AIN SHAMS UNIVERSITY
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RELIABILTY OF WATER DISTRIBUTION NETWORKS

A DISSERTATION

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ABSTRACT

Most of the aged-infrastructures in our communities, including water distribution networks, have deteriorated to the point that their serviceability has drawn much attention. There has been growing awareness that water distribution networks should be designed and maintained to sustain a certain level of reliability. In the phase of planning and design of the optimal system configuration, required reliability should be included as an important parameter. Existing practice, the mutual comparison of different systems without including reliability as criteria, can lead the designer to an unreliable solution that needs further repairs or remediation.

This thesis demonstrates the use of Monte Carlo techniques in evaluating the reliability of water resources systems. The proposed methodology considers both: mechanical reliability (probability of pipe and pump failure) and hydraulic reliability (pressure and demand). This model is useful for determining reliability of systems with different configurations and complexity. Also, methodology for optimal reliability allocation, based on genetic algorithms, is proposed. That methodology, coupled with the reliability evaluation method, is an efficient tool for solving problems of optimal allocation of water distribution network reliability.

Monte Carlo Analysis is a powerful tool for modeling reliability of systems. Proper application of this technique requires understanding of its underlying principles. In this, thesis, Monte Carlo analysis is explained at a fundamental level with emphasis on its application in estimating the reliability of water distribution systems. The first part of this thesis, explains step-by-step how to perform a Monte Carlo analysis. The second part describes the different sources of variation in water distribution networks, their statistical distribution and how they are affected by aging. The final part of this thesis describes proposed reliability analysis methodology in detail. The proposed network reliability analysis methodology was coded using MATLAB and was applied it to a real water

distribution network designed for the city of Abusweir. The analysis results for the Abusweir network are then discussed and different alternatives to improve the network reliability are proposed and evaluated. The proposed alternatives improve the network reliability from 64% for the original design to up to 94%. Extending the proposed statistical network solver to optimization frameworks is also explained.

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CHAPTER 1. INTRODUCTION

1.1. General

Water Distribution Networks play a vital important role in preserving and providing a desirable life quality to the public. In the past that the much of the effort in the design of the water distribution networks emphasized on the aspect of least cost. The amount of effort and attention given to develop a procedure for system performance reliability evaluation has not attained a comparable scale.

Water utilities are concerned construct, operate, and maintain water supply systems. The basic objective of these water utilities is to obtain water from a source, treat the water to an acceptable quality, and deliver the desired quantity of water to the appropriate place at the required time.

The analysis of a water system is usually to evaluate one or more of the major functional components of the utility: source development; raw-water transmission: raw water storage, treatment, finished water storage; and finished water distribution. The water distribution network will be our main concern in this study for which we have applied the reliability measures.

1.2. Components of Water Distribution Networks

The purpose of a water distribution network is to supply the system's users with the required water demand such as fire demands at different nodes; peak daily demands; a series of patterns varying throughout a day; or a critical load when one or more pipes are broken, and to supply this water with adequate pressure under various loading conditions (pattern of nodal demands).

In order to insure that a design is adequate, a number of loading conditions including critical conditions must be considered. The ability to operate under a variety of load patterns is required to have a reliable network.

Distribution system infrastructure is generally considered to consist of the pipes, pumps, valves, storage tanks, reservoirs, meters, fittings, and other hydraulic

accessories that connect treatment plants or well supplies to consumers' taps, as shown in Figure 1-1. The characteristics, general maintenance requirements, and desirable features of the basic infrastructure components in a drinking water distribution system are briefly discussed below.

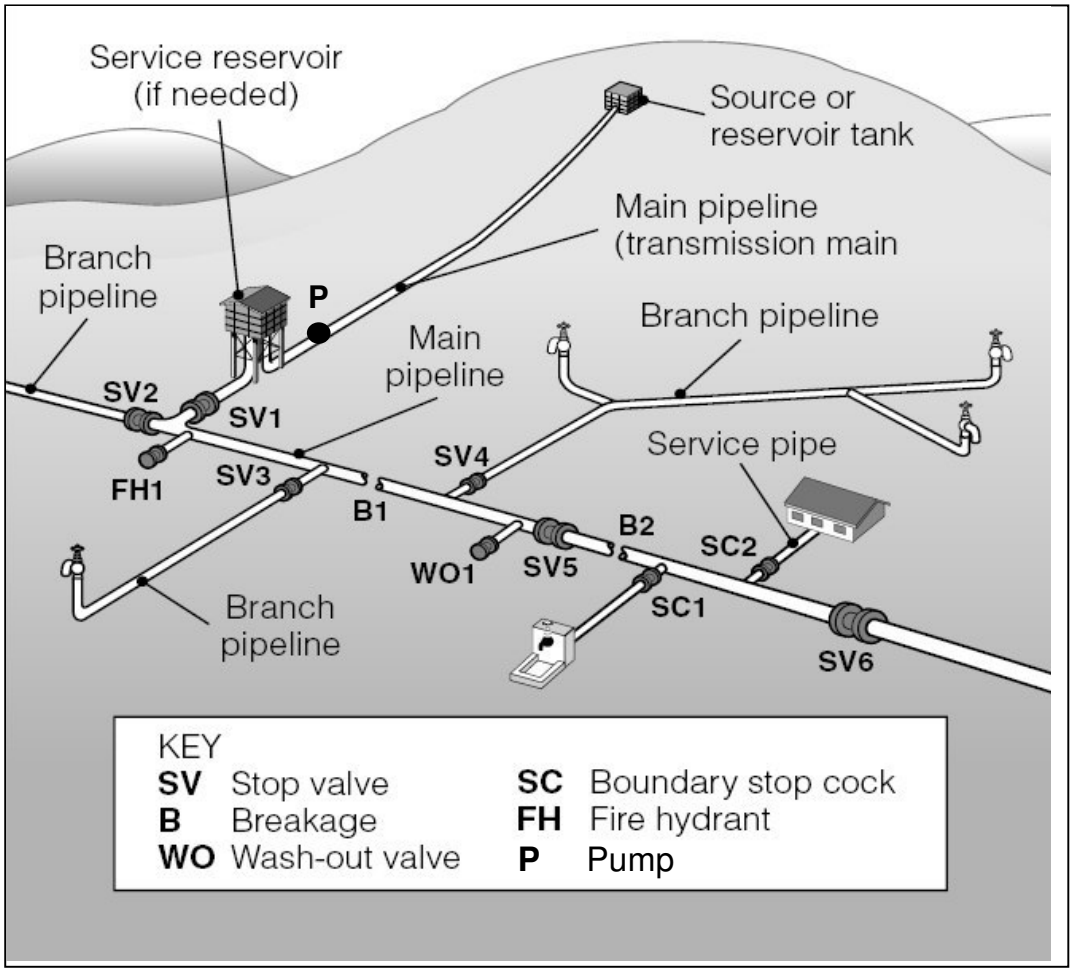

Figure 1-1. Water Distribution System

1.2.1. Pipes

The systems of pipes that transport water from the source (such as a treatment plant) to the customer are often categorized from largest to smallest as transmission or trunk mains, distribution mains, service lines, and premise plumbing. Transmission or trunk mains usually convey large amounts of water over long distance such as from a

treatment facility to a storage tank within the distribution system. Distribution mains are typically smaller in diameter than the transmission mains and generally follow the city streets. Service lines carry water from the distribution main to the building or property being served. Service lines can be of any size depending on how much water is required to serve a particular customer and are sized so that the utility's design pressure is maintained at the customer's property for the desired flows. Premise plumbing refers to the piping within a building or home that distributes water to the point of use. In premise plumbing the pipe diameters are usually comparatively small, leading to a greater surface-to-volume ratio than in other distribution system pipes.

The three requirements for a pipe include its ability to deliver the quantity of water required, to resist all external and internal forces acting upon it, and to be durable and have a long life (Clark and Tipper, 1990). The materials commonly used to accomplish these goals today are ductile iron, pre-stressed concrete, polyvinyl chloride (PVC), reinforced plastic, and steel. The material of the pipe is a major element for changing the reliability of a network.

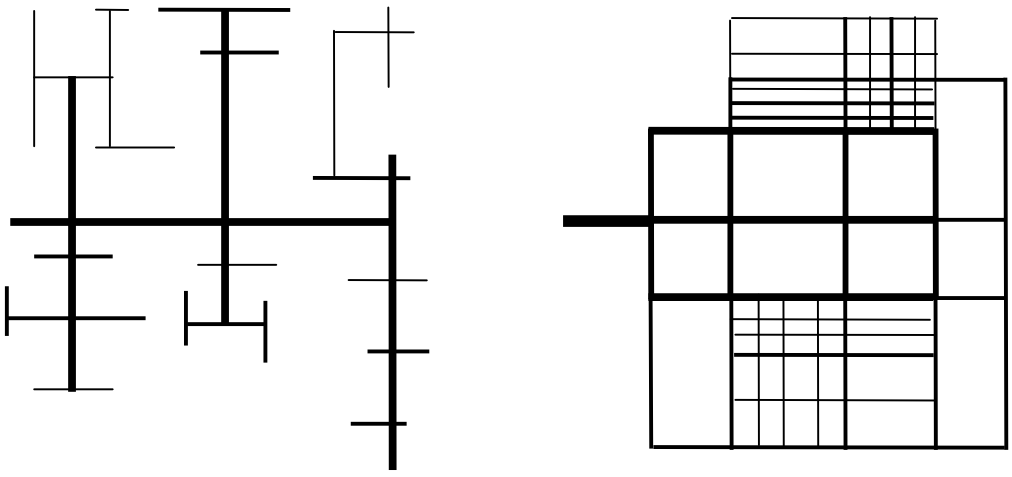

Figure 1-2. Two Basic Configurations for Water Distribution Systems
(A) Branched configuration (B) Looped configuration