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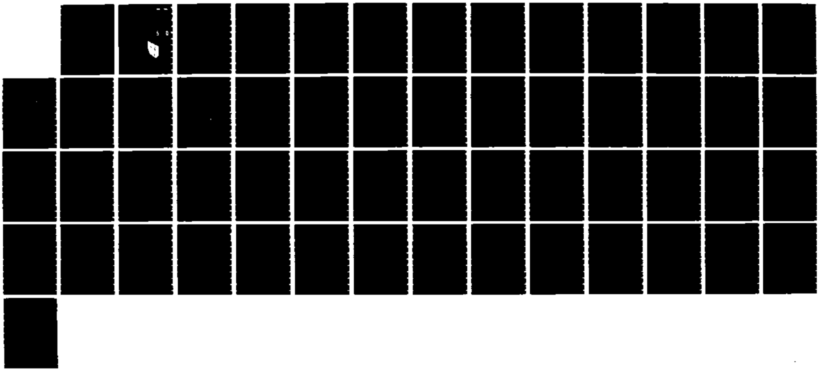

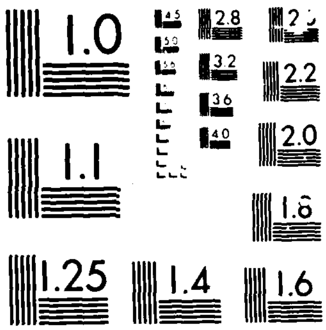
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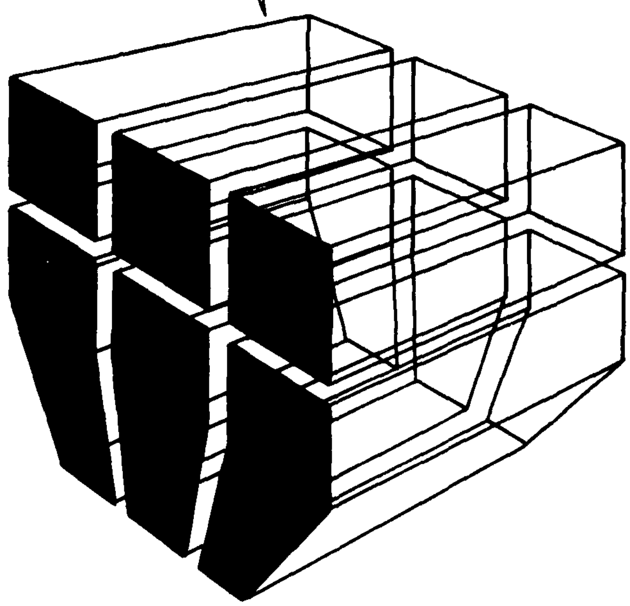
US Army Corps of Engineers
Construction Engineering Research Laboratory

USA-CERL

TECHNICAL REPORT N-86/11
June 1986
Closed-Loop Water Conservation/
Supply Augmentation Techniques

Emergency Water Supply Planning for Fixed Army Installations

by
Stephen W. Maloney
John T. Bandy



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This report summarizes the various types of disasters that can impair a water utility and provides a basis for estimating water requirements during an emergency. In addition, it provides information for assessing the vulnerability of various system components to damage from disaster, and gives a checklist of activities to be carried out in developing and updating an emergency water plan.

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FOREWORD

This work was performed for the Office of the Assistant Chief of Engineers (OACE), under Project 4A162720AQ896, "Environmental Quality Technology"; Task Area A, "Installation Environmental Management"; Work Unit 031, "Closed-Loop Water Conservation/Supply Augmentation Techniques." The OACE Technical Monitor was T. Wash, DAEN-ZCF-U.

The work was done by the U.S. Army Construction Engineering Research Laboratory (USA-CERL) Environmental Division (EN). Dr. R. K. Jain is Chief of USA-CERL-EN.

COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

TABLES

FIGURES

EMERGENCY WATER SUPPLY PLANNING FOR FIXED ARMY INSTALLATIONS

1 INTRODUCTION

Background

Water utilities usually operate in a crisis management status, having developed standard operating procedures to cope with common emergencies such as water main breaks. Emergencies can be grouped as resulting from natural disasters (e.g., earthquakes, hurricanes), accidental disasters (e.g., plane crashes, blackouts), and deliberate action (e.g., riots, acts of war). The water utility must be as well prepared as possible for all such events, even though some emergencies may result in prolonged periods of interrupted water service. It is particularly important for a water utility facing 1 week or more without the use of some portions of its physical plant to have a plan of operation that will minimize the loss of and/or maintain vital services (e.g., hospital or critical industry operation).

Development of a plan at an Army installation involves hypothesizing probable emergencies based on the facility's location, estimating installation requirements, and estimating the vulnerability of system components to each type of disaster. For example, hurricanes and tornadoes should have little effect on a distribution system, whereas earthquakes or freak low temperatures may cause water-main breaks.

The absence of complete emergency plans is noted in the Army Environmental Hygiene Agency's (AEHA) *Water Quality Information Paper No. 24*[1] which states that the most common documentation is a "plan to make a plan." Army Regulation (AR) 420-46[2] states, "A standing operating procedure for alerting personnel in national and local emergencies (enemy attack, subnormal service, main breaks, fires, etc.), and clearly defining the duty of each individual during emergencies will be prepared and kept current." Technical Manual (TM) 5-660[3] contains more extensive guidance on emergency planning. Other guidance is found in TMs 5-813-1 through 5-813-7.[4]

The U.S. Army Construction Engineering Research Laboratory (USA-CERL) conducted a survey in 1984 which included questions with respect to water supply emergency planning. The survey[5] indicated that only 13 percent of the installations had

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[1] *Water Quality Information Paper No. 24* (Army Environmental Hygiene Agency, undated).

[2] AR 420-46, *Water and Sewage* (Department of the Army [DA], July 1978).

[3] TM 5-660, *Real Property Operation and Maintenance--Maintenance and Operation of Water Supply, Treatment, and Distribution Systems* (DA, August 1984).

[4] TM 5-813-1, *Water Supply--General Considerations* (DA, July 1965); TM 5-813-2, *Water Supply—Water Sources* (DA, July 1958); TM 5-813-3, *Water Supply--Water Treatment* (DA, September 1966); TM 5-813-4, *Water Supply--Water Storage* (DA, July 1958); TM 5-813-5, *Water Supply--Water Distribution Systems* (DA, January 1963); TM 5-813-6, *Water Supply--Water Supply for Fire Protection* (DA, July 1958); TM 5-813-7, *Water Supply for Fire Protection* (DA, March 1975).

[5] J. F. Langowski, et al., *A Survey of Water Demand Forecasting Procedures on Fixed Army Installations*, Technical Report N-85/07/A153040 (U.S. Army Construction Engineering Research Laboratory [USA CERL], 1985).

a plan. Since this would be part of an overall emergency plan, the survey indicates a general lack of complete plans at this time. To prepare a workable plan, installation personnel require guidance on the best ways to collect pertinent information and tabulate the collected data. TM 5-660 contains general information on emergency water planning at Army installations. This study expands on the guidance provided in TM 5-660.

Objectives

The objectives of this report are to (1) summarize hypothetical disasters that would cause water shortages, (2) provide a basis for estimating water requirements under emergency situations, (3) illustrate the vulnerability of various system components to various disasters and provide methods to minimize these vulnerabilities, and (4) provide a checklist for developing and updating an emergency water plan at Army installations.

Approach

The following steps were used to develop an emergency planning procedure. These steps are based on concepts and practices used in the private sector.

1. A set of hypothetical disasters was developed, and the probability of these disasters occurring was estimated based on the installation's location.

2. A grid was developed that would associate type of disaster with its effects on components, since the actual magnitude of the effect is related to the disaster's magnitude.

3. Water requirements were estimated for various activities, since all but essential services must be eliminated during an emergency.

4. The vulnerability of system components was assessed relative to the potential effects of disasters.

5. A checklist was developed to assist Army installations in developing emergency plans.

Scope

The techniques developed in this study apply to all fixed Army installations that own and/or maintain potable water systems or any portion of a water system (i.e., wells, surface water plants, ground or elevated reservoirs, distribution systems, pumping stations, etc.).

Mode of Technology Transfer

It is recommended that the information in this report be issued as an Engineer Technical Letter.

2 DEFINITION OF SYSTEM COMPONENTS

A water utility is a complex operation which is not self-sufficient. It relies heavily on other aspects of the installation's infrastructure, including power generation, communication lines, and transportation. Emergencies that arise in any of these areas can impact an unprepared water utility.

A water utility has four major subsystems: (1) collection, (2) transmission, (3) treatment, and (4) distribution. Each one can be broken down into componen' parts such as communications, fixed structures, materials and supplies, personnel, power, and transportation. These components may also be interrelated. For example, an emergency which primarily affects transportation can immediately affect personnel availability.

Collection systems can include surface impoundments, river intake structures, pumps and associated power generation equipment, and wells. Some forms of pretreatment often occur at collection systems; for example, screening removes large debris from the raw water, and predisinfection protects transmission systems.

Transmission systems may be comprised of open canals or aqueducts, or enlosed conduits or water mains. These systems carry nonpotable water and often include sections that are open to the atmosphere, making them more vulnerable to accidental or deliberate contamination.

Treatment works include all unit processes for providing water quality acceptable for human consumption. They can range from very simple processes such as injection of chlorine into water from a high-quality well supply, to a complex series of unit processes, including sedimentation, filtration, chemical stabilization, adsorption, and ion exchange. The treatment works include the storage and management of chemicals. Chemical stocks management can be important in bringing treatment back online after an emergency.

The distribution system includes all water mains carrying potable water, all potable water storage reservoirs, all valves, pumps and associated buildings, and any communication equipment used for remote monitoring of line pressures or tank levels. Much of the distribution system is out of sight, so slow deterioration is not visually evident. However, a broken main can rapidly lead to a water emergency that is not associated with any other type of "disaster" situation.

The development of an emergency water plan relies heavily on an accurate knowledge of the base infrastructure and all supporting elements. The infrastructure should be detailed on a master plan with "as-built" modifications incorporated. This master plan should be updated by verifying system components when they are serviced; i.e., note pipe sizes and material found when doing construction or rehabilitation work, check against the master plan, and correct the master plan as necessary. Supporting elements include the power supply system, transportation system, parts and material suppliers.

3 DEVELOPMENT OF POTENTIAL DISASTER SCENARIOS

The first step in developing an emergency water plan is evaluating hazards based on the installation's location. For example, hurricanes are most common on the eastern seaboard and Gulf Coast states and in the Pacific islands; tornadoes occur most often in the center of the United States, and avalanches occur in mountainous areas. Thus, location can, in part, determine the types of risks an installation faces. On the other hand, riots and acts of war may occur anywhere.

The effects of disasters on water utilities have been discussed extensively in an American Water Works Association report.[6] Several of the tables in this chapter are based on information from that publication, with some modifications to tailor the information to Army installations.

Natural Disasters

Natural disasters occur randomly and do not involve man-made force. The range in damage is very wide due to the range of energy found in nature. Natural disasters include earthquakes, volcanoes, tornadoes, hurricanes, floods, and tsunamis.

Earthquakes

An earthquake results when two land masses move in relation to each other. The division between the land masses is not clearcut, and there is substantial cohesion between the land masses prior to a quake. This results in a buildup of stress, which is released as soon as the earthquake occurs. Thus, an earthquake can release enormous amounts of energy which have been stored up over a long time.

Earthquakes are rated on a logarithmic scale called the Richter scale, which is based on the energy they release. Table 1 shows the relation between magnitude, estimated incidence, distance and area affected, and energy released. These magnitudes are sometimes compared to energies released by nuclear weapons; however, it is an inappropriate comparison, because an earthquake's energy is not concentrated at one point. Any earthquake with a magnitude greater than 7 on the Richter scale is considered major. Figures 1 through 3 can be used to hypothesize disasters associated with earthquakes.

Theoretically, earthquakes occur anywhere, but some areas are at much greater risk than others. Eighty percent of the energy released by earthquakes occurs around the borders of the Pacific Ocean.[7] Codes have been developed[8] for constructing buildings that will resist seismic forces.

Earthquakes can affect a water utility in many ways. There can be structural damage to water plant buildings and equipment, raw and finished water reservoirs, well casings, intake and transmission structures, elevated storage tanks, and water mains. After an earthquake, power lines can be damaged, and access to the water utility

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[6] *Emergency Planning for Water Utility Management*, Manual No. M19 (American Water Works Association, 1984).

[7] L. D. Leet and S. Judson, *Physical Geology* (Prentice-Hall, Inc., 1971).

[8] *Uniform Building Code*, 1985 Edition (International Conference of Building Officials).

Table 1

Earthquake-Energy Relationships
(From *Emergency Planning for Water Quality Management*, Manual No. M19
[American Water Works Association, 1984].)

Magnitude	Expected Annual Incidence	Distance Felt (mi)	(km)	Area Affected (sq mi)	(km^2)	Energy Released (tons of TNT)
3.0-3.9	49,000	15	(24)	0.75	(1.9)	10
4.0-4.9	6,200	30	(48)	3	(7.8)	14 - 200
5.0-5.9	800	70	(113)	15	(39)	230 - 10k*
6.0-6.9	120	125	(201)	50	(129)	14k - 200k
7.0-7.9	18	250	(403)	200	(520)	230k - 10M**
8.0-8.9	1	450	(723)	800	(2070)	14M - 200M

*k = 1,000
**M = 1,000,000

components may be severely limited. Earthquakes may also be responsible for starting landslides or tsunami waves.

Many attempts have been made to predict the occurrence of earthquakes, but so far no reliable method has been developed. This uncertainty adds to the potential for destructive effects, because there is no advance warning.

Volcanoes

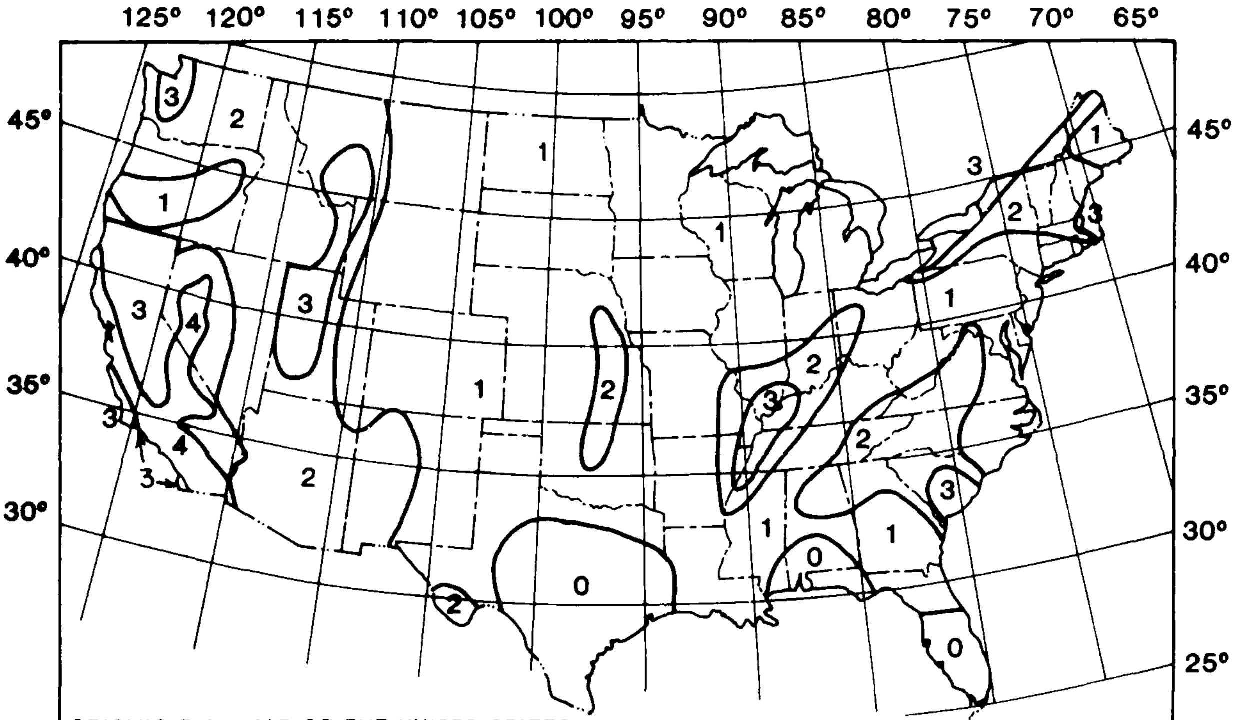
Volcanoes occur where molten rock, called magma, breaks to the earth's surface. As the magma nears the surface, dissolved gases escape and put pressure on the overlying rock. When enough pressure builds up the gases break through explosively, turning the overburden into projectiles and allowing the magma (called lava when it reaches the surface) to escape.

Volcanoes are located primarily around the rim of the Pacific basin and along the mid-Atlantic (Ocean) ridge. However, no specific geologic environment is required for volcanoes; they occur in high mountain ranges, on open plains, and on the ocean floor.

The explosion can throw enormous amounts of dust great distances. This dust can contaminate water supplies, dramatically increase the particulate load on treatment plants, and shorten filter runs. It can also limit transportation of materials and supplies. An emergency plan for Army installations near active volcanoes should address these types of problems.

Hurricanes and Tornadoes

Hurricanes and tornadoes are quite different meteorological phenomena, but both result in high winds. Hurricanes, most often associated with the eastern seaboard of the Continental United States (CONUS) and the Pacific islands, can cause both flooding and



SEISMIC RISK MAP OF THE UNITED STATES

ZONE 0 – No Damage

ZONE 1 – Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the M.M.* Scale

ZONE 2 – Moderate damage; corresponds to intensity VII and of the M.M. Scale

ZONE 3 – Major damage; corresponds to intensity VII and higher of the M.M. Scale

ZONE 4 – Those areas within Zone No. 3 determined by the proximity to certain major fault systems

*Modified Mercalli Intensity Scale of 1931

Figure 1. Seismic zone map for Continental United States. (Reproduced from the Uniform Building Code, 1985 Edition, copyright 1985, with permission of the publisher, the International Conference of Building Officials.)

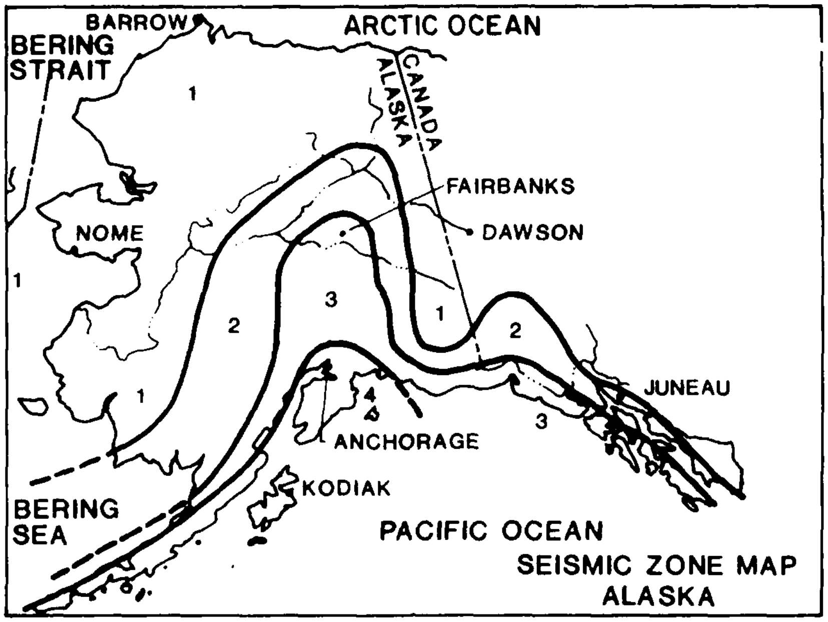


Figure 2. Seismic zone map for Alaska. (Reproduced from the Uniform Building Code, 1985 Edition, copyright 1985, with permission of the publisher, the International Conference of Building Officials.)

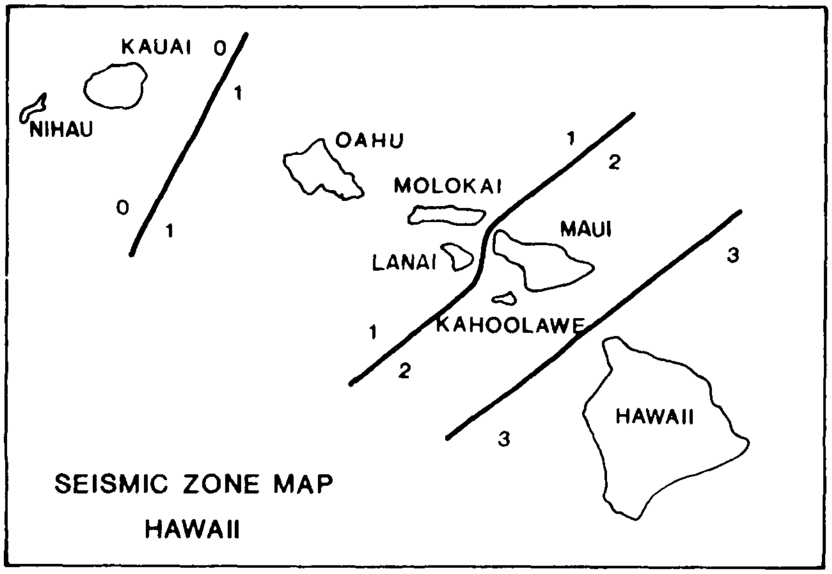


Figure 3. Seismic zone map for Hawaii. (Reproduced from the Uniform Building Code, 1985 Edition, copyright 1985, with permission of the publisher, the International Conference of Building Officials.)

high winds. Tornadoes are most often associated with the middle of CONUS, but can occur anywhere.

Hurricanes are classified in terms of damage produced, ranging from 8 for least damaging to 1 for most damaging. Table 2 shows the seasonal occurrence of hurricanes in a typical year. The most damaging hurricanes occur mostly between June and November. Table 3 gives the frequency of occurrence in this period and the probability of occurrence in specific locations.

The Uniform Building Code contains some guidance for designing buildings that can resist high wind speed. Figure 4 shows design speeds in miles per hour for CONUS and Alaska. Design speed for Hawaii is 80 mph and is 95 mph* for Puerto Rico.

Hurricanes can be spotted by weather radar, and followed through their development from tropical depression, to tropical storms, and to hurricane (the status depends on windspeed). Thus, advance warning is available, which is especially important for emergency planning. Responses to various levels of hurricane warning should be incorporated into emergency plans of areas susceptible to hurricanes and their effects.

Tornadoes can also be tracked by weather radar; however, their formation is more complicated. Unlike a hurricane, they do not follow a natural progression from one set of conditions or storm. Tornadoes usually form during warm and humid weather and are frequently associated with thunderstorms.[9] Several tornadoes can result from a single thunderstorm. Tornadoes occur with the least advance warning of any natural disaster

Table 2

Seasonal Distribution of Hurricanes by Intensity for Each Month of a Typical Year
(From *Emergency Planning for Water Quality Management*, Manual No. M19 [American Water Works Association, 1984].)

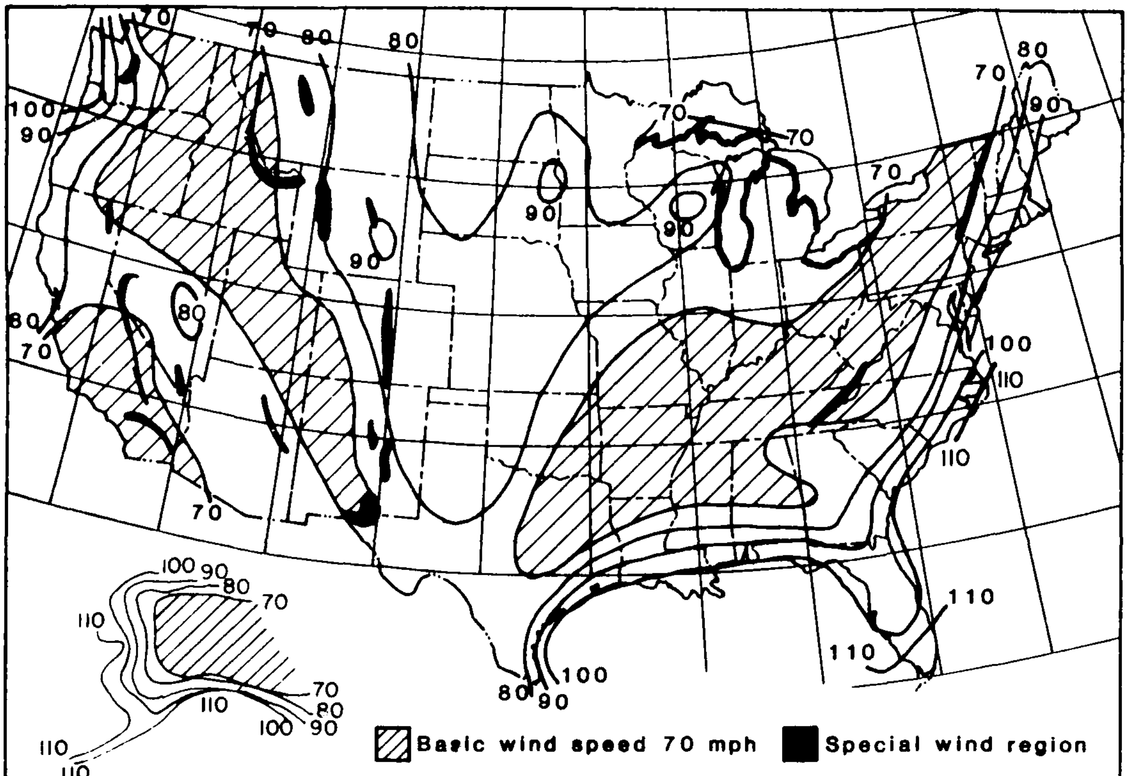
Class	J	F	M	A	M	J	J	A	S	O	N	D	Total for Year
1	1				1	3	15	24	1	5	3		62
2	2							1		2	3	1	9
3	3	1	2	1	1	1		3	4	5	6		27
4	2	4	5	3	2				2	2	3	2	25
5	2	3	2	1		1		1			3	2	15
6	3	4	3	5	1	1				1	4	4	26
7		3	3	1	1					3	4	2	17
8	1				1		1	1	3	1			8

*Metric conversion factors are provided on p 43.
[9]M. E. Melaragno, *Wind in Architectural and Environmental Design* (Van Nostrand Reinhold Co., 1982).

Table 3

Number and Relative Frequency of Hurricane Occurrence Among States by Months (1885-1958)
(From *Emergency Planning for Water Quality Management*, Manual No. M19 [American Water Works Association, 1984].)

State(s)	June	July	Aug.	Sept.	Oct.	Nov.	Total
North Carolina South Carolina Georgia							
No. of Storms	0	4	18	13	7	0	42
Probability of Occurrence	0.00	0.09	0.43	0.31	0.17	0.00	1
Louisiana Mississippi Alabama							
No. of Storms	2	1	5	13	5	0	26
Probability of Occurrence	0.08	0.04	0.19	0.50	0.19	0.00	1
Florida							
No. of Storms	6	6	13	21	22	3	71
Probability of Occurrence	0.08	0.08	0.19	0.3	0.31	0.04	1
Texas							
No. of Storms	6	4	11	10	3	0	34
Probability of Occurrence	0.18	0.12	0.32	0.29	0.09	0.00	1



1. Values are fastest Mile speeds at 33 feet above ground for Exposure Category C and are associated with an annual probability of 0.02.
2. Linear interpolation between wind speed contours is acceptable.
3. Caution in use of wind speed contours in mountainous regions of Alaska is advised.
4. Wind speed for Hawaii is 80 and Puerto Rico is 95.
5. Where local records or terrain indicate higher 50-year wind speeds, they shall be used.
6. Wind speed may be assumed to be constant between the coastline and the nearest inland contour.

Figure 4. Design wind speed for Continental United States and Alaska. (Reproduced From the Uniform Building Code, 1985 Edition, copyright 1985, with permission of the publisher, the International Conference of Building Officials.)

except earthquakes. Advance warning usually involves observing conditions conducive to tornado formation even though no high winds have formed yet. This makes emergency planning for tornadoes more difficult.

A tornado's high wind speed can impact structures directly, or indirectly by carrying debris with its force. Objects can be turned into projectiles either by the tornado's uplifting vortex or by lateral wind forces. Buildings can experience structural damage, and debris can block intake structures, open transmission systems (e.g., canals), and limit access by blocking roads. Communication and power lines and elevated storage tanks can be tipped over. A distribution system's buried components are least affected by high winds.

Floods

Any area along river banks, lake shorelines, bays, estuaries and/or oceans is a potential flood site. Flooding is often a side effect of another natural phenomenon such as a hurricane. Along rivers and streams, man-made activity such as construction of bridges and buildings, has often tended to aggravate damage associated with flooding by restricting flow through the natural channel.

Unlike hurricanes, there is little available methodology for predicting flood levels from forecasts of weather patterns. Instead, engineering practice has been to develop predicted flood levels based on level of recurrence. Thus, the terminology reflects the expected frequency, and is most often characterized as "10-year flood," "25-year flood," "50-year flood," etc. The term "50-year flood" refers to a level of flooding which is expected to occur an average of once every 50 years, based on a statistical analysis of previous flood levels. A 50-year flood level is higher than a 25-year level, which is higher than a 10-year level, etc.

When great damage from several floods occurred during the mid-1970s, the Federal government began developing flood insurance programs. One aspect of the program was to conduct flood insurance studies for communities throughout the United States. Part of the studies involved developing predictions of flood levels along many streams. Although the information did not include Army installations, flood insurance studies for adjacent areas may be available that will allow flooding levels expected from a 50-year flood, for example, to be determined. The Flood Plain Management Coordinator of the local Army Corps of Engineers District can determine if flood insurance studies have been completed adjacent to a specific base.

A second source of information would be previous studies performed by the Army installations themselves. Since these studies may have been conducted outside the scope of the flood insurance studies, the Flood Plain Management Coordinator may not be aware of them. In this case, the installation's records would be the best source of information. Thus, to gain a complete picture of previous flood-plain planning, a check should be made of the installation's records, master planning documents, environmental impact statements, and with the local Army Corps of Engineers office.

The purpose of determining the expected flood level is to find out which structures are susceptible to flood damage. It is essential to isolate water-soluble chemicals from potential flood levels; they may be placed either in secured, sealed containers or at elevations above expected flood levels. All items below that level must be considered vulnerable to flood damage. Debris carried along by flood waters can structurally damage buildings and tanks. Mud associated with floods can fill sedimentation basins and exposed filtration units. Debris can clog intake structures and open transmission structures, such as canals. In general, floods have little effect on a buried distribution system, but can cause water, mud, and/or structural damage to pumping facilities. In extreme cases, floods can wash away enough ground surface to expose distribution system components such as water mains. Once exposed, these components are susceptible to structural damage.

Tsunami Waves

Tsunami waves are generated by undersea earthquakes and volcanoes, and can cause damage a great distance from the disturbance. Although a tsunami can occur along any shoreline, most are associated with the Pacific basin, since most of the earthquake activity occurs along the rim of the Pacific.

A tsunami wave is very destructive. For example, the 1964 Alaska earthquake was a major quake with a magnitude of 8.6 on the Richter scale. Fifteen people died from landslides and building collapse. The tsunami associated with that quake caused 98 deaths in Alaska, 11 in Cresent City, CA, and 1 in Seaside, OR. Thus, many more people died over a much wider area from the tsunami than from the causative earthquake.[10] Furthermore, tsunamis travel at great speed. A 1946 Alaskan earthquake created a tsunami that traveled at 500 mph and caused 40-ft waves on the island of Oahu in Hawaii. The Chilean earthquake of 1960 caused a tsunami that resulted in 61 deaths in Hawaii.

Tsunami waves cause structural damage similar to floods and can affect a water utility's transportation, communication, and power components. Since they are of oceanic origin, they are most likely to affect shoreline structures, and may be of concern in planning for desalinization plants. Inland water utilities are not affected by this type of disaster.

Severe Weather

This category includes natural phenomena that do not warrant separate consideration. Freak weather patterns, or even normal lightning storms, can result in an emergency if a water utility is not prepared.

One of the most common problems is broken water mains; the magnitude of the problem is proportional to the size of the main. Cold weather is a contributing factor to main breaks. "Frost heave" occurs when the soil moisture freezes and places unusual stress on the water mains. When this occurs, mains that have been weakened by other processes, such as corrosion, can break. More than half of all main breaks occur between November and February in the northern United States.[11] When the soil thaws, water in the main can flow freely, and water loss can be great.

Extended periods of cold weather can also freeze water in elevated storage, and ice flows can disrupt water intake structures and open or aboveground transmission facilities. These types of problems have been generally recognized by design engineers, but unusually cold weather in normally temperate climates can cause problems for water utilities without emergency plans.

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[10] L. D. Lett and S. Judson.

[11] W. H. Smith, "Frost Loadings on Underground Pipe," *JAWWA*, Vol 68, No. 12 (December 1976), p 673.

Electrical storms can cause fires or strike power lines. Since water utilities use microprocessors extensively to control treatment, transmission, or distribution systems, adverse effects on power lines cause problems. Voltage surges in a power supply can break microprocessor control and/or be misinterpreted by the microprocessor. Backup systems become important, and verifying computer readouts becomes a necessary first step in evaluating if a real state of emergency exists.

The following example of microprocessor control and slight misinterpretation is given to highlight the need for verification. Many public and private water utilities use pressure sensors throughout the system to monitor operation and flag problems when they arise. Rather than having a worker constantly monitor the sensor readout, a microprocessor is used. If there is a sudden sharp drop in pressure, the microprocessor sounds an alarm, and utility personnel verify the reason for the alarm. However, under certain circumstances sudden pressure drops occur that are not associated with any real system problem. For example, a major television event can affect system pressure, because large segments of the population remain in front of the television, except during commercials. During commercials, use of toilet facilities increases dramatically, and flushing a toilet is the largest instantaneous water demand in a typical house. Many water utilities which keep charts of water pressure have noted a definite pattern of water pressure drop that closely follows the pattern of television commercials. However, the first time this phenomenon occurred, many operators frantically tried to determine the cause of the sudden pressure loss.

Accidental Disasters

Accidents range from minor problems to major disasters. They may affect the raw water supply, the treatment process, or the operating personnel.

Hazardous Material Spills

Hazardous materials spills can impact a water supply in three ways: (1) the materials themselves can be hazardous, (2) they could interfere with water treatment unit operations, or (3) water treatment unit operations could transform them into different hazardous materials.

Materials considered hazardous by themselves are an ever-changing matrix of compounds commonly referred to as priority pollutants.[12] The U.S. Environmental Protection Agency (USEPA) consent decree originally contained 65 toxic pollutants, but the production of new chemicals and continuing research into the effects of chemicals on man has added many compounds to the list. However, the existence of a chemical on the list does not mean it is regulated. Regulations on various chemicals are set by state regulatory boards, and/or by the USEPA. Outside Continental United States (OCONUS) installations may have other regulatory agencies to consult (e.g., the European Economic Community).

Materials which are not hazardous themselves can interfere with water treatment unit operations. For example, dramatic increases in sediment load can create demands for chlorine beyond a water plant's capacity, or competing, nonhazardous substances could overload and displace hazardous materials from an adsorption unit process such as granular activated carbon.

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[12]Natural Resources Defense Council, et al., vs. Train, 8 ERC 2120 (D.D.C., 1976).

A water treatment process can transform innocuous compounds into hazardous materials, or increase the level of hazard. The best known example is the production of trihalomethanes from humic materials (natural organic material present in most surface waters due to the breakdown of plant materials) during chlorination.[13] Phenol, which is listed as a toxic pollutant, reacts with chlorine in the water treatment to form the more hazardous chlorophenols.[14] Furthermore, the mono- and di-chlorophenols produced cause taste and odor problems in drinking water, which bring a rapid consumer reaction.

Hazardous chemical spills can affect both treatment processes and treatment plant personnel. In some cases, treatment processes may be overloaded and unable to function properly. In other cases, appropriate treatment processes (such as facilities for feeding powdered activated carbon) may not be in place. Treatment plant personnel in confined areas may be affected by volatile materials that enter the plant.

Chemical Handling

Water treatment processes use a variety of chemicals that are often stored in concentrated form, and can be a hazard themselves. Strong acids and bases are used to adjust the pH during treatment processes, and can be hazardous to personnel if improperly handled. Chemicals can also be mixed inadvertantly, resulting in dangerous byproducts.

Sodium hypochlorite can be used for disinfection as an alternative to gaseous chlorine. It is generally safer because it is not a gas and does not have to be stored under pressure. Ferric chloride is a coagulant used either as an alternative to alum or in sludge dewatering. These chemicals are reasonably safe when separated, but can produce free chlorine gas if mixed. Concentrated solutions of these compounds are not mixed during treatment (except after dramatic dilution in the water stream), but mixing can occur accidentally. An example of such an accident was recently reported[15] at Knoxville, TN, when a tank truck of ferric chloride was accidentally connected to storage tanks containing sodium hypochlorite. A cloud of chlorine gas formed immediately, and three workers were affected. Fortunately, a plant chief was able to turn off the valve on the truck, so no serious injuries occurred. Also, an emergency plan was activated which evacuated plant personnel and halted and/or rerouted traffic around the plant site.

Table 4 lists chemicals which are incompatible for storage. This table should be used when assessing the vulnerability of the system.

Mishandled chemicals can affect the quality of the drinking water, the treatment plant structures and machinery, and the distribution system. Little effect would be expected on intake structures or transmission facilities, because the chemicals are not used until the treatment plant. However, some utilities practice pretreatment, such as prechlorination, at the intake. Thus, these areas must also be considered in developing an emergency plan.

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[13] J. J. Rook, "Formation of Haloforms During Chlorination of Natural Waters," *Journal of Water Treatment Examination*, Vol 23, No. 2 (1974), p 254; T. A. Bellar, et al., "The Occurrence of Organohalides in Chlorinated Drinking Water," *JAWWA*, Vol 66 (1974), p 703.

[14] J. G. Smith, et al., "Model Studies of Aqueous Chlorination: the Chlorination of Phenols in Dilute Aqueous Solution," *Water Research*, Vol 10 (1976), p 985.

[15] G. R. Brower, "A Chlorine Gas Cloud from Sodium Hypochlorite," *Public Works*, Vol 114, No. 9 (1976), p 91.

Table 4

List of Incompatible Chemicals

(Reprinted from *Opflow*, Vol 11, No. 11 [November 1985], by permission.

These Chemicals	Should Not Be Stored With or Near These Chemicals
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver
Alkaline metals such as other chlorinated hydrocarbons, carbon dioxide, the halogens	Water, carbon, tetrachloride, or sodium and potassium, or powdered aluminum, or magnesium
Ammonia, anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, powdered meals, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Carbon, activated	Calcium hypochlorite, all oxidizing agents
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials
Chromic acid	Acetic acid, naphthalene, camphor, glycerine, turpentine, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Copper	Acetylene, hydrogen peroxide
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, the halogens
Fluorine	Isolate from everything
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrofluoric acid, anhydrous	Ammonia, aqueous or anhydrous
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline nitromethane, flammable liquids, combustible materials
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Mercury	Acetylene, fulminic acid, ammonia, oxalic acid
Nitric acid, concentrated	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases
Oxalic acid	Silver, mercury
Potassium permanganate	Glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate, or similar compounds with light metals

Computer or Communications Failure

Many water utilities now rely on automated control of various aspects of the water utility operation. For example, pumps may be controlled by levels in storage tanks, chemical feed may be based on pump operation, and filter backwash may occur automatically based on headloss across the filter. These innovations in water treatment have greatly increased the plant efficiency, but backup facilities are essential. Backup facilities include instruments to manually read water levels in tanks and headloss across filters, manually activate pumps, valves, and backwash cycles, and backup power and data storage facilities for computers.

The loss of communications or computer facilities could affect water treatment and operations, as well as records of flow, materials, purchase orders, etc. Minimal effects would be expected on fixed structures such as buildings, transmission and distribution systems, and water supply systems.

Deliberate Acts

Acts of war, civil unrest, and vandalism can also create emergencies. Water supplies can be deliberately polluted, structures and machinery damaged, power cut off, and plant personnel harmed or prevented from reaching duty stations.

The deliberate nature of these emergencies makes them particularly hard to plan for. Having enough supplies on hand can reduce problems associated with disruption of transportation. Backup personnel on the installation should be available to operate facilities if plant personnel cannot reach work. Backup power can be provided at critical locations such as pumps and communications.

Deliberate acts can affect all aspects of water utility operations. Inaccessible components, such as buried distribution systems or raw water wells, are least likely to be disrupted.

Summary

The matrix in Table 5 shows the interrelationship between disasters and their effects on various water utility components. This table, in conjunction with information about the installation's vulnerability can be used to set priorities for emergency water planning.

Table 5

Disaster Effects Matrix
(From *Emergency Planning for Water Quality Management*, Manual No. M19
[American Water Works Association, 1984].)

	EQ	V	H&T	F	TW	SW	HMS	CH	C&CF	DA
Plant Const. Damage	*	*	*	*				*		*
Watershed Damage		*					*			
Reservoir Damage	*	*		*			*			*
Storage Tank Damage	*		*							*
Broken Mains	*			*		*				*
Contamination	*	*	*	*	*		*	*		*
Power Loss	*	*	*	*	*					*
Communication Disruption	*	*	*	*	*			*	*	*
Transportation Failure	*	*	*	*	*	*				*
Employee Shortages	*	*	*	*		*				*

EQ = Earthquake
H&T = Hurricanes and tornadoes
TW = Tsunami waves
HMS = Hazardous material spills
C&CF = Communications and computer failure
V = Volcano
F = Floods
SW = Severe weather
CH = Chemical handling
DA = Deliberate acts

4 ESTIMATING WATER REQUIREMENTS DURING EMERGENCIES

Under emergency conditions, critical needs must be met first. Many other water uses can be temporarily suspended or curtailed, which can alleviate stress on capacity. The availability of water will also depend on the nature of the emergency. A short-term emergency (less than 4 hr) that would completely stop water pumpage to the system would go totally unnoticed during low water-use periods, and would be relatively unnoticeable during peak domestic use if adequate elevated storage were available. On the other hand, reduction of capacity by 75 percent over several days would eventually result in slow emptying of elevated storage unless dramatic measures were taken to reduce water demand.

The first step in determining where water consumption can be reduced is to estimate normal water demands. Table 6 shows a breakdown of typical water uses on Army installations. Each installation should use Table 6 as a guide to estimate its water demand distribution.

Two water demands not shown in the table, but which are part of every water distribution system, are fire demands and water loss. Water loss through leakage from the distribution system will continue as long as there is pressure on the system. Water loss will vary depending on the condition of the distribution system, but an estimated loss figure is 15 gallons per capita per day (gpcd).[16]

The fire fighting demand is not shown because it is not continuous. The magnitude of a fire demand varies with the type of building, its size, and construction materials. Estimates of this demand are reported as flowrate and time. The flowrate multiplied by the time yields a quantity of water which should be a portion of the water contained in elevated storage. Thus, this portion of the elevated storage is always available, even when all pumps are out of service, assuming that the elevated storage tanks have survived the emergency. TM 5-813-6 should be used to determine water supply requirements.

Domestic water requirements can be subdivided into four use categories: drinking and cooking, bathing and personal, laundry and dishwashing, and toilet flushing. These categories can be prioritized and controlled during a prolonged emergency. The range of water use, as a percentage of total domestic water use, has been estimated as follows:[17]

Drinking and cooking	4-5%
Bathing and personal	20-34
Laundry and dishwashing	14-23
Toilets	41-56

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[16] J. C. Kammerer, "Water Supply Requirements for Public Supplies and Other Uses," *Handbook of Water Resources and Pollution Control*, H. W. Gehm and J. I. Bregman, eds. (Van Nostrand Reinhold Company, 1976).

[17] C. W. Howe and W. J. Vaughn, "In-House Water Savings," *JAWWA*, Vol 64, No. 2 (1972).

Table 6

Typical Activities Related to Water at Army Installations
(From J. T. Bandy, and R. J. Scholze, *Distribution of Water Use at Representative Fixed Army Installations*, Technical Report N-157/A133232, USA-CERL, 1985.)

Administrative/Institutional

Unclassified Office Space
Shipping and Receiving
Communications Facilities
Command-level Headquarters
Radar Installations
Military Training and Instruction Facilities
Hospitals

Housing

Family Housing
Barracks
Bachelor Officer Quarters
Visiting Officer Quarters
Mess Halls

Commercial

Commissary
Post Exchange
Gas Station
Laundromats
Restaurants/Cafeterias
Post Office
Bank

Recreational

Swimming Pools

Industrial

Vehicle Washracks
Aircraft Wash
Steam Cleaning
Metal Plating and Finishing
Autoclaves
Boilers
Metal Cleaning
Paint Booth Water Wall
Air Pollution Wet Scrubbers
Laboratories
Cooling Towers
Dynamometers
Engine Test Cells
Ash Handling Facilities
Industrial Laundries
Pesticide Management Area
Photographic Laboratory
Motor Pools

Irrigation

Parade Grounds
Athletic Facilities
Golf Courses
Cemeteries
Lawns
Parks
Commercial Landscaping

The highest priority for water use (drinking and cooking) is a very small percentage of water use. During an emergency, this high-priority demand can be met easily, as long as some small treatment capacity exists.

Another high-priority item is hospital water demands. This demand is dependent on potential patient population and can be determined from TM 5-813-1. Other high priorities may be for sensitive industrial activities on base. These would be related to the installation's mission and should be determined by the individual facility. Appendix A provides a worksheet for assigning priorities.

Estimating water demand is an essential step in developing an emergency water plan. Using Table 6, an estimate of all water use on an installation should be developed. Estimates of water loss and fire demand should also be generated. Installations should assign the highest priorities to fire fighting, hospital, and drinking and cooking demands. Other priorities should be assigned to critical industries. Thus, when an emergency arises, the required capacities for the highest priorities will be known, and water can be allocated based on the established priorities.

5 VULNERABILITY OF SYSTEM COMPONENTS

Vulnerability can be defined as the degree to which the system is adversely affected by stress situations.[18] Stress situations can be normal (main break) or extraordinary (destruction of a water tower); however, the vulnerability of the overall system depends not only on the stress situation, but the degree to which other system components rely on the stressed component. For example, a main break on the single supply main to an entire distribution system is more severe than the destruction of a water tower in a system that has several water towers.

Schematic

A schematic diagram of the entire water utility can be used to assess the system's vulnerability to the failure of any one component. The diagram should show each component and should illustrate and complete flow through all treatment processes. Generalizations should be avoided (i.e., if a pump station contains three pumps, show all three pumps). Each input should be traced to its source, and alternate routes noted. Inputs to the system may include raw water, electrical power, fuel, treatment chemicals, spare parts, and personnel for normal operation or repair. Locations of high-priority water demands and critical components, such as pumping stations or elevated storage tanks, should be noted on the distribution system to determine if they could become isolated during an emergency.

Figure 5 shows a hypothetical water utility to be used as an example in determining system vulnerability. This diagram does not show transportation or communication components. These parts of the system can be overlain on the same base map without the details of the water distribution, treatment, transmission, and collection systems. The components of the distribution system in Figure 5 include:

1. Intake Structures:

   a. River intake with mechanical screen and pump

   b. Wellfield with three wells.

2. Transmission:

   a. 18 in. raw water line from stream intake

   b. 12 in. raw water line from well field.

3. Treatment:

   a. Surface water plant

      - Hypochlorite predisinfection (one feed)

      - Single raw water sedimentation basin

[18] *Emergency Planning for Water Utility Management.*

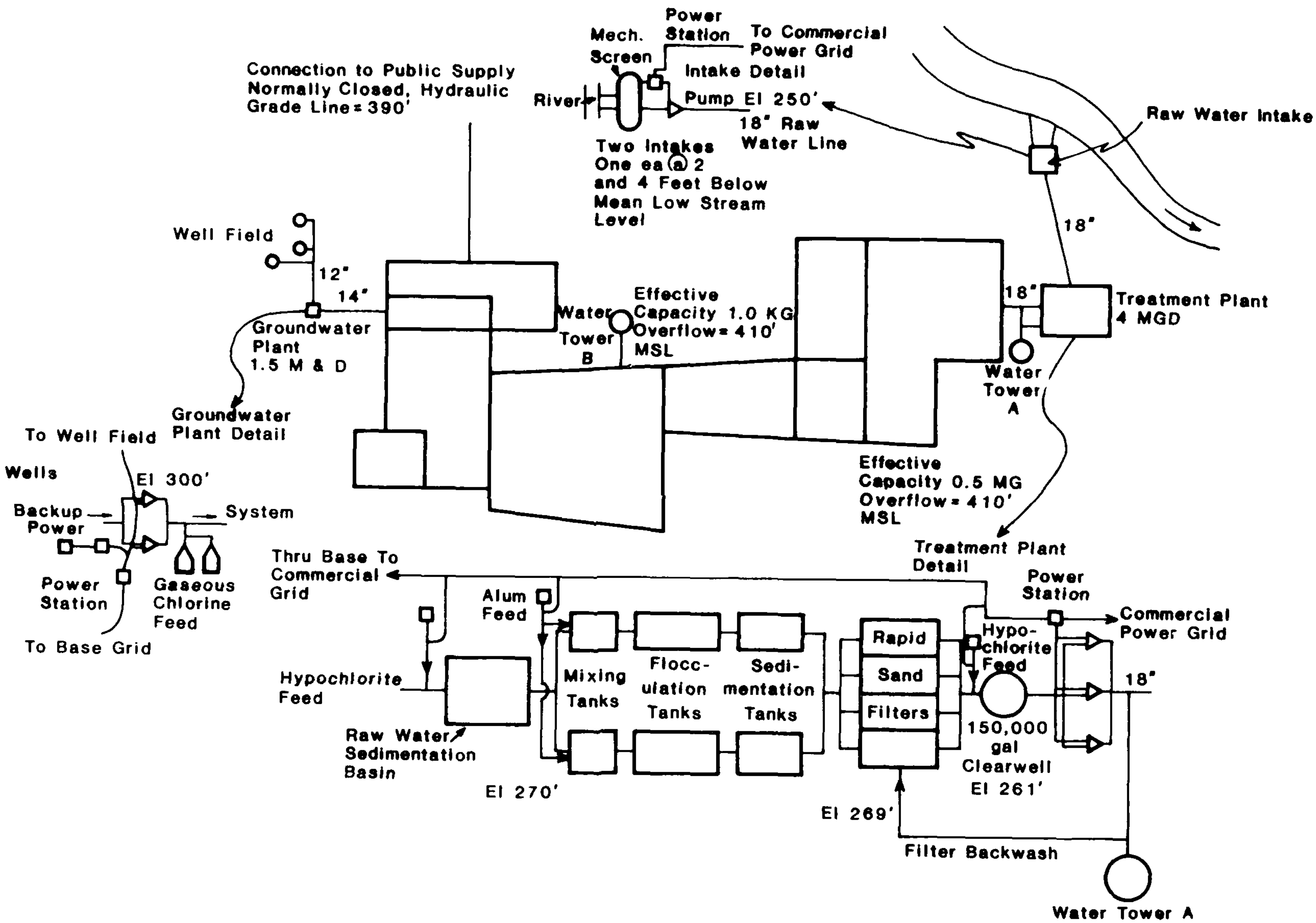

Figure 5. Hypothetical water utility schematic diagram of facilities.

- Two identical flocculation/sedimentation lines

- Four rapid sand filters

- Hypochlorite for final disinfection

- One 150,000-gal clearwell

- Three discharge pumps

- One 0.5-million-gal storage tank.

b. Groundwater plant

- Two discharge pumps

- Backup power and fuel tank

- Gaseous chlorine disinfection, two tanks.

4. Distribution system:

a. Major mains shown

b. One 1.0-million-gallon storage tank.

Not all sizes of water mains are shown on the schematic. The lack of detail in the distribution system results from showing only major water mains. Sizes of single pipes which feed major areas should be noted so that the materials required for repair can be requested at the first indication of a break. Looped system details are not as important, because the immediate solution for those systems will be to valve off broken sections.

The communication system would include lines connecting the water tower level indicators to the treatment plant pump systems, the clearwell level indicators to the raw water intake system, and any pressure indicators used in the distribution system. The communication system should also show details and locations of manual level indicators on the tanks and manual overrides for the pump stations. The next level of communications should include systems used to notify employees, supervisors, stockroom employees, and individuals responsible during emergencies. This should include locations of radio equipment (if available) and telephone lines. The third level of communications should be a list of the names and phone numbers (both work and emergency numbers if available) of off-installation suppliers and contractors, who may be called for supplies or repairs during emergency.

The transportation system would show all roads and track used to supply materials (parts and chemicals) and personnel to water treatment plants, pump stations, and control locations. Structures such as bridges and tunnels, which could be destroyed during disasters, should be noted. Floodplain boundaries should be noted to highlight areas that would be inundated during a flood.

Redundancy and Reliability

Vulnerability must be assessed both in terms of the redundancy of available units, and the reliability of each unit. The relationship between reliability and redundancy[13] is shown in Eq 1. This equation is for illustration only; actual values of reliability for varicus unit processes, structures, and system components are difficult to group in a range from 0 to 1.

$$Rs = 1 - (1 - r)^m \qquad \text{[Eq 1]}$$

where:
- Rs = system reliability
- r = unit reliability
- m = number of components in parallel

A unit or operation with 100 percent reliability has an r-value of 1. For example, gravity flow has 100 percent reliability, so the system reliability for gravity is 1. For a process with 0.8 reliability, one unit yields a system reliability of 0.8, while two parallel units increase reliability to 0.96.

Redundancy means a complete and separate unit fully capable of providing full service. Strict application of this principle would mean constructing a plant with twice the capacity required; however, complete redundancy is rarely practiced. Table 7 shows minimum requirements developed by the Great Lakes-Upper Mississippi Board (commonly referred to as "10 states standards") and the State of Virginia. They do not require complete redundancy, with a standby unit required only for filtration. However, this is not a stringent requirement. For example, a plant with eight rapid sand filters would be required to have only one extra unit, which means redundancy of 12.5 percent of the filtration capacity.

Structural reliability depends on the construction and design considerations used. The Uniform Building Code gives design stresses for earthquakes and wind, as well as equations to determine design forces. These must be determined by inspecting buildings and/or as-built drawings for the individual installation.

Reliability of buried mains is an ever-changing value because they are often installed in a hostile environment. They are exposed to soils which may be corrosive, soils which may subside (thereby removing bedding support), and weather conditions (frost penetration) that produce unusual and nonuniform stresses. As a result, buried mains lose their capacity to withstand stress. Therefore, good engineering practice has always required a "loop" rather than "tree" type distribution system. Segments of a distribution system fed by one pipe are extremely vulnerable and should be assumed to be isolated and without water during an emergency.

Vulnerability Evaluation

After developing the schematics for the water utility (showing sources, intake facilities, transmission systems, treatment plants, distribution systems, power supplies,

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[13] C. L. Hamann and L. G. Suhr, "Reliability and Redundancy: Dual Protection for Water Treatment Plans," *JAWWA*, Vol 72, No. 4 (1980), p 182.

Table 7

Minimum Requirements for Selected Treatment Processes for Surface Waters
(From C. L. Hamann and L. G. Suhr, "Reliability and Redundancy: Dual Protection for Water Treatment Plans," *JAWWA*, Vol 72, No. 4 [1980], p 182.)

Treatment Process	10-State Standards (1976)	Virginia (1974)
Rapid Mix	2 units	Duplicate units or spare mixers
Flocculation	2 units	Multiple units for plants > 0.5 ML/day (0.14 MGD)
Clarification	2 units	Multiple units for plants > 0.5 ML/day (0.14 MGD)
Filtration	2 units (where more than 2 units provided, add 1 redundant unit)	For Q > 0.5 ML/day (0.14 mgd)* but < 7.6 ML/day (2 mgd), provide 2 units; for Q > 7.6 ML/day (2 mgd), provide units = 2.7*(Q)0.5
Chlorinators	Standby capacity equal to largest unit	Standby capacity equal to largest unit

*Q = plant capacity in mgd

material supplies, communication systems, and transportation systems) and listing the components under each category in the schematic, the facility may begin evaluating its vulnerability to various disasters. Figure 6 shows a worksheet used to estimate effects of assumed disasters on system components. Table 5 shows the matrix that correlates disasters and their effects. Using Figure 6 and Table 5, a detailed plan can be developed for the hypothetical system shown in Figure 5.

The hypothetical Army installation is located on the east coast of the United States, with an emergency plan being developed for a hurricane/flood. The effective population of the base is 30,000, and the maximum fire demand arises from an industrial building of ordinary construction. The fire demand is 3000 gpm for 4 hr. The storage requirement for this fire demand is 0.72 million gal.

The flood associated with the hurricane is hypothesized to reach an elevation as determined by the 50-year flood level. This means an elevation of 259 ft, which inundates the intake structure and disrupts power. Damage to one of the elevated tanks by the hurricane will also be assumed. The damage requires that the tank be drained until repair, so only one tank--the smaller of the two--is still online.

System: ______________________ Analyst: ___________

Assumed Disaster: ___________________ Date: _________

Description of Disaster: ____________________________

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Component	Effects of Disaster				
	None	Partial	Total	Type & Extent	Corrective Measures
Source					
Intake Facilities					
Transmission					
Treatment Plants					
Distribution					
Power Supplies					
Material Supplies					
Communications					
Transportation					

Figure 6. Vulnerability analysis worksheet.

Appendix B shows the detailed evaluation of the storm's effects. The appendix uses only the features shown in Figure 4; a complete analysis would also consider communications and transportation systems. The disaster effects hypothesized can be derived from engineering predictions, such as flood level, or from local history of the effects of storms on similar structures.

The location of the water utility's vulnerable parts are apparent from a detailed schematic diagram, such as the one shown in Figure 5, or from a tabular form, such as Appendix B. The 4-mgd surface water treatment plant is fed by a single 18-in. raw water main. The raw water main is fed, in turn, by an intake pump without backup power. Although the treatment plant received little direct damage from the hurricane, it cannot function without raw water. Fortunately for this system, a second and third source of supply exist.

The second supply, from the well field, was relatively unaffected by the hypothesized storm. It can continue to supply part of the installation's demand while the larger surface water plant is reactivated.

The third source of supply is the connection to the adjacent public water supply. However, this supply should not be tapped during this type of emergency, unless the water towers remain consistently drawn down by more than 20 ft (the difference in hydraulic grade line between the Army installation and the public water supply). If the Army installation tanks were full when the emergency began, opening the connection too soon (i.e., before tank drawdown is greater than 20 ft), would only aggravate the situation by bleeding water into the public water supply. This problem has occurred during fires when valves were opened, which decreased pressure and available water. This type of problem accentuates the need to have a detailed plan for emergencies.

After the damage is assessed (or assumed, as in the case of emergency plan preparation), the remaining water resources must be estimated. In the hypothetical example, the remaining water resources are 1.5 mgd. This is about 1000 gpm--far less than the design fire demand (3000 gpm). Thus, it is essential to maintain the fire reserve in the storage tanks. However, one storage tank has been damaged and must be taken off-line. This leaves only 0.5 million gal in storage. The design fire calls for 3000 gpm for 4 hr, or a total of 0.72 million gal.

A 0.5-million gal tank could deliver about 2000 gpm over 4 hr. The rest would have to be made up from the remaining water treatment plant capacity, which is about 1000 gpm (1.5 mgd). Thus, since the system can barely meet fire flow capacity, other demands would have to be almost totally eliminated during a fire.

Regardless of the presence or absence of a fire, the emergency has left the installation with only 1.5 mgd of reliable supply, or about 23 percent of normal capacity. The allocation of these resources and the measures invoked to control demand should follow the priorities established in the section on estimating water demands (pp 24) and then detailed using Appendix A.

After an emergency has occurred and the immediate problems have been identified, a course of action must be set to bring the water utility back to full operation. Many undamaged portions of the system will require little or no special attention to reactivate. However, when some systems are down, a number of problems can occur to other system components that were undamaged by the initial emergency. The following discussion outlines components that are vulnerable to damage because of circumstances created by an emergency.

Pumps may require priming, and may require a certain amount of back pressure, referred to as net positive suction head (NPSH), to operate efficiently. The NPSH is a function of the pump and associated piping. More problems with pumps result from inaccurate determination of NPSH than from any other single cause.[20] When restarting a pump, the required value of NPSH must be maintained. If damage to the plant has reduced capacity such that the pump is operating with the clearwell drawn down below the required level for NPSH, cavitation and associated permanent damage may result to the pump. It is important that all personnel who may restart a pump, including normal operating personnel and all backup personnel who may be involved in an emergency, understand the pump's requirements.

Granular filter material may become cemented together if left dry. This filter material may be slow or rapid sand filters, granular activated carbon, ion exchange filters (green sand filters, synthetic resins), or synthetic resins for nonpolar organic

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[20] T. G. Hicks and T. W. Edwards, *Pumping Application Engineering* (McGraw-Hill, 1971).

removal. Synthetic resins may crack if left dry. Therefore, filters should always remain wet during downtime to avoid compacted filters or cracked media.

Certain types of valves require a minimum amount of backpressure to close and properly seat. This has been a particularly difficult problem on Army installations when broken mains have depressurizd portions or all of a system. After the main is repaired, it may not be possible to instantaneously create enough pressure to close the valves. This problem has been observed at Fort Hood, TX[21] (see Appendix C), where flush valves remained open, and the system could not be repressurized until they had been isolated from the system.

[21] *Water Outage on Fort Hood, Texas, After Action Report* (Directorate of Engineering and Housing, Fort Hood, Texas, 3 May 1984).

6 DEVELOPMENT OF AN EMERGENCY PLAN OF ACTION

The methods for developing an emergency plan have been outlined in Chapters 4 and 5. The actual development requires a responsible individual to assign tasks, delegate authority, and manage the project. TM 5-660 states that, "Operating and maintaining water treatment facilities and appurtenant equipment are a command responsibility. They are considered maintenance-of-installation functions." One person at each installation should be assigned responsibility and authority to develop the plan, regardless of whether he/she will have a major role in implementing the plan during an actual emergency.

Following is a checklist of activities involved in developing a plan. It has been adapted with minor modifications from AWWA Manual M-19. (Refer to this manual for greater details regarding the development of emergency water plans.)

I. Review the organization and make assignments.

   a. Appoint responsible personnel for plan development, training, and security.

   b. Appoint an advisory committee to these personnel. Members can come from the installation, civil defense organizations, U.S. Army Corps of Engineers, and surrounding nonmilitary water utilities.

   c. Designate disaster organization staff and teams.

      1. Designate alternates

      2. Prepare telephone list for alerting all members

      3. Define responsibilities and channels of command.

   d. Contact civil defense, U.S. Environmental Protection Agency, Federal Emergency Management Agency, and any local emergency operation centers to do the following:

      1. Learn local plans

      2. Obtain possible help in planning

      3. Establish liaison channels.

II. Make vulnerability assessment

   a. Identify and describe separate components of the entire system. Make a schematic diagram and a detailed list, such as the one shown in Appendix B, to include the following items:

      1. Source of supply

      2. Collection works

3. Transmission system

4. Treatment facilities

5. Distribution system

6. Personnel

7. Emergency power supply

8. Emergency materials and supplies (maintain a list of sources of materials with phone numbers)

9. Emergency fuel transportation capability

10. Primary and backup communications

11. Current emergency plans, if any

12. Emergency leasing agreements (maintain a list of phone numbers for sources)

13. Mutual aid agreements and/or interconnections.

b. Develop characteristics of assumed or design stress situation or disasters for the following:

1. Earthquakes and landslides

2. Volcanoes

3. Hurricanes and tornadoes

4. Floods

5. Tsunami waves

6. Severe weather

7. Hazardous materials spills

8. Chemical handling

9. Computer and communications failure

10. Civil disturbance, riots, work stoppages

11. Drought.

c. Estimate the effects of each assumed disaster on each system component. Apply the assumptions of the degree of impact of each effect of the disaster under study as developed in item b to each component considered in item a. Each disaster should yield a table such as the example in Appendix B. The disaster effects matrix (Table 5) can be used to relate an assumed disaster to affected components. The extent of damage can be estimated from historical patterns or engineering predictions (i.e., flood studies, seismic zone maps, etc.).

d. Estimate water requirements for:

1. Fire fighting

2. Administrative/institutional

3. Industrial

4. Housing

5. Commercial

6. Irrigation

7. Recreational.

e. Estimate remaining system capacity under each of the assumed disasters.

f. Identify critical components. These components form the basis for immediate restudy of improving capability as suggested in item X (p 41).

III. Specify priorities and program the best apparent way of using remaining resources.

a. Establish baselines on water quality levels.

b. Establish priorities for allocation of water.

1. Priorities should be established for use, along with estimating water requirements using Appendix A.

2. Procedures should be established for emergency treatment, pumping, and distribution of water, and for maintenance of emergency water supply stations.

IV. Provide personnel protection.

a. Determine number and location of communication points needed.

b. Determine effectiveness of existing structures as operational centers.

c. Determine possible relocation of normal control centers to other facilities.

d. Determine whether operational centers have space for storing needed supplies and food for an appropriate period of time. (An "appropriate period of time" depends on the disaster. If an installation would be isolated by a disaster, how long would it take to clear roads, repair bridges, etc.)

e. Plan for providing food and shelter for operational personnel.

f. Determine whether families or other installation personnel should be allowed in the operational center, or set up a method to keep disaster personnel in touch with their families.

g. Inventory and test communication capability and backup systems.

h. Plan instructions for potential failure of other public utilities required for meeting water utility needs (e.g., power failure).

V. Inventory communications equipment and plan emergency use.

a. Study and coordinate all possible means of communications.

b. Inventory existing equipment:

1. Operations center and alternates

2. Control points and alternates

3. Assembly areas and reporting centers.

c. Redistribute equipment for the best command and control, or plan for such redistribution during the readiness period (e.g., hurricane warning).

d. Identify all personnel who have communications equipment experience.

e. Prepare procedures for release of information (e.g., "boil all water for human consumption," "consume bottled water only," etc.) to installation personnel via an Emergency Operations Center (EOC) or directly, if circumstances require.

1. Designate personnel to be in charge of releasing information.

2. Establish relations between the public information designee of the EOC and the press and radio.

3. Establish procedures for using loudspeakers, leaflets, etc.

4. Prepare releases in advance for emergency conditions likely to develop.

5. Prepare emergency placards in advance.

VI. Assess protection of plant inventory, equipment, and records.

a. Determine the degree of physical security needed.

b. Determine where security can be provided by the installation police and police in adjacent jurisdictions, and find out what hospital facilities are available.

c. Provide security procedures.

d. Inventory essential equipment, material, and supplies for recovery; disperse as necessary, and provide security for them.

e. Provide copies of records needed to facilitate recovery:

1. Maps and engineering plans

2. Personnel records

3. Emergency sources of supply, availability, and means of using

4. Up-to-date stockpile list of items in supply

5. Emergency operating methods and procedures.

f. Keep a record log readily available at all levels of operation for eacn incident that occurs.

g. Plan to keep all records up to date. For computer records, make "hard copies" for use in emergencies.

h. Plan to keep mutual aid parties informed of content and location of records.

i. Plan for security of original legal copies of financial records, purchasing/receiving records, and personnel records.

VII. Initiate mutual aid and other cooperative agreements.

a. Provide agreements with related utility, service, and civil defense agencies.

b. Define and assign responsibilities.

c. Provide for exchange or assignment of personnel, equipment, and materials.

d. Provide for coordination of communications, training, reconnaissance and assessment, inventory taking, standardization, etc.

e. Consider legal problems and military security risks.

f. Plan to provide interconnections with adjacent systems. Note hydraulic grade lines on all plans that show interconnections.

VIII. Determine emergency phase action steps.

a. Increased tension period or long period of warning (e.g., weather reports indicate a tornado warning); increased readiness steps:

1. Personnel notification and assignment

2. Abbreviated (re)training

3. Public information

4. Increased protection of personnel quarters

5. Increased protection of plant and equipment

6. Review emergency plans and procedures

7. Test communications and establish contact with the EOC

8. Monitor supplies for radiological, biological, and chemical quality.

b. Warning period (e.g., tornado is spotted):

1. Personnel

2. Plant and equipment

3. Community action liaison

4. Public information.

c. Disaster, impact, and shelter (e.g., a tornado strikes):

1. Operations as limited by conditions

2. Public information.

IX. Plan post-disaster recovery operations.

a. Provide for operational control.

1. Activate disaster organization.

2. Mobilize regular and auxiliary disaster staff.

3. Implement procedures for protection of personnel.

b. Develop a plan to initiate or maintain liaison with civil defense, other utility units, and mutual aid agencies.

c. Provide time-phased procedures.

1. Assess damage.

2. Determine priorities and any deviations from previously established priorities.

3. Decontaminate.

4. Initiate procedures for operation of surviving facilities.

(a) Conserve water

(b) Isolate damaged facilities

(c) Repair

(d) Operate

(e) Monitor water supply

(f) Advise installation personnel and public.

X. Plan for improving capability of system as indicated by deficiencies.

a. Reduce vulnerability of system.

1. Increase strength of supply, treatment, and distribution facilities.

2. Improve "hardness" of system by eliminating vulnerable areas.

3. Acquire necessary equipment to isolate parts of system.

4. Increase stockpile of materials and supplies as necessary.

b. Provide personnel shelters in any new construction.

c. Add communications as required:

1. Fixed

2. Mobile

3. RACES (Radio Amateur Communication Emergency Services)

4. Citizens band.

d. Develop auxiliary power sources; provide for fuel supply.

e. Train auxiliary communications personnel.

f. Recruit and train personnel:

1. Volunteer

2. Retired

3. Related workers.

g. Acquire additional repair equipment.

h. Improve emergency procedures.

i. Upgrade plan as a result of new additions.

j. Repeat Item X activities a through i at least annually.

Items I through IX deal directly with the development of a plan. Item X is intended to improve the emergency procedures over time by requiring acquisition of new equipment and review of the plan. There is some redundancy in the checklist, but redundancy is one of the key elements to hardening a system against unexpected disasters.

"Hardening" a system is a common term of emergency planning which does not always mean increasing the strength of any particular component. Rather, it refers to supplying redundant systems and alternate means of supply, power, etc. This makes it "harder" for a single or even multiple disasters to completely inactivate an entire water supply system.

Developing an emergency plan for the first time will require 6 months or more for initial data collection, such as information on flood frequency, historical seismic data, etc. Establishing contact with all associated agencies for the first time will also be time-consuming. However, once the plan is in place, the plan can be updated quickly and will only require significant changes when new components are added to the water utility, power utility, transportation system, etc. An emergency plan should be a dynamic plan which is improved as experience with the system progresses. It is very important to acknowledge the ever-changing aspect of emergency planning. Otherwise, a plan may be developed, rigorously checked, and placed on the side. Then, when a real emergency arises, the plan used will be based on obsolete operating conditions, and will only add to the confusion and distress.

7 SUMMARY

This report has presented a method for developing a plan for maintaining water utilities at fixed Army installations during an emergency. Planning for the unexpected allows orderly operation to continue under stress conditions.

Developing an emergency plan involves several steps in which potential disasters are hypothesized, water demands are estimated, effects of various disasters are assumed based on system vulnerability, and remaining water capacity is determined and allocated based on a system of priorities.

This report has outlined various types of disasters that could affect Army water operations and their components. Typical water demands have been compiled and a form designed that can be used to estimate water demands at Army installations. The form, which also allows designation of water use priorities, can be used when allocating remaining capacity during assumed emergencies.

A tabular method has been presented for determining a system's vulnerability to disasters. Army installations can use the method to determine how a disaster could affect each water system component and to indicate the system's remaining capacity. Finally, a checklist has been generated for developing and maintaining an emergency water plan. The checklist gives a thorough list of activities that must be completed to provide a plan that is effective and up to date.

METRIC CONVERSION FACTORS

1 mph = 1.609 km/hr

1 ft = 0.3048 m

1 gal = 3.785 L

1 in. = 25.4 mm

1 ton = 0.907 tonne

REFERENCES

AR 420-46, *Water and Sewage* (Department of the Army [DA], July 1978).

Bandy, J. T., and R. J. Scholze, *Distribution of Water Use at Representative Fixed Army Installations*, Technical Report N-157/A133232, U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1985).

Bellar, T. A., et al., "The Occurrence of Organohalides in Chlorinated Drinking Water", *JAWWA*, Vol 66 (1974), p 703.

Brower, G. R., "A Chlorine Gas Cloud from Sodium Hypochlorite," *Public Works*, Vol 114, No. 9 (1983), p 91.

Emergency Planning for Water Utility Management, Manual No. M19 (American Water Works Association [AWWA], 1984).

Hamann, C. L., and L.G. Suhr, "Reliability and Redundancy: Dual Protection for Water Treatment Plants," *JAWWA*, Vol 72, No. 4 (1980), p 182.

Hicks, T. G., and T. W. Edwards, *Pump Application Engineering* (McGraw-Hill, 1971).

Howe, C. W., and W. J. Vaughan, "In-House Water Savings," *JAWWA*, Vol 64, No. 2 (1972).

Kammerer, J. C., "Water Supply Requirements for Public Supplies and Other Uses," *Handbook of Water Resources and Pollution Control*, H. W. Gehm and J. I. Bregman, eds. (Van Nostrand Reinhold Company, New York, 1976).

Langowski, J. F., et al., *A Survey of Water Demand Forecasting Procedures on Fixed Army Installations*, Technical Report N-85/07/A153040 (USA-CERL, 1985).

Leet, L. D., and S. Judson, *Physical Geology* (Prentice-Hall, Inc., 1971).

Melaragno, M. E., *Wind in Architectural and Environmental Design* (Van Nostrand Reinhold Co., 1982).

Natural Resources Defense Council, et al., vs. Train, 8 ERC 2120 (D. D. C., 1976).

OpFlow, Vol 11, No. 11 (AWWA, November 1985).

Rook, J. J., "Formation of Haloforms During Chlorination of Natural Waters," *Journal of Water Treatment Examination*, Vol 23, No. 2 (1974), p 254.

Smith, J. G., et al, "Model Studies of Aqueous Chlorination: the Chlorination of Phenols in Dilute Aqueous Solution," *Water Research*, Vol 10 (1976), p 985.

Smith, W. H., "Frost Loadings on Underground Pipe," *JAWWA*, Vol 68, No. 12 (December, 1976), p 673.

TM 5-660, *Real Property Operation and Maintenance--Maintenance and Operation of Water Supply, Treatment, and Distribution Systems* (DA, August 1984).

TM 5-813-1, *Water Supply - General Considerations* (DA, July 1965).

TM 5-813-2, *Water Supply—Water Sources* (DA, July 1958).

TM 5-813-3 *Water Supply—Water Treatment* (DA, September 1966).

TM 5-813-4, *Water Supply—Water Storage* (DA, July 1958).

TM 5-813-5, *Water Supply—Water Distribution Systems* (DA, January 1963).

TM 5-813-6, *Water Supply—Water Supply for Fire Protection* (DA, July 1958).

TM 5-813-7, *Water Supply for Fire Protection* (DA, March 1975).

Uniform Building Code, 1985 Edition (International Conference of Building Officials).

Water Outage on Fort Hood, Texas, After Action Report (Directorate of Engineering and Housing, Fort Hood, Texas, 3 May 1984).

Water Quality Information Paper No. 24 (Army Environmental Hygiene Agency, undated).

APPENDIX A:

ASSIGNING PRIORITIES AND ESTIMATING WATER DEMANDS*

Water Use Activity	Demand (gpm)	Priority (1-4)
Administrative/Institutional		
Unclassified Office Space	____	____
Shipping and Receiving	____	____
Communications Facilities	____	____
Command-Level Headquarters	____	____
Radar Installations	____	____
Military Training and Instruction Facilities	____	____
Hospitals	____	____
Housing		
Family Housing	____	____
Barracks	____	____
Bachelor Officer Quarters	____	____
Visiting Officer Quarters	____	____
Mess Halls	____	____
Commercial		
Commissary	____	____
Post Exchange	____	____
Gas Station	____	____
Laundromats	____	____
Restaurants/Cafeterias	____	____
Post Office	____	____
Bank	____	____
Industrial		
Vehicle Washracks	____	____
Aircraft Wash	____	____
Steam Cleaning	____	____
Metal Plating and Finishing	____	____
Autoclaves	____	____
Boilers	____	____
Metal Cleaning	____	____
Paint Booth Water Wall	____	____
Air Pollution Wet Scrubbers	____	____
Laboratories	____	____
Cooling Towers	____	____

*Adapted from J. T. Bandy and R. J. Scholze, *Distribution of Water Use at Representative Fixed Army Installations*, Technical Report N-157/A133232 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1985).

Water Use Activity	Demand (gpm)	Priority (1-4)
Dynamometers	______	___
Engine Test Cells	______	___
Ash Handling Facilities	______	___
Industrial Laundries	______	___
Pesticide Management Area	______	___
Photographic Laboratory	______	___
Motor Pools	______	___
<u>Irrigation</u>		
Parade Grounds	______	___
Athletic Facilities	______	___
Golf Courses	______	___
Cemeteries	______	___
Lawns	______	___
Parks	______	___
Commercial Landscaping	______	___
<u>Recreational</u>		
Swimming Pools	______	___
Fire Demand (Determine from TM 5-813-6)		
__________	______	1
Unavoidable Loss (Estimate at 15 percent of Average Day Flow If Unknown)		
__________	______	1
Other		
__________	______	___
__________	______	___
__________	______	___
__________	______	___
__________	______	___
__________	______	___

APPENDIX B:

EXAMPLE OF VULNERABILITY ANALYSIS

	Effects of Disaster				
Component	None	Partial	Total	Type & Extent	Corrective Measures
Source	X				
Intake Facilities					
Stream Intake			X	Clogged w/debris	Send crew to clean Priority = 2
Mech. Screen	X				
Pump at Stream		X		Mud and debris in pumphouse	Send crew to clean Priority = 2
Power Station at Stream		X		Power out, extent unknown	Contract repair Priority = 1
Well Field	X				
Power Station at Ground Water Plant	X				
Transmission					
18-in. Raw Water Main at Stream	X			No flow due to no power at intake	
12-in. Raw Water Main at Wells	X				
Treatment Plant					
Surface Water					
Hypochlorite Feed	X			No flow due to no power at intake	
Raw Water Basin		X		Large debris in basin	Send crew to clean Priority = 2
Floc/Sed Basins	?	?		No flow due to no power at intake	Check for debris in basin Priority = 3

Effects of Disaster

Component	None	Partial	Total	Type & Extent	Corrective Measures
Treatment Plant					
Surface Water-cont.					
Rapid Sand Filters		X		Heavy silt load from storm	Backwash and leave wet Priority = 1
Hypochlorite Feed	X				
Clearwell	X			No flow due to no power at intake	
Power Station	X				
High Lift Pumps	X			No flow due to no power at intake	
Groundwater Plant					
Pump	X				
Chlorine Feed	X				
Backup Power	X				
Fuel Tank	X				
Distribution					
Underground Mains	X				
1.0 Million-Gal Water Tower		X		Structural damage to support	Drain Tank Priority = 1 Contract for inspection/ repair Priority = 2
0.5-Million-Gal Water Tower at Plant	X				
Power Supplies		X		Commercial grid damaged slightly	
Material Supplies	X				
Communications	X				
Transportation	X				

APPENDIX C:

AFTER ACTION REPORT: WATER OUTAGE ON FORT HOOD, TEXAS

AFZF-FE-A
3 May 84

SUBJECT: Water Outage on Fort Hood, Texas

ISSUE: Between 1730 hrs, 22 Feb 84, and 0800 hrs 29 Feb 84, the water supply to Fort Hood, Texas, was severely curtailed.

FACTS:

1. The project to upgrade the main pump station on Fort Hood (Bldg 6898) began 21 Feb 84. The work is being accomplished by contract administered and inspected by the Fort Worth District Engineer. Excavation began next to the 30" gravity-fed water pipe, the only incoming water pipe to the Fort Hood Water Pump Station, and the 30"/24" pressure line, the only water pipe exiting the pump station, on 22 Feb 84.

2. The removal of the dirt close to a thrust block enabled the water pressure to not only move the thrust block but also cause separation at a 45° ELL in the 30" pressure pipe.

3. The line began to leak at 1725 hrs, 22 Feb 84. John Riddle, Central Texas Area Engineer for the Fort Worth District Engineer, called Dave Emmert when the leak was discovered. By the time Mr. Emmert arrived, the leak was a jet of water. Procedures were begun to shut down the four water pumps, 100 HP, 200 HP, 300 HP, and 500 HP, a total of 13000 GPM, and to close valves to isolate the leak from the rest of the piping system.

4. Before Mr. Emmert arrived, Mr. Riddle contacted Gifford-Hill, the manufacturer of the water pipe and responsible for major repairs on their products. The team from Gifford-Hill was scheduled to arrive at 2000 hrs, 22 Feb 84. Mr. Emmert and Mr. Stanuszek reported to the office and began contacting DFE employees that would be needed to assist.

5. Prime Contractor employees and the team from Gifford-Hill had to enlarge the excavation around the water pipes. DFE employees began locating and shutting off valves to isolate the leak and dewater the pipes at 0400 hrs. The contingency plan for interruption of water distribution lines was utilized to isolate elevated water towers. Actual repair to the 30" water pipe began at 0800 hrs, 23 Feb 84. Repairs were completed and the first pump operating at 1600 hrs and all water pumps were working at maximum by 1800 hrs, 23 Feb 84. During this outage, contingency plans were refined for mobilizing, filling, and placing water trailers. At 1500 hrs, 24 Feb 84, another joint came apart. This was a major break and all pumps were shut down immediately. The principal valves isolating the pump station were closed and the disrupted water main contingency plan was partially implemented.

6. The "railhead water tower" was isolated for use exclusively by the hospital as outlined in the existing contingency plan for Fort Hood. Bldg #11000 (2AD water tower), Bldg #1673 (east of Hood Road between Park and Central Avenues) and the Comanche Tower were also isolated to preserve water. Because water levels did not get back to normal after the first outage several towers including the railhead tower, for the hospitals, were almost empty. Water trailers used in the housing and troop areas and at Hood Army Airfield were filled at hydrants supplied by the water tower, Bldg 1673.

7. The Gifford-Hill team returned to the site. The excavation was pumped out and repair was begun on the second separated joint. Railroad ties and bridge timbers from the Ft Hood inventory and steel beams on site for vertical construction of an addition to the pump station building were used to provide expeditious thrust blocking.

8. The 100 HP pump was started at 1830 hrs, 25 Feb 84, and movement was noted in the 24" pipe inside Bldg 6898. It was shut down and a dial indicator gauge was attached to the pipe to measure any movement. Continued careful monitoring of the dial indicators showed that the pipe was not restrained and continued pumping would cause catastrophic failure of the pump station. Employees from B&G were called in to weld steel angle iron straps and plates to the pipe to anchor it to the concrete supports. Subsequently, one pump at a time was started beginning with the smallest. By 2330 hrs that same day, the three smaller pumps were back in operation.

9. As soon as the pumps were started, crews of plumbers and maintenance mechanics started checking flush valves in 29000 and 39000 areas. The Bell County Water Control and Improvement District reported that sewage flow from Fort Hood was above normal at midnight 25 Feb 84. Continued reports of high rates of sewage flow plus failure to reestablish water pressures indicated that flush valves were possibly a problem in restoring water service.

10. A flush valve is a pressure operated device. Once it is open or activated it requires 25PSI in the supply line to close the valve. At lower pressures, the valve will not close and will continue to pass water. Where large number of flush valves exist, e.g., military installations with barrack facilities, and other non-residential facilities, the valves do not automatically reset properly and use so much water that pumping stations can not restore water pressure. This situation occurred at Fort Hood and caused the problems in reestablishing water pressure and the increased sewage flow.

11. The water pressure remained low. Suspecting another leak, Mr. Anderson, Supervisory Engineer in Utilities Division, went up in a helicopter to West Fort Hood. No leaks were found. Land Management Branch inspectors checked improved grounds in the main cantonment area for exterior water leaks from 1200 hrs until dark 26 Feb 84 and from dawn to 1100 hrs, 27 Feb 84. They found several small breaks in 2" and 4" lines and some leaking hydrants. These were reported to Utilities Division, and crews were dispatched to make repairs. This type action continued all day, Sunday, but no progress was made in reestablishing the pressure. At 1900 hrs, 26 Feb, the Utilities Division concluded that DFE was not getting access to or information about running flush valves so managers arranged through the III Corps Command Operations Center for an order to be disseminated to all military units to inspect every latrine and report to DFE utilities

locations of running flush valves. There was prompt reporting by the units, but not many running valves were noted. As pressure conditions were not improving, utilities managers at 2300 hrs ordered crews to cut off water master valves to every permanent barracks building and large administration or community building.

12. All motor pools were valved off by 0300 hrs, 27 Feb 84, and work order crews began valving off barracks, starting on the east side of post by 0640 hrs.

13. Preventative Maintenance teams started through the temporary buildings at 0945 hrs, 27 Feb 84, checking flush valves. At 1400 hrs, 27 Feb 84, the Bell County Water Control and Improvement District reported sewage flow had decreased but was not back to normal.

14. Late afternoon on 27 Feb 84, the water towers were beginning to fill. By mid-morning 28 Feb 84, the towers were half full.

15. Plumbers started turning water back on at 0400 hrs, 28 Feb 84, and PM teams started checking interiors of buildings for open flush valves. By mid-morning crews began turning the water in the motor pools back on. That afternoon PM teams began going through barracks east of Hood Road to make sure flush valves were on and functioning properly.

16. System was back in full operation by 0800 hrs, 29 Feb 84.

OTHER KEY EVENTS:

1. Fire Prevention and Protection Division.

a. FPP personnel manned water points to assist filling military water trailers for human use in barracks and family housing area from 23 Feb 84 through 27 Feb 84.

b. FFP Div assisted units in filling water trailers from DIO, Trans Div, and 13th SUPCOM for essential health and sanitation needs at Hood Army Airfield and housing areas.

c. FFP personnel were on standby with a pumper truck at Darnall Army Community Hospital in the event of a fire at the hospital during the water shortage. One FFP pumper pumped water from a trailer to a small section of the hospital piping to cool a medical air compressor. This compressor was required to sustain life for a new born infant.

2. Operation Division.

a. 62d Engineers furnished 14 soldiers to assist in turning the water back on providing relief for DFE personnel.

b. Operations personnel manned the telephone in the work order section and provided up-to-date information to COC.

3. LTG Ulmer assisted with water conservation by personally contacting his subordinate commanders and stressing the need for curtailed water usage in troop areas. He also inspected the completed repairs at the main pump station on 28 Feb 84.

4. A request for chemical latrines was processed through the system without any delay. Companies from Austin, Fort Worth, and the local area began setting up the latrines, 27 Feb 84. Employees from Utilities Division ensured the latrines were placed in the proper locations. Removal of the latrines began late 28 Feb 84.

5. At the request of DFE, the adjacent civilian community hospital, Metroplex Hospital, opened a valve connecting their water supply with Fort Hood's system. Water was diverted from the Metroplex system into the Fort Hood water line and Fort Hood's distribution system valves were operated so the water primarily served Darnall Army Community Hospital. Metroplex pumped into the Fort Hood system from 1800 hrs, 24 Feb 84, to 1200 hrs, 25 Feb 84.

6. At the request of DFE, an arrangement was made with the City of Copperas Cove for connecting their water supply with the one on Fort Hood. Copperas Cove began pumping into Fort Hood water lines at 1500 hrs, 25 Feb 84. Montague Village, Darnall Army Community Hospital, and West Fort Hood benefited from this diversion of water. This operation continued until 1315 hrs, 28 Feb 84. Metroplex had shut off their water prior to Copperas Cove coming on line because of a loss of pressure from a main break.

OBSERVATION:

1. Dedicated civilians worked long hours and kept problems at a minimum.

2. Knowledge of the post for DFE employees enabled them to work out of their normal areas of operation without detailed supervsion.

3. The COC, village mayors, residents, and employees of Fort Hood were kept well informed during the water crisis. These individuals responded not only by understanding the situation but by decreasing their water usage.

LESSONS LEARNED:

1. The outside water master valves to buildings with large quantities of flush valves should be cut off in situations where there is a major loss of water pressure. Once the water pressure is restored, station a crew of repairmen in the building and then open the water master valve.

2. Public affairs announcements should keep the community updated on progress. Definite dates and times for completion of repairs should be avoided.

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