Water Storage Systems
## Water Storage Module Objectives

- Identify the basic Principles of Well Pump Operation
- Identify the Types of Water Storage Facilities
- Identify Water Storage Inspection Techniques
- Identify the Requirements for Storage Startup
- Operate and Maintain a Water Storage Tank
- Identify Proper Corrosion Protection
- Sample Storage Facilities
- Disinfect a Storage Tank
- Understand Proper Storage Tank Maintenance Procedures
Brief Review of Well Systems for Water Distribution System Operators
Types and Uses of Well Pumps

**Turbine Pumps**
Most Commonly Used
- Single Stage < 28’
- Multi-Stage 50 – 300’

**Submersible**
moderate head & flow
(smaller water systems)

**Vertical Turbine**
high head and high flow
(larger water systems)

**Positive Displacement**
- Shallow ~ 25’
- Deep ~ 600’
- Limited to ~25 GPM

**Jet Pumps**
- Shallow ~ 20’
- Deep 50 - 200’
- Generally limited to small capacities < 50 GPM
Turbine Well Pumps

Vertical Turbine

Submersible

Turbine Booster
Component Parts and Operation of a Well

- Well Pad
- Well Casing
- Grouting and Sealing of Casing
- Well Casing Vent and Sounding Tube
- Well Head Covers or Seals
- Well Column
- Well Screen
- Air Vacuum Breaker
- Check Valve
- Sampling Valve
- Static Level
- Pumping Level
- Drawdown

The difference between the static water level and the pumping water level in a well is known as the drawdown.
Jet Pumps

- Jet pumps utilize a suction pipe submerged in the water source to feed water to the pump, which, along with the motor, is located above the water source in a dry location within the pumphouse.
- Foot valves are a type of check valve.
- A foot valve located on the suction pipe keeps the pump primed with water when not in use.
DEP Well Site Protection and Security Requirements

- Area around well must be fenced, clean, and free of debris
- No hazardous materials can be stored on-site
- Minimum Setbacks from a sanitary hazard such as a sanitary sewer or residential septic tank must be at least 100’ (sewage flow ≤2000 gpd)
- Unauthorized entry, sabotage, or suspicious incident shall be reported to the State Warning Point immediately (within 2 hours) of discovery.
- Shall be reported to DEP in the MOR.
Water System
Well Capacity Requirements

- Total well capacity connected to a water system using only ground water shall equal at least the system’s design maximum water demand (including design fire-flow if fire protection is provided)

- CWS serving or design to serve 350 persons or 150 connections the total well capacity with the largest well of operation shall equal at least the design average daily water demand and preferably the design maximum-day water demand

- A minimum of two wells must be provided.
Water System Auxiliary Power Requirements

- Community systems with 350 or more people, or 150 or more connections shall provide auxiliary power for the operation of the source and treatment at a rate at least equal to the average daily demand.

- Auxiliary power shall be equipped with automatic startup unless 24 hr., 7 days per week supervision is provided.

- Auxiliary power shall be operated at least once per month.

- Requires an audio-visual alarm system.
Distribution System Capacity Summary

- All Wells can be used to supply peak demand (occurs on highest demand day of the year)
- Wells must meet average demand with largest out of service
- Typically this assurance will require an engineering hydraulic network analysis
- The water system must provide 20 psi minimum pressure under all conditions
- In Small Water Systems pressure is supplied by wells connected to a hydro-tank
- In larger Water Systems Distribution Storage is often necessary
Water Storage for Water System Operators
Water Storage Tank Types, Applications and Operational Controls

- **Gravity or Elevated Tanks** are located near center of demand with the maximum tank level controlled by an altitude valve.

- **Ground Storage Tanks** are often located near point of water production and level controlled by level sensor to a pump.

- **Hydropneumatic Tanks** are supplied at smaller water systems and controlled by pressure sensors.
Water Storage Tanks

- **Ground Storage**: Very high volumes of water at low head.
- **Elevated Storage**: Moderate Volumes at High head.
- **Hydropneumatic**: Low volumes of water at high head.
Purpose of Water Storage

- Storage is provided to meet the peak demand placed on a water system
- Moderate or equalize the changes in Water Demands that occurs in a Water System
- Storage tanks also provide surge protection to water distribution systems
- Provide minimum pressures to fight fires

In selecting and evaluating a tank, storage capacity must be matched to the ___________ of the system? [Peak Demand]
Which of the following is not an advantage of an elevated tank?

a. High service pumps are used to equalize water pressure in the distribution system
b. Eliminates the need for continuous pumping
c. Provides water for fire flow
d. Provides water to meet average and peak demands
Diurnal Flow Pattern

Diurnal Flow Pattern

**Plant Flow**

- **Flow Rate (MGD)**
  - Equalized Storage
  - Peak
  - System Demand at any time of day
  - Ave Demand

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>12M</th>
<th>6 AM</th>
<th>1 PM</th>
<th>4PM</th>
<th>7 PM</th>
<th>12M</th>
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<tr>
<td>Flow Rate</td>
<td></td>
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Schematic Illustrating the Benefits of a Storage Tank
Conventional Hydropneumatic Tank

- Air compressor replenishes air to prevent “waterlogged” condition
- Well pump provides water pressure normally at 40 cut-in and 60 cut-out psi
Hydropneumatic Tank (cont.)

A hydropneumatic tank serves three main functions:

- Delivers water within a selected pressure range.
- Prevents a pump from starting up every time there is a minor call for water.
- Minimizes pressure surges (water hammer).

If a pressure tank becomes waterlogged (tank filled with water), the motor cycles on and off too frequently (more than six times an hour). This leads to:

- Higher energy costs.
- Inefficiency.
- Equipment failure.
Benefits of Elevated Tanks

- Provides water to meet peak demands.
- Stabilizes distribution system pressures.
- Keeps pumps from cycling and operating in efficient ranges.
Standpipe

Used for Surge protection in water systems

Some are fitted with pumps to allow water to be used for fire protection
Elevated Tank and Standpipe Comparison

- Atmospheric pressure is the weight of air above a 1 square inch area. It is equal to 14.7 psi.
- Water also exerts a pressure. Used to provide pressure head to the distribution system.
- Large storage capacity
- Shallow tanks with large diameter are preferred over deep one with small diameters.

Pressure = Water Elevation (ft) * Water Density (lb/ft³) * (1 ft²/144 in²)

Where:
Water Density = 62.4 lb/ft³
How to Use Head Pressure to Calculate Tank Height

This calculation can be used to compute the height of water in a tower without climbing it.

- Water head pressure is static pressure caused by the weight of water solely due to its height above the measuring point.
- The pressure at the bottom of a 40-foot lake or a 40-foot high thin tube would be identical, since only height is involved.

Density of Water $= \frac{62.4 \text{ lb}}{\text{ft}^3} \times \frac{1 \text{ ft}^2}{144 \text{ in}^2} = 0.433 \text{ lb} \text{ ft}^3$ or $0.433 \text{ psi} \text{ ft}^3$

Therefore:
- 1 ft of water = 0.433 psi
- 2.31 ft of water = 1 psi

Given a pressure of 17.3 psi what is the water elevation?

Water Elevation (ft) $= \frac{2.31 \text{ ft}}{\text{psi}} \times \frac{17.3 \text{ psi}}{\text{psi}} = 40 \text{ ft}$
Summary of the Advantages Offered by Elevated Tanks

1. Less variation in pressure
2. Available water for fire fighting
3. Storage to meet peak demands
4. Allows use of lower capacity wells
5. Cycling of well pumps is reduced
6. Wells can be better matched to average water demand
7. High service pumps and the treatment plant can operate more efficiently
Troubleshooting Water Quality Problems in Elevated Storage Tanks
Tastes and Odors

- Probable Cause – high/low chlorine residual or bacterial growth
  - Low velocity or stagnant water allows suspended matter to settle and eat up Cl residual, allowing bacteria to grow
  - Bacteria convert inorganic and organic substances found in the water to more bacteria

- Likely Solution – flush tank and lower/raise CL dose
Turbidity

- Turbidity – the cloudy appearance of water caused by the presence of suspended and colloidal matter

- Probable Cause – colloidal matter, calcium carbonate or precipitated iron/sulfide
  - Pipeline repairs
  - Treatment plant upset (filter breakthrough)
  - Water tank problems

- Likely Solution – flush tank, flush mains or adjust treatment
Color

Probable Cause
– Vegetative decay or bacteria

- Dissolved Organic material entering the system
- Inadequate treatment

Likely Solution – flush tank, flush mains or adjust treatment
Coliform

Probable Cause – contaminated water distribution system

- Contaminants in the distribution system
- Faulty seals
- Leakage points
- Unprotected vents
- Backsiphonage

Likely Solution – backflow prevention, raise Cl dose and flushing
# Troubleshooting Water Quality Problems in Elevated Storage Tanks

<table>
<thead>
<tr>
<th>Problem</th>
<th>Probable Cause</th>
<th>Likely Solution</th>
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</thead>
<tbody>
<tr>
<td>Tastes and Odors</td>
<td>- High/Low Cl residual</td>
<td>- Lower/Raise Cl Dose</td>
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<tr>
<td></td>
<td>- Algal or Bacterial Growth</td>
<td>- Flush Tank</td>
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<tr>
<td>Turbidity</td>
<td>- Colloidal Matter</td>
<td>- Flush Mains</td>
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<tr>
<td></td>
<td>- Calcium Carbonate</td>
<td>- Adjust Treatment</td>
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<tr>
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<td>- Precipitated Iron/Sulfide</td>
<td>- Flush Tank</td>
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<tr>
<td>Color</td>
<td>- Vegetative Decay Bacteria</td>
<td>- Increase Cl dose</td>
</tr>
<tr>
<td>Coliform</td>
<td>- Contaminated WD System</td>
<td>- BFP, raise Cl dose, &amp; Flushing</td>
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</table>
Maintenance Considerations for Elevated Water Storage Tanks

- Check for intrusion of Water
- Secure tank site from unauthorized access
- Clean Tank yearly recommended (DEP 5-yr. required by P.E.!) to prevent bacterial growth and nitrification
- Ensure that overflow structures are working, secure and properly drained
- Inspect Structures for Stability, Blockages and Surface and Internal Corrosion.
Factors Effecting DBP Formation ~ Tank Turnover & Sediments

Finished Water Storage Tank
Sediments & Cleaning

✓ Sludge in a ground storage tank
Ground Storage

- Used for storing large amounts of water.
- New Tanks must be Covered!
- Not under pressure uses transfer pumps to pressurize or pump to elevated tank.
- Aerators are often used for source waters to remove hydrogen sulfide prior to chlorination.
# Troubleshooting Ground Storage Tank Problems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Likely Cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tastes &amp; Odors</td>
<td>- Low/High Chlorine</td>
<td>- Raise/Lower CL</td>
</tr>
<tr>
<td></td>
<td>- Biological Growth</td>
<td>- Increase Chlorine</td>
</tr>
<tr>
<td></td>
<td>- Sedimentation</td>
<td>- Flush</td>
</tr>
<tr>
<td></td>
<td>- Suspended Material</td>
<td>- Flush/Adjust treat.</td>
</tr>
<tr>
<td>Turbidity</td>
<td>- Calcium Carbonate</td>
<td>- Adjust Treatment</td>
</tr>
<tr>
<td></td>
<td>- Precipitant Iron</td>
<td>- Adjust Treatment</td>
</tr>
<tr>
<td></td>
<td>- Microorganisms</td>
<td>- Increase Chlorine</td>
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<tr>
<td></td>
<td>- Floc Carryover</td>
<td>- Adjust Treatment</td>
</tr>
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<td>- Air entrainment</td>
<td>- False turbidity</td>
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<tr>
<td>Color</td>
<td>- Vegetative Decay</td>
<td>- Increase Chlorine</td>
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<tr>
<td>Bacteria/colliform</td>
<td>- Cross Connection</td>
<td>- Eliminate</td>
</tr>
<tr>
<td></td>
<td>- Broken Main</td>
<td>- Flush and Disinfect</td>
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Factors for Microbial Colonization in Storage Tanks and Pipelines

- Source of Nutrients (found in sediments in dead-end lines, fire hydrants and water storage reservoirs)
- Protective Habitat (sediments and tuberculation)
- Favorable Water Temperature (warm temperature)
- Lack of Proper Disinfection Levels
Nitrification Cycle in a Water Storage Tank

1. Sediment and Deposits

2. High Temperature

3. Long Detention Time

4. Low Chloramine Residual

5. High Nitrite Levels (5 : 1 Ratio)

6. High Bacterial Counts (HPC> 500/ml)

7. Coliform Regrowth
Exterior Water Tank Inspection

- Check foundations for cracking, spalling (flaking), exposed reinforcing metal or settling
- Keep vegetation away from foundations
- Trim limbs that may scratch surfaces
- Look for rust stains that may indicate leaks
- Inspect vent and overflow screens for holes or debris
- Check for signs of overflow
- Check for signs of unauthorized entry
- Look for loose bolts/nuts
- Check for paint flaking
- Look for rotation of columns or tower
Interior Water Tank Inspection

1. Interior roof condition
2. Corrosion
3. Leaks
4. Silt depth
5. Cathodic protection system
Interior Tank Inspection
Methods Employed

**Dry Inspection**
- The tank must be taken out of service
- The interior of the tank can (and should) be cleaned
- A lot of water is wasted
- The method has the greatest potential for tank worker injury
- It is the most expensive method
- Once drained, the tank must be disinfected before returning it to service

**Wet Inspection**
- The tank must be taken out of service
- There is no opportunity to clean the tank
- There is no wasted water
- There is less potential for personal injury to tank workers
- It is not as thorough method of inspection as dry method
- It is less expensive than dry method
- There are some sanitary concerns or
- Remotely Operated Vehicle.
AWWA Approved Methods for Disinfecting a Water Storage Tank

**Method 1**
- Fill tank with potable water that has been treated to provide a Chlorine residual of at least 10 mg/l after a contact time of:
  - For bleach and Tablets: 24 hours
  - For Gas: not less than 6 hours

**Method 2**
- Spray or brush interior with 200 mg/l chlorine and let sit 30 min.
- California State Univ. also requires - Fill tank with potable water that has been treated to provide a Chlorine residual of 3 mg/l. Let stand for 3 to 6 hours.

**Method 3**
- Add enough chlorine to produce 50 mg/l of available chlorine with tank ~ 5% full. Let stand for not less than 6 hours.
- Fill tank and allow to sit for not less than 24 hours.

Note: all methods must pass bacteriological tests and chlorine residual must be reduced to acceptable limits.

Which of the following is not an acceptable cleaning method? Be able to recognize these and discard a distractor.
DEP Requirements for Placing New or Existing Tank in Service

- Total Cl Residual must be conducted per DEP SOP 001/01
- Must be conducted by a certified lab
- Sampling Procedure
  - Reduce Total Chlorine Residual to < 4mg/l
  - 2 samples, separate days, 6 hours apart
  - Analyze sample for Total Res. CL & TC
  - If > 4 mg/l Total Res. CL or TC+, repeat
- For new construction, must notify appropriate DEP/ACHD office; for existing tanks report on next MOR
- If activities may lead to TC+, issue PBWN
The Eight Requirements of the Sanitary Survey per GWR

1. Source water
2. Treatment
3. Distribution system
4. Finished water storage
5. Pumps, pump facilities, and controls
6. Monitoring, reporting, and data verification
7. System management and operation
8. Operator compliance with State requirements
Finished Water Storage System Evaluation

EPA Priority Criteria that Affects Public Health

- Capacity of Storage Tanks
- Design of Storage Tanks
- Cleaning and Maintenance of Storage Tanks
- Site Security
Finished Water Storage Evaluation

Significant Deficiencies: inadequate internal cleaning, maintenance, improper screening of overflow pipes, drains and vents, failure to make necessary repairs to structure.

- Review Finished Water Storage Components
- Review Storage Operational Records
- Review Integrity of Storage Structure(s)
- Review potential sanitary risks
- Ensure that maintenance checks have been made
DEP Water Storage Deficiency Index

- Types of Storage including improper use of Hydropneumatic Tank for Fire Storage
- Location and Inadequate Capacity of Storage
- Improper Design of Vents and Overflow
- Corrosion resulting from paint deterioration
- Cleaning, Inspection and Maintenance
- Site Security
Review Finished Water Storage Components

- Roof Sloped to prevent standing water
- No leaks in roof
- Lockable access hatch with raised curbs
- Vent on roof facing downward with screen
- Water measurement device
- Overflow at ground with flapper
- Piping that ensures circulation of water
- Drain to remove accumulated sediment
- Access ladder
- Inlet/outlet isolation valves
- Control and monitoring water level system
- Low and high water alarms
Inspection of Hydropneumatic Tank Components

- Tank is located above ground
- Tank meets ASME standards with nameplate attached
- Access port for periodic inspection
- Pressure relief device with pressure gauge
- Control system for proper air/water ratio
- Site glass to determine water level
- Slow closing valves and time delay pump to prevent water hammer
Review of Finished Storage Operational Records

- Ensure periodic flushing of tank
- Perform periodic sanitary checks
- Ensure that tank is protected from corrosion
- Performance of storage tank Cl residual monitoring
- Ensure adequate storage disinfection provided
- Ensure that water is circulating and turnover is adequate
- Ensure that operating personnel are trained
Integrity Review of Water Storage Structures

- Check for Intrusion of Water
- Ensure that overflow structures are working, secure and properly drained
- Inspect Structures for Stability, Blockages and Surface and Internal Corrosion.
Sanitary Hazards Review of Water Storage Structures

1. Ensure that tank drain is plugged with flapper valve at outlet end
2. Ensure that vents are screened and that birds are not entering tank
3. Ensure that areas around access are secure from water intrusion
4. Ensure that hatches are secure and locked
Maintenance Checks for Finished Water Storage

- Does the tank appear structurally sound?
- Is inspection and cleaning performed at minimum every 5 years?
- Is inspection performed by qualified PE?
- Is the paint coating inside and outside in good condition?
- Is the tank properly disinfected after maintenance is performed?
Storage Tank Security

- Is tank properly fenced and gated with lock?
- Is there evidence of intrusion under fence?
- Does the system make periodic security checks?
Pumps, Facilities and Controls
Evaluation
EPA Priority Criteria that Affects Public Health

- Capacity of Pumps
- Condition of Pumps
- Pump Location
- Pump Security
Pumps, Facilities and Controls Evaluation

**Significant Deficiencies:** inadequate pump capacity, inadequate maintenance, and inadequate or inoperable control system.

- Ensure proper application of pumps and that they are in working order
- Ensure that pumps are in reliable condition from maintenance records and/or pumping records
- Ensure that monitoring and controls are properly functioning
Proper Application and Condition of Pumps

- What is average and peak system demand and are the well pumps and high service pump capacities able to meet the anticipated demand conditions per state requirements?
- Is information recorded for manufacturer, model, and serial number of pumps?
- Are all pumps operational?
- Is there excessive noise or vibration?
- Is there a preventative maintenance program in place?