Improving Operation of Sewerage Facilities on Basis of Real-time Stormwater Information

Japan Institute of Wastewater Engineering Technology
Masataka Ikeda

METAWATER Co., Ltd.
Shinichiro Oki
Kazunori Matsumoto
Contents

1. Rainfall Trends and Flood Damage in Japan
2. Background and Objectives of Research and Development
3. Outline of the Real-Time Urban Drainage Management System
4. Effects of Introduction
5. Case Study Area
6. Modeling
7. Calibration Results
8. Improving Operation for Drainage pump
9. Improving Operation for Energy Conservation
10. Cost effect
11. Accuracy of the Forecast rainfall data
12. Summary and Tasks Ahead
1. Rainfall Trends and Flood Damage in Japan

Rainfalls with high intensity increasing annually.

No. of occurrences of rainfall over 50mm/h

- 1977: 200 times on average
- 1987: 234 times on average
- 1997: 313 times on average

Flood damage increasing in urban areas: 120 billion yen/year (Average for 1994 - 2003)

Source: Ministry of Land, Infrastructure, Transport and Tourism

No. of occurrences of rainfall over 100mm/h

- 1977: 2.2 times on average
- 1987: 2.4 times on average
- 1997: 5.1 times on average
Background:
The MLIT (Ministry of Land, Infrastructure, Transport and Tourism) has shifted to a policy using public support and self-help for structural and **non-structural measures against flood**.

**METAWATER** and **Japan Institute of Wastewater Engineering Technology**
Starting joint research for development of system for flood countermeasures

Objectives: For Administrator of urban stormwater
(1) **Effective operation of facilities for CSO control and flood countermeasures**
(2) Provide information to enable residents to reduce damage by themselves
3. Real-Time Urban Drainage Management System

Administrator determine the operation based on the Information

- Data Management System
- Real-time Runoff Analysis System
- Information Transmission System

Input data
- Radar (rainfall forecast)
- Rain gauge
- Water Level / Flow Meter
- Pumping Station
- Gate

Collecting data
- Measured /forecasts data
- Analytical value

Measured data
- Distributed Model

Data distribution
- Operation switch
  - CSO control
  - Flood control

Administrator judgment
- Normal operation
- Operation at high-water level
- Operation with pump
- Interceptor

Hydrologic / Hydraulic model

Administrator determine the operation based on the Information
Realization of efficient urban stormwater management!

- Measures against floods
- CSO control
- Energy reduction
5. Case Study Area

- Radar 1km Grid
- Rain Gauge
- Water Level/Flow
- Water flows
- Pumping Station

Combined system Area: 240ha
Field Area: 530ha
Separate system Area: 290ha

Stormwater Storage Pipe
6. Modeling

- 640 Nodes
- 250mm (Minimum Pipe size)
- Rainfall loss & double liner reservoir model
- 1D unsteady flow model
- 2D unsteady flow model
- Ground water infiltration model

Real time pump ON/OFF data

Storage pipe A
Storage pipe B
Storage pipe C

A pumping station
B pumping station
C pumping station

Mountain
Paddy field

Calibration result point

Delayed runoff
Improving the Water Level with Ground Water Infiltration Model

- Infiltration to Soil Store
- Infiltration to Ground Store
- Drainage network
- Baseflow

Qs + Qg = Q

Groundwater inflow

October 4, 2010
Total rainfall: 37mm
Hourly maximum: 22mm/h

Rainfall (mm/15min)

Water Level (m)

- Rainfall
- Observed Water Level
- Analysed Water Level (After)
- Analysed Water Level (Before)

Improving Water Level

7. Calibration result 1

Improving the Water Level with Ground Water Infiltration Model
Improving the Water Level with real time pump data

Water Level(m)

- Observed Pump data
- Analyzed pump data (with Pump data)
- Analyzed pump data (No Pump data)
- Observed Water Level
- Analyzed Water Level (with Pump data)
- Analyzed Water Level (No Pump data)

Pump ON/OFF

ON

OFF
8. Improved Operation drainage pump of storage pipe

Securing of the storage capacity to prepare for the next rainfall

[Current]

Pump operation when the destination water level has lowered after rainfall stopped

Storage pipe
Drainage pump
Discharge sewer pipe

[After Introduction]

Pump operation according to the capacity of the destination water level

Storage pipe
Drainage pump
Discharge sewer pipe

Monitoring Point (Bottleneck point)
8. Simulation Result

Stormwater storage pipe B

- Activation
- Stoppage
- Improvement of water level differential

Stormwater storage pipe C

- Activation
- Stoppage
- Improvement of water level differential

Rainfall (mm/10min)

- 39 mm/h
- 43 mm/h equivalent to 5-year probability
8. Improvement Effect

Storage Capacity were Increased
Inundation area were decreased

<table>
<thead>
<tr>
<th>Storage pipe</th>
<th>Storage capacity ($m^3$)</th>
<th>Current status ($m^3$)</th>
<th>After introduction ($m^3$)</th>
<th>Increase ($m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>1400</td>
<td>0</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>C</td>
<td>12700</td>
<td>4500</td>
<td>9300</td>
<td>4800</td>
</tr>
</tbody>
</table>

Current status

After introduction

Triangles: Water depths (m)

- $>= 0.5$
- $>= 0.3$
- $>= 0.1$
Energy Conservation

Energy conservation using intercepting pump at high-water level

Shifted Operation basis of forecast rainfall data and predicted water level

Normal operation

Operation at high-water level

Actual pump head

Interceptor

Actual pump head reduced

Interceptor

Monitoring Point for Shifting Operation (Bottleneck point)
9. Simulation result

Shifted from Hi-level to Normal with **1 hour ahead predicted water level**

Maximum water level during operation at normal-water level

Maximum water level during operation at high-water level

**Recovery time 38 minutes**
### CSO Control Effect

#### Storage facilities used for CSO control to cope with floods

<table>
<thead>
<tr>
<th>Dry weather</th>
<th>Weather with light rain (CSO control)</th>
<th>Weather with heavy rain (measures against flood)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combined trunk system</strong></td>
<td><strong>Combined trunk system</strong></td>
<td><strong>Combined trunk system</strong></td>
</tr>
<tr>
<td><strong>Inflow gate: Closed</strong></td>
<td><strong>Inflow gate: IQ weir height</strong></td>
<td><strong>Inflow gate: Height of weir against flood</strong></td>
</tr>
<tr>
<td><strong>Storage pipe</strong></td>
<td><strong>Storage pipe</strong></td>
<td><strong>Storage pipe</strong></td>
</tr>
</tbody>
</table>
## 10. Cost effect

The ratio of improvement effect to cost of introduction is as high as **2.8**

<table>
<thead>
<tr>
<th>Item</th>
<th>Annual cost (thousand yen/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs for introduction and operation (C)</td>
<td>27,000</td>
</tr>
<tr>
<td>(Equipment replacement in ten years)</td>
<td></td>
</tr>
<tr>
<td>Improvement effect (B)</td>
<td></td>
</tr>
<tr>
<td>Flood control measures</td>
<td>64,400</td>
</tr>
<tr>
<td>CSO controls</td>
<td>10,000</td>
</tr>
<tr>
<td>Energy reduction</td>
<td>300</td>
</tr>
<tr>
<td><strong>B/C</strong> = 2.8</td>
<td></td>
</tr>
</tbody>
</table>
11. Accuracy of the forecast rainfall data

- We use the forecast rainfall data of the Meteorological Agency, which is **one hour ahead**
- Simulation based on Hydrologic/hydraulic model uses the **observed rainfall data and the forecast rainfall data**

![Diagram showing observed rainfall and forecast rainfall with initial value for simulation updated by observed rainfall and simulation based on forecast rainfall.](image)
11. Accuracy of forecast water level

The margin of error for forecast levels are about 20%
12. Summary and Tasks Ahead

Summary:
- The effect of introduction of this system is large.
- The margin of error between observed water level and forecast water level is about 20%.
  This margin of error depends on the accuracy of forecast rainfall.

Tasks:
1. To raise the forecast analysis accuracy
2. Positive verification of effects of introduction
12-1. About X-Band Multi-Parameter (MP) Radar

MP radar enables greater accuracy and higher frequency data distribution than existing radar

- Currently under test operation. Full-scale operation scheduled for 2013

Existing Radar (C band)

- High accuracy (16-fold)
- High frequency (5-fold)

Minimum observation area: 1km mesh
Observation interval: 5 min
Time lag before data distribution: 5-10 min

MP Radar (X band)

Minimum observation area: 250m mesh
Observation interval: 1 min
Time lag before data distribution: 1 min

Source: MLIT Websites
Calculated values obtained with MP radar are equivalent in effect to using of densely installed rain gauges

Verification result graph of rain gauges and MP radar calculated values

Error of rainfall intensity relative to rain gauges:
Existing radar: 100% or more may occur in certain cases
MP radar: 30% or less

Source: National Research Institute for Earth Science and Disaster Prevention
12-2. Positive verification by using MP-radar data

**27 MP-radars Working NOW**
(Test Operation)

Positive verification field
Now we have constructed the system.

Source: MLIT
Thank you for kind attention.

Kazunori Matsumoto
International & New Business Engineering Dept.
Engineering Division

Phone: +81-3-6403-7513
FAX: +81-3-5401-2603
Email: matsumoto-kazunr@metawater.co.jp
Accuracy of forecast rainfall

Forecast rainfall data have the margin of error for actual rainfall data.

Sample data: about 1700

RMSE

1 hour ahead

Forecast time
#### Rainfall data

- **Duration**: 2010年7月3日～10月28日 (118日間)
- **Number of rainfall**: 21 rainfall data
- **Total (Max)**: 122.5mm（9月15日～16日）
- **Intensity (Max)**: 27.5mm/h（9月16日）

<table>
<thead>
<tr>
<th>降雨開始時刻</th>
<th>降雨終了時刻</th>
<th>総雨量 (mm)</th>
<th>時間最大雨量 (mm/h)</th>
<th>総雨量 (mm)</th>
<th>時間最大雨量 (mm/h)</th>
<th>総雨量 (mm)</th>
<th>時間最大雨量 (mm/h)</th>
<th>総雨量 (mm)</th>
<th>時間最大雨量 (mm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010/9/15 17:00</td>
<td>2010/9/16 7:40</td>
<td>118.5</td>
<td>26.0</td>
<td>113.5</td>
<td>27.5</td>
<td>122.5</td>
<td>26.5</td>
<td>108.0</td>
<td>21.5</td>
</tr>
<tr>
<td>2010/7/12 0:20</td>
<td>2010/7/12 12:00</td>
<td>38</td>
<td>21.5</td>
<td>38.5</td>
<td>22</td>
<td>37</td>
<td>22</td>
<td>32.5</td>
<td>20</td>
</tr>
<tr>
<td>2010/10/4 3:00</td>
<td>2010/10/4 13:10</td>
<td>36</td>
<td>17</td>
<td>35.5</td>
<td>14</td>
<td>39.5</td>
<td>22</td>
<td>37</td>
<td>20.5</td>
</tr>
<tr>
<td>2010/7/13 2:40</td>
<td>2010/7/14 5:10</td>
<td>60.5</td>
<td>23</td>
<td>59.5</td>
<td>21</td>
<td>59.5</td>
<td>20.5</td>
<td>56.5</td>
<td>18.5</td>
</tr>
<tr>
<td>2010/08/13 17:50</td>
<td>2010/08/14 11:00</td>
<td>32</td>
<td>17</td>
<td>41.5</td>
<td>27.5</td>
<td>36</td>
<td>19.5</td>
<td>30.5</td>
<td>14.5</td>
</tr>
</tbody>
</table>
Risk hedge against lost or missing rainfall observation data

Data Management System

Rainfall data

Collection

Yes

Re-collection in one minute

Yes

No

No

Nearest rain gauge data

Yes

Complement with the average of the nearest rainfall data

Analysis

No

Real-time Runoff Analysis System

Yes

Complement with the radar data

Radar priority order
1. Rainfall nowcast
2. Short-term rainfall forecast

Radar data
About METAWATER

History

Expert of Electric technology
Fuji Electric
Water Environmental Systems

Expert of Machinery
and equipment technology
NGK
Water Environment Systems

Fuji Electric Holdings, Co., Ltd.
Separated as a daughter company (2007)

NGK Insulators, Ltd.

April 1st, 2008
Consolidation

Outline

<table>
<thead>
<tr>
<th>Capital</th>
<th>JPY 7.5 Bil.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Sales</td>
<td>JPY 100 Bil. (FY2009)</td>
</tr>
<tr>
<td>Employees</td>
<td>Approx. 1,800 (consolidated)</td>
</tr>
<tr>
<td>Location (JPN)</td>
<td>Tokyo (Head Office), Hino Office, Nagoya Office</td>
</tr>
<tr>
<td>(Intl.)</td>
<td>China, Korea, Germany, USA, Vietnam</td>
</tr>
</tbody>
</table>
Drinking Water Treatment

- Ceramic membrane filtration system
- Ozone system
- Rapid sand filtration system
- UV disinfection system
- Thickening/Dewatering system
- Electric equipment & Instrumentation
- Monitoring/Controlling system
- Operation & Maintenance service
Wastewater & Sludge Treatment

- High speed CSO filtration system
- Electric equipment & Instrumentation
- Monitoring/Controlling system
- Operation & Maintenance service
- Ceramic diffuser system (Bio. treat.)
- Sludge incineration/gasification system
- Advanced tech. (Membrane, Ozone, UV)
- Thickening/Dewatering system
- Sludge dryer carbonizer
- Ceramic dust filter (system)
- Phosphorus recovery system
- Power generation/storage system