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WATER SUPPLY SYSTEMS SECURITY

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PREFACE

In the mid-1980s I chaired a task committee for the American Society of Civil Engineers (ASCE), which culminated in the book, *Reliability Analysis of Water Distribution Systems*, published by ASCE in 1989. As the editor and a major contributor to this book I was extremely excited about this effort, which emphasized various methodologies for the reliability assessment of water distribution systems and their components. The risk/reliability methodologies we presented were state-of-the-art methodologies, many of which, are used in the nuclear power industry, the chemical processing industry, and the electrical power industry. Unfortunately to this date these methodologies are still not used by the water utility industry. We defined failures in the framework of mechanical failures and the resulting hydraulic performance failures. At that time we never fathomed the idea of terrorist threats to our water infrastructure. Even eleven years later in 2000, as editor-in-chief of the *Water Distribution Systems Handbook*, published by McGraw-Hill, the topic of security from terrorist threats never crossed my mind as important for that handbook. The two succeeding McGraw-Hill books on urban water supply that I developed as editor-in-chief, *Urban Water Supply Handbook* in 2002 and *Urban Water Supply Management Tools* in 2003, each have a chapter on the topic of security, but nothing to the extent of *Water Supply Systems Security*.

The events of September 11, 2001 have forced a new focus on our water utility infrastructure in the United States. Prior to these events the consideration of terrorist threats to drinking water supply systems was minimal. Now our approach to the management of these systems has changed significantly with the passage of two very important acts in 2002, that focus on the water infrastructure and give directives for the future. The Public Health, Security, and Bioterrorism Preparedness and Response Act (PL 107-188) (June 2002), requires community water systems serving populations greater than 3300 to conduct vulnerability assessments and submit these assessments to the U. S. Environmental Protection Agency. The Homeland Security Act (PL 107-296), November 25, 2002, directed the greatest reorganization of the federal government in decades by consolidating a host of security-related agencies into a single cabinet-level department.

This book was developed as a response to the critical needs of engineers and utility managers to have a resource on the security of water supply systems. The future of water supply security analysis will hopefully include some of those risk/reliability methodologies that exist for our future design methodologies, vulnerability assessments, and emergency response planning.

Water Supply Systems Security presents state-of-the-art methodologies for the various aspects of water supply infrastructure. The topics have been chosen to represent what we feel are the most important for engineers, utility managers, and others working on the security of water supply infrastructure. The wide set of topics range from the various types of threats to various levels of vulnerability assessments, risk assessments, reliability assessments, to surveillance hardware, the next generation of contaminant detection devices, to many other topics. All chapter authors are leading experts and were chosen because of their proven knowledge in the specific area of their contribution.

Each book that I have worked on has been a part of my lifelong journey in water resources, and *Water Supply Systems Security* certainly is no exception. I have gained more from my experiences in developing books than can ever be measured in words. This book certainly will never have the impact upon history that the treatises of Vitruvius and Frontinus of the Roman Empire have had, but hopefully it will provide a little insight for the present generation of water distribution systems engineers and managers. Vitruvius and Frontinus of the Roman Empire were also faced with security issues of their water supply systems, but of a far different nature than what we face today.

This book has been a part of my personal journey in life to learn as much as possible about water and to use this knowledge in my teaching, research, and writing. I hope that you will be able to use this book in your own journey of learning about water. As I continue my efforts in the study and photography of ancient water structures, especially those built by the Romans, I am placing many of my photographs on my web site (www.public.asu.edu/~lwmays/). These may be of interest to some of you readers.

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ACKNOWLEDGMENTS

I must first acknowledge the authors who made *Water Supply Systems Security* possible. It has been a sincere privilege to work with such an excellent group of dedicated people. I would especially like to acknowledge that Dr. Robert Clark was involved in developing six of the chapters in this book and was lead author on four of these chapters. His distinguished career with the U.S. EPA along with his extensive research and many publications on water distribution systems, without a doubt, has made him one of the leading experts in the world on the security of water distribution systems. Dr. Clark's contributions to this book are very much appreciated by myself and I am certain the entire profession will appreciate his efforts for this book. I would also like to give a special thanks to Dr. Walter Grayman who was involved in the development of three chapters and was lead author on three of these. All the authors are experienced professionals who are among the leading experts in their fields and I would like to express my sincere appreciation to them for their efforts. Any references to material in this handbook should be attributed to the respective chapter authors.

This has been the eighth book that I have developed with Larry Hager of McGraw-Hill. I sincerely appreciate his efforts and he is always a joy to talk to, as he is one of the few willing to listen to my adventures hiking, fly fishing, and snow skiing in Colorado. I would also like to acknowledge Arizona State University, especially for the time afforded me to pursue this book.

During the 28 years of my academic career as a professor I have received help and encouragement from so many people that it is not possible to name all of them. These people represent a wide range of universities, research institutions, government agencies, and professions. They also represent all of my former students and particularly my former Ph.D. students. To all of you I express deepest thanks.

I must also acknowledge my three children, Travis, Elyssa, and Tyler for their love and willingness to enjoy the water-related sports with me, especially at our second home in Pagosa Springs, Colorado. They may never read this book, but they do represent the most valuable part of my life.

My hope in life has always been to get the most out of what the world has to offer and the most out of the talent with which God has blessed me. I've realized that once I shed the burden of the real or imagined values and expectations of others, it has been much easier to tell where my real passions lie. Certainly one of my real passions in the journey of life has been in the development of the books such as this one. I am having a great journey in life and hope the same for all of you.

I dedicate this book to humanity and human welfare.

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CHAPTER 1
WATER SUPPLY SECURITY: AN INTRODUCTION

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1.1 HISTORY

A long history, in fact since the dawn of history, of threats to drinking water systems during conflicts has plagued humans. Water has been a strategic objective in armed conflicts throughout history. Gleick (1994, 1998, 2000) has developed a water conflict chronology in which he categorizes the conflicts as the following: control of water resources, military tool, political tool, terrorism, military target, and development disputes. Terrorism is defined as, "water resources, or water systems, are either targets or tools of violence or coercion by nonstate actors." There are many historical conflicts that caused flooding by diversion or eliminated water supplies by building dams or other structures, whereas in the following only a few examples of some of the water conflicts that included water supply systems are summarized.

During the time of King Hezekiah—the period of the First Temple (the latter part of the eighth century B.C.), Jerusalem was under military threat from Assyria (2 Kings 20:20; Isaiah 22:11; 2 Chronicles 32:2-4,30). The Gihon spring, located just outside the city walls, was the main water source for the ancient city of Jerusalem (Bruins, 2002), requiring strategic planning on King Hezekiah's part. He had a water tunnel (533 m) dug to channel the water underground into the city, with the outlet at a reservoir known as the Pool of Siloam. Two crews of miners dug through solid limestone from both ends of the tunnel, meeting at the same spot (Bruins, 2002).

During the second Samnite War, ca. 310 B.C., the Romans realized the need for alternate water sources for Rome due to the insufficient and unreliable local supplies. The Roman Senate procured and distributed water rights from estates surrounding Rome in order to develop the supply and security needed for Rome.

In 1503, Leonardo da Vinci and Machiavelli planned to divert the Arno River away from Pisa during the conflict between Pisa and Florence.

During the Civil War (1863) in the United States, General U.S. Grant cut levees in the battle against the Confederates during the campaign against Vicksburg.

In 1948, during the first Arab-Israeli War, Arab forces cut off the West Jerusalem water supply.

In 1982, Israel cut off the water supply of Beirut during the siege.

In 1990 in South Africa, the pro-apartheid council cut off water to the Wesselton township of 50,000 blacks following protests over miserable sanitation and living conditions.

During the 1991 Gulf War, the Allied coalition targeted Baghdad's water supply and sanitation system. Discussions were held about using the Attaturk Dam to cut off flows to the Euphrates to Iraq. Also during the Gulf War, Iraq destroyed much of Kuwait's desalination capacity during retreat. In 1993, Saddam Hussein reportedly poisoned and drained water supplies of southern Shiite Muslims.

In Kosovo (1999), water supplies/wells were contaminated by Serbs who disposed of the bodies of Kosovar Albanians in local wells. Serbian engineers shut down the water system in Pristina prior to occupation by NATO. Also during that same year in Yugoslavia, NATO targeted utilities and shut down water supplies in Belgrade.

Gleick (2000) developed a water conflict chronology (1503 to 2000) that can be found at the following site: http://www.worldwater.org/conflict.htm.

1.2 THE WATER SUPPLY SYSTEM: A BRIEF DESCRIPTION

The events of September 11, 2001 have significantly changed the approach to management of water utilities. Previously, the consideration of the terrorist threat to the U.S. drinking water supply was minimal. Now we have an intensified approach to the consideration of terrorist threat. The objective of this chapter is to provide an introduction to the very costly process of developing water security measures for U.S. water utilities.

Figure 1.1 illustrates a typical municipal water utility showing the water distribution system as a part of this overall water utility. In some locations, where excellent quality groundwater is available, water treatment may include only chlorination. Other handbooks on the subject of water supply/water distribution systems include Mays (1989, 2000, 2002, 2003).

Water distribution systems are composed of three major components: pumping stations, distribution storage, and distribution piping. These components may be further divided into subcomponents, which in turn can be divided into sub-subcomponents. For example, the pumping station component consists of structural, electrical, piping, and pumping unit subcomponents. The pumping unit can be divided further into sub-subcomponents: pump, driver, controls, power transmission. The exact definition of components, subcomponents, and sub-subcomponents depends on the level of detail of the required analysis and, to a somewhat greater extent, the level of detail of available data. In fact, the concept of component-subcomponent-sub-subcomponent merely defines a hierarchy of building blocks used to construct the water distribution system. Figure 1.2 shows the hierarchical relationship of system, components, subcomponents, and sub-subcomponents for a water distribution system.

A water distribution system operates as a system of independent components. The hydraulics of each component is relatively straightforward; however, these components depend directly upon each other and as a result effect the performance of one another. The purpose of design and analysis is to determine how the systems perform hydraulically under various demands and operation conditions. These analyses are used for the following situations:

- Design of a new distribution system
- Modification and expansion of an existing system

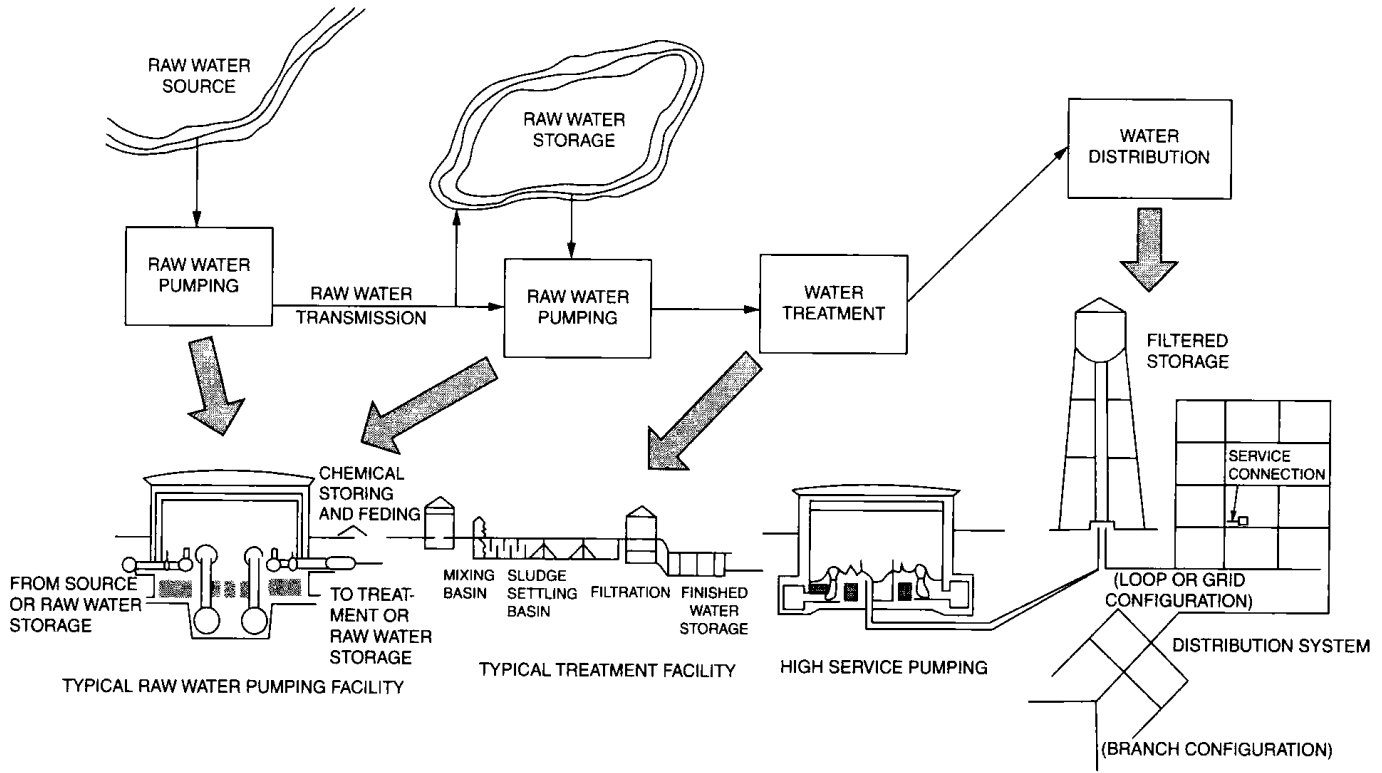

FIGURE 1.1 A typical water distribution system.

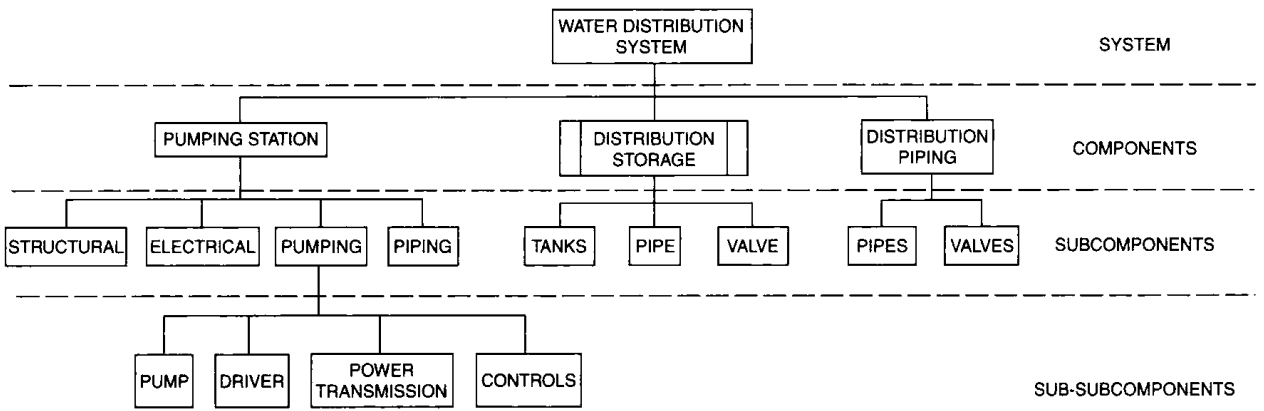

FIGURE 1.2 Hierarchy of building blocks in water distribution systems.

- Analysis of system malfunction such as pipe breaks, leakage, valve failure, pump failure
- Evaluation of system reliability
- Preparation for maintenance
- System performance and operation optimization

1.3 WHY WATER SUPPLY SYSTEMS?

A distribution system of pipelines, pipes, pumps, storage tanks, and the appurtenances such as various types of valves, meters, etc. offers the greatest opportunity for terrorism because it is extensive, relatively unprotected and accessible, and often isolated. The physical destruction of a water distribution system's assets or the disruption of water supply could be more likely than contamination. A likely avenue for such an act of terrorism is a bomb, carried by car or truck, similar to the recent events listed in Table 1.1. Truck or car bombs require less preparation, skill, or manpower than complex attacks such as those of September 11, 2001. However, we must consider all the possible threats no matter how remote we may think that they could be.

TABLE 1.1 Recent Terrorist Attacks Against American Targets Using Car-Bomb Technologies

Date	Target/location	Delivery/ material	TNT equivalent (lb)	Reference
Apr. 1983	U.S. Embassy Beirut, Lebanon	Van	2,000	www.beirut-memorial.org
Oct. 1983	U.S. Marine Barracks Beirut, Lebanon	Truck, TNT with gas enhancement	12,000	www.usmc.mil
Feb. 1993	World Trade Center New York, U.S.A.	Van, urea nitrate and hydrogen gas	2,000	www.interpol.int
Apr. 1995	Murrah Federal Bldg Oklahoma City, U.S.A.	Truck, ammonium nitrate fuel oil	5,000	U.S. Senate documents
June 1996	Khobar Towers Dhahran, Saudi Arabia	Tanker truck, plastic explosive	20,000	www.fbi.gov
Aug. 1998	U.S. Embassy Nairobi, Kenya	Truck, TNT, possibly Semtex	1,000	news reports, U.S. Senate documents
Aug. 1998	U.S. Embassy Dar es Salaam, Tanzania	Truck	1,000	U.S. Senate documents
Oct. 2000	Destroyer USS Cole Aden Harbor, Yemen	Small watercraft, possibly C-4	440	www.al-bab.com news.bbc.co.uk

Source: Peplow et al. (2003).