RISK ANALYSIS FOR NASR CITY WATER DISTRIBUTION SYSTEMS

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ABSTRACT

Nasr City (Egypt) was considered one of the most critical areas in Greater Cairo till the second half of year 2005. Prior to that date, the Greater Cairo Potable Water Company has installed new facilities that ended all hydraulic problems occurred in the system under normal conditions. Although the system is currently working properly without any problem, some risk conditions such as pipeline breakage, valve breakage, pump failure, or tank failure cause service interruption. With people's luxury developing, service unavailability is no longer acceptable, thus, the system should provide the service under risk condition without massive increase of the system cost and service unit price. In this paper, risk causes and risk analysis benefits had been reviewed and the Nasr City Water Distribution System was analyzed under several risk conditions. As a result, short term plan is recommended for minor risk causes that lead to local service unavailability. On the other hand, long term plan, as terms of installing new facilities, is recommended for major risk causes that lead to global service unavailability.

Keywords: Hydraulics, Water Distribution Systems, Risk Analysis, Nasr City

INTRODUCTION

The traditional approach in designing the water distribution systems is defined as supplying the required service to the customers with the minimum price. This means that the system should supply the required water demand having a suitable pressure during the whole day with the minimum water price. In the past, this approach was suitable for designing the water distribution systems for small and large cities, however, in the recent time, with the people's luxury developing, it is no longer sufficient for systems design. A new dimension should be granted, that is the system should provide the required service under risk conditions. As the expected risk probability increase, additional facilities to the system should be installed. This means that the total cost of the system will increase and hence the service unit price (cubic meter of water) will increase.

The water distribution system designer should optimize the system resistance to risk probability and service unit price in order to obtain an optimum system that provides the service under normal risk probability conditions with acceptable unit price. It should be noticed that covering all risk probability conditions is practically and economically impossible because it requires a very expensive system and will leads to a customer unacceptable service unit price.

The risk conditions of the water distribution system include, but not limited to, pipeline breakage, valves damage, pump failure, tank failure … etc. Massive increase of the water demand more than the design demand is not a risk condition because the Egyptian code of practice requires that the design demand for the network is the maximum demand required during the maximum hour of the year.

The more often risk condition occurs in Egypt is the pipeline breakage because of the availability of standby pumps at the pump stations and the low probability for tanks to be immediately out of service. About 150 main and secondary pipelines are being broken every day in Greater Cairo. Some of these risk conditions happened in Nasr City Water Distribution System during only one month of year 2005 are reviewed and listed hereafter.

- In the 29th of January 2005, the main pipeline 1400 mm diameter feeding south Nasr City from Abu Awekel pump station was broken at Al-Qattameyya highway. This pipeline is one of three main pipelines feeding Nasr City. It provides 300,000 m^3/d out of 450,000 m^3/d to the water distribution system of Nasr City. As a resulted, an unavailability of water problem occurs for six days until the line has been repaired. That case was environmental disaster case because poor people can not buy bottled mineral water and they used turbid water from the green areas at the streets. This turbid water come from sewage treatment plants and not suitable for drinking.

- In the 8th of February 2005, a pipeline 1000 mm diameter coming from Abu Awekel pump station to supply Nasr City was broken. This breakage did not interrupt the water distribution system in Nasr City because this pipeline was a spare one for the pipeline diameter 1400 mm coming from Abu Awekel.

- In the 16th of February 2005, a pipeline 1400 mm diameter inside Zahraa El Maadi pump station has been broken. This breakage resulted in water problems in Abu Awekel pump station which lead to water problems in the Nasr City water distribution system for one day.

- In the 26th of February 2005, a pipeline 600 mm diameter was broken at Al Tayaran Street. This breakage results in local water problems for six hours. This condition is often repeated in several pipelines and several places and it causes local water problems for several hours.

Nasr City was considered one of the most critical areas in Greater Cairo till the second half of the year 2005. Khadr, El-Dyasti, and Khalifa [6] reported that the problems occurred previously in the water distribution system (WDS) were solved by adding a pipeline 1000 mm diameter from Zahraa El-Maadi to Nasr City WDS caring 50,000 m^3/d in addition to a pipeline 800 mm diameter from El-Tagammoa El-Khames WDS to Nasr City WDS carrying another 50,000 m^3/d. The system is now working with almost no hydraulic problems but it should be analyzed for risk since some zones of the system are critical. In this paper, a risk analysis for Nasr city water distribution system for different risk cases will be presented.

WATER DISTRIBUTION SYSTEMS RISK CAUSES

The risk condition in water distribution systems is defined as any condition that prevents the system from supplying the required service suddenly. These conditions can be summarized as follows:

- Sudden partial or complete breakage in any pipeline or valve in the system. This breakage might happen due to failure to replace old parts in a regular maintaining. It might also happen accidentally due to other works beside the pipeline or valve which was the case when the 1400 mm diameter pipeline has been broken due to a nearby excavation for other works.

- Sudden stop of a pump stations either in the water treatment plant or an intermediate pump station inside the water distribution system. It should be noticed that pump stations at the water treatment plants is of a very low probability of sudden stop because it contains standby pumps and standby generator to be used in case of electricity unavailability. Although intermediate pump stations have a standby pumps, those that have no generators available still be a risk cause as they will suddenly stop if an electric power interrupts.

- Tanks in general are of a very low probability of being suddenly out of surface. So they are considered a minor cause for risk of water unavailability. However if a water pollution happen in a tank due to a water quality problem, this tank should be isolated from the system, drained to the sewage, and refilled with a fresh water. This process might require a few hours and the tank is out of service during that period which is a risk condition.

It should be noticed that the area of interest for this research is the service availability, which is supplying required water with the required pressure. Other factors could be considered risk conditions from another point of interest such as water quality.

RISK ANALYSIS BENEFITS

The risk analysis study will facilitate the determination of the cause and location of any potential hydraulic problem occurs in the water distribution system under risk conditions. It will help the water distribution system managers and engineers to consider the optimum decisions in solving any hydraulic problem that may occur in the system. These decisions may include short term plans and long term plans for managing the water distribution system.

Short term plan for managing the water distribution system under risk may include redistribution of the water flow in the system by changing the operation roles of the different components of the system such as valves, pumps, tanks … etc. This change of the operation roles leads to minimization of problem duration, problem effects, and customer complains but it will not make the problem vanish.

Long term plan for managing the water distribution system under risk include replacement of the old facilities and installation of a new facilities, such as pipelines, valves, pumps, tanks, and generators in the pump stations. These facilities will help to better minimization of the problem duration and effects than the short term plans and this will leads to vanishing customer complains. The only disadvantage of this process is that it will require addition funds and this will leads to service unit price increase.

NASR CITY RISK ANALYSIS AND RESULTS

1. Pumps

In order to perform risk analysis for the pump stations regarding the availability of the service, several site visits for all pump stations have been performed. Data for each pump station such as the number of available pumps, maximum number of simultaneously operating pumps, design discharge, design head, generator availability, generator capacity… etc. were collected and listed in Table 1. Analyzing pump station data, the following risk conditions could be obtained:

- Pump station Abu Awekel is of a very high risk condition specially large and medium pumps because they have zero percent standby pumps. These pumps are considered main pumps in the system because they deliver about 250,000 m^3/d out of 550,000 m^3/d and hence any defect of them will lead to huge problem.

Table 1: Nasr City pump stations characteristics and protection availability

Pump Station Name		No. of available pumps	Q (m^3/sec)	H (m)	No. of operated pump	% of Standby	Generator available	Generator capacity	% of pump at risk
Nasr City-1		5	540	100	1	400	Yes	3	300
Nasr City-2		4	1080	100	1	300	No	----	0
Nasr City-3		4	1080	100	1	300	No	----	0
Nasr City-4		6	540	90	4	50	No	----	0
Tank Zahraa NC		2	216	80	1	100	Yes	1	100
Masken Elsheraton		4	1440	100	1	300	No	----	0
Zahraa NC	Large	4	720	70	1	300	No	----	0
	Small	2	500	70	1	100	No	----	0
Elwafaa we Elamel		2	216	80	1	100	No	----	0
Eltawfeek	Vertical	2	216	80	1	100	No	----	0
	Horizontal	6	108	75	1	500	No	----	0
Elastethmar		8	1440	90	2	300	No	----	0
Abu Awekel	Large	5	2000	80	5	0	No	----	0
	Medium	1	1500	95	1	0	No	----	0
	Small	2	1000	150	1	100	No	----	0
Tank NC-5	Large	1	500	70	1	0	No	----	0
	Small	4	400	75	2	100	No	----	0
Nasr City-5		5	1440	90	3	67	No	----	0

- Pump station tank NC-5 is of a normal risk condition it has one large pump with zero standby pumps and four small pumps two of them are standby pumps. The risk condition happen if the large pump became out of order. However it is defined as normal not high risk condition since one or two of the small standby pumps can be operated if this condition occurs.

- All pump stations except Nasr City-1 and Tank Zahraa NC are of normal risk condition because they have no standby generators and this will leads to sudden stop for these stations in case of electric power interrupts. Although some of these stations could be accepted under this risk condition, the authors believe that this condition is unacceptable for major pump station such as Abu Awekel, Nasr City-5, Nasr City-4, and Zahraa NC.

2. Tanks

As discussed before, tanks are considered a minor cause for risk of water unavailability. For this reason, the authors consider tank risk conditions are out of the scope of this research. They recommend that future work including tank risk condition such as water quality problem in a specific tank could be performed.

a. Pipelines

In order to perform risk analysis for the pipelines in Nasr City, a mathematical model named WaterCAD was used. It was setup according to the following steps:

- The population for Nasr City has been estimated for the current condition using the population census of 1986 and 1996.
- The water demand in the maximum hourly condition (2.5 times average discharge) was calculated for residential, industrial, green areas, and fire flow.
- Paper maps were collected and scanned for Nasr City network.
- Nodes location and properties were defined for the model.
- Pipelines location and properties were defined for the model.
- Pump stations location and characteristics were defined for the model.
- Tank location and properties were defined for the model.

The network including the nodes, pipeline, pump stations, tanks as defined to the model is shown in figure 1. The model was calibrated and verified in order to grantee a mathematical model representing the actual network. The results for the above mentioned steps were discussed in a pervious paper by Khadr, El-Dyasti, and Khalifa [6]. The same model was used herein in order to analyze risk conditions for pipelines by defining certain pipeline as closed to simulate pipeline breakage. Several cases of main pipelines and secondary pipelines breakage were tested out. The results for these cases are as follows:

i. Case Abu Awekel Pipeline Breakage

This case assumes that the pipeline 1400 mm diameter coming from Abu Awekel was broken or Abu Awekel pump station has been completely stopped. This case is similar to the case happened on 29th January 2005 except that the pipeline 1000 mm diameter from Elestethmar pump station and pipeline 800 mm diameter from El-Tagammoa El-Khames has been operated.

Running the model showed that although the pipelines 1000 mm diameter and 800 mm diameter have improved the system performance comparing to 29th of January 2005, major problems still will happen if this condition repeated. Immediately after the line breakage, the water will be unavailable in El-Haiy El-Ashire, Elwafaa we El-Amal, and El-Mantiaa El-Tamena. Other locations of Nasr City will be fed by the elevated thanks if they are filled. Three hours later, all tanks will be empty and most of the Nasr City will suffer from water unavailability. The pipelines 1000 mm diameter and 800 mm diameter will be unable to support the network with the required demand and pressure.

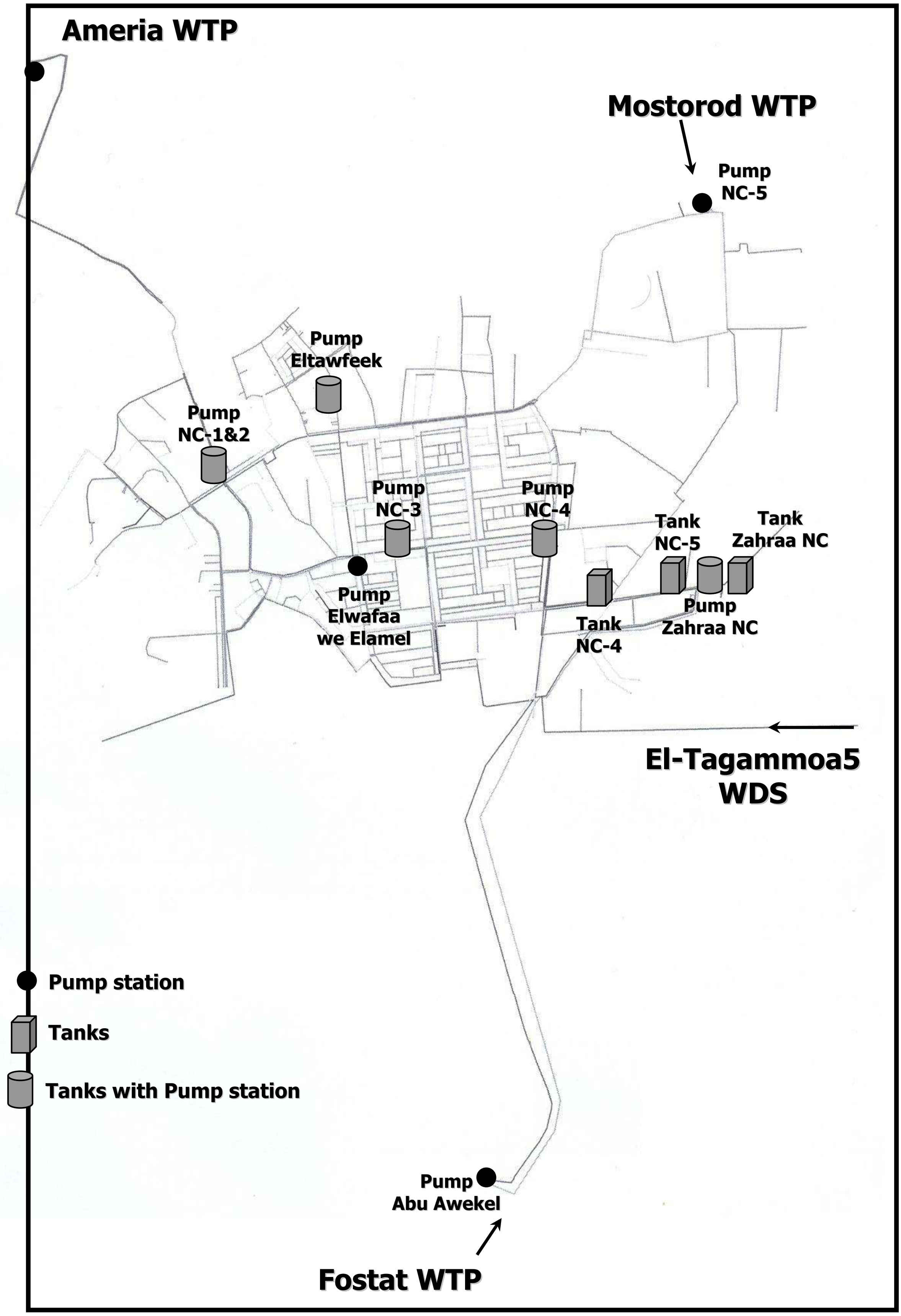

Figure 1: Water distribution system model for Nasr City

In order to solve this problem, a new pipeline with 1000 mm diameter was suggested. This pipeline starts at Abu Awekel pump station and pass parallel to Cairo Ring Road till the intersection of Cairo Ring Road with Axis NB connecting El-Haiy El-Ashire with the New Cairo City. At that intersection, booster pump station should be installed and then the proposed pipeline turn left to connect with the end of the 600 mm diameter pipeline feeding El-Haiy El-Ashire. Figure 2 shows a map of east Nasr City indicating the inflow before and after the proposed pipeline. The advantages of this suggested pipeline and booster are expected to be as follows:

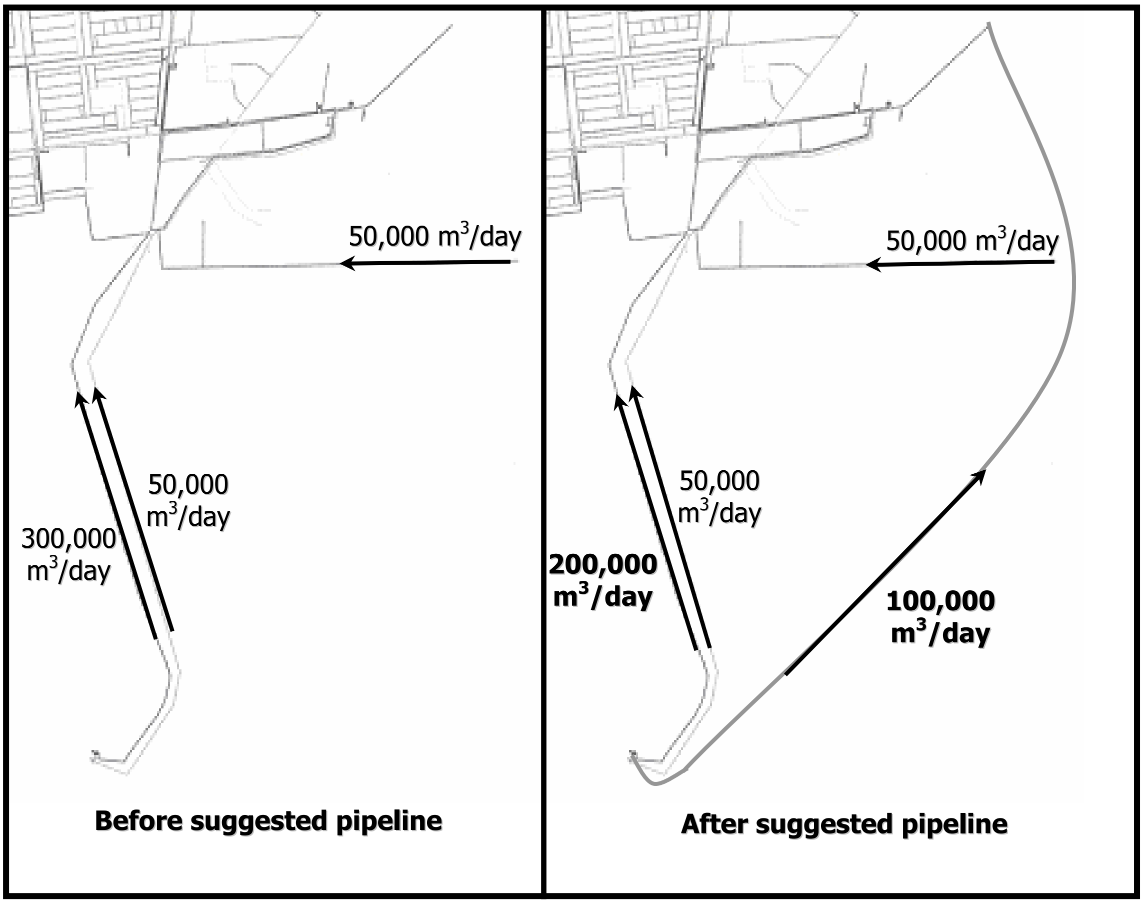

Figure 2: Suggested pipeline for East Nasr City

- Three pipelines (1400 mm diameter from Abu Awekel, 1000 mm diameter from Elestethmar pump station, and 800 mm diameter from El-Tagammoa El-Khames) are feeding Nasr City almost at the same node with about 400,000 m^3/d. The proposed pipeline feed Nasr City at different node with about 100,000 m^3/d and reduces the three pipelines to 300,000 m^3/d which improves the network performance.

- Under normal condition, it improves the pressure at El-Haiy El-Ashire and Ezbet El-Hagana and most of east Nasr City.

- In the near future, when the population grows at east Nasr City area, this pipeline will prevent the occurrence of hydraulic problems due to demand increase.

- In the current situation it will reduce the effect of such risk condition and it will help to provide water, but with low pressure, to the areas affected by the risk condition.

ii. Case Ameria Pipeline Breakage

This case assumes that the pipeline coming from Ameria was broken or Ameria pump station (or pump station NC1 and pump station NC2) have been completely stopped.

Running the model showed that West Nasr City, that is fed by this pipeline, is slightly affected by this breakage. Since this area has lower elevation rather than other areas of Nasr City, water redistribute its flow direction and areas that should be fed by Ameria pipeline is fed by other sources (Abu Awekel and Mostorod). This redistribution causes a reduction of water pressure in other areas but the pressure is still within acceptable range under risk condition.

iii. Case Other Pipeline Breakage

Several cases assuming several pipeline breakages were tried out. In each case, single pipeline was assumed to be broken. Running the model indicated that local problems occurs in local areas. Water pressure reduces below normal pressure or even in some nodes water will be unavailable. These conditions could be accepted if the repair time is short and high rise building roof tanks are filled to provide roof storage to cover repair time

CONCLUSIONS

- Nasr City water distribution is frequently subjected to risk conditions. These conditions include, but not limited to, pipeline breakage, valve breakage, pump failure, and tank failure.

- Analyzing Nasr City water distribution system for pump risk condition showed that pump station Abu Awekel is of very high risk condition while pump station Tank NC-5 is of normal risk condition because they have no standby pumps. The analysis also showed that all pump station except Nasr City-1 and pump station tank Zahraa NC are of normal risk condition because they have no standby generator.

- Analyzing Nasr City water distribution system for the case of breakage of the pipeline 1400 mm diameter coming from Abu Awekel pump station showed that this case is the most critical risk condition for the system. Although two pipelines, 1000 mm diameter and 800 mm diameters, were installed carrying 50,000 m^3/d each since 29th of January 2005, this pipeline (1400 mm diameter) carry about 300,000 m^3/d which is about 55 percent of Nasr City demand. As a result, any breakage of this pipeline will repeat the risk condition happened on 29th of January 2005.

- Analyzing Nasr City water distribution system for the several cases of pipeline breakage showed that normal risk condition will occur where water will be available in general with acceptable risk condition pressure except in some local area where water will be unavailable during the risk period.

- As a short term plan for risk condition, high rise building roof tanks should be filled all the time and the repair time for the pipeline breakage should be filled.

- As a long term plan, a new pipeline 1000 mm diameter should be installed from Abu Awekel parallel to the Cairo Ring Road till its intersection with Axis NB connecting Nasr City with New Cairo City. At that intersection, booster pump should be installed then the line connects to the 600 mm diameter pipeline feeding El-Haiy El-Ashire. This pipeline will improve the system performance in current, future, and risk conditions.

- The long term plan should include the installation of standby pumps and generators for all pump stations that has no standby.

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