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A Registration System for Preventing/Mitigating Urban Flood Disasters as One Way to Smartly Adapt to Climate Change in Japanese Cities

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Abstract: Intensive rainfall and frequent inundation have become a serious problem in urban areas all over the world. Climate change and heat island effect may be the cause of the phenomena. Widespread impervious pavement/surface of the ground makes things worse. In order to promote an effective river basin management in urban areas and reduce runoff, a registration system called "Safety Plan for 100mm/h-Rainfall" ("100mm/h Anshin Plan" in Japanese), a scheme for preventing and mitigating inundation caused by extremely heavy, short-term rainfall (such as 100mm/h-rainfall) was established in April 2013 by the central government in Japan. This study carried out a questionnaire survey to examine how municipalities effectively utilize the registration scheme for their watershed management. As a result, it is found that there are municipalities who have started/revised subsidizing installation of private rainwater retention/infiltration facilities in association with the registration system; however, municipalities in general are not so active in promoting runoff reduction by subsidizing private facilities. In addition, in the plans emphasizing public works for runoff reduction, public involvement is not so active, whereas in the plans devised with relatively new committees of watershed management, public involvement as well as private retention activities tend to be active. Based on the results, prospects of how a safety plan should be utilized in an urban watershed are discussed and examined from practicality's point of view.

1. INTRODUCTION

Intensive rainfall and frequent inundation have become a serious problem in urban areas all over the world. Climate change and heat island effect may be the cause of the phenomena. Widespread impervious pavement/surface of the ground makes things worse. Measures such as dredging rivers, increasing the capacity of the rainwater drainage system and constructing flood walls

are not always effective. It should be necessary for people to reduce direct runoff by retaining/infiltrating rainwater within the entire urban watershed as there are a number of private properties and enterprises situated there. Harvesting the retained rainwater may contribute to recovering a sound hydrologic cycle in urban areas, which must be one way to smartly adapt to climate change.

In order to promote effective river basin management in urban areas and reduce runoff, a registration system called "Safety Plan for 100mm/h-Rainfall" ("100mm/h Anshin Plan" in Japanese), a scheme for preventing and mitigating inundation caused by extremely heavy, short-term rainfall (such as 100mm/h-rainfall) was established in April 2013 by the central government in Japan (MLIT (Ministry of Land, Infrastructure, Transport and Tourism), 2013).

A national policy for comprehensive flood control in the face of rapid urbanization in the city has been enforced since 1977 in Japan. The policy is focused not only on river-system/drainage management but also on surface-runoff reduction by retaining/infiltrating rainwater in the watershed. However, the policy has been applied to only 17 rivers and their watersheds from 1977 up until 2015. 12 of them are managed directly by the central government; and thus, they tend to depend on the rainwater retention/infiltration function from public facilities and properties in spite of the policy's emphasis on runoff reduction involving private-sector collaborations (Shimatani, Y., Yamashita, S. et al., 2010).

Moreover, storm-water management incorporating green infrastructure involving the private sector has been implemented, especially in recent years, in developed countries because of its cost effectiveness in maintenance (NYC Environmental Protection, 2014; Furumai, H., 2015); this approach is critical in a society with population decline like Japan. The registration system of "Safety Plan for 100mm/h-Rainfall" was established in these circumstances.

This study is to get information directly from the municipalities that have their officially-registered schemes and to contribute to subsequent planning for flood control in other urban areas.

2. METHOD

2.1 The registration system

"Safety Plan for 100mm/h-Rainfall" was introduced in April 2013 by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). This has much to do with one of the policies the Japanese government has implemented to tackle flood disasters especially in urban areas in a comprehensive way since the late 1970s (MLIT, 2013). The plan is intended to mitigate food damage in urban areas not only by improving river channels and drainage systems but also by installing rainwater retention/infiltration facilities/functions all over the urban river basin. It expects river and drainage-system administrators, residents and private firms to collaborate and mitigate flood disasters by reducing surface runoff and sharing safety/risk information.

MLIT requires potential municipalities first to devise and implement the legal river development project and storm-water drainage project and then to incorporate the following three aspects into their safety plan:

1) The target rainfall intensity must be greater, more local and shorter-lasting than the intensities set in both their legal river development project and storm-water drainage project.
2) River and drainage-system administrators, residents and private firms must work collaboratively and mitigate flood disasters by reducing surface runoff and sharing safety/risk information.
3) Measures focused on flood-damage reduction must be emphasized.

The first requirement implies a Safety Plan for 100mm/h-Rainfall is to cover what both the river development project and storm-water drainage project by the municipalities do not. That is why collaboration involving citizens/private firms and "flood-damage reduction" are emphasized in the second and third requirement, respectively. The registered municipality can get a grant from the central government and provide tax breaks/subsidies for those who install rainwater retention/infiltration facilities on their premises.

2.2 Questionnaire survey

A questionnaire survey was carried out to ask the registered local governments how they have planned and managed their rivers and watersheds. The questions included: 1) basic information such as urbanization rate, targeted rainfall intensity, etc., 2) watershed management measures, 3) damage mitigation measures, 4) relevant regulations, 5) public awareness, etc. (see *Table 1*, below). In this study, whether registering a plan is effective or not is judged by the disaster-mitigation measures newly implemented in association with the registration.

The questionnaires were sent by mail firstly on October 29, 2014 and secondly on May 7, 2015, and the responses were returned by November 19, 2014 and by May 27, 2015, respectively. The municipalities registered include the city of Nagoya and Kitakyushu, major cities/metropolises of Japan (population: 2.28 mil. and 0.96 mil., respectively), and 13 mid- to small-sized cities registered as of the end of October, 2015.

The outlines of the plans are open to the public (MLIT, 2014) and are referred to in the analysis of the survey results. The sewer/rainwater drainage system and relevant recent floods are also listed for reference (see *Table 2*).

Table 1. Outline of the questionnaire survey

Period	Oct.15-Nov.19, 2014 and May 7-27, 2015
Items	· Basic information (Urbanization rate, targeted rainfall, etc.) · Watershed management · Damage mitigation · Public awareness · Others
Format	Structured & open-ended

Table 2. Overview of the registered plans

No.	Registration date	City	Urbanization rate in registered watershed*	Coverage of sewer/ rainwater drainage systems	Inundation referred to in the plan			Period (yrs.)	Targeted rainfall intensity
					Mo.-Yr.	Above 1st floor level	Below 1st floor level		
1	Sep.4, 2013	Takaoka	(17.3%)	89.6%	Jul-12	179 (cases)	348 (cases)	10	67mm/h
2		Kanazawa	18.4%	97.5%	Jul-08**	507	1,476	10	55mm/h
3		Numazu	24.0%	56.5%	Jul-07	16	23	5	49mm/h
4		Yaizu	34.5%	22.5%	Jun-04	57	58	5	88mm/h
5		Hamamatsu	(6.3%)	79.5%	Sep-98	21	107	river:10 drain: 7	73mm/h
6	Feb.4, 2014	Kanuma	29.5%	60.1%	Jul-13	45	62	10	94mm/h

7		Tajimi	(34.0%)	92.1%(storm drain:59.7%)	Sep-11	439	183	5	74mm/h
8		Fuji	43.4%	72.5%	Jul-03	2	31	5	62mm/h
9		Nagoya	97.0%	99.2%	Sep-00	218	2,244	5	535.5mm/day
10		Nagoya	97.0%	99.2%	Sep-00	56	890	5	535.5mm/day
11	Sep.9, 2014	Koriyama	(9.1%)	71.7%	Jul-10 Sep-11	62 1,510	141 157	9	74mm/h
12		Mobara	19.4%	100%	Oct-15	320	183	10	51mm/h
13		Okaya	(17.8%)	99.5%	Aug-13	11	33	10	72mm/h
14		Fukuroi	77.0%	42.1%	Nov-04	4	75	4	76mm/h
15	Feb.3, 2015	Kitakyushu	100%	99.8%	Jul-13	1	54	10	73mm/h
16		Saga	100%	100%	Jun-08 Jul-09 Jul-12	24 11 9	484 591 489	6	64mm/h

* [Urbanization designated area/cite area] for Takaoka, Hamamatsu & Koriyama. [Use district/city area] for Tajimi & Okaya.

** Inundations that are not mentioned in the plan but occurred recently.

3. RESULTS

3.1 Overview

The urbanization rate and the coverage of sewer/rainwater drainage systems differ among the municipalities (*Table 2*). The major cities such as Nagoya and Kitakyushu have urbanization rates of 97.0% and 100%, respectively, within the registered watersheds (*Table 2*). The registered watershed of Saga also has an urbanization rate of 100% and the rate of Fukuroi is relatively high (77%). The rates are 20-40% in the other 12 municipalities/plans. The coverage of sewer/rainwater drainage systems is lowest in Yaizu (22.5%). The rates are over 90% in Nagoya (99.2%), Kitakyushu (99.8%), Saga (100%), Okaya (99.5%) and Tajimi (92.1%).

Most of the targeted periods are either five or ten years and the targeted rainfall intensities are less than 100mm/h (see *Table 3*, below). The scheme does not require municipalities to set the goal exactly at 100mm/h as its name indicates. The goals have been set based on recent heavy rainfalls which caused flood disasters in the river basins, however it may sound confusing for a wide variety of stakeholders who would like to get involved in implementing the plans.

A committee has been set up to draw up and carry out a plan for comprehensive flood control. It is to enhance cross-sectional collaborations among the administrators of river and storm-water drainage systems. Needless to say, public involvement is important especially when flood-disaster mitigation is pursued in urban areas. In this regard, Takaoka, Numazu, Yaizu, Fuji, Nagoya, Fukuroi and Saga stand out as they have no residents involved in the committees (*Table 3*).

Table 3. Committee for comprehensive flood-disaster management

No.	City	Month of foundation (Mo.-Yr.)	Participants						
			Central gov.	Pref. gov.	City gov.	Resident	Academic	Business/co-op	Local assembly member
1	Takaoka	Nov-12		○	○				
2	Kanazawa	Oct-09		○	○*	○	○	○	
3	Numazu	Feb-07		○	○				
4	Yaizu	Sep-05		○	○				
5	Hamamatsu	Dec-05		○	○	○		○	○
6	Kanuma	Dec-13		○	○	○			
7	Tajimi	Dec-11	○	○	○	○	○		
8	Fuji	Mar-07		○	○				
9	Nagoya	Mar-87			○				
10	Nagoya	Mar-87			○				
11	Koriyama	Aug-14	○	○	○	○	○	○	
12	Mobara	Dec-14		○	○	○			
13	Okaya	Mar-12		○	○	○			
14	Fukuroi	Mar-07		○	○				
15	Kitakyushu	Aug-03		○	○	○			
16	Saga	Jul-10	○	○	○				

* Secretariat

3.2 Changes in measures in association with registration

Tables 4-7 below illuminate changes in: 1) watershed management measures, 2) damage mitigation measures, 3) relevant regulations, and 4) public awareness, in association with the registration of a Safety Plan for 100mm/h-Rainfall, respectively.

Watershed management measures have changed in seven plans/cities (*Table 4*). Numazu, Kanuma and Koriyama started to install various sizes of rainwater retention/infiltration facilities such as storm-water reservoirs, infiltration trenches and inlets. Takaoka has installed major storm sewers and Fuji has emphasized the importance of a storm sewer network. Tajimi has strengthened collaboration with the central government. Mobara claims that the measures have enhanced the safety of the middle reaches of the watershed.

These cities, excluding Mobara, also report changes in damage mitigation measures (see *Table 5*). Takaoka, Numazu and Koriyama have revised the procedures of making and distributing flood hazard maps and disaster-risk information. Kanuma and Tajimi have strengthened collaboration with relevant administrators. Fuji has emphasized the importance of storm sewer networks as a damage mitigation measure as well.

Table 4. Changes in watershed management measures

No.	City	Measures
1	Takaoka	Collaboration between river and storm-water drainage system administrators. Installation of major storm-water drains.
3	Numazu	Flood-control reservoirs development
6	Kanuma	Flood-control reservoirs development. Reduction in river-development project period.
7	Tajimi	Collaboration with the central government.
8	Fuji	No change in measures that had been already implemented; Increasing importance of storm-water drainage systems.
11	Koriyama	Installation of private rainwater retention tanks and infiltration trenches. Conversion of old septic tanks into rainwater retention tanks.
12	Mobara	Enhanced measures taken in middle reaches of the watershed.

Table 5. Changes in damage mitigation measures

No.	City	Measures
1	Takaoka	Creating/distributing flood hazard maps. Providing residents with risk/safety information via e-mail, etc.
3	Numazu	Creating/distributing flood hazard maps. Providing risk information via the internet.
6	Kanuma	Collaboration between private and public sectors for effective evacuation. Information sharing for self-help. Cooperation between prefectural and city governments. Creating flood hazard maps.
7	Tajimi	Subsidies from the central and prefectural governments.
8	Fuji	No change in measures that had been already implemented; Increasing importance of storm-water drainage systems.
11	Koriyama	Providing residents with risk/safety information. Creating flood hazard maps and using them for education. Flood drills and seminars. Installing water bars.

Table 6. Changes in relevant regulations

No.	City	Measures
1	Takaoka	Implementing a subsidy program for installing private rainwater retention tanks (since Apr.1, 2013).
3	Numazu	Subsidizing river cleanups by residents.
11	Koriyama	Subsidizing two thirds of the cost of a private rainwater retention

		tank (continued project).*

*"Continued project" but described as a change in measures in association with the registration.

Table 7. Changes in public awareness for risk management

No.	City	Measures
1	Takaoka	Strengthening public awareness about risk management by drills of sandbagging and by civic education for damage mitigation.
3	Numazu	Public awareness has been improved by providing residents with information on river stages and rainfall intensities in real time.
6	Kanuma	Inundation prevention measures have been promoting public awareness of risk management.
7	Tajimi	The importance of evacuation activities has become better understood.
12	Mobara	Public interest has been enhanced because of media attention.
8	Fuji	Residents' awareness of risk management remains low.
11	Koriyama	Awareness of the importance of self-help remains low; it should be strengthened by all means.

As for relevant regulations, three plans/cities report that there was a change (*Table 6*). Takaoka has provided a subsidy program for those who want to install private rainwater retention tanks and infiltration trenches/inlets. Numazu has subsidized citizens' environmental activities, and Koriyama has renewed its subsidy program for citizens to install private rainwater retention/infiltration facilities.

Five plans/cities report changes in public awareness (*Table 7*). Takaoka, Numazu, Kanuma and Tajimi claim that the public awareness for flood-disaster risks and management has been increased. Mobara points out that public interest has been enhanced because of media attention. On the other hand, Fuji and Koriyama report the awareness remains low. The former group provides no objective evidence for increasing awareness in their response. It may be that the public awareness of risk management in general needs to be improved.

In addition, Fukuroi reports the registration system has enabled them to dredge rivers intensively to prevent inundation along them in a short time.

In contrast, Kanazawa, Yaizu, Hamamatsu, Nagoya, Okaya, Kitakyushu and Saga show no changes in relation to the registration of their Safety Plan for 100mm/h-Rainfall (*Tables 4-7*). Kanazawa, Yaizu, Hamamatsu and Nagoya have the same reason: because they had taken measures of comprehensive flood control long before their registrations, much earlier than the other cities. For instance, the city of Yaizu says: "Our Safety Plan for 100mm/h-Rainfall is no different than before because it was drawn up and registered base on the measures that the Committee of Comprehensive Watershed Management for the Ishiwaki/Takakusa Rivers (of Yaizu) had already been implementing". Kanazawa explains: "We had already enforced an ordinance (concerning comprehensive flood control), so it (our Safety Plan for 100mm/h-Rainfall) does not necessarily include different measures (from those stipulated by the ordinance)".

On the other hand, Kitakyushu and Saga imply, from the viewpoint of effectiveness, that change would occur in the future; Okaya says, "we just continue what we have implemented for flood control since before the registration".

Moreover, the city of Fuji, which suggests changes in their storm-water drainage system, shows: "The measures (of our Safety Plan for 100mm/h-Rainfall) are not so different than before".

Kanazawa, Yaizu, Hamamatsu, Nagoya, Kitakyushu and Fuji had launched their committee for comprehensive flood control before the other

cities, who clearly report the changes in the measures. Kanazawa, Yaizu, Hamamatsu, Nagoya, Kitakyushu and Fuji established their committees in 2009, 2005, 2005, 1987, 2003 and 2009, respectively (*Table 3*). They have tackled urban flood disasters from relatively early on.

3.3 Facilitating watershed management measures

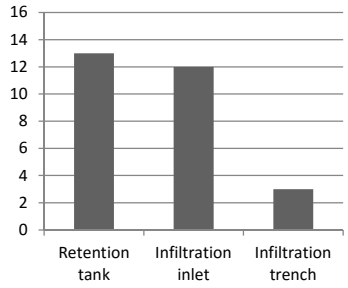

Figure 1. Promotions for private rainwater retention/infiltration facilities

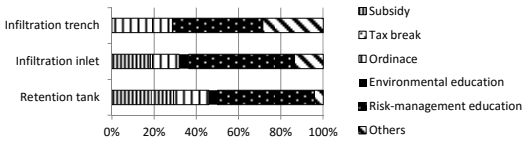

Figure 2. Programs for private rainwater retention/infiltration facilities

Figure 1 shows whether the plans/cities have promotion programs for the installation of private rainwater retention tanks, storm-water infiltration trenches and inlets. Private tanks (13 plans/cities) and infiltration inlets (12 plans/cities) tend to be promoted more than infiltration trenches (three plans/cities). *Figure 2* illustrates how the municipalities are trying to stimulate installation of these facilities. Risk-management education accounts for 40-50% of all the stimuli, including subsidies, tax benefits, ordinances, environmental education, risk-management education, etc.. Subsidy programs account for 20-30% in terms of both private retention tanks and infiltration inlets; and it is not considered, in this survey's responses, as a stimulus for installing private infiltration trenches.

Table 8. Private rainwater retention tanks

No.	City	# of installation	Total capacity (m^3)
1	Takaoka	7	1.2
2	Kanazawa	231	52
3	Numazu	0	0
4	Yaizu	0	0
5	Hamamatsu	0	0
6	Kanuma	1	-
7	Tajimi	281	50
8	Fuji	240	48
9	Nagoya	0	0
10	Nagoya	0	0
11	Koriyama	1,721	3,400
12	Mobara	9	1.43
13	Okaya	136	-
14	Fukuroi	219	58.8
15	Kitakyushu	0	0
16	Saga	0	0

Note: Black represents cities emphasizing both private and public rainwater retentions.

Table 9. Public rainwater retention tanks

No.	City	# of installation	Total capacity (m^3)
1	Takaoka	15	-
2	Kanazawa	4	3,410
3	Numazu	5	5,300
4	Yaizu	1	1,400
5	Hamamatsu	1	0.18
6	Kanuma	2	-
7	Tajimi	86	60*
8	Fuji	5	163,000
9	Nagoya	5	837,00
10	Nagoya	13	149,800
11	Koriyama	2	25,073
12	Mobara	-	-
13	Okaya	3	1,188
14	Fukuroi	5	18,600
15	Kitakyushu	2	18,170
16	Saga	-	934,000

Note: Gray represents cities emphasizing public retention; black: private and public.
* Approximate capacity shown as an example.

Tables 8 and *9* are to examine how private and public rainwater retention facilities are subsidized, installed or built in the registered plans/cities. Nagoya, who has been tackling urban flooding from early on, has no subsidy program for private rainwater retention tanks, but the total capacity of its public rainwater retention facilities are overwhelming (*Table 9*). In a similar fashion, Numazu, Yaizu and Kitakyushu have no subsidy for private rainwater retention tanks, but they have installed or built relatively large, public rainwater retention facilities. Saga also has no subsidy for private rainwater retention/infiltration, but has the largest capacity of public retention function. Saga has developed irrigation-pond networks since ancient times because it was not able to irrigate water from major rivers that did not have enough longitudinal gradients. Those ponds can function not only for irrigation but also for runoff reduction (Kato, H., 1994).

As mentioned earlier (see Section 3.1), in the plans of Numazu, Yaizu, Nagoya (with 2 plans) and Saga, there are no descriptions of public involvement in the framework of their watershed management committees. In Nagoya's response, they point out limitation of private retention/infiltration facilities in flood control. The emphasis/dependency on public works may imply a trend in addressing comprehensive flood control by those who have been tackling it from relatively early on.

In contrast, Kanazawa, Tajimi, Fuji, Koriyama, Okaya and Fukuroi have both many private tanks subsidized by the local governments and public rainwater retention facilities that are overwhelming either in the number or in the total volume. They are well-balanced from the perspective of comprehensive, all-out effort that is indispensable for urban flood-disaster prevention/mitigation.

Furthermore, Koriyama stands out from all the other cities with the number and total capacity of the installed rainwater retention tanks the city subsidized. According to an additional interview with the city, the reasons include: 1) relatively long period of time for the subsidy program (since 1996), 2) reusing old septic tanks, and 3) high public awareness of flood risk management because of frequent occurrence of flooding.

3.4 Facilitating/strengthening self-, mutual and public help as mitigation measures

Figures 3-5 show how the registered plans/cities facilitate/strengthen self, mutual and public help as mitigation measures.

As a measure for facilitating self-help, flood hazard maps are employed in 14 plans and social events and workshops are used in four plans (*Figure 3*). Mutual help is facilitated with comprehensive disaster-preparedness drills and workshops in 13 plans and risk education is employed for mutual help in eight plans (*Figure 4*). Public help is strengthened by utilizing hazard maps in all the 15 plans; other measures such as risk/evacuation information collection/distribution, etc., are used in less than seven plans (*Figure 5*).

In summary, for flood-disaster mitigation, the municipalities who registered their Safety Plan for 100mm/h-Rainfall tend to utilize hazard maps to facilitate/strengthen self- and public help and educational activities to drive mutual help.

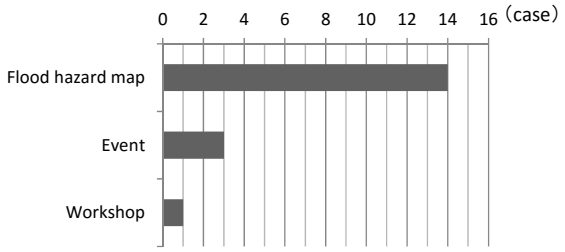

Figure 3. Promotions for self-help

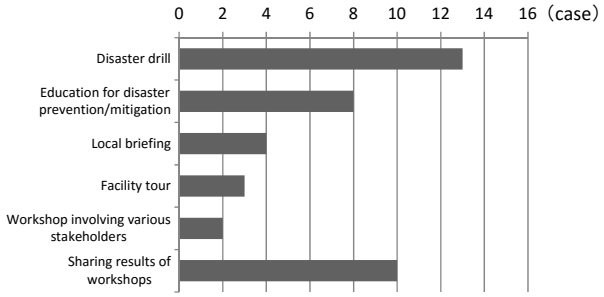

Figure 4. Promotions for mutual help

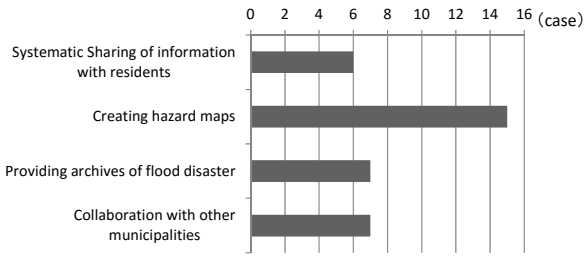

Figure 5. Promotions for public help

3.5 Other responses

Other, important free responses to the questionnaire survey includes: “the name of the plan (Safety Plan for 100mm/h-Rainfall) is difficult to explain to the public, as the target rainfall can be different from (less than) 100mm/h”; “the plan is beneficial only to the municipalities who have a full-coverage of storm-water sewer systems to be improved by newly installing arterial storm drains”; “the scheme in itself is not a subsidy program but a registration system, so it is necessary for the municipalities to provide their own subsidy programs to promote watershed management. The process may negatively affect comprehensive, systematic flood control in the watershed”, etc.

In addition, the importance of: 1) clear description of how to prevent inundation, 2) administrative leadership, 3) enhancement of civic collaboration, and 4) collaboration between river and storm-water drainage systems’ administrators, is also pointed out in their responses as an issue to be addressed.

These responses may be meaningful for future registrations as these are from the municipalities who registered their plans earlier and are quite active in promoting urban flood-disaster prevention/mitigation.

4. DISCUSSION AND CONCLUSION

4.1 Findings

This study carried out a questionnaire survey to examine how municipalities effectively utilize the registration scheme of “Safety Plan for 100mm/h-Rainfall” for their watershed management. The findings obtained are as follows:

1) All the targeted rainfall intensities are below 100mm/h, so the name of the scheme does not fit well with the plans.
2) In association with the registration, watershed management measures including main storm-water drains and small- to mid-sized rainwater retention/infiltration facilities and damage mitigation measures such as hazard maps and risk/safety information distribution are progressing.
3) There are municipalities who have started/revised subsidizing installation of private rainwater retention/infiltration facilities in association with the registration; however, as it now stands, municipalities in general are not so active in promoting runoff reduction by subsidizing private facilities.
4) The registration does not necessarily strengthen public awareness for risk management.
5) There are three patterns in disseminating rainwater retention systems: public-oriented, private-oriented and both.
6) In the plans emphasizing public works for runoff reduction, public involvement is not so active, whereas in the plans devised with relatively new committees of watershed management, public involvement as well as private retention activities tend to be active.
7) For flood-disaster mitigation, the municipalities who registered their Safety Plan for 100mm/h-Rainfall tend to utilize hazard maps to facilitate/strengthen self- and public help and educational activities to drive mutual help.

4.2 Prospect

In summary, there are municipalities who have started/revised subsidizing installation of private rainwater retention/infiltration facilities in association with the registration; however, municipalities in general are not so active in promoting runoff reduction by subsidizing private facilities. In addition, in the plans emphasizing public works for runoff reduction, public involvement is not so active, whereas in the plans devised with relatively new committees of watershed management, public involvement as well as private retention activities tend to be active.

Based on the results obtained, what can be said about watershed management in a city who is considering utilizing the scheme of a Safety Plan for 100mm/h-Rainfall in the near future?

The Hii River Watershed (population: 190 thousand) needs to draw up a plan for comprehensive flood-disaster prevention/mitigation, as it has experienced major flood disasters three times over the past 50 years (Yamashita, S., Watanabe, R. et al., 2015; Yamashita, S., Shimatani, Y. et al., 2013). The latest took place in July 24, 2009, which led citizens to get involved in discussing and implementing comprehensive flood control within the watershed. In association with the disaster and the subsequent move, the prefectural government of Fukuoka, who administers the Hii River System, enforced the Hii River System Development Project in 2014 (Fukuoka Prefecture, 2014). This legal project clearly mentions the future incorporation of a Safety Plan for 100mm/h-Rainfall. The watershed is included entirely within the city area of Fukuoka (population: 1.53 million), one of the metropolises of Japan.

In Fukuoka, 116mm/h was recorded on July 24, 2009. At that time, the spatially-averaged rainfall that caused inundation in the Hii River Watershed was 80.1mm/h. It is greater than the targeted rainfall intensities of both the river development project and the storm-water sewer development project: 72.0mm/h (return period: 40 years) and 59.0mm/h (10 years), respectively. It may be reasonable to set the target for the Safety Plan for 100mm/h-Rainfall of the Hii River Watershed between 80mm/h and 116mm/h and avoid confusion as pointed out in other plans.

The coverage of a storm-water sewer system for the Hii River Watershed is 99.6%. The city of Fukuoka has a subsidized private rainwater retention/infiltration program and had subsidized 692 rainwater retention/infiltration facilities by 2010 (City of Fukuoka, 2010). It is important not only to improve storm-water drainage networks but also to strengthen private rainwater retention/infiltration. The city of Koriyama has 1,721 subsidized rainwater retention tanks installed as of Dec. 2014. The population of the city is a fifth of that of Fukuoka.

As we see in Nagoya and Kitakyushu, public works for runoff reduction should be indispensable also in Fukuoka, as a metropolis of Japan. However, too much dependence on public works may weaken public awareness for disaster-risk management and self-help/mutual help needed in a depopulating society like Japan. Moreover, the installation of a private rainwater retention tank and the domestic use of the retained rainwater can enhance daily preparedness for heavy rainfall (Yamashita, S., Watanabe, R. et al., 2015; Yamashita, S., Shimatani, Y. et al., 2013). Private and communal activities for runoff reduction can and should be rigorously pursued in Fukuoka in order to prevent watershed management from performing poorly (Johnson, N., Ravnborg, H.M. et.al.. 2001), this approach should be beneficial in other urban areas as well.

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