# Development of Wet-Weather Sewage Treatment Technologies and their Application to the Combined Sewer System Improvement Plan of Osaka City

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**Abstract:** In Osaka City, since 97% of the city area is served by combined sewer systems (CSS), the Osaka City Government has been originally carried out researches and experiments on CSS improvement methods, particularly wet weather combined sewage treatment technologies. Among them, "wet weather sewage activated sludge process" and "sedimentation using inclined plate settlers with coagulant addition" have been successfully developed to a practical level, which can effectively increase continuous wet weather sewage treatment capacity of existing sewage treatment facilities with relatively lower cost and shorter period. The city government has revised its CSS improvement plan by applying these technologies, with the objective of reducing discharge pollutant loads in effluent and overflow from the CSS during wet weather to the equivalent level of separate sewer system. This paper presents the performance of the above newly developed technologies and the basic concept of the CSS improvement plan.

**Key words:** combined sewer system, plate settler sedimentation, wet-weather activated sludge process

## Introduction

Osaka is the largest city in western Japan with a resident population of about 2.63 million (daytime population of about 3.66 million) and area of about 220 km$^2$. Most of the city area lies below the river flood level, and gravity drainage area is only about 10% of the city area. Therefore, most of the stormwater needs to be collected once at sewage treatment plants or pumping stations then pumped and discharged to public water bodies.

In the modern sewerage construction projects in Osaka City started in 1894 in response to cholera epidemics, CSS was adopted in order to improve public hygiene and control flooding at lower cost and in a shorter period. Currently, the sewer system covers almost 100% of the city area, and 97% of the sewered area are served by CSSs (Figure 1).

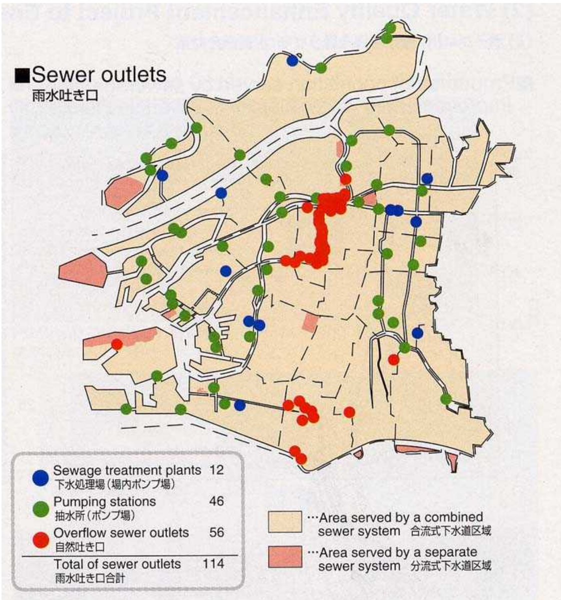



Fig. 1: Areas Served by Combined Sewer Systems

In CSSs, when sewage flow exceeds a certain level during wet weather, untreated sewage may be discharged directly from combined sewer overflow (CSO) outfalls and pumping stations to public water bodies. A survey conducted by the City Government revealed that, among the pollutant loads flowing into sewage treatment plants, the proportion discharged to public water bodies was 14% in terms of BOD and 36% in terms of SS. Out of this pollutant load discharged to public water bodies, 70% of BOD and 80% of SS are discharged during wet weather conditions. This result shows that it is the key issue to reduce the pollutant load in wet-weather discharges for the further improvement of the quality of public water bodies.

Since the 1970s, when the coverage of the sewer system increased and the safety against floods was improved to a certain level in the city, the City Government has been carried out researches and studies on technologies for CSS improvement. Especially, in Osaka City, almost the entire city area has been already urbanized, therefore, it is very difficult to acquire lands for the construction of new treatment facilities. Furthermore, the cost for CSS improvement has to be minimized as possible because the scale of CSSs in Osaka is so huge. From these points of view, the City Government has been actively developed and introduced original technologies to increase continuous wet-weather sewage treatment capacities by fully utilizing existing facilities, instead of other CSS improvement methods commonly adopted in Japan such as construction of wet-weather sewage storage facilities and sewer separation.

This paper introduces the major technologies for CSS improvement newly developed by the Osaka City Government and the city's CSS improvement basic plan applying these technologies.

## Wet-Weather Sewage Treatment Technologies for CSS Improvement Developed by the Osaka City Government

### Wet-weather sewage activated sludge process

In Osaka City, sewage treatment plants are designed to receive up to three times of the design peak dry weather flow (3Qsh) in wet weather conditions. In the conventional method, 1Qsh among 3Qsh was treated by the activated sludge process and the remaining 2Qsh was treated by only primary sedimentation and discharged (Figure 2). In the wet-weather activated sludge process, this 2Qsh of wet-weather sewage is fed into the latter section of aeration tanks and is treated by the activated sludge process (Figure 3).

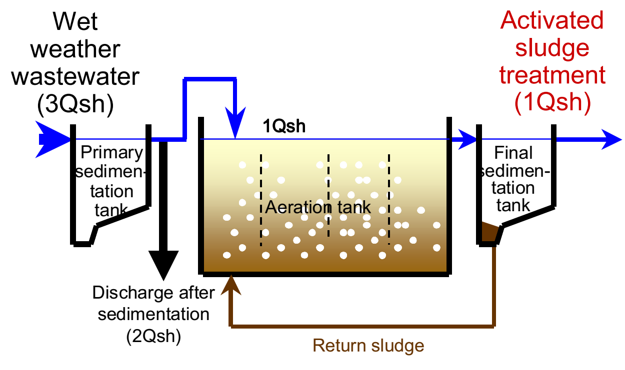



Fig. 2: Conventional Wastewater Treatment during Wet Weather

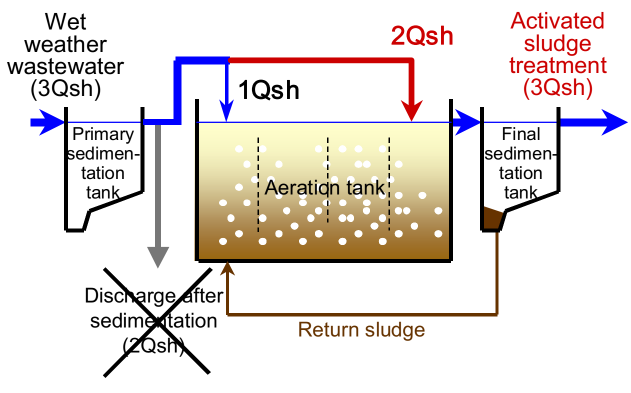



Fig. 3: Wet Weather Activated Sludge Process

With the conventional activated sludge process, pollutants are absorbed by activated sludge in the first 30 minutes or so, and then gradually decomposed. In the wet-weather activated sludge process, the hydraulic retention time of wet-weather sewage fed into the latter section of aeration tanks is about 30 minutes, and pollutants in the wet-weather sewage are quickly removed due to the absorption by the activated sludge suspended in the aeration tanks.

Furthermore, the aeration tanks in sewage treatment plants in Osaka City have been equipped with channels for step feeding to be applicable for both the conventional activated sludge process and the step feed aeration process. Thus, this new process could be introduced with relatively small modifications of existing facilities.

The Osaka City Government started design studies on this treatment process in 1988, and carried out performance surveys at treatment facilities using this process from 1992 to 2002. The results verified stable operations while processing sewage volume ranging from 1.48 to 4.62 Qsh (2.70 Qsh on average) with the average effluent quality at 9.3 mg/L in SS and 7.7 mg/L in BOD. In addition, results from four surveys verified that this new method could reduce the amount of pollutant discharge by 59 to 91% (73% on average) in SS, and by 27 to 78% (61% on average) in BOD for a single rainfall event, when compared with the conventional method employing primary sedimentation (Figure 4).

In September 2000, when there was a prolonged rain event with the total rainfall of 165 mm, this process was continuously operated for 45 hours stably, and it was verified that the new process was capable of prolonged continuous operation.

Since these results have demonstrated the effectiveness of the wet-weather activated sludge process, the Osaka City Government has been introducing this process to all 12 sewage treatment plants by March 2007.

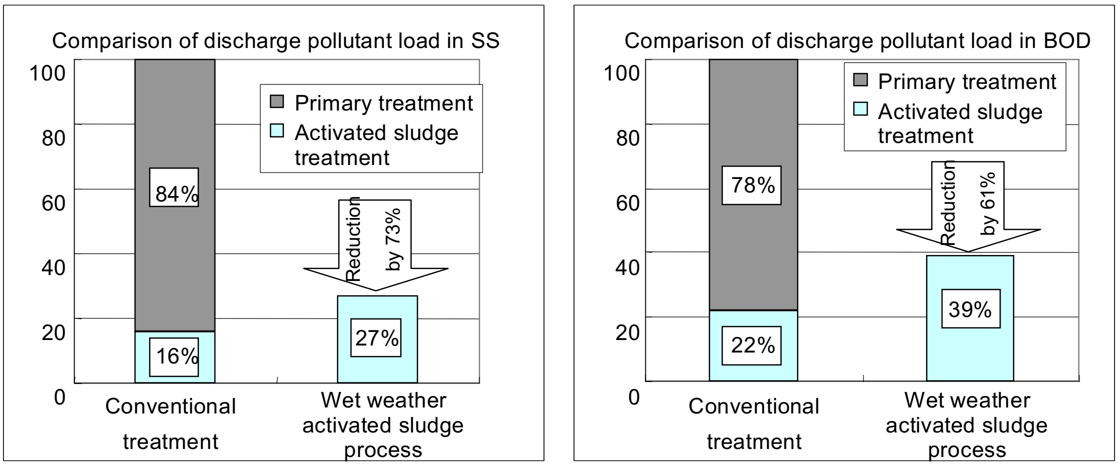



**Fig. 4: Effect of the Wet Weather Activated Sludge Process**

### Sedimentation process using inclined plate settlers with coagulant addition

Sedimentation process using inclined plate settlers is adopted in the treatment of drinking water supplies. The Osaka City Government has carried out studies on this process for treating wet-weather sewage, which tends to increase rapidly, within limited land area. From the late 1970s, the City Government carried out monitoring on the characteristics of wet-weather sewage and experiments on the plate settler sedimentation process, and obtained the following results:

1) Wet-weather sewage contains high content of suspended solid (SS) with a high sedimentation velocity, therefore, it is reasonable to use this process to separate this high settleable SS component.

2) At an average flow rate of 0.5 to 0.6 m/min. in the plate settler module with the detention time of about 10 minutes, effluent quality is equivalent to the one from a conventional sedementation tank.

Besides, experiments were carried out to investigate the effect of coagulant dose to sedimentation efficiency and resulted in the following:

3) Poly-aluminum chloride (PAC) is most suitable as a coagulant for the wet-weather sewage sedimentation process.

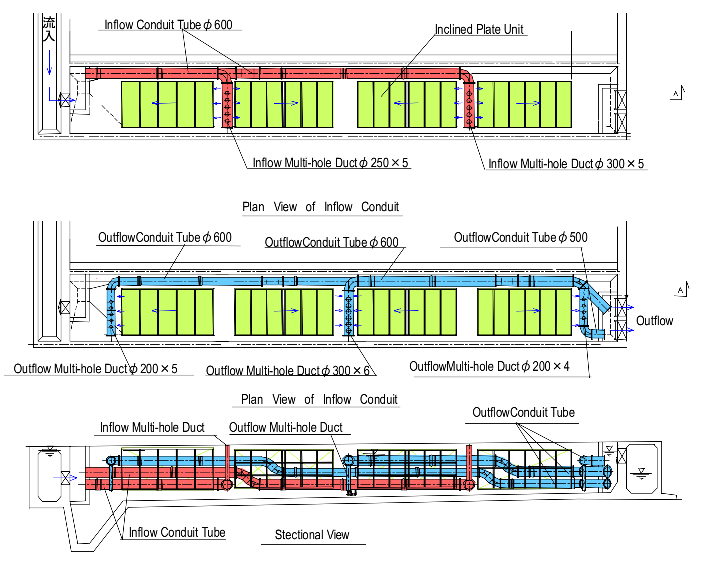
4) By adding PAC at the concentration of 2.5 to 10 mg-Al/L, influent sewage with BOD of 100 to 200 mg/L can be treated to produce an effluent with BOD of 20 to 25 mg/L with the detention time not exceeding 10 minutes.

However, as mentioned earlier, it is very difficult to acquire lands in Osaka City for the construction of new treatment facilities, therefore, the City Government started design studies on modifying existing primary sedimentation tanks to plate settler sedimentation tanks as an alternative engineering option, and installed inclined plate settler modules to an existing primary sedimentation tank in the Osaka City's Chishima Sewage Treatment Plant as a pilot treatment facility for this process. The performance surveys were carried out for 29 rainfall events for one-year period from October 2004. The specifications of the experimental facility are as follows:

- Inclined plate settler type: Horizontal flow, flat plate type
- Length of inclined plates: 3 to 6 m
- Angle of inclination: 60º
- Height of a settler module: 2.5 m
- Intervals of inclined plates: 100 mm
- Inclined plate material: Vinyl chloride resin and recycled plywood
- Coagulant: PAC
- Rapid Mixing: Utilize pre-aeration
- Flocculation: No special equipment/device is provided
- Inclined plate cleaning: Air blowing and water spraying
- Sludge collector: N/A
- Sludge removal: Discharge sludge by water flushing after rainfall events

In order to effectively utilize the existing sedimentation tank, it is necessary to place multiple inclined plate settler modules in the tank and distribute the influent sewage to each module. Therefore, influent main pipes are placed in the tank and connected with perforated pipes at their end as shown in Figure 5.

Fig.5 Design of Inclined Plate Settler in Chisima Sewage




The hole size of perforated pipes must be determined to distribute influent sewage to the individual modules equally. Perforated pipes are vertically placed near the inlet cross-section of plate settler modules to distribute the influent sewage evenly in horizontal and vertical directions of the module cross-section and mitigate density currents.

For the inclined plates, vinyl chloride resin plates and recycled plywood plates (made from waste paper and plastic) are used. In the survey, treatment performance was measured under different surface loading rates by changing the length of the inclined plates.

Sludge collectors were not installed, therefore, sludge is stored on the bottom of tank during rainfall events. Then after rainfall events, water in the tank is once drained together with most of the stored sludge, and the remaining sludge is flushed from the rear end of the tank using settled water from the adjacent primary sedimentation tank.

## Influence of flow rate in the plate settler modules

Figures 6 and 7 show the relationship between the flow rate in the plate settler modules and the effluent quality when the surface loading rate is less than 35 $m^3/(m^2 \cdot d)$. SS concentration in the treated effluent increased when the flow rate exceeded 0.5 m/min. and the BOD concentration increased when the flow rate exceeded about 0.55 m/min. It is observed that the impact of the flow rate is less evident in BOD than in SS. This may be attributed to the soluble BOD. From these results, it is considered that the flow rate in the plate settler modules should be set 0.5 m/min or less.

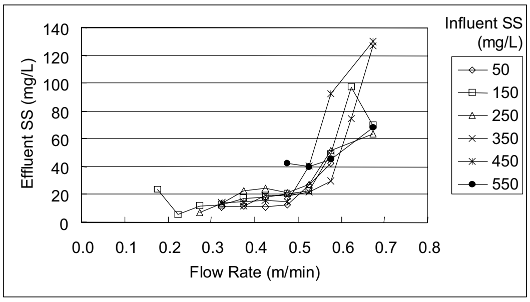



Fig.6 Influence of Flow Rate to Effluent SS

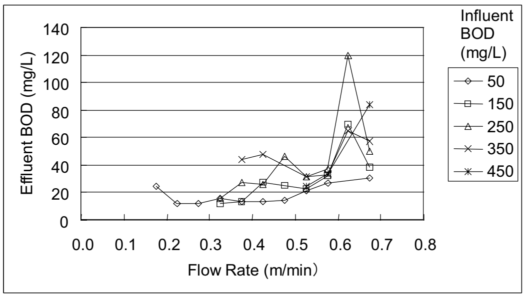



Fig.7 Influence of Flow Rate to Effluent BOD

## Influence of surface loading rate

Figure 8 shows the relationship between the surface loading rate and the treated effluent quality when the flow rate is below 0.5 m/min. As shown in the graph, it is observed that the effluent with sufficient quality is obtained stably when the surface loading rate is 40 $m^3/(m^2 \cdot d)$ or less.

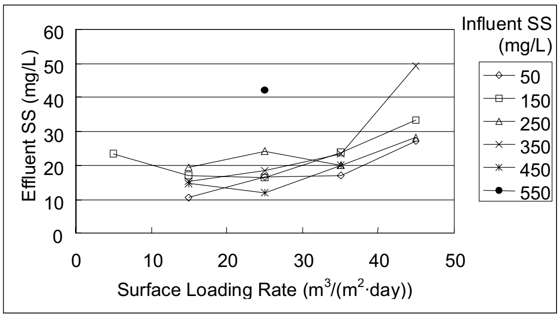



Fig.8 Influence of Surface Loading Rate to Effluent SS

## Treated effluent quality

Based on the above observations, the relationship between the influent sewage quality and the treated effluent quality was analyzed under the conditions when the flow rate is less than 0.5 m/min. and the surface loading rate is less than 35 $m^3/(m^2 \cdot d)$. The results are shown in Figures 9 and 10. The SS values were averaged within each 100 mg/L range; and the BOD values were averaged within each 50 mg/L range. The vertical bars show the standard deviation. It is considered that pollutants can be removed to the level of the average effluent quality approximately at 20 mg/L in SS and 20 to 30 mg/L in BOD, except when the pollutant concentration of the influent sewage is extremely high. Since little data was available under the condition of the influent sewage with high pollutant concentrations, such data need to be collected furthermore.

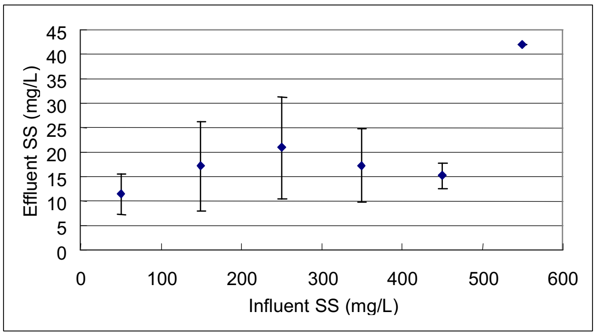



Fig.9 Average Influent and Effluent SS

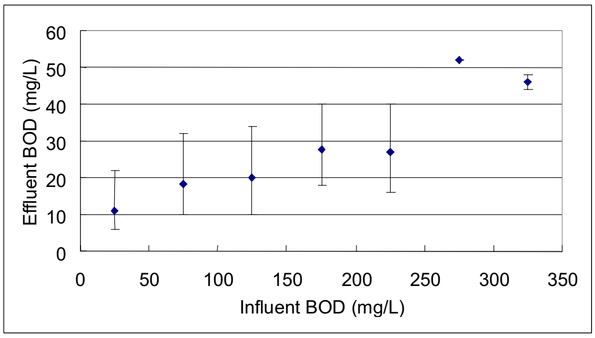



Fig.10 Average Influent and Effluent BOD

## Removal rate

Under the same conditions, the relationship between the influent sewage quality and the removal rate is shown in Figures 11 and 12. The removal rate is approximately around 90% in SS and 80% in BOD, although it shows low value when the pollutant concentration of the influent is at low level.

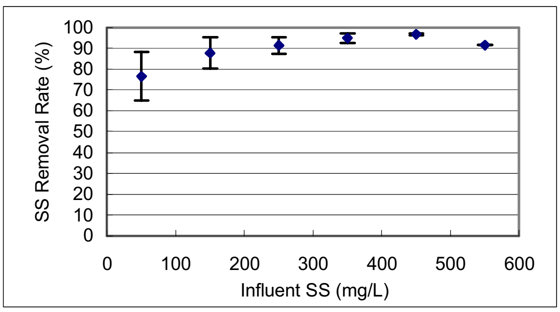



Fig.11 Average SS Removal Rate

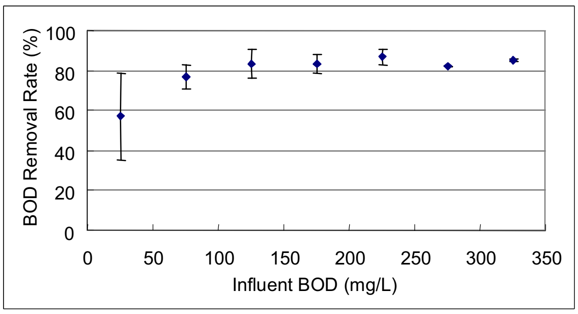



Fig.12 Average BOD Removal Rate

From these findings based on the survey results, it is estimated that existing primary sedimentation tanks can be capable of treating wet-weather sewage flow equivalent to five times its present design maximum daily dry-weather flow by installing inclined plate settler modules with inclined plate intervals of 100 mm, flow rate in the plate settler module of less than 0.5 m/min., and surface loading rate of 25 $m^3/(m^2 \cdot d)$.

Furthermore, the city government is conducting performance surveys when applying this plate settler sedimentation process to the primary sedimentation process under dry weather conditions. It is expected that the plate settler sedimentation process will be able to have the equivalent treatment capacity of the existing primary sedimentation tank with 1/2 to 1/3 of its original surface area. In this case, the remaining space can be used for wet-weather sewage treatment by the plate settler sedimentation process with coagulant addition. Then, the wet-weather sewage treatment capacity can be increased without constructing new tank facilities.

## The Newly Revised CSS Improvement Plan of Osaka City

In the previous CSS improvement plan of Osaka City, the objective was set as "to reduce the annual discharge pollutant load including dry weather period to the equivalent level of separated sewer system", and various programs have been implemented such as eliminating sediment traps at the bottom of manholes, introducing the wet-weather sewage activated sludge process, and constructing stormwater reservoirs for storage of wet-weather sewage. However, in 2004, the Sewerage Law Enforcement Order was amended and the wet weather effluent quality standard for CSSs was newly stipulated. On the other hand, the city government has been originally studied the plate settler sedimentation process as a CSS improvement method and developed to a practical level. In response to these changes and new developments, the Osaka City Government established a new CSS improvement plan in March 2006.

### Objectives

#### Mid-term objectives (target year: 2018)

- Within each treatment area, the annual discharge pollutant load including dry weather periods should be reduced to the equivalent level of separated sewer system. Here, it is assumed that the average quality of wet weather discharge from a separated sewer system is 18 mg/L in BOD.
- The wet weather effluent quality should meet the standard stipulated in the Sewerage Law Enforcement Order amended in 2004, that is the average quality of wet weather effluent during a single rainfall event with the total rainfall of 10 to 30 mm should be not more than 40 mg/L in BOD in each treatment area
- The number of overflow events from CSO outfalls should be reduced by half.

#### Long-term objective

- The wet weather effluent quality should be the same level of dry weather effluent quality. Specifically, the annual average effluent quality from each outlet should be not more than 15 mg/L in BOD.

### Major approaches

In order to reduce discharge pollutant load to public water bodies, increasing wet weather sewage treatment capacity was selected as the basic strategy, and the above objectives should be achieved mainly by the combination of following four major approaches.

1) Introduction of the wet weather sewage activated sludge process
2) Introduction of the plate settler sedimentation process with coagulant addition
3) Storage of wet-weather sewage utilizing large stormwater sewers designed for flood control
4) Newly construction of facilities for storage of wet-weather sewage such as stormwater reservoirs

In the implementation of the CSS improvement program, priority should be given to projects concerning those public water areas that are important in terms of water quality protection and landscape conservation.

### Modification of primary sedimentation tanks

There are two necessary steps when the plate settler sedimentation process for wet weather sewage treatment is introduced in the existing sewage treatment plants. First, the required area for primary sedimentation of dry weather flow should be reduced to 1/2 to 1/3 by modifying existing sedimentation tanks to the plate settler sedimentation process (without coagulant addition) or the high rate filtration process. Then, the plate settler sedimentation process with coagulant addition should be introduced using the remaining 1/2 to 2/3 of the area for wet weather sewage treatment.

### Cost and Benefit

Simulation analysis was conducted for one treatment area in the case of wet weather sewage treatment up to 6Qsh by introducing the wet weather activated sludge process and the plate settler sedimentation process with coagulant addition modifying existing facilities. The result shows that the following effects can be obtained.

1) 84% of wet weather sewage flows and 94% of the pollutant loads in the sewage can be captured for treatment, and 83% of captured pollutant loads can be removed.
2) The annual discharge pollutant loads can be reduced to the equivalent level of a separate sewer system.
3) Comparing the conventional CSS improvement approach of constructing stormwater reservoirs, the construction costs and the annual recurrent costs can be reduce to about 20% for removing the equivalent amount of pollutant load.

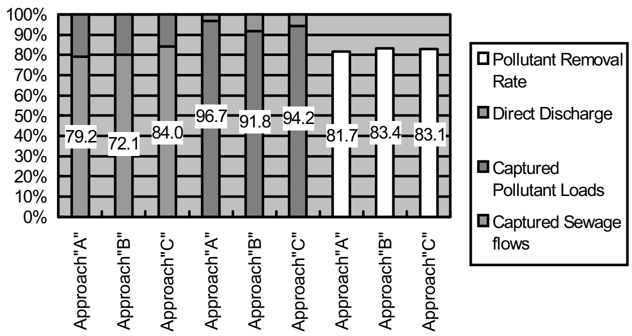



Fig 13: Comparison of effect in alternative approaches

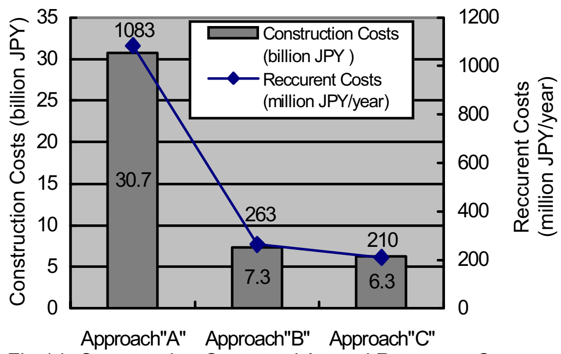



Fig 14: Construction Costs and Annual Recurrent Cost

Approach "A": Stormwater reservoir (13mm) + sedimentation (2Qsh)
Approach "B": Wet-weather activated sludge process (3Qsh) + Stormwater reservoir (3mm)
Approach "C": Wet-weather activated sludge process (3Qsh) + Plate settler sedimentation with coagulant addition (3Qsh)

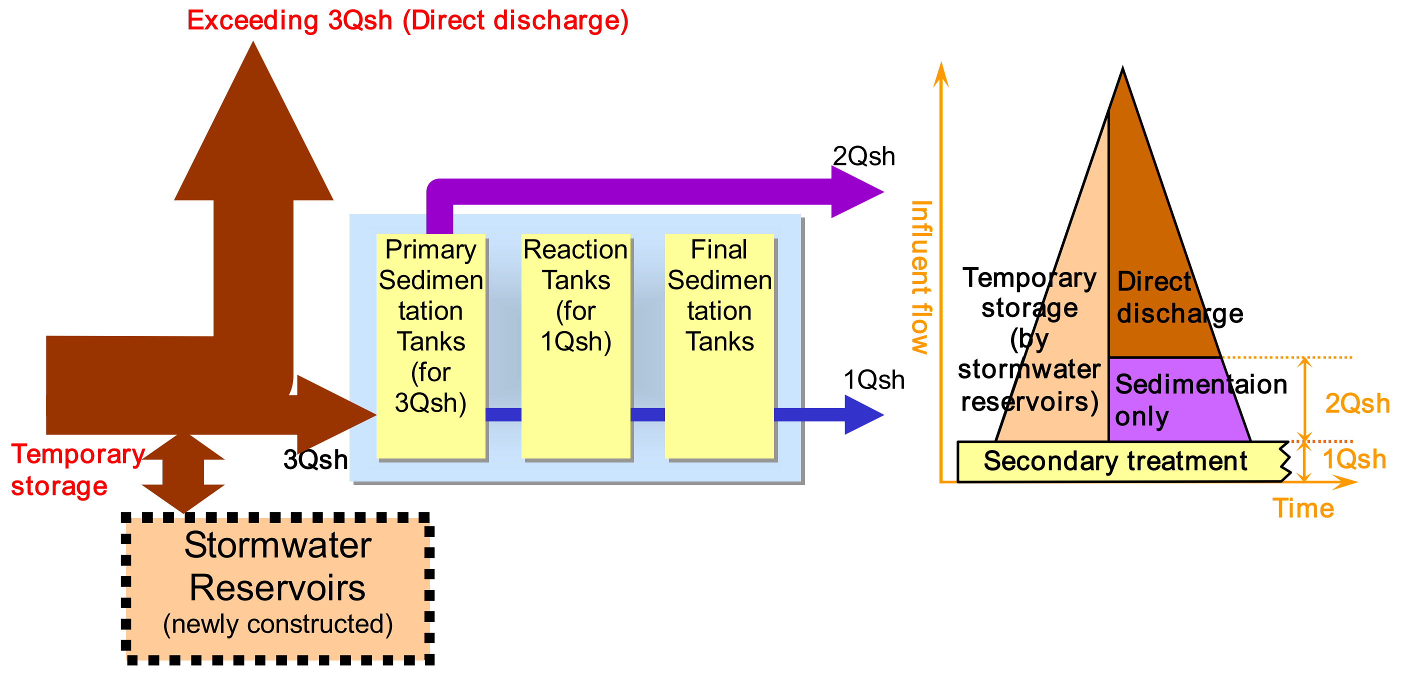



Fig 15: Image of Conventional Treatment Process in Wet Weather Events

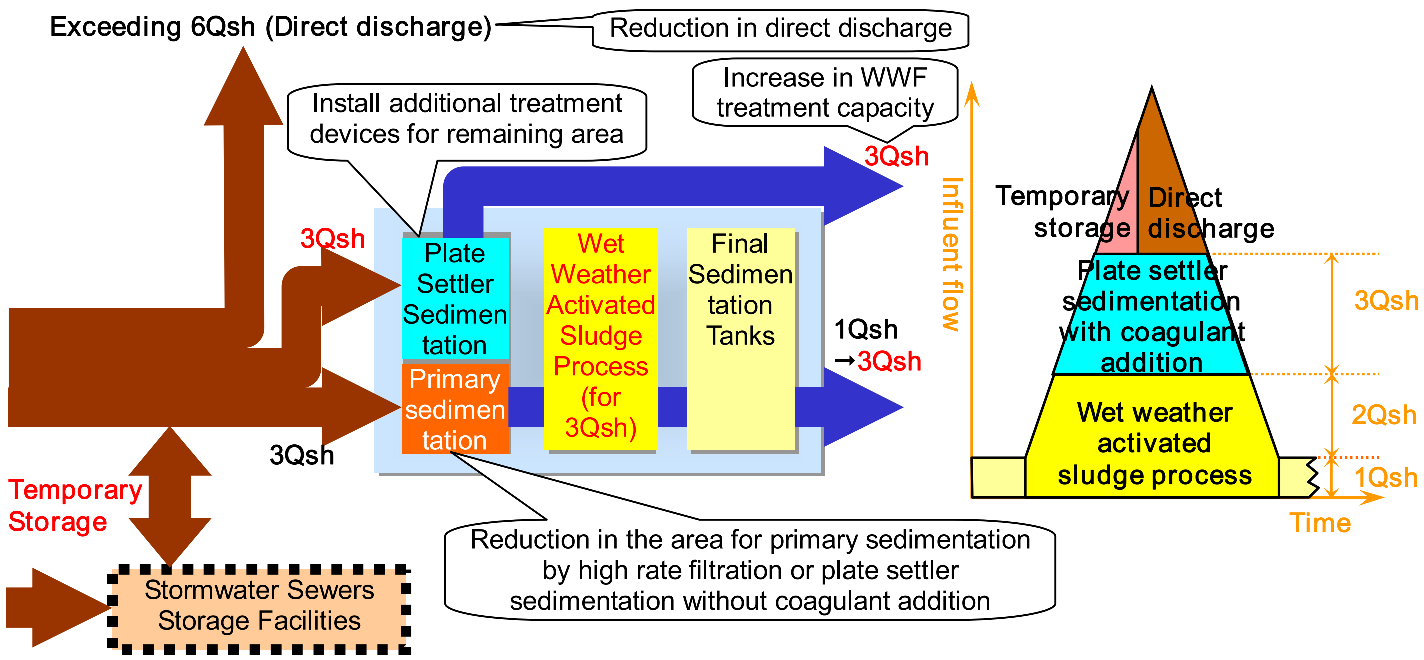



Fig 16: Image of Wet Weather Sewage Treatment in the New CSS Improvement Plan

Furthermore, the total project costs for the previous improvement plan was estimated to be about 300 billion yen. However, based on the above results, the total project costs to achieve the mid-term objectives for the entire city area was estimated to be about 200 billion yen as shown in Table 1, a saving of about 100 billion yen.

Table 1: Estimated Project Cost for CSS Improvement

| Approaches | Cost (billion JPY) |
|---|---|
| Wet Weather Activated Sludge Process | 18 |
| Plate Settler Sedimentation Process | 57 |
| Construction of Storage Facilities | 87 |
| Other Approaches<br>Filling Sediment Traps in Manhole Bottoms<br>Replacement of Screens, etc. | 30 |
| Total | 192 |

### Future issues

- In order to significantly increase the amount of sewage processed at sewage treatment plants, further studies are required regarding transfer of sewage to treatment plants, distribution of sewage to various treatment processes in each plant, capacity of effluent channels, etc.
- For actual operations of storing wet weather sewage utilizing large stormwater sewers, technologies such as real-time control need to be studied to ensure CSO control and flood control without lowing safety level against floods.

## Conclusions

The Osaka City Government has selected CSS to achieve the flood control and public hygiene improvement at the same time. Thereby, the sewer systems were constructed rapidly over the entire city area. CSSs were able to cope with increase in wastewater flow due to urban density growth. Currently in Japan, the problem of wet weather discharge pollutant load by CSOs is one of the priority issues for water environment protection. The Osaka City Government is now planning to take comprehensive countermeasures by combining various methods including some originally developed technologies, and expects to be able to eventually capture and treat almost all of wet-weather sewage except in the case of extremely heavy rains comparable to the probable maximum precipitation. If such improvements are achieved, CSS has the potential to become an excellent system that can also deal with non-point source pollutants released in wet weather conditions.

The City Government will continuously monitor CSOs at main overflow outlets in order to adequately investigate CSO characteristics and clearly identify the benefits and costs of various program components for implementing the improvement plan with public consensus.

## References

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Takayanagi E., Abe T, Taruya T and Fukui S. (1997): Introduction of Plate Settler for Combined Sewer Overflow Treatment, Water Science and Technology, Vol. 36, No. 8-9, pp.207-212, 1997, IAWQ


## Presentation Topics

- Profile and features of Osaka City and its sewerage system
- Wet weather sewage treatment technologies developed by Osaka City Government to a practical level
  - Wet weather sewage activated sludge process
  - Plate settler sedimentation process with coagulant addition
- Combined sewer systems (CSSs) improvement plan of Osaka City, which was recently revised applying the above technologies.

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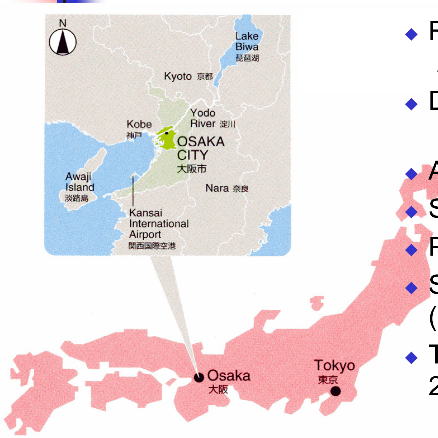
## Profile of Osaka City




- Resident population: 2.63 million
- Daytime population: 3.66 million
- Area: 220 km$^2$
- Sewers: 4,830 km
- Pumping Stations: 57
- Sewage Treatment Plants (STPs):12
- Total Treatment Capacity: 2,844,000 m$^3$/day

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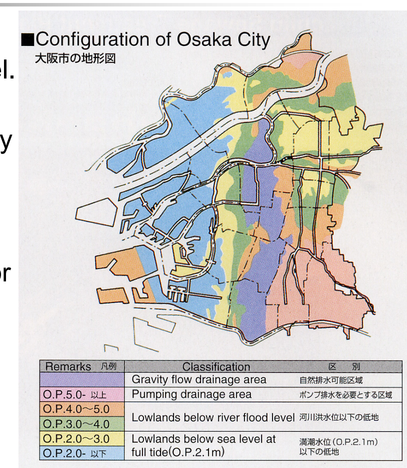
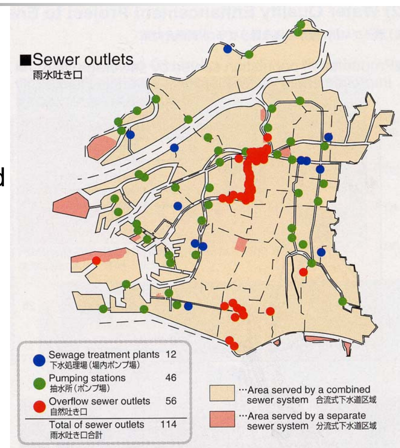
## Geographical Feature

- Most of the city area lies below the river flood level.
- Gravity drainage area is only about 10% of the city area.
- Therefore, most of the stormwater need to be collected once at STPs or pumping stations, then pumped and discharged to public water bodies.



## Sewage Collection System

- In the modern sewerage construction projects stared in 1894, combined sewer system (CSS) was adopted for public hygiene improvement and flood control at the same time with lower cost and in a shorter period.
- Currently, the sewer system covers almost 100% of the city area, and 97% is served by CSSs.

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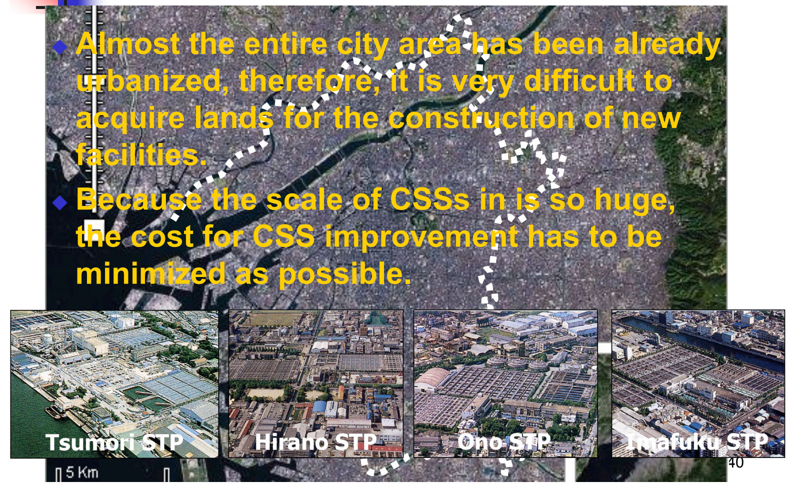
## Constraints in CSS Improvement in Osaka City

- Almost the entire city area has been already urbanized, therefore, it is very difficult to acquire lands for the construction of new facilities.
- Because the scale of CSSs in is so huge, the cost for CSS improvement has to be minimized as possible.




## Selected Alternatives for CSS Improvement in Osaka City

- From the these points of view, the City Government has been actively developed and introduced original technologies to increase continuous wet weather sewage treatment capacities by fully utilizing existing facilities, instead of other CSS improvement methods commonly adopted in Japan, such as construction of stormwater reservoirs and sewer separation.

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## R&D on CSO Control Technologies carried out by Osaka City Government

| | |
|---|---|
| Wet Weather Sewage Sedimentation Tank | 1971 Design, 1974 Performance survey |
| **Wet Weather Sewage Activated Sludge Process** | 1980s Experimental studies, 1988 Design studies,<br>1990 Pilot plant studies,<br>1998 Introduction to full scale treatment facilities started |
| **Inclined Plate Setter Sedimentation Process** | Late 1970s Experimental studies, 1987 Design studies, 2002 Experiments on coagulant addition, 2004 Pilot plant studies |
| Fine Mesh Screens for Wet Weather Sewage | 1980s Experimental studies, 1987 Design studies,<br>1998 Installation of a full scale unit |
| Storage of Wet Weather Sewage utilizing Stormwater Sewers | 1983 Research studies, 2000 Operation started |
| Filling Sediment Traps at the Bottom of Manholes | 1984 Effectiveness surveys in pilot areas, 1995 Modifications started for the entire city area, 2003 Completion |
| Wet weather sewage high rate filtration | 2003 Pilot plant studies |

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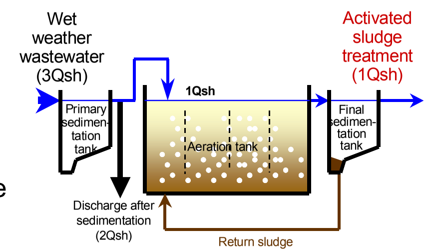
# Wet Weather Sewage Activated Sludge Process

# Conventional Sewage Treatment during Wet Weather

- In Osaka City, STPs are designed to receive up to 3 times of the design peak dry weather flow (3Qsh).
- In the conventional method, 1Qsh was treated by the activated sludge process, and the remaining 2Qsh was treated by only primary sedimentation and discharge.

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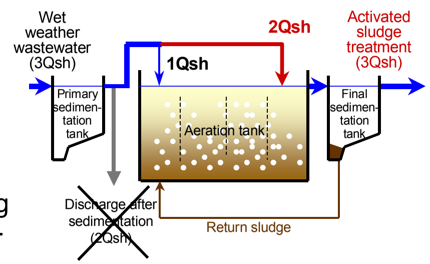
# Wet Weather Sewage Activated Sludge Process

- In the “wet weather activated sludge process”, 2Qsh is fed into the latter section of aeration tanks and treated by the activated sludge process.
- The results of 27 surveys verified stable operations in processing sewage volume of 1.48-4.62 Qsh with the average effluent quality at 9.3 mg/L in SS and 7.7 mg/L in BOD.

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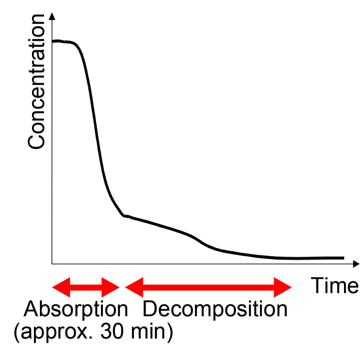
# Pollutant Removal in the Activated Sludge Process

- In the conventional activated sludge process, pollutants are absorbed by activated sludge in the first 30 minutes and gradually decomposed.
- In the wet weather activated sludge process, the hydraulic retention time of 2Qsh wet weather sewage fed into the latter section is about 30 min, therefore, pollutants in the sewage are quickly removed.

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## Advantages

- The aeration tanks in STPs in Osaka City have been equipped with channels for step feeding to be applicable for both the conventional activated sludge process and the step feed aeration process.
- Thus, this new process could be introduced with relatively small modifications of existing facilities.


Before (hand


After (automatically

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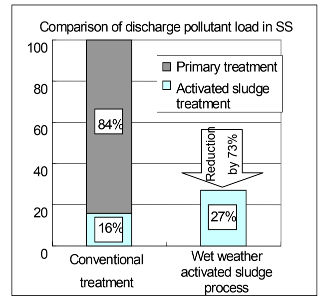
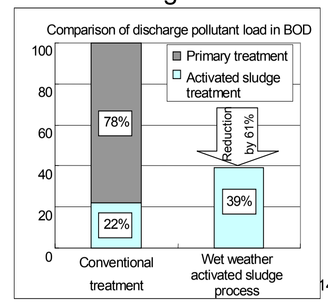
## Effect of Wet Weather Activated Sludge Process

- Results from 4 surveys verified that this new process could reduce the amount of pollutant discharge by 59-91% (73% on average) in SS, and by 27-78% (61% on average) in BOD for a single rainfall event, compared with the conventional wet weather sewage treatment.

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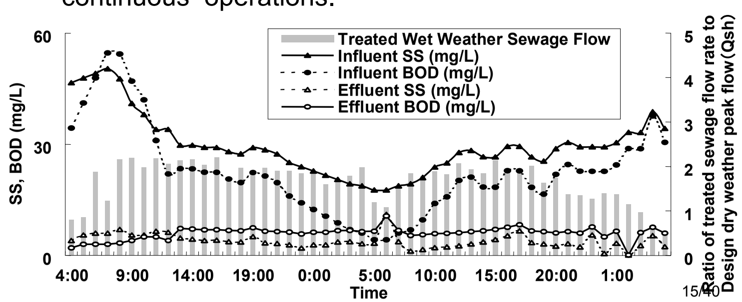
## Result of Prolonged Continuous Operation (45 hours)

- In September 2000, when there was a prolonged rain event with the total rainfall of 165 mm, this process was continuously operated for 45 hours stably, and it was verified that the new process was capable of prolonged continuous operations.

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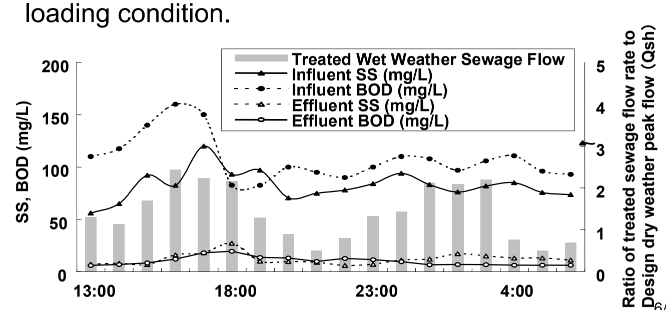
## Operation under High Pollutant Loading Condition

- In January 2001, when the influent pollutant load was high for a long time (the highest BOD was 160 mg/L, the average BOD was 120 mg/L), it was verified this process was capable of operations under high pollutant loading condition.

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## Summary - Wet Weather Activated Sludge Process

- From the results of performance surveys, it was verified;
  - The operation of this process can run stably, while treating up to 3 times of the design peak dry weather flow .
  - This process is capable of prolonged continuous operations and under high pollutant loading condition.
  - The amount of pollutant discharge can be considerably reduced, compared with the conventional method.
- Since these results have demonstrated the effectiveness of the "wet weather activated sludge process", Osaka City Government has been introducing this process to all 12 STPs by March 2007.

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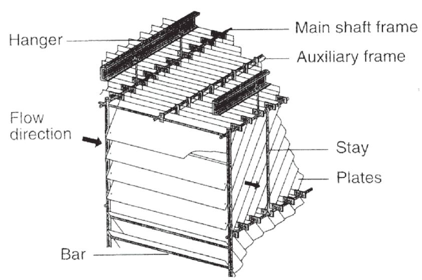
## Plate Settler Sedimentation Process with Coagulant Addition

## Sedimentation Process using Inclined Plate Settlers

- Plate settler sedimentation process is adopted in the treatment of drinking water supplies.
- Osaka City Government has carried out studies and experiments on the application of this process for treating wet weather sewage since the late 1970s.

Inclined Plate Settler Module

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## Findings from Basic Studies and Experiments

- Wet weather sewage contains high content of SS with a high settling velocity, therefore, it is appropriate to use this process to separate the high settleable SS components.
- At an average flow rate of 0.5-0.6 m/min in the plate settler module with the detention time of about 10 min, effluent quality is equivalent to the one from conventional setting tanks.
- PAC is most suitable as a coagulant for wet weather sewage sedimentation process.
- By adding PAC at the concentration of 2.5-10 mg-Al/L, influent sewage with BOD of 100-200 mg/L can be treated to produce an effluent with

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## Modifying Existing Primary Sedimentation Tanks

- Since it is very difficult to acquire lands for the construction of new facilities, the city government started design studies on modifying existing primary sedimentation tanks to plate settler sedimentation tanks using a pilot treatment facility at Chishima STP.


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## Specifications

- Length of inclined plates: 3-6 m
- Angle of inclination: 60º
- Plate Material:
  - Vinyl chloride resin
  - Recycled plywood
- Intervals of inclined plates: 100 mm
- Height of a settler module: 2.5 m
- Coagulant: PAC (JIS K 1475 $Al_2O_3$:10.0-11.0 wt%)
- Dosage of PAC: 3-10 mg-Al/L

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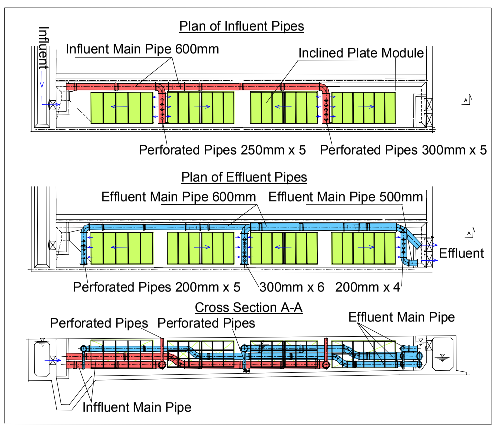
## Installation of Inclined Plate Settler Modules

- In order to utilize the existing sedimentation tank effectively, it is necessary to place multiple plate settler modules in the tank and distribute the influent sewage to each module.

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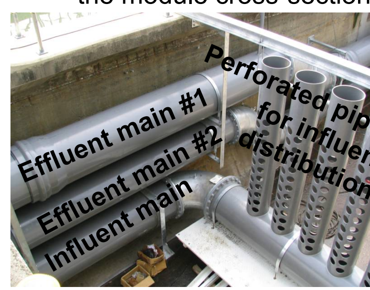
## Equalization of Influent Sewage Distribution to Each Module

- Influent main pipes are placed in the tank and connected with perforated pipes at their ends.
- Perforated pipes are vertically placed near the inlet cross-section of plate settler modules in order to distribute the influent sewage evenly in horizontal/vertical directions of the module cross-section and to mitigate density currents.




## Sludge Removal

- Sludge collectors were not installed, therefore, sludge is stored on the bottom of the tank during rainfall events. After rainfall events, water in the tank is once drained together with most of the stored sludge. Then, the remaining sludge is flushed from the rear end of the tank using settled water from the adjacent settling tank.

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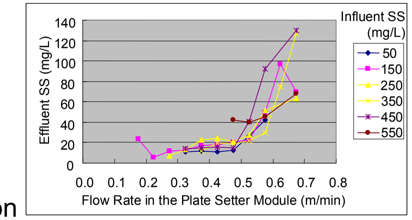
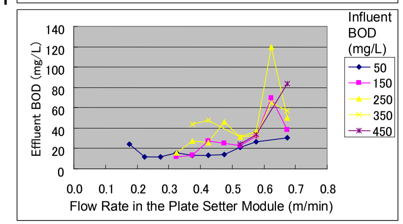
## Results of Performance Surveys
## 1) Influence of Flow Rate

Under the condition that the surface loading rate is less than 35m$^3$/(m2·day),

- Effluent SS concentration increases when the flow rate exceeds 0.5m/min.
- Effluent BOD concentration increases when the flow rate exceeds 0.55m/min.
- It is proposed that the flow rate in the plate settler modules should be set 0.5m/min or less.

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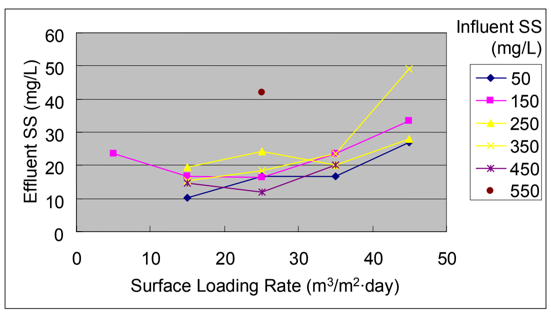
## Results of Performance Surveys
## 2) Influence of Surface Loading Rate

- Under the condition that the flow rate is less than 0.5m/min, it was observed that the effluent with sufficient quality was obtained stably, when the surface loading rate was less than 40m$^3$/(m2·day).

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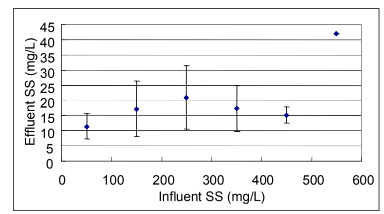
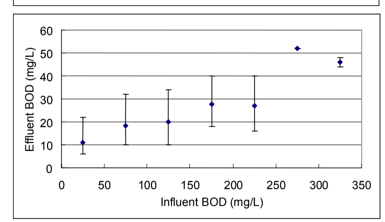
## Results of Performance Surveys
## 3) Treated Effluent Quality

Under the condition that the flow rate is less than 0.5m/min and the surface loading rate is less than 35m$^3$/(m2·day),

- It is considered that pollutants can be removed to the level of the average effluent quality at 20mg/L in SS and 20-30 mg/L in BOD, expect when the influent pollutant load is extremely high.

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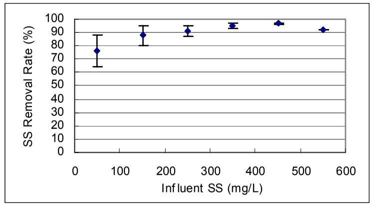
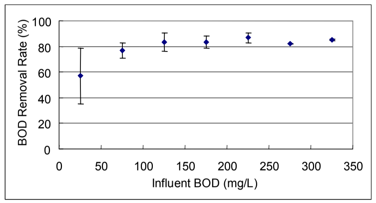
## Results of Performance Surveys 4) Pollutant Removal Rate

Under the same condition,

- The removal rate is approximately 90% in SS and 80% in BOD, although it shows low value when the influent pollutant concentration is at low level.

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## Summary - Plate Settler Sedimentation Process

- From the results of performance surveys, it is estimated that the existing primary sedimentation tanks can be capable of treating wet-weather sewage flow equivalent to 5 times its present design maximum daily dry-weather flow, by installing inclined plate settler modules with the following specifications.
  - Intervals of inclined plates: 100mm
  - Flow rate in the settler modules: less than 0.5m/min
  - Surface loading rate: 25m3/(m2·day)

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## Next Application of Plate Settler Sedimentation Process

- The city government is also conducting performance surveys when applying this process to the primary sedimentation process under dry-weather conditions.
- It is expected that the plate settler sedimentation process will be able to have the equivalent treatment capacity of the existing primary sedimentation tank with 1/2-1/3 of its original surface area.
- In this case, the remaining space can be used for wet-weather sewage treatment by the plate settler sedimentation process with coagulant addition.

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## Newly Revised CSS Improvement Plan of Osaka City

## Needs/Background for Revision

- In 2004, "Sewerage Law Enforcement Order" was amended, and the wet weather effluent quality standard for CSSs was newly stipulated.
  "The average quality of wet weather effluent during a single rainfall event with the total rainfall of 10-30mm should be not more than 40mg/L in BOD in each treatment area. (The tentative standard is 70mg/L for the next 20 years.)"
- The plate settler sedimentation process has been developed to a practical level.

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## Objectives of the Revised CSS Improvement Plan

***Mid-term Objectives (target year: 2018)***

- Within each treatment area, the annual discharge pollutant load including dry weather periods should be reduced to the equivalent level of a separate sewer system (18mg/L in BOD).
- The wet weather effluent quality should meet the standard stipulated in the Sewerage Law Enforcement Order amended in 2004.
- The number of overflow events from CSO outfalls should be reduced by half.

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## Major Approaches

- In the previous CSS improvement plan
  - Wet weather activated sludge process
  - Filling sediment traps in manhole bottoms
  - Replacement of screens
  - Construction of stormwater reservoirs
- In the newly revised CSS improvement plan
  - Wet weather activated sludge process
  - Plate settler sedimentation process
  - Storage of wet-weather sewage using large stormwater sewers designed for flood control
  - Construction of wet-weather storage facilities

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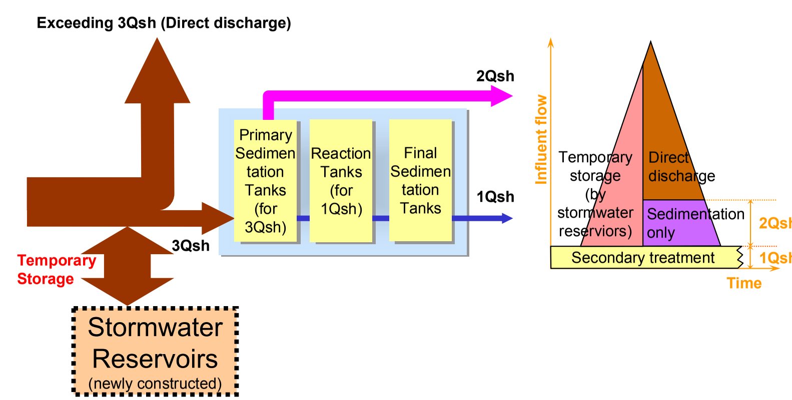
## Image of Conventional Treatment Process during Wet Weather

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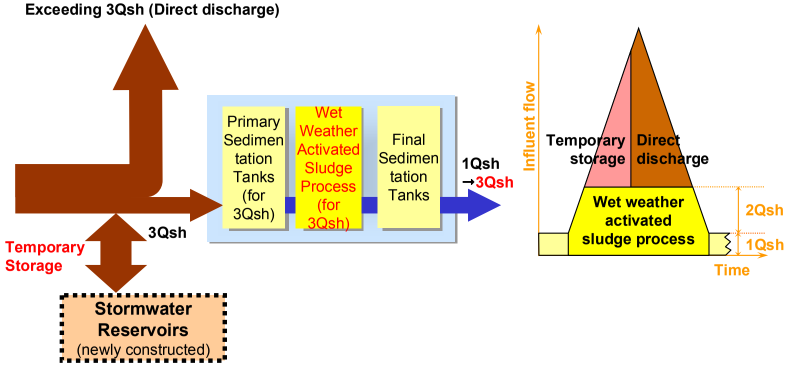
# Image of Wet Weather Sewage Treatment in the Previous Plan

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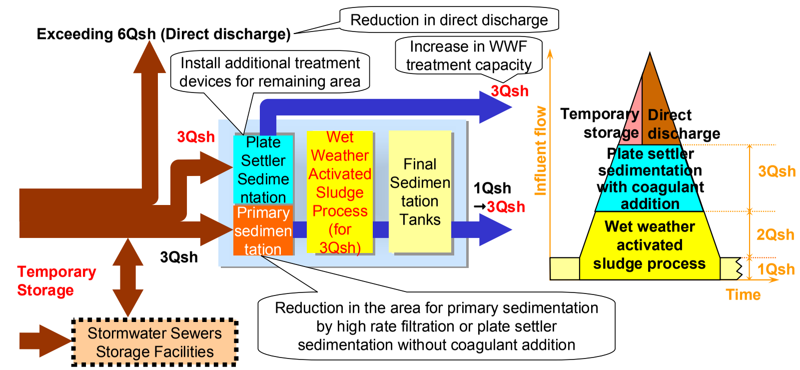
# Image of Wet Weather Sewage Treatment in the New Plan

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# Project Cost

- For the previous improvement plan, the total project cost was estimated to be about 300 billion yen.
- Whereas in the new improvement plan, which fully utilizes existing facilities to increase the wet-weather sewage continuous treatment capacity, the total project is estimated to be about 200 billion yen, a saving of about 100 billion yen.

Table 1: Estimated Project Cost for CSS Improvement

| Approaches | Cost (billion JPY) |
|---|---|
| Wet Weather Activated Sludge Process | 18 |
| Plate Settler Sedimentation Process | 57 |
| Construction of Storage Facilities | 87 |
| Other Approaches<br>Filling Sediment Traps in Manhole Bottoms<br>Replacement of Screens, etc. | 30 |
| Total | 192 |

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# Summary

- "Wet weather activated sludge process" and "plate settler sedimentation process" have been developed to a practical as widely applicable economic continuous treatment technologies, which can;
  - Utilize existing facilities effectively,
  - Reduce CSS improvement costs significantly,
  - Show rapid impacts on CSS improvement,
  - Facilitate the progress of CSS improvement, and
  - Suggest that CSS has the potential to become the most appropriate water pollution control system for densely populated urban areas where flood control is also a critical issue.

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