

# An Experimental Catchment to Assess the Hydrological Effect by the Pangyo New Town Development in Korea

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## EXTENDED ABSTRACT

The Pangyo new town development was planned in 2001 in order to relieve the chronic housing shortage problem in the Seoul metropolitan area.

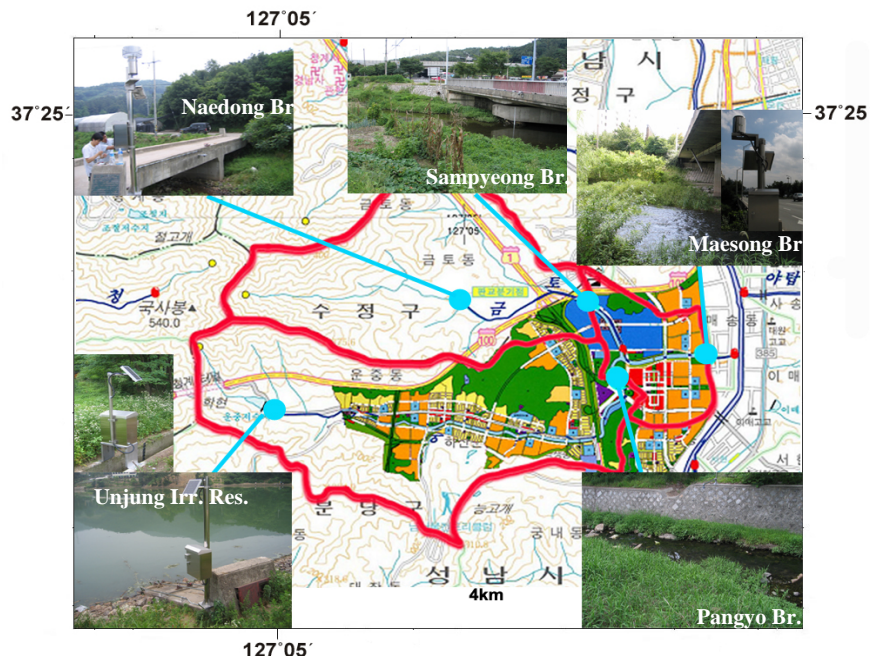
To assess the watershed response to urbanization, such as short- and long-term streamflow and water quality changes, an experimental catchment was designed and the real time hydrological monitoring system was established in this research.

Pangyo experimental catchment is located in Unjung Stream, which is the second tributary of the Tan River, the first tributary of the Han River, as well as Geumto Stream, which is a tributary of Unjung Stream. The area of the entire catchment is 23.1 km<sup>2</sup>, with the Geumto Stream catchment spanning 9.84 km<sup>2</sup> and the Unjung Stream catchment 13.26 km<sup>2</sup>.

Four ultrasonic stream gauges, one water level gauge using a water pressure sensor in a irrigation reservoir, and two rainfall gauges were set up in the Pangyo experimental catchment. The water level and rainfall depth have been measured every 10 minutes since August 2004.

Since early 2005, streamflow have been monitored during the dry and rainy periods to define the stage-discharge relationship. And additional 13 items, such as water temperature, pH, electrical conductivity, BOD, DO, SS, TN, TP, and etc. are also periodically monitored.

In the future, it will be able to assess quantitatively and qualitatively the hydrological effect with the urbanization through the continuous monitoring and data compilation of high quality. Also, the data will be useful for modelers to simulate the hydrological effect by the land use changes.



**Figure 1.** Hydrologic monitoring stations at the Pangyo experimental catchment (<http://www.kict.re.kr/wed/kict-cat/index.html>)

## 1. INTRODUCTION

Urbanization is known to transform permeable areas such as forest and farmland into impermeable areas, including buildings and roads, thereby generating hydrological changes by reducing the travel time of flood wave and increasing the peak flow. In urban areas, which are largely covered by roads and buildings, water evaporation from the ground surface and plants into the atmosphere is generally lower than in agricultural areas or forests. In addition, the amount of water infiltrated into the soil and the amount of water on the ground surface are also much smaller in cities (Cheng and Wang, 2002; DeFries and Eshleman, 2004; Kim, 2004).

The water problems in cities are not restricted in quantity. The direct delivery of water and pollutant from impervious surfaces to streams has a detrimental effect on stream health (Ladson et al., 2004). Delleur (2003) makes the point that all urban water problem, whether runoff quantity or quality, or water supply and wastewater treatment, can no longer be evaluated in isolation but will have to be looked at in an integrated way.

The purpose of this study is to quantitatively assess changes in flow rate and water quality of a new urban development site where a large-scale change in land use is anticipated due to urbanization. To this end, we intend to designate an appropriate experimental catchment and conduct long-term monitoring of hydrology and water quality. By utilizing data measured at an experimental catchment and a hydrologic model, the study will investigate the characteristics of floods and runoff before and after development, and quantitatively analyze and compare the effect of urbanization on the hydrology and water quality of rivers, in order to assist in establishing an efficient reduction measure.

## 2. SELECTION OF EXPERIMENTAL CATCHMENT

Three new urban development sites were selected as appropriate candidates for area for an experimental catchment: Pangyo, which was recently designated as a new urban development site; Gimpo; and Eunpyeong. The final selection was made after preliminary surveys and on-site assessment of these areas.

The Pangyo new town development was planned in 2001 in order to relieve the chronic housing shortage problem in the Seoul metropolitan area through city planning and to build a residential

alternative to Gangnam. The area of the development is 937.6 ha. Unjung Stream and Geumto Stream are located in the area, as is the well-forested Cheonggae Mountain, which envelopes the development on two sides. Although farmland accounts for about 37% of the total surface area, most is used for the cultivation of flowers and vegetables in greenhouses. The land utilization plan for the Pangyo development includes 336 ha (35.8%) to be developed as green spaces, parks and a riverside green zone, and a central park is to be built by the junction of Geumto Stream and Unjung Stream. Residential and commercial areas will occupy 284.4 ha (30.4%) of the total area, and six roads and two railways are to be constructed and operated within the development.

The evaluation items were established in such a way that the adequacy of the experimental catchment selection could be objectively assessed. Those evaluation items with great significance, such as the appropriateness of the purpose and the modification of land use, were given more weight in the overall evaluation. Based on the on-site survey results, the evaluation items were applied to the three candidate developments to select an experimental catchment. In a comparative evaluation with the particular weight of each evaluation item taken into account, Pangyo received the highest score in most evaluation items other than the area's scale and accessibility.

The size of the Pangyo development, 937.6 ha, is adequate for assessing hydrological changes caused by urbanization. Also, in terms of accessibility, its location one hour from the Korea Institute of Construction Technology (KICT) is not a critical issue, although it is a little farther than Gimpo or Eunpyeong. The Pangyo area is already close to Seongnam and Gungnae water level monitoring station at the nearby Tan River and the Naksae Rainfall Monitoring Station, all of which can be used to gather and produce data. In addition, it is expected that Unjung Stream will be urbanized at a fast pace while Geumto Stream is to remain in a relatively natural state. This offers the advantage of being able to compare two catchments and assess the effect of urbanization, which led to the selection of Pangyo as an experimental catchment.

### 3. CHARACTERISTICS OF THE PANGYO EXPERIMENTAL CATCHMENT

Pangyo experimental catchment is located in Unjung Stream, which is the second tributary of the Tan River, the first tributary of the Han River, as well as Geumto Stream, which is a tributary of Unjung Stream, in the northern region. The area of the entire catchment is 23.1 km<sup>2</sup>, with the Geumto Stream catchment spanning 9.84 km<sup>2</sup> and the Unjung Stream catchment 13.26 km<sup>2</sup>. Its geographical location is 37°19'54"N to 37°25'23"N and 127°11'22"E to 127°1'17"E. The area population is 75,885 with a density of 235 persons/ km<sup>2</sup>, and there are 24,190 households in the area (2002 data). Figure 2 is a digital elevation map (DEM) of the Unjung Stream and Geumto Stream catchments.

By soil texture, the northern section of the Geumto Stream catchment is composed of sandy loam (62.4%), clay loam (32.7%), rock (3.0%) and sand (1.9%), whereas the Unjung Stream catchment, the main stream region, consists of sandy loam (47.6%), clay loam (47.2%) and clay (5.2%). While both catchments are covered mostly with

sandy loam, clay loam is the most common soil along the banks in the Unjung Stream catchment, where the new town is to be developed. As seen in Figure 3, the highest concentration of sandy loam is in the hilly regions along the edge of the catchment border, and clay loam is found along the rivers and plains downstream.

The land utilization status indicates the area is consists of 73.9% forest region (13.1% coniferous, 60.8% mixed forest) in the Geumto Stream catchment, 1.4% water, 1.7% rice field, 13.8% farmland, and 9.2% urbanized region, which includes residential areas, roads, public buildings and industrial facilities. Forested region also accounts for the largest part of the Unjung Stream catchment at 69.1% (18.9% coniferous, 8.8% deciduous, 41.4% mixed forest), followed by 15.2% urbanized region, 12.2% farmland, 1.8% rice field and 1.7% water (Table 1). The Pangyo experimental catchment, including the Unjung Stream and Geumto Stream catchments, is mostly forested with dense foliage and a well-preserved natural environment in its natural state. Figure 4 below is the land use map of the Pangyo experimental catchment.

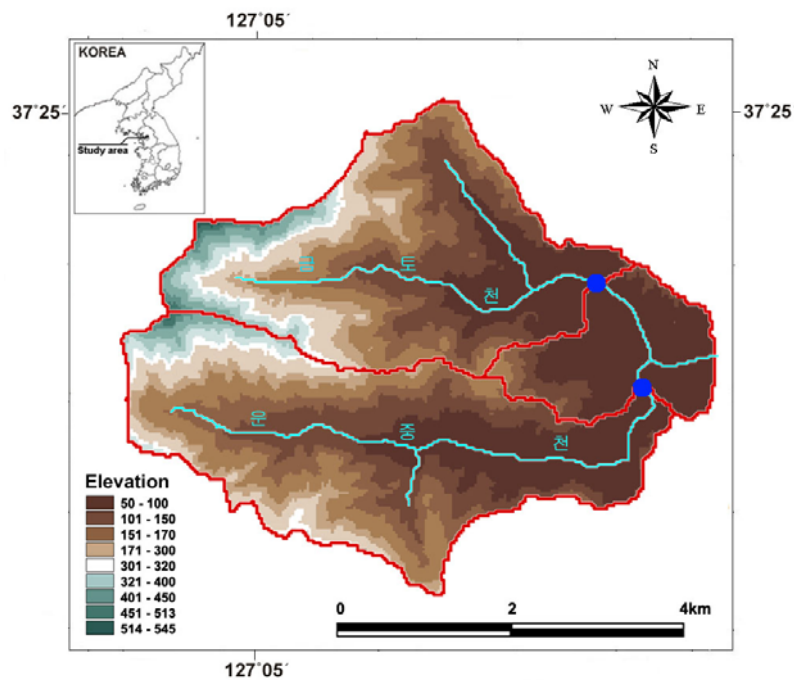


Figure 2. Digital elevation map of the Pangyo experimental catchment

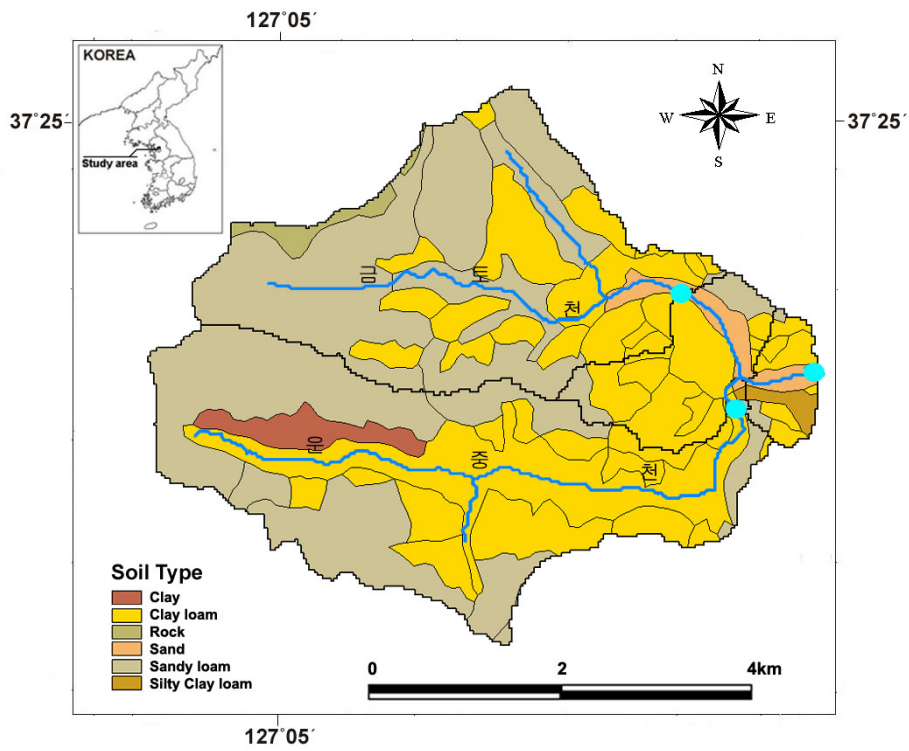


Figure 3. Soil map of the Pangyo experimental catchment

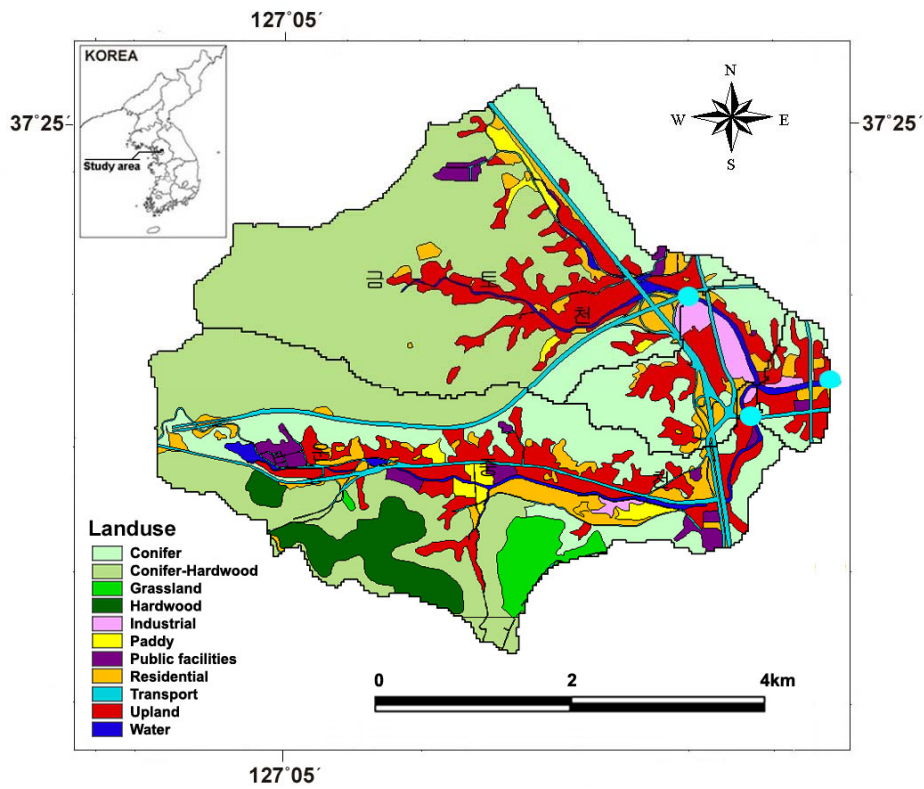


Figure 4. Land use map of the Pangyo experimental catchment

**Table 1.** Current land use in the Pangyo experimental catchment (Unit: km<sup>2</sup>)

Classification		Pangyo Bridge	Sampyeong Bridge	Maesong Bridge
Forest	Conifer	1.97	1.20	4.27
	Broad-leaf	0.93	-	0.93
	Mixed	4.32	5.55	9.86
	Sum	7.22	6.75	15.1
Urban	Residential	0.66	0.37	1.36
	Road	0.57	0.36	1.19
	Public facilities	0.30	0.1	0.41
	Industry	0.04	0.03	0.31
	Sum	1.53	0.86	3.30
Agriculture	Paddy	0.19	0.16	0.35
	Upland	1.28	1.27	3.72
	Sum	1.47	1.43	4.10
Water	Water	0.18	0.12	0.44
	Sum	0.18	0.12	0.44
Total		10.54	9.33	22.90

#### 4. ESTABLISHMENT OF HYDROLOGIC MONITORING SYSTEM

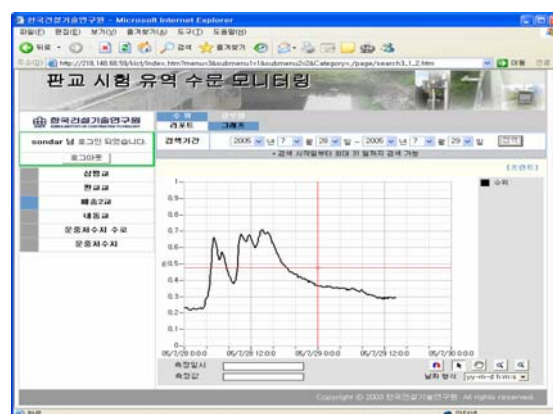
In order to monitor the hydrological response of the catchment, three stream gauges were installed on Pangyo Bridge at lower Unjung Stream, Sampyeong Bridge at lower Geumto Stream, and Maesong Bridge in the main stream of Unjung Stream where two rivers meet, and one rainfall gauge was set up on Maesong Bridge (see Figure 4). All four gauges were put into operation on August 16, 2004, and monitoring takes place at ten-minute intervals.

In May 2005, two water level gauges were put into operation at Unjung Reservoir at upper Unjung Stream to monitor water level and the supply of irrigation water. During the same period, a stream gauge and a rainfall gauge were installed on Naedong Bridge in the upper Geumto Stream.

All of the water level gauges are a supersonic wave type except Unjung reservoir (in which water pressure sensor was installed), which transmits supersonic waves to the water's surface and measures the time it takes to travel back to the sensor after reflecting off the surface. Using this data, the distance to the surface is calculated and converted to water level. The rainfall gauges are a real-time transmitting type with a measuring unit of 0.5 mm. Readings are taken every 10 minutes and are stored in a data logger. All data, including water levels and rainfall depth, are periodically

sent to a monitoring server connected to a TCP/IP network via an internal CDMA communication module using a wireless Internet system. The server then manages the monitoring and equipment status at the sites, and analyzes and stores all data.

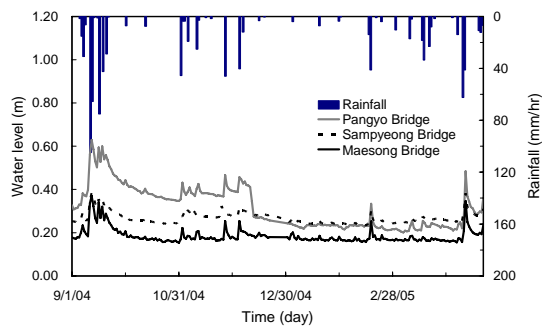
The hydrological monitoring system at the Pangyo experimental catchment will be in long-term operation, until the completion of the Pangyo new urban development, and additional monitoring networks, such as for rivers, underground water, infiltration systems and ponds, are to be incorporated into the system. All data collected are available to the public through a web site (<http://www.kict.re.kr/wed/kict-cat/index.html>).



**Figure 5.** Real-time hydrological monitoring system for the Pangyo experimental catchment

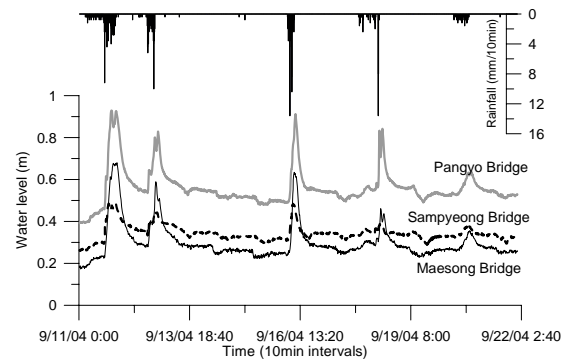
#### 5. MONITORING OF STREAM WATER LEVEL, FLOW, WATER QUALITY AND RAINFALL

Although hydrological monitoring of the Pangyo experimental catchment commenced on August 16, 2004, for reasons such as equipment improvement, stable data gathering did not begin until August 18 for meters at Sampyeong Bridge, August 19 for Maesong Bridge, and September 11 for Pangyo Bridge. Figure 6 shows the raw data in daily water levels and rainfall at each monitoring station in the Pangyo experimental catchment. The hydrological monitoring data used for analysis in this study were gathered between September 1, 2004 and April 20, 2005. During this period, the total rainfall was 465.1 mm, which is greater than the 431.1 mm in Seoul and 409.9 mm in Suwon. Also, the water level at Pangyo Bridge was at minimum 0.16 m and at maximum 0.92 m (an average of 0.54 m), while at Sampyeong Bridge and Maesong Bridge the range was between 0.20 m and 0.48 m (an average of 0.34 m), and 0.08 m and 0.67 m (an average of 0.38 m), respectively.



**Figure 6.** Daily water levels and rainfall in the Pangyo experimental catchment. The sudden drop in water level in Pangyo bridge is due to instrument problem and after the data quality control, the reliable data can be offered.

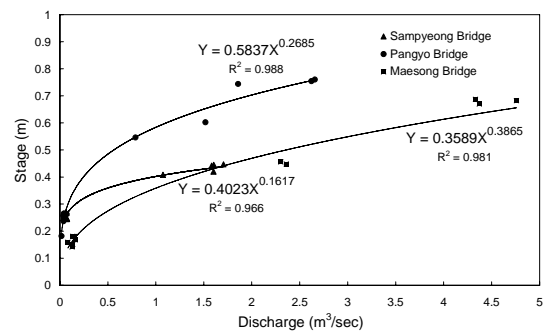
Figure 7 shows the flood hydrographs at 10-minute intervals in the Pangyo experimental catchment, produced based on rainfall measurements taken at Maesong Bridge from September 11 to September 22 in order to assess changes in water level during rain. Because the size of the catchment and the distances between monitoring stations are not large, the runoff delay is minimal between Pangyo Bridge and Sampyeong Bridge at the upper stream and Maesong Bridge at the lower stream. Meanwhile, the change in water level caused by rainfall was most substantial at Pangyo Bridge and the smallest at Sampyeong Bridge. The change in water level caused by rain, however, indicated similar levels at all stations. During the period, the rainfall measured was 159.6 mm, which was close to the 160.5 mm measured at the Korea Meteorological Administration's Seoul Meteorological Station and the 141.4 mm observed at Suwon Meteorological Office. Based on this, we conclude that the characteristics of runoff are similar at this time - prior to the launch of construction for new urban development - in both the rainy and dry period in the Unjung Stream catchment (downstream), which has been chosen as the site for the new development, and between the Geumto Stream catchment and the Unjung Stream mainstream catchment, both of which are not new development sites. If we continue to assess how these characteristics change over the course of future urbanization, we will be able to identify how urbanization affects the characteristics of runoff both quantitatively and qualitatively.



**Figure 7.** Flood hydrographs (10-minute intervals) in the Pangyo experimental catchment

Since early 2005, streamflow have been measured during the dry and rainy periods to define the stage-discharge relationship. And additional 13 items, such as water temperature, pH, electrical conductivity, BOD, DO, SS, TN, TP, and etc. are also periodically monitored.

Figure 8 shows stage-discharge relationships for three stage gauging stations measured until July 2005. There are no data for high stages, so the flow measurement will be carried on until September for flood event. The discharge at Maesong Bridge (located at the outlet of the watershed) shows the largest variation (from 0.1 to 4.8 m<sup>3</sup>/sec). At Pangyo Bridge with the steepest slope among three sites, stage varied very sensitively as discharge.



**Figure 8.** Stage-discharge relationships of each stream gauging stations measured in 2005

## 6. CONCLUSIONS

This study aims to identify the quantitative and qualitative effects on floods, long-term runoff and water quality in a catchment that are brought about by urbanization. To do so, an experimental catchment was selected in an area where rapid urbanization is taking place due to a new urban development project, and the hydrological cycle in the catchment was investigated. A few new urban developments and districts subject to city renovation were chosen as candidates for experimental catchments, and their development plans and characteristics were reviewed. Based on the selection criteria, an area suitable for the purpose of the study was chosen as an experimental catchment, and a plan to monitor the streamflow and water quality of the catchment was formulated. Since then, monitoring tools have been put in place and they are currently in trial operation.

In order to observe the streamflow and precipitation of the Pangyo experimental catchment in real-time, a total of five stream gauges have been installed in various locations: Unjung Reservoir and Pangyo Bridge at Unjung Stream; Naedong Bridge and Sampyeong Bridge at Geumto Stream; Maesong Bridge in the upper Unjung Stream where two rivers meet. In addition, two rainfall gauges have been set up at Maesong and Naedong Bridges. There are plans to expand current operation by adding networks to monitor the water levels of streams, underground water, infiltration systems and ponds in near future.

All data collected are available to the public through a website (<http://www.kict.re.kr/wed/kict-cat/index.html>) or e-mail, and the hydrological data gathered to date, which provides information on daily changes in water level and real-time change in water level during rain.

The authors hope that the changes in hydrologic characteristics including quantity and quality can be analyzed during the process and after the Pangyo new town development through continuing hydrological monitoring.

Also, the data will be useful for modelers to simulate the hydrological effect by the land use changes

## 7. REFERENCES

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