An Example of Stormwater Drainage System Utilizing Unmanned/Non-Powered Stormwater Intake

Un exemple d'amélioration du système de réseau pluvial lui permettant de maintenir ses fonctions à faible coût et sans intervention humaine

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RÉSUMÉ

Le quartier cible en question est une zone fréquemment inondée, où l’inondation pourrait être causée même par des précipitations d’environ 10 mm/h. Ce qui est particulier dans l’évacuation des eaux pluviales, c’est qu’il y a deux cas différents : le cas où l’évacuation par gravité est possible et celui où l’évacuation par pompage est nécessaire pour éviter l’inondation et ce, selon l’intensité de la pluie et la fluctuation du niveau d’eau de la rivière à marées vers laquelle les eaux pluviales sont évacuées. Pour faire face à une telle situation, nous avons conçu un système d’évacuation des eaux pluviales qui consiste à procéder, dans la mesure du possible, à une évacuation gravitaire, tout en permettant, par le biais d’une conduite de dérivation menant à une station de pompage des eaux pluviales, d’utiliser l’un ou l’autre type d’évacuation, évacuation gravitaire ou évacuation forcée. Cela a permis de réduire la fréquence de fonctionnement des pompes et donc, le coût d’exploitation ainsi que les contraintes liées à leur entretien. Nous indiquons un exemple dans lequel nous avons en fait atteint les objectifs de notre projet en améliorant, dans la conception détaillée, le mécanisme de l’ouvrage de prise d’eaux pluviales reliant le canal d’évacuation gravitaire et la conduite de dérivation.

ABSTRACT

The target district covers the frequent flooding areas where the inundation could be caused even by the rain water of approximately 10mm/hr. The stormwater drainage is characterised by its flexibility that some conditions, such as the intensity of precipitation and the fluctuation of water level in the tidal river as the water destination, could divide the cases of the drainage into two cases: a case of possible gravity flow and a case of possible inundation without the pumping drainage to be conducted. As a countermeasure, a stormwater drainage system was planned to make the gravity flow as much as possible, by installing a by-pass pipeline to the stormwater pumping station to divide the gravity flow and the pumping discharge. This has enabled the frequency of the pump operation to be manageable and to mitigate the operation cost as well as maintenance work. The implementation design is to report a successful case, as an example, where the objectives of the plan were realized by improving the devices in the stormwater intake to connect the water channel for the gravity flow and the by-pass pipelines.

KEYWORDS

Low running cost, Stormwater drainage system, Tidal river, Unmanned/non-powered operation, Upper hinge type floating gate

1 SUMMARY OF STORMWATER DRAINAGE FACILITIES PLAN

1.1 Summary of Drainage District

This is a report on the stormwater drainage facilities plan in the frequent flooding areas in Sumoto City, Awaji Island (Awaji-shima). The target areas are shown in the Figure 1-1, covering a residential/commercial area in the southern part of Hidono River, its neighbouring mountains and an area surrounded by the Chigusa River.

This drainage district comprises vulnerable areas where the ground heights are lower than the planned water level of the Hidono River. Furthermore, Hidono River is a tidal river characterised by the high likelihood of the inundation due to the backwater effects that the water level of the river might cause. All these conditions make this district a vulnerable district towards the stormwater drainage.

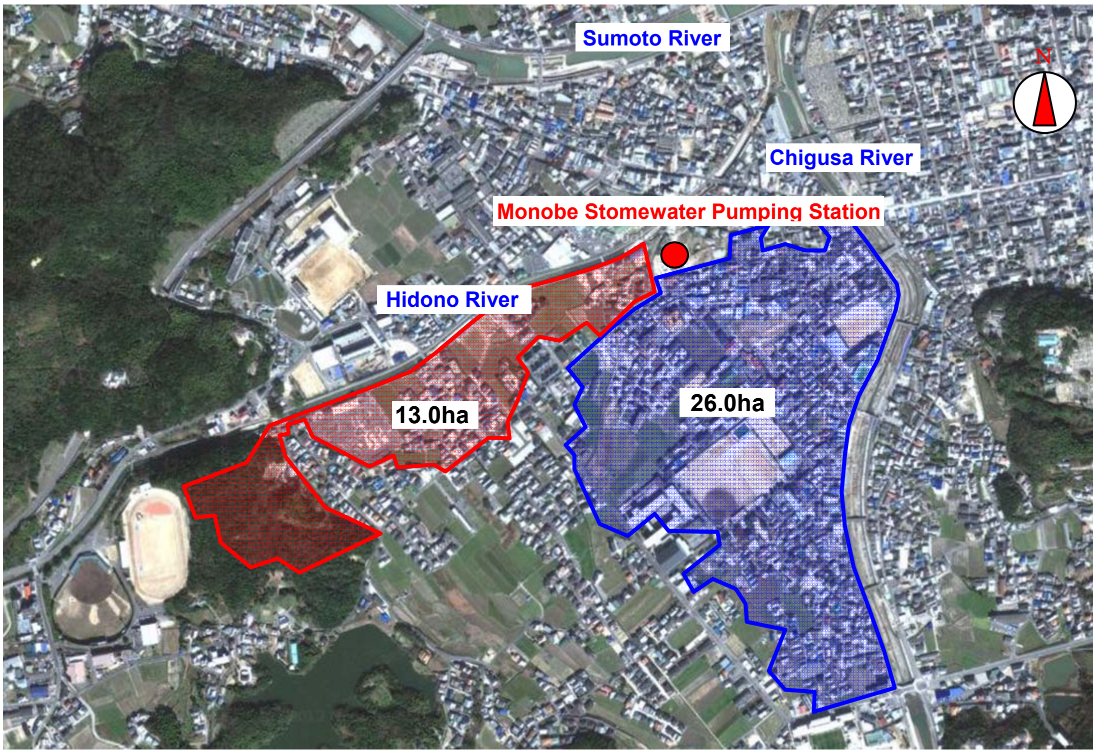

Figure 1-1 Summary of the target district

1.2 Planning Data

The planning data of this drainage district is as follows.

- The name of the drainage district : Mononobe No. 1-1 Drainage District
- Drainage area : Approximately 39 ha（Hidono13ha+Chigusa26ha）
- Return period : 7 years
- Planned rainfall intensity : 60.5mm/hr
- Planned drainage quantity : 6.4m^3/s
- Stormwater destination : Hidono River

1.3 Problems in the drainage district

1.3.1 Damages by the inundation

Typhoon No. 23 in October 2003 hit the record of rainfall level of 309mm per day which was the most rainfall level in the past and caused the record-setting damages in the City as well. The target drainage district was not out of the exception and witness enormous number of damages of inundation above and under the floor level. In recent years, local heavy rainfalls and concentrated heavy rainfalls, called “Guerrilla Downpours”, have occurred frequently, resulting in the increasing number of the inundation damages compared to the previous years.

1.3.2 The tidal river and the ground height

Hidono River is a tidal river and poses a risk of possible inundation for the area of 19 ha within the drainage district of approximately 39 ha, taken into account possible backwater effects of the planned water level in the river.

1.3.3 Water channel with incapability of water discharge

There do exist a considerable number of water channels that are not able to discharge the water properly for the planned drainage quantity. In these urban dense areas, the rehalibitation of the water channels is not easy and expectedly requires the considerable construction cost and the long-term construction period.

2 DESIGN ISSUES AND COUNTERMEASURES OF THE STORMWATER DRAINAGE SYSTEM

2.1 Issues to be considered

- The following issues need to be examined, taken into account some problems in the drainage district, the municipal budgetary conditions and the sustainability in the maintenance management.
- These are the frequent flooding areas and inevitably require the implementation of the stormwater drainage measures leading to tangible quick effects, taken into account the increasing local heavy rainfalls and concentrated heavy rainfalls in the recent years.
- The rehabilitation of the water channels is not a realistic countermeasure, since there are many channels with possible backwater effects and lack of water discharge capacity.

In case of the high water level, pumping discharge is required instead of the gravity flow drainage. On the contrary, the gravity flow drainage is possible to be conducted in case of low water level, which needs to establish the system to enable the shifting between the pumping discharge and the gravity flow drainage.

2.2 Countermeasures to the issues

The drainage system here is assumed to be a system with the following functions, based on the aforementioned issues to be considered.

- It should be a system to enable the operation shift between the gravity flow and the pumping discharge according to the rainfall conditions, through clarifying the rainfall conditions that could be manageable by the gravity flow drainage for the drainage district.
- In order to realize the quick and tangible results, the stormwater drainage countermeasure envisages, instead of the rehabilitation of the water channels within the drainage district, that the rainfall quantity more than the discharge capacity of water channels is to be cut and the water is to be conveyed to the drainage system by pumping discharge.
- The water intake to cut the rainfall quantity more than the discharge capacity of the water channels assumes a system that enables the operation shift with unmanned and non-powered operation taken into account the maintenance management and cost reduction.

2.3 Summary of the stromwater drainage system

2.3.1 Controlling the number of pumping discharge

As the stromwater drainage system, a system enabling the adjustment of the number of pumping discharge by the pumping facilities is to be established. In order to examine the basic conditions for this objective, the relevant data from the meteorological observatory for the previous years in this district were surveyed.

The following table 2-1 shows the number and the quantity of the rainfalls according to the rainfall intensity in the past 10 years during the period from 1996 to 2005.

The annual average of rainfall quantity reaches at 1,469mm while the average number of the annual rainfall is 117 times. The number of rainfall exceeding the rainfall intensity of 10mm/hr is observed as 15 times (117-102).

A basic condition for this drainage system assumes establishing the drainage system which is able to shift the drainage methods around 10mm/hr of the rainfall intensity, taken into account some points including the drainage capacity of the existing channels, backwater effects and the number of operating the pumping discharge.

Table 2-1 The number and quantity of the rainfall
according to the rainfall intensity (1996～2005)

Rainfall Intenstity	Number of rainfall / 10 years	Ratio of rainfall intensity	Rainfall quantity / 10 years
Less than 1mm/h	545 times	46.7%	14,686mm
Less than 5mm/h	867 times	74.2%	10,379mm
Less than 10mm/h	1,022 times	87.5%	7,451mm
Less than 20mm/h	1,109 times	94.9%	4,551mm
Less than 30mm/h	1,146 times	98.1%	2,646mm
Less than 40mm/h	1,156 times	99.0%	1,598mm
Less than 50mm/h	1,160 times	99.3%	1,240mm
Less than 60mm/h	1,163 times	99.6%	957mm
Less than 70mm/h	1,165 times	99.7%	664mm
Less than 80mm/h	1,167 times	99.9%	257mm
Less than 90mm/h	1,168 times	100%	0mm

Source : The Data Sumoto Observatory Station in the Meteorological Observatory Reference Electronic Unit

2.3.2 Stormwater drainage system

The Figure 2-1 shows the summary of the stormwater drainage system. This is a system that, in case of the rainfall exceeding 10mm/hr of the rainfall intensity or in case of the difficulty in the gravity flow due to the backwater effects, the stormwater could be taken from the intakes of M1 and M2 respectively to be conveyed through the by-pass pipelines of ϕ1,200mm～1,650mm to the pumping station where the pumping facilities would conduct the pumping discharge. An important point in this drainage system is that taking the stormwater in each intake is conducted by the operation shift at the time of 10mm/hr with unmanned and non-powered operation.

Further details of the intake structure will be explained in the following section.

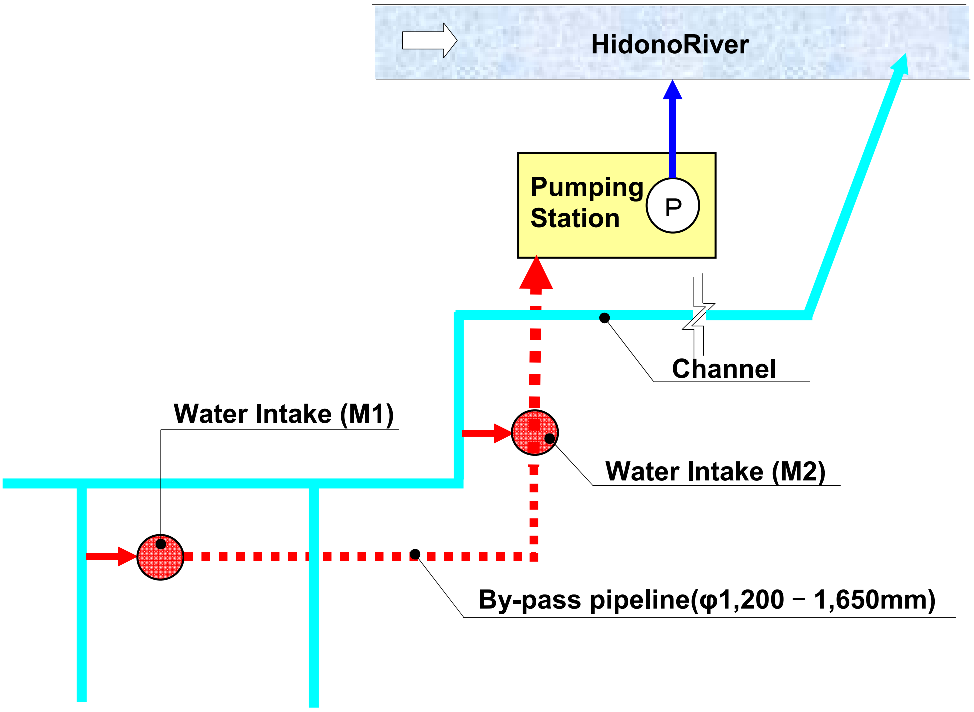

Figure 2-1 Summary of the drainage system

3 FACILITY PLAN OF THE STORMWATER INTAKE

3.1 Water Intake Structure

Water Intake M1 will be explained here as an intake of this drainage system.

The intake is to be installed between the existing channels together with an intake function enabling the operation shift by the rainfall intensity and backwater effects.

The flow at the normal time is as shown in the Figure 3-1 flowing along the red line to be conveyed via the upper hinge floating gate to the following channel. As for the rainfall under 10mm/hr, it needs to be arranged to continue to follow the red line, based on the plan keeping it under the weir height of the corner as described in the Figure as below.

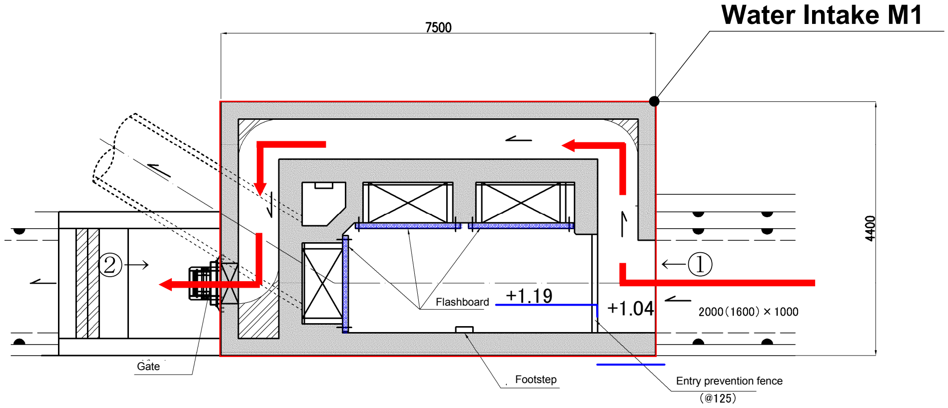

Figure 3-1 Water Intake M1 Structural 2D Diagram
(at the normal time/limited rainfall)

The Photo 3-1 shows what could be seen from ① of the Figure 3-1. The front grate is to hinder any entry for the security reasons. The Photo 3-2 shows what could be seen from ② in the Figure 3-1. The gate is an upper hinge floating gate, with an advantage of limited risks in sucking any exogenous objects in between the gate and the doorstop since a certain level of open space is ensured at the normal time.

Photo 3-1 The Flow Intake (taken from ①)

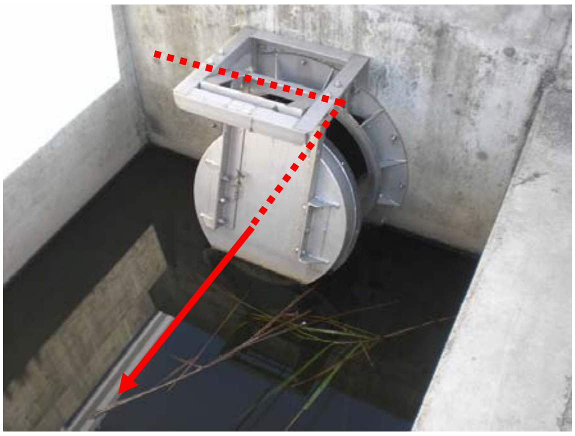

Photo3-2 Upper Hinge Floating Gate (taken from ②)

Taking the stormwater from the intake is conducted at the time of water level of the channel to rise or at the time of the water level of the channel to become high in the lower stream due to the backwater effects. After the water taken, the water is to be discharged through the by-pass pipeline to the pumping station.

The upper hinge floating gate is adopted to enable an automatic switching utilizing the buoyancy according to the water levels, in order for the switching of the backwater gate to automatically operate whether or not the backwater would have effects.

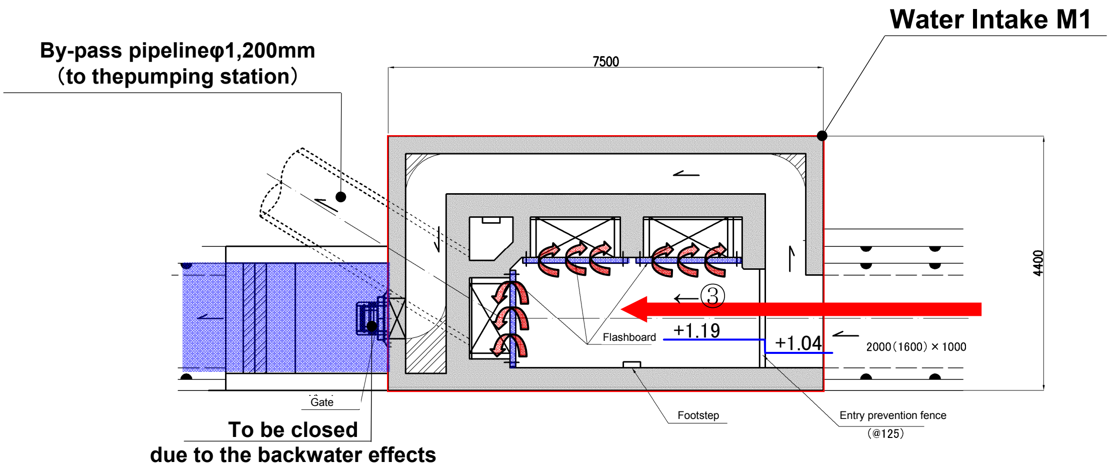

Figure 3-2 Water Intake M1 Structural 2D Diagram
（at the time of taking stormwater）

The Figure 3-3 shows the cross-sectional diagram of Water Intake M1. After taking the stormwater, it is to be flown to the by-pass pipeline through the drop structure.

The Photo 3-3 shows what could be seen from ③ in the Figure 3-2. The adjustment for the stormwater intake is considered by arranging the sliding timber weir. In further concrete, the adjustment for the stormwater intake according to the rainfall intensity could be conducted by changing the number of installed artificial timber fixed weir in vertical direction by 5mm/hr, 10mm/hr and 15mm/hr. This consideration is for the purpose of leaving a space for a case where any adjustment is needed for any inconsistency in the relations between the designed and the actually constructed objects or between the rainfall and the water level in the channel and so forth. This will be useful for any adjustment in the maintenance management.

The Photos 3-4 and 3-5 show what could be seen from ④ and ⑤ in the Figure 3-3. The rectangular grate in ④ is installed as a slip prevention device from the security perspective. ⑤ shows the inside of the pipeline with diameter of ϕ 1,200mm. As shown in the Figure 2-1, there are Water Intake M2 in the destination of this pipeline and a pumping station via Water Intake M2.

The Photo 3-6 shows what could be seen from ② in the Figure 3-1. In case of the water level in the downstream to rise due to the backwater effects, the gate with a floating structure of the front cover is to close its open space by the buoyancy automatically. When the gate is closed, the stormwater is to flow into the by-pass pipeline as the destination of the stormwater flow gets stopped and the water is obliged to change its flow to a lower direction as shown in the Figure 3-2. When the rainfall stops, it results in the lower water level to open the gate again, ensuring a certain level of the open space.

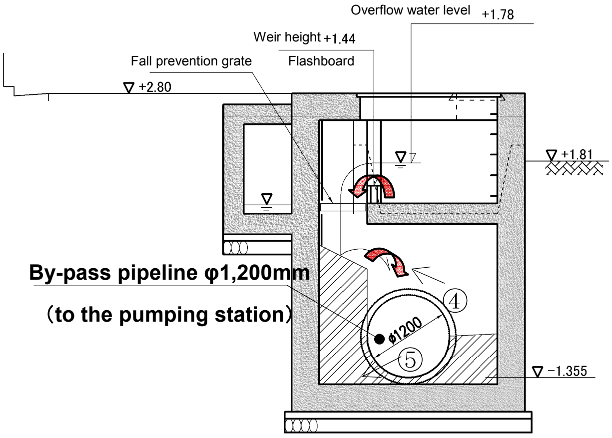

Figure 3-3 Water Intake M1
Structural Cross-Sectional diagram
(at the time of taking stormwater)

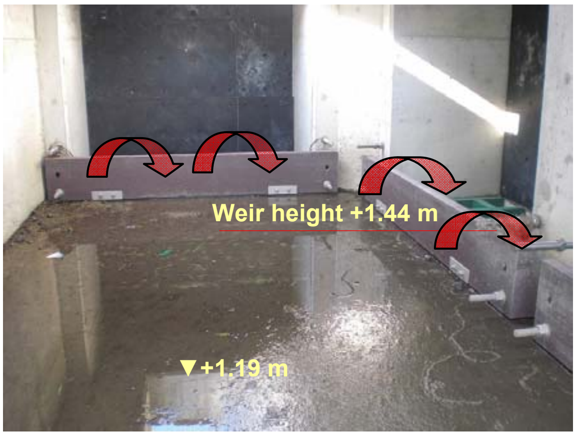

Photo 3-3 Overflow Weir
(taken from ③)

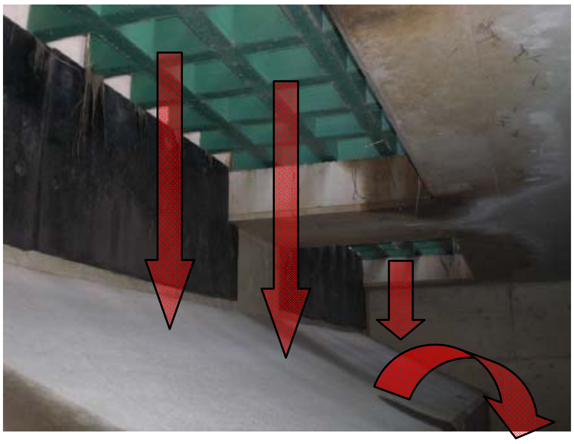

Photo 3-4 Inside the Water Intake
(taken from ④)

Photo 3-5 By-pass Pipeline
(taken from ⑤)

Buoyancy due to the rising water level in the downstream caused by the backwater effects would close the gate.

Photo 3-6 Upper Hinge Floating Gate
(taken from ②)

3.2 Characteristics of the upper hinge floating gate

The upper hinge floating gate is installed for the purpose of preventing the back streaming of the river from the levees and seaside sluice gates/pipes. As a countermeasure to avoid a risk of sucking any objects in between the gate and the doorstop which used to be observed in the existing non-powered/automated gates (flap gate, etc), this system keeps the gate open at the normal time to avoid this risk and enables the non-powered operation by utilizing the buoyancy at the switching of the gate.

The discipline of switching the gate is as shown in the Figure 3-4, where the rotation moment occurs focusing on the hinge point (the original point) in the moment of the buoyancy and the gravity centre affecting on the gate along with the rising water level. This power brings about the automatic switching structure.

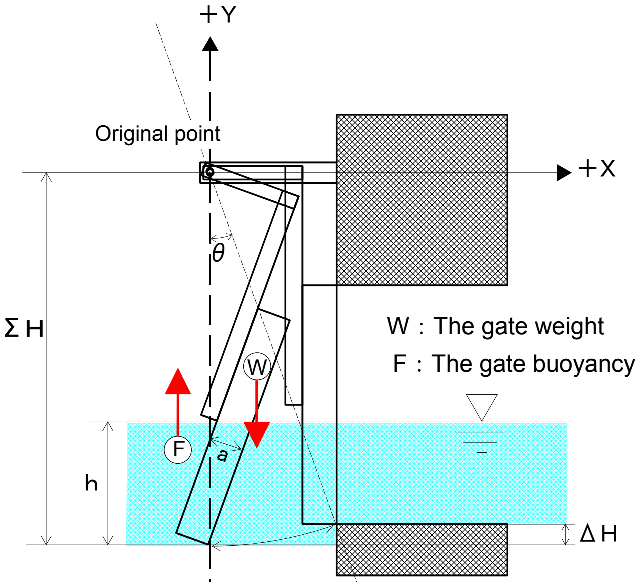

Figure 3-4 The Figure on the switching characteristics of the upper hinge floating gate

3.3 The application of the upper hinge floating gate

This gate was developed for the purpose of preventing the back streaming of the river from the sluice gates/pipelines. An example of this design assumes that the installation of this gate in the water intake of the stormwater drainage is to enable the higher water levels in the downstream to repeat the switching operation between the pumping discharge and the gravity flow drainage.

This operation is expected not only to enable the unmanned/non-powered operation, but also to considerably contribute to the improvement in the maintenance management and the cost reduction with the advantage of the quick operation switch due to the possible switch of the gate for a couple of seconds, which will be useful for the local heavy rainfalls and intermittent rainfall in the recent years.

4 FURTHER PROSPECTS

4.1 The situations after supplying the service

This drainage system, which required 2 years for the planning and 3 years for the construction, has commenced the supply of the service since June 2010. From its commencement up to the current, this drainage system has operated smoothly with no flooding damages occurred.

The effectiveness of this drainage system could be assessed as quite clear after its prevention of inundation was obviously confirmed at the time of the rainfall (323 mm per day: as of 2011/9/20) exceeding the rainfall (309 mm per day) by the Typhoon No. 23 as of October 2004 which was the highest record of the rainfall in the previous years.

4.2 The applicability of this system to other cases

We believe that this drainage system could be applicable, regardless of drainage scopes, by conducting the following measures;

- A water intake needs to be installed in the water channel or the destination area of the pipeline in each flooding area;

- Each water intake needs to be linked by the by-pass pipeline and the pumping station needs to be arranged in the last point of the stream;
- As for the water intake types, it is desirable that one of the types (non-powered type for this case or a manned operation type utilizing a powered gate) should be selected according to the water intake quantity;
- The non-powered water intake for this case enables the confirmation of the water level in the intake as well as the switching situation of the upper hinge floating gate by installing a measuring machine (water level meter) and a TV set as ancillary facilities. This could underpin the application of the big-scale water intake to be worthy to consider.

4.3 Further system improvement after this drainage system

We consider this drainage system to be contributing to further system improvement by concurrently taking the following measures;

- A water intake is to be installed in a frequent flooding area, the intake of which is to be connected by the by-pass pipeline. Substituting this by-pass pipeline as a stormwater storage pipe and making a rainwater reservoir inside a vacant space at a lower land or the pumping station area will enable the peak cut of the stormwater flow and minimizing the scope of pumping facilities.

LIST OF REFERENCES

Kuniaki Sato, Yasuhiko Uchida and Katuyuki Uchida (2001). Study on the hydraulic characteristics of upper hinge floating gate. *Proceedings of 56th annual conference of Japan Society of Civil Engineering* page 286-287.