

Research Article

# Assessing Water Losses in Drinking Water Distribution Systems Using the SCADA System: The Erzincan Case

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## Abstract

*Reasons such as rapid population growth, urbanization, unconscious water use, environmental pollution, and changes in climate conditions increase water consumption, and water is consumed before completing its cycle in nature. This situation has directed the water producers to search for new resources in the face of increasing water demand and decreasing resources, but due to the high cost of the resource search, the water producers have turned to the understanding of reducing the high amounts of lost water and using water resources in a more planned and efficient manner. Minimizing water losses in drinking water distribution networks is among these objectives.*

*In this study, drinking water data between January 2014 and January 2020 in Erzincan was examined, and the SCADA (Supervising Control and Data Acquisition) system placed in the drinking water distribution network in March 2018 was evaluated by considering the pre and post-drinking water data in the system. First of all, the terms between January 2014 and March 2018 which means before the installation of the SCADA system were examined, the data of the amount of water produced and the data of water consumed by the subscribers was collected from the Municipal Waterworks Unit, these data were transferred to the Water Balance Table, the results was analyzed and the actual water loss rates in the system were estimated. As a result of this estimation, before the SCADA system was established, the total physical and administrative water loss rate was seen as 64%, while the physical water loss rate was 28%. After the establishment of the SCADA automation system after March 2018, the date of the amount of water produced received from the SCADA system and the amount of water consumed was transferred to the Water Balance Table and the total physical and administrative loss was seen as 37% while the physical water loss rate was 14%. According to these results, it was observed that the water*

*loss rate approached the minimum level within a short period with the SCADA automation system.*

**Keywords:** Water losses, Water leaks, SCADA, Line pressure, Water flow values

## 1. Introduction

Today, as the population growth and the water need increase day by day, the water resources used to meet these needs are rapidly decreasing. While some of the resources are consumed to meet the increasing needs, some of them are depleted either by being polluted or wasted due to not taking the necessary precautions in a timely manner.

Although the amount of water on earth constitutes three quarters of the earth, 97.5% of this water is salt water and 2.5% is a fresh water source. 70% of the 2.5% is frozen at the poles. Therefore, the ratio of fresh water that people can easily access in total fresh water resources is only 0.3% [1].

The biological and vital minimum water consumption of a person is 25 L, and the daily average water consumption standard of modern life is 150 L. This amount, which is variable in the countries of the world, is 217 L in Turkey [2]. According to the statistics of the State Hydraulic Works, it is predicted that in 2030, when the population of Turkey will reach 100 million, it will become a country suffering from water shortages with an annual water supply of 1.120 m<sup>3</sup> per capita, and that Turkey will experience a very serious water crisis in 2050 and the following years [2]. For this reason, every country has to prepare plans and programs that will ensure the most appropriate use of water resources and take the necessary measures. The issue of "preventing water loss and leakage", which is among the measures to be taken for the most appropriate use of water resources, is one of the issues that should be emphasized both in the world and in our country. Implementing and developing methods to reduce water losses is more economical than searching for new water resources [3].

The water taken from the source for transmission does not coincide with the water coming out of the network in terms of both the amount and the billed portion. The reason for this is the losses and leakages that occur both in the transmission line and in the network. There are many causes of losses in water networks. Water losses occur due to incorrect or incomplete records, calculations made below the water value, incorrect meter readings, water consumption in public places without a meter, and illegal subscribers. In addition, leaks in tanks, pipes, meters, valves and fire hydrates also cause losses [4].

The difference between the amount of water supplied to the main network and the amount of water sold to subscribers is called "water losses". Water losses are considered as physical and commercial losses.

**Physical Water Losses:** All water escaping from transmission lines, water tanks and the network from the water source to the subscriber connection is called physical leakage. It

is very difficult to detect physical losses. The age of the network, workmanship quality, material quality, maintenance and operating pressure losses directly affect it.

**Commercial Water Losses:** These are the waters that are not recorded even though they are consumed. Those coming from the commercial reputations in question are called billed and uncontrolled waters, which consist of parts that are not charged in some way from the official institution and school. Although water is used for commercial purposes, no water is recorded in the income section [5].

During the demonstrations during the total water losses payments of physical and water losses about 60% of the total water loss during the demonstrations are water losses that manage their losses and about 40% [3].

Reducing physical and commercial water losses ensures the protection of water resources. Thanks to effective water resources management, it is also possible to maintain water quality by reducing investment and operating costs. In order to prevent water losses; prevention of unauthorized consumption, pressure management, detection and repair of leaks, maintenance and renewal of infrastructure. Water leaking from bursting, breaking, or cracks in pipes is considered lost water [6].

Water losses can be expressed differently for each institution. Some organizations subtract discharge and irrigation water from the produced water when calculating water losses. Some institutions see discharge and irrigation water as water loss. Water leaks that occur during a fault are taken as usage by some institutions [7].

Every institution tries to minimize water losses. However, it is not in question that water leaks can never be reduced to zero. Therefore, there is an acceptable level of water loss. This level is taken as 15%. However, institutions are struggling to reach this value. There is a certain economic investment to prevent lost waters. Therefore, the question is asked whether the economic advantage of water trying to prevent loss outweighs the economic investment required to prevent loss [8].

The difference between the measured water consumption of metered subscribers and the water produced by the consumption gives the water losses. If we express the amount of water loss in terms of the percentage of water;

$$\text{Water Loss} = (\text{Produced} - \text{Measured Usage}) \times \frac{100(\%)}{\text{Production}}$$

The amount of water loss varies with the development levels of the countries. Water losses are between 8-14% in developed countries, between 15-24% in newly developed countries, and between 25-45% in developing countries. In Turkey, it has approached 45% [9].

There are many technological methods used to detect water leaks. SCADA (Supervisory Control and Data Acquisition), which is one of the systems where monitoring and control is made from a single center, is one of these technologies. With this system, it is ensured

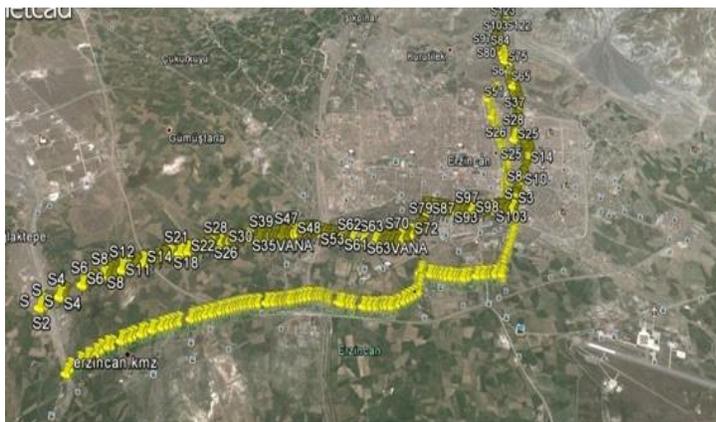
that the data obtained by the instruments and sensors installed in the field areas are transferred to the computers, processed and recorded. In other words, it can be said that the system is a remote monitoring and control system [10;11]. Many studies have been carried out from the past to the present to determine and reduce the amount of water loss and leakage [12-17].

In our study, the SCADA system used for the province of Erzincan was evaluated in order to determine the water losses and leaks in the drinking water networks. With this thesis, it will be understood whether the real-time control of the enterprise, reducing the operating investment costs, ensuring the efficient use of resources and whether the water losses exceed the expected value.

## 2. Materials and Methods

### 2.1. Working Site and Features

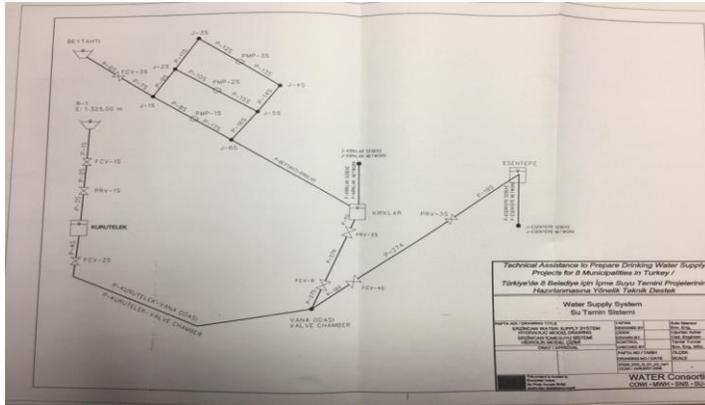
Erzincan drinking water distribution system is shown in Figure 2.1. Drinking water of the province of Erzincan is supplied from a total of 9 wells and 4 warehouses, from drilling wells in two different regions (Beytahtı and Kurutilek). The first one has 8 boreholes and a 2000 water tank. Here, 1000 m<sup>3</sup> of water is transferred alternately from the wells to the 2000 tanks in the region.



*Figure 2.1. Erzincan Drinking Water Distribution System*

This water obtained is rested in tanks and chlorinated. After this process is done, the water in the tank is conveyed to the warehouse located at the second location with a 12 km long Q800 steel pipe, together with 6 horizontal shaft engines, and then to the 5000 and 15000 tanks to the Q200 tanks at the high elevation of the city (Kırklar Hill). 22 L/s

water is conveyed along the main transmission line during the day using font pipe. From here, it is transported to the city center with a Q600 outlet pipe with 275 L/s by gravity.



*Figure 2.2. Erzincan Drinking Water Distribution Project*

In Figure 2.2, valve connection points and tanks are shown along the transmission line, starting from the outlet of drinking water in Beytahtı and Kurutilek locations.

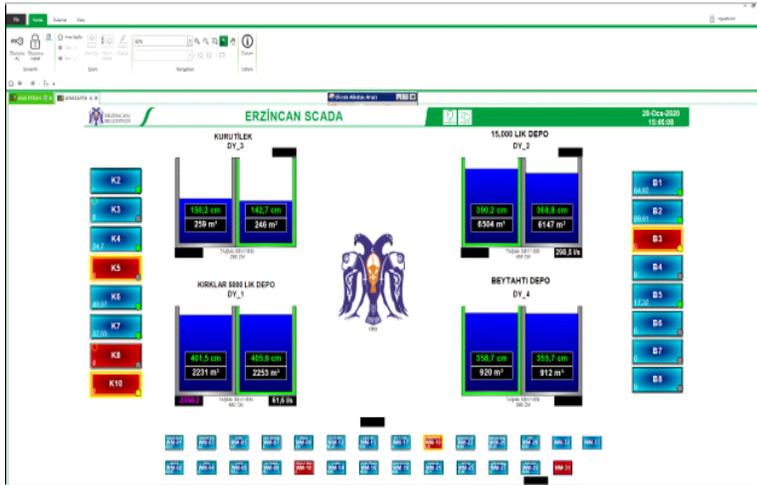
## 2.2. SCADA System

SCADA consists of the initials of the words "Supervisory Control and Data Acquisition" and means Central control and data acquisition. SCADA System; It has a wide application area in industry.

With SCADA, you can easily manage very large geographical areas and systems at very distant points from a single center, access real-time data instantly and intervene immediately. With the rapid development of technology, the costs of establishing a SCADA system have decreased and technological advances have greatly improved the SCADA functionality [18].

Data-Based Control and Surveillance Systems (SCADA) usually consist of a base station and several geographically distributed RTUs. RTU (short for Remote Terminal Unit in English) is an electronic device containing a microprocessor control system, providing communication between physical field equipment and SCADA system, transmitting signals and information from the field to the central control system and carrying commands. central control system to the field. They are connected to the base stations in the SCADA center using many communication units such as radio links, cables, leased lines, and microwaves. RTUs are Remote Terminal Units with different sizes and functions depending on the make and model [19].

In the province of Erzincan, the SCADA system and infrastructure works were started in 2015 within the scope of the life water project, the infrastructure works were completed in February 2018 and the SCADA system was fully integrated into the system in March 2018. The control of this system is provided by creating Regional Measurement Areas (DMA). The SCADA system used is shown schematically in Figure 2.3.



*Figure 2.3. Erzincan SCADA System*

In order to use this system more effectively, the network is divided into 3 DMAs. There are 389 valves on the water transmission line. These valves are integrated into the SCADA system and are controlled through the system. These valves are protected from external factors by marking their locations with Cors-TR compatible GPS receivers.

Electromagnetic flow meters (flow meters) are placed in the inlet pipes of each DMA, where the valves are located, and they are connected to the SCADA system. There are 46 electromagnetic flow meters in total. Thanks to this system, the flow, pressure and water quality values of the relevant DMA are monitored instantly and recorded over the system and controlled over the SCADA network system of the entire city.

In addition, in order to better monitor water loss rates, the identity information of each building is created and monthly water data transmitted to the customer are monitored. Therefore, a customer information system integrated into the Geographic Information System (GIS) has emerged. With the integrated process, the monthly calculation of the total consumption in DMA has been simplified. In this way, the water loss amount and non-revenue water percentage of each DMA in Erzincan can be calculated to a certain extent.

## 2.1. Method

In order to calculate the amount of water loss, American Water Works Association (AWWA) and International Water Association (IWA) methods were used [4]. Thanks to these methods, the water balance table was created and the amount of loss and leakage was calculated. The water balance table, which was created in accordance with the Regulation on the Control of Water Losses in Drinking Water Supply and Distribution Systems, was made according to the "Drinking Water Timetable" given in Figure 2.4.

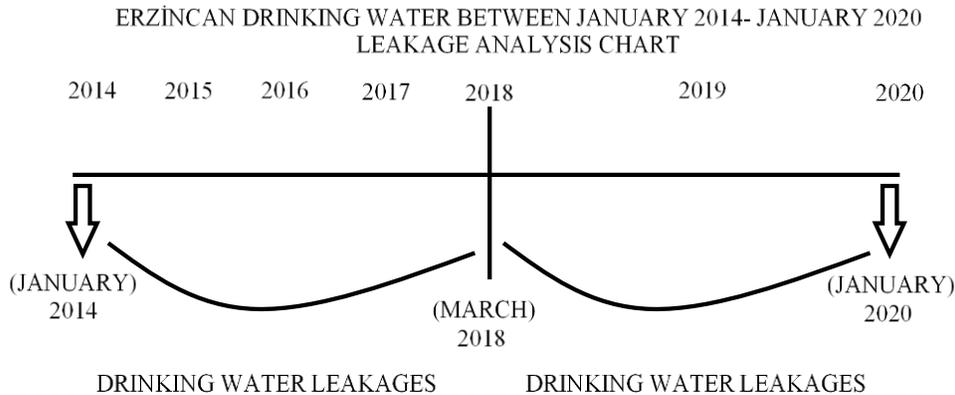


Figure 2.4. Drinking water leakage timeline

In the part between January 2014 and March 2018, there is no SCADA system, and the drinking water calculation given to the city is done manually. From March 2018 to the present, the SCADA system has been included on the drinking water line, and with this system, electromagnetic flow meters are placed on the drinking water transmission line and the drinking water data passing through the pipes are recorded instantaneously, hourly, daily, weekly, monthly and yearly. water values have been reached.

In order to determine the physical water losses, a water balance table is first created as shown in Table 2.1. Thanks to the equations given below, the necessary calculations are made and the water balance table is created.

Table 2.1. Standard Water Balance Chart [20]

(1) Amount of Water Entering the System ...	(10) Permitted Consumption... <b>m<sup>3</sup>/year (...%)</b>	(4) Billed Permitted Water Consumption ... <b>m<sup>3</sup>/year (...%)</b>	(2) Billed Measured Usage ... <b>m<sup>3</sup>/year(...%)</b> (3) Billed Unmetered Usage ... <b>m<sup>3</sup>/year(...%)</b>	(5) Amount of Income Generating Water... <b>m<sup>3</sup>/year(...%)</b>
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<b>m<sup>3</sup>/year (100%)</b>		(9) Unbilled Permitted Water Consumption ... <b>m<sup>3</sup>/year(...%)</b>	(7) Unbilled Measured Usage... <b>m<sup>3</sup>/year(...%)</b>	(6) Amount of Non-Revenue Water... <b>m<sup>3</sup>/year (...%)</b>	
			(8) Unbilled Unmetered Usage ... <b>m<sup>3</sup>/year(...%)</b>		
	(11) Water Losses... <b>m<sup>3</sup>/year (...%)</b>	(14) Administrative Losses... <b>m<sup>3</sup>/year(...%)</b>	(12) Unauthorized Consumption... <b>m<sup>3</sup>/year(...%)</b>		(13) Measurement Errors in Meters... <b>m<sup>3</sup>/year(...%)</b>
			(15) Physical Losses... <b>m<sup>3</sup>/year(...%)</b>		
			(16) Leaks and Overflows in Warehouses ... <b>m<sup>3</sup>/year(...%)</b>		

**Amount of water supplied to the city** = water drawn by a motor from the well in 1 hour (m<sup>3</sup>/h) x daily worker number of engines (pieces) x daily operating hours of engines (hours/days)

**Amount of Non-Revenue Water** = Amount of Water Entering the System-Amount of Revenue-Generating Water

**Billed Permitted Water Consumption**=Billed Metered Use-Billed Unmetered Use

**Permitted Consumption Amount**=Billed Permitted Water Consumption+Unbilled Permitted Water Consumption

**Amount of Water Losses** = Water Entering the System - Allowed Consumption

**Administrative Losses**=Unauthorized Consumption+Measurement Errors in Meters

**Physical Loss Amount**=Water Losses-Administrative Losses

**Leakage in Supply and Distribution Lines and Service Connections**=Physical Losses-In Warehouses Missing Losses

### 3. Discussion and Conclusion

### 3.1. All Amounts of Water Consumed by Years

Before SCADA, the drinking water given to the city between January 2014 and March 2018 was calculated by multiplying the drinking water drawn in 1 hour by 24 hours, which is the operating hours of the engines, provided that 10 of the 12 engines of equal capacity in the wells are operated alternately 24 hours a day. The amount of water drawn by one motor from the wells in 1 hour is 126 m<sup>3</sup>. In this way, the amount of water entering the system during the year is calculated and given in Table 3.1. The reason why the amount of water entering the system changes over the years is due to reasons such as periodic maintenance of the motors and power cuts. Conclusion

The amount of water supplied to the city before SCADA was calculated as follows.

Amount of water supplied to the city = Water drawn by an engine from the well in 1 hour (m<sup>3</sup>/hour) x Number of daily running engines (pieces) x Daily operating hours of engines (hours/days)

The amount of water supplied to the city in a day = 126 (m<sup>3</sup>/hour) x 10 units.x 24 (hours day) = 30.240 m<sup>3</sup>/day

The amount of water supplied to the city in a year = 30.240 x 365 =11.037.600 m<sup>3</sup>

The amount of water supplied to the city between March 2018 and January 2020 after SCADA was calculated using the SCADA database (Table 3.1) and is given in Table 3.3.

**Table 3.1.** Amount of Water Entering the System Monthly Between March 2018-January 2020 After SCADA

Months	The amount of water entering the system in 2018 (m <sup>3</sup> )	The amount of water entering the system in 2019 (m <sup>3</sup> )
January	782.485	620.825
February	717.668	717.626
March	801.528	784.810
April	741.597	755.034
May	840.904	861.431
June	850.515	747.732
July	990.207	1.035.952
August	995.759	781.246
September	966.345	701.942
October	620.825	699.780
November	692.690	701.980

December	739.804	694.309
<b>Annual total</b>	<b>9.740.329</b>	<b>9.780.670</b>

While the total number of subscribers registered in 2014 was 37588 according to Table 3.2, this figure increased over the years and reached 41544 people in 2019. Depending on this increase, there should be an increase in the amount of water given to the city, but when Table 3.3 is looked at, the amount of water given to the city decreased. The reason for this decrease is the reduction of physical and administrative losses thanks to the SCADA.

*Table 3.2. Erzinçan Province Drinking Water Subscriber Information*

Year	2014	2015	2016	2017	2018	2019
<b>Number of Subscribers (person)</b>	37588	38490	39408	40352	41002	41544

As seen in Table 3.3, the amount of water entering the system between 2014 and 2019 is 11.037.600 m<sup>3</sup>/year, 10.986.430 m<sup>3</sup>/year, 10.947.136 m<sup>3</sup>/year, 60.645.854 m<sup>3</sup>/year, 9.740.329 m<sup>3</sup>/year, 9.102.670 m<sup>3</sup>/year respectively. 100% of the water in the network meets this value.

Since there is no SCADA system between January 2014 and March 2018, it is not possible to reach a clear figure regarding the leakages that occurred in the warehouses. In 2019, when the SCADA system was observed for 12 months, the 100% value of the amount of water entering the system was measured as 9.102.670 m<sup>3</sup>/year and the actual amount of drinking water supplied to the city was reached.

Tablo 3.3'teki verilere göre 2019 yılında 9.102.670 m<sup>3</sup> olan su tüketim miktarına göre getirilen su miktarı sadece 5.778.502 m<sup>3</sup>'tür. 2014 yılından 2018 yılına faturalı sayaçlı kullanımın arttığı gözlemlenirken, 2019 yılındaki düşüş, bazı belde belediyelerinde itfaiye, çeşme gibi yerlerin kapatılmasından kaynaklandı.

While the measured usage value invoiced in 2019 corresponded to 64% of the amount of water supplied to the city, this value was found to be 36%, 49%, 51%, 56% and 62%, respectively, in the years before SCADA. (Fig. 3.1). It showed a rapid increase in 2018 and 2019 when the SCADA system started to be implemented.

*Table 3.3. Water amounts before and after SCADA [21]*

Water quantities	Year →	2014	2015	2016	2017	2018	2019
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↓ (m <sup>3</sup> /year)							
<b>Amount of water supplied to the city</b>	11.037.600	10.986.430	10.947.136	10.645.854	9.740.329	9.102.670	
<b>Invoiced Measured Usage</b>	3.652.458	5.410.937	5.606.952	5.920.692	6,098.669	5.778.502	
<b>Invoiced Unmetered Usage</b>	0	0	0	0	0	0	
<b>Invoiced Permitted Use</b>	3.652.458	5.410.937	5.606.952	5.920.692	6.098.669	5.778.502	
<b>Amount of Income Generating Water</b>	3.652.458	5.410.937	5.606.952	5.920.692	6.098.669	5.778.502	
<b>Amount of Non-Revenue Water</b>	7.385.142	5.575.493	5.340.184	4.725.162	3.641.660	3.324.168	
<b>Prepaid Measured Usage</b>	252.916	252.916	252.916	252.916	373.249	373.249	
<b>Invoice Unmetered Usage</b>	17.640	17.640	17.640	17.640	18.620	26.603	
<b>Unpaid Permitted Water Consumption</b>	270.556	270.556	270.556	270.556	391.869	399.852	
<b>Permitted Water Consumption Amount</b>	3.923.014	5.681.493	5.877.508	6.191.248	6.490.538	6.178.354	
<b>Water Losses</b>	7.114.586	5.304.937	5.069.628	4.454.606	3.249.791	2.924.316	
<b>Unauthorized Water consumption amount</b>	2.040	2.040	2.040	2.040	4.080	4.080	
<b>Measurement Errors</b>	1.778.00	1.778.00	1.778.00	1.778.00	1.730.35	1.679.360	
<b>Administrative Losses</b>	1.780.040	1.780.040	1.780.040	1.780.040	1.734.429	1.683.440	
<b>Physical Losses</b>	5.334.546	3.524.897	3.289.588	2.674.566	1.515.362	1.240.876	
<b>Losses and Overflows in Warehouses</b>	978.000	978.000	978.000	978.000	1.220.000	487.005	
<b>Losses on Lines</b>	4.356.546	4.356.546	4.356.546	4.356.546	753.870	753.870	

It is not possible to talk about invoiced and unmeasured legal consumption in the Erzincan region. All subscribers have water meters, which are read monthly by the Erzincan Water and Sewerage Administration.

Postpaid authorized usage is the expression in m<sup>3</sup>/year of the total amount of water obtained by reading the indexes of any subscriber (residential, commercial, official institution, etc.) registered in the subscriber database (with a subscription agreement) at certain periods. The invoiced authorized usage amount is calculated as equal to the invoiced metered usage amounts since there is no invoiced unmetered usage.

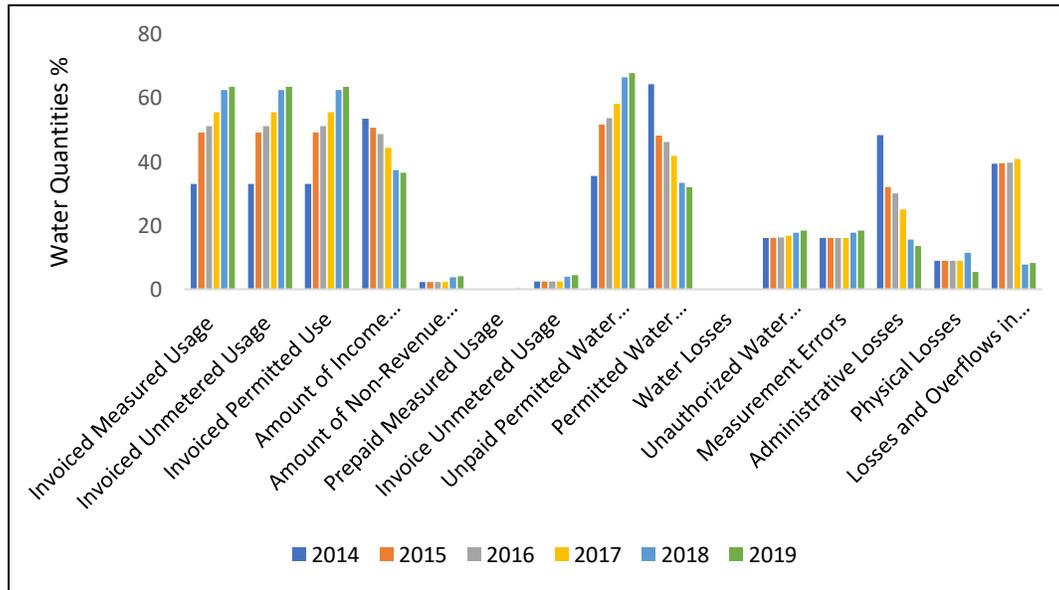


Figure 3.1. Amounts of water before and after SACADA

The total amount of water obtained by reading the indexes of any subscriber (residential, commercial, official institution, etc.) registered in the subscriber database (with a subscription agreement) at certain periods is expressed as the amount of revenue generating water. When the amount of income generating water is calculated, it is seen that the values are the same as the invoiced authorized water consumption, as seen in Table 3.3. The amount of income generating water in Erzincan province in 2019 is 5,778,502 m<sup>3</sup>/year and this value covers approximately 64% of all waters. It represents the amount of water that brings income 46% in 2014, 49% in 2015, 51% in 2016, 56% in 2017 and 63% in 2018 (Figure 3.1). Looking at this table, it is seen that the amount of income generating water is gradually increasing. One of the most important reasons for this increase is the network inspections made with SCADA, newer subscriber meters, more frequent readings, and the use of illegal water has been brought under control. The amount of non-revenue water in the Erzincan region reflects quite different values for two different periods. While it was 7.385.142 m<sup>3</sup>/year in 2014, the amount of water that does not generate income decreased to 3.324.168 m<sup>3</sup>/year between 2019. According to the results obtained from Figure 3.1, the percentage of non-revenue water amounts was calculated as 54%, 51%, 48%, 44% and 37% between 2014 and 2019, respectively.

When we look at this table, it is observed that the amount of water that does not generate income gradually decreases with SCADA and the dominance of drinking water gradually increases. Leaks, illegal use, faulty meter readings and old meters play a major role in the increase in the amount of non-revenue water. With the developing technology, preventing illegal use, using newer meters and making meter readings by a professional team also lead to a decrease in the amount of water that does not generate income.

When it comes to unbilled metered use, areas such as places of worship, parks, fire department, charity, municipal vacuum trucks should be included in the system in order to clearly express the consumption amount. Because in such places, invoicing is not done even though the measurement is made. As seen in Table 3.3, unbilled measured usage in 2019 was calculated as 373.249 m<sup>3</sup>/year, and the corresponding rate was 4%. While this value was 3.8% in 2018, unbilled metered usage between 2014 and 2017 has a rate of 2.3%. This rate has increased in 2018 and 2019, as some newly opened parks receive water from the drinking water line.

If unbilled unmeasured uses are to be mentioned, water wasted in maintenance works due to fire hydrates and pipe failures should come to mind. Looking at the province of Erzincan, it is seen that there are 76 fire hydrants. According to Table 3.3 and Figure 3.1, the unbilled unmeasured usage rate in 2019 shows a water consumption of 26.6 m<sup>3</sup>/year. This water consumption corresponds to 0.3%. Between 2014 and 2017, unbilled unmetered use corresponds to 0.15% of water consumption. In 2018, this value was calculated as 0.04%.

Between 2014 and 2017, the unbilled authorized water consumption is 270.556 m<sup>3</sup>/year and the water consumption percentage is 2.45%. This value is 391,869 m<sup>3</sup>/year in 2018, and the unbilled authorized water consumption in 2019 is 399.852 m<sup>3</sup>/year, which is 4.4%. Permitted water consumption amount was 6,178,354 m<sup>3</sup>/year in 2019 and 68% was calculated for the other years (2014-2018) as 36%, 52%, 54%, 58% and 67%, respectively. The amount of water losses in 2019 is 2.924.316 m<sup>3</sup>/year, and 32% of the incoming water is considered as lost water. In other years, this value was 64% in 2014, 48% in 2015, 46% in 2016, 42% in 2017, and 33% in 2018, and a remarkable decrease was observed with SCADA.

In order to obtain the amount of unauthorized consumption, the approximate calculation method should be used. It is important to use GIS in order to prove accuracy, especially with analysis processes. The aim here is to calculate how much usage is without subscribing. According to Table 3.3, the amount of unauthorized consumption in 2018 and 2019 is 4.080 m<sup>3</sup>/year, and 0.04% of them use water without a subscription. The amount of unauthorized consumption between 2014 and 2017 is 2.040 m<sup>3</sup>/year and has been calculated as 0.018%.

Many factors are effective in calculating the amount of measurement error in meters. First of all, incorrect assembly causes incorrect measurements to be taken. In addition, the fact

that the usage period of the meters exceeds 10 years or that they are not noticed causes erroneous measurements. Although the measurement error in the meters decreased in Erzincan province, it increased due to the decrease in the amount of water supplied to the city. While it was 18% in 2019, it was found to be 16% between 2014-2017.

While the amount of administrative loss was 1.780.040 m<sup>3</sup>/year in 2014-2018, this value decreased to 1.683.440 m<sup>3</sup>/year in 2019. Looking at Figure 3.1, a decrease in the percentage value of administrative loss was observed according to the amount of water used.

The amount of physical loss has been greatly reduced. Between 2014 and 2019, this decrease was calculated as 48%, 32%, 30%, 25%, 15% and 13%, respectively, according to Figure 3.1. The amount of physical loss expected for 2019 was higher than expected. The reason for this is that physical losses have occurred due to reasons such as breaking the connection points during the new connection and road construction works.

In some cases, not placing the tank correctly or not adjusting the water level at the optimum level causes flooding. The water losses in the tanks must be added to the water balance, and the amount of loss must be determined. Thanks to the SCADA system located at 38 different points, the measurement of water at the entrance and exit of the tank can be done easily and accurately. Since there was no SCADA system between the processes until March 2014-2018, the figures for these years were found by estimating. The amount of leakage and overflow in the warehouses in 2019 is 487.005 m<sup>3</sup>/year and this amount corresponds to a rate of 5%. The estimated value of leakage and overflow in the warehouses for the years 2014-2017 is 978.000 m<sup>3</sup>/year and 8.86%.

Leaks can be caused by gaps in the installation of supply and distribution lines, and damage to service connections. At this stage, the age or type of the pipe is not important. It is completely caused by pipe bursts that may occur during assembly and operation. While the losses in the lines between 2014-2017 were around 40%, this rate decreased to 8% in 2018 and 2019.

### **3.2. Change of Income and Non-Revenue Drinking Water Data by Years**

A remarkable success has been achieved since 2015, with the efforts to reduce the amount of loss and leakage carried out both before and after the SCADA system. According to Figure 3.2, while the amount of income-generating water increased between 2014-2019, the amount of non-income-generating water decreased. While the amount of income generating water was approximately 50% in 2015, it increased to 63% in 2019. While the amount of non-revenue water was 51% in 2015, it decreased to 37% in 2019. With the SCADA system and necessary studies, the desired level has been reached [22]. He stated that non-revenue water causes energy loss, and therefore there is a 50% water loss worldwide. He stated that the Mediterranean is having difficulties in meeting its water needs, and pressure management is very important at this stage.

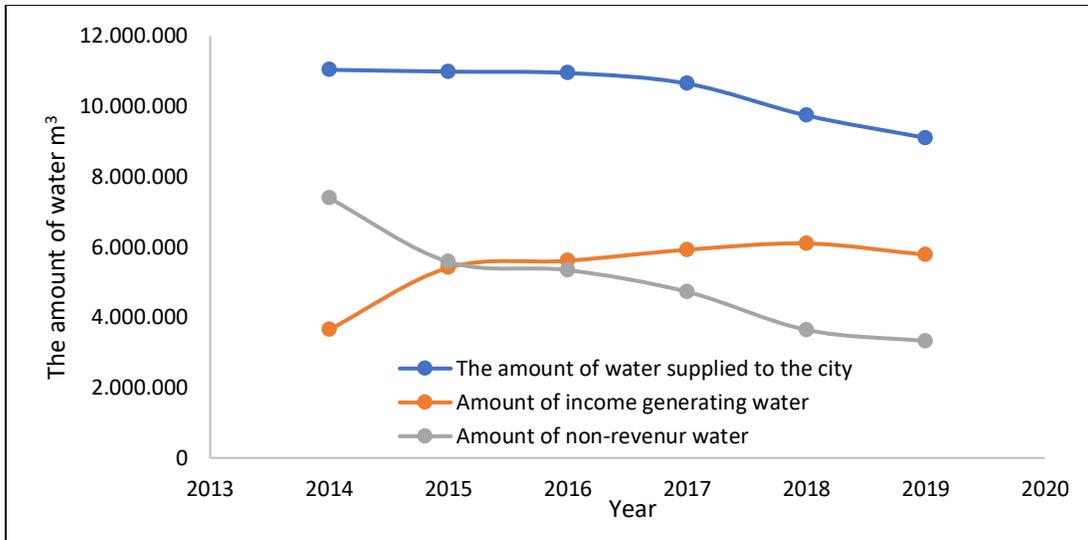


Figure 3.4. Change of income and nonRevenue water amount by years

### 3.3. Change of Physical and Administrative Water Losses by Years

According to Figure 3.3, both physical and administrative water loss amounts have decreased considerably. The percentage of physical loss was calculated as 48%, 34%, 30%, 25%, 16% and 14% between 2014 and 2019, respectively.

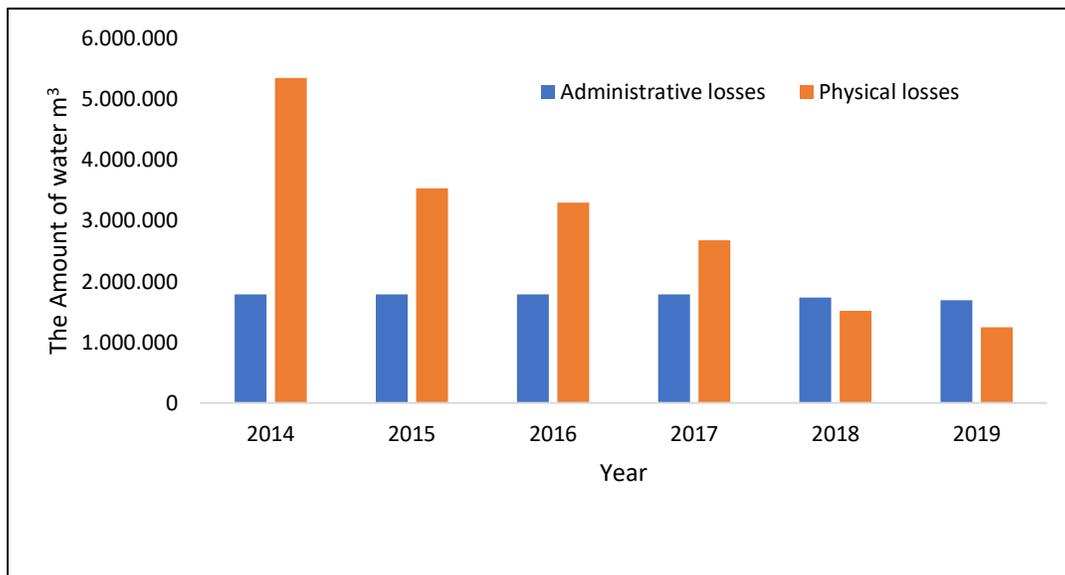


Figure 3.5. Changes in Physical and Administrative Water Losses by Years

Among the water balance inventories prepared according to the water consumption amounts calculated for all years, only the Water Balance Inventory for 2019 is given in Table 3.4.

**Table 3.4. Water Balance Inventory for 2019**

(1) Amount of Water Entering the System <b><u>9.102.670</u></b> <b>m<sup>3</sup>/year</b> <b>(100%)</b>	(10) Permitted Consumption <b><u>6.178.354</u></b> <b>m<sup>3</sup>/year</b> <b>(67,87 %)</b>	(4) Billed Permitted Water Consumption <b><u>5.778.502</u></b> <b>m<sup>3</sup>/year</b> <b>(63.47%)</b>	(2) Billed Measured Usage <b><u>5.778.503</u></b> <b>m<sup>3</sup>/year</b> <b>(63.47%)</b>	(5) Amount of Income Generating Water <b><u>5.778.502</u></b> <b>m<sup>3</sup>/year</b> <b>(63.47%)</b>
			(3) Billed Unmetered Usage <b><u>0</u></b> <b>m<sup>3</sup>/year</b>	
		(9) Unbilled Permitted Water Consumption <b><u>399.852</u></b> <b>m<sup>3</sup>/year</b> <b>(4.4%)</b>	(7) Unbilled Measured Usage <b><u>373.249</u></b> <b>m<sup>3</sup>/year</b> <b>(4.1%)</b>	(6) Amount of Non-Revenue Water <b><u>3.324.168</u></b> <b>m<sup>3</sup>/year</b> <b>(36.53%)</b>
	(11) Water Losses <b><u>2.924.316</u></b> <b>m<sup>3</sup>/year</b> <b>(32,13%)</b>	(8) Unbilled Unmetered Usage <b><u>26.603</u></b> <b>m<sup>3</sup>/year</b> <b>(0.3%)</b>		
		(14) Administrative Losses <b><u>1.683.440</u></b> <b>m<sup>3</sup>/year (18.49%)</b>	(12) Unauthorized Consumption <b><u>4.08</u></b> <b>m<sup>3</sup>/year</b> <b>(0.04%)</b>	
		(15) Physical Losses <b><u>1.240.876</u></b> <b>m<sup>3</sup>/year</b> <b>(13.64%)</b>	(13) Measurement Errors in Meters <b><u>1.679.360</u></b> <b>m<sup>3</sup>/year (18.45%)</b>	
		(17) Loss Leakage Occurring in Supply and Distribution Lines and Service Connections <b><u>753.871</u></b> <b>m<sup>3</sup>/year</b> <b>(8.28 %)</b>		

			(16) Leaks and Overflows in Warehouses <b>487.005 m<sup>3</sup>/year</b> <b>(5.36%)</b>	
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#### 4. Conclusion

Infrastructure works with the SCADA system started in Erzincan Province in 2015, and full system integration was achieved in March 2018. As can be seen from the results, as of February 2015, with the renewal of the infrastructure for the SCADA system, reductions in physical and administrative losses have been observed. The detection of water leaks in the form of leaks in pipes, pipe connections, tanks and occurring in drinking water supply and distribution systems has been made in a more controlled way and their losses have been prevented.

Especially at the entrances and exits of the warehouses, thanks to the 38 measurement stations located on the main pipeline, data is obtained once every 5 minutes, thus preventing losses by early intervention in case of leakage.

Thanks to these controls and the measures taken, it was calculated that the total water losses were 64% in 2014, 48% in 2015, 46% in 2016, 42% in 2017, 33% in 2018, and 32% in 2019. The rate of physical water losses was 48% in 2014, 34% in 2015, 30% in 2016, 25% in 2017, 16% in 2018, and 14% in 2019. In this way, the amount of water supplied to the system has also decreased. While the amount of water entering the system was 11.037.600 m<sup>3</sup>/year in 2014, it decreased to 9.102.670 m<sup>3</sup>/year in 2019.

One of the most important factors in the reduction of water losses is the registration of the subscribers and the prevention of unauthorized use by 50% and the monitoring of drinking water starting from the wells until it reaches the consumer along the conveyance line, intervening immediately in case of leakage and minimizing the amount of loss.

Along with the integration of the SCADA system, an increase was observed in the invoiced measured usage amount with the renewal and control of the subscribers' records. Thanks to the correct follow-up of subscribers and invoicing, physical losses were reduced, and lost water was prevented, and this lost water was transformed into revenue-generating water. Likewise, the amount of water that does not generate income has decreased thanks to the SCADA system.

Unbilled Permitted Water Consumption appears to have increased from 2014 to 2019. The reason for this is that while the number of places of worship such as mosques was 76 in 2014, the number of mosques in 2018 increased to 88. In order for this data to be examined and recorded in a healthier way, meters should be placed by the municipality

in all places of worship, parks and gardens, areas where firefighters, charity and municipal vacuum trucks are filled, and these meters should be read and recorded by the municipality in 2-month periods.

It is seen that Permitted Consumption has increased approximately two times from 2014 to 2019, that is, illegal water use is prevented by 50% with the SCADA system.

The reason for so many meter reading errors is that the meters used do not measure precisely and precisely. The meters are the sand etc. escaping into them over time. It cannot read fully and accurately because it is malfunctioning due to various reasons. Counters that are used in buildings for 10 years or more should be determined and these counters should be replaced or used counters should be replaced with electronic smart meters.

Within the scope of the study, it is seen that the SCADA system is sufficient to reach more accurate data, and the real water losses are based on more scientific results. Thanks to SCADA, wasted water is prevented by preventing water losses in drinking and utility water supply and distribution systems, thus protecting the existing water resources. This showed that an efficient result was obtained from the SCADA system, which was started to be implemented in Erzincan Province.

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