Manual for Introducing Wet Weather Wastewater Treatment Process

First English Edition

July 2026

Clearwater OSAKA Corporation

Revision History

Date	Version	Record of change
July 2026	1.0	Initial release

Conventions Used in This Manual

The symbol § indicates a numbered topic. Topic numbers are assigned consecutively throughout the manual, regardless of chapter or section.

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Preface to the English Edition

The Wet Weather Wastewater Activated Sludge Treatment Process (hereinafter referred to as the “3W Treatment Process”) is a cost-effective secondary treatment approach that utilizes existing activated sludge facilities—without the need for new construction—to treat temporarily increased wastewater flows, such as those occurring during rainfall events especially in combined sewer systems. This process was originally developed by the Municipal Government of Osaka in Japan.

The development of the 3W Treatment Process began when an Osaka City engineer, who had been exploring options for wet weather wastewater treatment, came across a technical report. The report stated: “To examine the treatment capacity of the final clarifier, additional flow was introduced from the adjustable weir at the downstream end of the aeration tank, which resulted in a total amount of three times the maximum dry weather influent. Despite the increase in water volume, no carryover of activated sludge was observed.” Inspired by this finding, Osaka City initiated a feasibility study on applying activated sludge treatment to wet weather flows, which ultimately led to the establishment of the 3W Treatment Process in 2000. By 2006, the process had been fully implemented at all 12 wastewater treatment plants in the city and has been in operation for more than two decades.

The 3W Treatment Process is now referenced in Japan’s national guidelines for the planning and design of wastewater facilities as one of the recommended approaches for improving combined sewer system performance. However, despite its clear advantages in cost, ease of operation, and reliability in performance, it has not yet been widely adopted in Japan. One contributing factor could be the absence of publicly available planning and design methodologies necessary for its implementation.

Clearwater OSAKA Corporation (hereinafter referred to as “CWO”) is a company established through the privatization of the sewerage operation and maintenance section within the Osaka City’s Sewerage Division. In order to promote the widespread adoption of the 3W Treatment Process, an innovative treatment process developed by Osaka City, CWO conducted extensive literature reviews, interviews with original developers, and surveys of all municipalities that had implemented the process in Japan. Through these efforts, CWO developed detailed documentation on the process, particularly by clarifying aspects that had previously relied on empirical knowledge through engineering-based analysis. The documentation was compiled into the Technical Implementation Manual for the Wet Weather Activated Sludge Treatment Process and released to the public in 2024.

As part of our ongoing efforts to promote the understanding of this process globally, CWO has now prepared and released an English edition of the manual. We hope that this manual will serve as a useful resource for wastewater professionals who are facing challenges associated with increased wet weather influent flows at treatment plants, regardless of whether operating a combined sewer system or a separate one.

Finally, we would like to express our sincere gratitude to everyone who contributed to the development of this manual, including personnel from Osaka City and other municipalities using the process, as well as the engineers involved in the development and refinement of the process and its operational procedures, for their invaluable advice and generous support.

July 2026
Clearwater OSAKA Corporation
Sewerage Technology Research Institute
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Chapter 1 Terms and Definitions

3W Treatment Process:

The Wet Weather Wastewater Activated Sludge Treatment Process, referred to in this manual as the “3W Treatment Process.” The abbreviation "3W" stands for "Wet Weather Wastewater.”

Effluent Pollutant Load:

The amount of pollutants contained in the treated wastewater discharged from a wastewater treatment plant.

Excess Flow:

The wastewater flow exceeding 1.0 Qsh (design peak hourly wastewater flow) in the 3W treatment process. When the wastewater flow is n Qsh, the excess flow is (n-1) Qsh.

Initial Adsorption:

An early stage of pollutant removal in the activated sludge process during which pollutants are adsorbed onto the surface of activated sludge.

Modification:

The implementation of small or partial changes to the structure or equipment of an existing facility to make it suitable for the 3W treatment process.

New Construction:

In practice, the construction of entirely new treatment plants is now rare; in this manual, the term also includes the reconstruction of an existing facility through the decommissioning of old units and the installation of new components.

Primary Treatment:

The initial stage of wastewater treatment, in which solids are removed from wastewater by physical processes such as sedimentation separation in primary settling tanks.

Qsd:

Design peak daily wastewater flow. Osaka city sets 1.0 Qsh/1 Qsd = 1.2.

Qsh:

Design peak hourly wastewater flow.

Solids Loading Rate:

The mass of solids applied to a unit surface area during a given period of time and used as a design criterion for sedimentation tanks, thickeners, and similar facilities. The unit is $kg/(m^2 \cdot day)$.

Step Feeding:

A feeding method in which wastewater is introduced at multiple points along a biological reaction tank rather than at a single inlet point. The influent is divided and distributed through a step-feed channel.

Step-feed Movable Weir:

A weir used to distribute flow from a step-feed channel to the final compartment of the biological reaction tank. It is adjustable in height and watertight on three sides. Motorized versions enable automatic adjustment of the weir height in response to changes in flow rate.

Step-feed Ratio:

The ratio of the capacity of a specific step-feed section to the total capacity of the biological reaction tank.

Surface Overflow Rate:

The flow rate applied per unit surface area of a sedimentation tank, used as a key design parameter for evaluating hydraulic loading. The unit is $m^3/(m^2 \cdot day)$.

Chapter 2 Basic Concepts of This Manual

§ 1 Scope of Application

This manual is intended for the activated sludge process using the suspended-growth process and provides guidance for the planning, design, operation, and maintenance of facilities incorporating the 3W treatment process, under the conditions described below.

(1) New construction, expansion, and modification of wastewater treatment plants serving combined sewer systems.

(2) Implementation of measures against inflow and infiltration (I/I) during rainy weather in wastewater treatment plants serving separate sewer systems.

[Explanation]

This manual was prepared to facilitate the adoption of the 3W treatment process in wastewater treatment facilities employing the suspended-growth activated sludge process and provides guidance for their planning, design, operation, and maintenance. This manual covers the planning, design, operation, and maintenance of facilities with the 3W treatment process and provides guidance tailored to two situations: (1) introduction as a combined sewer overflow countermeasure, and (2) introduction as a countermeasure for I/I during wet weather in separate sewer systems.

§ 2 Role of This Manual

This manual clarifies the principles and mechanisms of the 3W treatment process, as well as the design and equipment specifications. In addition, it summarizes the basic approach to operation and maintenance for the 3W treatment process based on operational data from full-scale facilities in Osaka City.

[Explanation]

Although the 3W treatment process has already been adopted at many wastewater treatment plants, there are no guidelines or documents that systematically explain the process, and the technical information necessary for its implementation—such as planning and design specifications and evaluation procedures—has not been clearly communicated.

Therefore, this manual presents the principles and mechanisms of the process in a structured and systematic manner and provides design specifications and associated equipment specifications with explanations of their functions, which are essential for sewerage professionals in local governments and the private sector when considering adoption of the 3W treatment process.

The 3W treatment process has been in operation at wastewater treatment plants in Osaka City for more than 20 years, during which a wide range of operational data and technical know-how on its operation and maintenance have been accumulated. Therefore, based on accumulated operational experience and data, this manual also outlines the basic approach to, and precautions for, the operation and maintenance of the process, serving as a reference for plant operators and engineers responsible for its operation.

Chapter 3　Fundamentals of the 3W Treatment Process

Section 1　Overview of the 3W Treatment Process

§ 3　The 3W Treatment Process

The 3W treatment process is a process that treats wastewater exceeding the plant's treatment capacity in dry-weather conditions (1Qsh) by feeding the wastewater into the final compartment of the biological reaction tank for further treatment by the activated sludge process, when a treatment plant, in both combined and separate sewer systems, receives excess wastewater due to rainfall or other factors.

[Explanation]

The 3W treatment process was developed as a measure for wet-weather wastewater treatment in combined sewer systems, but it is effective for separate sewer systems as well in managing the surge in water to be treated, which has resulted from inflow and infiltration (I/I) of rainwater or extraneous waters. Generally, in combined sewer systems, when influent flow exceeds the volume of the design maximum hourly wastewater (1Qsh), water equivalent to 1Qsh is fed into biological reaction tanks after sedimentation and the remaining excess water is discharged to public waters after sedimentation (primary treatment).

The 3W treatment process treats excess flow that would otherwise be discharged as primary-treated effluent by introducing it into the final compartment of the biological reaction tank via a step-feed channel, where it is further treated by the activated sludge process. (In the case of Step Aeration Process, the excess flow is introduced via the fourth step-feed movable weir.) (See Figure 3-1)

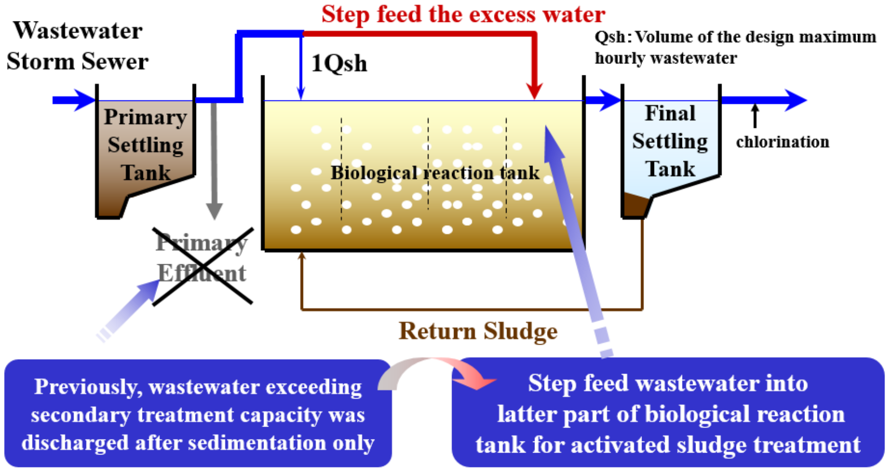


Figure 3-1　Conventional Process Flow and 3W Treatment Process Flow Under Wet-Weather Conditions in a Combined Sewer System

§ 4 Combined Sewer Systems and the 3W Treatment Process

In combined sewer systems, which collect both sanitary wastewater and stormwater in a single pipe system, when stormwater increases, raw wastewater could be released into public water bodies from storm overflow chambers in the collection network and some part of wastewater arriving at treatment plants could be discharged without treatment or after sedimentation only. The improvement of combined sewer systems is an urgent issue, and the Sewerage Act stipulates the need to take necessary measures.

The 3W treatment process can reduce pollutant load caused by discharge of primary effluent from treatment plants during wet weather, therefore, it will be an effective measure to improve combined sewer systems.

[Explanation]

Combined sewer systems inflict a negative impact on the water quality of public water bodies because the water quality of effluent from the systems deteriorates significantly during stormy weather. Effluent from combined sewer systems is categorized into three types: raw sewage discharged from sewer outlets, primary effluent from treatment plants (treated only by sedimentation), and properly treated water after secondary treatment (or advanced treatment). The level of impact on water quality depends on the ratio among the three types of effluent. Figure 3-2 shows locations of discharging points in the treatment process.

Table 3-1 shows the types of treatment applied to effluent in treatment plants in three cities which adopt the combined sewer system and the ratios of discharged pollutant loads of each treatment type to the whole pollutant loads. At wastewater treatment plants in combined sewer systems in Japan, generally three times the volume of design maximum hourly wastewater flow in dry weather is conveyed to treatment plants during storm events. When the influent volume triples, the load ratios of discharged wastewater after primary treatment range from 26% to 37% by water volume and 49% to 64% by pollutant load. The target of the 3W treatment process is primary effluent. Compared with directly discharged wastewater, which is vast in amount and requires immediate response without any delay, the 3W treatment process can reduce the amount of primary effluent and the pollutant loads to be discharged effectively.

To improve a combined sewer system, a comprehensive approach, not a set of isolated solutions, is necessary because it requires implementing all sorts of measures covering all wastewater service area. As a matter of course, it requires significant costs and time for construction; therefore, functional improvement of existing facilities should first be examined.

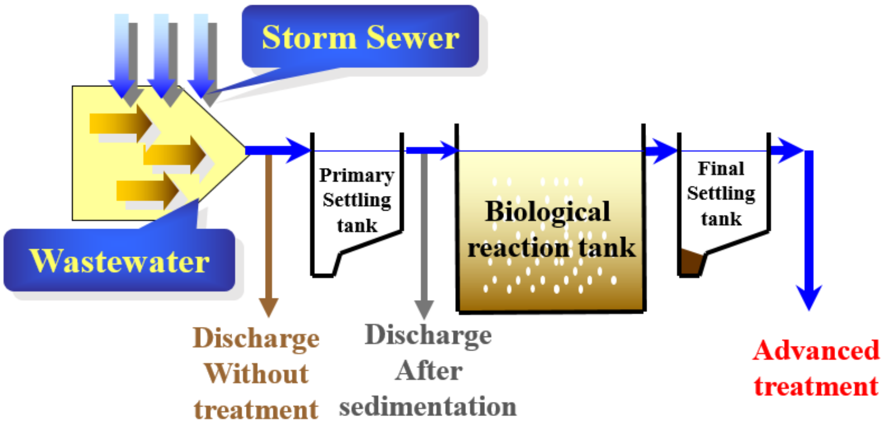


Figure 3-2　Locations of Discharging Points Under Wet-Weather Conditions

Table 3-1　Proportions of Effluent Volume and BOD Load by Treatment Type Under Wet-Weather Conditions in Three Cities

	Discharged flow during rainy weather（%）			Discharged BOD pollutant load during rainy weather(%)		
	Without treatment	Primary treatment	Advanced treatment	Without treatment	Primary treatment	Advanced treatment
A city	28	37	35	19	64	17
B city	24	26	50	31	49	20
C city	18	27	55	18	50	32

§ 5　Separate Sewer Systems and the 3W Treatment Process

Although the 3W treatment process was originally developed for combined sewer systems, it can also treat wastewater flows exceeding the capacity of conventional activated sludge processes in separate systems, and is applicable to treatment plants in separate sewer systems where influent flow significantly increases due to wet-weather inflow and infiltration (I/I).

[Explanation]

It is similarly feasible to treat wastewater of two to three times the designed capacity of a treatment plant in separate sewer system by applying the 3W treatment process. There are some considerations in applying it to separate sewer systems and one of them is as follows: Generally, the SVI's of mixed liquor in biological reaction tanks in separate sewer systems are higher than those in combined sewer systems, which results in low sludge settling velocity; therefore, special attention to the condition of solid-liquor separation in final sedimentation tanks is required.

§ 6 Characteristics of the 3W Treatment Process

The 3W treatment process can utilize existing facilities without the need for construction of new facilities or significant alteration, resulting in low initial investment

[Explanation]

Generally, a flow of approximately three times the design peak hourly wastewater flow (1Qsh) is conveyed to treatment plants during wet weather and only 1Qsh of it is treated with the activated sludge process. The 3W treatment process, however, sends the remaining 2Qsh wastewater exceeding the design capacity into the final compartment of the biological reaction tank.

In treatment plants with step-feed channels, the 3W treatment process can be implemented by operating the step-feed movable weirs to introduce wastewater into the final compartment of the biological reaction tank during wet weather. In plants without step-feed channels, the 3W treatment process can be applied by installing pipes and channels to convey wastewater to the final compartment of the reaction tank. Major characteristics of the 3W treatment process are listed below.

(Advantages)

- Land acquisition is not necessary since the process can be introduced by partially modifying existing facilities.
- Initial investment cost is low since the process requires only modification of existing facilities.
- Operation and maintenance is easy and the electricity cost is low since the process can be operated by controlling only step-feed movable weirs for the most part.
- Air flow rate and return sludge flow rate in the process is equivalent to those in dry conditions and energy consumption increases only for operation of step-feed movable weirs.
- Chemicals are not used.

(Disadvantages)

- The performance of the 3W treatment process could be affected by characteristics of activated sludge (MLSS and settleability of sludge).
- When biological nitrogen and phosphorus removal is used simultaneously with the process, the performance of the former process will decrease.

§ 7 Meaning of the Name “3W Treatment Process”

The process was developed to treat increased wastewater during wet weather. It was named the Wet Weather Wastewater Activated Sludge Treatment Process and abbreviated as the “3W treatment process” from its initial letters.

[Explanation]

In 1990’s, Osaka City government, which developed this method, presented it at international academic conferences under the English name “Wet Weather Wastewater Activated Sludge Treatment Process.” Now, this is referred to as the “3W Treatment Process” after the following developments:

(1) In 2000’s, the nickname was adopted after a vote among the City’s sewerage personnel.

(2) This process is effective not only for improvement in combined sewer systems but also for inflow and infiltration (I/I) in separate sewer systems and temporal increase in wastewater during facility renovation work. The scope of application extended beyond wet weather events.

(3) Through over 20 years’ observations of normal operations of the 3W process in Osaka City’s treatment plants, it was found and proved that average treatment capacity was almost three times that in dry weather based on maximum hourly treatment capacity.

Section 2 Facilities using other processes than the standard activated sludge treatment process

§ 8 Considerations for Implementing Alongside an Advanced Treatment Process

When the 3W treatment process is carried out with biological nutrient removal process, it becomes difficult to achieve water quality standards specified for the advanced wastewater treatment process.

[Explanation]

During the 3W treatment process, wastewater fed into the final compartment of the biological reaction tank stays there for a shorter time than the usual retention time, which results in an overflow of ammonia nitrogen and reduces ammonia removal capacity. As for the performance of biological phosphorous removal, due to the excess water flowing into the final sedimentation tank without passing through the anaerobic tank, it also declines. Consequently, it will be difficult to attain the water quality specified for the advanced wastewater treatment during the 3W treatment process.

On the other hand, once the 3W treatment process is finished and the system returns to normal dry weather processing, the original function of the advanced wastewater treatment will be restored immediately.

Please note that during rainy weather, regardless of whether the 3W treatment process is in place or not, the treatment capacity for biological phosphorus removal tends to decline due to factors such as inflow of DO into the anaerobic tank and insufficient carbon sources resulting from dilution of the influent water.

§ 9 Considerations for Implementing Alongside a Carrier-Added Activated Sludge Process

When using the 3W treatment process and carrier-added activated sludge process at the same time, it is necessary to consider measures to address the increased water volume at the carrier separation screen and to prevent clogging on the screen.

[Explanation]

In addition to the considerations around the combined use with advanced wastewater treatment (see 8. Considerations for Implementing Alongside an Advanced Treatment Process), other issues involving the increased amount of water passing through the carrier separation screen and preventive measures for clogging on the screen must be addressed.

Section 3　Basic Mechanisms of the 3W Treatment Process

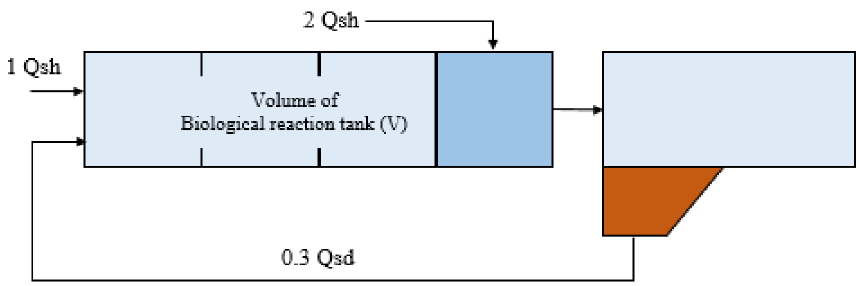
§ 10　Activated Sludge Treatment in the 3W Treatment Process ~ Why is it possible to remove pollutants in such a short retention time?

In the activated sludge treatment process, dissolved organic matter in sewage is removed through initial adsorption onto the biomass in activated sludge. Pollutants (dissolved organic matter) in sewage flowing into the final compartment of the biological reaction tank can be removed in a short time by this function.

[Explanation]

Among pollutants in wastewater, dissolved organic matter is removed in a short time by initial adsorption. Figure 3-4 shows the changes in amount of dissolved organic matter, which was measured by using activated sludge from a sewage treatment plant under actual operation. Within about 20 to 30 minutes, 60–70% of dissolved organic matter was adsorbed and removed. Microorganisms in activated sludge mixed with inflowing sewage at the inlet of a biological reaction tank immediately adsorb dissolved organic matter in the wastewater and decompose and assimilate it at a substantial speed as they pass through the reaction tank and recover their initial adsorption capacity in approximately 5 hours, by which time they reach the final compartment of the reaction tank.

Figure 3-3 shows the correlation between step-feed inflow volume and retention time. When excess wastewater to be fed from the fourth step is 2Qsh, the HRT in the reaction tank for 1Qsd is 6.5 hours, and the return sludge rate is 30%, the retention time (t_t) (including return sludge) in the final compartment of the reaction tank (the fourth step) during the 3W treatment process will be calculated in the following way.



$$t_t = \frac{{}^{1}\!/_{4} \cdot V}{3Qsh + 0.3Qsd} = \mathbf{0.42}\ (hrs)$$

From the given condition：$\frac{V}{Qsd} = 6.5\ (hrs)$

$$1\text{Qsh} = 1.2\text{Qsd}$$

Figure 3-3 Step Feed and Retention Time

<u>Dissolved organic matter in sewage</u> introduced from the fourth step is adsorbed onto activated sludge in the initial adsorption phase **<u>within the retention (contact) time of about 20 to 30 minutes.</u>** (See Figure 3-4)

Figure 3-5 illustrates that the activated sludge is separated by sedimentation in the final sedimentation tank and then returns to the reaction tank as return sludge. While returning to the reaction tank, the activated sludge decomposes and assimilates adsorbed organic matter and restores its adsorption capacity, thereby allowing the 3W treatment process to continue.

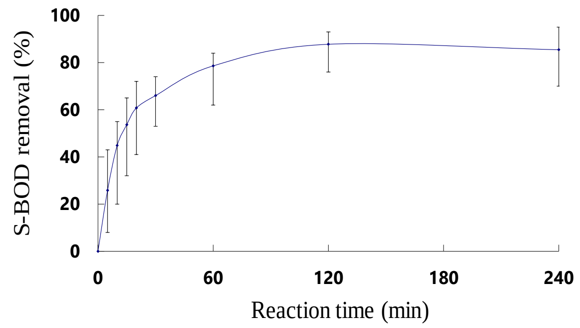


Figure 3-4 Changes in S-BOD Removal Rate over Time by Batch Test

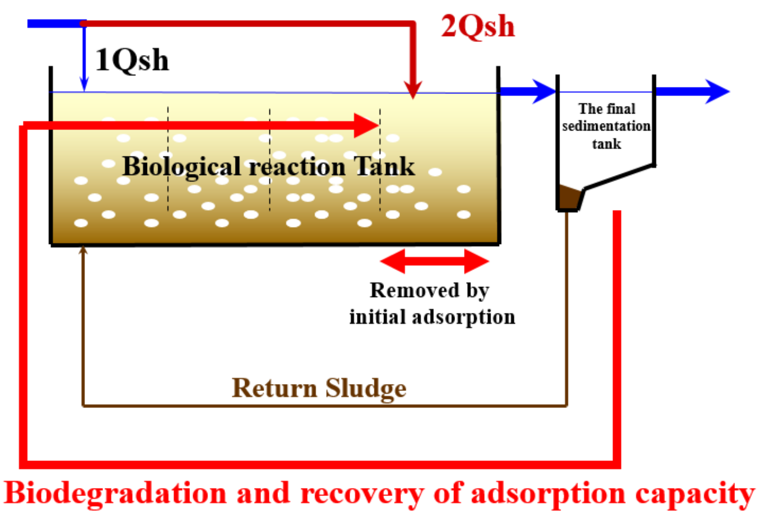


Figure 3-5 Removal of Organic Pollutants by Activated Sludge

§ 11 Behavior of Final Sedimentation Tank During Wet Weather ~ Why is it possible for the final sedimentation tank to hold a larger volume of water than that in dry weather?

In the 3W treatment process, MLSS concentration in the final compartment of the biological reaction tank is greatly diluted by sewage flowing into the final compartment of the biological reaction tank. Therefore, compared with a case where the same amount of water is introduced from the primary inlet of the biological reaction tank, the solids load on the final sedimentation tank is significantly low, and solid-liquid separation can be performed effectively even when the water volume is increased.

[Explanation]

Sedimentation tank is normally designed based on "overflow rate (= influent / sedimentation tank area)." However, in final sedimentation tank, solids concentration (the concentration of activated sludge transferred from biological reaction tank) is generally high, so it is necessary to consider the "solids load (= influent solids mass / sedimentation tank area)" in addition to the overflow rate.

Immediately after the 3W treatment has gone into operation, the activated sludge in the reaction tank is pushed into the final sedimentation tank with an average MLSS concentration and the solids load in the final sedimentation tank increases at a rate equivalent to the increase in hydraulic loading. However, it is diluted by the excess water (e.g., when the total treatment volume is 3Qsh, the flow rate of the excess water will be 2Qsh) introduced into the final compartment of the reaction tank (the fourth step in the case of 4-step aeration), and the MLSS concentration in water coming to the final sedimentation tank decreases rapidly. As a result, after the start of the operation of the 3W treatment process, in the final sedimentation tank, the hydraulic loading is maintained at a high level while the solids load is reduced along with the decrease in MLSS concentration.

Figure 3-6 shows a comparison of amounts of influent solids in a final sedimentation tank under two different conditions: (1) among 3Qsh of wastewater to be treated in wet weather, 2Qsh of excess water is introduced into the final compartment of the reaction tank (the fourth step of the 4-step aeration), (2) among 3Qsh of wastewater to be treated in wet weather, the whole 3Qsh is introduced into the beginning of the reaction tank. The case (a) at the top illustrates the normal treatment during sunny weather, and the (b) and (c) show the cases of treating three times the amount of wastewater (3Qsh). In case (b), the entire amount is introduced from the initial step of the reaction tank, and in case (c), 2Qsh is introduced from the fourth step of the tank (the 3W treatment process). In all cases, the sludge concentration and solids load of the mixed liquor transferred from the reaction tank to the final sedimentation tank are shown as a ratio (times) to the case (a).

In case (b), where the entire volume of water is introduced through the upstream inlet of the reaction tank, the solids load to the final sedimentation tank is 2.6 times that of normal treatment in dry-weather, whereas in case (c), under the 3W treatment process, it remains at 1.18 times. In the 3W treatment process, the increase in solids load can be significantly suppressed even during peak periods immediately after the start of treatment by step feeding wastewater into the final compartment of the reaction tank.

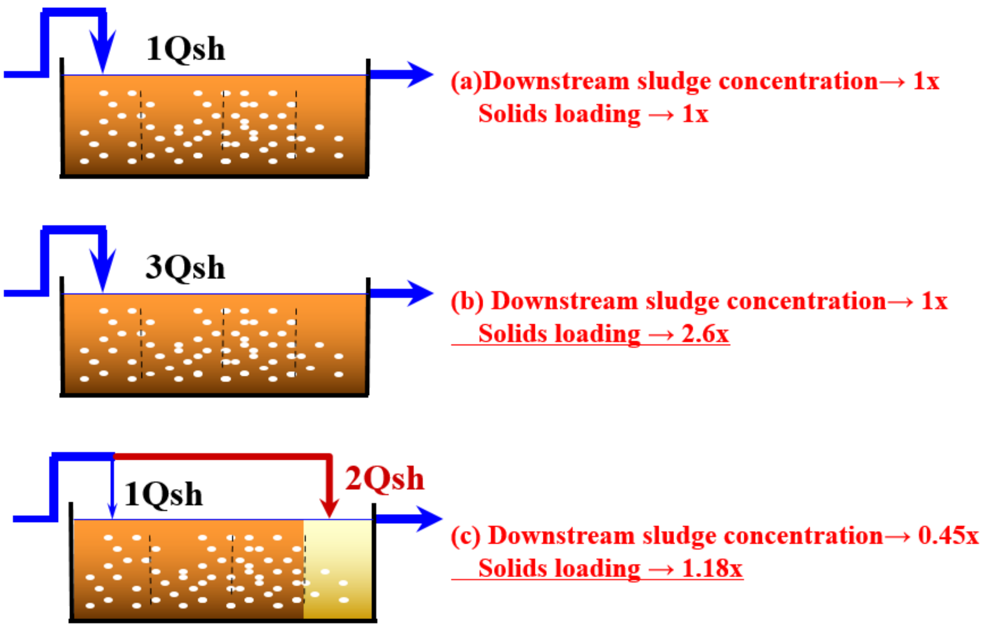


Figure 3-6 Sludge Concentration in the Final Compartment of the Biological Reaction Tank and Solids Load to the Final Sedimentation Tank

Chapter 4　Effects of Implementing 3W Treatment Process

Section 1　Effective Measures for Reducing Combined Sewer Overflows

§ 12　Comparison of Treated Water Quality Under Dry-Weather Operation, Normal Wet-Weather Operation, and 3W Treatment Process

In the 3W treatment process, as described in §11, the solids load in the final sedimentation tank is significantly reduced, and solid-liquid separation can be achieved smoothly even when the water volume increases.

Since a large volume of sewage is treated with existing biological reaction tanks and final sedimentation tanks, the quality of the secondary effluent is slightly lower than that obtained under standard-flow conditions. However, compared with the case in which the same large amount of sewage is discharged after primary treatment only, the overall effluent quality is significantly better.

[Explanation]

Since the 3W treatment process treats a large amount of wastewater using existing biological reaction tanks and final sedimentation tanks, the quality of the secondary effluent is slightly lower compared with that achieved under standard-flow conditions. However, compared with the primary-treatment-only discharge at the same flow rate, the overall effluent quality is significantly better. Table 4-1 shows the differences in water quality of the final sedimentation tank effluents under each treatment method.

Table 4-1　Final Sedimentation Tank Effluent Quality: 3W Treatment Process vs. Standard Activated Sludge Process

	SS(mg/L)		BOD(mg/L)	
	3 W treatment process	Conventional activated sludge treatment	3 W treatment process	Conventional activated sludge treatment
	8	5	11	6.9
	9	4.7	12	6.8
	13	6	13	6.7
	7	6	4.3	4.8
	6	5	6.4	5.2
	7.9	9.7	5.9	8.6
	3.8	5.7	4.5	5.1
Average	7.8	6.0	8.2	6.3
Water quality ratio	1.30		1.30	

・Survey location：Osaka City Hirano Sewage Treatment Plant

§ 13 Operating Records

A survey of the performance of 3W treatment process at facilities which routinely operate the process and have experienced multiple rainfall events demonstrated satisfactory **overall effectiveness.** Furthermore, the process maintained stable performance under high-load conditions (both hydraulic and pollutant loads) and during continuous long-term

[Explanation]

A long-term survey of the 3W treatment process performance at operating facilities in Osaka City has confirmed the effectiveness of the process and its stable treatment performance under high-load conditions (both hydraulic and pollutant loads) and during long-term continuous operation.

(1) Overall Treatment Effect

A study of 19 rainfall events confirmed that all 3W treatment operations achieved satisfactory effluent quality, indicating that the process was performed appropriately. The duration of the 3W treatment ranged from 2.5 hours to 45 hours (averaging 11.1 hours), while the treated water volume ranged from 1.31Qsh to 3.38Qsh (averaging 2.46Qsh). Additionally, the MLSS concentration in the biological reaction tank at the start of the 3W treatment ranged from 680 mg/L to 1,970 mg/L (averaging 1,280 mg/L). The 3W treatment process was found to be feasible for virtually all anticipated rainfall events and capable of treating up to approximately 3Qsh of wastewater. In all cases, no operational anomalies, such as sludge overflow from the final sedimentation tank, were observed. After the completion of the 3W treatment, the system quickly returned to dry-weather operation and the treatment performance was restored to pre-3W-treatment levels. The 3W effluent qualities from 19 rainfall events over a period of more than one year were all sufficient, with SS and BOD averaging 9.1 mg/L and 7.1 mg/L, respectively. The 90th percentile of treated water BOD was 9.5 mg/L.

(2) High-Load Operation

The maximum treatment volume reached 3.38Qsh and the BOD concentration of the influent to the reaction tank peaked at 87 mg/L. However, the maximum BOD concentration in the treated effluent was 12 mg/L, with an average of 7.2 mg/L.

(3) Long-Term Operation

The longest continuous 3W process operation was 45 hours due to prolonged rainfall totaling 165 mm. The treated water quality (average BOD, 3.8 mg/L; average SS, 6.2 mg/L) remained stable throughout the 3W operation, demonstrating that the 3W process is capable of long-term continuous operation.

§ 14 Effluent Pollutant Load Reduction Performance

Assuming a wastewater treatment service area of approximately 1,500 ha, the 3W treatment process is expected to reduce pollutant loads—such as BOD and SS—discharged into public water bodies, including rivers, by about 20–30% annually compared with the conventional process, which treats 1Qsh by the activated sludge process and discharges the remaining flow after primary treatment alone.

[Explanation]

A study of the 3W treatment process was conducted at the South Train of the Hirano Sewage Treatment Plant in Osaka City, covering four rainfall events from September 2000 through January 2001. The study compared pollutant loads discharged during rainfall events under the 3W treatment process with those under the conventional treatment process, which treats up to 1Qsh by the activated sludge process and discharges excess flow after primary sedimentation only.

The summary of pollutant load reduction performance is shown in Table 4-2. For each rainfall event, the pollutant load was reduced by 59.1–90.7% (average 70.6%) for SS and by 26.3–77.6% (average 61.0%) for BOD. When considering the total pollutant load discharged over the course of a year, the reductions in BOD, SS, and COD were approximately 20–30% for all three parameters.

Table 4-2 Effect of the 3W Treatment Process on Pollutant Discharge Load Reduction

No.	Discharge load（SS）			Discharge load（BOD）		
	3 W kg	Conventional process kg	Reduction rates %	3 W kg	Conventional process kg	Reduction rates %
1	176.8	640.2	72.4	315.8	428.4	26.3
2	13.4	144.4	90.7	36.1	149.1	75.8
3	141.6	346.1	59.1	127.2	354.7	64.1
4	129.8	441.9	70.6	118.3	528.3	77.6
Total	461.6	1572.6	70.6	597.4	1460.5	59.1
Average			73.2			61.0

Conventional Process：1Qsh is treated by the activated sludge process, and the excess wastewater is discharged after sedimentation treatment only.

§ 15 Comparison of 3W Treatment Process with Other Combined Sewer Overflow Control Measures

Compared with alternative measures, the 3W treatment process is more cost-effective and yields results more rapidly, as it can be implemented with only minor modifications to existing facilities.

[Explanation]

The 3W process is more economically efficient (see 17. Comparison of Cost-Effectiveness) and can achieve results more rapidly, requiring relatively less implementation time than other combined sewer overflow control measures. Major reasons are as follows:

- The 3W treatment process does not require new facilities because they can be implemented through modifications to existing facilities.
- Power consumption is low because the process is operated primarily through the control of step-feed weirs.
- The process does not require additional chemicals.
- Since biological treatment effectively reduces coliform bacteria and odor, the disinfectant dosage rate remains the same as that used under dry-weather conditions.

§ 16 Costs for Implementing, Operating, and Maintaining 3W Treatment Process

Implementing the 3W treatment process incurs costs for the installation of movable weirs and, depending on the condition of existing facilities, modifications to civil structures.

Operation and maintenance costs are primarily associated with the electrical power required to operate the step-feed movable weirs.

[Explanation]

Capital costs for equipment installation in existing treatment plants can be estimated using the cost functions presented in Figure 4-1.

<Conditions for Cost Estimation of Movable Weir Installation>

(1) Electrification of Movable Weirs

- Number of movable weirs: 1–15 weirs (1 weir per reaction tank)
- Motorized movable weirs (direct-coupled type); motor output: 1.5 kW;

weir width: 1,000 mm; stroke: 500 mm

The width and the stroke of movable weirs shall be calculated considering head losses in channels and other hydraulic elements for each flow rate.

For this calculation, the weir width and stroke are assumed to be 1,000 mm and 500 mm, respectively.

(2) Electrical Work for Equipment Installation and Functional Upgrade

- Remote monitoring systems, control panels, instrumentation (e.g., water level gauges) and other equipment

Four different panel configurations are assumed: 1 panel for 1 reaction tank, 1 panel for 5 reaction tanks, 2 panels for 10 reaction tanks, and 3 panels for 15 reaction tanks.

Assumption: a monitoring system consists of a general-purpose Programmable Logic Controller (PLC) and a standard personal computer.

Assumption: one water level gauge monitors the entire inlet channel.

Assumption: a locally installed monitoring and control panel system is used instead of a centralized control system.

(3) Civil Engineering Work, Including Structural Modifications Required for the Installation of the Equipment Described Above

(4) Overhead Costs

Installation costs for a newly built treatment plant are lower than that for existing facilities, as removal of existing weirs and associated structural modifications are not required.

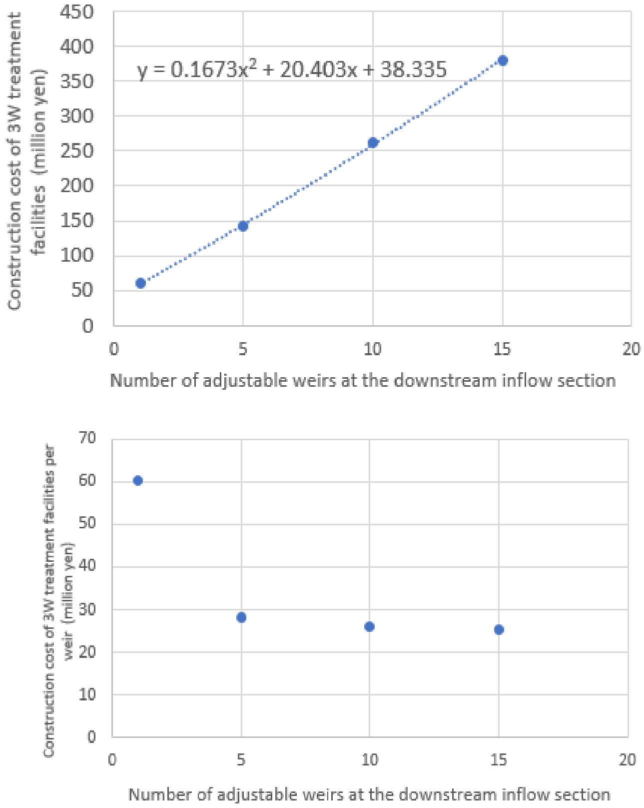


Figure 4-1 3W Treatment Process Implementation Cost (FY2024 Unit Price)

<Costs for Operation and Maintenance>

Although power is required to operate the step-feed movable weirs, energy consumption is sufficiently low to be neglected in the planning stage.

Power Consumption: Negligible on an annual basis and therefore not considered.

Basic Electricity Charge: No changes to the electricity supply contract are required.(1)

Note (1):

The step-feed movable weirs do not operate continuously; therefore, their power consumption is negligible. For example, even if 20 movable weirs are added and each weir consumes 1.5 kW, the peak demand does not necessarily increase by 30 kW (1.5 kW × 20 weirs). The power consumed by the step-feed movable weirs remains within the normal fluctuation range of the plant's electrical load and is therefore unlikely to affect the peak demand, which is primarily determined by larger existing electrical equipment.

§ 17 Comparison of Cost-Effectiveness (Pollutant Load Reduction per Unit Cost)

The 3W treatment process is more cost-effective than other combined sewer overflow control measures in terms of pollutant load reduction per unit cost.

[Explanation]

The implementation cost per unit of pollutant load reduction is shown in Table 4-3. Even if some civil structure modifications—such as elevation works or channel/weir expansions—are required to address hydraulic issues, the 3W treatment process remains more cost-effective than other combined sewer overflow control measures.

In addition, an example hydrograph used in a feasibility study for the adoption of the 3W treatment process as part of a combined sewer overflow control improvement plan is shown in Figure 4-2. Table 4-4 and Figure 4-3 present a comparison of the 3W treatment process and a stormwater retention basin in terms of pollutant load reduction performance and costs.

When comparing the costs required to achieve equivalent BOD load reduction performance, the annual cost of the facility incorporating the 3W treatment process is approximately one-tenth to one-fortieth that of a stormwater retention basin, excluding land acquisition costs. Therefore, the 3W treatment process can be considered more cost-effective than a stormwater retention basin.

Table 4-3 Costs per Unit BOD Load Reduction

Control facilities	Cost per unit BOD load reduction Million yen/ t・BOD
3W Treatment Process （average construction cost）	0.05
3W Treatment Process （maximum construction cost（including civil engineering work））	0.11
Storm water retention basin	0.99～1.25
Inclined-plate settling basin with coagulant addition	0.46～0.65

Note: The costs of the 3W treatment Process are calculated based on actual construction costs in Osaka City.

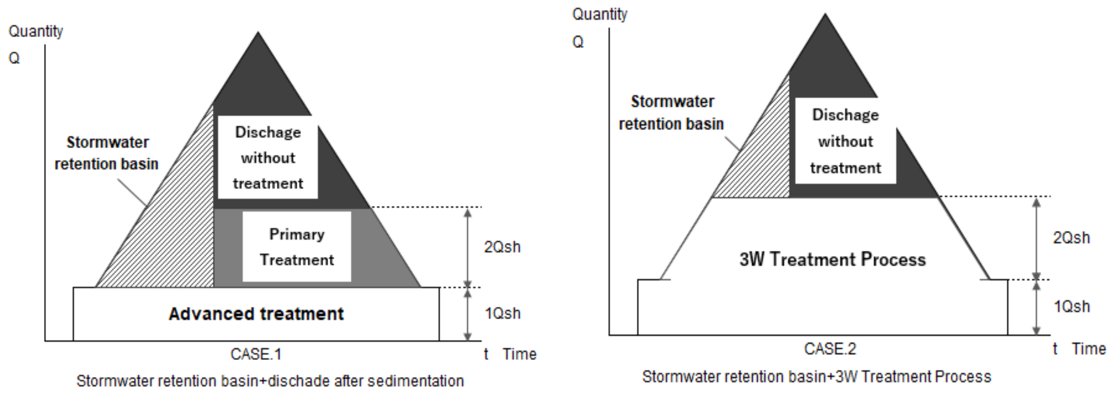


Figure 4-2 Example Hydrographs for Evaluating the Implementation of the 3W Treatment Process in a Combined Sewer Overflow (CSO) Improvement Plan

Table 4-4 Comparison of BOD Load Reduction and Costs for 3W Treatment Process and Stormwater Retention Basin

	Annual BOD load reduction (1) t/year	Construction cost (million yen) (2)			Annual cost (2) (million yen)
		Civil engineering	Machine	Total	
3W Treatment Process (average actual construction cost)	319	2	215	217	12
3W Treatment Process (maximum actual construction cost)	319	325	500	825	33
Stormwater retention basin middle	284	9,660	2,265	11,925	318
Stormwater retention basin large	357	13,524	3,171	16,695	444

Notes:

(1) The annual BOD load reduction values for the 3W treatment process are based on averages of actual reduction data, while those for the stormwater retention basin are based on simulation results.

(2) As the values are based on cost estimation framework and unit prices applicable in FY2004, actual project conditions, including the project location and fiscal year, should be taken into account.

(Comparison Conditions)

- Target service area 1,500 ha
- Peak hourly wastewater flow (Qsh) 285,000 m³/day
- 3W treatment process capacity (treatment capacity) 3Qsh: 855,000 m³/day
- Stormwater retention basin capacity (storage capacity) Middle (5 mm): 75,000 m³
  Large (7 mm): 105,000 m³
- Construction costs Civil works costs and mechanical and electrical installation costs

(Note: Land acquisition costs required for stormwater retention basins are not included in this cost estimation.)

- Annual operating costs   O&M costs + depreciation costs

  Depreciation costs = (Civil works costs ÷ 50) + (mechanical and electrical installation cost ÷ 20)

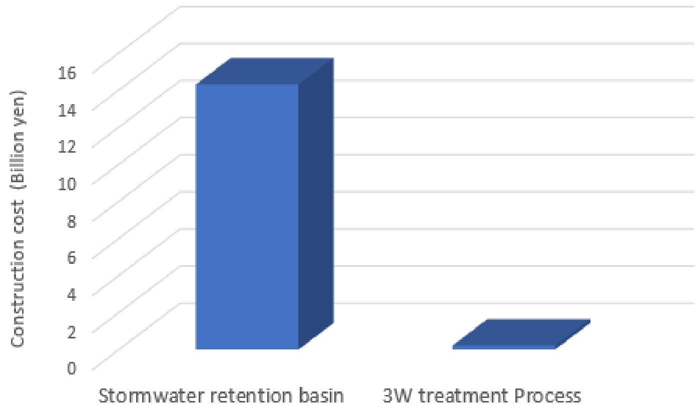


Figure 4-3 Economic Benefits of the 3W Treatment Process

Note: The cost of the 3W treatment process is based on the average of actual construction costs, while the cost of the stormwater retention basin is based on estimated average costs.

Section 2　Measures Against Wet-weather Inflow and Infiltration (I/I) in Separate Sewer Systems

§ 18　Current Conditions of Wet-weather Inflow and Infiltration (I/I) into Sanitary Sewers

The majority of local governments operating separate sewer systems are facing maintenance and management challenges associated with I/I during wet-weather conditions and require urgent countermeasures.

[Explanation]

In 2018, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan conducted a questionnaire survey of local governments operating separate sewer systems regarding rainwater I/I into sanitary sewers. Based on the survey results, it published a draft guideline on rainwater I/I countermeasures in 2020.

According to this draft guideline, of the 2,962 treatment service areas nationwide that responded to the survey, more than half (1,681 areas, or approximately 57%) reported experiencing operation and maintenance problems, but only 40% of them had actually conducted investigations to identify the locations and causes of I/I. Even fewer organizations had implemented measures to control and manage the sources of I/I, indicating that although rainwater I/I is widely recognized as a problem, progress in addressing it has been slow and that effective and efficient countermeasures are urgently needed.

Under these circumstances, treatment plants serving separate sewer systems are required to report to MLIT when untreated or primary-treated effluent is discharged, in accordance with the Ministry's Notice, *Regarding Reports on Incidents Caused by Wet-weather inflow and Infiltration*.

§ 19 Current Status, Challenges, and Countermeasures for Wet-Weather Wastewater Treatment in Separate Sewer Systems

Current countermeasures for wet-weather inflow and infiltration (I/I) in Japan focus primarily on source control, with particular emphasis on preventing and reducing I/I within the sewer network. However, other than the 3W treatment process, the *Draft Guideline on Wet-weather I/I Countermeasures* provides neither measures nor implementation examples for wastewater that exceeds the dry-weather treatment capacity of wastewater treatment plants. The 3W treatment process is an effective solution to this challenge.

[Explanation]

The *Draft Guideline on Wet-weather I/I Countermeasures* (2020) states that source control should be implemented as the primary countermeasure against wet-weather I/I. If source control alone is insufficient to prevent I/I, the remaining I/I should be accounted for in the design wet-weather flow and addressed through more comprehensive measures, such as operational adjustments and facility modifications and improvements.

The *Q&A for Draft Guideline on Wet-weather I/I Countermeasures* (March 2022 edition) does not refer to primary-effluent discharge or emergency discharge in separate sewer systems. It recommends implementing operational adjustments to the normal treatment process after applying source control measures, facility modifications and improvements, and temporary storage measures.

The facility modifications and improvements described in this draft guideline include increasing pump capacity, enhancing sedimentation capacity through coagulant dosing, installing high-rate filtration equipment, increasing disinfection capacity, and increasing chlorine dosing rates. In addition, step-feed methods in reaction tanks, including the wet-weather activated sludge treatment process, are also mentioned.

However, source control measures require extensive investigations and are difficult to implement, yet even the case studies published in April 2022 under the *Draft Guideline on Wet-weather I/I Countermeasures*, issued in 2020, provide only limited guidance on implementing wet-weather influent treatment measures.

The 3W treatment process is designed to treat increased wet-weather flow, and an increasing number of reports have confirmed its effectiveness at treatment plants in separate sewer systems. The 3W treatment process is a cost-effective wastewater treatment process that treats increased wet-weather flow and requires a relatively short preparation time; therefore, it is suitable as a countermeasure for treating wet-weather wastewater in separate sewer systems.

§ 20 **Effects of Implementing the 3W Treatment Process in Separate Sewer System Treatment Plants**

There are examples of the 3W treatment process being introduced in some separate sewer system treatment plants as part of operational measures to address wet-weather inflow and infiltration (I/I). Implementation of this treatment process is expected to reduce the frequency of primary effluent discharges and the pollutant loads during wet-weather events.

[Explanation]

The 3W treatment process was originally developed for combined sewer systems, but it is also effective as a measure against wet-weather inflow and infiltration (I/I) in separate sewer systems, as it can handle temporary increase in the volume of wastewater. According to operational record data of a certain wastewater treatment plant in Japan, the primary effluent discharge happened 17 times. Under the assumption that the 3W treatment process is applied and up to 3×Qsh wastewater is treated with secondary treatment, the number of primary-effluent discharge events can be reduced to as few as two.

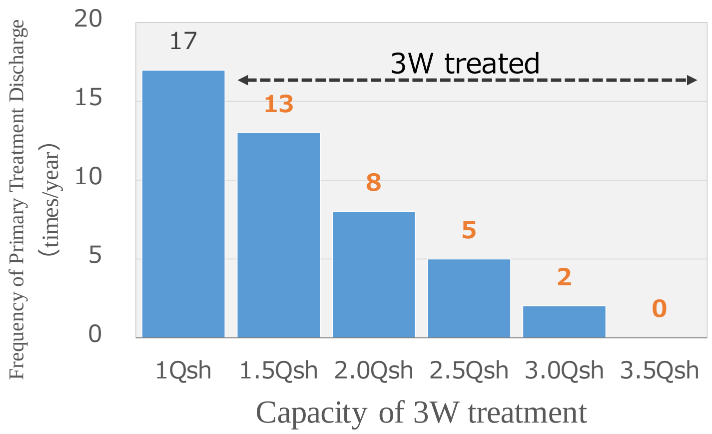


Figure 4-4 Illustration of Reduced Primary Effluent Discharge Events Using the 3W Treatment Process

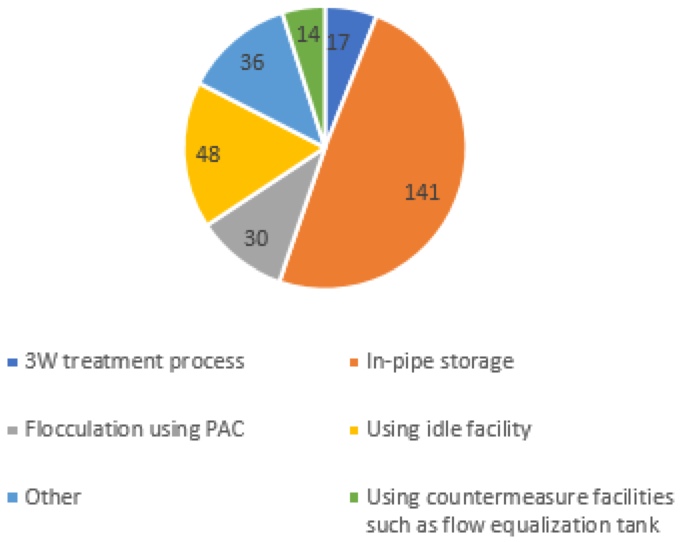


Figure 4-5 Distribution of Implemented Measures Against Inflow and Infiltration (I/I) in Separate Sewer Systems

As shown in Figure 4-5, the most common countermeasure against I/I in sanitary sewers is in-pipe storage, accounting for approximately 50% of all measures. However, in-pipe storage has inherent problems, such as upstream backwater, sludge accumulation in pipes, temporary closure of pumping station inlet gates, and exceedance of storage capacity, all of which can increase flood risk. Therefore, the 3W treatment process, which continuously treats incoming wastewater, including I/I during wet-weather events, is an effective solution.

Wet Weather Wastewater Treatment Prosess