AN ENGINEERING APPROACH TOWARDS APPROPRIATE HYDROLOGICAL WATER CYCLE IN URBAN AREAS : FIRST REPORT

都市域における望ましい水循環系構築に向けての工学的アプローチ

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本論文は、都市化により悪化した水循環を改善する水循環再生構想策定における技術的アプローチを示したものである。具体的な検討を行うにあたり、新河岸川流域（流域面積390km^2）を取り上げ、過去、現在、将来の水循環の定量評価を数値計算モデルにより行った。水循環再生のための目標値の設定は、行政と流域住民の合意形成を経て、注意深く行う。水循環改善に関わる対策は、様々な組み合わせがあり、得失を定量的に踏まえた上で決定していく。また、流域内関係者の合意形成を行いやすくするための策定組織を提案した。さらに、技術的な評価を流域内関係者に理解しやすい形で示していくことの重要性も示した。

Key Words : *hydrological water cycle, water environment, engineering assessment, consensus building, comprehensive master plan*

１．INTRODUCTION

Urbanization generally boosts expansion of urban areas, improvement of lifestyles, high population density and high grade of land utilization. Those urbanization processes have resulted in an expansion of impermeable areas such as roofs and pavements, an increase in water demand, an increase in industrial and domestic waste water and a reduction of water surface areas and green lands. The phenomena tend to distort the appropriate hydrological water cycle and bring about the following six issues to be solved [1] : 1) Increase of ordinary water discharge, 2) Flood control, 3) Conservation and development of water resources, 4) Conservation and revival of ecological System, 5) Pollution control and 6) Improvement of heat environment.

In order to implement a policy for solving these issues, the Ministry of Construction in Japan set up a committee to draw up a manual for planning the renewal of hydrological water cycle in urban areas. The paper [2] explains the design concept authorized by the committee which was finally involved into the manual [3]. According to the paper [2], the word of "hydrological water cycle" is useful for the discussion among the people with different backgrounds to plan the comprehensive measures to improve the aqua-environment. The paper [2] also proposes an investigation procedure as shown in **Fig.1**.

Recently, an interim report "How should an appropriate water cycle be in river basins." [4], proposed in July,1998 by the sub-committee of water cycle, the River Council for river control, proposed the necessity of a sustainable water cycle. This report [4] also pointed out that comprehensive master plans for appropriate water cycle should be urgently drafted for urbanized areas which suffer from serious problems concerning the deterioration of water cycle.

This paper presents only the preliminary consideration applied for the study area in order to draft a comprehensive master plan for an appropriate water cycle. This study is supposed to

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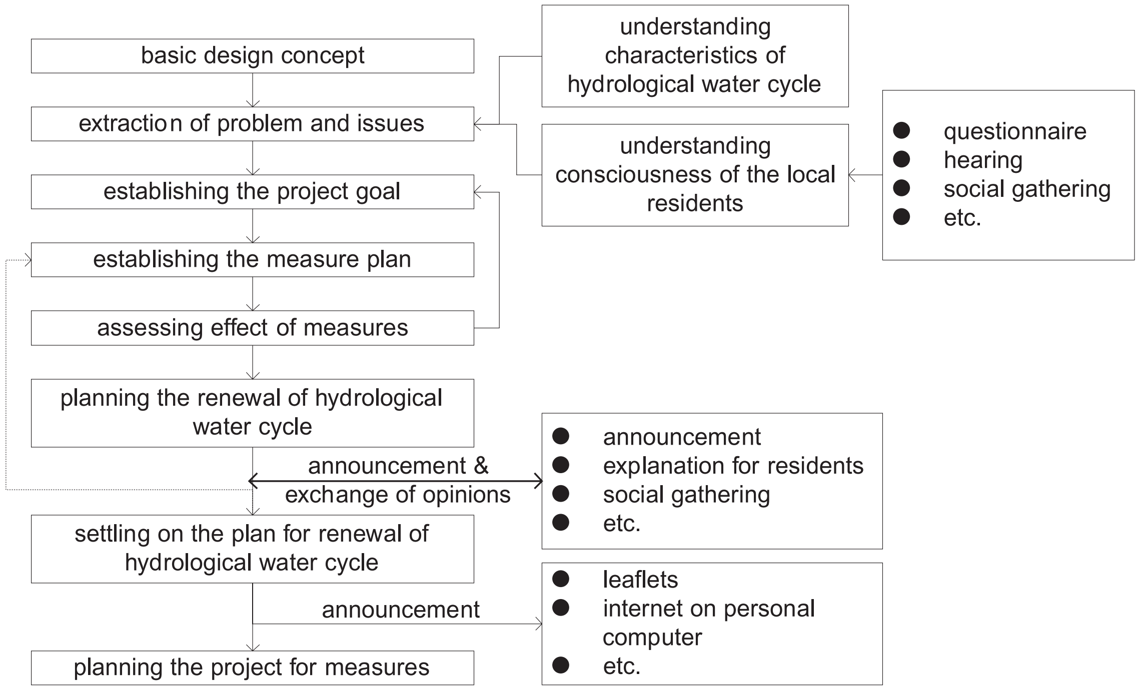

Fig.1 Investigation procedure for planning the renewal of hydrological water cycle

Table 1. Basic urbanization data for the Shingasi River Basin (as of 1990)

Items	Shirako	Kurome	Yanase	Sunagawabori	Furo	Others	Total
Basin Area (km^2)	25.0	37.6	95.5	44.0	56.6	131.2	389.8
River Length (km)	10.0	19.1	26.8	17.7	17.0	20.1	34.6
Population (1000 persons)	294	277	527	170	163	471	1902
Ratio of Urbanization (%)	59.6	44.4	40.9	25.7	28.6	39.5	38.5
Ratio of Sewerage Propagation (%)	91.7	77.6	74.3	71.1	55.5	77.0	76.2

continue in order to finalize the comprehensive master plan.

2. OUTLINE OF STUDY AREA

The Shingasi River of the study area is a tributary of the Arakawa River and runs northeast of Tokyo. Most of the catchment area belongs to Saitama prefecture and has been rapidly urbanized since the 1950s when the Tokyo metropolitan area was widened to involve this area. The Shingasi River has five major tributaries namely Shirako River, Kurome River, Yanase River, Sunagawabori River, and Furo River. The basic urbanization data are tabulated in **Table 1**.

The Shingasi River Basin comprises two different areas, lowland and terrace. The lowland is of an alluvium spread along the main stream. The terrace occupies a large area along the tributaries. The gradient of the basin is 1/1000 to 1/4000 in the main stream areas, and 1/100 to 1/400 in the tributary areas.

The lowland areas are covered with silty soil. The terrace areas are covered with a layer of the Kanto loam which is 2 to 10 meters thick with a gravel layer approximately 30 meters thick underneath. Groundwater levels are generally low, about 5 to 10 meters below the surface. The direction of the groundwater aligns with the configuration of the land. Saturated hydraulic conductivities are approximately 1 x 10-3 to 5 x 10-2 cm/s in the Kanto loam, 1 x 10-4 cm/s in the silt and 1 x 10-2 cm/s in the gravel. **Fig.2** shows the distribution of the contour line of the unconfined ground-water and the saturated hydraulic conductivities of the surface soil.

3. EXTRACTION OF PROBLEMS AND ISSUES

Changes of water cycle in the Shingasi River Basin, from the past to the present as well as changes predicted in the future, have been estimated by focusing on the influential factors. The quantitative estimation was conducted by applying the

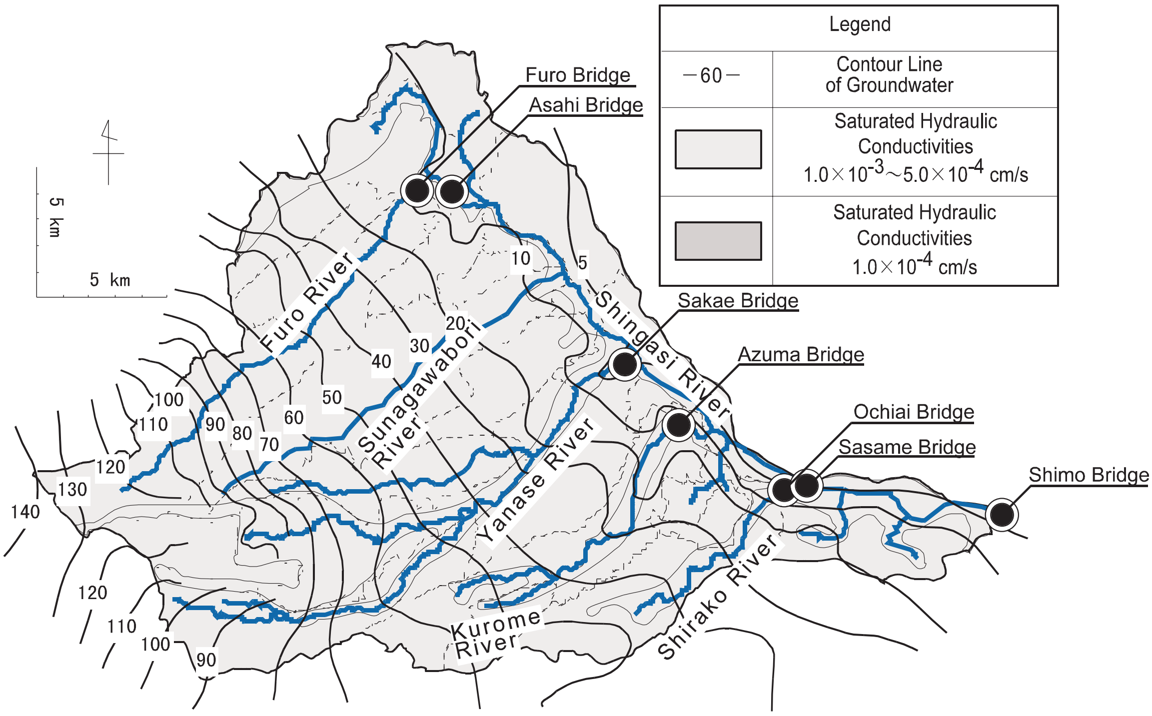

Fig.2. Contour lines of the unconfined groundwater and saturated hydraulic conductivities of the surface soil

simulation model which represents the physical characteristics of the natural flow mechanism of a river basin [5]. The past refers to around the year 1945 when the basin was assumed to be in a natural state. The future is supposed to be the year 2025 when urbanization will have further progressed.

Increase of peak flood flow ; Due to the expansion of impermeable areas and the improvement of urban storm drainage systems, the present peak flood flow is estimated to be 1.5 times that in 1945 and it is predicted to increase in the future as shown in **Fig.3(a)**.

Increase of water demand ; Water transmitted from outside of the basin is significant due to the industrial and living uses. In the future, all the water supply is predicted to rely on the transmitted water from outside of the basin and it is equivalent to the water volume of the precipitation inside this area as shown in **Fig.3(b)**.

Deterioration of water quality ; Due to the discharge of waste water, the water quality of the river has been deteriorated as shown in **Table.2**. The river water used to be utilized for the agricultural and living use but not now. In proportion to the deterioration of water quality, the area for habitat of animals and plants is decreased and the river has already lost the function as the water amenity for the local residents.

Decrease of base runoff ; The decrease of rainwater infiltration and the bypass of the sewerage system have caused the decrease of base runoff. In addition to the absence of water amenity, the utilzation of water for emergency has become difficult.

Fig.3(c). shows the change in base runoff of Furo River. Exponential growth of population from past to present has increased runoff of wastewater into the river. The amount of wastewater is accounted a fair percentage of river water in present condition. Bypassing wastewater by the sewerage system will decrease base runoff in the future.

Decline of groundwater level and dry-up of spring water ; Excess pumping of groundwater lowers the groundwater level and causes ground subsidence. In addition to the excess pumping, the decrease of rainwater infiltration dries up spring water and reduces groundwater flow into the rivers. **Fig3.(d)** shows the change in groundwater level and **Fig3.(e)** shows the change in spring water discharge.

Change of climate ; The decrease of green land and water surface (marsh, river etc.) and the increase of exhaust heat cause the change in heat environment. **Fig3.(f)** shows the change in evaporation quantity.

4 . BASIC IDEA FOR SETTING UP PROJECT GOALS

Before setting up the various measures for improving the water cycle, appropriate project goals should be set based on the

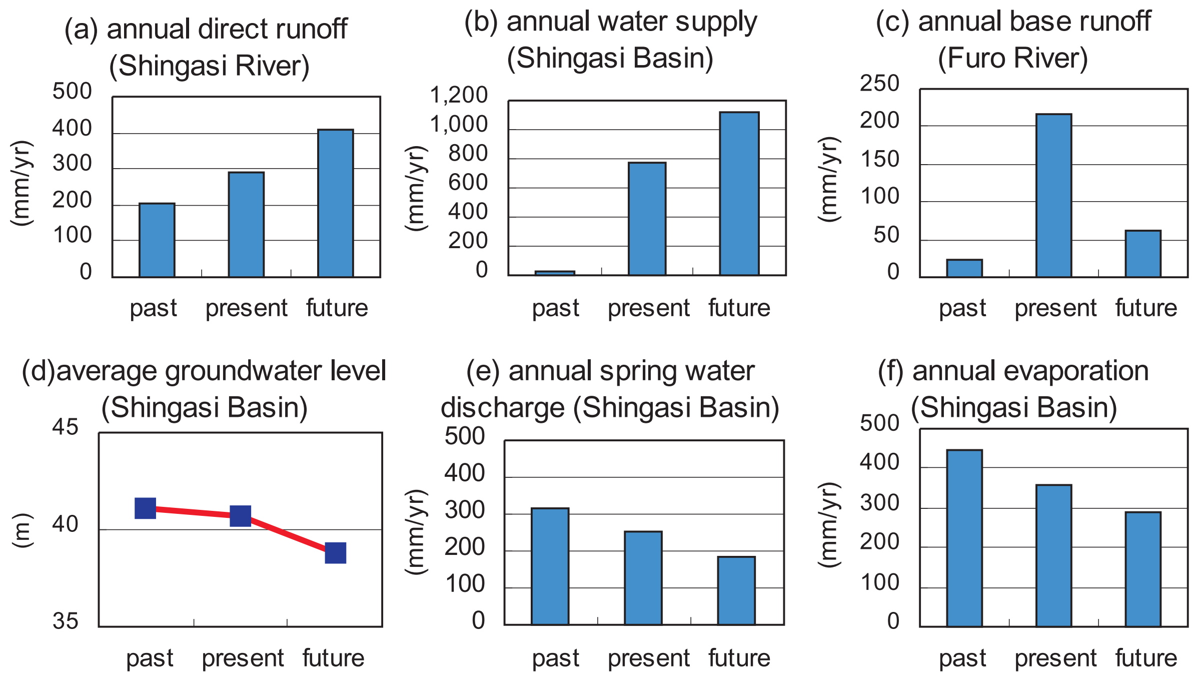

Fig.3. Transition of hydrological quantity and quality from past to future

Table 2. Water quality (Biochemical Oxygen Demand : BOD) of dominant rivers in Shingasi River Basin

name	observation point	observed value(mg/l)
Furo River	Furo Bridge	28.7
Yanase River	Sakae Bridge	11.2
Kurome River	Azuma Bridge	12.0
Shirako River	Ochiai Bridge	6.4

name	observation point	observed value(mg/l)
Shingasi River	Asahi Bridge	9.1
	Sasame Bridge	8.0
	Shimo Bridge	6.4

extracted problems and issues. The viewpoints for the desirable image of the catchment area can be classified into two types. One is the effect directly derived by the improvement of water cycle and the other is the effect indirectly derived. In other words, one is the quantitative index for the amount of water or the water quality such as water discharge, ground-water level, biochemical oxygen demand (BOD) etc., which is rather an engineering approach. The other is the environmental condition related with aqua-culture, ecological system, water amenity etc., which is more understandable for ordinary inhabitants in spite of the difficulty for the quantitative estimation. It is very important to explain the relationship between the improvement of water cycle and the life of inhabitants and to present project goals that we understandable for not only engineers but also ordinary inhabitants.

It is necessary to consider various viewpoints such as the past condition, the intention of inhabitants, the political goals and the ability of implementation, etc., to set up the appropriate target values.

5. SETTING UP MEASURES

The available measures and their quantitative effects are listed in **Table 3**. The quantitative indexes are classified into either the effect directly specified or the effective factor related indirectly with the specified effect. For example, the influential factor of a quantity of infiltration is related with various effects such as flood discharge, ordinary river discharge and groundwater level. It means that the infiltration facility is effective for not only flood control but also aqua-environment. The various measures listed in Table 3 should be allotted among the government, inhabitants, and private enterprises depending on their characteristics.

6. CO-OPERATIVE SYSTEM FOR DRAFTING MASTER PLAN

In order to build the consensus of the master plan among the government, the inhabitants, and the enterprises, as co-operative

Table 3. Relation between available measures and quantitative effects

Available Measures \ Quantitative Effects		flood discharge	quantity of infiltration	discharge and quality of ordinary	influential factor: quantity and quality of sewage	influential factor: quantity and quality of treated water	influential factor: quantity and quality of spring water	influential factor: quantity of water intake from river	water demand and supply	groundwater level and spring water discharge / quality	influential factor: quantity and quality of	influential factor: quantity of leakage from waterworks	influential factor: quantity of pumping water from ground water	influential factor: quantity of groundwater seepage into sewerage	influential factor: quantity and quality of ground water flow through a boundary of basin	quantity of evapotranspiration
river improvements	improvement of river channel	○														
	regulating reservoir	○														
	natural river channel bond						○				○					
	diluent flume			○												
	clarification of river or pond directry			○												
	effective utilization of river water			○				○					○			
sewerage improvements	improvement of rainwater drinage	○												○		
	improvement of sewerage system					○								○		
	propagation of advanced treatment					○										
	effective utilization of treatment water					○										
	renewal of sewer channel					○	○							○		
rainwater storage and infiltration	propagation of rainwater infiltration facility	○	○				○				○					○
	propagation of rainwater storage facility	○														
conservation of green zone and agricultural land	conservation of green zone		○				○				○					○
	conservation of agricultural land		○				○				○					○
effective utilization of water resource	rationalization of water utilization				○	○		○	○			○				
	utilization of rainwater							○	○							
	utilization of waste water				○	○		○	○							
conservation of groundwater	regulating for or monitoring ground water pollution						○			○						
	providing a groundwater cultivating facility, maintenance of spring outlet		○				○									
	monitoring groundwater level						○			○						
	regulating for pumping up ground water						○	○					○			
reduction of pollution load	promoting combined septic tank				○											
	regulating for or monitoring water waste				○											
urban afforestation	providing public gardens		○				○				○					○
	afforestation along with road		○				○				○					○
	afforestation on building		○				○				○					○

system should be carefully constructed. Under this organizing system, the master plan should be authorized by the river council which consists of the representatives from the Ministry of Construction, the local governments, and the tributary working groups.

Before the river council finalizes the master plan, the each tributary working group should build the consensus through the discussion among the academic advisories of professors, the administrative officers of relevant local governments, and some local residents. During this process, it is also very important to encourage the relevant members through social gathering, explanation and discussion, symposium, festival and so on.

7. CONCLUSIONS

This paper indicates the investigative procedure and consideration to draw up the master plan for the appropriate hydrological water cycle. The problems and issues of the water cycle in the Shingasi River Basin were extracted and explained in this first report.

According to the future schedule, many steps of discussion should be done under the organizing system presented in this paper in order to build the consensus among the governments, the inhabit-ants and the enterprises. To make the results successful, the desirable image of water cycle should be discussed from the various view points not only with the governments but also with the local residents.

It is also important to select the most suitable plan among the various alternatives. The effectiveness of each alternative can be calculated, but in order to make the master plan comprehensible, reasonable and sympathetic, the great effort should be paid for producing the positive activity of the organizing system and interpreting the engineering assessment to be easily understandable for all the relevant members.

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