Dirasat, Engineering Sciences, Volume **32**, No. **1**, 2005

Reduction of Leakage in Drinking Water Supply Systems: Ramallah District as a Case Study, Palestine

Ziad Mimi *

ABSTRACT

Water is one of the most valuable natural resources in Palestine. Therefore, it is very crucial for the Palestinians to achieve maximum efficiency in the management of their water resources. Many Palestinian localities still lack the existence of water networks while many others suffer from the poor conditions and high losses in their networks. This paper presents a method to determine water leakage and procedures for leakage reduction in the existing network in Ramallah District. The method is based on three main steps: (1) tracing leaks of the supply network; (2) pinpointing the leaks; (3) repairing leaks. Consequently, the amount of leakage for the study area will be largely reduced (from 5.6 L/sec to 0.16 L/sec).

KEYWORDS: Leakage detection, Water conservation, Water losses, Distribution Networks, Water Supply Systems.

1. INTRODUCTION

Palestine is composed of two separate areas, Gaza Strip and the West Bank. The West Bank is bounded to the east by the Jordan River and the Dead Sea and to the west north and south by the country of Israel (Figure 1). Water research studies for Palestine are required to cater for existing requirements. Research goals include preservation and protection of aquifers, improving efficiency of water distribution and use, securing reliable sources of supply to meet future water demands, and development of centralized national data banks and trained national cadres in water resource science and technology. Different partners are involved in rebuilding and reshaping the Palestinian water sector, against the background of ongoing regional negotiations for sharing water resources.

Jerusalem Water Undertaking (JWU) provides water to the population of the Ramallah District (the case study of this research). The water losses in the supply network are high (JWU, 2000); therefore, the main objective of this paper is to study leakage in the existing network and to suggest solutions to reduce leakage.

* Department of Civil Engineering, Birzeit University, Palestine. Received on 6/5/2004 and Accepted for Publication on 9/3/2005.

Evaluation of Leakage in Drinking Water Supply Systems

Losses during distribution (water loss) includes both: (1) Physical losses (known as leakage) which is the amount of water lost without being used due to failures and deficiencies in the distribution facilities. This includes leaking pipes, leaking pipe connections, leaking fittings (gate valves, hydrants, etc.) and (2) Non-physical losses which is that amount of water that is not registered due to measurement errors or water theft (Trow and Farley, 2003). Leakage will be within the scope of this research and will be evaluated and controlled. There are two major steps in any systematic leakage control program. These are:

(1) Water audits for tracing leaks: water audits involve detailed accounting of water flow into and out of the distribution system. The audits help to identify areas having excessive leakage. Many methods can be used for tracing leaks (Niemeyer et al., 1996). The Minimum Night Flow method was applied for the case study area. The Minimum Night Flow should be compared with the estimated Reference Flow (RF), if it is larger; this indicates the presence of leakage in the distribution

system. The flow for large night consumers should be measured and added to the RF. The Estimated Leakage (EL) is the difference between RF and the average minimum night flow as shown in Figure 2.

The flow can be measured by using electronic equipment, which is placed on the main water source pipeline that supplies the area. Flow is recorded for one week in order to ensure that the reading will repeat itself since it varies during days of the week. During this period, the large night consumption is recorded at night and it should be taken into account during data analysis. Fixed water meters and automatic data logging equipment are used in this method which include: (a) Aquaprobe that comprises an electromagnetic sensing head mounted on the end of a support rod; (b) Aquamaster which is a device that transmit the received data from aquaprobe to the loggermate and (c) Loggermate which is a recorder that takes the data from aquamaster, and save it until uploading is done.

(2) Pinpointing leaks (leak detection surveys): Unfortunately water audits for tracing leaks do not provide information about the specific location of leaks. In order to locate leaks in areas that have been identified by water audits, pinpointing leaks must be undertaken. Many methods can be used for pinpointing leaks (Niemeyer et al., 1996). The correlator analysis (Transit time method) was applied for the case study area. The main pieces of equipment that are used in this method are: Aquacorr, two microphone sensors and radio transmitter for wireless signal transmission from the microphone sensor to the Correlator (Figure 3). In this method, two sensors are placed directly on a continuous pipe, the distance between the two sensors is usually taken 100 m, but it should not exceed 500 m. The position of the leak is calculated from the speed of sound that depends on the material pipe, the length of the pipe section between the sensors, and the difference in transmitting time to the sensors. To determine the exact location of leakage, Equation 1 can be used.

$$a = (t*v - L)/2 \qquad \dots(1)$$

where:

a = unknown distance between leak and microphone A

v = speed of sound

L = pipe length between microphones A and B, and

t = difference in transit time = (2a - L)/v

Water Losses in Ramallah District

JWU provides water to the population of the Ramallah District. The total length of the distribution system including all the different sizes of pipes owned by JWU was about 750 km (JWU, 2000). The overall losses are about 25% of the total input in the distribution system, this percentage is high compared to the normal losses. Table (1) shows water loss analysis for the years 1996 – 2000.

To trace the leakage, the study area has been divided into seven sub-areas labelled from A to G. The division has been based on isolating the water distribution network of each area, so that each area has its own water-supplying source. The aim of dividing and isolating areas is to make leak detection easier, by tracing and pinpointing leak in each sub-area rather than doing that for the whole system at the same time. The following steps were carried out for each sub-area:

1. Data collection: this includes locating the main water sources and determining the network length.
2. Application of Pressure Zero Test (PZT): PZT was done to ensure that each separate area has its own water sources. The first step in doing the PZT was to install several gauge pressures at the consumers' connection points; meanwhile the pressure readings were recorded. The second step was closing the valves of the main inlet and outlet water sources, afterwards the pressure in the existing network started to drop. Few hours later, the gauge pressure readings were taken, they were zero, this means that there is no other water supplying source for the study area.
3. Determination of the night flow for the Large Consumers (LC) whose consumption exceeds 250 m^3/month (like hospitals). LC for the study area was 0.5 L/s (JWU, 2000).
4. Estimation of Reference Flow (RF): To estimate the Reference Flow for the area the following points have been taken into consideration (JWU, 2000): (1) water consumption during night: this value varies between 0.2 and 0.5 L/s/km considering the development of the area, number of persons per km^2, social habits of the people, and the season when the measurements are taken. For the study area, a value of 0.2 L/s/km was considered (2) value of the physical losses in the network: for the study area, a value of 0.05 L/s/km was assumed considering the small leaks in the network before the consumers'

meters. These leaks cannot be found with the available equipment and it is not economically wise to search and repair it. For the study area, RF was considered 0.25 L/s/km, which is the summation of water consumption during night and the physical losses in the network.

5. Tracing Leaks: to trace the leaks Aquaprobe, Aquamaster and Loggermate were programmed using computer software (winfluid). Internal diameters, direction of the flow, starting time and the duration were entered in the software during the analysis process. Thereafter, the data logging devices were installed on the points of measurement for a certain period of time. Flow and pressure readings were recorded and the data was uploaded from loggermate to the computer in site. Data were analysed using winfluid software, the relationship between flow and time was drawn. Based on the flow curve, if the difference between peak consumption and minimum consumption was small, this indicated a presence of water losses. Furthermore the average minimum night flow obtained from the flow curve was compared with RF in order to know the amount of leakage.
6. The net flow for the study area equals the flow at the inlets minus the flow at the outlets. Sub-area E (south-eastern part of Al-Bireh) will be discussed here to describe the methods used and efficiencies achieved in this research. The net flow curve for the sub-area E is shown in Figure 4. The flow readings were recorded for 6 days (from 31 Dec. until 5 Jan.) to ensure that the flow curve repeats itself since the consumption varies during the days of the week. It was noticed that water consumption in feasts and holidays are higher than the normal consumption in any other day. It was noticed also that on the New Year's day (1 Jan.) and on Fridays (4 Jan.) the water consumption during the daytime is higher than the normal consumption in any other day. The estimated leakage in sub-area E was 5.6 L/s as shown in Table (2).

Step Testing

Step testing is a night flow-based method of identifying leakage in a metered area. It is a method of narrowing down the position of a leak to a length of a pipe. The step testing was carried out for each sub-area. Each sub-area was divided into steps in order to minimize and facilitate operating each part for inspection and to trace the leaks easily. The total length of the network in sub-area E was 31.5 km; hence, it was divided into 10 steps, each with 3 km approximately.

The flow was recorded for each step every one minute for a period of 15 minutes for each step. Step flow equals the total flow of the whole sub-area before the step was isolated minus the flow that was measured when that step was closed. The steps were arranged according to priorities, which were based on the amount of estimated leakage for each step. Table (3) shows step testing and detection priorities. Consequently, it was required to pinpoint the precise location of leaks in the steps that have the highest amount of leakage using Correlator analysis.

Table (3) shows seven steps that should be pinpointed and repaired. Accordingly, the researcher started with step No. 2 (Al-Amari camp), since it occupies the first priority. During the pinpointing step No. 2, it was found that the existing network is in a bad condition since it has large number of leak points. Moreover, many pipes were laid under houses, which makes it difficult to pinpoint the leaks; hence, these pipes cannot be pinpointed, repaired or replaced. The optimal solution was to design and implement a new network for the camp.

As for the remaining steps, leak points were pinpointed and repaired. Most of the leaks were due to small damages and holes in pipes that were not discovered easily, in addition the old leaky fittings were changed in order to reduce amount of leakage.

Flow Measurement and Data Analysis After Repair

The aim of this stage was to determine the amount and percentage of leakage after the maintenance actions were carried out. The net flow curve for the repaired system for sub-area E is shown in Figure 5. It can be noticed that from 12 March till 13 March there was a big jump in the flow curve since the main supply pipeline was damaged which results in a high amount of water losses.

The amount of leakage in sub-area E was reduced from a value of 5.6 L/s before repair (Table 2) to 3.0 L/s after repair (Table 4). The repairing actions were done for all the steps that needed except step 2, which represents the Amari camp, since it is recommended to design a new network. The amount of leakage after repair was 3.0 L/s, which represents the amount of leakage only in the Amari camp since the leaks in the whole network were pinpointed and repaired. It is expected that after replacing the network of the Amari camp, the amount of leakage will drop largely to a value of 0.16 L/s.

CONCLUSION

Leakage can be considered as one of the most important part of water losses in the distribution system. Therefore, leak detection must be given much attention from water undertakings, in order to reduce water losses and save money.

There are many methods for leak detection; selection of the method depends on the percentage of leakage aimed at and the budget of the undertaking. In this paper, leak detection study was mainly based on the minimum night flow that is compared with the estimated reference flow in order to estimate the amount of leakage.

Pinpointing and maintenance actions were applied for the study area. Consequently, the amount of leakage will be largely reduced (from 5.6 L/sec to 0.16 L/sec). The network should be monitored continuously in order to detect leaks as soon as they occur.

Table 1: Water loss analysis for the years 1996 – 2000.

Description	1996	1997	1998	1999	2000
Total water supplied (m^3)	9051257	9630019	10646356	11289582	10987726
Water sold (m^3)	7029756	7577918	8344745	8624099	8304316
Uncounted for water (m^3)	2021501	2052101	2301619	2665483	2683410
Percentage (%)	22.33	21.31	21.61	23.61	24.42

Source: JWU (2000).

Table 2: Estimated leak in sub-area area E.

Length (km)	AMNF [(1)] (L/s)	RNF [(2)] L/s	LC [(3)] (L/s)	EL [(4)] (L/s)
31.5	14	7.9	0.5	5.6

[(1)] AMNF = The average minimum night flow is determined by taking an average minimum night flow for the whole period of measurements.

[(2)] RNF = Reference Night Flow = Length* RF = 31. 5 km* 0.25 L/km/s = 7.9 L/s.

[(3)] LC = night flow for the Large Consumers

[(4)] EL=Estimated leakage = AMNF – RF - LC = 5.6 L/s

Table 3: Step testing and detection priorities for sub-area E.

Step Number	1	2	3	4	5	6	7	8	9	10
Step length (km)	4.4	2.7	1.9	3.9	3.6	5.0	2.7	2.2	2.1	3.1
Estimated leakage (l/km/s)	0.1	2.0	1.0	0.8	0.4	0.9	1.3	0.25	0.6	0.1
Detection Priority [*]	No leak	1	3	5	7	4	2	No leak	6	No leak

[*] If the estimated leakage (l/km/s) is more than RF (0.25 L/s/km), then there is leakage in the pipes and it should be pinpointed.

Table 4: Estimated leak in sub-area E (after repair).

Length (km)	AMNF (L/s)	RNF L/s	LC (L/s)	Estimated leakage (L/s)
31.5	11.3	7.9	0.5	2.9

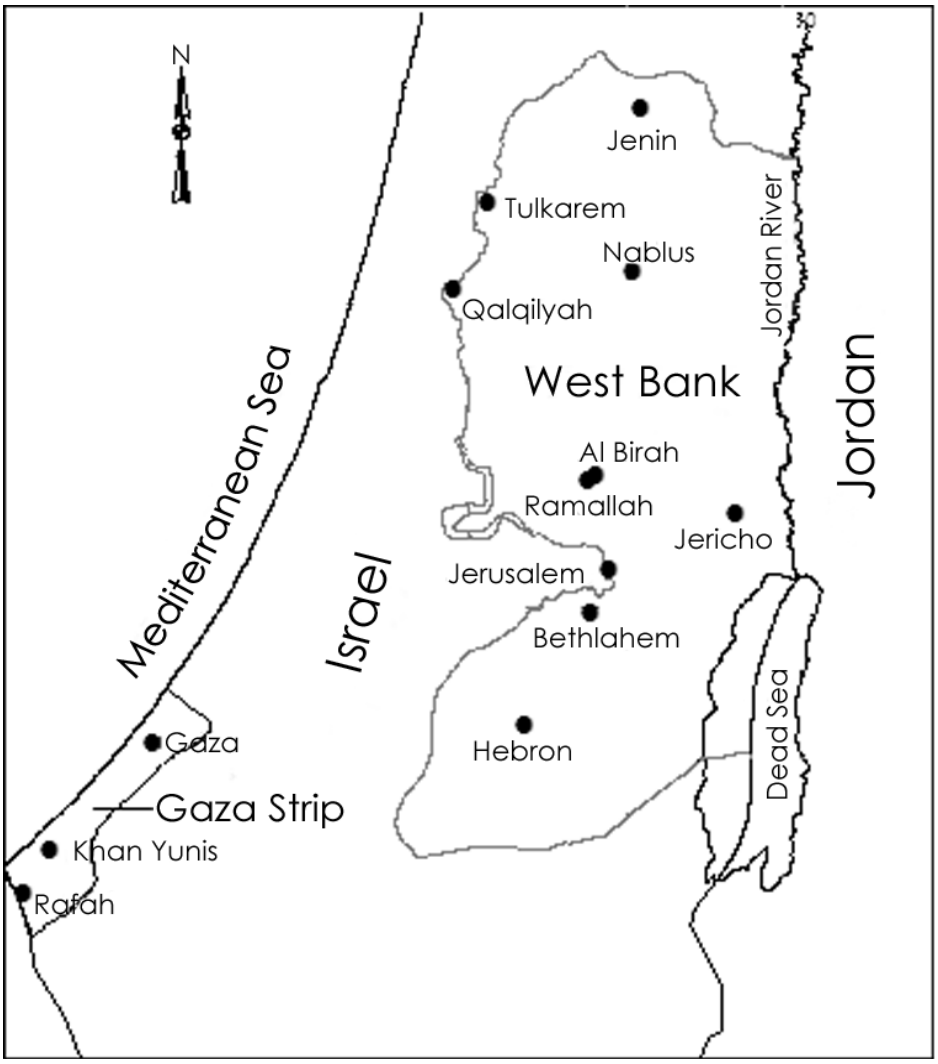


Fig.1. Study area location map.

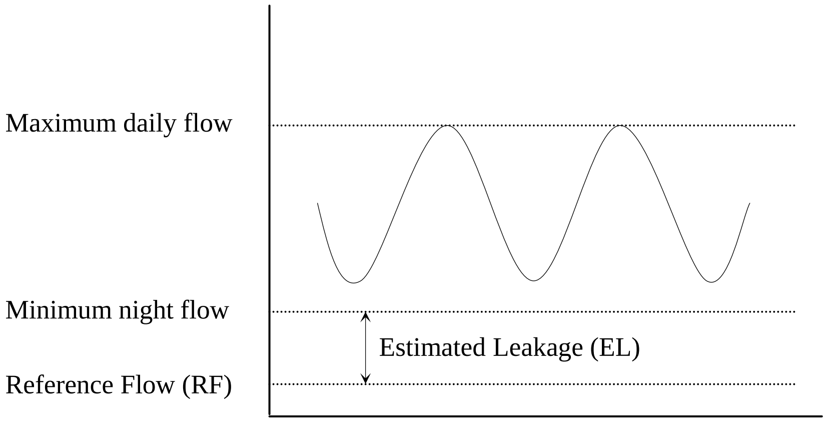


Fig.2. Leakage Estimation.

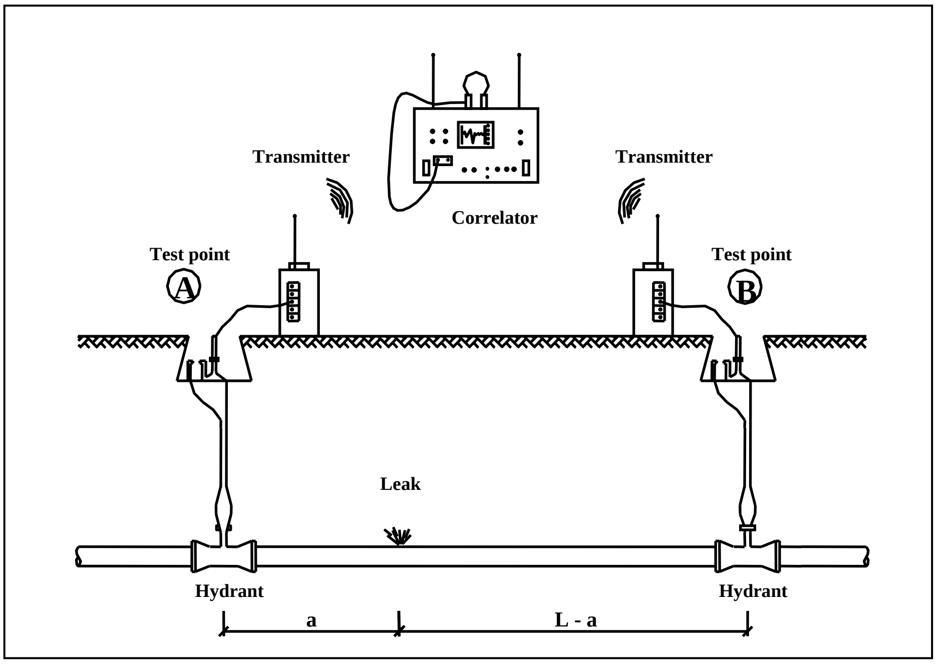
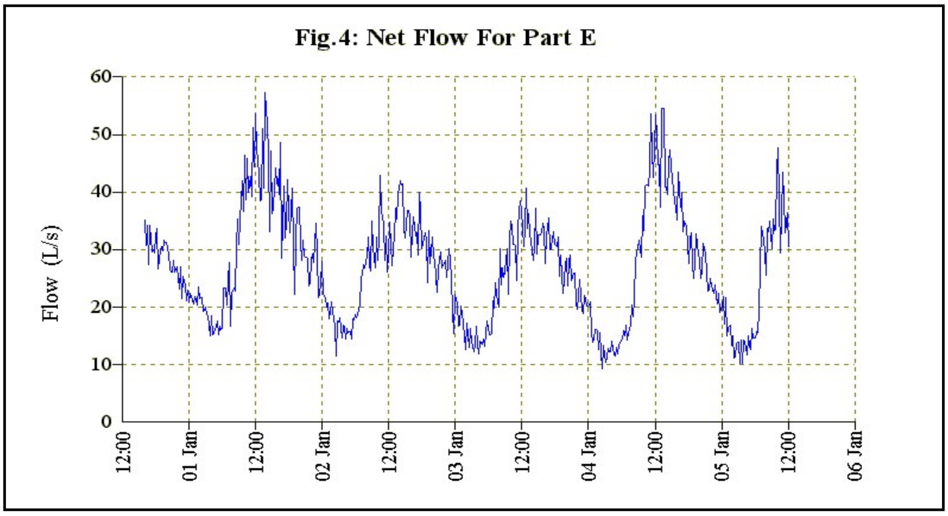
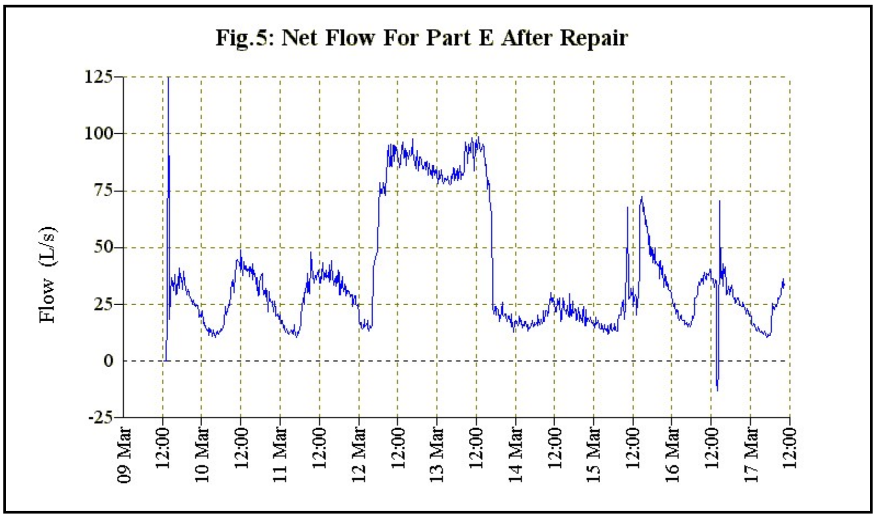


Fig. 3. Principle of the correlation method.





REFERENCES

JWU (Jerusalem Water Undertaking). 2000. Performance and Prospects, *Ramallah.*

Lonergan, C. and Brooks, D. 1994. Watershed: The Role of Fresh Water in the Israeli-Palestinian Conflict, International Development Research Centre, IDRC Publishers Ottawa.

Mimi, Z., Ziara, M. and Nigim, N. 2003. Water Conservation and Its Perception in Palestine - A Case Study. Water and Environmental Management, (CIWEM), 17(3): 152-156.

Niemeyer, R., Gilles, K. and Riggers, B. 1996. Reduction of Water Losses in Drinking Water Supply Systems in Developing Countries, Weltorum Verlag, Cologne.

Trow, S. and Farley, M. 2003. Developing A Strategy For Leakage Management in Water Distribution Systems, *Proceedings of the 2nd International Conference on Efficient Use and Management of Urban Water Supply*. Tenerife Island, Spain, 1-3 April.

تخفيض نسبة الفاقد من المياه في شبكات توزيع مياه الشرب
(مدينة رام ا   كمثال نموذجي)

زياد عبدالحميد الميمي *

ملخـص

تعاني فلسطين من شح مصادر المياه ولذا يتوجب على الفلسطينيين استغلال المياه بأقصى فعالية ممكنة. ان العديد من القرى الفلسطينية لا توجد فيها شبكة توزيع مياه، اما الشبكات المنتشرة في المدن والقرى الاخرى فهي تتصف بفاقد عالٍ من المياه واهتراء لقدم عمرها.

ان هذا البحث يستعرض طريقة علمية لتحديد اماكن التسرب وكمية الفاقد في شبكة توزيع المياه المنتشرة في مدينة رام ا   باستخدام أجهزة علمية متطورة. إن دراسة الفاقد من شبكة المياه واصلاحه في منطقة الدراسة أدت الى تخفيض فاقد المياه من 5.6 لتر/ ثانية الى 0.16 لتر/ ثانية.

* قسم الهندسة المدنية، كلية الهندسة، جامعة بيرزيت، بيرزيت، فلسطين. تاريخ استلام البحث 2004/5/6، وتاريخ قبولـه 2005/3/9.