Development of an Automatic Monitoring System for the Assessment of Urban Wet-Weather Discharge in the DTV (Daedeok Techno Valley), Daejeon, Korea

Développement d'un système automatique de surveillance pour l'évaluation des rejets urbains de temps de pluie dans la "techno valley" de Daedeok (DTV), Daejeon, Corée

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RÉSUMÉ:

Ce travail de recherche est destiné à évaluer la faisabilité d'un système de contrôle automatique de débit et de surveillance de la qualité des eaux de surface, ainsi que son utilisation dans tous types d'environnements.

Un essai pilote a été conduit avec l'installation d'un système de contrôle des charges polluantes sur un exutoire d'eau de pluie immédiatement en amont d'un bassin de rétention sue une petite rivière à Daejeon, en Corée. Des capteurs ont été installés pour mesurer la turbidité, la conductivité, l'oxygène dissout, etc. Les débits ont été mesurés au moyen de débitmètres à ultrasons et calcul de l'équation de seuil. Un équipement d'échantillonnage automatique et un pluviomètre ont été ajoutés pour contrôler la qualité de l'eau et suivre en temps réel le fonctionnement du système. Il a également été possible d'établir un graphique de pollution estimant simultanément avec précision les débits et la qualité de l'eau. Cette étude va être intégrée au système de gestion et de suivi de la qualité de l'eau.

MOTS CLÉS

Eau de pluie, pollution source non-ponctuelle, modèle de bassin versant MGEP (SWMM), pollutogramme, contrôle automatique

ABSTRACT

This study was performed to test feasibility of integrated automatic flow rate and water quality monitoring system from urban storm water runoff events. Rainfall gauge, water quality sensors, water sampler and ultra sonic water level meter were used to estimate rainfall, water quality and flow rate, respectively on real time basis. A pilot test was performed by installing the monitoring system in a storm water outlet before wet-weather detention pond in Daedeok Techno Valley, Daejeon, S. Korea. Remotely controlled automatic water sampler was used for laboratory water quality analysis of storm water due to detection limitation of currently available water quality sensors in the field. Flow rates were measured by using ultra sonic water level meter with a rectangular weir equation. Flow rates and water quality concentrations were verified using intensive field measurements in storm events. The SWMM watershed model was applied to analyze cause and effect of flow rate and waste load in the study area and thus to support decision making processes. By using this system, it was possible to estimate hydrograph and pollutograph simultaneously from in storm events. This system can be used to develop water quality management strategies of surface water by accurately monitoring and modelling flow and pollutant load from a basin especially in storm events.

KEYWORDS

Automatic Storm Water Monitoring, Nonpoint Source Pollution, SWMM Watershed Model, Pollutograph, Water Quality Management

1. INTRODUCTION

Environmental conditions of rivers and streams are closely related to hydrological characteristics and status of water pollution sources from their basins. As rapid urbanization of basin area in Korea, fractions of impervious area and sewer coverage rate in the basin increase and these also lead increase in transport efficiency or delivery ratio of water and pollutants from basin to streams. Therefore, it would be appropriate to apply hydrological models in the prediction of delivery rates of water and pollutants for the management of surface water environment. Though storm water plays essential role in the above processes, its data are not readily available due to difficulties in the measurement in both temporal and spatial scales.

Due to advancement in modern technologies, automatic water quality monitoring has become more feasible than before. Use of water quality sensors for various parameters such as dissolved oxygen concentration, conductivity, pH and turbidity has become popular. Seo et al. (1997a; 1997b) introduced automatic water quality sensors for the analysis of stratification characteristics of the lakes. They used automatic water quality sensor with depth measurement system. Their system was designed to move a set of water quality sensors along the depth continuously. Lee et al. (2002) applied the above system to verify stratification modelling of Daechung Lake by using CE-QUAL-W2 model. Lee et al. (2006a, 2006b) suggested to use water quality monitoring system to identify the cause of fish kills thus to overcome the water quality problem in Yudeung stream in Daejeon, Korea. Seo and Lee (2009) developed VeMAS system that can send data from water quality sensors for surface water via cellular phone technology to a host computer and then made data available on the web. However, there have not been many attempts to monitor flow rate and water quality at the same time in the fields. It is essential to have both water quality and quantity data to estimate pollutant load and thus to develop water quality management strategies. This paper reports the design and operations of automatic water flow and water quality monitoring system to accurately estimate pollutograph from watershed area due to storm water runoff.

2. METHODS

2.1 Study Site

As a study site, a small stream, Gwanpyungcheon (will be called as the G-stream from now on) in Daejeon, Korea was selected. The basin area of the stream, Daedeok Techno Valley (DTV) is the newly developed town in Daejeon for promoting industrial and economic development of the city by hosting industries of highly advanced technologies. However, in the environmental point of view, the basin and its stream are under serious stress and thus basin-wide environmental management plan is necessary. The G-stream is a small stream passing through DTV basin. Its basin area is 10.85 km^2 and length is 5.35 km. A block of its basin of 1.85 km^2 is connected to a strom water detention pond and this location is selected as a site for monitoring system installation as shown in Figure 1. Pond area is 5,000 m^2 and maximum storage volume is 9,700 m^3.

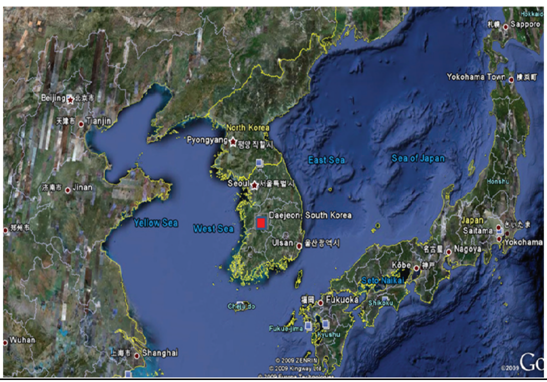


Figure 1-(a) The Location of Daejeon, Korea

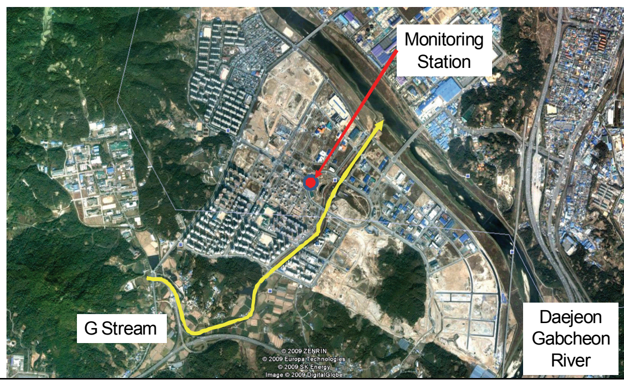


Figure 1-(b) Location of Monitoring Site, G Stream

2.2 Automatic Monitoring System

Figure 2 shows picture of the pilot study site and the monitoring station. Storm water runoff flows into detention pond via storm water discharge outlet. Storm water is stored in the detention pond as shown in the Figure 2-(a) and discharged to G-stream through a flap gate operated by water pressure. Rainfall gage is installed on the roof of the station as shown Figure 2-(b).

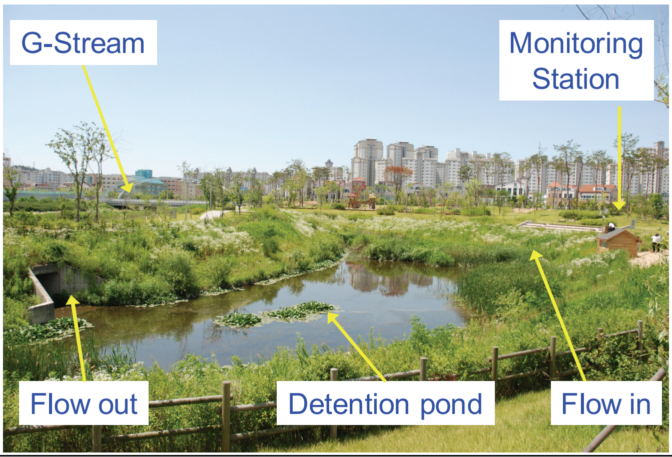


Figure 2-(a) Monitoring station, Detention pond, Flow inlet, Flow outlet and G-stream.

Figure 2-(b) Rain Gage on the Roof of Station

Figure 3 shows water flow monitoring system, water intake and inside of monitoring station. The monitoring system is equipped with water quality sensors and automatic samplers. It is designed that water sample is pumped to a flowing through water tank inside station where water quality sensors are installed and samples are taken to refrigerated container. In this way, it was possible to protect sensors from damaged from foreign object in the storm sewer. Temperature, Conductivity, Turbidity, Dissolved Oxygen, ORP and pH can be measured at site and data can be sent immediately using data logger and internet. However, water quality sensor for commonly used water quality variables such as BOD, COD, TN, and TP are not readily available. To automatically such important water quality variables, it is common to install automatic analysis system in the field. However, installation and operation cost of these equipments are usually very high. Seo et al. (2009) suggested to use automatic water sampler and send samples to laboratories where proper experts and equipments are available if more detailed and accurate water quality analysis are required.

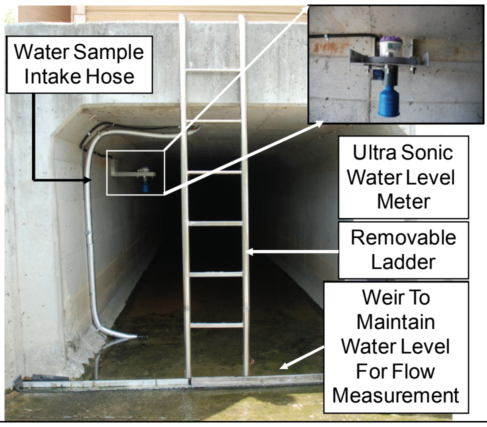


Figure 3-(a) Flow Monitoring Equipments and Water Intake Hose for Water Quality Samples

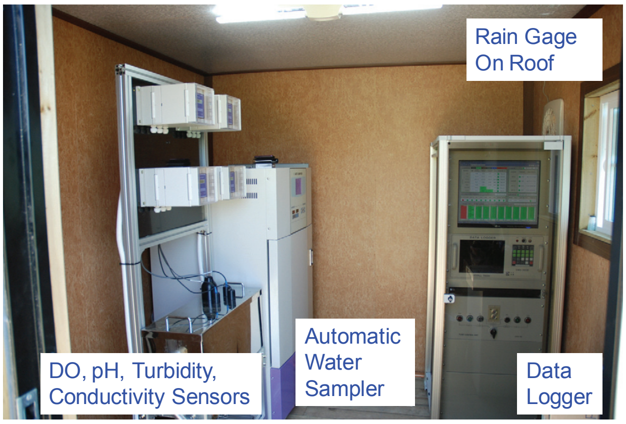


Figure 3-(b) Inside Water Quality Monitoring Station.

Flow rate was estimated using the weir equation in eq(1) and Figure 4-(a). Field measurements were performed to confirm flow rate estimation using this equation as shown in Figure 4-(b)

$Q = KBH^{2/3}$ (1)

Where Q = Flow rate (m^3/sec), K = coefficient (m/sec); 1.84 for this study,

B = width of weir (m), H = water depth (m)

Specification of equipment used for automatic monitoring system is as shown in Table 1.

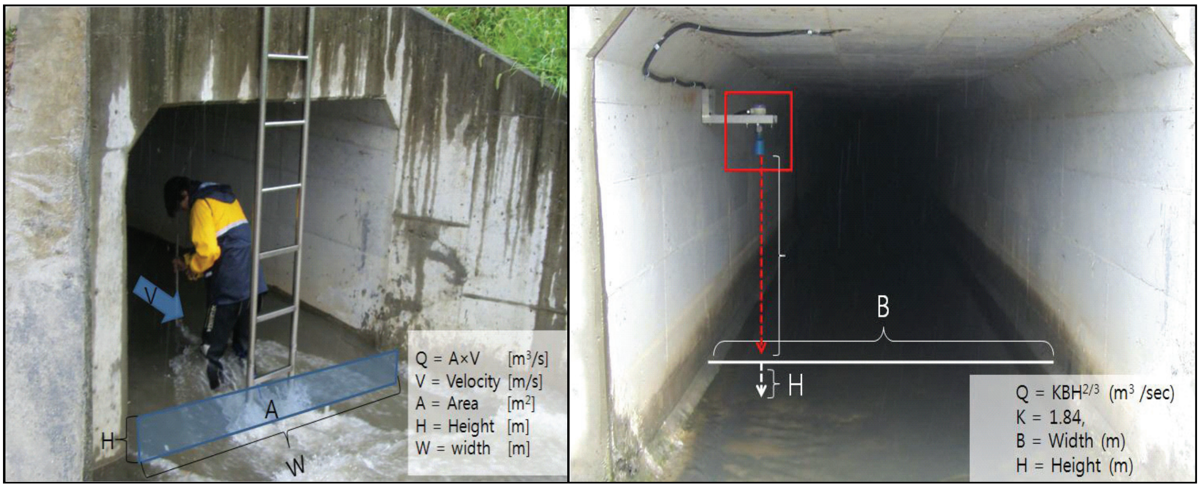


Figure 4. Water Flow Measurement System Using Ultrasound Level Meter (Seo et al., 2009)

Item	Range	Unit
DO meter	0 – 20	mg/L
Turbidity	40 - 4,000	NTU
Conductivity	0 - 2,000	Micro Siemens
ORP	-1,000 - 1,000	Mv
Water Level Meter	0 - 3.0	M
Rain Gage	0.2	Mm
Automatic Water Sampler	Temp. : 4℃, No. of Bottles : 24	Sampling Volume 100mL~ 1,000mL

Table 1. Specification of equipment used for automatic monitoring system

3. RESULTS

Figure 5-(a) and Figure 5-(b) show data from automatic flow rate and water quality sensors in the field. Two peaks of flow, 544 m^3/sec and 480 m^3/sec, were detected in 3 hour interval. As shown in Fig 5-(a), it was evident that turbidity and conductivity were increased right after the first peak but increase of both variables was not clear after the second peak. This indicates first flush may washed the most debris and dirt from the surface of the basin. DO concentrations were less than 2 mg/L and became lower after the first peak. Compared to turbidity and conductivity, DO level recovery was slower. pH became lower during the storm and recovered in 5 hours after the second peak. It was notable to observe abrupt changes in turbidity, conductivity, DO and pH at the same time at 18:20. It is believed totally different water might have been introduced at that time, though it was not possible to identify the cause of the event.

Figure 6 shows verification of automatic flow rate estimation using intensive field measurement using current meter. As shown in the figure automatic flow rate measurement using flow level meter seems to provide reasonable flow rate estimation. However, when flow rates were too high it was not possible to measure flow rate manually. For these cases, SWMM watershed model (Rossman, 2008) was used to estimate flow rate form the basin during the storm events as shown in Figure 7-(a) through Figure 7-(d). The flow rate estimation seems to be reasonable when flow rates were less than 1 m^3/sec. However when flow rate was greater than 1 m^3/sec, there are considerable difference between automatic measurements and prediction results. This may be caused by the flow pattern inside detention pond. Since water level of the pond is operated by still flap gate, it is possible that backwater from the pond may affected water depth in the vicinity of ultra sonic water level meter.

Figure 8 shows automatically mesaured flow rate and some important water quality variables collected by auto sampler and subsequently analyzed in the laboratory. To include variabels in a graph TSS value was reduced 10 times and TP value enlarged 10 times. Variation of water concentration values were not obvious compared to changes of flow rate. However, this figure shows that this system can be applied successfully to derive pollutograph of any water quality variable of interest.

As shown iun Figure 9, this system was designed to monitor flow rate and water quality data continuously from a remote site using internet on a real time basis. This system can be easily linked with water quality modelling system for decision making and also with water quality management actions for timely control of pollutant.

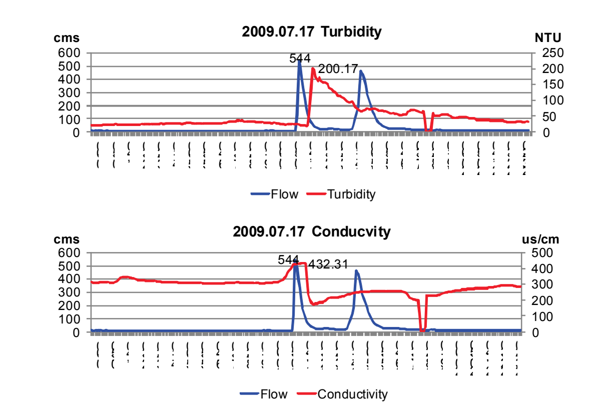


Figure 5-(a) Flow vs Turbidity and Flow vs Conductivity Measurements using Sensors

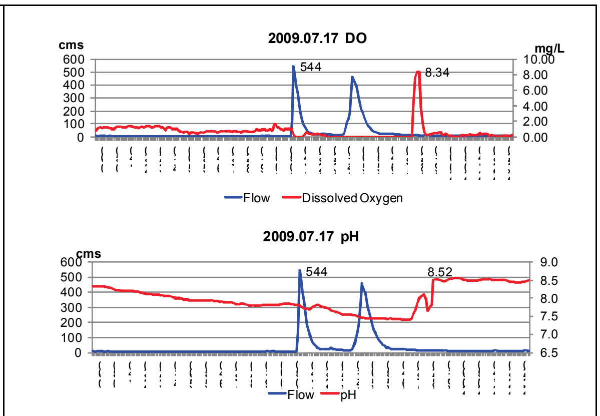


Figure 5-(b) Fow vs DO and Flow vs pH Measurements using Senors

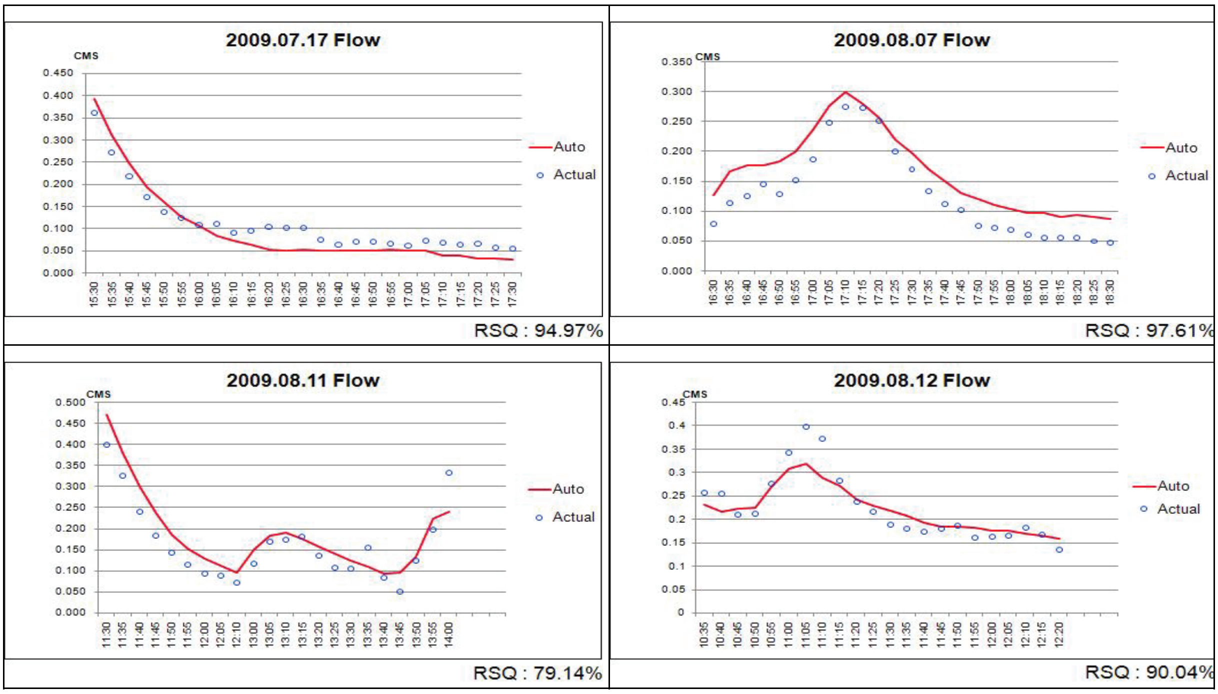
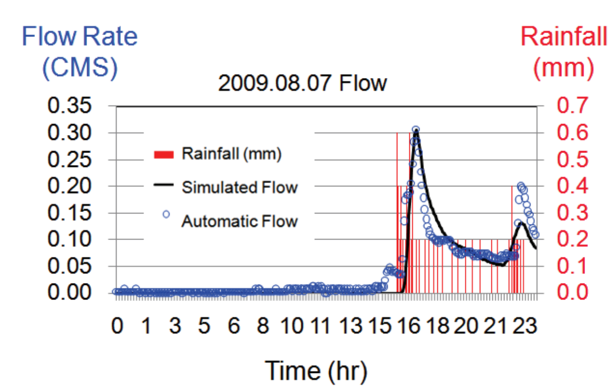
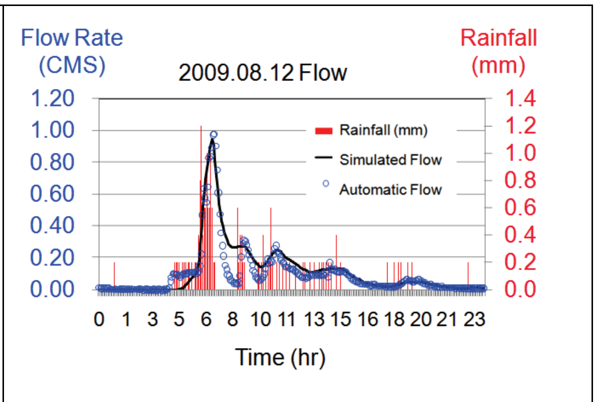


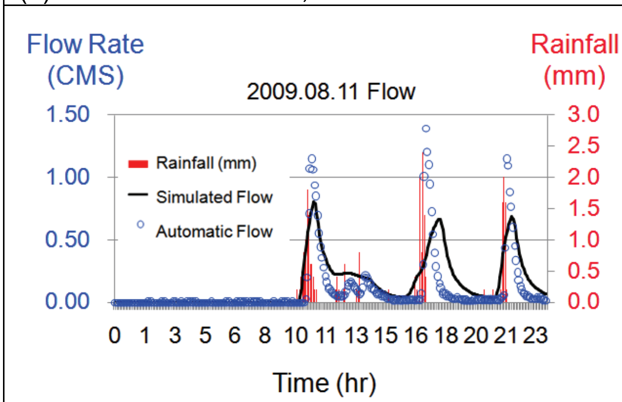
Figure 6. Automatic Flow Rate Measurements and Vefication Using Manual Measurements



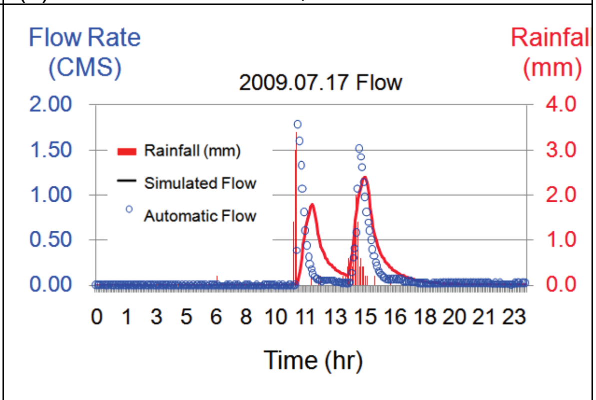
(a) Maximum Flow Rate, 0.3 m^3/sec



(b) Maximum Flow Rate, 1.0 m^3/sec



(c) Maximum Flow Rate, 1.5 m^3/sec



(d) Maximum Flow Rate, 1.8 m^3/sec

Figure 7. Flow rate measurement and Flow Prediction using SWMM program

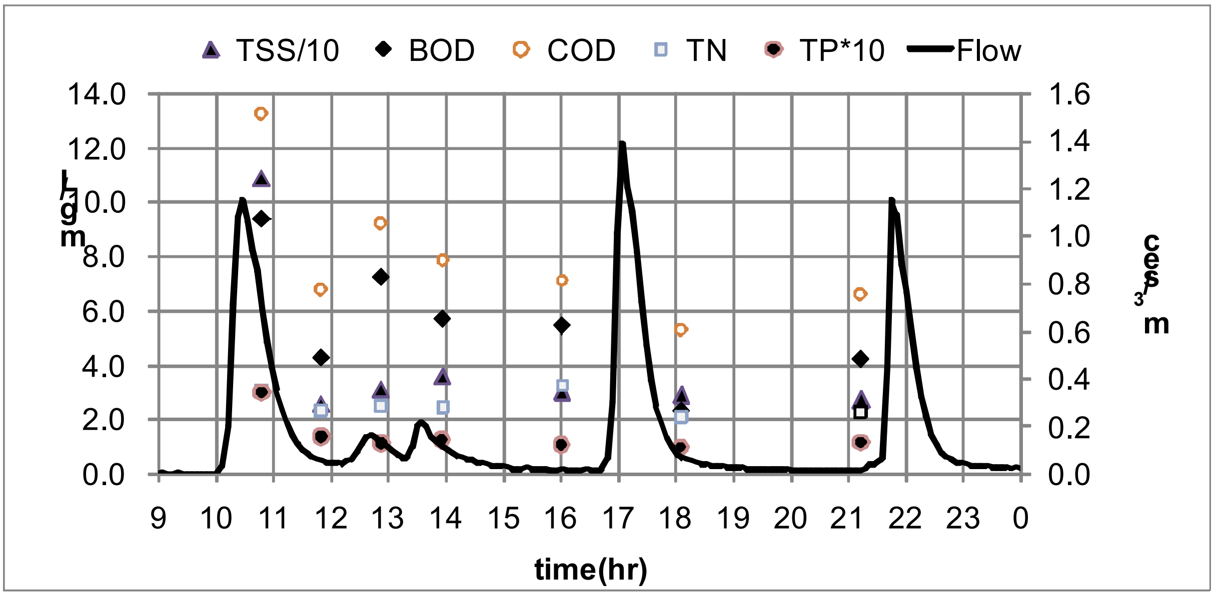


Figure 8. Automatic Flow Rate Measurement and Water Quality Concentrations Using Auto Sampler and Laboratory Analysis (2009. 08. 11)

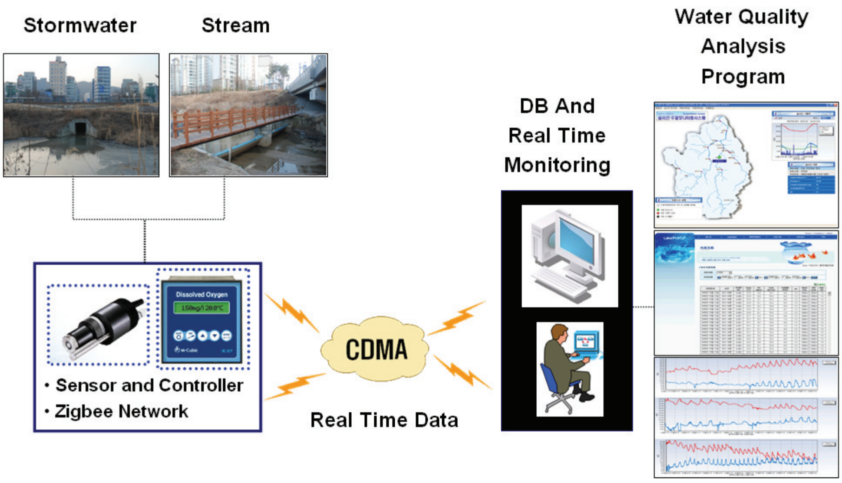


Figure 9. Schematic Diagram of Real Time Water Monitoring System

4. CONCLUSIONS

Accurate information of flow rate and pollutant concentrations from basin area is the essential factor for development of effective water quality management plan. Using the developed system in this study, it is possible to accurately estimate flow rate and water quality concentrations in time and to develop hydrograph and pollutograph for a basin. Flow rate estimations were accurate when flow rate was less than 1 m^3/sec. It seems to be appropriate to develop multi-step weir equation considering hydraulic characteristics of detention pond in the study site to appropriately consider high flow rates. While water quality sensors can generate real time measurement of storm events, water samplers can be used to collect samples for further detailed water quality analysis in the laboratory.

SWMM watershed model was successfully applied for the prediction of flow rate and it was possible to provide flow information when manual measurement was not available. The system also equipped with real time data sending system and it also is possible to visualize the data through web pages. This information can further be used for water quality modelling for various water quality management scenarios in the basin. The prediction results can be used to determine which water and water quality management actions can be implemented.

In conclusion, automatic flow and water quality monitoring system will initiate entire real time environment control in basin scale. This system can be used to protect environment in basin and in surface water more effectively.

This system can be regarded as a good sample of fusion technology that applied IT (Information technology) and ET (Environment technology) together.

5. ACKNOWLEDGEMENT

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