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Non-revenue Water Management in Amman: a Case Study of Yadoudeh Area

Online Workshop , 16 December 2020

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نقابة المهندسين الأردنيين
Jordan Engineers Association

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Outline

- Introduction
- Methodology
- Results and Discussion
- Conclusion and Recommendations

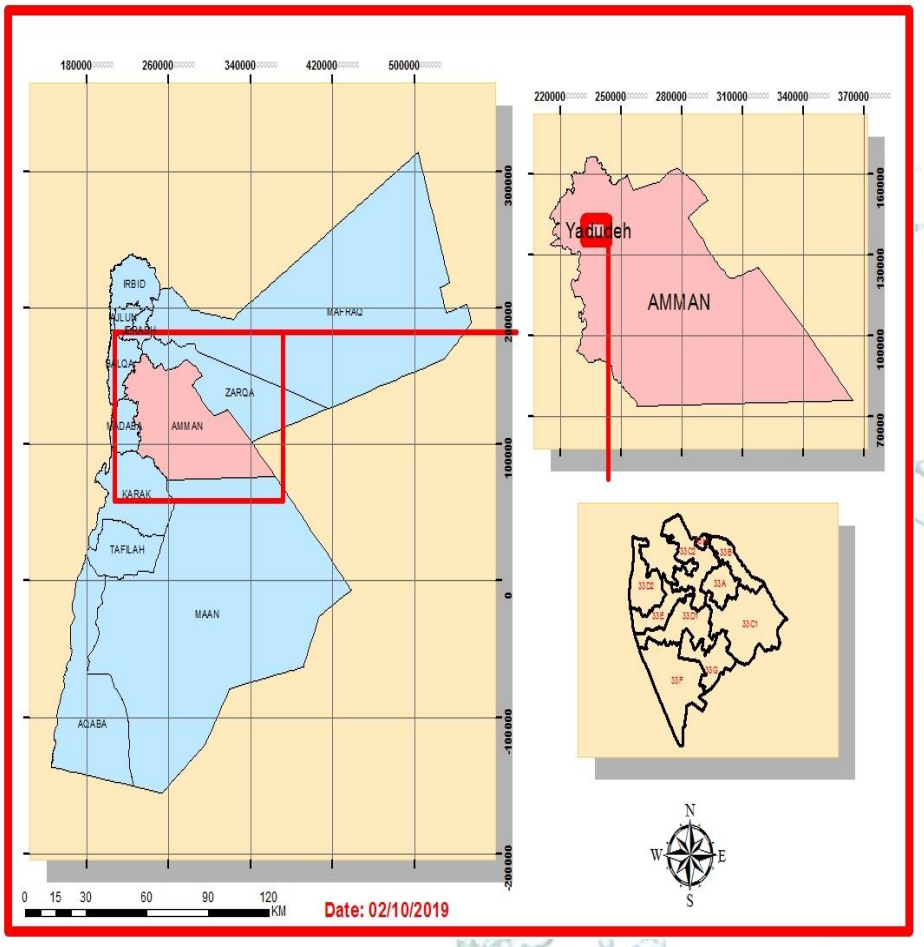
1 Introduction

Introduction

Non-revenue water (NRW) is expected to be as one of the extensive challenges that Jordan water sector faces. Jordan is among the world poorest water country.

The study aims to reduce NRW in Amman by taking Yadoudeh distribution area (DZ 33) as a case of study.

DZ33 has an area of 36.5 km^2 and located in the Southern part of Amman. The water supply system is intermittent with approximately 9175 customers currently being serviced by Miyahuna.The topography of the area is very complex encompassing hilly and low areas.



Objectives

- **Assess of the existing NRW;**
- **Quantify the real losses and apparent losses in Yadoudeh distribution network; and**
- **Recommend an integrated NRW management in Amman distribution system.**

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2 Methodology

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The methodology includes

- **Data collection of different water supply sources**
- **Analysis and modeling of NRW using Water GEMS software**
- **Analysis and modeling of NRW using applicable IWA tools**
- **Testing NRW options and management tools**
- **Developing the guidelines and best management practices to reduce NRW in the study area and Jordan.**

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Water network analysis and hydraulic modeling using Water GEMS software

For the study of DZ 33 Yadoudeh network, the following are points needed to be realized:

Collecting all the needed data related to the water distribution network in this area:

- Main sources with elevations : Reservoirs , Pumps , Towers
- Full Existing network with clear connections &fittings: Primary, Secondary and Tertiary Pipes (connection nodes , valves , PRVs ,…..(shp. file))
- Borders for Existing DMAs with names(shp. file)
- Base map including names of main streets and landmarks.
- No. of customers within DZ 33 border.
- Amount of water supply and Consumption.
- Contour map or any Topographic data to recognize the elevations in DZ33.

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Analysis of Existing data includes:

- Topography of the area (Elevations analysis for the max. &min. elevations), taking in to consideration the elevation of source for each DMA.
- Determine main pipes supply DZ 33.
- Create elevation diagram for the existing system.
- Create existing and proposed hydraulic model for the area.
- Start thinking of solutions upon the results of hydraulic analysis & according to design criteria.
- Create elevation diagram for the proposed system.

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Modeling of NRW using applicable EPA and AWWA tools

AWWA free audit water software

Figure below represents IWA 'Best Practice' Water Balance and Terminology

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Metering Inaccuracies and Data Handling Errors	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakae and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to Point of Customer Metering	

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Real loss component analysis model

- This model is used to provide the water authorities with a utility-tested software tool to assure a leakage component analysis.
- Also it is used to identify economic options for the reduction of real loss, through enhance the speed and the quality of leak repair, proactive leak detection and pressure management.
- This model also was used to help water authorities in evaluating options for implementing sustainable leaks control programs.

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3 Results and Discussion

Non-revenue water reduction in Amman: a case study of Yadoudeh area

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Some preliminary analysis are shown below according to the complaints, control and communication center from 2017 to 2018. Most of the received complaints are documented as pipe blockage. High significant pipe blockage in the network are an indicator of low efficiency and the condition of the system.

DZ	Water Leaks		Pipe Blockage		HC		Main Pipe	
	2017	2018	2017	2018	2017	2018	2017	2018
33A	64	29	123	54	19	6	12	1
33B	26	25	19	96	8	12	5	1
33C1	135	301	108	504	43	93	21	35
33 C2		464		829		153		59
33D1	1189	254	975	319	315	83	171	42
33 D2		36		14		11		7
33E	70	366	57	697	29	123	7	48
33F	78	123	116	97	23	39	11	20
33G	25	12	32	26	5	7	5	2
33H	943	67	1410	150	259	22	147	7
Sum.						549		

Non-revenue water reduction in Amman: a case study of Yadoudeh area

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Water leaks per pipe diameter

Most of the water leaks occur in pipes diameter between 3/4 inch and 2 inch. These pipes usually used in water connections between main lines and the costumers.

Diameter (mm)	Diameter (in)	No. of complaints (Frequency) 2017	No. of complaints (Frequency) 2018
Dn 15	1/2	66	74
Dn 20	3/4	459	407
Dn 25	1	75	41
Dn 50	2	264	153
Dn 100	4	31	25
Dn 150	6	1	4
Dn 200	8	0	3
Other		2	1

Leaks per pipe material

According to the received data in the table, the poly ethylene pipe has the highest leaks frequencies

Material type	No of Complaints (Frequency) 2017	No of Complaints (Frequency) 2018
GI	197	157
PE	696	549
ST	12	7
Cast Iron	0	0
PVC	0	0

Non-revenue water reduction in Amman: a case study of Yadoudeh area

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Based on the data that were collected from Miyahuna, three models are applied to find and audit NRW in Yadoudeh distribution network

Previous conditions

The DZ 33 was originally designed to include 8 hydraulic districts A,B,C,D,E,F,G and H all fed by Yadoudeh reservoir and tower.

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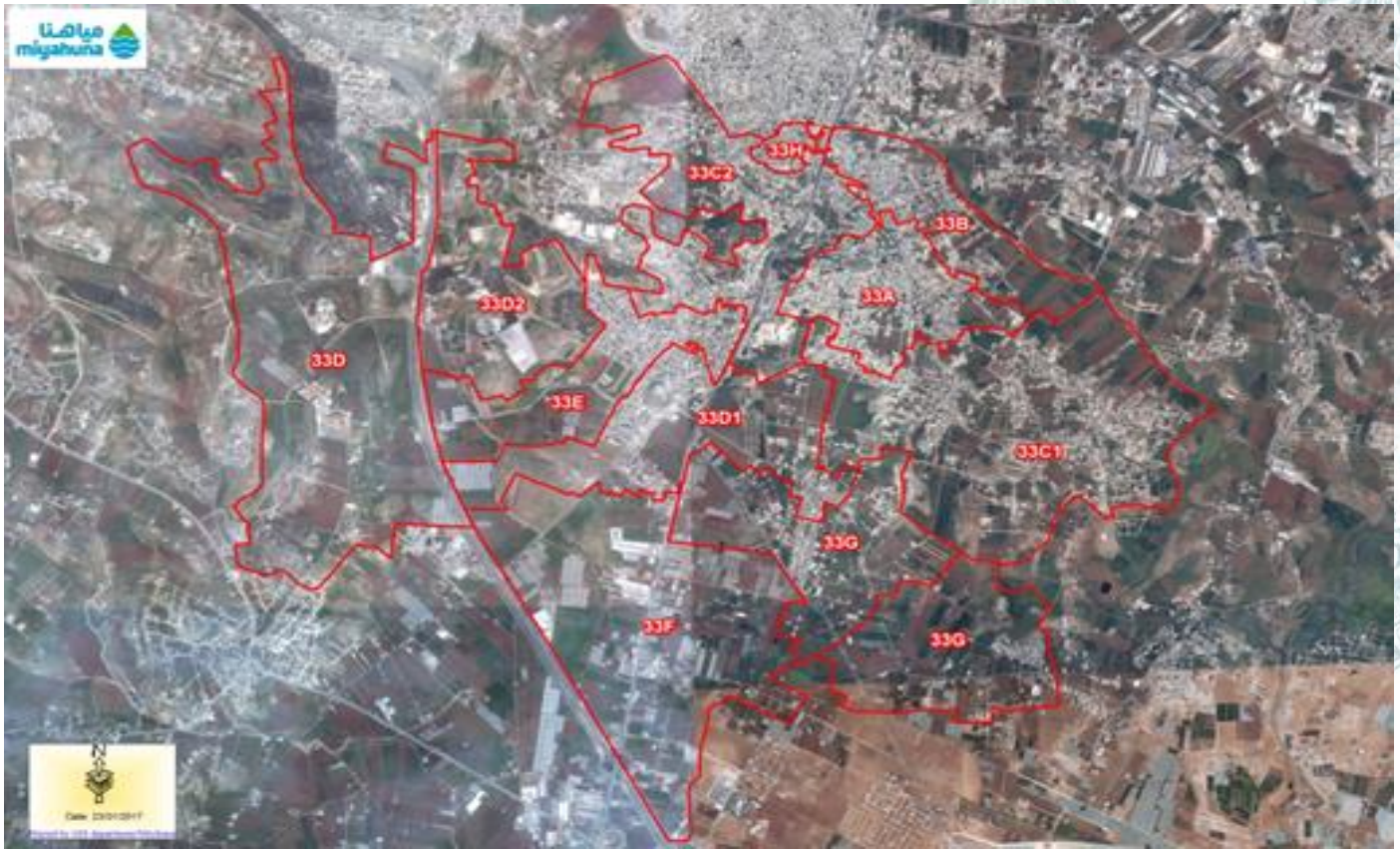
Present Conditions (After Hydraulic modeling)

This Hydraulic model divided DZ-33 into Ten (10) districts, A, B, C1, C2, D1, D2, E.F, G and H.



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Characteristics of the distribution zone

The characteristics of the 10 districts in the Yadoudeh are listed as it is in the table

DMA Name	Customers	Area (km^2)
33 A	1507	1.53
33 B	1171	5.65
33 C1	1323	3.43
33 C2	2099	6.58
33 D1	974	2.42
33 D2	22	2
33 E	1226	5.29
33 F	131	2.34
33 G	334	2.54
33 H	388	0.19
Total	**9175**	**31.97**

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Distribution zone analysis and hydraulic modeling

In order to reduce of NRW in DZ-33 there area group of activities and corrective actions that are conducted as the following:

- Hydraulic analysis and computer modeling were conducted for DZ-33 including installing new feeders and redefining the distribution zone and districts boundaries.
- Procurement of pipes, fitting, and valves .
- Pipe rehabilitation work and residential water meter installation.
- Measurements and quantifications of NRW.
- Pressure management and control (Design & Implementation)
- Districts and distribution zone isolation (10 districts) .

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Elevations analysis of the proposed districts (original model)

DMA name	Customers	Highest Elevation (m)	Lowest Elevation(m)	Difference in Elevation Within District (m)	Reservoir. Elevation (m)	Tower Elevation(m)	Static Head (m) Max. Elevation	Static Head (m) Min. Elevation
33 A	1507	923	857	66		933.5	76.5	10.5
33 B	1171	882	852	30	911		59	29
33 C1	1323	893	838	55		933.5	95.5	40.5
33 C2	2099	850	812	38	911		99	61
33 D1	974	875	803	72	911		108	36
33 D2	22	890	816	74	911		95	21
33 E	1226	874	824	50	911		87	37
33 F	131	877	785	92	911		126	34
33 G	334	841	793	48	911		118	70
33 H	388	890	860	30		933.5	73.5	43.5
Total	9175							

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Average & Peak Demand of DZ 33

As it's indicated in the table, we realize that the total average demand for DZ 33 463m3/hr.

Average & Peak Demand of DZ 33									
DZ Name	Customers from GIS	No. of Persons	Population 2025	Current Demand (L/D)	Average Current Demand (m3/hr)	Peak Demand (m3/hr)	No. of Junctions	Ave. Demand/ Junction	Peak Demand/ Junction
33 A	1507	8,138	9118	1823540	76	266	200	0.38	1.33
33 B	1171	6,323	7085	1416964	59	207	147	0.40	1.41
33 C1	1323	7,144	8004	1600891	67	233	284	0.23	0.82
33 C2	2099	11,34	12699	2539887	106	370	281	0.38	1.32
33 D1	974	5,260	5893	1178585	49	172	155	0.32	1.11
33 D2	22	119	133	26621	1	4	3	0.37	1.29
33E	1226	6,620	7418	1483517	62	216	107	0.58	2.02
33 F	131	707	793	158516	7	23	27	0.24	0.86
33 G	334	1,804	2021	404155	17	59	65	0.26	0.91
33 H	388	2,095	2347	469498	20	68	28	0.70	2.45
Total	**9,175**				**463**	**1619**			

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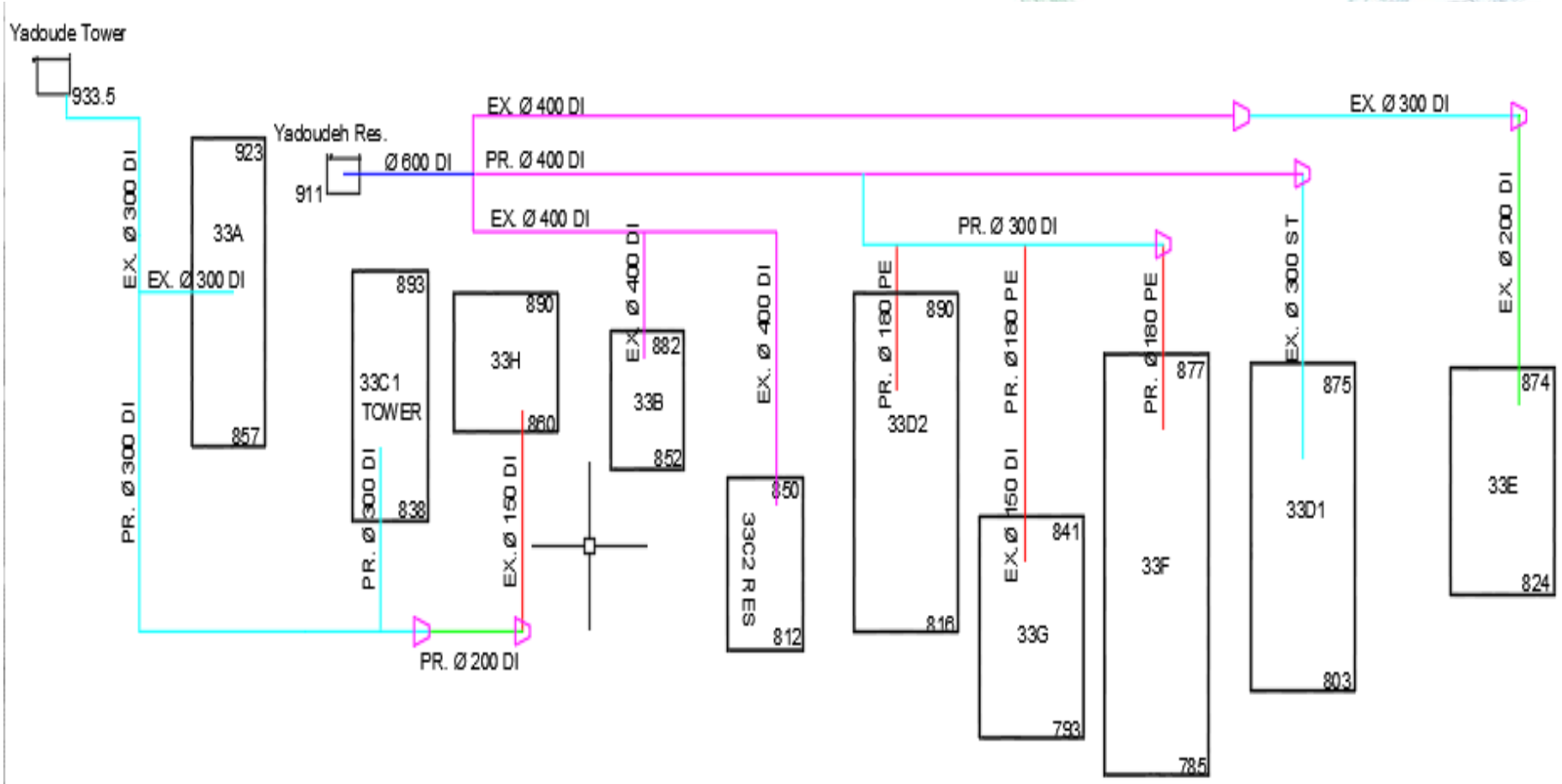
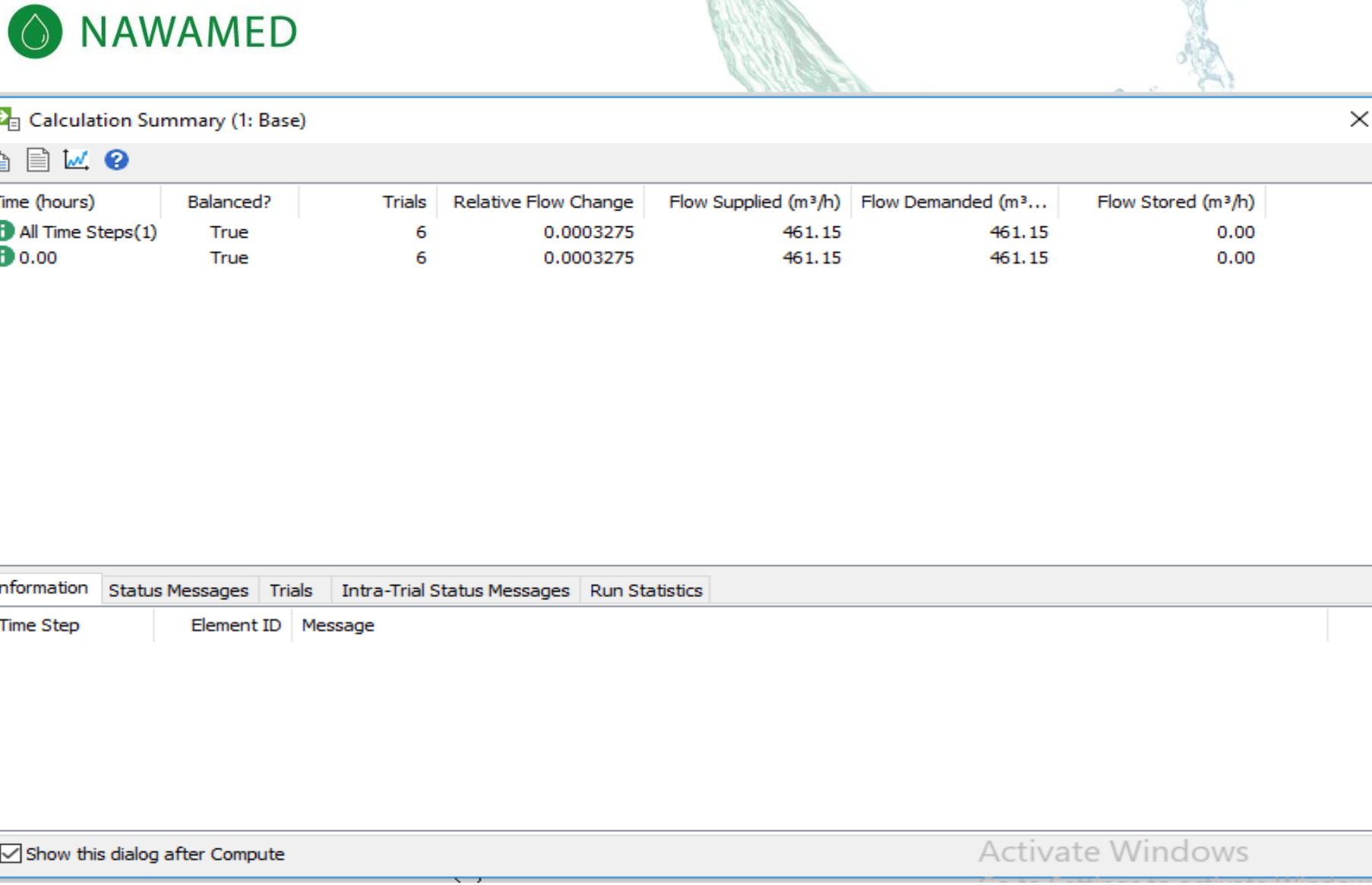
The schematic diagram of DZ33

Figure show the primary and secondary main feeders for each district in DZ 33



Calculation Summary



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Determination and quantification of NRW

Table illustrate NRW measurements and calculations

Intervention	Remarks	NRW%
Isolation (baseline)	Hydraulic isolation of 10 districts in DZ-33	36%
Water meter replacement	Replacement of 1,041 mechanical water meters to E33 -DZIN ultrasonic	27%
Rehabilitation, leak detection campaign	Broken lines, illegal use	24.6%

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Summary of DZ 33 flow balance results

As it is indicated in table, the NRW values baseline at Yadoudeh area (DZ33) was 36.3% in 2016 then decreased to 24.6% at the end of 2017 after the rehabilitation works made, then increased to (40-50) % at the beginning of 2019.

DMA	MONTH	NRW%
2016		
DZ 33E	Aug-16	36.30%
DZ 33E	Sep-16	36.00%
DZ 33E	Oct-16	36.60%
DZ 33E	Nov-16	24.70%
2017		
DZ 33E	Jun-17	23.85%
DZ 33E	Dec-17	24.63%
2018		
DZ 33E	Feb-18	28.19%
DZ 33E	May-18(1/5-9/5)018	37.05%
DZ 33 E	May-18(21/5-28/5)018	25.09%
DZ 33E	May-18(30/5/018)	35.16%
DZ 33E	Aug-18	28.25%
DZ 33E	Nov-18	30.25%
2019		
DZ 33E	Jan-19	50%
DZ 33E	Feb-19	38%
DZ 33E	Mar-19	45%
DZ 33E	Apr-19	42%

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Hydraulic modeling using Water GEMS software

In this field and to reduce NRW value, new hydraulic model using Water GEMS software, is suggested by the researcher.

New hydraulic model includes a lot of corrective actions for district E:

- Redefining E district boundaries by dividing E districts to 4 DMAs E1, E2, E3, and E4 with individual main feeder for each one.
- 150 mm Poly Ethylene (PE) pipe was proposed as main feeder at the entrance of district E3 including probability of future expansion in district.
- New water meter were added at the entrance of proposed districts E1, E2, E4.
- Two Pressure Reducer Valves (PRV) was added at the proposed district E1 and the entrance of E3.

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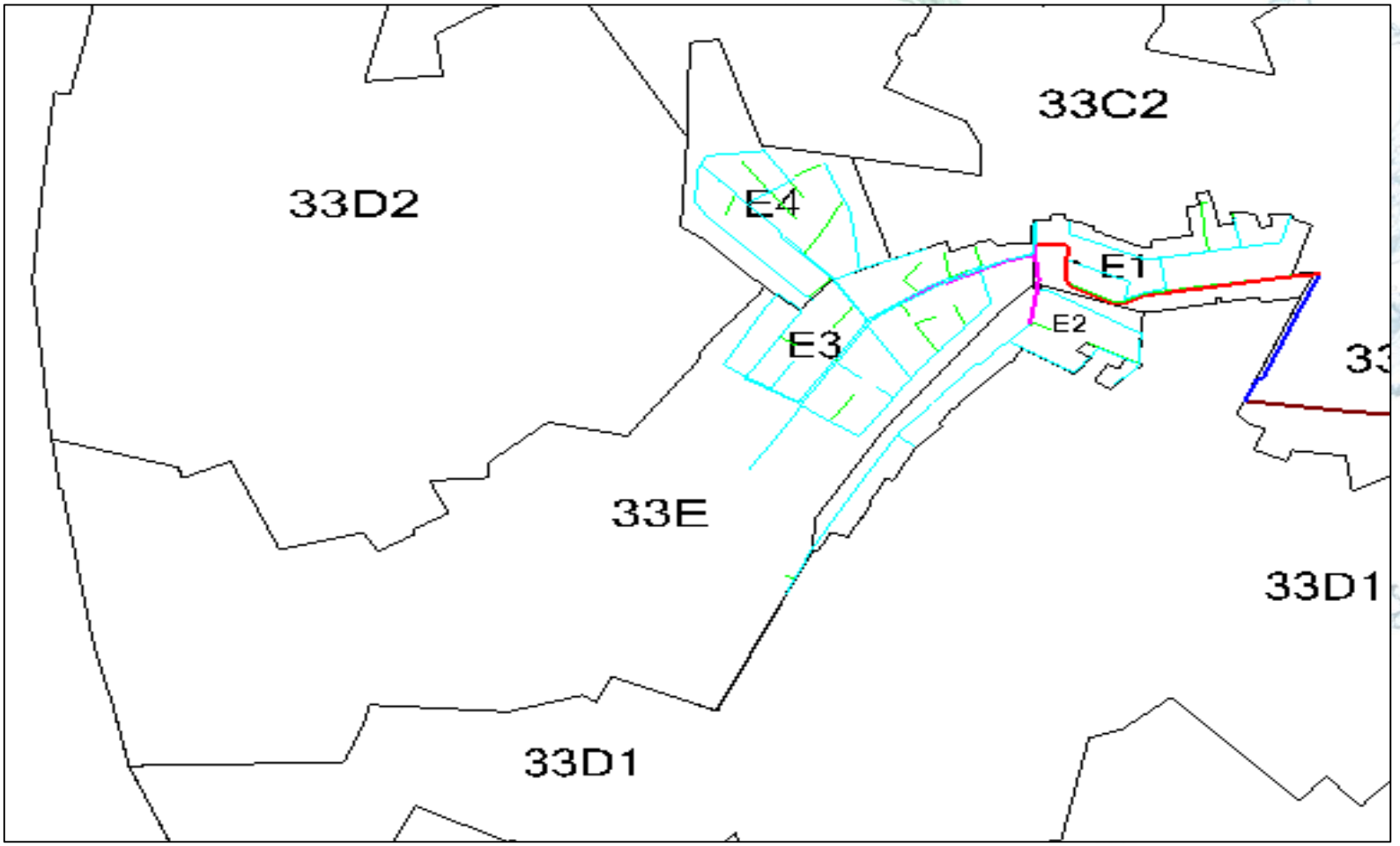
New boundaries of district E. Its worked through the Water GEMS software



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Elevations of the proposed districts

DMA name	Customers	Highest elevation (m)	Lowest elevation (m)	Difference in elevation within district (m)	Reservoir Elevation (m)	Static head (m) max. Elevation	Static head (m) min. Elevation
E1	236	850	825	25	911	86	61
E2	197	845	819	26	911	92	66
E3	476	854	818	36	911	93	57
E4	317	883	830	53	911	81	28

Average& peak demand of the proposed districts of E in DZ 33

DZ name	Customers from GIS	No. of persons	Population 2020	Current demand (L/D)	Average current demand (m^3/hr)	Peak demand (m^3/hr)	No. of junctions	Average demand /junction	Peak demand/ junction
E1	236	1,274	1428	285571	12	42	20	0.59	2.08
E2	197	1,064	1192	238379	10	35	9	1.10	3.86
E3	476	2,570	2880	575982	24	84	34	0.71	2.47
E4	317	1,712	1918	383585	16	56	24	0.67	2.33

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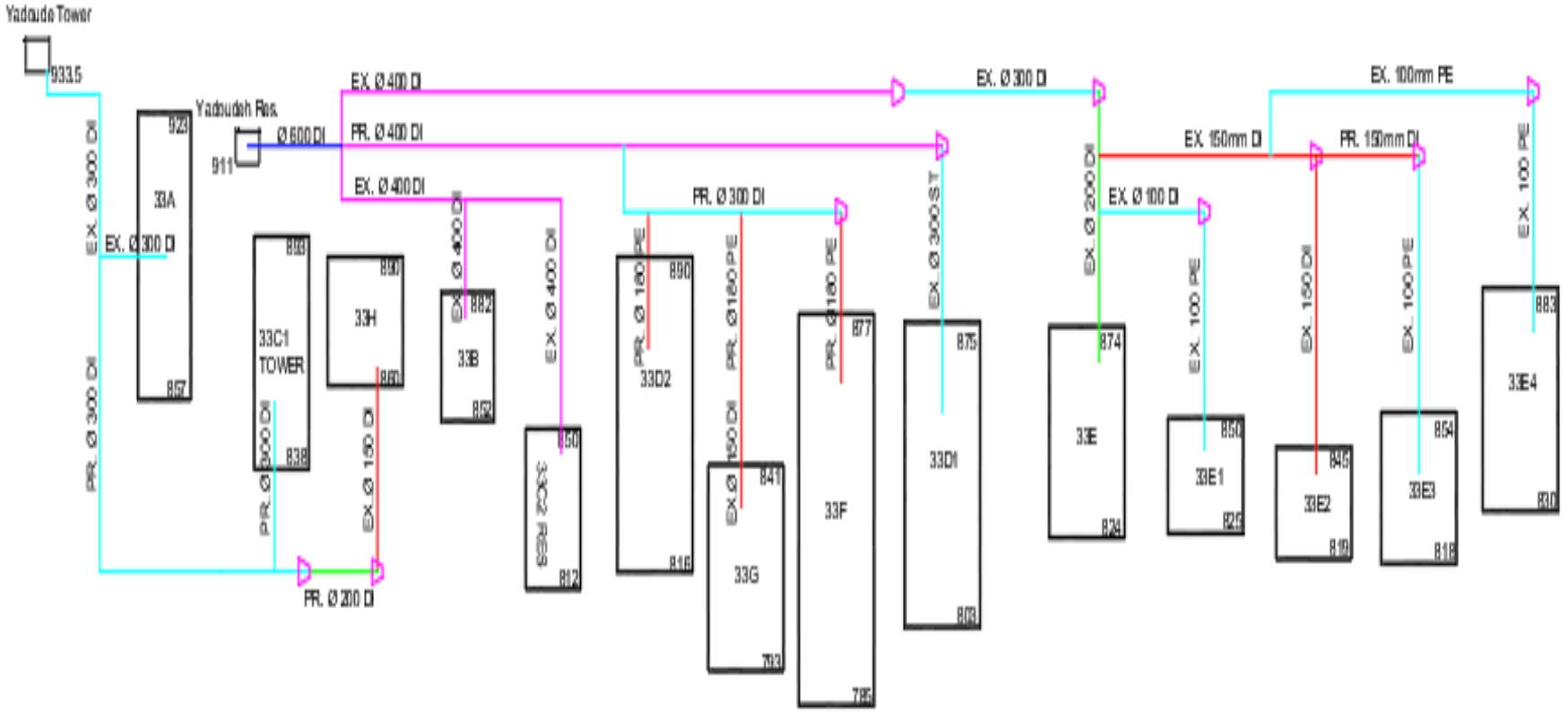
The proposed schematic diagram of DZ33



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It can be seen from the tables below, after the implementation of the correct parameters, the pressure decreased from 8.5 bar to (2-6) bar

Flex table-Pipe table of E4

FlexTable: Pipe Table (Current Time: 0.000 hours) (DZ33-ONLY E..wtg)

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	zen-Willia C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (m³/h)	Velocity (m/s)	Headloss Gradient (m/m)	Has User Defined Length?	Length (User Defined) (m)	Age (Calculated) (hours)	Age (Maximum) (hours)	Is Active?
389: E4-13	389	E4-13	3	E4-5	E4-8	50.0	PE	130.0	☐	0.000	1.76	0.25	0.002	☐	0	(N/A)	(N/A)	☑
4581: E4-14	4581	E4-14	71	E4-21	E4-22	50.0	PE	130.0	☐	0.000	-1.76	0.25	0.002	☐	0	(N/A)	(N/A)	☑
5548: E4-15	5548	E4-15	64	E4-9	E4-2	50.0	PE	130.0	☐	0.000	1.76	0.25	0.002	☐	0	(N/A)	(N/A)	☑
8413: E4-16	8413	E4-16	101	E-27	E4-10	50.0	PE	130.0	☐	0.000	-1.76	0.25	0.002	☑	101	(N/A)	(N/A)	☑
8435: E4-17	8435	E4-17	172	E4-16	E4-20	50.0	PE	130.0	☐	0.000	-1.76	0.25	0.002	☑	177	(N/A)	(N/A)	☑
9675: E4-18	9675	E4-18	49	E4-15	E4-8	50.0	PE	130.0	☐	0.000	-1.76	0.25	0.002	☐	0	(N/A)	(N/A)	☑
9676: E4-19	9676	E4-19	3	E4-8	E4-5	50.0	PE	130.0	☐	0.000	-1.76	0.25	0.002	☐	0	(N/A)	(N/A)	☑
9686: E4-20	9686	E4-20	91	E4-13	E4-17	50.0	PE	130.0	☐	0.000	1.76	0.25	0.002	☐	0	(N/A)	(N/A)	☑
9713: E4-21	9713	E4-21	72	E4-4	E4-3	50.0	PE	130.0	☐	0.000	-1.76	0.25	0.002	☐	0	(N/A)	(N/A)	☑
1809: E4-6	1809	E4-6	8	E4-10	E4-11	100.0	PE	130.0	☐	0.000	-3.53	0.12	0.000	☐	0	(N/A)	(N/A)	☑
5590: E4-10	5590	E4-10	65	E4-23	E-7	100.0	PE	130.0	☐	0.000	-5.29	0.19	0.001	☐	0	(N/A)	(N/A)	☑
8541: E4-7	8541	E4-7	12	E4-12	E4-13	100.0	PE	130.0	☐	0.000	3.53	0.12	0.000	☑	12	(N/A)	(N/A)	☑
8581: E4-8	8581	E4-8	18	E4-5	E4-3	100.0	PE	130.0	☐	0.000	3.53	0.12	0.000	☑	18	(N/A)	(N/A)	☑
9095: E4-2	9095	E4-2	167	E-98	E4-23	100.0	PE	130.0	☐	0.000	-1.76	0.06	0.000	☐	0	(N/A)	(N/A)	☑
9096: E4-3	9096	E4-3	317	E4-23	E4-6	100.0	PE	130.0	☐	0.000	1.76	0.06	0.000	☐	0	(N/A)	(N/A)	☑
9602: E4-12	9602	E4-12	265	E4-1	E4-7	100.0	PE	130.0	☐	0.000	6.35	0.22	0.001	☑	265	(N/A)	(N/A)	☑
9634: E4-23	9634	E4-23	2	E4-7	E4-5	100.0	PE	130.0	☐	0.000	8.82	0.31	0.001	☑	2	(N/A)	(N/A)	☑
10301: E4-27	10301	E4-27	56	E4-14	E4-12	100.0	PE	130.0	☐	0.000	14.83	0.52	0.004	☑	56	(N/A)	(N/A)	☑
10499: E4-24	10499	E4-24	5	E4-12	E4-11	100.0	PE	130.0	☐	0.000	9.53	0.34	0.002	☑	5	(N/A)	(N/A)	☑
10500: E4-9	10500	E4-9	53	E4-11	E4-7	100.0	PE	130.0	☐	0.000	4.24	0.15	0.000	☑	54	(N/A)	(N/A)	☑
11793: E4-22	11793	E4-22	493	J-4423	E4-1	100.0	PE	130.0	☐	0.000	6.51	0.23	0.001	☑	493	(N/A)	(N/A)	☑
9757: E4-5	9757	E4-5	40	E4-9	E4-14	100.0	DI	120.0	☐	0.000	-5.14	0.18	0.001	☐	0	(N/A)	(N/A)	☑
10892: E4-4	10892	E4-4	63	E4-18	E4-20	100.0	DI	120.0	☐	0.000	-1.76	0.06	0.000	☑	63	(N/A)	(N/A)	☑
11253: E4-11	11253	E4-11	95	E4-20	E4-22	100.0	DI	120.0	☐	0.000	-5.29	0.19	0.001	☑	95	(N/A)	(N/A)	☑
11738: E4-1	11738	E4-1	119	E4-1	E4-9	100.0	DI	120.0	☐	0.000	-1.61	0.06	0.000	☑	119	(N/A)	(N/A)	☑
11795: E4-25	11795	E4-25	5	E4-22	E4-24	100.0	Ductile I	130.0	☐	0.000	8.64	0.31	0.001	☐	0	(N/A)	(N/A)	☑
11798: E4-28	11798	E4-28	294	E4-19	E4-14	100.0	DI	120.0	☐	0.000	21.73	0.77	0.009	☑	292	(N/A)	(N/A)	☑
11799: E4-26	11799	E4-26	3	E4-24	E4-19	100.0	Ductile I	130.0	☐	0.000	8.64	0.31	0.001	☐	0	(N/A)	(N/A)	☑

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Flex table- Junction table of E4

FlexTable: Junction Table (Current Time: 0.000 hours) (DZ33-ONLY E..wtg)

	ID	X (m)	Y (m)	Label	Elevation (m)	Zone	Demand Collection	Demand (m³/h)	Hydraulic Grade (m)	Pressure (bars)	Is Active?
5441: E4-1	5441	235,872.54	140,517.51	E4-1	861.00	E	<Collection:	1.76	888.44	2.69	☑
5549: E4-2	5549	235,928.25	140,375.07	E4-2	858.00	E	<Collection:	1.76	888.32	2.97	☑
1576: E4-3	1576	236,081.78	140,482.50	E4-3	855.53	E	<Collection:	1.76	888.23	3.20	☑
6068: E4-4	6068	236,145.20	140,517.09	E4-4	855.00	E	<Collection:	1.76	888.08	3.24	☑
7800: E4-6	7800	236,154.19	140,524.83	E4-6	855.00	E	<Collection:	1.76	891.01	3.52	☑
390: E4-5	390	236,075.57	140,470.36	E4-5	854.82	E	<Collection:	1.76	888.24	3.27	☑
3115: E4-7	3115	236,073.51	140,469.20	E4-7	854.75	E	<Collection:	1.76	888.24	3.28	☑
391: E4-8	391	236,077.05	140,468.27	E4-8	854.69	E	<Collection:	1.76	888.23	3.28	☑
2387: E4-9	2387	235,952.16	140,434.75	E4-9	854.00	E	<Collection:	1.76	888.45	3.37	☑
1810: E4-10	1810	236,024.41	140,447.69	E4-10	853.50	E	<Collection:	1.76	888.26	3.40	☑
1811: E4-11	1811	236,028.58	140,440.90	E4-11	853.09	E	<Collection:	1.76	888.26	3.44	☑
1063: E4-12	1063	236,024.00	140,438.03	E4-12	852.93	E	<Collection:	1.76	888.27	3.46	☑
1600: E4-13	1600	236,032.87	140,437.95	E4-13	852.92	E	<Collection:	1.76	888.27	3.46	☑
363: E4-14	363	235,978.76	140,405.06	E4-14	852.00	E	<Collection:	1.76	888.48	3.57	☑
5001: E4-15	5001	236,105.60	140,428.07	E4-15	849.00	E	<Collection:	1.76	888.13	3.83	☑
6091: E4-16	6091	236,195.55	140,414.35	E4-16	846.00	E	<Collection:	1.76	890.59	4.36	☑
2330: E4-18	2330	236,064.32	140,315.80	E4-18	845.00	E	<Collection:	1.76	890.96	4.50	☑
6458: E4-17	6458	236,087.33	140,365.11	E4-17	845.00	E	<Collection:	1.76	888.08	4.22	☑
11796: E4-19	11796	236,172.03	140,193.20	E4-19	842.08	<None>	<Collection:	0.00	891.01	4.79	☑
1061: E4-20	1061	236,106.42	140,268.91	E4-20	841.00	E	<Collection:	1.76	890.96	4.89	☑
3808: E4-21	3808	236,122.86	140,147.06	E4-21	837.00	E	<Collection:	1.76	890.87	5.27	☑
1761: E4-22	1761	236,171.40	140,199.30	E4-22	834.00	E	<Collection:	1.76	891.02	5.58	☑
11794: E4-24	11794	236,174.76	140,195.12	E4-24	833.00	<None>	<Collection:	0.00	891.02	5.68	☑
5591: E4-23	5591	236,234.98	140,221.54	E4-23	831.00	E	<Collection:	1.76	891.03	5.88	☑

Calculation summary

As the calculation summary show in Figure below, peak flow supplied=flow demanded=1614m^3/hr and its very close to the calculated demanded = 1618m^3/ hr.

Calculation Summary (11810: PEAK)

Time (hours)	Balanced?	Trials	Relative Flow Change	Flow Supplied (m³/h)	Flow Demanded (m³...	Flow Stored (m³/h)
All Time Steps(1)	True	7	0.0001056	1,614.04	1,614.04	0.00
0.00	True	7	0.0001056	1,614.04	1,614.04	0.00

Information | Status Messages | Trials | Intra-Trial Status Messages | Run Statistics

Time Step	Element ID	Message

☑ Show this dialog after Compute

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AWWA analysis

Water balance in Yadoudeh (DZ33) distribution network

- According to the water balance of the case study Yadoudeh (DZ33), the total water been supplied was about 2.929 MCM while the total billed consumption amounts to 1.784 MCM.
- The Non-Revenue Water for DZ33 is 26.1% in 2018 which constitutes about 0.765 MCM. As it can be inferred that the model shows that 0.382 MCM (64%) of water losses are real losses while 0.216 MCM (36%) accounts for apparent losses.

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AWWA Free Water Audit Software: Reporting Worksheet

WAS v5.0
American Water Works Association.

Click to access definition
Click to add a comment

Water Audit Report for: Migahuna-Jordan Water Company
Reporting Year: 2018 1/2018 - 12/2018

To select the correct data grading for each input, determine the highest grade where the utility meets or exceeds all criteria for that grade and all grades below

Master Meter and Supply Error Adjustments

WATER SUPPLIED

(Enter grading in column 'E' and 'J')

			Pcnt:	Value:	
Volume from own sources:	2,929.280	ML/Yr			ML/Yr
Water imported:	0.000	ML/Yr			ML/Yr
Water exported:	0.000	ML/Yr			ML/Yr

Enter negative % or value for under-registration
Enter positive % or value for over-registration

WATER SUPPLIED: 2,929.280 ML/Yr

AUTHORIZED CONSUMPTION

Click here: for help using option buttons below

			Pcnt:	Value:	
Billed metered:	1,784.200	ML/Yr			
Billed unmetered:	380.452	ML/Yr			
Unbilled metered:	130.211	ML/Yr			
Unbilled unmetered:	36.616	ML/Yr	1.25%		ML/Yr

Default option selected for Unbilled unmetered - a grading of 5 is applied but not displayed

Use buttons to select percentage of water supplied OR value

AUTHORIZED CONSUMPTION: 2,331.479 ML/Yr

WATER LOSSES (Water Supplied - Authorized Consumption) 597.801 ML/Yr

Apparent Losses

			Pcnt:	Value:	
Unauthorized consumption:	7.323	ML/Yr	0.25%		ML/Yr

Default option selected for unauthorized consumption - a grading of 5 is applied but not displayed

Customer metering inaccuracies:	204.109	ML/Yr		204.109	ML/Yr
Systematic data handling errors:	4.461	ML/Yr	0.25%		ML/Yr

Default option selected for Systematic data handling errors - a grading of 5 is applied but not dis

Apparent Losses: 215.893 ML/Yr

Real Losses (Current Annual Real Losses or CARL)

Real Losses = Water Losses - Apparent Losses: 381.908 ML/Yr

WATER LOSSES: 597.801 ML/Yr

NON-REVENUE WATER

NON-REVENUE WATER: 764.628 ML/Yr

= Water Losses + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains:	335.8	kilometers	
Number of active AND inactive service connections:	5,400		
Service connection density:	16	conn./km main	
Are customer meters typically located at the curbstop or property line?			
Average length of customer service line:	8.0	metres	(length of service line, beyond the property boundary, that is the responsibility of the utility)
Average operating pressure:	85.0	metres (head)	

COST DATA

Total annual cost of operating water system:	$2,646,665	$/Year
Customer retail unit cost (applied to Apparent Losses):	$0.86	$/1000 litres
Variable production cost (applied to Real Losses):	$6.62	$/Megalitre

☐ Use Customer Retail Unit Cost to value real losses

WATER AUDIT DATA VALIDITY SCORE:

*** YOUR SCORE IS: 67 out of 100 ***

A weighted scale for the components of consumption and water loss is included in the calculation of the Water Audit Data Validity Score

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components:

1: Volume from own sources
2: Billed metered
3: Customer metering inaccuracies

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The water balance in DZ 33 (Yadoudeh) distribution network

Water Audit Report for:	Miyahuna-Jordan Water Company
Reporting Year:	2018 (1/2018 - 12/2018)
Data Validity Score:	67

		Water Exported 0.000			Billed Water Exported	Revenue Water 0.000
Own Sources (Adjusted for known errors) 2,929.280	System Input 2,929.280	Water Supplied 2,929.280	Authorized Consumption 2,331.479	Billed Authorized Consumption 2,164.652	Billed Metered Consumption (water exported is removed) 1,784.200	Revenue Water 2,164.652
					Billed Unmetered Consumption 380.452	
				Unbilled Authorized Consumption 166.827	Unbilled Metered Consumption 130.211	Non-Revenue Water (NRW) 764.628
					Unbilled Unmetered Consumption 36.616	
			Water Losses 597.801	Apparent Losses 215.893	Unauthorized Consumption 7.323	
					Customer Metering Inaccuracies 204.109	
					Systematic Data Handling Errors 4.461	
Water Imported 0.000				Real Losses 381.908	Leakage on Transmission and/or Distribution Mains Not broken down	
					Leakage and Overflows at Utility's Storage Tanks Not broken down	
					Leakage on Service Connections Not broken down	

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System attributes and performance indicators of DZ33 (Yadoudeh) distribution network

AWWA Free Water Audit Software:
System Attributes and Performance Indicators

WAS v5.0

Water Audit Report for: Miyahuna-Jordan Water Company
Reporting Year: 2018 | 1/2018 - 12/2018

*** YOUR WATER AUDIT DATA VALIDITY SCORE IS: 67 out of 100 ***

Return to Reporting Worksheet to change this assumption

Performance Indicators:

Financial:	Non-revenue water as percent by volume of Water Supplied:	26.1%	
	Non-revenue water as percent by cost of operating system:	7.2%	Real Losses valued at Variable Production Cost
Operational Efficiency:	Apparent Losses per service connection per day:	109.53	litres/connection/day
	Real Losses per service connection per day:	N/A	litres/connection/day
	Real Losses per length of main per day*:	3,116.19	litres/km/day
	Real Losses per service connection per day per meter (head) pressure:	N/A	litres/connection/day/m
	From Above, Real Losses = Current Annual Real Losses (CARL):	381.91	ML/year
	? nfrastructure Leakage Index (ILI) [CARL/UARL]:	1.08	

* This performance indicator applies for systems with a low service connection density of less than 20 service connections/kilometre of pipeline

Real loss component analysis

Summary of real loss component analysis

REAL LOSS COMPONENT ANALYSIS RESULTS				
System Component	Background Leakage	Reported Failures	Unreported Failures	Total
	(ML)	(ML)	(ML)	(ML)
Reservoirs	-	-	-	-
Mains and Appurtenances	131.46	45.56	-	**177.02**
Service Connections	160.31	89.83	-	**250.14**
Total Annual Real Loss	**291.77**	**135.40**	-	**427.17**
			Real Losses as Calculated by Water Audit	**381.91**
			Hidden Losses/Unreported Leakage Currently Running Undetected	- **45.26**

Failure frequency analysis

The Infrastructure failure frequency analysis here in main pipes and service connections for water distribution network in Yadoudeh in comparison with the average failure frequency in North America is indicated in Figures below.

WaterRF 4372: Real Loss Component Analysis: A Tool for Economic Water Loss Control

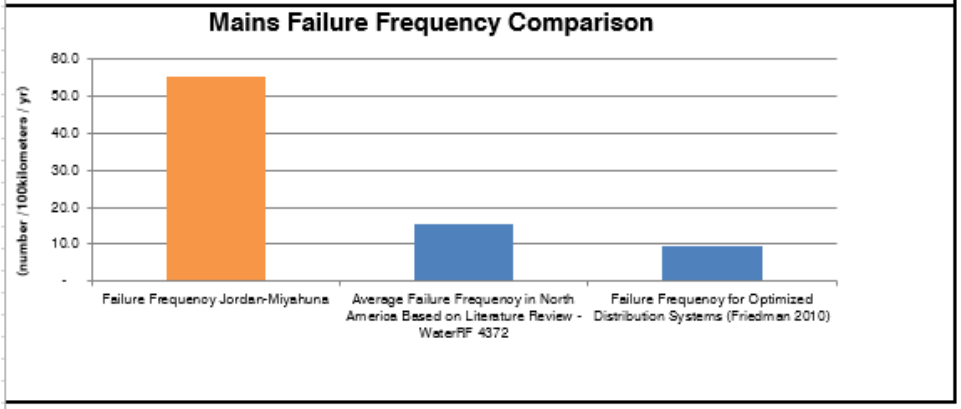
Water Audit: Jordan-Miyahuna, Amman, Jordan, 2018

INFRASTRUCTURE FAILURE FREQUENCY ANALYSIS

Value to be entered by the user		
Value is automatically filled in/calculated by Model		
Recommended default value		

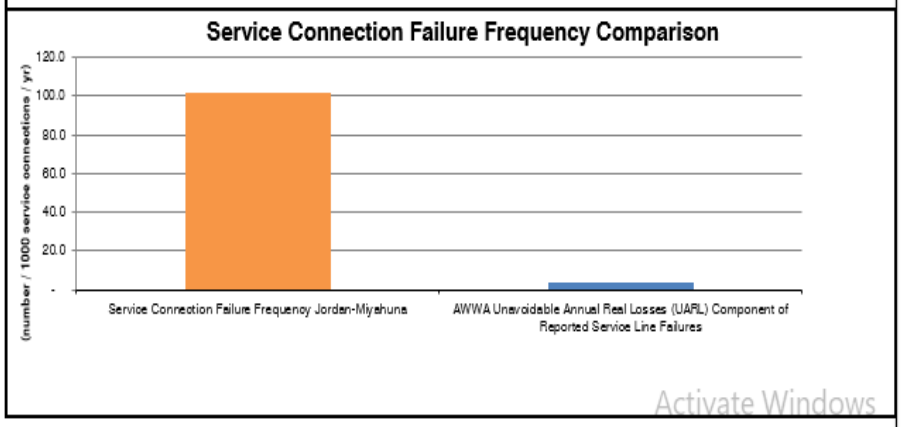
Jordan-Miyahuna

Total Number of Mains Failures Reported for Water Audit: Jordan-Miyahuna, Amman, Jordan, 2018	185	
Total Length of Mains	335.8	(kilometers)
Failure Frequency Jordan-Miyahuna	55.1	(number /100kilometers / yr)
Average Failure Frequency in North America Based on Literature Review - WaterRF 4372	15.5	(number /100kilometers / yr)
Failure Frequency for Optimized Distribution Systems (Friedman 2010)	9.3	(number /100kilometers / yr)



Jordan-Miyahuna

Total Number of Service Connection Failures Reported for Water Audit: Jordan-Miyahuna, Amman, Jordan, 2018	549	
Total Number of Service Connections	5,400	(service connections)
Service Connection Failure Frequency Jordan-Miyahuna	101.7	(number / 1000 service connections / yr)
AWWA Unavoidable Annual Real Losses (UARL) Component of Reported Service Line Failures	3.75	(number / 1000 service connections / yr)
Ratio of Failure Frequency to UARL Break Frequency	27.1	



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Awareness -location- repair time options for DZ33 (Yadoudeh)

Figure below show the total potential savings if location and repair time in the failures on main pipes and service connections is reduced to (30-50)% The total potential savings in leakage volume will be 0.062 MCM with a total potential cost savings is 407 USD.

Reported and Unreported Failure Events

Failures on Mains	*Reported*	*Unreported*	
Total Number of Failures on Mains in 2018	185	-	
Average location and repair duration	1.0	-	days
Total Volume lost (stemming from location and repair duration)	36.5	-	(ML)
Total Cost of Volume lost (stemming from location and repair duration)	$ 241	$ -	
What IF Location and Repair Duration is Reduced to	0.3		days
Percent Reduction	70%	0%	
Potential Related Savings in Leakage Volume	25.5	-	(ML)
Potential Related Savings in Leakage Volume Cost	$ 169	$ -	

Service Line Failures	*Reported*	*Unreported*	
Total Number of Failures on Service Connections in 2018	549	-	
Average location and repair duration	1.0	-	days
Total Volume lost (stemming from location and repair duration)	71.9	-	(ML)
Total Cost of Volume lost (stemming from location and repair duration)	$ 476	$ -	
What IF Location and Repair Duration is Reduced to	0.5		days
Percent Reduction	50%	0%	
Potential Related Savings in Leakage Volume	35.9	-	(ML)
Potential Related Savings in Leakage Volume Cost	$ 238	$ -	

Failures on System Appurtenances	*Reported*	*Unreported*	
Total Number of Failures on System Appurtenances in 2018	-	-	
Average location and repair duration	-	-	days
Total Volume lost (stemming from location and repair duration)	-	-	(ML)
Total Cost of Volume lost (stemming from location and repair duration)	$ -	$ -	
What IF Location and Repair Duration is Reduced to			days
Percent Reduction	0%	0%	
Potential Related Savings in Leakage Volume	-	-	(ML)
Potential Related Savings in Leakage Volume Cost	$ -	$ -	
Total Potential Savings if Location and Repair Duration is Reduced as Simulated in the Above Sections	61.4	-	(ML)
Total Potential Cost Savings if Location and Repair Duration is Reduced as Simulated in the Above Sections	$ 407	$ -	Per Year

14-10-19

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Economic intervention frequency

The calculation of economic intervention frequency for proactive leak detection

WaterRF 4372: Real Loss Component Analysis: A Tool for Economic Water Loss Control

Water Audit: Jordan-Miyahuna, Amman, Jordan, 2018

CALCULATION OF ECONOMIC INTERVENTION FREQUENCY FOR PROACTIVE LEAK DETECTION

	System Characteristics		
	Total Length of Mains	335.8	kilometers
	Number of Service Connections	5,400	service connections
	Service Connection Density	16.1	conn./kilometer main
	Average System Pressure	85.0	metres (head)

	Water Balance Results		
TBL	Current Annual Background Leakage	291.77	ML/Yr
CRL	Real Losses from Current Reported Leakage	135.40	ML/Yr
UL	Unreported Failures Identified Through Existing Proactive Leak Detection Program	-	ML/Yr
	Hidden Failures/Unreported Failures not Identified or Captured by Current Leakage Management Policy	- 45.26	ML/Yr
CARL	Current Annual Real Losses	381.91	ML/Yr
UARL	Unavoidable Annual Real Losses	355.06	ML/Yr
	Infrastructure Leakage Index (ILI) [CARL/UARL]	1.1	

	Variable Cost of Real Losses		
CV	Variable Production cost (applied to Real Losses):	0.01	$/m3
		6.62	$/ML
CI	Cost of comprehensive leak detection survey (excluding leak repair cost)	90.00	$/km
		30,222	$/for entire system
RR	Average Rate of Rise of Unreported Leakage	3.00	m3/km of mains/day in a year
		1.01	ML/day in a year
	CI/CV	13595.2	m3/km
EIF	Economic Intervention Frequency [0.789 * (CI/CV)/RR] ^0.5	59.8	months
		1,818.8	days
	Economic Intervention Frequency - Average Leak Run Time	909.4	days
	Economic Percentage of System to be Surveyed per Year	20	%
ABI	Average Annual Budget for Intervention (Proactive Leak Detection)	6,065	$/year
EUL	Economic Unreported Real Losses	916,171	m3/year
		916.2	ML/year
	Economic Infrastructure Leakage Index (ILI)	3.8	
PRL	Potentially Recoverable Leakage (CARL-CRL-EUL-TBL-UL)	- 961.4	ML/year

Pressure management options

The estimated cost for the implementation of the alternative pressure management policy in order to minimize the pressure to 50 meters head is almost 4 million USD. The simple payback Period for implementing alternative pressure management policy is 2.7 years.

Pressure management has an effect of the volume of real losses. Also it has another benefits and impacts such as; reduction in infrastructure failure numbers, reduction in the annual cost of repair and maintenance, increasing infrastructure lifetime.

Pressure Management Opportunities

	Existing Pressure Management Policy	
Current Average System Pressure	85.0	metres (head)
Total Annual Real Losses	381.9	ML/Yr
Value of Real Losses	2,528	$/year

FAVAD N1 Value Used for Calculation of Real Loss Reduction Due to Reduction of Average System Pressure

	(•) Use Default N1	1.0
	( ) Use System Specific N1	1.2
Enter % of rigid pipes and service connections in system	71%	
ILI	1.1	

	Alternative Pressure Management Policy	
Assumed Reduction in Average System Pressure	50.0	metres (head)
Assumed % Reduction in Average System Pressure	59%	
Real Loss Volume Saved Through Alternative Pressure Management Policy	224.7	ML/Yr
Value of Real Loss Volume Saved Through Alternative Pressure Management Policy	1,487	$/Year
Enter Estimated Cost of Implementing Alternative Pressure Management Policy	4,000,000	$
Simple Payback Period for Implementing Alternative Pressure Management Policy	2,689.6	Years

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4 Conclusions and Recommendations

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Conclusions

- **The NRW values base line 36.3% in 2016 then decreasing to reach 24.63% at the end of 2017 after rehabilitation works then increase to (40- 50)% at the beginning of 2019.**
- **New hydraulic model is proposed using Water GEMS software aim to reduce pressure values from 85bar to (2-6) bar.**
- **DZ-33 was further subdivided to additional districts, Because of the redistricting, the number of DZ- 33 districts increased from 8 to 10 according to original hydraulic analysis model and from 10 to 13 according to new proposed model.**
- **Leakage frequencies are so significant in Yadoudeh which indicates to low efficiency of the distribution system. About 95 % of leaks are recorded in the service connections in which pipe diameters are less than 100 mm and most of the leaks took place in polyethylene.**
- **DZ 33 (Yadoudeh) water balance was developed based on AWWA water audit software according to the data provided to the model its revealed that the total water supplied about 3 MCM while the total billed consumption amounts to 1.784 MCM.**

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Conclusions

- **The Non-Revenue Water for DZ33 in 2018 constitutes about 0.765 MCM.**
- **As it can be inferred that the model shows that 64% of water losses are real losses while 36% accounts for apparent losses.**
- **The component analysis found that the total annual reported losses in main pipes are 0.045 MCM while the total reported losses in service connections are 0.090 MCM**
- **The estimated cost for the implementation of the alternative pressure management policy in order to minimize the pressure to 50 meters head is almost 4 million USD. The simple payback Period for implementing alternative pressure management policy is 2.7 years.**

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Recommendations

- **There is need to identified water loss areas at distribution areas of the network in other areas to conserve water in Jordan.**
- **It is recommended to automate the data collection process in the distribution network that can be simply ease the work and enhance the data accuracy. Updating GIS maps have also a critical impact on data analysis.**
- **The hotspots area located in district E. so it's recommended to make cross sections at the borders of E1, E2, E3, E4 districts including excavation works to determine if there is any pipes at location and not identify in the drawings.**
- **It is recommended instead of rehabilitating the entire network to apply systematic pipe replacements.**
- **It is recommended to increase the accuracy of meters and billing system through the other districts of DZ 33 and applying automatic meter reading (AMR)**

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Thank you