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Kent County Water Authority
Distribution Storage Tank Hydraulic Evaluation

Technical Memorandum No. 2A
Development of Water System Evaluation Criteria
September 2006

1.0 Purpose and Scope

This project relates to utilizing the updated computerized hydraulic model of the Kent County Water Authority (Authority) water system to complete a detailed hydraulic study and evaluation of the entire supply and distribution system in regards to distribution storage for the next twenty (20) year planning period. This evaluation is intended to consider system demand for both existing and the projected planning period and an evaluation of the ability of the water system infrastructure distribution storage components to effectively meet these demands.

The project has been divided into various sub tasks and each of which will be further detailed in a specific technical memorandum. The purpose of this technical memorandum is to establish the criteria by which the existing and any proposed water storage facilities will be evaluated and if necessary sized. It is intended that the information gathered as part of this task will be the basis for evaluation and analysis as part of this study and ultimately for development of recommendations in subsequent portions of this study. The following are the specific efforts associated with this task.

1. Develop criteria to be utilized to evaluate the water supply and distribution system and the design of any proposed improvements, most critically for new distribution storage tanks for the twenty-year planning period.

2. It is intended that criteria will also be applied to the evaluation of the existing tank facilities in the system in order to gauge their effectiveness in meeting these criteria for the immediate and long term planning goals.

3. Utilizing the established criteria, provide recommendations for new storage facilities as may be required for the twenty year planning period.

1.1 Storage Facilities - Overview

Finished water storage in the water distribution system have traditionally been designed to equalize water system demands, reduce pressure fluctuations in the distribution system and provide reserves for fire fighting, power outages and other emergencies.

Traditionally, it has been common practice of many water utilities to keep storage tanks in a full or near full condition to be better prepared for peak water use periods that typically occur during maximum day demand conditions and for emergencies such as fires. This emphasis in past designs has resulted in many storage facilities operating today with larger water storage capacity than is needed for non-emergency usage. Also, some storage facilities have been designed or changes have been made to system operations such that the high water level in the tank (the overflow elevation) is below the hydraulic grade line of the system, resulting in conditions where the tank rarely drains and making it difficult to turnover the tank. Only when the hydraulic grade line of the system drops below the tank overflow will water flow out of the storage tank. Depending upon time this could result in aged water being returned to the system such that water quality is affected.

Regardless of the type of tank facility constructed it is critical that the overflow elevation be set to match the hydraulic grade of a particular pressure zone as this allows the water tanks to "float" on the system. In other words, the water elevation in the tank will determine the hydraulic grade (pressure) in the distribution system. When tanks are being filled via pump stations, etc., the hydraulic grade of the system is increased and subsequently the distribution system pressure will increase proportionately and water flows into tank facilities.

It will be critical in this tank study evaluation to examine several of the Authority's water storage tanks (i.e. Fiskeville Reservoirs, West Street Standpipe and Wakefield Tank), which experience this type of problem due to proximity to the Clinton Avenue Pump Station. Options will be evaluated with the use of the computer model to provide a means to optimize use of these tank facilities either through routine shut down of the Clinton Avenue Pump Station (currently this rarely occurs except during early morning hours) or through an isolation of the storage tank(s) with possible option to pump back into the distribution system from the tank or alternatively to relocate distribution storage where it is best suited. The extended period simulation (EPS) function of the hydraulic model will be utilized to evaluate various storage alternatives as well as water main sizing associated with the storage facilities.

Normally, the water level in a storage tank routinely fluctuates on a daily basis through a fill and drain cycle. The variation in the fluctuation will vary depending upon the size (diameter and height) of the storage facility (i.e. gallons per foot), system demand and location in the distribution system. Nevertheless, the water in the tank should fluctuate several feet prior to the start of the pump station or additional pumps coming on line to ensure that proper circulation in the tank is occurring.

If for example, model simulations indicate that the tank level does not drop sufficiently, then the tank may be too large or the pump may be set to cycle too frequently. If the water level in a tank drops too quickly during peak demands then the tank may be too small. Increasing the tank size may serve to correct this problem. For situations in which a tank cannot recover following a period of maximum day(s) or emergency conditions, the source of supply or distribution system serving the tank may have insufficient capacity to satisfy demands.

Although there are general design guides and criteria to evaluate and size storage facilities, ultimately the assessment of any storage tank or combination of tanks in a water system also includes sound engineering judgment and operational specifics of the water system. Each individual water system is unique with regard to demand patterns and fire flow requirements, etc. and it is not common to simply rely on a standard "formula" to evaluate the water tank(s) in any particular water system. Therefore, although the general criteria that is referenced herein will provide a general rule to evaluate and size water storage tanks, the hydraulic computer simulations that predict how a water system will operate will be an important aspect when analyzing the system and providing recommendations for size, location and effectiveness of the water system storage tanks.

1.2 Types of Storage Facilities

Required distribution storage capacity for potable water systems is traditionally met by the use of elevated, reservoir - ground storage or standpipes or some combination of all three. In certain instances, reservoirs have been installed below grade in instances where a suitable overflow elevation can be maintained. The Authority maintains a combination of all three tank styles within the distribution system including a below grade reservoir.

Reservoir - Ground Storage

A reservoir is a ground supported, flat bottom cylindrical tank with a shell height less than or equal to its diameter. Reservoirs represent the most common type of water storage structure and are usually constructed of steel or concrete. Of the three styles, reservoirs are also the most economical to fabricate, erect and maintain due to their low height (typically less than 50 feet although, the Authority has a reservoir that is 70 feet in height). An inherent problem with reservoirs is that typically not all the water in the facility can be utilized.

A storage reservoir can be broken down into distinctive water storage components and each of which serves a particular purpose. Equalization storage is that volume in the tank that is typically cycled on a daily basis and meets the water system demands that are in excess of the pumping capacity of the system. This storage is located at the top of the storage tank. Equalization storage can further be broken down into operational storage, which is that upper portion of the equalization storage where the supply pumps are normally set to cycle on and off. During a maximum day, the water level in the tank may continue to drop in the equalization storage zone such that additional supply (pumps) are required to replenish the tank and keep up with consumer demand. The low end of the equalization storage is defined as the level in which 35 psi can be maintained in the distribution system.

The effective storage is defined as the level in the tank above which 20 psi can be maintained within the distribution system for domestic service and to a point in the equalization storage where the normal low-end operational storage is maintained. Emergency storage is defined as the water level in the reservoir above which 20 psi can be maintained within the distribution system for fire flow and emergency service. The upper end of the emergency storage is typically defined as the bottom of the equalization storage component. The water below the emergency storage in the reservoir is considered to be "dead" storage volume and is not considered usable. This "dead" storage, especially if it is a relatively large volume and the tank is not turned over frequently, can lead to water quality problems in instances where internal tank mixing systems are not in place. A schematic of the various storage components is portrayed in Figure 1.

Water quality problems may also occur in tanks with single or common fill and draw pipes. It has traditionally been common practice in the water works industry to construct a reservoir with a single pipe in which water is added and drawn from the tank. Recently and with greater emphasis on water quality, new tanks are constructed with internal mixing systems or individual fill and draw pipes.

The Authority currently maintains the following reservoir style tanks in its system:

Crompton Tank (Setian Lane) – Low Service Gradient

Location:	Off Setian Lane at Flanders Drive / West Warwick, RI
Total Volume:	3,000,000 gallons
Height:	20 feet
Diameter:	160 feet
Overflow Elevation:	334.6 feet (based on site survey by Chas H. Sells Inc. August 2006)
Material:	Steel
Constructed:	1968
Description:	Single fill and draw pipe at base of tank

Fiskeville Underground Reservoirs (No. 1 and No. 2) – Low Service Gradient

Location:	Adjacent to Seven Mile Road near Spring Lake Reservoir No.1 / Cranston, RI
Total Volume:	1,500,000 gallons (combined)
Square Area:	80 square feet
Height:	11 feet
Overflow Elevation:	334.6 feet (based on site survey by Chas H. Sells Inc. August 2006)
Material:	Reinforced Concrete
Constructed:	1944 & 1960
Description:	Single fill and draw pipe at base of tanks

Frenchtown Tank – Low Service Gradient

Location:	Intersection of Frenchtown Road and High Hawk Drive / East Greenwich, RI
Total Volume:	1,500,000 gallons
Height:	50 feet
Diameter:	73 feet
Overflow Elevation:	334.03 feet (based on site survey by Chas H. Sells Inc. August 2006)
Material:	Concrete
Constructed:	1977
Description:	Single fill and draw pipe at base of tank

Wakefield Street Tank – Low Service Gradient

Location:	End of Carrie Ann Drive / West Warwick, RI
Total Volume:	2,000,000 gallons
Height:	70 feet
Diameter:	70 feet
Overflow Elevation:	333.7 feet (based on site survey by Chas H. Sells Inc. August 2006)
Material:	Concrete
Constructed:	1990
Description:	Single fill and draw pipe at base of tank

Tiogue Avenue Tank – Tiogue Tank Gradient

Location:	Intersection of Tiogue Avenue and Elton Street / Coventry, RI
Total Volume:	771,000 gallons
Height:	40 feet
Diameter:	58 feet
Overflow Elevation:	350.0 feet (based on Authority records and not surveyed as part of study)
Material:	Steel
Constructed	1957
Description:	Single fill and draw pipe at base of tank; supplied by booster pump station at base of tank and check valve to open to Low Service if hydraulic grade drops below 334 feet.

West Street Tank (currently out of service) – Low Service Gradient

Location:	West Street / West Warwick, RI
Total Volume:	1,000,000 gallons
Height:	50 feet
Diameter:	58 feet
Overflow Elevation:	331.5 feet (based on site survey by Chas H. Sells Inc. August 2006)
Material:	Steel
Constructed	1956
Description:	Single fill and draw pipe at base of tank

Read School House Road Tank – Intermediate High Pressure Gradient

Location:	Read School House Road / Coventry, RI
Total Volume:	1,500,000 gallons
Height:	40 feet
Diameter:	80 feet
Overflow Elevation:	430.0 feet (based on Authority records and not surveyed as part of study)
Material:	Steel
Constructed	1973
Description:	Single fill and draw pipe at base of tank

Standpipe

A standpipe is a ground supported, flat bottom cylindrical tank with a height that is greater than its diameter. Standpipes are commonly manufactured of welded steel and can be constructed up to a height of 100 feet, or higher. Only the portion of the storage volume of a standpipe that meets the requirements of elevated storage is considered useful storage for pressure equalization purposes. An inherent problem with standpipes much as in reservoirs is that not all the water in the tank can be utilized. In fact, the lower portion of the water storage column (often up to 2/3 of the tank volume) acts to support the useful storage and to provide a source of emergency water supply.

Standpipes are similar to reservoirs with regard to the various water storage components (i.e. equalization, effective, fire, emergency and dead storage) as previously described in the section on reservoirs. Again, Figure 1 graphically portrays the various storage components.

As with reservoirs, it has been common practice to construct standpipes with a single connection pipe to the distribution system that serves as both the fill and draw line to the tank. This line is usually installed at the base of the standpipe. When the hydraulic grade line of the system falls below the water level in the tank, water is drawn into the system. Conversely, when the hydraulic grade line is greater than the level of water in the tank, water is fed into the tank. With a common fill and draw line and assuming minimal mixing, the water that last entered the tank is the first to be withdrawn (i.e. last in - first out). Without circulation in the tank, it is likely that there are areas with poor mixing and aged water. This single fill and draw line can lead to water quality problems in instances where internal tank mixing systems are not in place. This is especially true in disinfected water systems when chlorine residuals can be reduced to below acceptable limits.

The Authority currently maintains the following standpipe style tanks in its system:

Carrs Pond Road Tank – High Service Pressure Gradient

Location:	Carrs Pond Road / West Greenwich, RI
Total Volume:	3,000,000 gallons
Height:	82 feet
Diameter:	80 feet
Overflow Elevation:	500.1 feet (based on site survey by Chas H. Sells Inc. August 2006)
Material:	Concrete
Constructed	September 2001
Description:	Single fill and draw pipe at base of tank

Elevated Storage

An elevated storage tank consists of two primary components: the tank (or bowl assembly which holds the water) and the supporting structure or tower (which supports the bowl). These types of tanks are commonly constructed where the ground elevation is insufficient for the use of reservoir style tanks or where greater storage capacity than could normally be achieved with a standpipe is required. There are several common constructed styles of elevated tanks including spheroid (same as Technology Park Tank), fluted column and composite (steel bowl with concrete support structure). These tanks have commonly been constructed of welded steel however most recently composite style (reinforced concrete support structure with steel bowl) tanks are gaining prominence. This type of tank is the most expensive to construct and can cost as much as 30 to 50 percent more per gallon compared to the ground storage styles.

The elevated storage tank does however provide distinct advantages. Similar to the other styles, it provides the distribution system with the ability to supply peak demand rates and equalize system pressures as well as provide reserve fire protection storage. The primary advantage with elevated tanks is that they can be designed so that all of the storage is available for use in an emergency or fire above the minimum 20 psi that needs to be maintained in the distribution storage. Therefore, theoretically there is no "dead" storage in the elevated tank however in practice the elevated tank is never drained to such an elevation as to compromise the fire reserve as it must always be maintained in the tank. It is therefore important to consider turn over cycles and mixing systems in elevated tanks as well in order to maintain water quality and increase water turn over rates.

The Authority currently maintains the following elevated style tanks in its system:

Technology Park Elevated (Spheroid Style) Tank – High Service Pressure Gradient

Location:	Hopkins Hill Road / West Greenwich, RI
Total Volume:	1,500,000 gallons
Overall Height:	150 feet
Bowl Height:	50 feet
Bowl Diameter:	75.25 feet
Overflow Elevation:	500.69 feet (based on site survey by Chas H. Sells Inc. August 2006)
Material:	Steel
Constructed:	1988
Description:	Single fill and draw pipe to base of tank bowl

2.0 Criteria for Storage Tank Design

The sizing, number and type of storage facilities will affect a water system's ability to provide an adequate supply at an adequate pressure during various demand scenarios as well as to manage water quality. Capital planning necessitates construction of facilities that have excess capacity for water storage and distribution throughout the system.

Standard design guidelines for hydraulic considerations in the planning and construction of storage tanks are contained in the following documents. Additionally, the criteria in these documents will also be utilized to assess existing storage facilities (i.e. plan for future growth).

➢ AWWA Manual M31 *Distribution System Requirements for Fire Protection* (AWWA 1998)

This reference provides guidelines for required durations for various fire flow rates; discussion related to the types of storage tanks and their effectiveness in meeting fire flows; determination of fire flow rates; establish criteria for system demands and design flow criteria.

➢ AWWA Manual M32 *Distribution Network Analysis for Water Utilities* (AWWA 1989)

This reference is specific to the evaluation of storage facilities including system storage requirements, elevated vs. ground storage, and guides on determining the number and location of storage facilities in a water system. The reference cites the following with regard to sizing storage facilities: "Equalization storage supplies all system demands above the average rate" and "Equalization storage generally makes up one half the total storage required and about 20 – 25 percent of the average day demand…"

➢ AWWA Manual M42 *Steel Water Storage Tanks* (AWWA 1998)

This reference provides guidelines for selection and sizing of water storage tanks, which involve a number of engineering considerations including detailed analysis of water demands, supply sources and the distribution system. The standard provides discussion related to these design parameters as well as providing a checklist of factors to consider in determining selection and sizing of a (steel) tank.

➢ Ten States Standards – *Recommended Guide for the Design of Waterworks Facilities*, 2003.: Great Lakes Upper Mississippi River Board of State Public Health & Environmental Managers, Albany, N.Y.: Health Education Services.

This standard is very specific with regard to tank sizing and indicates the following. "Storage facilities should have sufficient capacity, as determined from engineering studies; meet domestic demands and where fire protection is provided, fire flow demands.

a. Fire flow requirements established by the appropriate state Insurance Services Office should be satisfied where fire protection is provided.
b. The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to the average daily consumption. This requirement may be reduced when the source and treatment facilities have sufficient capacity with standby power to supplement peak demands of the system.
c. Excessive storage capacity should be avoided to prevent potential water quality deterioration problems."

The following references provide detailed description and techniques for computer hydraulic modeling of water systems and for analyzing the operation of storage tank systems. These hydraulic modeling references will be utilized in conjunction with the aforementioned standard design guides and manuals in order to assess particular storage tanks. Specifically, the model will be useful to determine size and dimensions of tanks, minimum and maximum rates of inflow and outflow, etc. More importantly, the model will provide an indication as to how the tanks work collectively throughout the water distribution system especially under extended period simulation such as multiple days of maximum day demand conditions.

- Cesario, L. 1995. "Modeling, Analysis and Design of Water Distribution Systems, American Water Works Association, Denver, CO.
- Haestad, Walski, Chase, Savic, Grayman, Beckwith, Koelle, 2003. *Advanced Water Distribution Modeling and Management*, Haestad Press, Waterbury, CT.
- Walski, T.M. 2000. "Hydraulic Design of Water Distribution Storage Tanks:, Chapter 10 in *Water Distribution Systems Handbook*, edited by L. W. Mays, New York, N.Y.: McGraw-Hill (AWWA).

These standard guidelines and text references ensure that the water system maintains adequate volumes of water storage for meeting domestic demands, fire flow and emergency storage as well as meeting the hydraulics of the water system (i.e. adequate pressures and flow).

State Regulations (including the aforementioned Ten States Standards), AWWA Standards and NSF are utilized to address specific design features and standards for the construction of water storage tanks. They do not generally address issues relating to sizing and locating of water storage tank facilities. Rather they are more specific with regard to construction and design standards for constructing a tank once the size and location is determined.

2.0 Storage Evaluation Criteria

2.1 General

In order to provide a general overall assessment of the existing and potential new storage tanks the basic concept of "effective" versus "total" storage shall be used. This concept applies to tanks, which "float" on the system as do all the existing tanks in the Authority's system as well would any new storage tanks. The term "float" on the system infers that the water level in the tank (which is open to atmosphere) at any given time will determine the pressure in the distribution system. This concept examines each individual tank and determines the "effective" storage volume to be located above the water elevation in the tank above which a minimum pressure of 20 psi can be maintained. This is defined as the minimum acceptable hydraulic grade line for the tank.

Equalization storage is that volume in the tank that meets the water system demands that are in excess of the pumping capacity of the system. This storage is located at the top of the storage tank. Equalization storage is further broken down into operation storage, which is that upper portion of the equalization storage where the supply pumps are set to cycle on and off. The defining low water level point in the tank for equalization storage is that where 35 psi can be maintained within the distribution system. The total storage volume of the tank refers to the nominal capacity of the tank.

Storage located below the equalization storage zone is referred to as emergency and fire storage and provides a minimum pressure of 20 psi. This is typically allowed for emergency purposes as would occur during a fire flow event. Below this water level storage is ineffective or "dead" storage that cannot effectively supply the distribution system with adequate pressure. Therefore, the total nominal storage of the tank(s) does not provide a true indication of the available "effective" volume in the tank(s) that would be readily available for use in the water system. Refer to Figure 1 for a graphical presentation of the various water storage components of a tank.

It should also be noted that there might be isolated areas of the distribution system (i.e. specific isolated higher elevations) that experience pressures below 35 psi on a routine basis. These areas will be identified in subsequent tasks of this study both descriptively and by mapping. These areas must be evaluated on a case-by-case basis and may be overcome by individual booster pumps, as it may be cost prohibitive to increase a water system's hydraulic grade line to address these isolated areas. An assessment must be made as to the most effective means to service these specific areas, which may not include increasing the overall system hydraulic grade.

2.2 Tank Volume Assessment Criteria

As previously indicated, there are two approaches that are generally utilized to evaluate and size storage tanks. These include regulatory driven design and functional design. An example of standards driven design includes the tank sizing criteria identified in the aforementioned Ten States Standards that indicate the following with regard to sizing of finished water storage tanks in the distribution system.

"Storage facilities should have sufficient capacity, as determined from engineering studies; meet domestic demands and where fire protection is provided, fire flow demands.

d. Fire flow requirements established by the appropriate state Insurance Services Office should be satisfied where fire protection is provided.
e. The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to the average daily consumption. This requirement may be reduced when the source and treatment facilities have sufficient capacity with standby power to supplement peak demands of the system.
f. Excessive storage capacity should be avoided to prevent potential water quality deterioration problems."

Although the regulatory standards must be met and considered in any evaluation, it is also important to closely examine the various components that make up the total storage capacity. This is referred to as functional design. This concept will be utilized when evaluating the storage tanks in the system, through the use of the extended period simulation (EPS) capability of the hydraulic model.

The criteria to size and locate water storage tanks are outlined in the various aforementioned standards and most notably the AWWA Manuals. The standards provide general guides for tank sizing however each water system is unique and there is not a definitive "formula" that can be used to define the size requirements of a particular water storage tank however there are general sizing criteria that are defined in the standards that can be utilized. These AWWA standards are to be used in engineering analysis and determination of final sizing and location. For example, the final tank size will necessarily be a function of various factors including but not limited to: volume of equalization storage, fire flow requirements, emergency storage, type of predominant use (i.e. residential or industrial), total number of storage tanks in the water system, historic fill and draw cycle of the existing tank, hydraulics of the system, etc.

In addition and where practical, it is considered good practice to have multiple storage tanks in the distribution system as this provides redundancy where one storage tank could be removed from service for routine inspection and maintenance as may be periodically required.

Each water storage tank in the water system has a dedicated volume of water for defined use that are identified as "equalization", "fire reserve" and "emergency" storage. As previously indicated each of these components can and will vary from tank to tank and water system to water system. Sound engineering judgment along with standards and recommendations from the AWWA and other relevant standards are utilized in determining proper allowances for each particular storage component. The three (3) volume components are further described and determined as follows:

Equalization (Peaking) Storage: Equalization storage is required to meet water system demands that are in excess of delivery (pumping) capability. The pumping and piping systems are typically designed to carry maximum day demands and equalization storage is sized to meet demands in excess of the maximum day demand up to peak hour demand. General sizing criteria in design standards dictate that equalization storage generally make up one half the total storage required and about 20 – 25 percent of the average day demand (Reference: AWWA Manual M32 *Distribution Network Analysis for Water Utilities*).

A more conservative standard for tanks with "smaller" service territories that can experience greater fluctuations in demand is to supply equalization storage equal to 25 – 50 percent of the maximum day demand. This has also been interpreted for larger systems as requiring 25 percent of the maximum day storage as equalization storage. The assessment must consider each of the tanks, as they are located in the various pressure zones. For example, it may be required that a greater relative volume of equalization storage be provided for the Reduced High Service Pressure zone than for the Low Service Pressure zone. This would be attributed to the smaller service area and the tendency to experience greater fluctuations in demand.

The final assessment of the required equalization storage would be evaluated and verified by use of the extended period simulation (EPS) function of the hydraulic model. This will allow an examination of the fill and draw rates for the various storage facilities and provide determination as to which tank(s) are most critical in meeting peak demand periods.

Fire Protection Storage: The volume of fire protection storage is determined by the desired rate and duration of fire demand requirements. This will vary from tank to tank depending upon its location in the distribution system. In the case of the predominately rural areas, fire flow requirements may be in the range of 1,000 to 2,000 gpm, which would be available for a two-hour duration and available at an elevation in the tank such that a minimum residual pressure of 20 psi is maintained for the entire duration. Tanks located in commercial or industrial areas could have fire flows up to 3,500 gpm or greater. Larger fire flows must be available for a longer duration (i.e. three to four hours), which increases this volume component.

For purposes of evaluating fire flow requirements for the distribution system, Insurance Services Office (ISO) studies, as available, will be consulted. Additional information as may also be available from local fire and building officials will also be considered. Ultimately, the available fire flow volume in existing tanks will be a function of the ability to provide a 20 psi residual.

Emergency Storage: Emergency storage provides water during emergency situations, such as pipeline failures, primary transmission main failures, equipment failures, water supply contamination, natural disasters, etc. at a minimum pressure of 20 psi. The amount of emergency storage included within a particular water distribution system is an owner option based on an assessment of risk and the desired degree of system dependability. There is no formula to compute the volume of emergency storage and ultimately it will be based upon the perceived vulnerability of the water system. Generally, the more available sources of supply and emergency power will reduce the amount of emergency storage required. Systems with a single source of supply and/or no emergency power provisions would require a relatively large volume of emergency storage. The volume of emergency storage must be balanced with the need to cycle storage for maintaining water quality.

In this assessment it will be critical to work with Authority personnel to develop an understanding as to the desired volumes of water that would be available in the event of an emergency. It should also be noted that large volumes of emergency storage while providing a degree of reliability could often lead to water quality problems, as large volumes of water remain stagnant if the tank is not effectively turned over. It is recommended that emergency storage be reduced where practical and in instances where pressure gradients are supplied by multiple sources or by supply sources that contain emergency power provisions.

2.3 Combined Storage Assessment and Determination

The required volume of effective storage for a storage tank(s) would then be the combination of the total storage required for fire and emergency storage as well as the portion of equalization storage below the operational storage zone, as previously detailed. Equalization storage must also be considered in the evaluation of the storage components. It should be noted however that the equalization storage at any given time (especially during a maximum day demand) will vary in the tank and may not be totally available as it is being consumed by the system demand. Once the peak demand subsides, the tank (the equalization portion) is refilled to its overflow elevation hence the turnover cycle. It will be critical to examine the volumes and drain / fill rates that occur in a particular tank during these differing demand conditions.

An evaluation will be performed for the existing tank facilities for the entire system for each distinct pressure zone with current demand scenarios. This will include determining and identifying the various storage components for each of the Authority's storage facilities. Areas of deficient storage, tanks that do not effectively cycle or are undersized, tanks that are problematic due to location in the system, etc. will be identified. Possible solutions to identified problems will be provided. Ultimately it will be necessary to work with Authority personnel to provide a prioritized plan in addressing any identified problems.

For purposes of assessing the existing tank systems the following criteria from the aforementioned standards will be utilized. This will be performed individually for each tank as well as collectively for all the tanks in a particular pressure gradient and will be presented in table form by each pressure gradient.

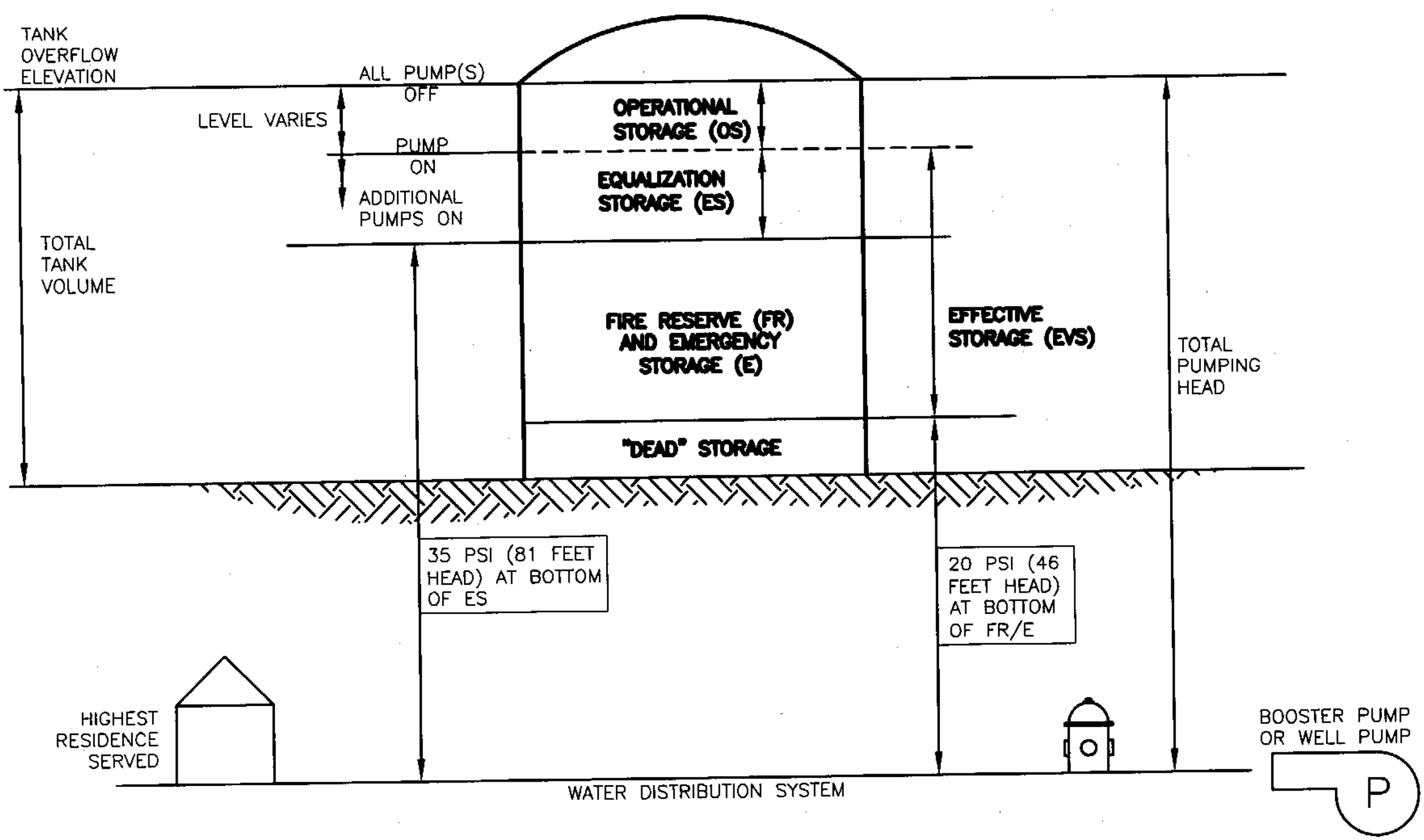
- Determine the volume of effective storage or that volume which provides a minimum pressure of 20 psi in the distribution system. It should be noted that there might exist small isolated areas in particular pressure zones that do not meet the 20 psi criteria. These must be examined on a case-by-case basis.
- Determine the volume of equalization storage or that volume above the minimum required 35 psi in the distribution system up to the tank overflow elevation. Again, it should be noted that there may exist small isolated areas in particular zones that do not meet the 35 psi criteria. These must be examined on a case-by-case basis. The measure by which the adequacy of total equalization storage will be premised is upon achieving 25% of the system average day demand, at a minimum. It is noted that a more conservative requirement would be to achieve 25 percent of the maximum day demand as equalization storage. The evaluation will provide determination as to what each of the tanks individually and collectively provide in each pressure zone.
- The final method of determining a reliable and reasonable equalization storage volume will be through use of the hydraulic model including examining the system under an extended period simulation which will employ the various diurnal flow curves of the pressure gradients. Other factors to consider are the number of supply sources in a particular zone as well as emergency

power. This will ultimately determine the maximum equalization storage required for each pressure zone.

- Determine the available portion of the tanks that is available for fire flow and emergency purposes.
- Determine the fire flow requirements for each community (ISO studies, etc.) in the various pressure zones. Compare this to the available fire flow that is provided by each tank. This fire flow volume will be that above which a minimum of 20 psi residual pressure can be maintained up to the bottom of the equalization storage. Fire flow requirements may vary significantly from Town to Town (City to City) and the specifics with regard to fire protection will need to be further evaluated in subsequent tasks.
- Provide a diagram of each tank with each of the various storage components identified along with a total of each storage component by pressure zone. This will be compared to the recommended storage volumes per the standards and deficiencies / surplus will be identified.
- An evaluation will be performed utilizing historical tank charts of the seasonal daily turnover in each of the Authority's storage tanks. It is recommended that each tank fluctuate throughout its operational storage portion of its equalization zone at minimum once or twice daily.

The projected growth for the twenty-year planning period will then be allocated to the distribution system demand database and the existing tanks will again be assessed. As required, recommendations for new storage facilities will be provided. Detail with regard to potential location, size, type of tank (i.e. reservoir or elevated), etc. shall also be provided.

FIGURE 1



TYPICAL WATER STORAGE FACILITY– WATER STORAGE COMPONENTS

N.T.S.

Civil & Environmental Engineering Partners, Inc.
342 Park Avenue, Woonsocket, RI 02895