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Provided Outline

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Introduction	750
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Maintenance	1250
Environmental Concerns	1000
General Regulations, Overview	1250
Troubleshooting	1000
Safety	1250
Conclusion	750
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INSTRUCTOR INTRODUCTION:

WELCOME

Welcome to the At Your Own Pace (AYOP) 2-hour course for water industry professionals on Water Pipelines. My name is ________________. I will be your instructor for the online lesson. My background is in ____.
I am licensed/certified by the state of ______________ in _____________________________.

Since you are attending this class, it is safe to assume you plan to or already work in the water industry. Most of you either want to become or already are water specialists, operators, or engineers. We may also be a few hydrologists, water quality analysts, water resource managers, or environmental engineers in attendance.

These positions typically work for government water departments, utilities, or private water companies. If my assumptions are correct, working with water systems and pipelines will be or already is part of your daily duties. Therefore, you already recognize it is essential for you to have a solid understanding and good working knowledge of water pipelines.

My goals for today's class are:

1. Introducing you to water pipelines
2. Instruct you on the areas of highest importance
3. Provide the criteria that are key for making good decisions
4. Share common water pipeline problems you can expect to occur
5. Instruct you on effective ways to troubleshoot problems and effective resolution methods

By the end of this class, you will have more confidence in your knowledge, understanding, and abilities in planning, operating, and managing water pipelines. You will also know where to focus and what to have successful outcomes. Let's get started…

Water Pipelines

I. Introduction

The total number of water pipelines in the United States (U.S.) infrastructure must be in the hundreds of thousands. While the actual total number is not published, data that is indicates there are roughly 152,000 public drinking water systems in the U.S., according to America's Ciber Defense Agency. The Environmental Protection Agency (EPA) reports there are 2.2 million miles of water pipes currently in use and they are located in all 50 states. These water pipelines transport approximately 39 billion gallons of water per day.

Nearly all of these water pipelines are owned by a state or local governments. They are used by water suppliers as transporters for potable (drinking) and non-potable from water storage vessels (i.e. water storage tanks) or holding reservoirs to customers. Potable (drinking) water is distributed to residential, commercial, institutional, and public buildings for consumption and domestic use like cooking. Non-potable water goes to mostly businesses in several industries for a variety of applications. Examples are crop irrigation, hydro power generation, chemical production, product manufacturing, and cooling towers.

The entities that are water suppliers are mostly utilities, and a small number of private water companies. For each of these, the main goals include some basics:

1. **Capacity** – An adequate amount of capacity in water pipelines to meet demand.
2. **24/7 Operation –** Maintain water pipelines in operation 24/7 despite risks and threats.
3. **Reliability –** Provide water service that is reliable 24/7, 365 days a year.
4. **Water Quality** – Maintaining water quality within regulatory requirements.

Other areas of focus include efficiency, performance optimization, costs control, sustainability, leak and damage prevention, and maintaining infrastructure integrity.

Achieving these basic goals and improving in other areas will require careful development and execution of strategies and plans. When decisions are made, they should aways be based on criteria that include factors (i.e., pressure) known to directly affect operations and outcomes. Plus, consider known areas of high importance, common problems, proven methods, techniques and technology that have are effective.

A. Key Considerations

1. **Intended Use: Potable or Non-Potable**

   When the intended or actual use of a water pipeline is decided it must be based on water quality requirements and FDA approved use (potable or non-potable water). For a water pipeline to be a transporter of potable water it must be approved for potable water use. A water pipeline approved for non-potable water use cannot be used for moving potable water unless the FDA required actions like cleaning and sanitation are completed and the pipeline has been approved for potable water use. A pipeline can only be approved and used for potable or non-potable water, not both at the same time.

2. **Risks**

   There are risks that can threaten the operation of water pipelines. Examples are high pressure, power outages, natural disasters, emergencies, pipe damage, and contamination. Preventive actions are essential for mitigating and managing risks to avoid interruptions in operations and service. Examples are factors that could potentially cause leaks, corrosion, and damage, and unauthored access.

2. **Route**

   When planning the route of a water pipeline, any obstacles (i.e., electric utility wires) or terrain changes (i.e., elevation) need to be considered. For example, a rise in elevation can change the pull of gravity and affect water's ability to flow.

3. **Design**

   The design of a water pipeline and materials selected can help or hinder its performance. For example, if pipes are too small their capacity for moving water may be too low for meeting demand. Pipes that are too large can increase energy use due to needing extra force to pump water through a pipeline.

4. **Security**

   Security for the entire pipeline must address not only the physical pipeline, but the systems like IT networks used to operate and manage it as well to avoid problems like cybersecurity attacks.

5. **Safety**

For the safety of water supply workers and the public who use distributed water, pipelines must comply with OSHA's Pipeline and Hazardous Materials Safety Administration (PHMSA) Rules. The actual water transported through a water pipeline must also follow the EPA's National Primary Drinking Water Regulations (NPDWRs) drinking water quality water standards which ensure it is safe to drink and use.

6. **Interior Pipe Environment**

   The inside environment of water pipes is affected by pressure and temperature levels. For water to flow efficiently and at an optimum flow rate these and other variables must be monitored and controlled. They directly affect a water pipeline's level of performance. A water pipelines performance should be tested regularly, logged, and compared over time to identify changes.

II. Preparation

As with all construction projects, project plans are critical to achieving success. They provide a roadmap for execution, facilitate progress tracking to stay on time, and help with managing expenses for a total final cost within budget. They also establish quality standards to make sure government and national regulations, standards, and codes are met. Construction plans also have actions to mitigate risk, outline the scope, and establish schedules to keep companies, suppliers, contractors, subcontractors, and consultants all in sink and on the same page.

Accuracy of project plans is critical for a water pipeline to fulfill its purpose. It ensures the pipeline is built as designed, meets high priority needs, and is following all national, state, and local requirements from government agencies and trade associations. Therefore, an additional preparation step should be added to the process for water pipeline construction projects.

The purpose of this step is to improve accuracy and decisions for better outcomes. This is accomplished by reviewing plans, assessing areas of consideration, and changing them if necessary. Plus, once again looking at the options available (i.e., type of pipe) and making needed changes to achieve goals like preventing corrosion. This extra step is where mistakes are often found and corrected. It is also the time when some decisions are changed to improve outcomes.

A. Plans, Selections & Decisions Review

1. Project Plan Review

The overall water pipeline construction plan is reviewed. Potential outcomes are estimated or projected using the current plans and decisions. The information is compared with the project's overall goals, stakeholder expectations, and what is needed or required. If any parts of the plan do not align, adjustments must be made to achieve the outcome desired.

2. Permits Secured

Construction projects, including water pipelines, require active permits in specialty areas like plumbing and electrical. Applications must be submitted to local government offices and related fees paid. Permits must be issued before any work begins.

3. Route Review

The planned water pipeline route needs to be evaluated one more time with precise mapping. This technique identifies any potential issue along the route that will require plan adjustments. Examples of areas where there may be issues are current infrastructure, electrical lines, gas pipelines, and sewage systems. Mapping also ensures the pipeline will be installed at the correct depth. It is especially important in locations with cold climates where the is the potential for the freezing of pipes.

4. Site & Soil Review

The physical location of where the water pipeline with be constructed and installed should be reviewed, evaluated, and revised if necessary. This includes completing soil testing to evaluate its feasibility and stability. If the soil is unstable or prone to erosion, techniques should be used such as soil compaction or reinforcement to prevent the pipeline from shifting or being damaged over time.

5. Alignment & Elevation Review

Measurements of water pipe alignment must be taken, and correct alignment must be confirmed. Pipes must be placed at the correct elevation to help rather than hinder water flow and pressure.

6. **Environmental Review**

The installation route should be visually inspected thoroughly from start to finish for anything that could potentially compromise the environment and properly. This action reduces the risk of possible damage during installation to natural resources and ecosystems. Barriers should also be placed around work areas to stop any materials from traveling outside the area. Plus, erosion control protection should be placed in areas of concern.

As part of the project plan, there should also be plans for environmental mitigation and restoration. The content should provide workers with protocols and actions to take if an accident occurs that could affect the environment.

7. **Safety Review**

Plans to ensure the safety of workers and the general public need to be reviewed, and revisions are made if necessary. Actions include checking worksites for hazardous substances or materials and removing them as designated in protocols. Looking for any man-made or natural obstacles and uneven surfaces that could potentially cause accidents during installation and construction.

Safety barriers are necessary and should be placed in areas where work is done. They prevent anything unsafe or hazardous from exiting outside the work area and causing contamination. The barriers should also prevent accidental damage from external forces or human activity.

The project plan should include a Safety Plan or section that provides safety procedures, equipment handling protocols, and personal protective equipment (PPE) requirements.

8. **Equipment Access Review**

The area of land where installation and construction will be done along with its surface is prepared. Roads for easy access and movement of large machinery and equipment are made. Any areas with difficult terrain or narrow spaces are taken care of so they are safe for workers.

9. **Materials Procurement, Handling & Storage Setup & Review**

To make sure installers have what they need to do their job from day one, the material should be ordered ahead of time. While waiting for arrival, establish a secure storage area that is close to where the work is done. Have manufacturers or distributors deliver the orders at least a week before work begins and place them in the storage area. This will create a one-week window to check the products and confirm that they meet the required quality standards.

10. **Trench Schematics & Markings Setup & Review**

The trench schematics diagrams or drawings need to be reviewed. This should include checking measurements like trench depth, width, and length to confirm the space excavated will be adequate. The trench must be wider than the pipe diameter. There also should be enough space for proper installation and maintenance. Plus, the trench should be deep and large enough to add enough backfilling for the pipe to be properly supported and protected from damage or cold temperatures.

The trench line needs to be clearly marked with flags or stakes before any digging begins. Where utility lines are located should also be rechecked to confirm none are in the area where trenches will be dug and installation done. Notifications also should be sent to local utilities and nearby property owners of when and where work is planned.

11. **Emergency Response Plan (ERP) Review**

The project plan should also include an Emergency Response Plan or section. The ERP should establish emergency protocols in case of accidents, spills, or other emergencies during construction.

III. Joining

There are several techniques used for joining pipes in water pipelines. Which method is used depends on the pipe material, manufacturers' recommendations or requirements, application, and level of water pressure. Below are established methods currently in use.

A. Methods

1. Butt Weld

Pipe Material: steel, plastic (HDPE)

This technique is used in large-scale pipelines for water distribution, wastewater, and industrial systems. Plus, for underground water supply networks and sewage systems. Making butt-welded connections requires a butt-welding machine, an alignment tool, and a heating element. The technique involves welding two pipes with heat, which melts the ends and fuses them into one solid piece. This creates a leak-proof, strong, and permanent connection.

2. **Flanged Joint**

   Pipe Material: steel, ductile iron

   This method is used for high-pressure water pipelines. It is ideal for large-diameter pipelines or systems requiring regular disassembly for maintenance. To make a joint, flanges (metal disks with holes) are welding or threading flanges onto the ends of pipes. The approach creates pipe joints that are reliable in high-pressure water pipelines.

3. **Mechanical Coupling**

   Pipe Material: steel, ductile iron, PVC

   Mechanical couplings are frequently used to quickly make connections or repairs in water pipelines that feed industrial water systems. A mechanical coupling is a sleeve that is placed over pipe ends and tightened with bolts or screws. These connections are easy to make since no welding or gluing is needed.

4. **Socket Weld**

   Pipe Material: steel

   Socket welding requires welding equipment along with the necessary training and skills. It is often used for small- to medium-sized steel water pipelines and industrial systems that carry high-pressure water. Pipes are joined by inserting one pipe end into a socket or fitting and then welding them together to form a strong bond.

5. **Gluing or Solvent Cement**

   Pipe Material: PVC, CPVC, ABS

   This method requires a bonding agent (glue, solvent or PVC cement), pipe cutter, and primer. It is used for joining pipes in residential and commercial pipelines. A joint is made by softening pipe ends with a solvent or heat and fusing them together. This method is not suitable for high-pressure systems or outdoor use in extreme temperatures.

6. **Fusion Weld**

   Pipe Material: HDPE

Fusion welding is widely used in large-scale water supply pipelines, irrigation systems, and sewage networks. It is perfect for applications requiring flexibility, resistance to corrosion, and durability in harsh environments. Using this method requires specialized equipment and training. Pipe connections are made by heating the pipe ends to a molten state and fusing them using a special fusion welding machine.

7. **Threaded Connection**

   Pipe Material: Steel, Cast Iron

   Threaded connections are usually made in medium- and low-pressure pipelines and are typically done when pipes are smaller (1 inch or less) in diameter. Common applications are fire protection systems and low-pressure water supply lines. For this method, pipes are threaded at the ends and screwed together using threaded fittings. To use this method a pipe threading tool and pipe wrench is needed. With this technique, precise adjustments and fine-tuning can be done.

8. **Rivet or Bolt**

   Pipe Material: Steel

   The riveting or bolting technique is used to join pipe sections in large-scale industrial applications, such as water treatment plants. Connections are made using metal fasteners and tightened with rivets or bolting equipment.

9. **O-ring & Gasket**

   Pipe Material: Metal, Plastic

   O-ring and gasket joints are used to join large-diameter pipes in water distribution or sewer systems. A joint or connection is made by placing a rubber or synthetic gasket between the pipes and then tightening them together with bolts or other securing mechanisms.

10. **Camlock**

    Pipe Material: Metal, Plastic

    When temporary or emergency connections are needed, camlock fittings are often used as a quick-connect coupling. This is typically done for firefighting and irrigation pipelines that are frequently disconnected and reconnected.

11. **Bell & Spigot**

    Pipe Material: Clay, Concrete, Plastic (PVC)

    The Bell & Spigot method is frequently used to join pipes in large-diameter pipelines in water distribution and drainage systems. Connections are made by pushing one pipe (spigot) into another pipe (bell) and bonding them with a gasket or sealant.

IV. Installation

There are a few different methods used for building and installing water pipelines. Using the right method is critical to ensure the efficient operation, dependability, and solid integrity of a water pipeline that is necessary to provide customer's reliable service. The most widely used approach is Open-Cut Trenching. Other non-trenching methods used are Pipe Jacking, Microtunneling, and Horizontal Directional Drilling (HDD).

A. Methods

1. Open-Cut Trenching

Open-cut trenching involves removing soil and creating trenches using heavy equipment like excavators, backhoes, and dump trucks. Water pipes are laid in the trenches and connected which creates a pipeline. Once the pipeline is installed, the trenches are backfilled with compacted soil to provide pipe support.

Trenching is popular for several reasons.

- Relatively Cost-Effective - Trenching is more cost-effective than non-trenching methods, especially for smaller projects in favorable soil conditions.
- Adaptability - Trenching is more flexible than other methods since it can be adapted to various soil conditions with proper trenching techniques and shoring.
- Direct Access – Maintenance personnel have direct and easy access to pipes for inspections, troubleshooting, maintenance, repairs, and replacements.

As with most methods, there are both pros and cons. For some people trenching is less appealing due to one or several reasons.

- Lost Landscapes – The significant excavation that is necessary is likely to disrupt at least some of the landscaping. This may include the removal of existing trees, plants, ponds, trails, etc.
- Restoration Costs - Trenching adds landscaping costs since areas disturbed will need to be restored.

- Traffic Disruptions – Depending on the location, some areas may experience traffic disruptions due to construction equipment and worker movements.
- Safety Concerns – Open trenches can be a safety hazard when precautionary actions are not completed to prevent accidents or injuries.

2. Pipe Jacking

This method installs water pipes with hydraulic jacks, hence the name pipe jacking. It is done with a jacking machine and prefabricated pipe sections made of steel, reinforced concrete, or fiberglass-reinforced plastic. Basically, the jacking machine applies hydraulic pressure to push the pipe segment through the ground, advancing it toward a reception pit. As each pipe section is pushed forward, it is joined to the previous one, creating a continuous pipeline.

To ensure accurate alignment, a guidance system like a laser is often used to steer the pipe along the desired path. The method works best in consistent granular or cohesive soils. Some professionals prefer it because it reduces the amount of surface disruption compared to open-cut methods. It also reduces the amount of construction traffic and contamination risks.

However, it still involves safety risks, particularly during shaft excavations. The method also restricts tunnel length and requires shaft excavations every 1,000 feet. For long water pipelines, this will increase costs and complicate planning.

3. Microtunneling

Microtunneling is similar to pipe jacking because it, too, does trenchless installation. This method uses a Microtunnel Boring Machine (MTBM) with rotating cutter heads to break up the soil, drill a shaft, and jack (push) pipe into it. The head design used depends on the site's ground and soil conditions. They need to be stable for this method to be effective.

The process begins with site preparation and system setting up. A launch shaft (pit) is excavated, and an MTBM is lowered into it. The MTBM will need lubrication for cutting, so a slurry of water and bentonite (a type of clay) is mixed. A delivery system of hoses, pipes, and pumps is built to move slurry into the pit.

The slurry will provide necessary drilling lubrication and transport out excavated material.

As slurry is pumped into the shaft, the MTBM is operated remotely by a trained professional at the surface. The operator uses MTBM's sensors, lasers, and monitoring system to guide the machine as the cutter head creates a tunnel and jacks (pushes) the pipe into place. The process continues until a receptor shaft (exit point) is reached.

The method of microtunneling is selected for several reasons. One reason why is the approach causes minimal surface disruption. It also eliminates the need to pay for landscaping restoration and reduces installation costs since less people are needed on-site. However, the method can be expensive for smaller-diameter pipes or shorter sections. It also may require more shafts, especially for longer runs. Plus, the diameter of a tunnel is limited by the size of the microtunneling machine.

4. Horizontal Directional Drilling (HDD)

Horizontal Directional Drilling (HDD) is a trenchless method used to install water pipelines without disturbing the surface, making it ideal for urban environments or locations where excavation is not feasible. The process begins by drilling a small horizontal pilot hole with specialized equipment along the pipeline route. The pilot hole is then reamed (expanded) to a diameter large enough to accommodate the pipeline. The pipe is drawn into the hole with a pullback rig directly or through a series of connected pipes.

The HHD method causes minimal disruption to the environment, roads, and buildings. It is also well suited for areas with limited space or where conventional trenching is difficult. HHD also makes it possible to efficiently install pipelines across rivers, roads, and other obstacles. At the same time, the method can be expensive due to the requirements of using specialized equipment and trained operators. Careful planning and monitoring must occur to avoid misalignment or damage. Soil conditions such as rocky or unstable soils can hinder success.

The main takeaways include the chosen water pipeline installation method, which must be compatible with the location, surface, and soil conditions. It must also be within acceptable levels for area and surface disruption. Costs must remain within limits to complete the project within the amount of investment planned.

V. Types

Water pipelines are used for several applications, including delivering clean drinking water, and transporting wastewater for treatment. The pipelines are constructed using several different kinds of pipes, fittings, and devices like valves that are made of various materials. The water industry groups pipes into types based on the material they were made with, such as cement. The reason is because the material indicates how the type of pipe will respond when exposed to variables like pressure and temperature. The standard types for potable (drinking) and non-potable water applications are metal, concrete, fiberglass, and plastic.

Water pipelines used for transporting potable (drinking) and non-potable water are required to meet the exact FDA water quality requirements as the water they transport and distribute. For example, if a water pipeline moves drinking (potable) water, it must meet the same water quality standards. These requirements are based on the Safe Water Drinking Act (SWDA). It is in place to protect public health by establishing requirements and standards for drinking water quality. Other federal laws and rules that apply to water quality and water pipelines are in Table 1.

Table 1: Federal Water Quality Rules

Contaminant Type	Regulation
Chemical contaminants	• Arsenic rule • Chemical contaminant rules • Lead and copper rule • Radionuclides rule • Variance and exemptions rule • Per- and Polyfluoroalkyl Substances (PFAS) rule
Microbial contaminants	• Aircraft drinking water rule • Ground water rule

	• Stage 1 and stage 2 disinfectant/disinfection byproducts rule • Surface water treatment rules • Total coliform rule and revised total coliform rule
Right-to-know rules	• Consumer confidence report rule • Public notification rule

These laws have corresponding EPA water pipeline and drinking water quality regulations, standards, and guidelines. They provide requirement specifications for the physical water pipeline, its components, operations, monitoring, and management. The federal requirements are in the following documents.

- National Primary Drinking Water Regulations (NPDWRs)
  These federal regulations set limits for the contaminants in public water systems.
- National Secondary Drinking Water Regulations (NSDWRs)
  These standards address contaminants like odor, pH, silver, and sulfate.
- National Recommended Water Quality Criteria
  This document sets the limits for acceptable amounts of 150 pollutants when testing the level of quality. Contaminants include microorganisms, disinfectants, and inorganic chemicals.
- Clean Water Act Section 304(a) Criteria
  This document provides scientific recommendations and how the EPA defines acceptable levels of pollutants in water. It also provides guidance for states and tribes to establish enforceable water quality standards.
- Water Quality Standards Handbook
  This handbook includes chapters on general provisions, water quality criteria, and procedures for reviewing and revising water quality standards.

The requirements mandate water quality testing of water from several sampling points within a pipeline, network, and system using the water quality index (WQI) in Table 2.

Table 2: Water Quality Index

WQI	Quality Level	Intended Use

76 - 100	Excellent	Water is considered clean and suitable for all intended uses.
51 - 75	Good	Water may require some treatment before drinking but is generally suitable.
26 - 50	Poor	Water may be unsuitable for drinking without significant treatment.
0-25	Very Poor	Water is not considered suitable for drinking and use is highly discouraged.

If testing scores reflect water is within the WQI excellent range of 76 to 100, it is approved as potable. Water that scores in the good or poor quality range of 26 to 75 is nonpotable. Any score below 26 indicates the water is unusable.

Potable is excellent quality and considered safe for people to consume and use in activities like cooking, washing, and bathing. In comparison, non-potable has been deemed unsafe for people to drink and use. Non-potable water is acceptable for use in multiple applications. Examples are for crop watering with irrigation systems, cooling and washing equipment in work areas for manufacturing, and cooling building systems like HVACs used for heating and air conditioning.

The addition of FDA water quality requirements create the water pipeline types of Potable Water Pipelines & Networks and Non-Potable Water Pipelines & Networks.

1. **Potable Water Pipelines & Networks (PWPN)**

   Potable water pipelines and networks must meet the federal and state requirements for potable water the entire time they are in use. They cannot be used for non-potable water. If a pipeline fails a WQI test for potable water, it no longer can be used for potable water.

   - **Key Characteristics**
     - **Restricted Use:** Only used to move potable water.
     - **Quality:** Within WQI range for potable water.
     - **Clean & Disinfected:** Cleaned and disinfected regularly.
     - **Quality Protected:** Quality protected with an epoxy resin coating.

- **Corrosion Prevented:** Internal corrosion prevention coating.
- **Potable Compliant:** Remains compliant with federal and state regulations, standards, and requirements for potable water.

- **Examples**
  - **Primary Distribution Pipeline Networks:** Large-diameter pipelines that move higher volumes of water from treatment plants to larger urban areas or regions.
  - **Secondary Distribution Pipeline Networks:** Smaller diameter pipelines that branch off from primary pipelines and networks to deliver water to certain neighborhoods or smaller communities.
  - **Transmission Lines:** Long-distance pipelines that transport water from remote sources (e.g., reservoirs, lakes, rivers) to water treatment plants or directly to large population areas.

2. **Non-Potable Water Pipelines & Networks (NPWPN)**

   Non-potable water pipelines are only suitable for use with water within the WQI range of 26 to 75.

   - **Key Characteristics**
     - **Restricted Use:** Use only for non-potable water.
     - **Quality:** Within the WQI range for non-potable water.
     - **Non-Potable Compliant:** Remains compliant with federal and state regulations, standards, and requirements for non-potable water.

- **Examples**
  - **Landscaping:** Pipelines that move water for landscaping at public facilities like parks and golf courses.
  - **Industrial:** Larger pipelines that distribute to industrial facilities for cooling, rinsing, washing, and mixing.
  - **Power:** Pipelines that move water to energy companies for generating power.
  - **Stormwater Drainage:** Pipelines used by cities for collecting and channeling rainwater and runoff.

VI. General Operations

In the U.S., about 39 billion gallons of water is distributed every day by water suppliers through public water systems, according to U.S. Geological Surveys. To accomplish it, water suppliers conduct and manage water operation. It includes water sourcing, treatment, pumping, transportation, storage, distribution, maintenance, monitor and control, emergency response, customer service, and regulatory laws and standards.

A. Core Areas

1. Water Sourcing

Water Sourcing ensures water suppliers have an adequate number of sources and amounts for treatment to fulfill demand. Without water sources, water suppliers can fail at delivering to customers water and in the amount needed.

Water sourcing entails finding acceptable natural water sources (i.e. rivers, lakes, aquifers, or reservoirs) and raw water, managing water sources, and collecting raw water. The process is done using water pipelines and systems to extract the raw water and transport it to water treatment facilities.

2. Water Treatment

Water treatment raises the quality of collected water. This is critical to ensure that water distributed is safe for public consumption and use. It prevents crisis situations like contaminated water being distributed that can cause disease outbreaks and threaten people's health.

The water treatment process that is done involves completing five stages.

- **Pre-Treatment**
  Large particles and debris are removed with screens or coarse filtration.
- **Coagulation and Flocculation**
  Chemicals called "coagulants" are added to the water that cause destabilization. This change facilitates the clumping together of tiny, suspended particles like dirt and bacteria. The clumps join together and form larger masses called flocs, which are removed through sedimentation.
- **Sedimentation**
  Water is left alone in tanks to settle. The flocs naturally rise to the top and are removed with filtration.

- **Disinfection**

  Disinfection is done with Chlorine, ozone, or UV light to kill microorganisms.
- **Post-Treatment**

  The pH of water is adjusted when necessary. Chemicals are also added for corrosion control.

3. **Pumps and Transport**

   Pumps are used to transport water through pipelines and networks. This involves water operators using pumping stations to create movement by pushing water through pipes.

4. **Storage**

   Water suppliers use storage tanks for different reasons, including storing raw water for later treatment to restore their current supply. Also, for holding a reserve supply of water for fluctuations in demand or emergencies like power outages or natural disasters. Reaching a balance between water holding capacity and demand is critical to keep water pipelines in operation and provide water service.

5. **Distribution**

   Distribution is the process of moving water from sources through water pipelines and networks to customers. During the process managing pipeline operations effectively and moving water efficiently is critical. When done successfully they ensure customers receive water, it arrives when needed, and the amount is adequate. In the process, water operators move potable or non-potable water from sources like water storage tanks by pumping and boosting stations into primary water pipelines and networks to water mains. Water is transported further with secondary pipelines that move it all the way to customers.

   Primary pipelines have pipes of large diameter since their purpose is to move large volumes of water to central locations for further distribution. Secondary pipelines are smaller in diameter and have branches. They move water from central locations customers. To ensure there is adequate water pressure for movement at the best flow rate, monitoring is done at pressure zones at points in pipelines. If the flow rate becomes inadequate, water operators use boosting stations to increase pressure and flow.

6. Maintenance

Maintenance is not something that can be ignored, skipped, partially done, or delayed. It must be part of water pipeline operations to remain in operation and provide uninterrupted service 24/7 to customers. Maintenance involves several types, including regular, scheduled, predictive, preventative, and emergency.

- **Regular Maintenance –** This type maintains function and performance of components and parts like valves.
- **Scheduled Maintenance –** It's the incorporation of manufacturer recommended maintenance to for equipment, component, and part longevity.
- **Predictive Maintenance –** This kind predicts issues early so repair or replacements can be done before it increases the risk of breakdowns that can cause service interruptions.
- **Preventative Maintenance –** It's completing maintenance that prevents issues and problem.
- **Emergency Maintenance –** This type of maintenance is done when a system emergency occurs like a broken pipe or device.

There is also more to maintenance than repairs and replacements. It also involves regularly conducting pipeline inspections to visually identify any potential issues or problems. Plus, cleaning and disinfecting pipelines at intervals of more than annually to maintain water quality.

7. Monitor and Control

It is critical that water operations monitor and control water pipelines and networks continuously. Methods often used include leveraging technology for early detection of leaks, potential failures, and water quality issues. Also, using the software of Supervisory Control and Data Acquisition (SCADA). Plus, installing and using sensors that provide real-time data automatically and alerts for pressure, temperature, and flow.

8. Emergency Response

As part of water pipeline operations, emergency response plans are necessity for all water suppliers because they provide structured procedures. These plans outline how to operate water pipelines and networks when emergencies occur like weather events and natural disasters (i.e., hurricanes, torrential rains, flooding), power outages, or contamination.

Emergency response plans prevent pipeline shutdowns, minimize the number of disruptions in water service, protect public health, and facilitate timely repairs. Developing emergency response plans involves identifying potential hazards, establishing procedures, designating relevant authorities for coordination, creating evacuation plans, and including actions for restoring service. For example, one action for restoring service could be switching to a standby power generation systems during a power outage to continue operations.

9. **Customer Service**

Customer service is a highly important part of overall operations. This is because it contributes to customer satisfaction, which is critical to customer retention. For a water supplier to remain in business customers must be retained.

10. **Regulatory Laws & Standards**

Water pipelines and systems are regulated by federal agencies with laws, regulations, and standards and compliance is mandatory. Compliance involves learning what is required, creating, and implementing plans that will keep everything within compliance.

VII. Monitoring & Management

In water supply systems and pipeline network operations, monitoring and management are closely related. Both are essential to ensure continuous, reliable, safe, and cost-effective pipeline operations that keep water flowing 24/7. At the same time, the areas to focus on are not the same. For water pipelines, effective monitoring should focus on data collection and analysis, early detection, condition, performance, efficiency, safety, and federal and state laws. For pipeline management, creating and executing a plan is critical to ensure all areas are addressed and managed effectively.

A. Monitoring

1. **Data Collection & Analysis**

Data collection is the process of gathering measurements and information from multiple points throughout water systems or networks. Its purpose is to identify potential issues, problems, and opportunities for improvement that can increase performance and efficiency. In the process, data is collected by sensors and monitoring device's location at points through water systems and networks and transmitted to control systems. It is often done using Supervisory Control and Data Acquisition (SCADA) systems.

The data and information are analyzed by pipeline operators who look. They look for trends and indicators. For example, data with pressure measurements may indicate that one or several points are too high within the system or network. High pressure can cause damage to water systems and pipeline networks. The data and analysis are used in several aspects of business, including operations, planning, maintenance, finance, quality control, and federal and state compliance.

The are significant benefits that come from using data and analysis. They include lower repair and maintenance costs, less water lost or wasted, improved operational efficiency, and lower risk of service interruptions.

2. **Early Detection**

Early detection means finding issues earlier with technology as compared to finding them during visual inspections. For example, monitoring devices can find leaks in pipelines as soon as they occur. This makes it possible to find and fix issues sooner which lowers costs. It also reduces the risk in areas such as the shutdown of water systems or networks which can lead to service interruptions.

There are a variety of continuous internal and external monitoring options for early detection. They include smart water meters, leak detectors, acoustic sensors, sensing cables, and meters (i.e., pressure, flow, temperature, turbidity, level).

3. **Condition**

It is always wise to use several methods for leak detection because when they occur, it can quickly become costly. Monitoring the condition of pipes is another way of finding potential leaks in water pipelines. Less damage is caused when leaks are drips rather than flows of water. Indicators to look for are excessive wear, holes, cracks, or breaks.

For example, a residential water main break can damage the home' and surrounding property. This includes the homes' structure and foundation as well as the basement's interior— floors, walls, windows, cabinets, furniture, and personal belongings. When an infrastructure water main breaks, it can flood the surrounding area and cause damage to roads, sidewalks, landscaping and the building of businesses.

There are several methods used for checking and assessing the condition of pipes. Examples are visual inspections, high-resolution cameras, electromagnetic waves, laser radiation, ultrasonic waves, acoustic sensors, eddy current, and thermal profiling. There are also Non-Destructive Testing (NDT) techniques like ultrasonic testing, pressure testing, and magnetic flux leakage for assessing pipeline integrity without causing damage.

4. Performance & Efficiency

Monitoring pressure, temperature, and flow is critical to the operation of water pipelines. If these variables are left uncontrolled it can lead to serious problems, cause breaches in safety, and threaten public health. High water pressure alone can significantly reduce the integrity of pipes and cause them to crack, break, or burst, which can cause further damage in pipelines, systems, networks, and the surrounding area. Uncontrolled flow rates can also cause significant damage through erosion and increased corrosion causing water hammers.

The level of performance and efficiency of water pipelines depends on the level of pressure, temperature, and flow. They must be maintained within their optimum range for a pipeline to exhibit high performance and efficiency. Levels are monitored and assessed as described in 1. Data Collection & Analysis. Based on analysis, Changes are made to improve performance and efficiency.

Additional benefits from effectively managing these variables include less energy needed, reduced water loss, lower operating costs, enhanced safety, and better quality control. It will also extend the pipeline and the lifespan of its components.

5. **Safety**

   Monitoring the safety of water pipeline operations through continuous observation and parameter analysis of variables (i.e., pressure, temperature, flow) is critical to ensure no person or property associated with water pipelines or their operation is harmed or damaged. Monitoring and testing of water intended for public distribution is mandated by the EPA for quality to ensure public safety.

   The safety monitoring is done using sensors installed directly within the pipes, which continuously measure various parameters like turbidity, pH, chlorine levels, conductivity, and temperature. Readings are transmitted and analyzed as described in 1. Data Collection & Analysis.

   If the safety breach of water contamination does occur, it must be reported to the EPA.

6. **Federal & State Laws**

   There are federal requirements for water pipeline monitoring that primarily fall under the Safe Drinking Water Act (SDWA). They mandate regular sampling and testing of water at various points in the distribution system to ensure compliance with established Maximum Contaminant Levels (MCLs) for contaminants like lead, nitrate, and bacteria. Monitoring frequencies depending on the contaminant and the size/type of water system involved.

B. Management

1. **Pipeline Plans**

   A water pipeline plan is crucial because it ensures the reliable delivery of clean water to communities over the long term. It accomplished this by addressing several areas of high importance to water pipelines.

   - **Leak Detection**

     For effective water pipeline leak detection, the most important factor is accurate and high-quality measurements throughout the pipeline for flow and pressure. Therefore, pipeline plans need to include an investment in technology with a system of sensors that is more advanced. This leak detection system needs to be highly sensitive and capable of detecting even small leaks through monitoring changes in volume or pressure over time.

- **Infrastructure Asset Management**
  There are thousands of components and parts in water infrastructure. Each is an asset that needs to be managed. All have a lifespan and will at some point fail. If failure occurs in parts critical to pipeline operations, it can cause breakdowns that interrupt water service. Therefore, it is important for pipeline plans to include initiatives that will effectively manage assets by repairing or replacing parts before they fail. This will ensure integrity is maintained in water infrastructure.
- **Capacity Management**
  Effective capacity management is critical to customer retention. Plans must ensure there in enough capacity for storage, pipelines, treatment, pumping and boosting stations to meet demand. It requires meeting current demand, including during peak periods and emergencies. It also requires having enough capacity for future demand that continues to increase each year due to populations growth. Plans must include investments and projects to ensure water suppliers stay ahead of and behind capacity.
- **Cost Optimization**
  As part of the cost optimization process, expenses are reduced and managed. One way this can be done more effectively is with the proactive approach of watching for potential issues and resolving them before they become major problems, thereby saving money on emergency repairs.
- **Prioritization**
  To improve water pipeline uptime and service reliability, prioritize repair projects in plans based on their level of severity and potential to affect operations or water service. Expansions or addition of WPNs should be prioritized as well. The focus should be on achieving continuous operation and providing reliable service.

Milestone 3

VIII. Pipeline Composition

A. The Material of Construction

Water pipelines and networks are built with several types of pipe. Each type is composed of a different material. The common materials of water pipes are metal, reinforced concrete, fiberglass, or plastic (PEX, PVC, CPVC). Each of these materials has its own properties and lifespans. For example, the lifespan of reinforced cement pipe averages 75 – 100 years vs. galvanized steel pipe’s 20 – 50 years.

1. Metals

Common metals used for water pipelines are copper, steel (stainless, galvanized), and cast iron. Copper is mainly used for residential water supply lines to carry hot and cold water throughout a house. Steel and cast iron are used for higher-volume applications like water pipelines and distribution networks.

- **Stainless Steel**

  Stainless steel is a material created using low-carbon steel and chromium. The manufacturing process produces a non-porous material that's inert in water. Steel pipes are chosen for their strength, durability, integrity, and longevity. Stainless adds to those properties’ corrosion and heat resistance. Plus, stainless steel is easy to clean and naturally hygienic. However, stainless steel pipes are expensive, and prone to pitting or scratching.

– **Galvanized Steel**

  Galvanized steel is made by coating steel with zinc. This process adds to the properties of corrosion, rust, and mineral build up resistance. However, galvanized steel pipes are heavy, making installation and replacement more challenging. They are prone to cracking, and clogging. Plus, older galvanized pipes may contain lead.

– **Cast Iron**

  Cast iron pipes are made with molds and molten iron using a pit, horizontal, or centrifuge method. As a material, cast iron is exceptionally durable and capable of withstanding high pressure. High-pressure tolerance is one reason cast iron pipes are frequently used for water mains. But some disadvantages come with selecting cast iron pipes as well. They are heavy, making them more challenging to install and replace, often leading to higher installation costs. Cast iron pipes are also susceptible to internal corrosion over time.

2. **Reinforced Concrete Pipes (RCP)**

Reinforced concrete pipe (RPCs) is produced with a precast process using steel rebar (reinforced bars) along with a mixture of cement and additives (i.e., fly ash, portland, sand, gravel, or crushed stone).

RCP's are often used in storm drains for managing stormwater by channeling runoff away from streets, parks, and other areas. They are also used for municipal sewer systems and culverts for channeling water under roads and bridges, allowing rivers and drainage ditches to flow. Another common application is distributing water to irrigation systems for fields and greenhouses. Plus, RCP's are also installed as part of water force mains that transport pressurized wastewater from lower to higher elevations when gravity isn't enough.

One big advantage of RCPs is their weight bearing capability. RCP's can be designed to handle any load (weight) requirements. The material is durable, reliable, and can withstand environmental stressors. RCP is also corrosion-resistant and maintains its integrity even when water pressure is high. These pipes are also known for longevity, lasting up to 100 years.

However, there are some disadvantages that come with deciding to use RCPs as well. The higher upfront costs are higher. RCP pipes and fittings are very heavy and rigid, making their transportation and installation both more challenging and expensive. Installation is complicated further due to the potential of RCPs cracking if installed too quickly. RCPs also need to be inspected regularly for cracks and maintenance needs to be done regularly to prevent issues and address those found early like cracks, leaks and algae growth.

3. **Fiberglass**

Fiberglass pipe, also known as fiberglass reinforced plastic (FRP) pipe, is produced with a process called forming. During this process glass, silica sand, soda ash, limestone, borax, magnesite, nepheline syenite, feldspar, and kaolin clay are molted together to form glass fibers. The glass fibers are bonded together with thermosetting resin to form pipes.

FRPs are chosen for water pipelines because of their excellent corrosion resistance. They also have the property of high heat resistance. Since FRPs are lightweight in nature it makes installation easier. However, installation can also be challenging if too much external pressure is applied when pipes are installed.

There are also disadvantages that come with selecting this type of pipe. For example, the fiberglass material can become brittle and crack, especially if it is exposed to ultraviolet light or heat. The material is also susceptibility to impact damage. FRPs have lower fire resistance than metal pipes. Plus, installation and repairs can be expensive since it requires a specialist trained in fiberglass repair techniques.

FRPs are used in water applications such as public water systems for distributing water to buildings. These pipes are also used for moving industrial process water and wastewater through the treatment process. In the oil & gas industry, FRP's transport of water from injection wells to reservoirs. Plus, these pipes are used to provide water to hydroelectric power plants to generate electricity.

4. Plastic (PEX, PVC, CPVC)

Plastic pipes are manufactured using either polyethylene (PEX), polyvinyl chloride (PVC), or chlorinated polyvinyl chloride (CPVC). These three materials are considered safe for pipes that carry potable (drinking) water. However, they may not be acceptable in some states due to additional state laws that add more requirements.

- **PEX - polyethylene**

  PEX pipe is made by cross-linking polyethylene (PE) to create a three-dimensional structure. This process used to produce pipes with this material is called extrusion molding. It chemically or physically modifies the polyethylene.

PEX pipes are used for pipes in residential, commercial, government, and public buildings to supply fixtures and systems for fire protection (sprinklers), snow melting, and heating (HVAC). PEX pipes are used because of their affordability, flexibility, durability, ease of installation, resistance to freezing, and corrosion. But they have disadvantages as well, including UV sensitivity, ease of damage by animals (rodent chewing), and potential of water contamination from the PEX material leaching into water.

- **PVC - polyvinyl chloride**

  Polyvinyl chloride (PVC) pipes are produced with polymerizing vinyl chloride monomers (VCM), which are made by combining chlorine and ethylene. PVC pipes are used for residential, municipal (wastewater, sewage, drain-waste-vents (DWV), irrigation, and stormwater (runoff).

  PVC pipes are popular due to their resistance to corrosion, contamination, and impact. The material is durable, ecofriendly, and cost-efficient. There are unattractive properties as well, such as the inability of PVC to handle high temperatures, meaning it’s not suitable for hot water systems. The material can also warp or melt under extreme heat. Plus, the material is vulnerable to UV which can compromise its integrity.

IX. Pressure

The importance of pressure cannot be overstated in the context of water pipelines. Pressure is a direct driver of water movement in pipes. The amount of pressure in a pipeline also drives the rate of water flow. Plus, if pressure is left uncontrolled it can cause damage, breach safety, and cause life threatening events.

A. Variable Fluctuation

The level of water pressure in pipelines can fluctuate between low, medium, and high levels. Changes are driven by several factors and variables. Factors are inherent characteristics of the pipe itself, like its diameter, length, material, age, and internal surface (smooth or rough). Variables are the more dynamic aspects of pipelines that can change over time. An example is mineral deposit buildup inside pipes that block flow which causes pressure to rise. Changes can also occur due to the water pressure level in connected systems and networks.

1. **Water Supply Systems**

   Utilities and private water companies operate water supply systems. These systems are used to collect and treat water intended for distribution to customers. The level of water pressure in these supply systems can significantly affect water's distribution.

   For example, if the pressure of water is too high (above safety limits) when it flows out of water supply systems into distribution pipelines and networks it can damage pipelines to include section or individual pipes. The higher water pressure climbs inside pipes the more force it will apply. When it exceeds the pipe materials limit it can burst, break, or crack pipes and fittings.

   For these reasons, it is critical that water pressure in water supply systems be managed and tested regularly, especially prior to discharge into distribution pipelines and networks.

2. **Pipeline Elevation**

   Over the route of water pipeline, there are changes in elevation. Pipeline sections are often installed at varying up and down angles to mirror changes in land features like hills, mountains or valleys. When there is a hill, the elevation of pipeline sections will increase as it the pipe gets closer to the jills peak. The increases make it harder for water to overcome the pull of gravity and continue flowing uphill. There needs to be enough pressure to compensate for extra pull that will force water forward and at the best flow rate.

   If there is the potential for water flow to be affected or it has already slowed, water operators can boost pressure. There are boosting stations a water operator can use to increase pressure in sections in question and keep water moving at the best flow rate.

3. **Pipeline Design**

   How water systems and pipeline networks are designed directly affect pressure. One contributing factor is the pipes, to include size, length, material, and number of pipes or sections. A second factor is the angle of bends, which are typically 45 degrees to 90 degrees. Fittings are yet another factor, like elbows which can have a long or short radius.

The design of a water pipeline or network should address all the ups and downs along a pipeline route to include the corresponding pipe angles and elevations to ensure water will have adequate pressure for movement and at the best flow rate.

4. **Age, Material & Condition**

   The age, material, and condition of pipes can affect pressure as well. For example, as galvanized iron pipes age, they tend to become corroded over time from a chemical reaction caused by exposure to water. This creates a narrower space with a rough rather than smooth surface which inhibits water flow whereby reducing water pressure. This reflects why older pipes need to be replaced sooner rather than later. Plus, the importance of adding and maintaining an anticorrosion layer in steel pipe.

5. **Blockages or Clogs**

   What is inside of pipes and pipeline networks can cause pressure to fall. Mineral deposits and debris that build up inside pipes create clogs and blockages. These restrict water flow which can significantly lower the level of pressure, especially at fixtures like faucets and showerheads. One more reason why monitoring and prompt issue resolution are very important.

6. **Demand & Usage Patterns**

   The level of demand and usage patterns can affect water pressure. As the demand for water rises water pressure will decrease. The simultaneous use of multiple appliances and fixtures can also cause water pressure to drop. These occurrences can strain water systems and pipeline networks if not promptly addressed and issues resolved. Pressure can be raised quickly when needed with pumps and booster stations.

B. Best Practices

Successfully management of water pressure within pipeline networks requires the use of technology, techniques, methods, and tools. Examples are in the following pressure management best practices.

1. **Monitoring**

   The importance of managing water pressure in pipelines has already been established. But managing pressure effectively requires more than traditional methods like site visits and manual adjustments. It takes monitoring and managing pressure 24/7 with the help of technology and real-time data. This enables water operators to detect brief fluctuations or longer ups and downs in pressure sooner. Plus, response faster to prevent from turning into bigger problems.

   For example, water operators use the Supervisory Control and Data Acquisition (SCADA) system. It enables them to manage pressure more effectively and efficiently due to the technology, its integration, automation, and user-friendly interface. With the SCADA system, water operators are able to monitor equipment and processes from a central location. The current status of pressure can be assessed easily with the real-time data collected by the SCADA system. If data indicates adjustments are needed, water operators can do them remotely with supervisory control.

2. **Control**

   Several devices or valves are used to effectively control pressure in a pipeline network. The primary device is a pressure reduction valve. The device is used to automatically lower incoming high water pressure to a desired level within a pipeline. Another is a check valve, also known as “one-way” or “non-return” valve, that is used to prevent the backflow of water to reduce the risk of water contamination. There is also a pressure relief valve that automatically releases excess water pressure when it reaches a predetermined level. Two additional devices are the globe valve for precision control, and the butterfly valve that controls flow.

3. **Detection**

   Regularly monitoring water pipeline networks for leaks and prompt repair can minimize water loss and maintain consistent pressure. Leak detection sensor-based devices often used are fiber optic sensors, distributed acoustic or vibration sensing (DAS/DVS), distributed temperature sensing (DTS), or distributed strain sensing (DSS).

X. Maintenance

To ensure the flow of water stays continuous and the water service remains reliable without interruption 24/7, maintenance must be a high priority in water supplier's operations and management plans. This is critical for gaining customer satisfaction, which influences retention most. Retaining customers must be a top priority in everything for a water supplier to remain in business.

Maintenance must be more than occasional repairs to fix issues like a cracked or broken pipe. This minimal approach has been used many times by water suppliers and has always failed to meet customer expectations. Water service customers demand an adequate and continuous flow of water and reliable service. Meeting these expectations requires an approach that keeps water pipelines operating 24/7 and distributing enough water to meet demand. Therefore, management plans and operation must include several different types of maintenance. They include regular, scheduled, corrective, adaptive, preventative, predictive, and emergency.

1. **Regular**

   In general, regular maintenance is work that is done to keep water pipelines in operation.

   – **Visual Inspections**

     Water pipelines should be visually inspected in their entirety for potential issues that are visible. This includes looking for excessive wear, breaks, cracks, broken seals, disjoined connections, and exposed pipe. The inside of pipes also needs to be visually checked for corrosion and mineral buildup.

     The frequency of water pipeline visual inspection depends on the pipe's condition, age, material, and location (i.e., cold or harsh climates). These factors may warrant more frequent inspections. The EPA requires visual inspections to be completed at least annually.

   – **Testing**

     The regular testing of water pressure within pipelines is recommended by the EPA. It is an effective way of identifying potential leaks or weaknesses. Water flow and temperature testing are recommended as well to ensure they are within the range deemed safe by the EPA. Plus, water quality testing is required by federal regulations to ensure it meets EPA water quality standards.

- **General Tasks**

  General maintenance tasks should also be completed for the purpose of maintaining pipeline operations. An example of a task is testing the operation of valves. Their capability to perform as specified by the manufacturer in areas like range of motion must be confirmed. A second task example is testing the operation of devices like pressure relief valves. Their ability to perform what they were designed to do, like relieving pressure, must be confirmed to ensure safety. Yet another example is replacing damaged or worn out parts.

Regular maintenance preserves the integrity and operability of water pipeline devices, parts, and equipment. It enhances efficiency and improves safety. Regular maintenance also contributes to lowering risks that can interrupt or stop pipeline operation and water service.

2. **Scheduled**

Scheduled maintenance is planned and performed according to a predetermined schedule. It does not require forecasting and can be done based on time or usage intervals. It ensures that pipeline components and parts receive the attention recommended by the manufacturers.

Examples of scheduled maintenance actions:

- Make replacements at times recommended by the manufacturer.
- Do repairs when recommended by the manufacturer to preserve integrity and function.
- Replace disposable parts like filters to maintain performance.
- Flush out of water pipelines to push out any water that remains in typical collection areas like joints.

- Remove sediment buildup, corrosion, clogs or matter that can inhibit flow.
- Clean and sanitize water pipelines to remove microorganisms like bacteria and viruses.
- Update fixtures with newer and more efficient models.

Scheduled maintenance prevents costly emergencies and expensive repairs or replacements. It also enhances performance and efficiency of a water pipeline and its individual parts. Furthermore, scheduled maintenance optimizes flow rates, improves water quality, extends the lifespan of devices and parts, reduces energy costs, and improves reliability. Plus, it ensures the safety of workers and the general public who consume and use the distributed water.

3. **Corrective**

Corrective maintenance is done to correct errors made in installation that are affecting system performance. An example is two pipes connected with fittings not designed for use with the type of pipe installed. This can create connections that become dislodged over time due to the effects of water movement like vibration. If the connection fails water will leak out which affects pressure and supply. The failure also makes the water pipeline vulnerable to contamination.

Corrective maintenance fixes installation errors whereby eliminating risks, issues, problems, or failures that may have occurred because it was done incorrectly. It also improves the water pipelines’ durability and integrity. Corrective maintenance also enables a water pipeline to operate at the capacity and perform level it was designed to do.

4. **Adaptive**

Adaptive maintenance is work that is done to modify water pipelines, so they meet current needs and regulatory requirements. There are several variables that can drive adaptive changes in water pipelines, including demand, climate change, and FDA requirements.

For example, an older water pipeline was designed and installed when water demand was lower. As a result, it lacks the necessary capacity to meet today's higher water demand. As a result, modifications are necessary like replacing current pipes with larger sizes. This modification will make the water pipeline capable of meeting current demand water volumes

A second example is changes in water quality or water pipeline FDA regulations and standards change. Both sets of requirements apply to water pipelines and compliance is required by law. Therefore, modifications are a must do and within the designated time frame for compliance.

Another example is the changing weather caused by climate change. In some parts if the U.S. temperature averages have dropped and resulting in more days below 30 degrees. As a result, the material of pipe and fittings in pipelines will likely need to be changed into an alternative than is capable of tolerating the cold and will maintain its integrity.

By performing adaptive maintenance, water pipelines once again align with the needs of the water supplier. They are also capable of handling higher water volume to keep up with increasing demand. Flow rate and pressure level can be managed and maintained at optimum levels.

5. **Preventative**

Preventative maintenance is completed for the purpose of preventing common problems that occur with water pipelines like periods of high pressure. If pressure is allowed to rise too high, it can cause damage throughout a pipeline. This includes broken pipes, fittings, devices and parts. Breaks make openings that allow water to flow out of a pipeline which can cause further damage. They also create opportunities for contamination of a pipeline and its water. If water becomes contaminated and it is distributed public health may be compromised.

Preventative maintenance lowers repair and replacement costs, improves energy efficiency, increases efficiency, improves safety costs, and reduces the risk of failures that can threaten your system's ability to provide water service.

6. **Predictive**

   Predictive maintenance focuses on anticipating potential issues before they occur. It involves using real-time data, data analysis, and predictive modeling to find indicators of changes that can cause issues or problems like a change in pressure or flow in a section of pipe. Predictive maintenance minimizes disruptions and keeps down repair costs.

7. **Emergency**

   This type of maintenance is unplanned and not scheduled. It is done in response to an emergency event like a tornado or earthquake that has damaged water pipelines. For example, an earthquake can cause a water main to break that requires immediate attention.

   Benefits of emergency maintenance include putting water pipelines back in service for operations and restoring water service.

Clearly, there is a strong case for performing several types of maintenance. It ensures water pipelines remain in operation, water keeps flowing to customers, and they are able to rely on their water service.

XI. Environmental Concerns

Water pipelines are predominantly owned and operated by water suppliers, which are utilities and private water companies. When they decide to build a water pipeline, it must be announced to the public as indicated in the EPA's Lead and Copper Rule Improvements" (LCRI). Frequently, the announcement will prompt the expression of environmental concerns by the community in potentially affected areas.

A. Shared Concerns

Members of communities in potentially affected areas often share concerns in the same areas, like habitat disruption and destruction, water source depletion, and pollution.

1. **Habitat Disruption**

   The construction of a pipeline often involves clearing land, which can disrupt local ecosystems and wildlife habitats. This may lead to the displacement of animals and the destruction of plant species, especially in sensitive areas.

2. **Habitat Destruction & Invasive Species**

   Water pipelines are often constructed by using heavy equipment. The equipment of bulldozers, excavators, track loaders, skid steer loaders, and backhoe loaders have tracks instead of wheels, which can destroy everything in its path. This leaves no vegetation behind, which is shelter and food critical for wildlife.

   The movement of heavy equipment can also unintentionally introduce invasive plant and animal species, which may outcompete native species and alter the local ecosystem balance.

3. **Water Source Depletion**

   If the water pipeline diverts natural resources such as lake water, it could strain the resource. Over-extraction can deplete natural resources as well. This would harm ecosystems, including plants and animals. It would also affect water availability for nearby communities or agriculture.

4. **Soil Erosion**

   The water pipeline construction process can lead to soil disturbance, which can accelerate the process, as well as increase amounts of erosion and sediment runoff into nearby rivers, lakes, or wetlands. This could negatively impact water quality and aquatic life.

5. **Pollution Risk**

The integrity of water pipelines can be compromised, which can lead to leaking or flowing water into the environment. Such an occurrence can cause contamination of natural resources from chemicals in the water, like Chlorine and disinfectants. These pollutants are capable of harming environments to include bodies of water, wildlife, and vegetation.

6. **Climate Impact**

   The carbon footprint associated with constructing and maintaining pipelines can contribute to climate change, especially if fossil fuels are used for energy during construction or operation.

7. **Aesthetics Lost**

   With minimal amounts of effort, time, and money being dedicated to restoration, the affected area can be left without the visual aesthetic beauty and landscapes it once had.

B. Frequency

According to the Association of Civil Engineering (ASCE), the U.S. and Canada experience approximately 260,000 water main breaks annually. The related maintenance costs are estimated at $2.6 billion annually. Overall, PVC pipe material has the lowest annual failure rate, at 2.9 breaks per 100 miles.

1. **Example: Mariner East 2**

   According to reports by the Pennsylvania Attorney General's office, the Mariner East 2 pipeline construction project in Pennsylvania caused significant environmental damage. The environmental damage included numerous drilling mud spills into waterways and wetlands, the creation of sinkholes, and contamination of drinking water supplies across the pipeline route. It was estimated that hundreds of spills and thousands of gallons of drilling fluid were released during construction. Pennsylvania’s Attorney General charged Energy Transfer with 48 counts of environmental crimes related to its construction.

2. **Example: Willamette River**

   In Portland, Oregon, the malfunction of a wastewater treatment plant caused an estimated 500,000 gallons of only partially treated wastewater to leak from pipelines into the Willamette River. An urgent public advisory had to be issued that urged residents to avoid the waterway for 48 hours due to bacterial concerns. The cost of cleaning up the Portland Harbor Superfund Site on the

Willamette River was estimated to be $1.05 billion and is expected to take 13 years.

1. Reduce Environmental Impact of Pipelines

The federal government is working to reduce environmental impact related to pipelines. The agency has put in place federal laws and regulations, mandating a series of actions and approvals before any pipeline construction begins. For example, an environmental impact assessment is required, because it ensures decision-makers consider the environmental consequences of a project before approving it.

Water suppliers can help with reducing the environmental impact of pipelines as well. It involves careful route planning, offsetting habitat loss, maintaining water pipelines and networks.

1. Plan Carefully

Water suppliers must invest the time, resources, and attention necessary to plan a water pipeline route carefully. It is critical for keeping the amount of environmental impact as low as possible. The alternative of quick and careless planning can have a negative impact. For example, quick site selection and installation can result in pipes laid in a crucial ecosystem with endangered species, thereby contributing to extinction.

Over the entire pipeline route, section by section, the areas for pipe, installation, equipment operation, and in/out access roads need to be identified, assessed, and selected with low environmental impact as a priority. This includes the soil, topography, proximity to water bodies, ecosystem, potential for erosion, floodplains, fault lines, groundwater levels, vegetation, wildlife, and climate conditions. Preferably, select areas that have already been disturbed and roads already in place.

2. Offset Habitat Loss

If despite careful planning and execution, some habitat is still lost or part of an ecosystem is negatively affected, a water supplier should be prepared. A water supplier should accept the responsibility and offset what has occurred. As part of the pipeline construction project plan, resources and funding must be included specifically for this type of occurrence.

3. Maintain Pipelines

Once construction is completed and the water pipeline operations are underway, the water supplier is responsible for ensuring it doesn’t cause further harm to the environment. Leaks, emissions, and pollutants from the pipeline or related equipment like pumps can destroy vegetation, harm local wildlife, and add to local water and air pollution levels.

Many issues can be avoided with regular inspections, testing, monitoring, maintenance, and operations within limits in areas like pressure and flow. For example, not managing pressure or doing it ineffectively can allow it to increase to an unsafe level. High pressure applies excessive force on pipes which can cause them to burst, break, or crack. All can cause pipes to leak treated water in drips or a flow into the environment, resulting in damage from chemicals like Chlorine.

XII. General Regulations, Overview

Pipelines transport a variety of liquids and gases, including oil, natural gas, water, sewage, and chemicals. All pipelines are regulated by the U.S. federal government as designated in national laws. There are several federal agencies that govern pipelines. For example, The Pipeline and Hazardous Materials Safety Administration (PHMSA), which is part of the U.S. Department of Transportation, regulates oil and natural gas onshore (on land) pipelines. The Federal Energy Regulatory Commission (FERC) is also involved when a natural gas pipeline extends over several states (interstate). The FERC must approve the construction of interstate natural gas pipelines.

The U.S. Environmental Protection Agency (EPA) is the governing authority over public water systems, including water pipelines. EPA also regulates drinking water to include designating the requirements for potable (drinking) and non-potable water. As part of governing, the agency develops and publishes regulations and standards. The EPA is also involved with water pipeline design, materials, construction, and operation.

Because water pipelines carry potable (drinking) water that is distributed to the public, all water pipelines must meet the EPA’s regulations, standards, and guidelines for either potable or non-potable water. Which ones depend upon a water pipelines intended use. For example, a water pipeline intended for the use of distributing drinking water to the public must meet the requirements for potable water quality, be classified and approved as a potable water pipeline for drinking water use. The same method applies to a water pipeline intended for use as a non-potable water pipeline. It is required to meet the requirements for non-potable water quality, be classified and approved for use with non-potable water.

A water pipeline can only be used for the classified level of water quality it has been approved for use. A water pipeline classified as potable cannot be used to move non-potable water. Such an occurrence would contaminate the water pipeline and make it unsafe and unusable for potable water.

The EPA's authority comes from The Safe Water Drinking Act (SWDA), which is a law. The EPA's regulatory requirements are based on several laws, rules, and regulations, including the following:

- Safe Water Drinking Act (SWDA)
- Clean Water Act (CWA)
- Lead and Copper Rule (LCR)
- Microbial and Disinfection Byproduct Rules (MDBR)
- National Primary Drinking Water Regulations (NPDWR)
- National Secondary Drinking Water Regulations (NSDWRs)

Additional regulations focusing on pipeline safety and integrity under the Department of Transportation (DOT) may apply. Plus, during construction and operation water pipelines must also meet workplace safety requirements of the Occupational Safety and Health Administration (OSHA). State and local governments usually have applicable requirements as well. They come from departments within the government like the Department of Health & Human Services.

In addition, the physical parts of a water pipeline, its design, materials, and installation must meet the requirements of the International Building Code (IBC), Uniform Plumbing Code (UPC), the National Standard Plumbing Code (NSPC), and the International Plumbing Code (IPC). Plus, the International Residential Code (IRC) when applicable, and the National Electrical Code (NEC).

A. Requirements

1. Water Pipeline Material

The most significant EPA requirement for water pipelines is the mandate to replace all lead service lines within a 10-year timeframe, as part of the "Lead and Copper Rule Improvements" regulation. Lead service lines make up over 9% of the national service line infrastructure. As of 2024, the EPA estimates that there are 9.2 million lead service lines in the U.S. These lines supply water to homes, schools, businesses, and public spaces.

The problem with lead pipes is the material loses its integrity over time. Lead particles can flake off and fall into drinking water whereby contaminating it. Even when consumed in small amounts, lead in drinking water can cause serious health issues. In young children, lead is particularly dangerous because exposure to it or consumption can damage their brain and nervous system which can alter cognitive development.

Owners of water systems are required to create a detailed inventory of their service lines and identify which ones are made of lead. Service lines need to be prioritized by their integrity condition from the worst to nominal. Replacements should begin with the worst lead pipes first. Manufacturers and importers have been targeted as well. They are now required to certify that their products meet lead-free requirements.

The EPA has developed an allotment formula to allocate funds for lead service line replacement for states. Each state receives a minimum allotment of 1% of the total amount available to states. There is also EPA help available for LCR implementation in the form of tools and resources. Topics include tier 1 - 3 public notifications, service line inventory development, water quality and tap monitoring, providing public education, corrosion control treatment, small systems, and simultaneous compliance (see https://www.epa.gov/dwreginfo/lead-and-copper-rule-implementation-tools#SLI%20Dev).

The EPA is also working on developing improved lead test requirements in homes. The agency is also going to require utilities to make in-home water filters available where homes repeatedly exceed the action level.

2. **Lead Testing**

   The EPA is updating the sampling methods to better detect lead contamination, including collecting both first and fifth liter samples from taps with lead service lines. The agency is also proposing to lower the allowable lead level in drinking water.

   The current allowable amount of lead in drinking water is 15 parts per billion (ppb), which is considered the "action level" meaning water systems must act if more than 10% of samples exceed this level. However, the EPA states that the maximum contaminant level goal (MCLG) for lead is zero, meaning there is no safe level of lead in drinking water. EPA sets lead level based on the best available science, which shows there is no safe level of exposure to lead.

3. **Lead Public Disclosure & Education**

   The EPA mandates water suppliers like utilities and water companies, disclose to the public places where lead pipes are located. The agency also adamantly recommends public education programs on the dangers of lead exposure and consumption in drinking water.

4. **Water Pipeline Operators (WPOs)**

   Water Pipeline Operators (WPOs) must meet the requirements of DOT and PHMSA.

   - **DOT**

     The DOT Operator Qualification (OQ) rule requires the development and maintenance of a qualification program that identifies covered tasks, establishes training requirements for those tasks, and ensures all personnel performing them adequately.

     WPOs are qualified through an initial evaluation and then periodic re-evaluations. This includes identifying and managing contractors and vendors to ensure they meet the same standards. WPOs must also prepare and follow an operation, maintenance, and emergency manual or plan. Plus, WPOs must do leak surveys. The WPO’s employer is also required to maintain detailed records of employee qualifications, training, evaluations, and any corrective actions taken.

- **PHMSA**
  To meet PHMSA requirements, WPOs must develop and follow a comprehensive Operator Qualification (OQ) program ensuring all personnel performing critical tasks on the pipeline system are adequately trained and qualified, including establishing a covered task list, defining training requirements, and verifying contractor compliance with the program. WPOs must also adhere to specific requirements regarding pipeline integrity assessments, maintenance procedures, emergency response plans, and reporting of incidents related to their water pipeline system.

5. **Water Pollution**

For the EPA, water pollution is also a top priority. About half of U.S. rivers and streams are considered "impaired" due to pollution, according to the EPA and US Geological Survey (USGS). The water is too polluted for treatment and use as drinking water, which is reducing raw water sources.

One contributor is old water pipelines. A significant portion lose treated water due to leaks. Estimates for water loss range from 20% to 50% in North America. The EPA is working to reduce losses by mandating water audits on public water systems, including water pipelines. Water suppliers like utilities must regularly assess their water usage, identify areas of loss, and promptly complete repairs.

XIII. Troubleshooting

Troubleshooting is a process used daily to resolve problems that disrupt business operations in many industries and applications like water supply, distribution, and pipelines. The approach is structured, with step-by-step movements to clearly identify the problem, gather information, establish a theory of probable cause, test that theory, implement a solution, and verify full resolution. All actions are documented throughout the process and progress is tracked.

When the troubleshooting process is done nearly methodically and thoroughly, it identifies the root cause or causes. The approach also determines what is affected, including where, how, and why. Troubleshooting provides full resolution and prevents future situations, issues, and problems. For example, the problem may be a dripping pipe within a pipeline. However, through further investigation more issues may be found in the area like cracked pipes, loose connections, damaged joints, or a device functioning intermittently.

All of these issues have the potential of creating future situations that could compromise water pipeline integrity, use, and water service. Finding and fixing these issues before they fail, which creates a big problem. This makes it possible to avoid interruptions in operations and reduce the risk of water pipeline short or long term shutdowns. It can also lead to faster problem resolution, improved decision-making, cost savings, and enhanced customer satisfaction.

A. Troubleshooting Process

1. **Identify the Problem**

   Clearly define the issue by gathering information about symptoms, error messages, and the context of the problem.

2. **Gather Information**

   Ask relevant questions to understand the issue comprehensively, including when, where, how, and why the problem occurs.

3. **Establish Root Cause**

   Analyze the gathered information to identify the most likely root cause or causes of the problem based on experience and knowledge.

4. **Test the Theory**

   Implement a test to verify if the suspected cause is or causes are indeed the problem.

5. **Plan Action**

   Develop a strategy to address the problem, including potential solutions and steps to implement them.

6. **Implement the Solution**

   Apply the chosen solution and monitor its effectiveness.

7. **Verify Full Functionality**

   Thoroughly test all affected parts, components, sections, and the entire water pipeline to ensure the problem is resolved and no new issues have been introduced.

B. Other Important Considerations

1. Team Rather Than Me

Leverage the knowledge and expertise of all team members by collecting input freely from all involved.

2. Simplify The Problem

Make the problem simpler to solve by breaking complexities into smaller, more manageable parts to isolate the issue.

3. Consider Past Successes

The issue or problem may have been successfully solved in the past. Check past documentation and leverage what has previously worked.

C. Common Water Pipeline Problems

There are several common problems that frequently occur in water pipelines. A sudden spike up of down in water pressure is one of them. Most of the time, problems create signs which are clues for identifying the root cause. Noticing them can speed up the troubleshooting process.

1. Corrosion

All types of pipes used for water pipelines can corrode over time. Metal pipes are more susceptible when made of steel, cast iron, or copper. Corrosion is the gradual break down of pipe material due to chemical reactions between water, pipe material, and the environment. Corrosion in pipes can limit, block, or even stop water flow. Signs that provide clues to corrosion as the cause are:

- Discolored water
- Strange smell and taste
- Regular clogs
- Pipe leaks
- Sudden temperature changes
- Reduced water pressure
- Rust stains

If the known corrosion problem in water pipes is not prevented or promptly addressed, it can lead to pipe failure. It a water pipeline’s pipe fails it can cause damage not only to the pipeline, but the area where it resides as well.

2. Low Water Pressure

The level of water pressure in water pipelines is critical for effective and efficient water movement. However, some issues frequently cause pressure in water pipelines to drop too low. They include clogged pipes due to mineral buildup and corrosion, leaks in the system, or faulty pressure regulator. It can also be caused by water demand exceeding the capacity of the water pipelines.

Signs of low water pressure:

- Weak water flows from faucets
- Dripping faucets
- Unusual pipe noises
- Water draining slowly
- Water temperatures that are inconsistent
- Noticeable leaks

If water pressure remains low in a pipeline it can interrupt water flow. Low pressure can also make it difficult to flush toilets and prevent appliances from working that need high pressure. Plus, it increases the potential for water contamination events from backflow.

3. **High Water Pressure**

Pressure in a water pipeline that is too high can cause pipe damage because of the added force in pipes that pushes the material beyond its limits. High pressure can be caused by malfunctioning pressure regulators, clogged pipes, closed valves, aging pipes, trapped air bubbles, leaks in the system, corrosion within the pipes, sudden changes in water temperature, and a water supply delivering pressure exceeding the system's capacity.

Signs of high pressure:

- Banging or knocking noises in pipes (water hammer)
- Leaking faucets
- Constantly running toilets
- Vibrating pipes
- Sudden bursts of water from faucets
- Noticeable wear and tear on plumbing fixtures

4. **Leaks**

One of the most noticeable pipeline problems is leaks. They can be caused by corrosion, damaged pipe joints, worn-out seals, high water pressure, tree root intrusion, extreme temperature fluctuations, improper installation (incorrect alignment), and clogged pipes.

Signs of leaking pipes:

- Musty odor
- Visible water stains
- Low water pressure
- Wet spots or puddles
- Hissing or dripping sound

A leaking water pipeline can cause significant damage to people, places, and things. Chlorine and other chemicals in drinking water can harm the environment to include soil and groundwater. Plus, the ecosystems where animals live. Water can cause structural damage to buildings due to water infiltration and property damage from flooding. This adds clean up and restoration costs to what is already needed for pipeline operations and maintenance.

XIV. Safety

Water pipeline safety is the plans, practices, procedures, protocols, actions, etc. taken to ensure the safety of a water pipeline. Its purpose is to protect the employees, owner (i.e., utility), property, public and environment. Safety should always be a top consideration during the entire lifespan of a water pipeline. It should start with initial pipeline discussions and continue all the way to the pipeline’s decommissioning and final sealing (end of life).

Safety must be integrated into a water pipeline’s plans, design, construction, and installation. Plus, in the necessary preparatory training of employees. Tracking water pipeline performance and integrity is also critical, which requires inspections, monitoring, and testing.

Moreover, emergency response and preparedness plans and procedures are always ready for execution if an event occurs, such as a natural disaster, water main break, or backflow contamination.

A. Key Areas

1. Plan & Design

- **Route Risk Assessment & Safety Plan**

  A through water pipeline route risk assessment is critical to identify any potential hazards, such as unstable ground, underground utilities, and adverse weather conditions.

  A comprehensive safety plan should be developed and executed to address these risks. It must outline the measures to take that will protect workers. Additional risk assessments should be done at regular intervals, and they must consider changes in factors like soil, surface (i.e., deterioration of ground), elevation, and climate. Adjustments must be made to maintain safety.

- **Design & Materials**

  The design of a water pipeline and selection of parts (i.e., pipes, joints, fittings), should consider the materials approved by federal regulations and standards for use with the quality of water (potable or non-potable) a pipeline will be transported. Plus, the materials properties such as durability and anti-corrosion. For example, water mains are often constructed of plastic, like High-Density Polyethylene (HDPE), which poses less risk of internal corrosion, rust, and sediment buildup, thereby contributing to safety.

  The selection of proper pipe sizing is another important consideration to maintain pressure at a safe level. If pipes are too small, it can cause high water pressure due to increased friction against the pipe walls as the water flows, which can overstress the pipes and lead to damage. If pipes are too large in diameter, it will lead to lower pressure because the fluid has more room to move with less resistance, which will inhibit water flow.

2. Construction, Installation & Commissioning

Before any construction or installation can begin, all workers must be trained in safety and emergency response. This includes all tradespeople that work for the water pipeline owner (i.e., utility), contractors, and subcontractors. While work is underway, all onsite workers must wear Personal Protection Equipment (PPE) for their own personal safety. Depending on the workers' duties, this may include a hard hat, steel-toed boots, safety glasses, and high-visibility clothing such as a reflective vest.

Equipment operators need to be trained in safe operation of equipment. Plus, be altered to work site-specific safety rules, restrictions, and hazards. Areas that may be dangerous for reasons like equipment weight need to be clearly marked with barriers and caution signs to prevent safety breaches that can cause accidents and injuries.

All work, such as excavations, pipe laying, and joint installation, etc., should be completed by licensed tradespeople in the appropriate specialty (i.e., licensed pipelayer for laying pipes). This will reduce the risk of work done incorrectly and ensure it complies with federal regulatory standards, state requirements, national construction and plumbing codes.

3. **Operations & Pipeline Inspections**

To operate a water pipeline legally and safely, the EPA requires frequent inspections and testing at designated intervals. The entire water pipeline must be visually looked at from beginning to end. And imperfections or damage like racked pipes, loose connections, broken seals or leaks must be evaluated. If what is discovered could compromise the pipeline's integrity, it must be promptly repaired or replaced to continue safe operation.

The inspection must include checking pipe interiors for issues such as corrosion (i.e., rust), sediment build up, blockages or clogs. If left unaddressed, these issues can drive water pressure to a high and dangerous level. When pressure is to high it can force pipes to burst. Such an occurrence would risk the safety of anything in the area, including employees and local residents.

Devices such as pressure relief, butterfly, ball, check, gate, and glove valves must also be inspected. They must be in full working order to maintain safe water pipeline operations.

4. **Pipeline Monitoring**

   In water pipeline safety, pressure plays a critical role as excessively high water pressure can significantly increase the risk of pipe breaks and leaks. Excessively low pressure can lead to stagnant water, potential bacterial growth, and inefficient water flow. Therefore, monitoring and managing the level of pressure in a water pipeline is critical to ensure safety.

   Flow rates, temperature fluctuations, and acoustic signals (potential leak indicators) also must be monitored using meters, sensors, and distributed fiber optic sensing technology to pinpoint the location of issues along a pipeline. Changes can indicate potential problems with the integrity of a water pipeline, which can risk safety.

   For example, a change in flow rate can indicate leaks or blockages with a water pipeline. Water temperature fluctuations along a pipeline could indicate issues like ground movement or pipe damage. Leaks can be detected by acoustic monitoring that pick up and recognizes hissing or rushing water.

5. **Pipeline Maintenance**

   Any time a pipe section, individual pipe, components, or part (i.e., joint, fitting) show damage or excessive wear that is visually seen what is broken must be repaired or replaced promptly to maintain integrity for safe operation. The same must be done for equipment like pumps or devices (i.e., pressure relief valve) for ensuring integrity and safety as well.

   Preventative maintenance is critical to maintaining water pipeline safety and staying in operation. Actions should include the following:

   - **Cleaning**

     Cleaning water pipelines thoroughly from the first pipe all the way to the last is a practice that should be done more than annually. The action will prevent issues including buildup, blockages, and clogs that can risk safety and continued operation.

This is especially important when the water pipes are made of material without anti-corrosion properties like galvanized steel. This type of pipe's material is prone to corrosion, like the buildup of rust inside pipes. If not removed, rust can limit, block, or stop water flow. Sediment buildup and foreign matter can cause the issues as well. Therefore, cleaning water pipelines is a must for water pipelines to remain safe and in operation. Cleaning is also very important to keep water quality within safety limits so it will be approved for distribution.

- **Sanitizing**

  Over time, the interior surface of pipes in water pipelines can change from smooth to rough. This can occur for several reasons, including pipe age, material erosion, and extended periods of high pressure. Rough surfaces in pipes tend to collect and hold what passes by in flowing water like bacteria and viruses.

  To keep a water pipeline safe enough to carry drinking water, the pipes must be sanitized more than annually. Any sections or pieces of pipe which cannot have a smooth interior surface restored have to be replaced with new pipe for public safety.

- **Repairs & Replacements**

  Regular, scheduled, preventative, predictive, and manufacturer recommended maintenance are all critical to preserve water pipeline integrity for ensuring safety.

6. **Emergency Response & Preparedness**

   The establishment of emergency plans, workers trained in procedures, and storage in a place where they are readily available are all critical to safe water pipeline operation. All involved must be able to handle issues such as malfunctions or pipe failure, and more serious emergencies like contamination events, power outage, or natural disaster.

XV. Conclusion

Water pipelines are located in all 50 states. They are used daily to deliver *39 billion gallons of water* to homes, businesses, institutions, and public facilities. Nearly all are owned and operated by the water suppliers of public utilities and private water companies.

Water pipelines owned and used by water suppliers must meet federal, state, and local laws and regulations set standards for water pipelines. The requirements pertain to several areas, including design, construction, installation, operation, maintenance, and management. The EPA also develops and publishes drinking water quality standards that specify the Maximum Contaminant Level (MCL) in potable water for over 80 contaminants. What water suppliers use and do to prepare and distribute water must be within compliance with all pertinent laws, regulations, rules, and standards.

Water suppliers are also responsible for ensuring their water pipelines are always reliable, safe, and efficient at transporting water to customers. They must also make sure their water pipelines, work areas, and pipeline locations are always safe for workers and people nearby. Plus, water from the end of treatment to distribution and delivered out of faucets or valves must always be safe. For drinking water to be safe, it must pass testing and score within the potable (drinking) water range. Water distributed for use other than drinking must also be tested score in the non-potable range.

The success of a utility or water company depends on their abilities in overcoming challenges. There will always be issues and problems that unexpectedly surface with water pipelines. A few examples are the failure of a pressure relief valve, water pump that starts working intermittently, or a sudden rise or drop in pressure. How a utility or water company responds to include the actions of water operators will directly affect the outcome.

Finding the root cause of an issue quickly and promptly fixing it brings resolution in less time. It also enables water pipeline owners and operators to avoid the issue turning into a more serious problem that can cause extensive damage, compromise safety, and threaten to halt water operations and service.

There are also effective methods for designing, building, operating, and maintaining a water pipeline. One method is to consider key areas when assessing options. This can lead to better decisions that bring greater outcomes. Examples of areas are the water pipelines intended use, risks, route, design, accessibility, security, safety, and interior pipe environment.

A second method is adding a preparation step to the construction process for a final review and confirmation of plans and details. This extra step is where mistakes are often found. Some decisions are often changed as well as the consideration criteria changes. Considering the most important factors for success in criteria leads to better decisions and outcomes. both time and money. Yet another approach that works is water sourcing, which protects and preserves sources of raw water like lakes and rivers from contaminants like pollution. The method makes sures there will be plenty of water for treatment and distribution to meet demand.

Leak detection is another common problem in water pipelines. Effective detection and management require a method and technology that provide measurements in real-time, that are accurate and of high quality. Therefore, pipeline plans should include an investment in leak detection sensing technology that is more advanced.

Managing every assets in a water pipeline (i.e., individual pipe) is a way to avoid problems like leaks. As parts become worn over time they are replaced before failure occurs. This method reduces the risk of water pipeline operations and water service reliability being threatened. Lack of capacity can also create risk in the same areas. A water supplier needs an effective method that secures enough potable and potable water to always meet demand regardless of fluctuations or emergencies. The amount of capacity needed in water pipelines for future water demand must be estimated and forecasted. If there is not enough, expansion plans need to be developed and executed to ensure capacity and demand are always aligned.

All of these methods along with others covered can improve water pipeline operations. When used, they can improve efficiency and performance, lower risks, increase reliability, prevent problems, and help control costs. Plus, further improvements can come from the information provided about installation, joining, pipe types, monitoring, management, maintenance, and troubleshooting.