Switching from Pumping Zones to Pressure Zones
Case Study of Nablus City

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ABBREVIATIONS:

PZ: pressure zone.
WLRP: Water Loss Reduction Program.
KFW: Kreditanstalt für Wiederaufbau / German Bank for Development.
MPCV: Modulating Pumping Control Valve.
WSSD: Water Supply & Sanitation Department.
NM: Nablus Municipality.
VFD: Variable Frequency Drive.
DMA: District Metering Area.
SCADA: Supervisory Control and Data Acquisition.
OA: Operational Assistance.
DI: Ductile Iron.
PE: Polyethylene.
NRW: Non Revenue Water.
ILI: Infrastructure Leakage Index.
GPRS: Gather Packet Radio Service.
Abstract

Previous Situation

The natural mountainous topography of Nablus city (see attached photo at the end of the report) is one of the main challenges in operating water system. More than 400 m was the difference in level between some water resources and distribution points (see attached photo at the end of the report). The pumping pressure reached up to 25 bars in some pumping stations, this lead to high operating and maintenance cost.

40% of water operating cost was energy, frequent failure in water distribution components (pipes, pumps, domestic water meters and fittings) happened due to high operating pressure.

Also the same pump was used to distribute water a on rotational basis to different distribution Pumping Zones that have various elevations. Therefore, the pump could not operate at optimum point. In addition to that, the previous situation had many problems which reduced the efficiency of operating water distribution system in the city.

Current situation

Water Loss Reduction project funded by Kreditanstalt für Wiederaufbau (KFW) with 20 Million € budget, this project was started in 2007 and completed in 2011. The main aim of the project was to reduce the Non Revenue Water (NRW) from 40% to 25% and to reduce the energy consumption.

Through water loss reduction the water distribution network and related facilities have been rehabilitated and restructured. The project included physical implementation comprised of laying new water pipes and house connections, installation of 28 pressure zones, as well as the rehabilitation and construction of relevant reservoirs and pumping & booster stations.

Major parts of the systems were put in operation at the beginning of 2012, however works are still ongoing and challenges have to be faced.

Although splitting of water distribution pumping zones into pressure zones required large investment because it needed additional pumping stations, reservoirs and transmission lines. It became more economical in operation since energy consumption had been reduced by 35 % compared to the past.

The main fruits of implementing the project are (but not limited to) the following:

- The energy consumption was reduced from 0.93 KWH per cubic meter to 0.59 KWH.
- The project resulted in reduction of physical damage of the distribution system components, even at the customer’s side behind the water meter.
- Facilitating the computation of water balance and managing NRW.
- Considerable reduction in customer complains.
- As well, physical water losses in zoned networks are reduced as a result of a lower pressure in pipes and especially in indoor installations.
- However, the commercial losses are still high due to over-aged domestic water meters which the municipality is intending to start to replace accordingly in the near future.
1. Problem Analysis

Introduction

The Nablus area has significant general and local variations in topography, necessitating clear differentiation of the supply to individual areas. A great part of the city area, except the old centre of Nablus, has recently faced rapid development of a primarily residential nature. To cope with the increased demand before Water Loss Reduction Program (WLRP), the pipe network had been extended on an ad-hoc basis, without sufficient attention being paid to designing for topography, friction losses, storage capacity, leakage control, pressure control and efficiency of operations as result of lack of primary facilities (pump stations, reservoirs and adequate network).

Distribution System status before implementing WLRP

Presently, storage facilities of the water supply system comprise 10 reservoirs with an overall useful capacity of 14,700 m$^3$. Their individual capacity reservoir ranges between 150 and 5,000 m$^3$.

Since 1932, the distribution network has been continuously expanded to the present with total length of about 290 km of transmission lines (diameter of 2” to 12”). This figure does not include the pipes with diameters less than 2” where the house connections are falling in. The pipe material of the networks at that time consisted mainly of steel, ductile iron, cast iron (some 500 m only) for the diameters more than 3” and of galvanized steel and polypropylene exclusively for the smaller pipes.

With over 37,000 house connections, the entire town population is connected to the water supply system (connection rate 100%). The distribution system is composed of several water supply zones. Some individual supply zones were interconnected. A continuous water supply is ensured only in the old part of town and areas connected along the transmission mains from the external sources. The modern quarters were divided into over 10 water pumping zones that were supplied with water mostly twice a week for several hours. By this operation mode, the municipality intended to distribute the available water equally and to limit the times of excessive pressures in the network and consequently the technical water losses. Before WLRP, there were 10 pumping stations distributed in different areas of the city.

Deficiencies in the distribution system before the WLRP

The water supply system was designed mostly without exact calculations but rather based on estimates and historical figures.

1. Due to the high differences in altitude within the city, insufficient definition of pressure zones and several sub-service areas being supplied by direct pumping without balancing reservoirs, water pressures can reach excessive levels in some parts of the network. This was one of the main reasons for high physical water losses and more than ten pipe breaks daily, mostly occurred in the house connections.

2. Most of the old pipes had been laid without proper sand bedding. In particular pipes of smaller diameter were laid very close to the surface or even on the ground. Thus, the increasing traffic also led to pipe bursts and other damages.

3. The undersized distribution lines (in particular in the outskirts of Nablus) caused high head losses and the customers in the areas of higher ground levels were supplied insufficiently.

4. The intermittent supply produced long idle periods of water in pipelines and house reservoirs and, as a result negative pressure, which possibly caused sewage to enter the drinking water.
network, and which led in individual cases to a contamination of drinking water. In addition to that the intermittent supply allowed the air to fill the pipes during the shut off time, and that affected the accuracy of water meter readings.

5. The intermittent supply regime in combination with overrated pumping facilities (usually one pump supplies areas located at substantially different altitudes, thus creating excessive pressure in the system and at the house connections. Having in mind that fittings (small diameters for private consumers) are usually not of the very best quality, the over pressure created was often reason for pipes bursts.

2. Methodology/ restructure strategy

The objective WLRP that have been funded by KFW was the rehabilitation and restructuring of the water distribution system of Nablus city in order to reduce technical water losses and increase energy and operating efficiency.

The German Government through KFW has allocated EURO 17.1 million as a grant for the implementation of Water Loss Reduction Nablus Project. The Executing Agency Nablus Municipality (NM) contribution was EURO 1.71 million. The implementation of the physical measures was concluded by the end of 2011 and major parts were put into operation at beginning of the year 2012.

The program is based on a long term planning concept until the year 2025 and on a hydraulic analysis study submitted in 2005.

The establishment of restructured areas (Pressure Zones), including construction of water transmission, storage facilities and new pumping facilities (Pump Stations) as well replacement of existing ones which cannot meet the restructuring philosophy. Reinforcements of primary and secondary mains and the installation of flow measurement facilities at reservoirs and pumping stations are also included. Each individual area of the restructured whole system will be termed further as “Pressure Zone” (PZ).

The redesign idea of the water supply system under WLRP program proposes to establish 28 separate pressure zones. Each zone shall be fed with water by a separate supply source, either by

- Direct pumping,
- Direct pumping through the zone into a balancing reservoir,
- Gravity supply.

Restructuring the water system enables:

1. To avoid high pressure and thus minimize pipe breaks and water losses.
2. To better monitor the water inflow and outflow (water balance).
3. To reduce energy consumption.

The scope of work included the following pipelines:

1. 66km of distribution mains DN90 and DN110 PE and DN150 to DN400 DI.
2. 15.6 km of transmission mains DN200 to DN350.
3. 2,590 Nos. house connections.
4. Structural, Mechanical and Electrical works which included the works in 17 locations (10 existing and 7 new) which implied the construction of new reservoirs and pumping stations.

3. Energy saving

Concerning the electricity costs for pumping, those for pumping inside the city (excluding the wells), have been separated from those pertaining to the wells. The former is reduced by the project. From 0.93 kWh per m$^3$ before the WLRP of water distributed (according to Hydraulic Analysis Study of the Nablus Water Supply Report in 2010 carried by the German Consultant Lahmeyer/SETEC/ACE) to 0.59 kWh per m$^3$ after WLRP.

To evaluate the effect of WLR on energy consumption, data analysis was carried out for energy consumption for the pumping stations for the years 2011, 2012 and 2013. The result is shown in figure (1), it is obvious that the energy consumption goes down to average annual value of 0.59 kWh per m$^3$ in 2013. That contributes to 36% reduction in energy consumption. The value of energy consumption goes beyond the target value (0.77 kWh pet m$^3$) that was settled by the consultant as a target to be achieved after the project implementation.

![Figure 1: Average annual energy consumption 2011-2013.](image)

4. Challenges and Obstacles

During the Water Loss Reduction project, the pressure zones were not isolated completely and also the old network was not separated totally from the new one. An additional fund from KFW is used by Water Supply and Sanitation Department (WSSD) at Nablus Municipality (NM); to complete the isolation of the pressure zones, to complete the monitoring system of network indicators and to install a SCADA system as a short term actions in the way to implement NRW strategic plan.
The main challenge is that the new installed pumping sets (two or three pumps) and their pump control have been designed assuming 24h supply/service, while presently, several pressure zones are supplied intermittently due to the deficit in water supply in relation to the demand. The current kind of operation leads to the fact that in some cases the pumps are operated outside their operating range and thus some of them get damaged. This holds especially for the time of filling the empty pressure zones. Furthermore it seems that some pump groups are not capable to deliver sufficient pressure to reach high elevated customers. This is because some of the pressure zones have been extended above their designed pressure zone boundaries. To solve the problem, first of all the operational conditions for each pump group and pressure zone have to be defined and analyzed in greater detail. This means:

1. The Pressure zones have to be physically separated in order to create constant operational conditions.
2. Operational data of each pump group needs to be collected and evaluated
3. Pressure loggers have to be temporarily installed within the pressure zones in order to monitor pressure during a pumping cycle.
4. Possible functions of the Modulating Pump Control Valve (MPCV) have to be investigated and checked in case of variable speed pumping.
5. If applicable, a hydraulic model has to be set up for each pressure zone. The model has to reflect the storage capacities of the roof top tanks to allow a realistic simulation of the system. When possible the hydraulic model needs to be calibrated.
6. Each pressure zone has to be verified, if operational conditions meet the individual characteristics of the installed pumps. Especially it has to be checked, whether the design head of the pumps is sufficient to supply the customers at upper elevations.

5. Accompanying measures

Water distribution network and related facilities have been rehabilitated and restructured. Physical implementation which comprised of installing new water pipes and house connections, installation of 28 pressure zones, as well as the rehabilitation of relevant reservoirs, pumping and booster stations, those works were concluded in 2011. Major parts of the systems were put in operation at the beginning of 2012, however works are still ongoing and challenges have to be faced.

After WLRP was put into operation still the water losses was high, accordingly KFW decided to investigate the reasons behind that by implementing Operational Assistance (OA) project, the objective of this project was to optimize the general management of efficient operation and maintenance of the water supply facilities. This especially concerns the pressure and water loss management in 28 pressure zones and future District Metering Areas (DMA5), as well as the sustainable and efficient operation of more than 80 pumps and their related reservoirs. Part of the assignment is to develop necessary operational strategies and concepts as well as to identify and to implement adequate training activities.

Overall the measures shall contribute to the main objectives of WLR program which are:
1. Reduction of water losses from presently 40 % to 25 %.
2. Reduction of energy costs by the development of a pumping concept and optimization of pump efficiency.
3. Increased availability of water resources to be able to supply 7 days/week instead of 2-3 days/week after finishing the construction of new transmission line of a new drilled well in Nablus west.
The following points shows the measures that are already finished and the others that are still ongoing:

**Implemented measures**

1. Determination the boundary of pressure zones and solve the problems of zone overlapping
2. Providing the WSSD-NM with the technical basis for collecting the data needed by installing measurement devices (pressure & flow) at each relevant point of the network in order to get an optimal information about the water production and the water consumption not only for the whole network, but also for each distribution zone and even for smaller units within the big distribution zone. Magnetic water meters will be installed at production points and distribution station inlets, at main stations outlet and at reservoirs.

**Measures under implementation**

1. Finalizing the separation of pressure zones in the water supply network of Nablus by replacement and new construction of pipes including house connections, disconnect the pipe from old system and removing the valves (Mostly done).
2. Although there was a Tele-control system depending on Gather Packet Radio Service (GPRS) communication, which implies hand shaking between the sending pumping stations and receiving reservoirs, a SCADA system with a central control room is being installed for water supply system of Nablus, including data evaluation tools, to monitor the flow and pressure in order to detect leakage (bursts) and monitor the chlorination system and control pumping station, the SCADA will be capable to make many computations like water balance and operational efficiency (will be under operation in February 2015).
3. Education and training: including training on the customization of the SCADA-system, training needs on pump operation and maintenance and training in predictive and preventive maintenance (ongoing).

**6. Action to be implemented**

After the analysis, an appropriated operational concept need to be developed. The main object of the concept shall be to operate the installed pumps in a way that damages and break downs are avoided. On a short notice there are the following scenarios:

1) Switch to a constant supply as soon as possible. This would mean that the systems are pressurized 24h and that the pumps could be operated according to their design by a pressure depending frequency control (new transmission line from the new drill well are under construction).
2) Stay with intermittent supply but reducing the intervals between pumping. This would prevent a complete emptying of the installed roof top tanks and thus reduce the time needed for filling the zones.
3) In cases where the lifting head of the installed pumps is not sufficient and adjustment of the impeller or the installation of additional booster pumps with higher head might be an option.
• Concerning the quality of repair the following challenges have to be faced:

Material management need to be improved. In general spare parts, pipes and fittings have to be on stock for all installed materials and dimensions. A big problem is that the new Ductile Iron (DI) for pipes and fittings installed under WLRP are not available on the local market. Strategies have to be found, how to purchase the required materials in a reliable way. Furthermore quality standards have to be improved. Skills of staff need to be improved. Especially the technicians and operators need to be trained on the correct handling of new pipe materials like DI and PE. Furthermore additional training on leak detection is required. Documentation of repair needs to be improved. All information collected during repair measures should be captured and used for updating of network documentation and failure statistics. To realize this necessary processes between workers in the field and GIS unit have to be defined. Necessary equipment and tools need to be purchased. For efficient and good quality repair additional tools, equipment and transport are required. Organization of preparatory works needs to be improved.

To improve reliability and quality of the water balance the following challenges have to be faced:

1) Improvement of customer water meter management. Customer water meters need regular replacement or calibration. Common mechanical water meters every six years. This means that the sixth part of all meters has to be calibrated or replaced during one year.

2) Quality of customer water meter needs to be improved and adapted to the operating conditions (intermittent supply, water quality, volumes to be measured). Quality standards should be introduced. Practice of meter installation and house installation needs to be improved and standardized.

3) Introduction of the infrastructure leakage index (ILI). The performance indicators which are presently in used (absolute water losses, water losses in %) don’t reflect the condition and the pressure of the networks. The infrastructure leakage index is a good addition to the applied water loss monitoring and will help to better compare the performance of the several pressure zones.

7. Learning lessons

1) Lacking in data base was the main obstacles in separating the pressure zones. Although there were drawings for the newly installed networks (since 2005), there was no documentation for the old distribution network systems including house connections. So it was very difficult to know the location of the pipes and fittings during the separation process of zones. Still there is no documentation for the maintenance works carried out by WSSD-NM staff.

2) It is important to insure that the old pipes are completely disconnected before backfilling and asphaltling the trenches and before operating the new systems.

3) As the water supply system in Nablus has special circumstances (limited water resources, intermittent supply, roof tanks, topography ...), it is recommended to work with local or regional consultants that have experience in the aforementioned operating conditions.

4) Never use Variable frequency Drive (VFD) and Modulating Pump Control Valve (MPCV) at the same time, there was a contradiction in function by using these two system together.

5) It is very efficient to use VFD in pressure zones for both energy saving and water loss reduction.
Photo shows the natural mountainous topography of Nablus City