Lecture 2
Infrastructure Management System
Water Supply Infrastructure Systems

Dr. Sari Abusharar
The Islamic University of Gaza
Faculty of Engineering
Civil Engineering Department
Graduate Program
Infrastructure Engineering

1ST Semester 2012/2013
Outline of Presentation

- Introduction
- Infrastructure Management Systems
- Building blocks for infrastructure management systems
- Benefits of Infrastructure Management Systems
- Infrastructure Integrity
- Current Integrity of Water, Sewer, and Stormwater Systems
- Water, Sewer, and Stormwater Systems and Services
- Water Supply Infrastructure Systems
If infrastructure is managed well, the benefits will be better service, longer system lives, and lower costs for citizens. The results will be improved water services for all.
Managers and engineers need clear guidelines for life-cycle management of infrastructure systems for water, sewer, and stormwater services.

Managing these systems as business assets will hold costs down and improve performance.

Failure rates will increase as systems age, and capital needs will increase when water, sewer, and stormwater systems need renewal at the same time.
Introduction

Water supply, wastewater, and stormwater are essential public services that require complex and expensive infrastructure systems.

These infrastructure systems require effective care over their life cycles to produce good service and high return on assets.

Without this care, service will suffer and costs will rise; in the worst case, the utility may suffer regulatory sanctions and customers may experience health problems, poor service, and possibly property damage.
Introduction

While water, sewer, and stormwater services use different components, the infrastructure systems are similar, as they involve piping systems, use of water resources, and utility management structures.

Other infrastructure services - such as roads and electric power - have different aspects, but their infrastructure management systems follow similar concepts.

Thus, much of the material in the book applies to all infrastructure systems, especially to water, sewer, and stormwater systems.
Infrastructure Management System

Infrastructure is the set of physical (hard) systems that provides public services.

In water, sewer, and stormwater infrastructure systems, the physical components are pipes, buildings, pumping plants, treatment plants, and other capital-intensive facilities.

Because the infrastructure value of these facilities is responsible for high annual revenues, they are said to be “capital-intensive” services.
Capital intensive refers to a project that requires a great deal of capital to undertake. A project or business that is capital intensive often has much more risk, since a larger investment of cash or tangible assets is required. Generally, many businesses or projects that produce tangible goods require more capital than service businesses.

An Infrastructure Management System is an integrated framework for infrastructure through its life cycle “from the cradle to the grave.”
Note that four lines of organizational activity converge on a common database. As we will discuss later, organizations have always been shaped to some extent by access to information; and with different utility departments using the same data, future management systems will look like this figure.

Data-centered infrastructure management system.
# Infrastructure Management System

<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Improvement Program,</td>
<td>CIP</td>
</tr>
<tr>
<td>Design and Construction,</td>
<td>D&amp;C</td>
</tr>
<tr>
<td>Maintenance Management System,</td>
<td>MMS</td>
</tr>
<tr>
<td>Operations Management System,</td>
<td>OMS</td>
</tr>
<tr>
<td>Asset Management System,</td>
<td>AMS</td>
</tr>
<tr>
<td>Needs Assessment,</td>
<td>NA</td>
</tr>
<tr>
<td>Supervisory Control and Data Acquisition,</td>
<td>SCADA</td>
</tr>
<tr>
<td>American Water Works Association,</td>
<td>AWWA</td>
</tr>
<tr>
<td>Environmental Protection Agency,</td>
<td>EPA</td>
</tr>
<tr>
<td>Safe Drinking Water Act</td>
<td>SDWA</td>
</tr>
<tr>
<td>State Revolving Fund,</td>
<td>SRF</td>
</tr>
</tbody>
</table>
Elements from which to construct an infrastructure management system include the following:

- Capital improvement plan
- Maintenance management system
- Asset management system
- Capital and operating budgets
- Needs assessments
- Inventories

These are not separate, independent processes, but they involve shared activity among the functional parts of organizations, especially planning, finance, operations, and maintenance.
Benefits of Infrastructure Management Systems

The benefits of infrastructure management systems are clear, for example:

When infrastructure works well, society has efficient transportation, safe water, reliable and affordable energy, a clean and attractive environment, and other essential support systems.

When it does not work, people waste hours in traffic, have bad water or no water, lack electricity, and live in unhealthy conditions.

As public works employees know, if infrastructure works well, people take it for granted. If not, they suffer and complain quickly.
Benefits of Infrastructure Management Systems

Infrastructure management systems therefore propose multiple benefits by providing information-based tools to:

- Offer better customer service
- Prepare and manage capital improvement programs
- Control costs for infrastructure management and operation
- Publish and achieve approval for capital improvements
- Guide operations and maintenance practices
- Comply with regulations and improve service
Infrastructure Integrity

Integrity of infrastructure is an integrated indicator that measures the quality of equipment, original construction, and current condition.

The figure shows that integrity produces better reliability, improved service, lower risk, greater safety, improved public health and environmental stewardship, and protection against flood damages.
The relationship between the original quality and the current condition is easy to see.

Well-constructed systems last longer and perform better. Figure 1.3 illustrates the curve that relates condition to time.

In the case of pipelines, replacement may only be needed after many years, and might even be achieved using trenchless technologies.

Treatment plants are usually “works-in-progress,” with renewal going on continually.

The condition curve obviously depends greatly on the quality of original construction.
The curve shows that the condition of a facility will hold up in its early years, but as it ages, more maintenance and upkeep are required.

Restoring the facility to its original condition may require only a little investment in its early years, but later on it takes much more attention — perhaps even replacement.

Figure 1.3 Infrastructure condition curve
Current Integrity of Water, Sewer, and Stormwater Systems

It is difficult to make a general statement about the current integrity of water, sewer, and stormwater infrastructure systems in the United States, but several panels have reported on it.

For example, the National Council on Public Works Improvement used a report card in its 1987 report to inform the public about infrastructure condition. The Council concluded that report cards would be a good vehicle for reporting infrastructure condition because the public understood them from school experiences.
The report card concept was adopted by the American Society of Civil Engineers (ASCE), which issued Infrastructure Report Cards in 1998 and 2001. In 2001, the ASCE gave the nation’s overall infrastructure a “D+,” including “D” for drinking water and wastewater. Stormwater was not a separate category in the Report Card, but is reflected, to some extent, in wastewater.

<table>
<thead>
<tr>
<th>Category</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads:</td>
<td>D+</td>
</tr>
<tr>
<td>Bridges:</td>
<td>C</td>
</tr>
<tr>
<td>Transit:</td>
<td>C-</td>
</tr>
<tr>
<td>Aviation:</td>
<td>D</td>
</tr>
<tr>
<td>Schools:</td>
<td>D-</td>
</tr>
<tr>
<td>Drinking Water:</td>
<td>D</td>
</tr>
<tr>
<td>Wastewater:</td>
<td>D</td>
</tr>
<tr>
<td>Dams:</td>
<td>D</td>
</tr>
<tr>
<td>Solid Waste:</td>
<td>C+</td>
</tr>
<tr>
<td>Hazardous Waste:</td>
<td>D+</td>
</tr>
<tr>
<td>Navigable Waterways:</td>
<td>D+</td>
</tr>
<tr>
<td>Energy:</td>
<td>D+</td>
</tr>
</tbody>
</table>

America’s Infrastructure G.P.A. = D+
Water, Sewer, and Stormwater Systems and Services

Integrated urban water system
Water Supply Infrastructure Systems

Chains and Hubs of Water Utilities

- Environment
- Raw Water Chain
- Hub: Source of Supply
- Hub: Treatment
- Hub: Admin & Support
- Hub: Distribution
- Finished Water Chain
- User
Water Supply Infrastructure Systems

Water supply systems must deliver enough water of high quality at sufficient pressure for domestic, commercial, industrial, and municipal uses.

Needs must be met during peak demand periods and during drought, as well as during periods of average supply and demand.

A percentage of the water is normally unaccounted for through leakage and other losses.

Also, standby water for fire fighting is essential
Data on surface water systems from the American Water Works Association (AWWA) illustrate management parameters that can be measured:

- Percentage of plant source water from lake, reservoir, river, or blended groundwater
- Plant design capacity in millions of gallons per day
- Average-day production in millions of gallons per day
- Peak-day production in millions of gallons per day
- Plant expansions in procurement or construction phase
- Expansions planned within the next 5 years in millions of gallons per day
Data on surface water systems from the AWWA illustrate management parameters that can be measured:

- Pretreatment
- Permanent pilot plant availability
- Average chemical cost for surface water treatment per millions of gallons
- Total costs for residuals treatment and disposal per year
For groundwater, the AWWA reports illustrate management parameters that can be measured:

- Total number of wells
- Number of well fields/clusters
- Number of entry points to the distribution system
- Average-day production across all wells in millions of gallons per day
- Peak-day production across all wells in millions of gallons per day
Water Supply Infrastructure Systems

For groundwater, the AWWA reports illustrate management parameters that can be measured:

- Capacity expansions in procurement or construction phase and expansions planned within the next 5 years
- Surface water effects on groundwater
- Wellhead (the equipment used to maintain surface control of a well) protection program status
- Average chemical cost for groundwater treatment per millions of gallons
- Total costs for residuals treatment and disposal per year
Water Supply Infrastructure Systems

For delivered water, the AWWA reports:

- Annual water production in millions of gallons per year for groundwater, surface water, and finished water purchased from other systems.

- Volume of water delivered annually in millions of gallons for residential, commercial/industrial, municipal government, agricultural, and other types not previously listed.
Water Supply Infrastructure Systems

Water Supply Treatment

Water supply treatment systems vary from none at all to advanced systems.

Depend on quality of source water and planned uses, treatment systems are classified as physical, chemical, and biological.

Treatment systems are normally located in compounds and buildings, and include concrete and steel tanks; filter basins; equipment for pumping, screening, chemical feed, and other mechanical operations; and electronic control systems.

Management of these infrastructure systems requires different approaches from that of underground piping.
Unit treatment processes can be classified by type:

- Pre-sedimentation
- Initial mixing
- Flocculation
- Sedimentation
- Filtration
- Disinfection
- Advanced techniques (to treat against inorganic, organic, and radiological compounds)
Water Supply Infrastructure Systems

Water Supply Treatment

The AWWA’s database includes a more detailed list (selected examples are shown):

• Raw Water Storage/Pre-sedimentation
• Aeration
• Pre- and post-disinfection (Chlorine, Chlorine Dioxide, Ozone, UV Radiation)
• Lime/Soda Ash Softening
• Re-carbonation with CO₂
• In-Line Hydraulic, Mechanical, and Static processes
• Aluminum Salts, Iron Salts
• PH and Alkalinity Adjustment (including for corrosion control)
• Activated Silica, Clays, Anionic Polymers, Cationic Polymers, Nonionic, Granular Activated Carbon, Powdered Activated Carbon, Adsorption, Air Stripping, and Other Treatment Practices
The AWWA describes four types of pipes:

- **Transmission lines**: lines that carry water from source to plant or from plant to distribution system
- **In-plant piping**: piping located in pump stations or treatment plants
- **Distribution mains**: pipelines that distribute water around a community
- **Service (services)**: small-diameter pipes from distribution mains to use points
Water Supply Infrastructure Systems

Arterial-Loop Network

Transmission line
Water Supply Infrastructure Systems
Water supply infrastructure systems
Water Supply Infrastructure Systems

Transmission and distribution infrastructure system

- Major-demand areas should be served by an arterial loop, with high-demand areas served by grid systems without dead ends.

- Critical health or fire-control areas should be connected to two arterial-loop systems wherever possible.

- Minor lines make up the secondary system, which serves fire hydrants and domestic and commercial customers.

- The tree system is not recommended because it has dead ends and is not looped.
Several types of pipe materials are used in transmission and distribution systems.

Design criteria include: strength, durability, corrosion resistance, flow capacity, cost, maintainability, and effect on water quality
Other key aspects of distribution systems include:

• **Tapping:** Pipes must be tapped to connect new services or laterals to existing lines.

• **Valves:** Different kinds of valves are used for different purposes, including shut-off, flow control, and bleeding off of air. Common valve types are gate, butterfly, globe, plug or cone, and ball valve.

• **Hydrants —** Fire hydrants are also important components of distribution systems.
Tapping Bridge

Shut-off valve
Flow control valve

Gate valve

Gate Valve Closed

Gate Valve Opened
Butterfly valve

Globe valve
Water Supply Infrastructure Systems

Transmission and distribution infrastructure system

- Services and meters — These provide for direct water diversion and measurement.

- Pumps — If gravity is insufficient to maintain system pressures and flows, pumping is used.

- Storage — Tanks of different kinds may be used for in-system storage.
meters

pumps
Figure 2.10 Fire hydrant.
(From American Water Works Association)

Figure 2.11 Water tank.
(From American Water Works Association)
The AWWA (American Water Works Association) provides the following data on use of materials in distribution systems

• Pipe material (Asbestos-Cement, Cast-Iron (Unlined), Cast-Iron (Cement-Mortar Lined), Concrete Pressure, Ductile-Iron (Unlined), Ductile-Iron (Cement-Mortar Lined), Fiberglass Reinforced Plastic, Polyethylene (PE), Polyvinyl Chloride (PVC), Steel, Galvanized, Copper, or other types not previously listed) See Table 2.3
### Table 2.3 Pipe Materials Used in Transmission and Distribution Systems

<table>
<thead>
<tr>
<th>Material</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos cement</td>
<td>Used in smaller sizes, easy to handle, might damage easily or deteriorate under aggressive soils.</td>
</tr>
<tr>
<td>Cast iron (ductile, cement-lined)</td>
<td>More cast iron pipes (gray and ductile cast iron pipe) are in use in distribution systems than any other type. They are used in smaller sizes and are strong, easily tapped, and subject to corrosion.</td>
</tr>
<tr>
<td>Concrete, prestressed</td>
<td>Used up to very large sizes, durable, may deteriorate in some soils.</td>
</tr>
<tr>
<td>Concrete, reinforced</td>
<td>Used more for transmission lines than distribution lines. Used up to very large sizes, durable, may deteriorate in some soils.</td>
</tr>
<tr>
<td>Polyvinyl chloride (PVC)</td>
<td>Used in distribution systems. Lightweight. Easy to install and resists corrosion. Care required when handling.</td>
</tr>
<tr>
<td>Steel</td>
<td>Used more for transmission lines than distribution lines. Found in wide range of sizes, up to very large. Adaptable to many conditions, subject to corrosion.</td>
</tr>
</tbody>
</table>
Water Supply Infrastructure Systems

The AWWA provides the following data on use of materials in distribution systems

• **Customer service lines** (Copper pipe, Lead pipe, Polybutylene (PB) pipe, Polyethylene (PE) pipe, Polyvinyl Chloride (PVC) pipe, Steel pipe, Cast-Iron pipe, Galvanized pipe, Asbestos-Cement pipe, or other types not previously listed, and the percentage of lead pipe that is replaced annually)
Copper pipes

Lead pipes

fittings

fittings
Polybutylene (PB) pipe

Lead pipes
PVC pipe

Steel pipe
Cast-Iron pipe

Galvanized pipe
Asbestos-Cement pipe
The AWWA provides the following data on use of materials in distribution systems:

- **Fire service lines** (Ductile-Iron pipe, Polyethylene (PE) pipe, Polyvinyl Chloride (PVC) pipe, Steel pipe, Cast-Iron pipe, Copper pipe, Asbestos-Cement pipe, or other types not previously listed, and the number of dedicated fire service lines)
Water Supply Infrastructure Systems

The AWWA provides the following data on use of materials in distribution systems

Storage facilities (welded steel elevated tanks, welded steel standpipes, welded steel ground storage reservoirs, bolted steel standpipes, bolted steel ground storage reservoirs, composite tanks (concrete supporting an elevated steel tank), conventional reinforced concrete, pre-stressed concrete or types not listed.)

Fire hydrants and storage tanks are important components of distribution systems. In addition, valves, meters, and service connections require regular maintenance to function well.
welded steel elevated tanks

welded steel standpipes
welded steel ground storage reservoirs

bolted steel ground storage reservoirs
bolted steel standpipes
reservoirs

welded steel standpipes
Water Supply Infrastructure Systems

The AWWA provides the following data on use of materials in distribution systems

- Main breaks, hydrants, retention time (data for total number of hydrants, number of main breaks, and average and maximum retention times in the distribution system)
Water Supply Infrastructure Systems

Water supply planning

Demands for water vary during the year and during the day.

Peak hour data fall in the range of 1.5 to 12.0 times the average hourly demand.

Peak day rates fall generally in the range of 1.2 to 4.0 times the average day rate for the year.

Treated system storage will usually be adequate for a few days of use, and raw water storage might be a year’s supply or more, depending on variability of supplies.
Today, there are about 57,000 water supply utilities in the U.S.

Most of the population is served by large systems (309 very large systems of more than 50,000 connections serve 44% of the population), and a large number of small systems serve a much smaller population (35,063 systems with fewer than 500 connections serve 2.3% of the population).
Management organizations for water supply

Most U.S. water supply utilities are city water departments, with private water companies and special-purpose districts rounding out the total number.

The publicly owned companies are usually part of a city department, a separate city department under a water board or water commission, or a separate utility district.
Interest groups working on water supply can include government, industry, health, or environmental organizations.

- American Water Works Association (AWWA)
- Water Services Association (IWSA)
- International Water Association (IWA)
- American Society of Civil Engineers (ASCE)
- Inter-American Association of Sanitary Engineers (AIDIS)
- American Society of Plumbing Engineers (ASPE)
- Association of Metropolitan Water Agencies (AMWA)
- Association of State Drinking Water Officials (ASDWO)
Trends in water supply systems

As population increases and the attendant environmental water needs are recognized, it becomes more difficult to find new, untapped sources of supply.

For this reason, a number of innovative approaches are used to develop water.

These include the following:
Water Supply Infrastructure Systems

Trends in water supply systems

• Dual use of water where reclaimed and impaired waters are used for non-potable applications for example:

• Conservation systems, where “new” sources are created by saving water such as?

• Innovative storage, such as aquifer–storage–recovery (ASR) systems

• Conjunctive use, where water from different sources, such as surface and groundwater, are managed jointly and perhaps blended

• Re-use, in which wastewater is treated and used again.

• Point-of-use treatment systems

• Bottled water
Future Trends in the Water Supply Industry

• As the population grows, use/capita will drop.
• Environmental pressures will increase; within 20 years, 30% of species will be threatened or endangered.
• Human Resources will continue to be a big challenge.
• Desalting will improve.
• Farmland will disappear.
• Global warming will be a factor.
Unresolved issues in the water supply industry are summarized periodically. Some that recur are:

- Funding for capital and O&M
- Public health concerns and health effects
- Access to water and water rights
- Disinfection practices and issues
- Public attitudes and political issues
- Protecting watersheds and surface water quality
- Preparedness for emergencies and disasters
- Managing small water systems
- Bacterial re-growth in distribution systems
- Sludge disposal practices
- Unaccounted-for water
Future water management

- Rising rates
- Stronger enforcement of regulations
- Broader regulatory focus (NPS) and tightening regulations
- Increasing privatization and outsourcing
- Greater water re-use
- More and better water information
- Continuing industry consolidation
- New water technologies
- Conservation and more efficient usage
Water Supply Infrastructure Systems

Future water management

• More innovation (trading, wheeling, water plus energy utilities)
• Growth in the U.S.
• Massive urbanization in developing countries
• Greater use of information technology
• Alternative sources of drinking water
• Focus on disaster preparedness and security
• New financing mechanisms
• Operating requirements for complex systems and plants