Modeling disruption and dynamic response of water/sewage line networks

Sifat Ferdousi

June 24, 2016

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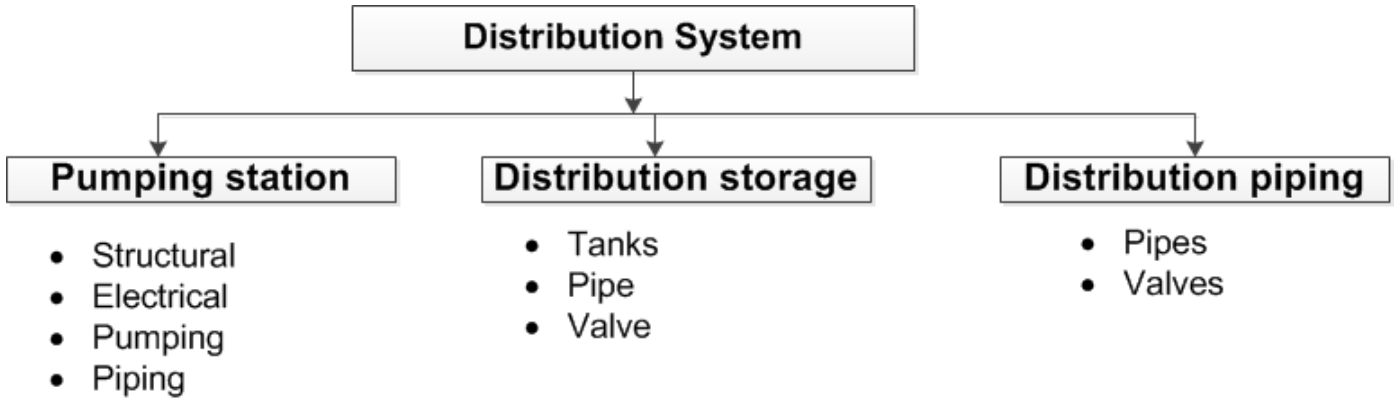
Water distribution network

- A distribution system is a network of pipes, pumps and storage tanks used to **deliver drinking water** to communities.

Components of Water distribution system:



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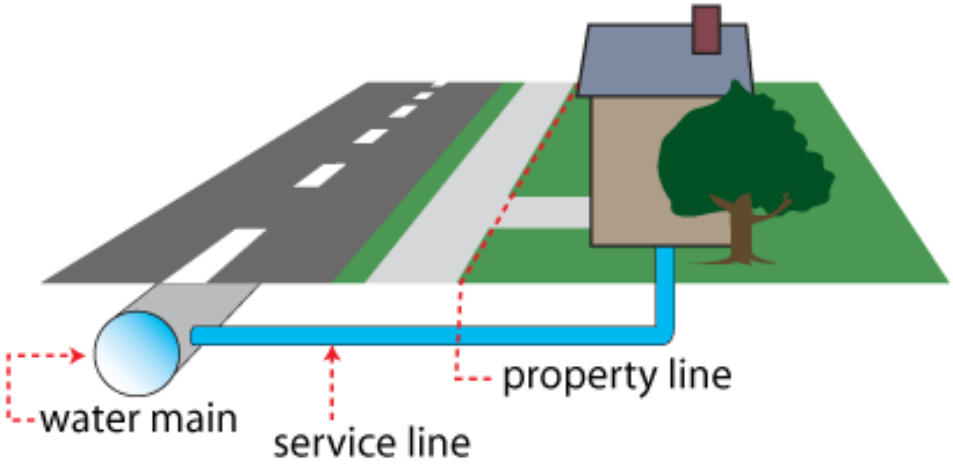
Distribution network:

- Primary or Main Pipeline: Main pipeline that carries water from pumping station or storage tank to the distribution district.
- Service Pipeline: Service line that connects the main and small distribution pipeline (connects to individual home or for a small grid).
- Water distribution systems are generally laid out so that any customer can fed from at least two directions.
- More reliability can be increased by installing more loops, isolation valves, standby pumps, etc.



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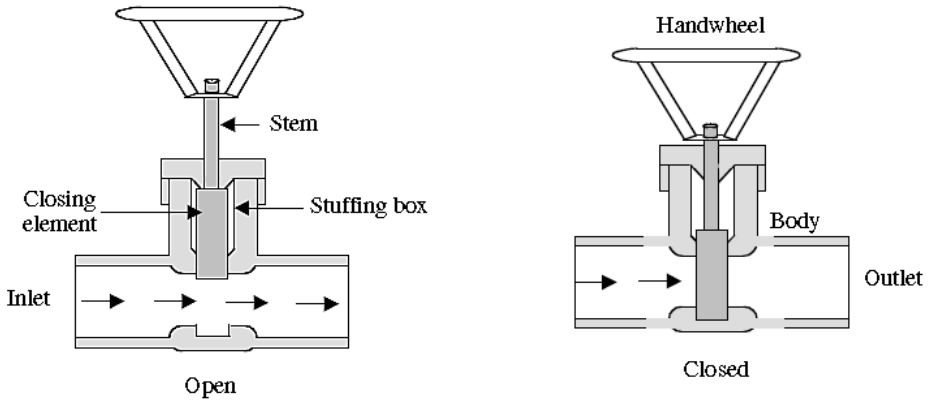
- Valves are commonly used for isolating a section of pipeline for maintenance or repairs, controlling the flow rate, releasing air, and preventing backwater flow.



- Isolation Valves (shutoff valve): Isolation valves are placed into the system to isolate a portion of the system for repair, inspection, or maintenance. Isolation valves are normally installed at junctions. The normal ''rule of thumb" for how many valves to install at a junction is one less valve than there are legs at the junctions.

Distribution Layout

Dead end system or branch system

- Suitable for small communities
- Shorter pipe lengths and easy to lay pipes
- Less shut-off valves
- Cheap and simple and expanded easily
- Results in dead ends, and therefore it prevents circulation of water
- Problematic if a pipe is damaged

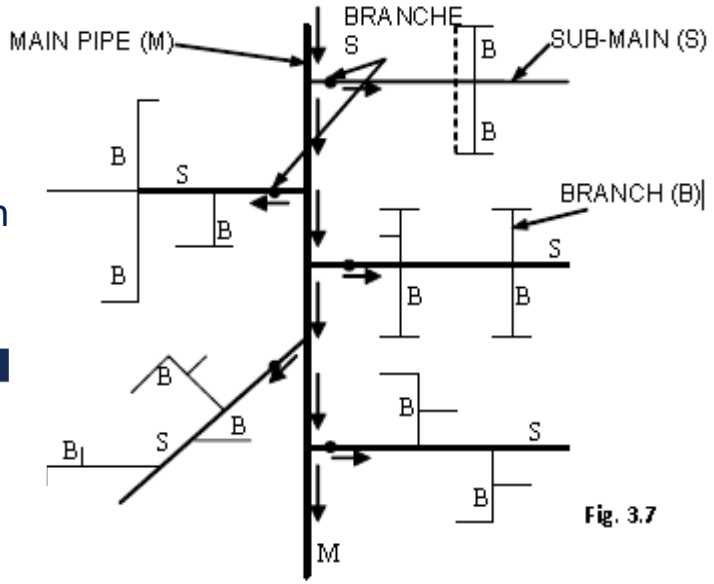
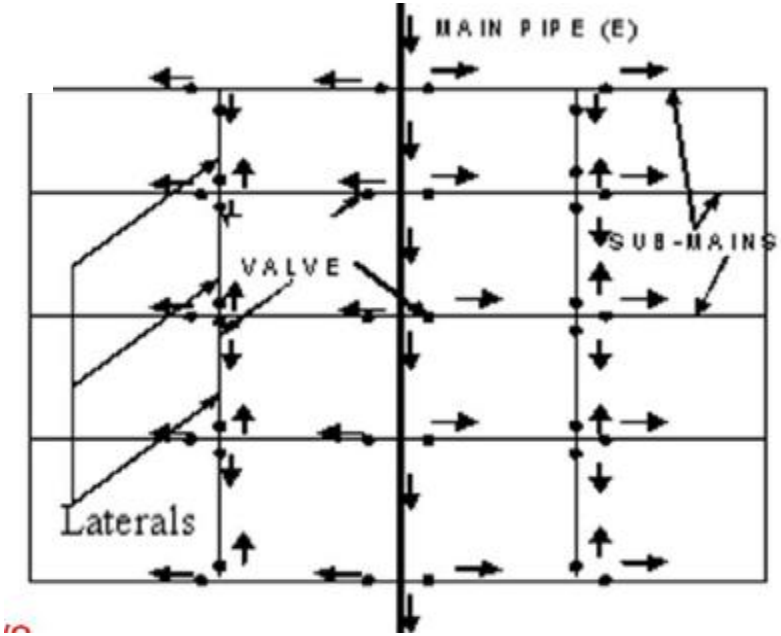


Fig. 3.7

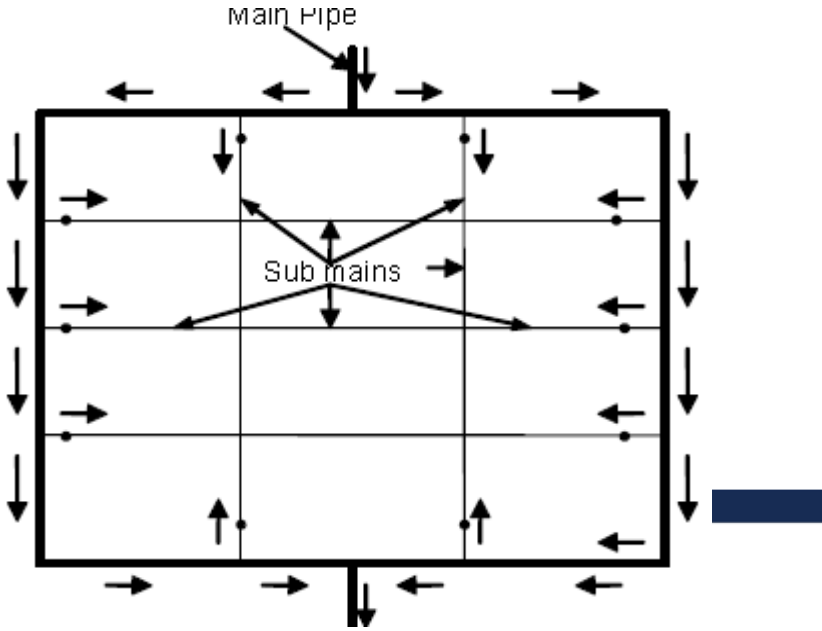
Gridiron system

- Discharge, friction loss and pipe size are less
- Not problematic if a pipe is damaged
- No dead ends, and therefore it allows circulation of water
- Good for fire fighting
- More pipelines and shut-off valves
- High cost of construction
- Design is difficult and expensive



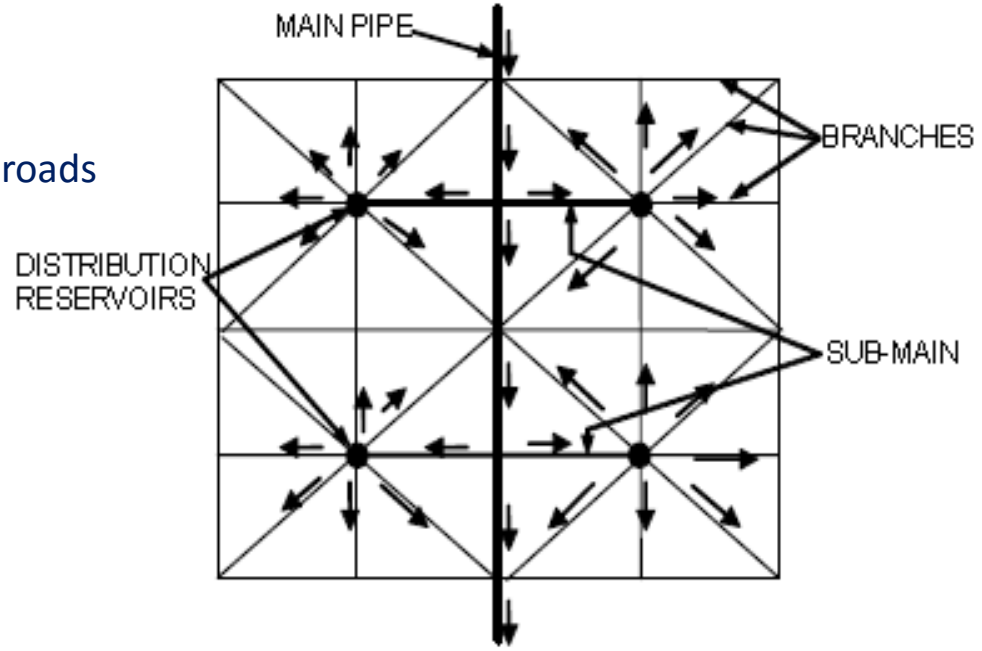
Ring system

- Closed ring, circular or rectangular
- Suitable for well-planned towns and cities
- Generally at high demand areas
- Not problematic if a pipe is damaged
- No dead ends, so it allows circulation of water
- Good for fire fighting
- More pipelines and shut-off valves
- High cost of construction
- Design is difficult and expensive



Radial system

- For city or a town having a system of radial roads emerging from different centers
- Distribution reservoirs at these centers
- Ensures high pressure and efficient water distribution



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Terrorist threat

- Our distribution systems are vulnerable to disruption and contamination by potential terrorist or malicious acts.
  - Such attack can cause substantial damage and could result in mass casualties.
  - Such attack require low level of technical knowledge and low cost materials are needed for such an operation.
  - Many parts of the water supply networks are not capable of being hardened in a physical mode with locks and fences due to their widespread geographic footprint and many access points.
  - Water is vulnerable to various types of attack from a denial of service by blowing up supply lines to an intentional contamination event.

The provision of drinking water to homes is a complex process that involves many steps. All of these steps are to some degree vulnerable to compromise by terrorist acts.

"The Terrorist Threat to Water and Technology's Role in Safeguarding Supplies" by Dan Kroll, World Federation of Scientists 45th Session of the International Seminars on Planetary Emergencies, 2012

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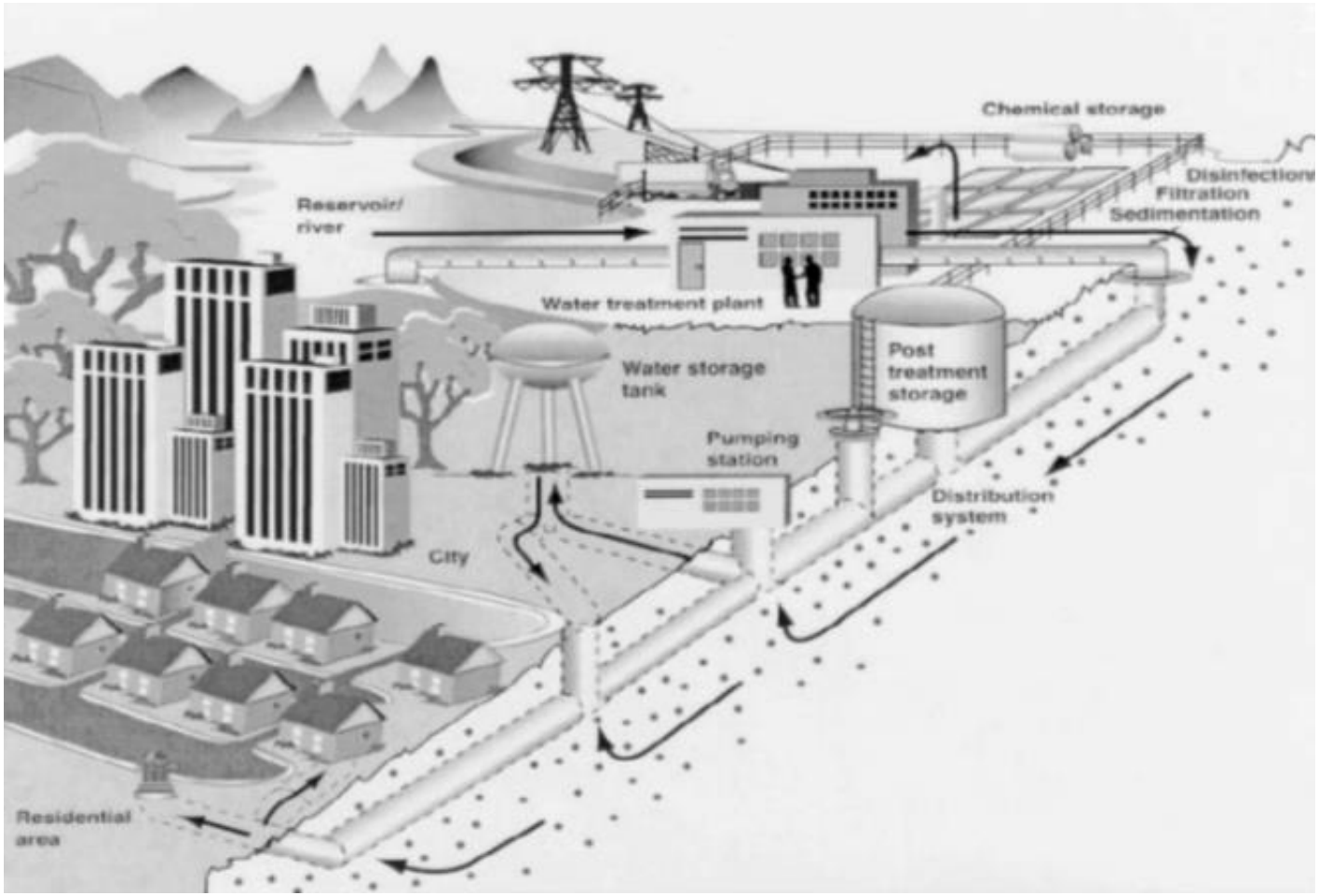
Vulnerability

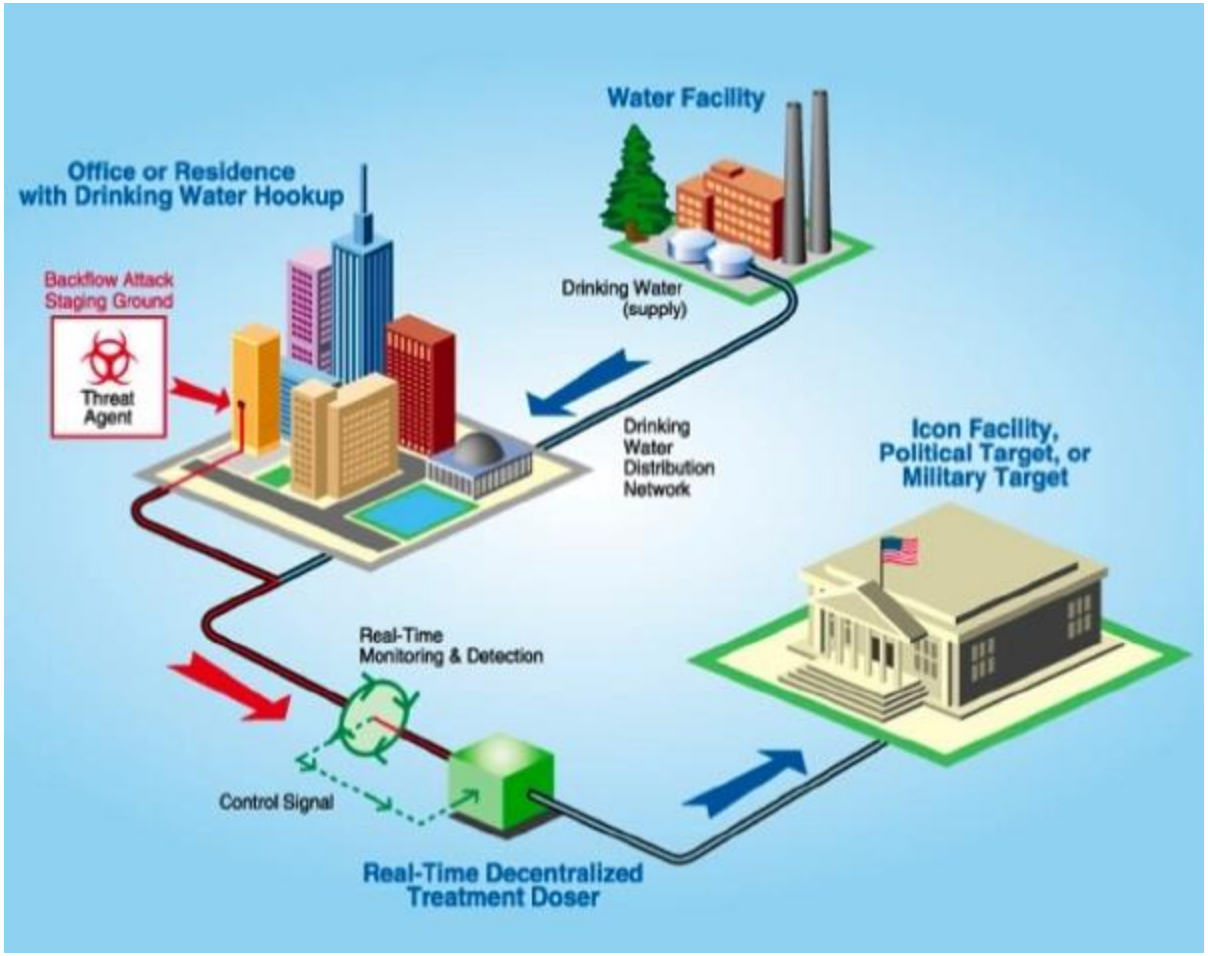


- While **source waters** are usually not vulnerable to physical attack, they are vulnerable to contamination.
- **Untreated water storage** includes facilities such as dams, reservoirs, and holding tanks. They vary dramatically in size and tend to be more closely watched than source waters making them a little harder to access.
- In most cases, the **treatment plant** represents the last barrier between natural, accidental, or deliberate contamination and the final end user. It is also the final point where continual routine monitoring of the chemical and physical characteristics of the water occurs. They offer terrorists many opportunities to inflict damage (ease of introducing chemicals and the decreased levels of dilution) – this could even be accomplished remotely via hacking into the plants Supervisory Control and Data Acquisition (SCADA) system.

- **Finished water holding sites**, represented by water towers and standpipes, are also locations with some degree of physical security. These tanks are post treatment plant, and if the residual disinfectant barrier is breached, there is little opportunity for contaminant neutralization before the water reaches the end user.

- **The distribution system** is the network of pipes, valves, pumps stations and other accoutrements that move the water from the treatment plant to the end user. It is widely recognized as the most vulnerable component of the water supply network.

- Backflow Attacks
  - A backflow attack occurs when a pump is used to overcome the pressure gradient that is present in the distribution system's pipes. After the pressure gradient present in the system has been overcome and a contaminant introduced, siphoning effects act to pull the contaminant into the flowing system. Once the contaminant is present in the pipes, the normal movement of water in the system acts to disseminate the contaminant throughout the network affecting areas surrounding the introduction point. The introduction point can be anywhere in the system such as a fire hydrant, commercial building, or residence



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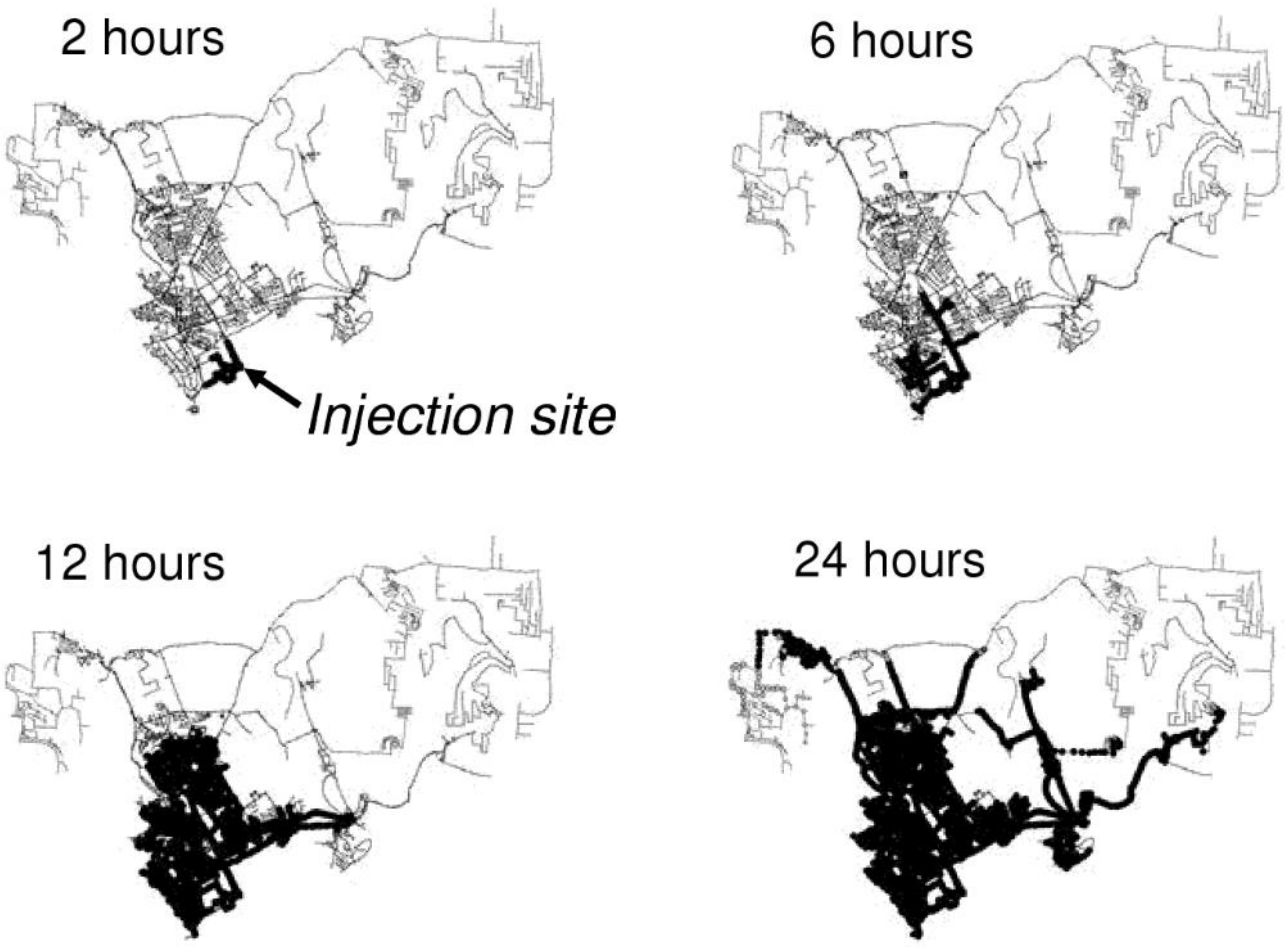
"Examining water distribution system vulnerabilities" by Dan Kroll, www.waterworld.com, 2010



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Monitoring as a means of detecting attacks

- Water quality monitoring
- Toxicity monitoring
- Multi-parameter Monitoring – big data analysis

Wastewater treatment

- Less attention has been focused on protecting wastewater treatment facilities than drinking water systems, perhaps because destruction of them probably represents more of an environmental threat (i.e., by release of untreated sewage) than direct threat to life or public welfare. Vulnerabilities do exist, however. Large underground collector sewers could be accessed by terrorist groups for purposes of placing destructive devices beneath buildings or city streets. Damage to a wastewater facility prevents water from being treated and can impact downriver water intakes. Destruction of containers that hold large amounts of chemicals at treatment plants could result in release of toxic chemical agents, such as chlorine gas.

"Terrorism and Security Issues Facing the Water Infrastructure Sector", CRS report for Congress, 2003