of the stored water should not exceed 3 days. After this time, the water should be disinfected again by chlorinating the water in the tanks or using a UV lamp.

The water supply company has three water tankers for transporting clean water with a capacity: two tankers with a capacity of  $1.3 \text{ m}^3$  and one with a capacity of  $4 \text{ m}^3$ . These vehicles are able to provide  $6.6 \text{ m}^3$  of water in a single trip, which constitutes 10.4% of the total demand for water for physiological needs ( $2.5 \text{ dm}^3/\text{person per day}$ ). To provide the required amount of water for 1 day, each vehicle must make 10 trips. This is the realistic number of courses. A potential increase in the number of water tankers is possible by signing contracts, e.g. with neighboring water supply companies. The lack of contracts concluded with nearby water companies for the purchase and delivery of the water they produce limits the water company's ability to supply water in a crisis situation.

The water supply company does not collect any water supplies in individual packages.

The water company's own resources are sufficient to ensure water supply in the event of a blackout for about a ten days. This applies to physiological water demand, assuming that clean water tanks will be half full. The city does not have alternative sources of water in working condition. Once the water stored in clean water tanks is exhausted, no source of water will be available. This is a very typical situation for Polish water supply companies. The vast majority of Polish cities are not properly prepared for the lack of drinking water caused by crises related to the water supply system [25]. The developed method of collecting treated water collected in the water supply network contributes to increasing the delivery time of drinking water in a crisis situation. Once safe drinking water resources are depleted, people will be forced to rely on unreliable water sources such as dug wells and rivers.

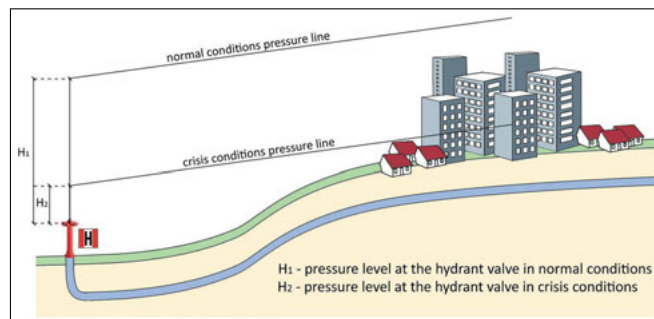
### Presentation of the idea of the developed solution

In the event of a power failure, the pumps stop operating. This results in an immediate drop in pressure in the water supply network, which reduces the water outflow pressure at recipients. Residents, trying to protect themselves from water shortages, take in increased amounts of water. The goal is to accumulate a supply of water. This causes subsequent pressure drops until there is no pressure at all. Water abstraction in the higher parts of the city becomes impossible, and the remaining water flows by gravity to the lower parts of the water supply network.

To enable the collection of water collected at the lowest points of the water supply network, a method of collecting water from an above-ground hydrant was proposed. Due to the gravity flow of water, intake points are located at the lowest points of the water supply network. The developed installation, together with the external hydrant, creates a water intake point. Water flows out spontaneously under the influence of the remaining pressure in the water supply network until the minimum pressure allowing water outflow is reached (min. 0.05 MPa). A diagram of the application of the developed installation in the water supply network is shown in Figure 1. The developed solution can be an important source of water in a crisis situation. It is recommended to draw water from the water supply network as soon as possible. Stagnation and contact with air entering the water supply system may cause water quality to deteriorate, disqualifying it as water fit for human consumption. If the age of water exceeds 3 days, it is necessary to disinfect the water before distributing it to residents. Water samples taken from installed

**Fig. 1.**  
**Operational diagram of the developed solution**

**Rys. 1. Schemat działania opracowanego rozwiązania**

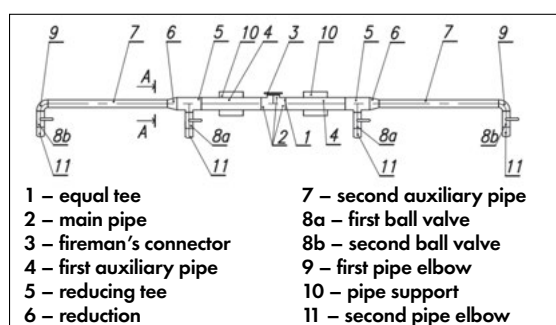


hydrants may give positive results for the presence of bacteria [17].

The DN80 above-ground hydrant is able to provide a water flow of 36 m<sup>3</sup>/h (at pressure 0.2 MPa). At a residual pressure of 0.1 MPa the hydrant capacity is approximately 18 m<sup>3</sup>/h, while at a pressure of 0.05 MPa the hydrant capacity is approximately 12 m<sup>3</sup>/h. The developed water tap will be

from external hydrants. The water obtained in this way can be used to supply water to the population both during a crisis and during normal operation of the WSS. Four people can use the new tap at the same time. The developed installation is presented in Figure 2, which shows the water tap from above. Figure 3 shows the water tap in cross-section along the line A-A shown in Figure 2.

**Fig. 2.**  
**A tap for drawing water from an external hydrant – top view**  
**Rys. 2. Bateria czerpalna do poboru wody z hydrantu zewnętrznego – rzut z góry**



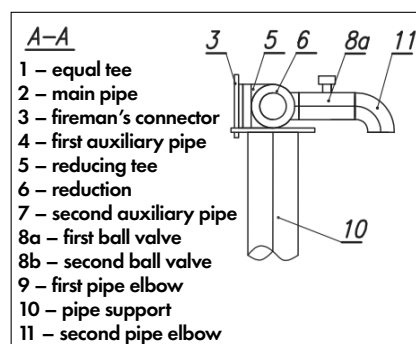
attached to the hydrant using fireman's connectors. The installation will be constructed of stainless steel. The smallest possible diameters will be used to increase the discharge pressure. The water will be distributed to 4 draw-off ball valves. The installation will be supported on telescopic legs. If the situation requires installation on an underground hydrant, it is necessary to use a hydrant stand.

After connecting the tap to the hydrant, water flows out when the valve is opened. Before you start drawing water, rinse the hydrant. It is necessary to drain some water to remove any contaminants. After rinsing, you can start drawing water into sterile containers or tanks as needed. The biggest advantage of the developed solution is the ability to collect water accumulated in water pipes (often inaccessible) and the mobility of the solution. The choice of where to install the tap is limited only by the presence of a hydrant and the minimum pressure in the water supply network.

### The concept of drawing water from an external hydrant, to be used especially in a crisis situation

#### A water tap for drawing water from an external hydrant

The new water tap allows the use of water accumulated in water pipes by drawing it



**Fig. 3.**  
**A tap for drawing water from an external hydrant – cross-section A-A**  
**Rys. 3. Bateria czerpalna do poboru wody z hydrantu zewnętrznego – przekrój A-A**

The water tap includes a tee 1 with a diameter of 2", which at the end of one of the main pipes 2 has a fireman's connector 3 with dimensions 75/52, for connection to an external above-ground hydrant DN80 and enables water to be drawn from it. One first auxiliary pipe 4 with a diameter of 2" is connected to each of the main pipes 2, the other end of which is connected to a reducing tee 5. A second auxiliary pipe 7 with a diameter of 5/4" is connected to one of the outlets of the reducing tee 5, through a reduction 6 with a diameter of 2" x 5/4". The first ball valve 8a with a diameter of

5/4" is connected to the second outlet of the reducing tee 5. The first pipe elbow 9 with a diameter of 5/4" is connected to the other end of the second auxiliary pipe 7, which is connected at the other end to the second ball valve 8b. The water tap has a pipe support 10, which is mounted on the ground with its opposite end. The hydrant can be underground and then it is connected to a hydrant stand. The installation is completed with second pipe elbows 11.

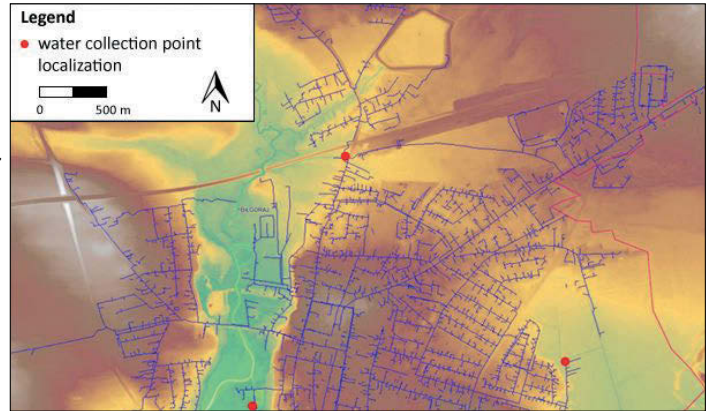
The water tap creates four draw-off points, enabling water to be drawn from the water supply network in a crisis situation. The installation is used especially when there is a pressure drop that prevents some residents from drawing water. The amount of water that can be drawn from a hydrant using a tap is at most 10 dm<sup>3</sup>/s, and this amount depends on the pressure in the water supply network and the amount of water remaining in the network. The amount of water drawn is regulated using ball valves 8a, 8b. As the pressure in the water supply system decreases, the efficiency of the water tap decreases. Due to the gravity flow of water in a crisis situation, water taps are located at the lowest points of the water supply network. Residents of the highest located houses who do not have access to water can draw it from the lowest-located draw-off points, distributed evenly throughout the city.

During normal operation of the water supply network, the water tap is usually not mounted on the water supply network. In the event of a pressure drop in the water supply network, which prevents residents of the highest located houses from drawing water, the water tap is installed on hydrants located in the lowest parts of the city. After connecting the water tap to the hydrant, water will flow after opening the ball valves 8a, 8b. Water consumption should be preceded by rinsing the installation, which is carried out with the ball valves 8a, 8b fully open. After rinsing the hydrant, water begins to be drawn into containers or tanks. The water tap allows for the same number of people to use it simultaneously as there are ball valves.

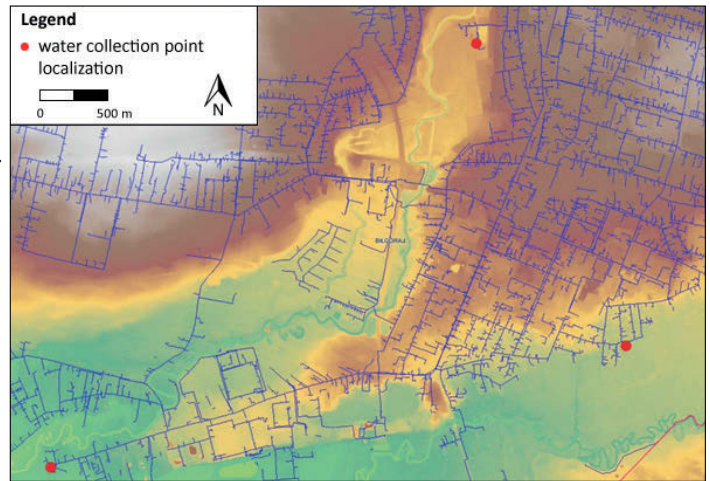
#### Assessment of the possibility of drawing water from an external hydrant in a crisis situation

Due to the specific nature of the solution, draw-off points should be located in the lowest parts of the water supply network. Thanks to this, it will be possible to collect as much water as possible. Analyzing the city's elevation, 6 places were selected with an appropriate slope and access to hydrants. The population density of individual parts of the city was also taken into account. Water collection points are located in different parts of the city, which are significantly distant from each other. This will divide the residents into smaller groups. Not all people will be gathered in one place. The location of water intake points against the back-

**Fig. 4.** Location of water intake points in the northern part of the city  
*Rys. 4. Lokalizacja punktów czerpalnych w północnej części miasta*



**Fig. 5.** Location of water intake points in the southern part of the city  
*Rys. 5. Lokalizacja punktów czerpalnych w południowej części miasta*



ground of the water supply network in relation to the height of the terrain is shown in Figure 4 and Figure 5.

It is estimated that the resources of treated water deposited in water pipes amount to approximately the average daily water consumption in the city under normal conditions. The basis for this estimate was the calculation of the capacity of water pipes based on their lengths and diameters. In a crisis situation, it will be possible to draw some of the water accumulated in the water pipes. The amount of water available depends on the topography of the area. The water resource will consist only of the water supply network located above the draw-off points. The proposed solution will not be effective for water supply networks located in flat areas. The analyzed water supply network varies in terms of terrain elevation. The height of the analyzed water supply network varies from 184 to 212 m above sea level. The lowest areas are located in river valleys, and most of the water intake points are located in these places. The actual amount of water that can be drawn from the water supply network will depend on the specific nature of the crisis situation and the associated rate of pressure drop. It should be emphasized, however, that collecting only 20% of the water accumulated in the water supply network will cover the minimum water demand ( $q_m = 7.5 \text{ dm}^3/\text{person per day}$ ) for about 4 days. The abstraction of this water may constitute an important source of water in the event of a crisis. Obtaining treated water

and distributing it among residents will reduce the health risks associated with the consumption of water of uncertain origin.

## Conclusions

The water supply system, as one of the elements of critical infrastructure, is particularly sensitive to the effects of extraordinary situations. It is crucial to counteract such situations by using tight security systems and risk management including response plans in the event of dangerous events. It is necessary to protect people against crisis situations and, when it was impossible to prevent them, to minimize their negative effects.

The work presents an original installation for obtaining water from the water supply network. In the event of a pressure drop that prevents residents from drawing water, the presented method of drawing water from a hydrant in a crisis situation may be used. The lowest points of the water supply network were indicated as the location, to which the remaining water flows by gravity. The connection of the developed water tap with a hydrant creates a draw-off point. The accumulated amounts of water inside the pipes can provide significant support for the population during periods of lack of electricity supply, which prevents the pumping station from operating. Water flows to the draw-off points under its own pressure. The water tap for drawing water from an external hydrant does not require electricity. The continuity of

operation of the developed installation is limited only by the water supply in the pipes and the remaining pressure in selected parts of the water supply network i.e. minimum 0.05 MPa (the capacity of the hydrant is about 12 m<sup>3</sup>/h). This is the pressure that allows for the efficient collection of water by the developed water tap. The capacity of 12 m<sup>3</sup>/h allows for the collection of water from each of the four taps simultaneously in the amount of approximately 0.8 dm<sup>3</sup>/s.

The implementation potential of the developed installation is very high. Creating the possibility of drawing tap water in times of crisis can be used by water supply companies. The lack of a power supply system makes the developed solution highly reliable. Further research should include the construction of a hydraulic model of the water supply network and hydraulic simulation in order to determine the actual conditions in the water supply network and the optimal arrangement of water intake points. The optimal location of water intake points can be determined based on multi-criteria analysis methods.

The developed solution is currently in the idea phase (utility model application W.131692 "Water tap"). It is planned to build a prototype and test it in operational conditions. During the research, special attention will be paid to the ergonomics of the developed solution. The operation of the developed water tap will require supervision, including operation of the hydrant valve and securing the water tap against disconnection from the hydrant.

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