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ENGINEERING AND DESIGN

**WATER SUPPLY, WATER STORAGE**

**MOBILIZATION CONSTRUCTION**



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DEPARTMENT OF THE ARMY  
CORPS OF ENGINEERS  
OFFICE OF THE CHIEF OF ENGINEERS

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No. 1110-3-163

9 April 1984

Engineering and Design  
WATER SUPPLY, WATER STORAGE  
Mobilization Construction

1. Purpose. This manual provides guidance in determining water storage requirements for U.S. Army mobilization facilities.
2. Applicability. This manual is applicable to all field operating activities having mobilization construction responsibilities.
3. Discussion. Criteria and standards presented herein apply to construction considered crucial to a mobilization effort. These requirements may be altered when necessary to satisfy special conditions on the basis of good engineering practice consistent with the nature of the construction. Design and construction of mobilization facilities must be completed within 180 days from the date notice to proceed is given with the projected life expectancy of five years. Hence, rapid construction of a facility should be reflected in its design. Time-consuming methods and procedures, normally preferred over quicker methods for better quality, should be de-emphasized. Lesser grade materials should be substituted for higher grade materials when the lesser grade materials would provide satisfactory service and when use of higher grade materials would extend construction time. Work items not immediately necessary for the adequate functioning of the facility should be deferred until such time as they can be completed without delaying the mobilization effort.

FOR THE COMMANDER:



PAUL F. KAVANAUGH  
Colonel, Corps of Engineers  
Chief of Staff

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## CHAPTER 1

### GENERAL

1-1. Purpose and scope. This manual provides design criteria for water storage requirements at Army mobilization facilities, gives a typical design analysis for tanks and reservoirs, and provides guidance on the procedures to be followed in selecting sites for such storage works. The manual covers requirements for treated water storage in the distribution system, but not the storage requirements for raw water supplies or fire deluge systems.

1-2. Definitions. Definitions will be as defined in EM 1110-3-160.

1-3. Objectives of storage. Storage should meet peak flow requirements, equalize system pressures, and provide emergency water supply. The water supply system must provide flows of water sufficient in quantity to meet all points of demand in the distribution system.

a. Peak flow requirements. Water supply systems must be designed to satisfy maximum anticipated water demands. The peak demands usually occur on hot, dry, summer days when larger than normal amounts of water are used for personal purposes and washing vehicles and equipment. In addition, most industrial processes, especially those requiring supplies of cooling water, experience greater evaporation on hot days, thus requiring more water. The water treatment plant can operate at a relatively uniform rate throughout the day of maximum demand if enough storage is available to handle variations in water use. The necessary storage can be provided in elevated, ground, or a combination of both types of storage.

b. Equalization of system pressures. Without storage, demand on the water system must be met by the ability of the treatment plant to process and pump water. Since demand can be so variable, the flow through the plant would vary significantly. This is not very well suited to efficient functioning of the treatment or pumping units. Elevated storage within the distribution system permits treatment units and distribution pumps at the plant to operate at uniform rates. The usefulness of elevated storage is shown in figure 1-1. The system illustrated in figure 1-1(A) (without elevated storage) requires storage at the plant sufficient to provide for system demand rates in excess of the plant production rate, assuming the plant is operated at a uniform rate. The pump station forces water into the service main, through which it is carried to three load areas: A, B, and C. Since all loads on the system are met without the use of elevated storage, the pump station must be capable of supplying the peak rates of water use to Areas A, B, and C, simultaneously, while maintaining the water pressure to Area C at a sufficient level. Figure 1-1(B) assumes the construction of an elevated storage tank on the service main between Areas B and C, with peak loads in Area C and part of the peak load in

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Area B being satisfied from this tank. The elevation of the tank insures adequate pressures within the system. The storage in the tank is replenished when water demands are low and the pump station can fill the tank while still meeting all flow and pressure requirements in the system. The figure 1-1(B) arrangement reduces required capacity of the distribution pumps. Most elevated storage tanks "float" on the distribution system. That is, the elevated tank is hydraulically connected to the distribution system, and the volume of water in the tank tends to maintain system pressures at a uniform level. When water use is high and pumping facilities cannot maintain adequate pressures, water is discharged from elevated tanks. Conversely, when water use is low, the pumps, which operate within a reasonably uniform head-capacity range, supply excess water to the system, and the elevated storage is refilled.

c. Distribution system pressures. Pressures in the distribution system will be in accordance with EM 1110-3-160, chapter 4.

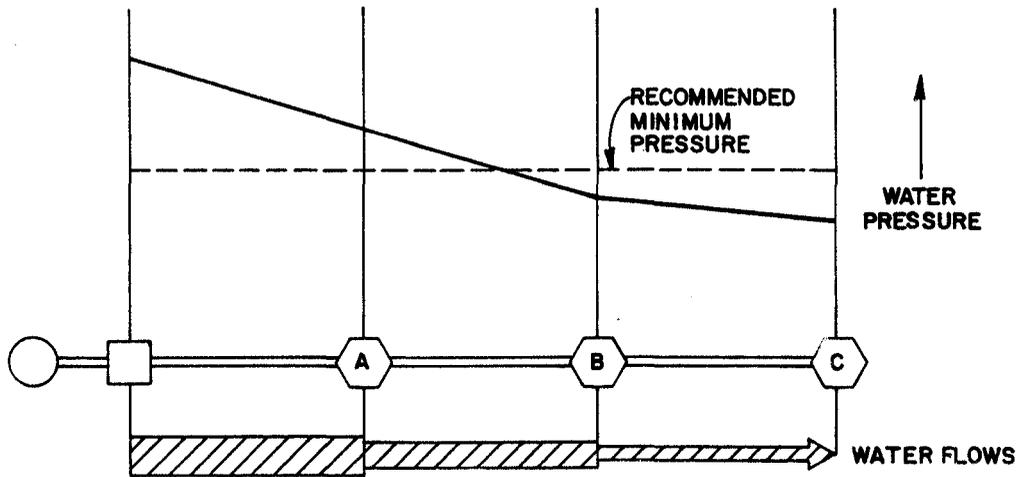
d. Provision of emergency water supplies.

(1) Firefighting flows. This demand can occur at any time, but may well coincide with other large water demands on the system. Necessary flows for firefighting purposes at mobilization sites are given in EM 1110-3-166. Storage and distribution facilities will include capacity for required firefighting flows at adequate pressures at any point of the installation.

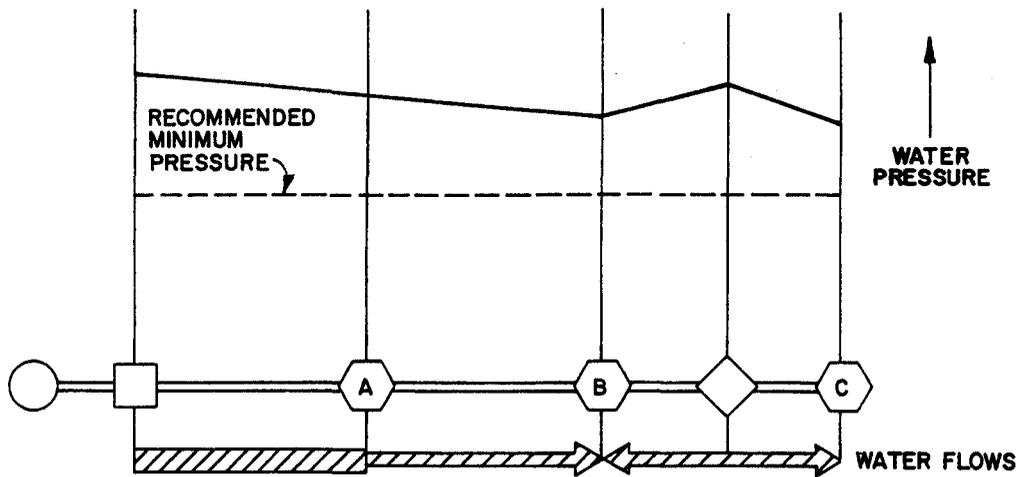
(2) Other emergencies. Water storage must provide an emergency supply of water in the event the water treatment plant, distribution pumps, or a principal transmission main is out of service. The amount of emergency storage required depends on the reliability of the system and the extent of other safeguards incorporated into the system, for example, finished water or interconnections with a municipality (for either normal or emergency use).

1-4. Location of storage facilities.

a. Elevated storage. Elevated storage tanks should be located in the areas having the lowest system pressures during intervals of high water use to be effective in maintaining adequate system pressures and flows during periods of peak water demand. These are those of greatest water demand or those farthest from pump stations. Elevated tanks are generally located at some distance from the pump station(s) serving a distribution pressure level, but not outside the boundaries of the service area, unless the facility can be placed on a nearby hill. Additional considerations for siting of elevated storage are conditions of terrain, suitability of subsurface soil and/or rock for foundation purposes, and hazards to low-flying aircraft. Elevated tanks are built on high ground to minimize the required construction cost and heights. The heights of elevated tanks should not be excessive. This will lead



(A) WATER FLOWS AND PRESSURES WITHOUT ELEVATED STORAGE



(B) WATER FLOWS AND PRESSURES WITH ELEVATED STORAGE

LEGEND

-  Water Treatment Plant
-  Pump Station and Pumped Storage
-  Demand Load Center
-  Elevated Storage

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FIGURE 1-1. EFFECTS OF ELEVATED STORAGE

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to higher pressures than required in low-lying areas as well as increased pumping costs.

b. Ground storage. Ground storage tanks or reservoirs, below ground, partially below ground, or constructed above ground level in the distribution system, must be accompanied by pump stations. In a single pressure level system, ground storage tanks should be located in the areas having the lowest system pressures during periods of high water use. In multiple pressure level systems, ground storage tanks are usually located at the interface between pressure zones with water from the lower pressure zones filling the tanks and being passed to higher pressure zones through adjacent pump stations.

## CHAPTER 2

### TYPES OF STORAGE

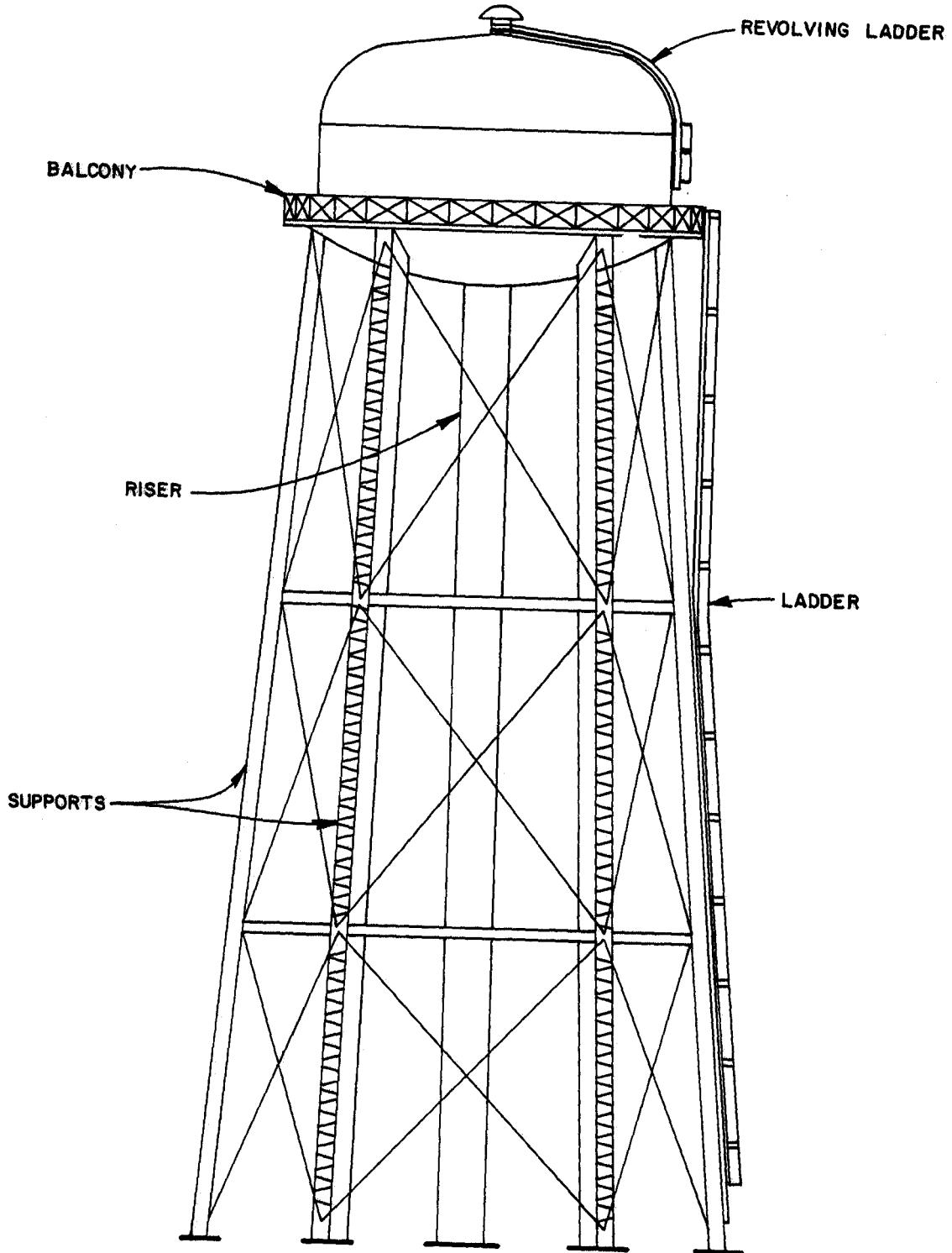
2-1. General. Required storage capacity at Army installations is met by use of elevated or ground storage. Elevated storage feeds the water distribution system by gravity flow. Storage which must be pumped into the system is classified as ground storage. Clearwell storage, which is usually part of a water treatment plant, is not included in computing storage.

2-2. Ground storage. Ground storage is usually located remote from the treatment plant but within the distribution system. Ground storage is used to reduce treatment plant peak production rates and also as a source of supply for repumping to a higher pressure level. Such storage for repumping is common in distribution systems covering a large area, because the outlying service areas are beyond the range of the primary pumping facilities. Ground storage may be in tanks on the ground surface or below natural ground elevation.

2-3. Elevated storage.

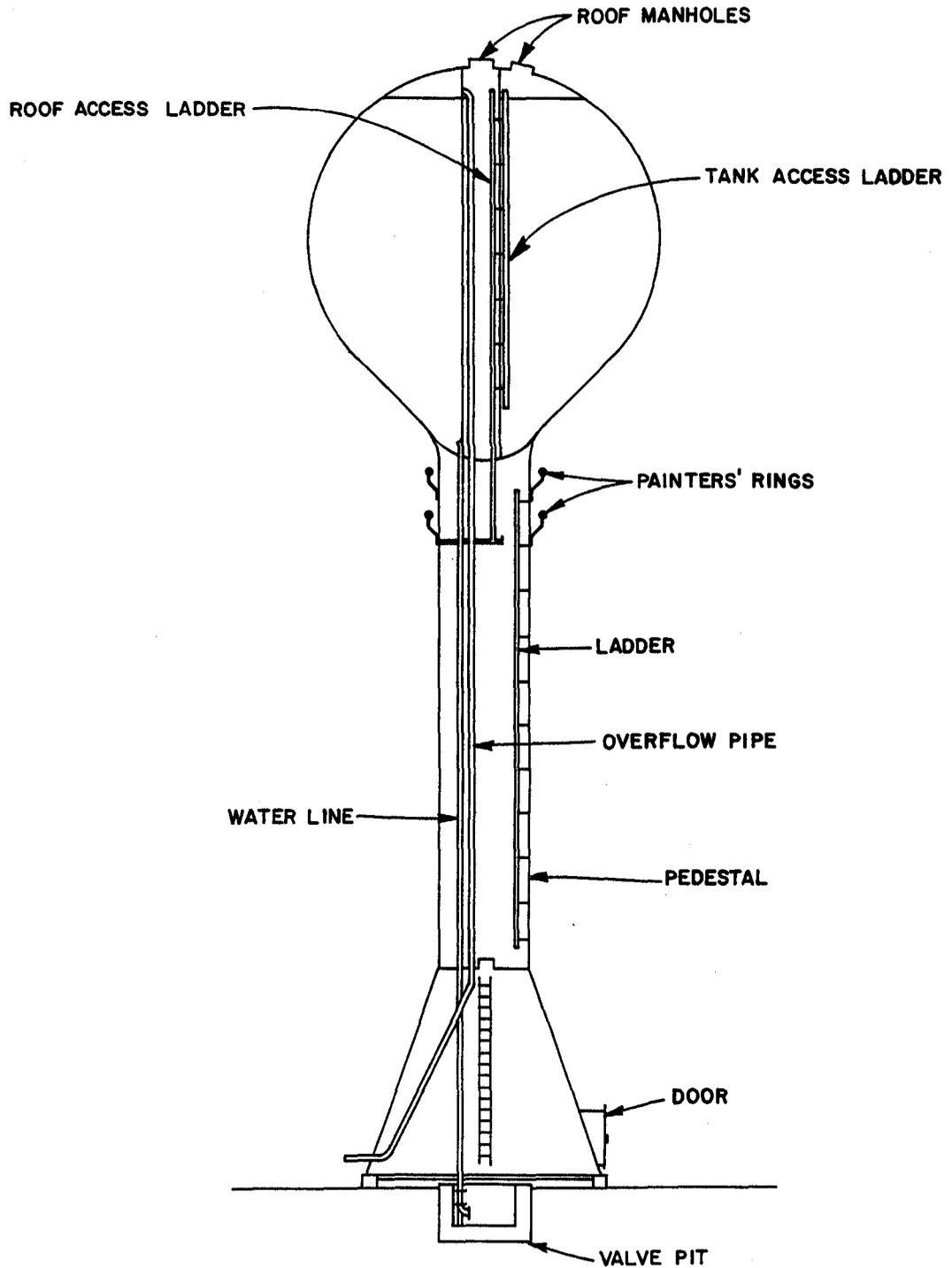
a. General. Elevated storage is provided within the distribution system to supply peak demand rates and equalize system pressures. In general, elevated storage is more effective and economical than ground storage because of the reduced pumping requirements, and the storage can also serve as a source of emergency supply since system pressure requirements can still be met temporarily when pumps are out of service. Elevated storage can be: 1) Above natural grade. The tank is supported by a tower or pedestal where all storage is contained above ground except for water in the feeder or supply pipes. 2) At natural grade. 3) Below natural grade.

b. Type. The most common types of elevated storage are elevated steel tanks, concrete tanks built above or below natural grade, and standpipes. Examples of conventional elevated steel tanks are given in figures 2-1 and 2-2. Storage at natural grade is preferred where local terrain will allow the placement of a tank (such as on a hillside) sufficiently above the facility to be served. Storage above natural grade should be discouraged since this construction would require steel, a highly skilled labor force, and special equipment - all would be in short supply. Storage above natural grade will be used only when the terrain is flat or when gravity-fed storage at natural grade would be impractical. Storage below natural grade is usually done for aesthetic reasons and will not be made for mobilization construction unless circumstances require this kind of storage.



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FIGURE 2-1. ELEVATED STORAGE TANK



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FIGURE 2-2. ELEVATED STORAGE TANK (ALTERNATIVE DESIGN)

## CHAPTER 3

### DETERMINATION OF CAPACITY REQUIREMENTS

3-1. Total storage requirements. The amount of water storage provided will conform to the requirements set forth herein.

a. All Army installations. In general, total storage capacity, including elevated and ground storage, will be provided in an amount not less than the greatest of the following items:

- Item 1: Fifty percent of the average total daily domestic requirements plus all industrial requirements. This will provide minimum operational storage needed to balance average daily peak demands on the system and to provide an emergency supply to accommodate essential water needs during minor supply outages of up to 1-day duration. For the purposes of this item, essential water needs do not include the fire demand.
- Item 2: The fire demand. The fire demand is the required flow needed to fight a fire in the facility (including water required to support fire suppression systems) which constitutes the largest requirement for any facility served by the water supply system, plus 50 percent of the average domestic demand rate plus any industrial requirement. This amount will be reduced by the amount of water available under emergency conditions during the period of the fire. The fire demand quantity must be maintained in storage for fire protection at all times except following a fire fighting operation when the fire demand quantity would be depleted. It is recognized that during daily periods of peak consumption due to seasonal demands, the amount of water in storage will be less than full storage capacity; however, conservation methods will be instituted to prevent drawdown of water in storage below the fire demand quantity. Particular attention must be paid to water usage for uncontrolled irrigation.
- Item 3: The sum of Item 1 and 2 above, that is, the sum of 50 percent of the average total daily domestic requirements, all industrial requirements for an average day which cannot be shut off during emergency conditions, and the required fire demand. The sum of the above items will be reduced by the amount of water available in 24 hours under emergency conditions. This will provide maximum storage where emergency water supply is a minimum over a 24-hour period or a supply main outage would significantly affect overall supply conditions.

b. Amount of water available under emergency conditions.

(1) The amount of water available under emergency conditions is considered to be that available from auxiliary powered pumps during electric power outage, from electric-motor driven pumps with the largest pump out of service, from one or more supply mains with the main of greatest capacity out of service, or from the water treatment plant with one filter out of service. Normally, the capacity of the clearwell storage at the treatment plant will not be considered part of the required storage.

(2) Where the water supply is obtained from wells, all of which are equipped with standby power and located within the distribution systems, the emergency supply will be considered as the quantity available from all but one of the wells. Where one well has a capacity greater than the others, that one will be assumed out of service. Where only 50 percent of the wells have standby power, the emergency supply will be considered as the quantity available from the wells having standby power.

(3) Where the project is supplied from a dependable existing source, such as a municipal system with adequate storage and standby facilities, through supply lines not subject to damage by floods, high pressure, or other unusual conditions, the amount of water available under emergency conditions is that obtainable with the largest connection inoperative.

(4) Where the supply is delivered through a single supply main, the maximum amount of storage as determined in paragraph 3-1.a. will be provided.

(5) Where the peak demand for water is available at adequate residual pressure through two or more lines while the line having the greatest capacity is out of service, no storage will be required.

(6) Where the peak demand for water is available through two or more lines but is not available if the line having the greatest capacity is out of service, storage will be required. The quantity of water available under emergency conditions with the line of greatest capacity out of service will be considered in calculating the amount of storage required.

3-2. Elevated storage capacity. The total elevated storage capacity at all Army installations, except plant and special projects, should not be less than the amount determined in paragraph 3-1.a. Item 2, nor less than 50 percent of the total required storage, unless special conditions prevail which would negate the need for such storage. For projects with design populations of 10,000 or less, consideration will be given to providing all elevated storage where the storage will result in an economical and reliable system. For projects such as storage depots or aircraft hangars with deluge sprinkler systems, ground storage reservoirs with booster pumps will generally be the more

economical method of supplying large volumes of water for fire protection. Elevated tanks will normally be provided for initial sprinkler demand in storage warehouses.

## CHAPTER 4

### DESIGN AND CONSTRUCTION OF WATER STORAGE FACILITIES

4-1. Fabric tanks. Embankment supported fabric tanks are an alternative to conventional steel tanks. The tanks are usually made of lightweight durable rubber. When placed within a space formed by earthen embankments, the fabric tanks act as a reservoir lining with a floating roof. The tanks can be used to store water for fire protection, drinking, and process water for domestic and commercial uses. Following are some of the principal advantages of this type of reservoir:

- More economical than conventional tankage in terms of materials and construction time.
- Easy transport and handling.
- Minimal maintenance.
- Essentially a closed system - no contamination and no evaporation of stored liquids.

Some of the disadvantages are:

- Extreme caution must be exercised to insure the tank is not punctured, either during construction or operation.
- Materials of manufacture could be scarce during a mobilization situation.
- Lack of excess pressure control could create major problems.

4-2. Reservoir covers. All treated water reservoirs must be covered to prevent contamination by dust, birds, leaves, and insects. These covers will be, insofar as possible, watertight at all locations except vent openings. Special attention should be directed toward making all doors and manholes watertight. Vent openings must be protected to prevent the entry of birds and insects; vent screens should be kept free of ice or debris so that air can enter or leave the reservoir area as temperature and water levels vary. All overflows or other drain lines must be designed so as to eliminate the possibility of flood waters or other contamination entering the reservoir. Reservoir covers also protect the stored water from sunlight, thus inhibiting the growth of algae. Further prevention of algae growth or bacterial contamination, due to the depletion of the chlorine residual, can be obtained by maintaining sufficient flow through the reservoir so that

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water in the reservoir does not become stagnant. Minimal flows through the reservoir also help to prevent ice buildup during cold periods.

4-3. Overflow. All storage tanks should be provided with altitude valves to prevent overflows. These altitude valves will be installed in concrete pits having provisions for draining either by gravity or pumping. When altitude valves are not available, overflow piping will be used. Overflow drainage piping will not be connected to sanitary sewers.

4-4. Drains. All storage tanks and reservoirs will be provided with drains for tank serviceability and maintenance. Drains will not be connected to sanitary sewers.

4-5. Instrumentation and control. Storage measurements are used for inventory and system controls. Elevated and ground storage measurements will be made to accomplish the following:

- determine the water depth in the tank.
- initiate the shut-down of supply pumping units and actuation of an overflow alarm in that order at high storage level.
- initiate the startup of supply pumping or well pumping units or distribution pumping unit shutdown.

4-6. Disinfection. Potable water storage facilities, associated piping, and ancillary equipment must be disinfected before use. Disinfection will be accomplished following procedures and requirements of AWWA D105 or the requirements of local regulatory authorities, whichever is more stringent. In no event will any of the above equipment or facilities be placed in service prior to verification by bacteriological tests that disinfection has been accomplished.

4-7. Design analyses. The design analyses will set forth the basis by which storage capacities and locations have been determined. Except where standard specifications for tanks or towers are used, the analyses will show the method by which the structural adequacy of the unit has been determined. Some typical design examples have been presented in appendix A.

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## APPENDIX A

## TYPICAL DESIGN EXAMPLES

A-1. General. The following typical design examples illustrate procedures to be followed in the determination of total capacity requirements for water storage facilities at Army mobilization installations. Exact fire flow requirements should be evaluated according to EM 1110-3-166.

A-2. Example No. 1. Communications base.

a. Effective population.

- Nonresident: 400.
- Resident: 700.
- Total:  $700 + 400/3 = 833$ .

b. Water source. Wells on post; average yield 150 gpm each.

c. Treatment. Chlorination.

d. Required daily demand and fire flows.

- Capacity factor: 1.5.
- Design population:  $833 \times 1.5 = 1,250$ .
- Per capita allowance: 150 gpd.
- Special demands: None.
- Required daily demand:  $1,250 \times 150 = 187,500$  gpd, equivalent to a rate of 130 gpm.
- Firefighting flow: 500 gpm for 2 hours.
- Maximum day demand:  $130 \times 2.5 = 325$  gpm.

e. Well requirements.

- Total well yield: Assuming 24-hour/day well operation, one well has sufficient yield to meet the required daily demand rate of 130 gpm. However, for firm production capability, it is necessary to have two wells, each capable of 130 gpm.

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- Minimum pump requirement: The dependable output of the source of supply, i.e., the two wells, must be equal to, or greater than, the required daily demand. Thus, each well should be equipped with a 150-gpm pump. Two reliable sources of electric service should be provided, or one pump should be equipped with both an electric motor and standby internal combustion engine. The size and number of distribution pumps required are related to the type, size, and location of storage facilities. Provision of elevated storage will reduce the required pump capacity.

f. Storage requirement.

- Item 1: Fifty percent of total daily domestic requirements:  
 $187,500/2 = 93,750$  gallons.
- Item 2: Fire demand:  $(500 + 130/2) \times 60 \times 2 = 67,800$  gallons. This item may be reduced by the amount of water available during the period of the fire demand under emergency conditions. The amount available under emergency conditions is the production of one well, so this item becomes  $67,800 - (150 \times 2 \times 60) = 49,800$  gallons.
- Item 3: Fifty percent of total daily domestic requirements plus the fire demand minus the production of one well in 24 hours:  
 $93,750 + 67,800 - (150 \times 24 \times 60) = -54,450$  gallons.

The largest of the above items, 93,750 gallons, governs the total storage requirements. Storage of not less than 100,000 gallons should be provided. In this case, it is suggested that a 100,000-gallon elevated tank be provided.

g. Water main sizes. The water distribution system will have mains of adequate size to meet peak domestic demand (see EM 1110-3-160) and pressure requirements at all locations. General design criteria for water mains are given in EM 1110-3-164.

A-3. Example No. 2: Mobilization camp.

a. Effective population.

- Nonresident: Negligible.
- Resident: 20,000.

b. Water source: Surface supply from river.

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c. Treatment: Coagulation, flocculation, sedimentation, filtration, and chlorination.

d. Raw-water pump station: Two 2,700 gpm electric motor driven pumps and a 1,350 gpm dual-drive (electric motor with standby internal combustion engine) pump are available and have been delegated for use at this camp.

e. Required daily demand and fire flows.

- Capacity factor: 1.15.

- Design population:  $20,000 \times 1.15 = 23,000$ .

- Per capita allowance: 150 gpd.

- Required daily demand:  $(23,000 \times 150) = 3,450,000$  gpd. Gpd equivalent to a rate of 2,396 gpm.

- Maximum day demand:  $2,396 \times 2.5 = 5,990$  gpm.

- Firefighting flows: (As would be determined from EM 1110-3-166).

- Quarters: 1,500 gpm for a duration of 2 hours =  $1,500 \times 60 \times 2 = 180,000$  gallons.

Warehouse: 2,800 gpm for a duration of 3 hours =  $2,800 \times 60 \times 3 = 504,000$  gallons.

Hospital: 1,500 gpm for a duration of 2 hours =  $1,500 \times 60 \times 2 = 180,000$  gallons.

To meet the required daily demand, a treatment plant with pump stations and appurtenances having a rated capacity of approximately 3.5 mgd would be provided. The emergency pumping capability of this plant will be 1,350 gpm as indicated in paragraph d above.

f. Storage requirements.

- Item 1: Fifty percent of total daily domestic requirements

$$= \frac{(23,000 \times 150)}{2} = 1,725,000 \text{ gallons}$$

- Item 2: Fire demand =

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$$2,800 \times 60 \times 3 + \frac{(23,000 \times 150 \times 3)}{24 \times 2} = 719,630 \text{ gallons}$$

The storage requirement for fire demands becomes  $719,630 - (1,350 \times 60 \times 3) = 476,630$  gallons.

- Item 3: Fifty percent of required daily demand plus fire demand minus the amount of water available in 24 hours under emergency conditions =  $1,725,000 + 719,630 - (1,350 \times 60 \times 24) = 500,630$  gallons.

The first item governs; storage of about 1,800,000 gallons should be provided. At least 50 percent of the storage should be elevated since the population exceeds 10,000. Two 500,000 gallon elevated tanks would be satisfactory with the remainder of the required storage provided in a ground storage reservoir.

g. High-lift pump station. Pumping facilities, similar to those for raw water pump station, must be provided.

h. Water main sizes. Water mains will be in accordance with the criteria of EM 1110-3-164.

APPENDIX B

REFERENCES

Government Publications.

Department of the Army.

- |               |  |
|---------------|--|
| EM 1110-3-160 | Water Supply, General<br>Considerations. |
| EM 1110-3-164 | Water Supply, Water Distribution.        |
| EM 1110-3-166 | Water Supply, Fire Protection.           |

Nongovernment Publications.

American Water Works Association (AWWA), 6666 West Quincy Avenue,  
Denver, CO 80235

- |         |  |
|---------|--|
| D105-80 | Disinfection of Water Storage<br>Facilities. |
|---------|--|