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DETERMINATION OF OPTIMAL STORAGE RESERVOIR LOCATION CONSIDERING REGIONAL IMPORTANCE

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Urban drainage systems are affected by various regional characteristics such as sewer properties, misaligned connections, manhole ground level, and design flood stage at outlet. Therefore, combinatorial characteristic of selecting optimal location of storage facilities from many candidate locations gets even more complicated and becomes a challenging task. The process of selection is conducted using system analyses to address the effects that provide for high efficiency and low damage. This paper focuses on developing an optimal design model for determination of the storage reservoir locations considering regional importance. For cases of urban inundation, importance of flooded region considering the damage needs to be included in the determination of reservoir locations. A multi-dimensional flood damage analysis (MDFDA) is employed for each important basin, where the higher the calculated cost of damage obtained by this method, the more important it is and thus, the greater the need for installation of a reservoir to prevent flooding. Flooding damage costs according to overflow volume were obtained by repeated precipitation-runoff analyses with overflow depth calculations. The depth calculation and a damage function analysis are combined using the multi-dimensional method and applied to urban watersheds in Korea. In conclusion, the approach of this paper can be considered as a methodology for the determination of storage reservoir location to reduce inland flooding and damage.

Introduction

As the urbanization proceeds, the extent of impermeability has expanded due to increase of land use changes and pavement percentage of the road. These factors have an effect on the time of concentration and the amount of peak runoff. In addition, the growth in occurrence of torrential downpour which exceeds the design frequency in sewer networks cause inundation very often. It is essential that related solution and research are preceded, because there are lots of human casualties and property losses from dense population and buildings in urban area.

To prevent these damages, construction of the rainwater storage has been discussed in local government. Rainwater storage is one of the structural measures which are very effective in reducing peak discharge that decreases the flood damage. Generally, this facility is expected to improve disaster protection performance when a number of installation are combined, because the rainwater storage have applicable size which is smaller than any other detention facilities. Although, appropriate design of rainwater storage is on the rise, there is not an eligible standard to determine the location of facility. This design can reduce the risk of inundation in basin more beneficially.

Determination of optimal storage reservoir location

The goal of this study is to determine the location of high flood risk area by installing a storage reservoir to find the place which minimizes the expected damages. Determining the optimum location of the entire drainage system and detention capacity have been investigated by minimizing the overflow volume and cost as the considered objective functions. However, for cases of urban inundation, importance of flooded region considering the damage needs to be included in the determination of reservoir locations. This shows different damage degree according to the social value of the region and inundation aspects differs in case of same inundation discharge in pipe from geological factors. In this study, relative importance is reflected to the region where inundation occurs in sewer network to determine the optimal location of storage facilities. Social importance was estimated for each subbasin to quantize overflow discharge inundation damage. Harmony Search (HS) optimization method was used for optimization purpose according to installed location and urban runoff analytical model SWMM DLL (dynamic linked library) was linked. According to the application of rainfall, considering that combination of install location can be changed, various rainfall events were applied to find the optimal combination.

1. Optimization Determining Model

To apply the algorithm for this study, Visual Basic (VB) and EPA-SWMM 5.0 DLL was linked to carry out the hydraulic and hydrologic analytical works for iterative simulation. EPA-SWMM 5.0 is rainfall runoff model using DLL file which can be linked with any programming language. Basic principle approach of the program is using the VB with SWMM DLL, to decide optimum alternative plan through input variable control and results derivation. For the sake of convergence speed improvement and search capability of optimal solution through iterative simulation, the HS algorithm was implemented on the VB.

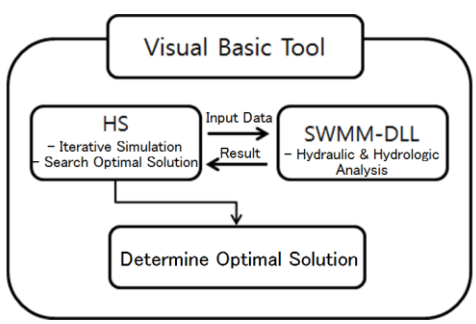

Figure 1. Optimization design model for storage reservoir

2. Research Basin

Research basin is Jeongeup-si, Jeollabuk-do which is located between Jeonju-si and Gwangju-si. Study basin is located among, 127 degrees 07 minutes to 126 degrees 43 minutes of east longitude, 35 degrees 27 minutes to 35 degrees 45 minutes of north latitude. Total area is 692.78km^2 which is second largest city in Jeollabuk-do and 120 thousand residences are living in this area. In 2011, over 400 mm heavy rainfall has occurred in Jeongeup-si, Jeonbuk which caused road, life, building, etc inundation damage. Sintaein-eup and Yeonji-dong are areas prone to floods, which flooded zone improvement program started in January 2013 in resulting applicability and necessity.

Candidate location for storage reservoir was selected firstly by designating adequate installing regions in site area; secondly, secure the possible storage capacity, thirdly, reduce flood reduction effects, and lastly, eliminate constructions and traffic managements problems. On the basis of public land or vacant lot, 10 high places possible for installing were selected in Sintaein-eup, Jeongeup-si. Maximum areas for each location are different, but considering the capacity of storage reservoir can be controlled by the height, it is regarded that enough land can be secured.

3. Importance calculation for each subbasin using MDFDA

In this study, each basin importance is basically used with multi-dimensional method calculation. In multi-dimensional method, higher the estimated damage cost the more important it is and storage reservoir is assumed that it is not flooded. The MDFDA is direct damage analysis method suggested in Ref. [2]. Multi-dimensional method estimates damage property in flooded area to multiply by inundation damage rate corrected by inundation depth for calculating flood damage.

Multi-dimensional method is partially modified in this study. Among entire flood damage used in multi-dimensional method, structure, agricultural land, public facilities damage were estimated and traffic flood, human life damage were not considered. After social value of subbasin was calculated, overflow discharge-estimated flood damage amount regression equation was computed through two dimensional flood analysis. Commercial program XP-SWMM was used for two dimensional analysis. Correlation between overflow discharges was increased according to the increase of rainfall events and two dimensional flood analysis results were calculated.

4. Optimization simulation

1) Application of rainfall events

In this study, recent local torrential rainfall damage occurred is applied to facility for Jeongeup-si probable rainfall 50, 70, 100 year frequency rainfall to analyze the effects of flood damage reduction. Three hour duration time was used and in Ref. [1] rainfall time distribution for choosing Huff rank is suggest to choose most rank but relative influence according to rank is very high, meanwhile the standard criteria is inadequate which needs additional standard establishment. However, the most rank is only arithmetically occurrence frequency which has high value for rainfall, hence in high frequency of calculating flood discharge, this application is meaningless.

2) Objective function and constraint condition

The objective function of optimal design model of storage reservoir is minimizing the flood estimated damage. To compare with simulation results considering basin social importance, objective function which minimizes overflow discharge of entire basin was additionally simulated. Objective functions are given as follows:

$$\min \quad C_{FD} = \sum_{i=1}^{n} C_i \tag{1}$$

$$\min \quad V_F = \sum_{j=1}^{m} V_j \tag{2}$$

Where C_i means overflow discharge occurred in i^{th} node changed to flood estimated damage, and CFD is total flood estimated damage of entire basin. In second objective function, V_j is overflow discharge occurred in j^{th} node, and VF is total overflow discharge in entire basin. Location and capacity of storage reservoir were control variables, capacity was chosen to select in 1,000m^3~9,000m^3 ranges, and constraint condition was set-up for maximum of 3 selected locations.

Conclusions

When determining the location of storage reservoir, an alternative approach to minimize the flood damage in basin was proposed in this study. Unlike existing rough decision making on storage reservoir at fixed point, this study reflects the importance of flood point on selecting location.

Social value of subbasin was estimated using MDFDA. Property according to residential district structure, industrial types were computed and social values were evaluated with area compare to social value, basin total property compare to property value.

According to various rainfall events, two-dimensional flood analysis was conducted using XP-SWMM to calculate inundation depth and area for each basin. Through the results, flood damage was estimated for each inundation depth and adding this up, overflow discharge and flood damage relation which is one dimensional result was shown. Damage estimation equation was differing from social value of basin and two-dimensional flood damage aspect. Overflow discharge produced at subbasin was computed with damage estimation equation for flood damage which social importance was considered as weighted value.

Objective functions were considered to minimize flood estimated damage and the entire overflow discharge for calculating optimal location. According to install place (1, 2, 3 number) and design frequency, optimal location and capacity of each storage reservoir were calculated. Depending on the objective function, optimal location and capacity results were different. For flood estimate damage, when objective function was minimizing the entire overflow discharge, the calculated optimal location results were significant; however, the entire overflow discharge represented lower values. This is because objective function for minimizing the entire damage resulted in inundation reduction at high social value regions and optimal location selection was to reduce bigger area flood compare to same overflow discharge.

Therefore, for the sake of installing storage reservoir through this study, designers considering social importance to determine optimal location are expected to design properly to minimize the flood damages.

Acknowledgments

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