Case Study 4. Block Distribution System for Equitable, Efficient and Resilient Distribution: Yokohama City and Fukuoka City

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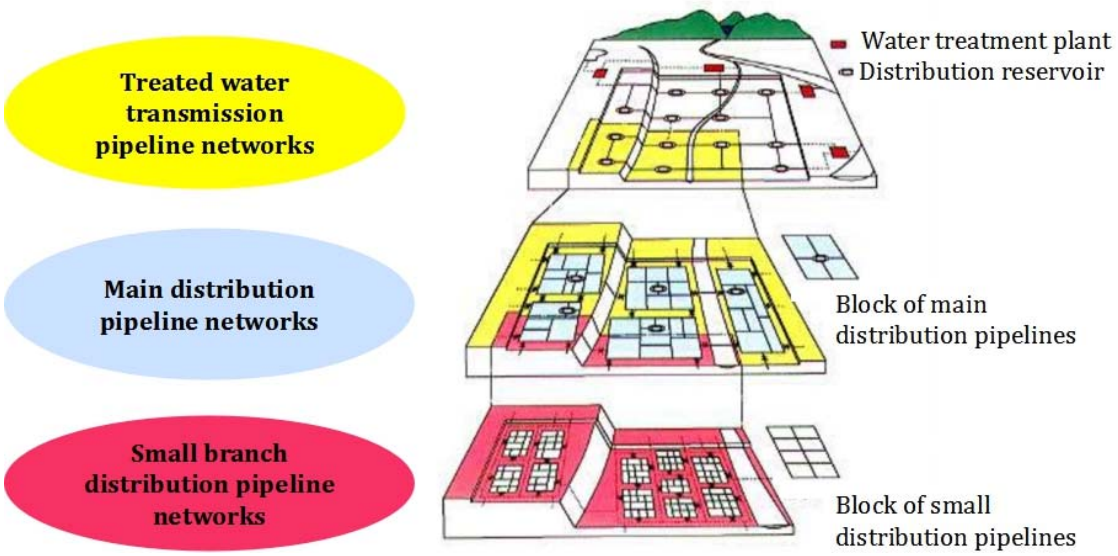
1. Introduction

The block distribution system is commonly used in Japan. This module explains the development and management of the system, with examples of Yokohama and Fukuoka City.



Source: The Bureau of Waterworks, Tokyo Metropolitan Government, https://www.waterworks.metro.tokyo.jp/suidojigyo/torikumi/kadai/step21/05.html

Figure 1. Conceptual Diagram of Treated Water Transmission and Distribution System

2. Block Distribution System (BDS)

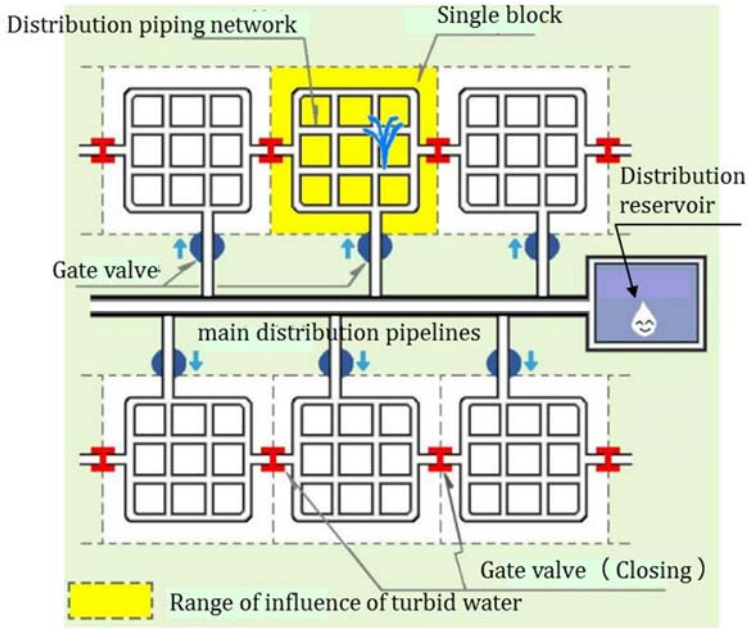
(1) General Features

The advantages of the “block distribution system” include: (1) ability to maintain optimal water pressure in distribution pipelines, (2) ability to measure flow in small areas for early detection of abnormalities, (3) ability to detect broken pipes, and (4) ability to make quick adjustments to the distribution route to provide backup supply.

Wide supply area may present problems such as (1) loss of pressure from friction along the distribution line, (2) uneven pressure and volume caused by elevation differences, and (3) large area can be affected in case of a pipeline accident. There has to be enough pressure to reach the highest elevation. In a supply area where there is big elevation difference, pumping loss will occur. The Block Distribution System (BDS) attempts to deal with these problems by partitioning the distribution network into controllable size.

The distribution network system which is like BDS but has different concept is District Metered Area (DMA). The water supply volume in each DMA is measured and managed using flow meters. Both DMA and BDS deal with partitioned water distribution network. While the aim of DMA is to control and manage leakages, the BDS, water in distribution pipelines can be (1) maintained at optimal pressure, (2) any unusual flow pattern can be detected quickly using flow meter, (3) location of broken pipes can be detected easily and (4) the problem area can be isolated for repair and quick adjustments can be made to the distribution route to provide backup supply.

The block distribution system can be designed according to the purpose it serves. Large blocks deal with water flow between water sources, treatment plants, and other distribution areas. Small blocks can be set up within a large block for switching the distribution route during network maintenance. Utilities can design the block size to match the available budget or the timing of introducing BDS.



Source: Sapporo City

Figure 2. Typical Arrangement of a Block Distribution

(2) Background and History

The block distribution system was initially introduced to reorganize pipeline networks that became difficult to manage because they were installed at various times and not based on well-coordinated plans. The block distribution system improves distribution control and reduces water leakage.

The block distribution system was introduced for various reasons. Yokohama City Waterworks was the first to introduce the system to reorganize the tangled web of pipeline networks that were not distributing water effectively. Fukuoka City adopted the system to improve water source management and supply operation to deal with severe droughts. Niigata City used it to localize water service suspension when liquefaction occurs during earthquakes. Block distribution helped Sendai City and Kobe City equalize water pressure in distribution networks which have to cover supply areas with big differences in elevation.

(3) Design

The block distribution system is designed with consideration of the maximum distribution volume, topographic and geographic characteristics of the area, and locations of distribution mains and reservoirs.

A block distribution system can have different size blocks. There is no standard definition for large, medium or small blocks. Each utility defines the sizes based on its own operations and not all utilities separate their networks into three sizes. The large block usually consists of a reservoir with a distribution main. Medium or small blocks are segmented large blocks, which consist of branch distribution pipelines.

The system is designed to accommodate the maximum distribution volume. Demarcation of blocks takes into consideration of topographic and geographic features, and where distribution mains and reservoirs are located. Medium or small blocks are designed to modulate the distribution pressure and volume according to the elevation of the area. It is important to improve reliability of service by developing connection pipes of distribution main for large blocks to secure backup function of the system and making 2 to 3 inlets from distribution main for medium and small blocks.

As prices of sensors and communications infrastructure become cheaper with further innovations, the block distribution system will become more universal. It will become easier to introduce advanced systems with distribution control and leakage detection, used in Fukuoka City.

3. Case 1: Block Distribution System in Yokohama City

Yokohama City was the first to introduce the block distribution system in Japan. The city had to drastically improve the poorly organized network when it began to receive bulk water supply. Its system is programmed to localize service suspensions and manage backup supply.

(1) Background and Purpose

The block distribution system in Yokohama City was built to reorganize the old patchwork of pipelines to receive Bulk Water Supply from Kanagawa Water Supply Authority.

The catalyst for the introduction of block distribution system in Yokohama City was the establishment of Kanagawa Water Supply Authority in 1968. At that time, water supply facilities in Yokohama City only had funds for the expansion of raw water transmission facilities and water treatment facilities. Without adequate budget, maintenance and improvement of water distribution pipelines and pumping stations were implemented in an ad hoc manner. The network was poorly organized. Apart from experienced senior staff, no one was familiar with how far or how much water was distributed from each reservoir, or the location of pipelines and connections.

When the city planned to increase the water supply volume by taking water from the Kanagawa Water Supply Authority, it had to know the distribution capacity and routes of the pipeline network. City-wide surveys to determine the volume of water used and distributed revealed that water distribution condition such as water pressure, water flow and pipe size varied and inconsistent with water consumption.

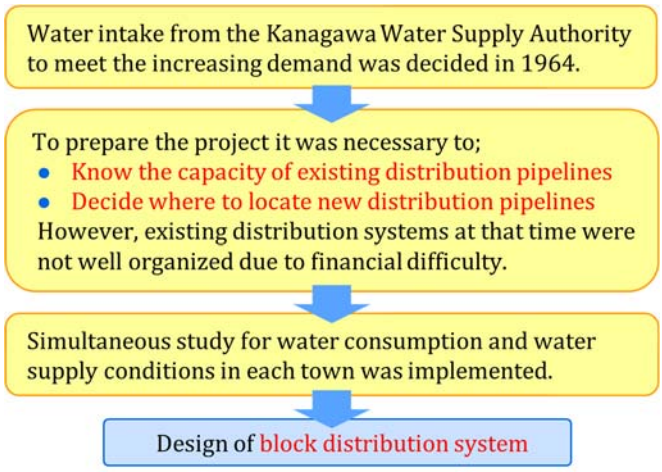
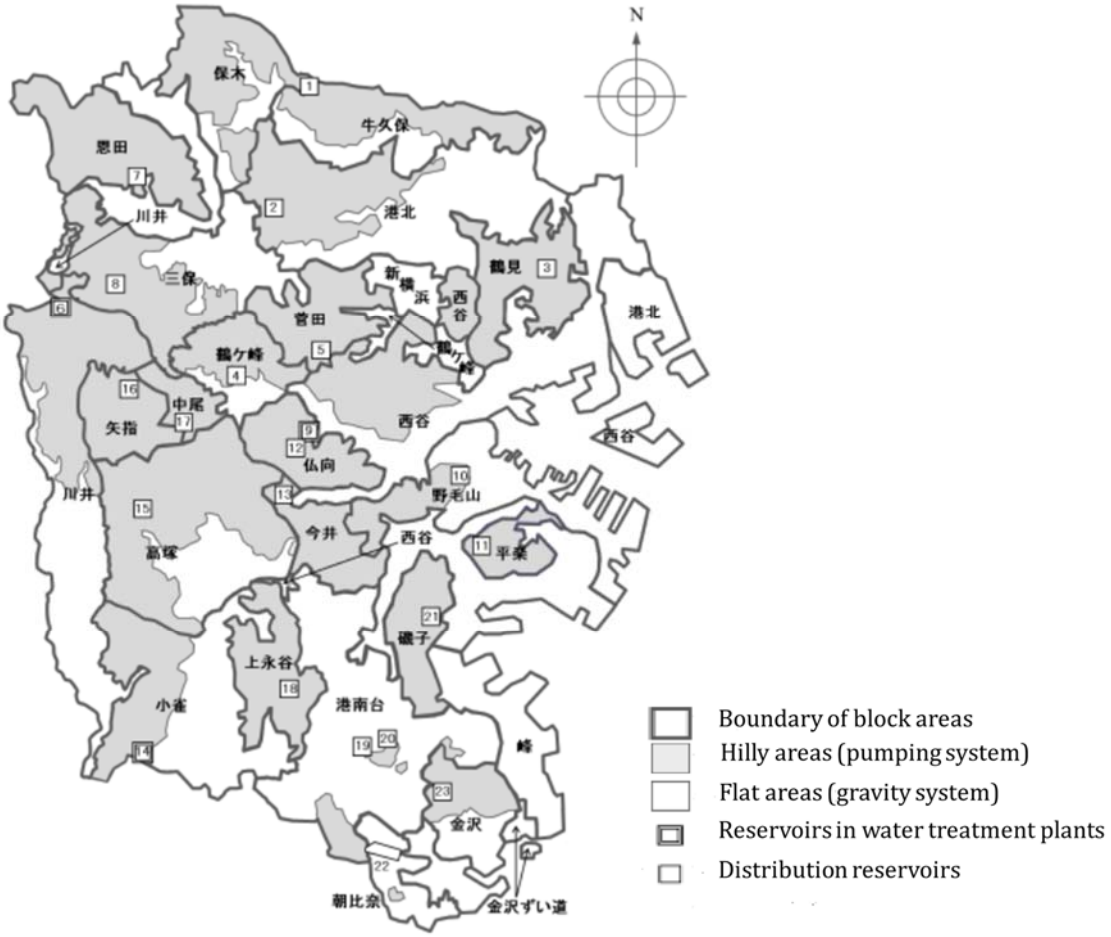


Figure 3. History of Introduction of Block Distribution System in Yokohama City

The block distribution system was introduced to improve these conditions. The area supplied by one distribution reservoir was set as one distribution block. A medium size block consisted of a pumping station. A small block was defined by a certain range of pressure and number of households served, with consideration of the elevation of the area. The system was designed

with computer control. The goals were to (1) expand the distribution network to distribute water from the Kanagawa Water Supply Authority; (2) prepare for the construction of distribution reservoirs to meet rapidly increasing demand, (3) systematize distribution flow by integration of existing pump stations and establishment of pressurized blocks and natural gravity flow blocks, and (4) introduce intensive remote control system with computers at a newly-constructed water distribution management center

The proposal to introduce the block distribution system was met with concerns for high construction cost and the need to raise tariffs. The initial reservation disappeared when the benefits (of better water pressure control and demand allocation, ease of pipeline repairs after accidental damage, and cross connections) became clear.



Source: Yokohama Waterworks Bureau,

http://www.city.yokohama.lg.jp/suidou/os/suidou-suishitsu/suidou/haisui.html

Figure 4. Block Distribution System in Yokohama City

(2) Benefits

The block distribution system improved management of the distribution network and significantly reduced water service interruption in the event of an accident.

The block distribution system is designed with consideration of elevation to achieve proper pressure control. The control valves adjust the distribution volume and easily isolate the problem area when an accident occurs. The advanced mapping system organizes pipeline information and enables appropriate management response to each incidence within the small block.

Block distribution together with advanced mapping provides a clear picture of the network and its operation. This makes daily operation and maintenance, response to accidents, and implementation of system upgrades much easier to manage. Damage to the water source or distribution pipelines can be repaired quickly, dramatically shortening service down time. In 1986, heavy snow damaged a high-voltage cable, causing power outage and water service suspension. Water services were quickly restored thanks to the block distribution system.

Installing a large number of instruments such as flow meters on numerous pipelines and at distribution reservoirs is complicated and expensive. The block distribution system requires fewer instruments to capture the status of the entire water distribution system.

4. Case 2: Block Distribution System in Fukuoka City

Fukuoka City is a regional hub with a population of around 1.5 million and has a network of water distribution pipeline of about 4,000 km. The block system was formed with mutual back up among distribution systems connected to different treatment plants by bridging distribution mains and remote controlling adjustable valves, which enables alternation of supply route. In addition, leakage detection in each block was enabled by isolating distribution networks. Fukuoka City experiences severe droughts and must minimize water leakage. The block distribution system in Fukuoka City contributes to efficient water supply operation and leakage reduction through water pressure control.

(1) Background and Purpose

After the severe drought in 1978, Fukuoka City was determined to improve water distribution so that all households at any elevation could receive water supply under steady pressure. The distribution system would manage the water supply from different water sources and treatment plants efficiently. The Water Management Center was established in 1986.

Fukuoka City has poor water resources and is vulnerable to drought. During the 287 day water restriction caused by severe drought in 1978, the City dedicated a workforce of 34,200 for valve exercising and other tasks to maintain distribution control. There were many areas where tap water ran slow or stopped. The experience prompted the City to make efforts in not only water resource development but also effective water distribution management, water conservation, and in developing a labor-saving distribution network. The new water distribution control system was constructed during FY 1979 to 1980 and started to operate in 1981 when the Water Management Center was established.

Photo 1. Water Trucks Dispatched during the Severe Drought in 1978

Photo 2. Parched Dam during Period of Abnormally Low Rainfall in 1978

The Fukuoka City Waterworks Bureau recognized that block distribution system was essential for effective distribution control. The city added connecting and branching pipes to the existing networks. The supply area was divided into 20 blocks with 6 distribution reservoirs. The division is based on location of distribution mains, main roads, rivers, and railways,

elevation of terrain, and segmentation under city planning. The initial plan to divide the area into 50 blocks according to the number of households, was changed to a layout of 21 blocks according to topography and elevation.

123 electronic control valves were installed on distribution mains and connecting points of each block. The system was equipped with 99 pressure gauges and 47 flow meters for remote monitoring and control from the Water Management Center.

Purposes of Water Management Center are: (1) adjust flow rate and determine allocation from different water treatment plants, (2) control water pressure to reduce leakage, (3) exercise valves during drought to minimize valve operations, (4) monitor for abnormal conditions 24 hours a day and take immediate corrective actions by remote control, and (5) collect and analyze data to improve operation efficiency. The Center's achievements include: (1) effective use of water sources by matching the output from different treatment plants to each water source's situation, (2) stable water supply for the entire city regardless of topographic elevation especially during droughts, no water stoppages at high elevations and end-of-pipe areas, and (3) significant reduction of serious leakages by being able to detect large scale leakages rapidly with continuous monitoring of water pressure and flow. More equipment was installed as the network was expanded in response to increasing water demand: 180 electronic control valves, 124 pressure gauges, and 83 flow meters as of 2016.

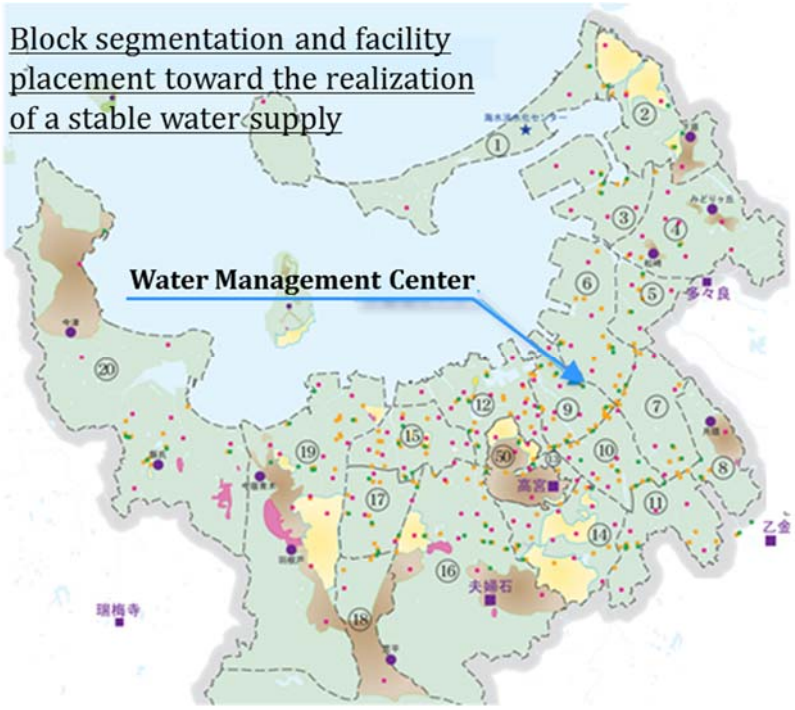


Figure 5. Division of 21 Blocks in Fukuoka City

The electronic control valves are operated manually from the Water Management Center. An alert system notifies staff of troubles of pressure and volume as well as breakdown of valves. Distribution can be adjusted instantaneously by adjusting the valves in response to water demand. The control valves are tested annually to ensure that they operate reliably with rare breaking downs. The valves are controlled electronically by skilled and experienced operators. It is important to develop and maintain this expertise for the long term to ensure continuous successful distribution control.

Photo 3. Fukuoka City Water Management Center, taken on April 19, 2016

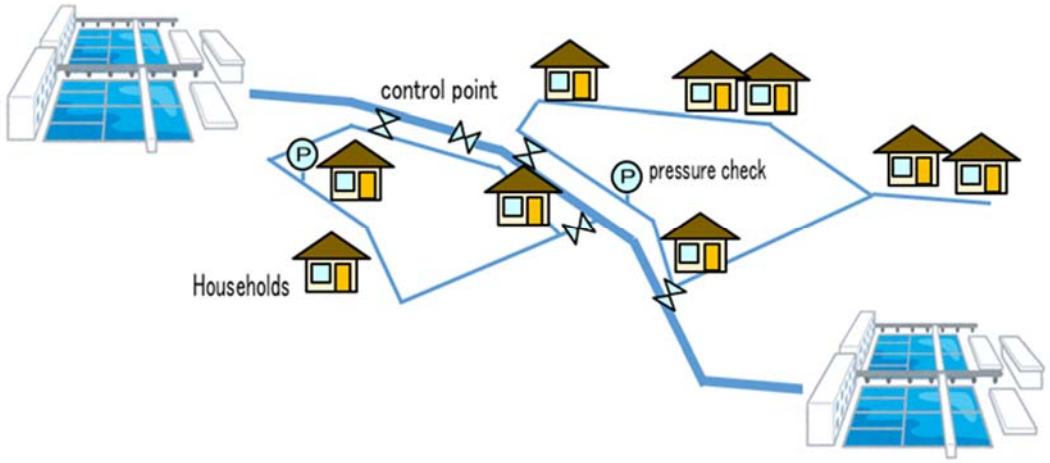
(2) Benefits

In Fukuoka City, block distribution system is effective in controlling water pressure, reducing leakage and saving precious water resources.

The block distribution system contributes to an estimated saving of 4,000 to 5,000 m^3/day. The precise pressure control minimizes excess water pressure at each block unit, controls water volume distributed daily according to each treatment plant output. The system reduced leakage accidents by 30% and brought the leakage rate from 13% (in 1980) to 2.3% (in 2014). The reduced leakage is also a result of replacement of aged distribution pipes.

The efficient regulation of distribution with mutual backup between treatment plants is credited with no water shutdown or pressure loss during the 1994 drought. Manual control of valves can be handled by half number of operators. Similarly when heavy rainfall causes

distribution stoppage at one treatment plant, water shutdown can be avoided by backup supply from another plant. The backup feature is also useful when accidents occur and during construction and maintenance of distribution mains.



Reduction of Leakage	Minimization of service suspension
• Reduced leakage volume 4,000-5,000 m^3/day • Lowered leakage incidents 30%	• Mutual back up between treatment plants when distribution is disrupted by accidents, construction, or repair at a certain point

Figure 6. Impacts of the Block Distribution System in Fukuoka

5. Lessons Learned

The following Japanese experience could be useful for other countries.

- **(Block Distribution System)** The system is used by most Japanese water utilities. It is very effective in reducing leakage and maintaining stable supply by: (1) optimizing water pressure in distribution pipelines, (2) measuring flows in small areas to allow early detection of abnormal conditions, (3) identifying the location of broken pipes quickly, and (4) allowing operators to make immediate adjustments to the distribution route and switch to a backup supply.

- **(Large and Small Blocks)** Large blocks allow switching between water sources and water treatment plants. Small blocks are discrete areas within a large block for switching distribution route during maintenance of the network.

- **(Yokohama System)** The block distribution system in Yokohama City drastically modified the disorganized water supply network and improved operation and maintenance by introducing a computerized system. The system makes it easier to identify broken distribution mains and provide a backup supply to minimize suspension of service.

- **(Fukuoka System)** The block distribution system in Fukuoka City established to deal with severe droughts is characterized by the advanced linkage between water sources and distribution reservoirs, switching of water sources by remote control of valve operation, and reduction of leakage in block units. The block system together with the Water Management Center and advanced mapping system is very effective in leakage reduction.

- **(Topographic Considerations)** The implementation of block distribution systems based on topographical characteristics (including the location of water sources and treatment plants) contributes to efficient water supply operations.