A Study on the Application of Flood Disaster Management Using GIS

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ABSTRACT: Recently, though damage caused by intensive rainfall and typhoon happens frequently, we could not forecast or predict a disaster, due to the difficulty of obtaining exact information about it. For efficient disaster management, the most urgent need is the preparation of a flood forecast-warning system. Therefore, we need to provide a program that has the ability of inundation analysis and flood forecast-warning using a geographic information system, and using domestic technology rather than that from foreign countries. In this research, we constructed a FDMS(Flood Disaster Management System) that is able to analyze real-time inundation data, and using the GIS(Geographic Information System) with prompt analyzing of hydrologic-topographical parameters and runoff-computation. Moreover, by expressing inundation analysis in three-dimensions, we were able to get to the inundation area with ease. Finally, we expect that the application of this method in the flood forecast-warning system will have great role in reducing casualties and damage.

1 INTRODUCTION

Recently, Damage by the localized downpours and typhoon has been increasing. But, real time estimates and warnings about areas for various kinds of rainfall are difficult to obtain. Therefore, we need a professional system for flood forecast-warning and FDMS(Flood Disaster Management System). For these reasons, we are applying an access flood forecast-warning system and inundation analysis using GIS(Geographic Information System). GIS's application has been attempted for many applications in the hydrology field a specially since the latter half of the 1990's although it has been used often in other fields. In addition, the analysis method used to output results from hydrologic analysis approximates the current true value.

Develop and introduce worldwide program that scientize hydrologic- topographical parameter by using GIS in foreign case. But in case of Domestic, we are just rely on this program, nothing more. Korea uses a program that has been designed abroad, and developed the GIS application system with this program. For that reason, the GIS application program in this country is insufficient to use in the specialized domestic situation which needs hydrologic analysis.

Therefore, this research, has achieved hydrologic analysis rapidly by utilizing hydrologic- topographical parameter and runoff-computation after input space data and attribute data was digitally mapped, using domestic

technology. In addition we have a constructed a flood disaster management system that can help us to achieve real time inundation analysis connected with RMS(Urban River Management System) and inundation analysis system. Our goal is to help preparedness and response to flood related damage and to take a bigger role in diminishing property's damage and injury to people.

2 METHOD OF STUDY

The FDMS (Flood Disaster Management System) analyzes input data and constructs a runoff model automatically linking this with space data after input attribute information that needed for the digital map. This system uses a runoff model that was constructed by MFC (Microsoft Foundation Class), it can analyze the effect of inundation in real time as it applies the result to the inundation analysis system. Also, FDMS is considered to help preparedness and response to calamity hereafter because it can detrmine the number of pumps needed the most suitable pump type and the best method for operation the pump in the system. We collected rainfall data of the Seolma river and volume of runoff data to authorize the FDMS. And, we decided on the Beombang river basins as the application target for collecting connected data, which is located in Kangseogu Pusan metropolitan city, for application of system by inundation analysis.

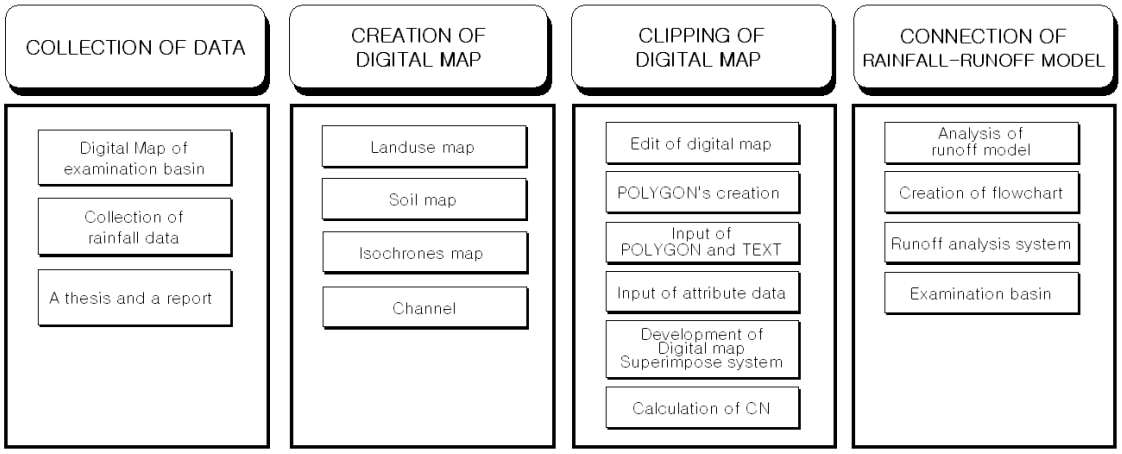

Fig. 1. Methods of study

Specially, we calculated the hydrologic parameters of the runoff model by constructing reiteration system, collecting the soil map, land availability, digital map etc.. And, we made out hydrologic parameters by using input data from the runoff model in the digital map. Thus the constructed digital map is kept as a drawing, and the FDMS receives this as input data for run each runoff model. This gave the name 'runoff analysis system'. Also, the of volume of runoff was used to calculate the inundation volume after calculating the undercurrent amount associated with the inundation analysis system. And, this can be used to recalculate the inundation level to get the inundation area. That is, it can display the function by series system from rainfall to inundation

analysis.

3 CONSTRUCTION OF FDMS

3.1 Composition of floods disaster management system

The flood disaster management system can perform inundation analysis caused by rainfall, using the target basin's digital map and shows the effect of possible provision and confrontation. This system can raise optical effectiveness and effect of the inundation map by achieving an effect-analysis of inundation by rainfall in three dimension. And, it is expected that fleeing people helping to manage a calamity and disaster by prompt confrontation, will establish a smooth and systematic spot command system at the calamity site and help to reduce damage. The flood disaster management system constructed through this research is easily separated into digital map reiteration system, a runoff calculating system and an inundation analysis system(Fig. 2.). The digital map reiteration system has the advantage that it can achieve runoff imitation repeatedly creating input data for the runoff calculation system automatically overlapping the other maps (small area, soil, land availability, isochrones map, channel). The runoff calculating system, that receives space data and attribute data that is created by in this way, calculates runoff from forecasts of rainfall using the runoff model(Clark, SCS, Nakayasu, Nash). This can examine the effects of inundation. Comparison through three-dimensional analysis by calculating runoff associated with the inundation analysis system again. Also, it is thought that can help recursive calculation choose the most suitable design in case we wish to design a pump for convention flooded districts.

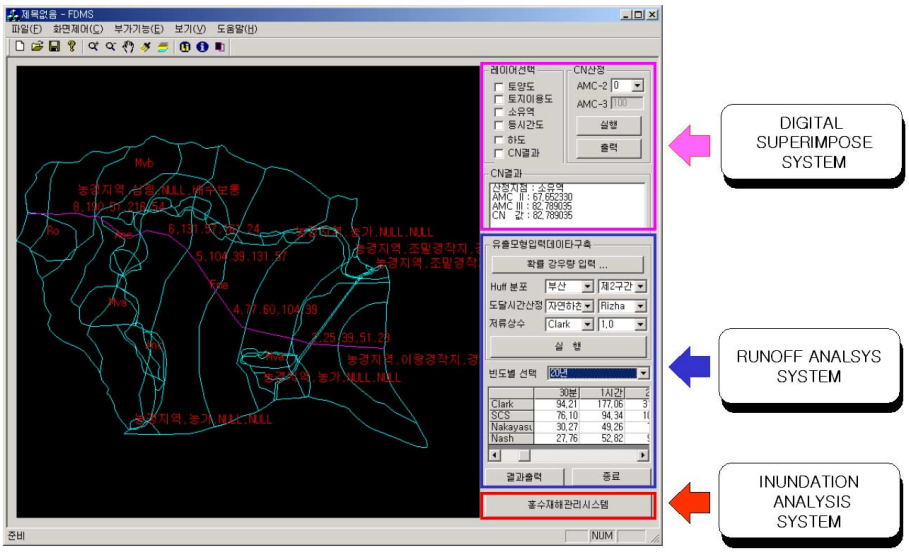

Fig. 2. Composition of FDMS

3.1.1 Digital map superimpose system

The digital map reiteration system reads topography data that is constructed by the digital map and separates it into side style data, fan shape data and character style data. It also, connects attributes of small area, soil map and land availability by an attribute connection algorithm. Accordingly, Polygons of small area and soil land availability can have attribute data. And, the attribute data is still linked to Polygon that are already clipped, in the case where clipping occurs. Also, attribute data overlaps each other and the reiteration area is calculated using a polygon clipping algorithm and each attribute is consed(Fig .3.).

3.1.2 Runoff analysis system

The runoff analysis system falls into three parts, input data of the runoff model construction part, the runoff model practice part and the output part. And, the runoff analysis system is divided to side style data, fan shape data and character style data. Side style data and fan shape data connect attributes of the basin that are segmentalized by isochrones using the point in polygon algorithm. Also, the fan shape data and character style data connect channel attributes that are divided by isochrones and by the point in liner algorithm(Fig .4.).

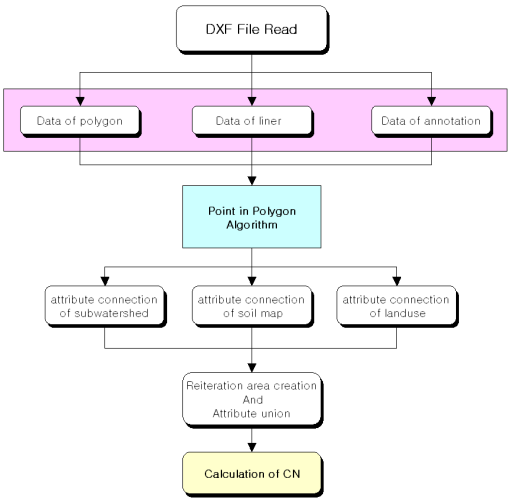

Fig. 3. Digital superimpose system

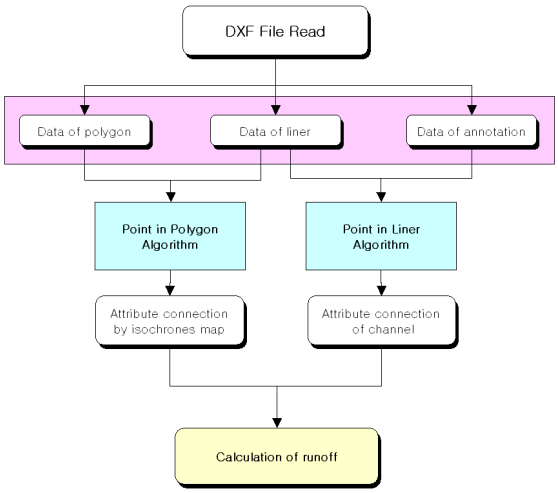

Fig. 4. Digital superimpose system

3.1.3 Inundation analysis system

The inundation analysis system creates irregularity triangulation by delaunay's triangulation. Next, it calculates volume by way of a developed volume calculating method. Therefore, we can reduce error in volume computation. The runoff used was based on Clark, SCS, Nakayasu and Nash's model. The inundation level by runoff was decided upon by the bisection method. We can get inundation area, inundation volume and information of the inundation level automatically by calculating the inundation level(Fig. 5.).

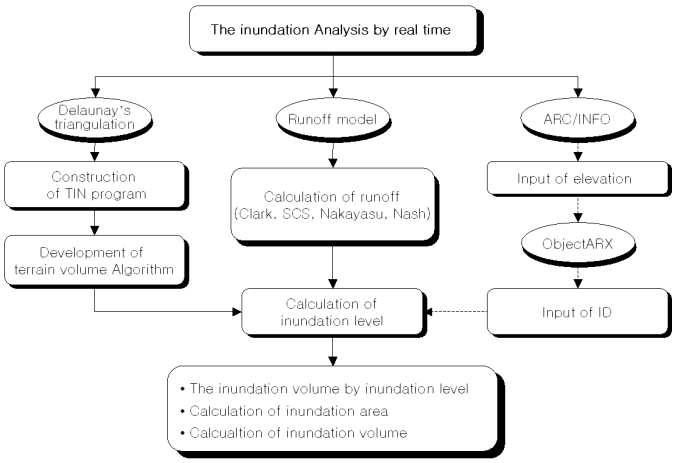

Fig. 5. Inundation analysis system

3.2 Calculation of terrain volume by change in inundation level

In this chapter we can calculate the inundation amount by inundation level, and calculate the volume that was been flooded by the change in inundation level. The inundation volume, according to inundation level (H) change, is divided and calculated as follows $H \le z_1$, $z_1 \le H \le z_2$, and $z_2 \le H \le z_3$. Here, it is elevation of point A, B, C in Fig .6. The inundation analysis system uses the basic idea of the city rivers management system construction (2003) that uses three dimensional Virtual GIS and is constructed as shown in Fig. 6. And, we connect this system to a digital map superimpose system and runoff analysis system. Using contour lines and elevation of the digital map that is inputted in the digital map reiteration system we can construct TIN and the calculated volume by formulas (1), (2) and (3).

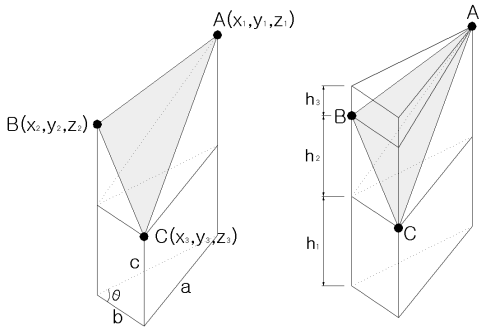

Fig. 6. Triangular pillar by TIN

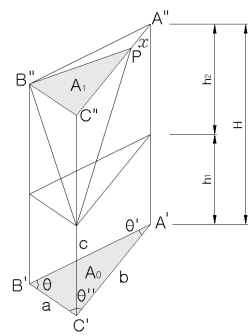

Fig. 7. Calculation of volume

3.2.1 Volume calculation in case of $H \le z_1$

In the case where the extent of the inundation level is $H \le z_1$, then the calculated volume (V_{S1}) is found by formula (1) using the volume calculation method of triangular pillar.

$$V_{S_1} = \sum_{i=0}^{n} [A_{0i} \cdot H] \tag{1}$$

3.2.2 Volume calculation in case of $z_1 \leq H \leq z_2$

If the volume of a triangular horn, which has a base area of **B″**, C″, P is removed from the volume of the triangular pillar which has a base of A_0 (Fig . 7.) and height H, it is arranged by formula (2).

$$V_{S_2} = \sum_{i=0}^{n} \left[A_0 \left(H - \frac{(H - h_{1i})^4}{3h_{2i}^2 (h_{2i} + h_{3i}} \right) \right] \tag{2}$$

3.2.2 Volume calculation in case of $z_2 \leq H \leq z_3$

Volume is arranged by (3) if the volume of the triangular horn, in the upper portion of the inundation level is removed from the terrain volume calculation formula. And in this system, we calculated the volume of terrain by change in inundation level using (4).

$$V_{S_3} = \sum_{i=0}^{n} \left[A_0 \left(h_{1i} + \frac{2}{3} h_{2i} + \frac{1}{3} h_{3i} \right) - \frac{1}{3} A_{0i} \left(H - \frac{(H - h_{1i})^4}{3h_{2i}^2 (h_{2i} + h_{3i}} \right) \right] \tag{4}$$

3.2.4 Inspection of volume calculation formula with change of inundation level.

We could get the volume by the inundation level's change from table 1, theoretically by theory, ArcView valid for in almost any type of cone. When assuming that the value from theory is correct, the error rate is known to be almost the same as that calculated for the other.

Table 1. Examination of volume by inundation level's change

Elevation (m)	Volum Calculation (m^3)			error rate (%)	
	theory value	ArcView	development formula	ArcView	development formula
50	20933.3	20838.0	20838.0	0.460	0.460
40	20765.9	20671.2	20671.3	0.460	0.460
30	19593.6	19504.2	19504.3	0.460	0.460
20	16411.7	16336.8	16336.8	0.460	0.460
10	10215.5	10168.8	10168.8	0.460	0.460
0	0	0	0	0.000	0.000

3.3 Calculation of inundation level

Inundation level can be decided by the runoff model is calculated under cast shadow sectional area (A_0)

inundation level (H) by volume (V_2) runoff model of part. That is, if the inundation volume and the discharge under the inundation level are added, the answer becomes $A_0 \cdot H$ as in formula (4). But, equation (4) is not an equation of the first degree because it is a function of inundation level.

Therefore, this research got the solution(H) using a bisection method that is the non-linear equation to solve formula (4).

$$A_0 \cdot H = V_2^{'} + S \tag{4}$$

In here, $\boldsymbol{A_0}$: Projections sectional area(m^2) of the terrain

$\boldsymbol{V_2}$: Volume (m^3) of terrain by change of inundation level

$\boldsymbol{S}$: Storage, inundation volume (m^3)

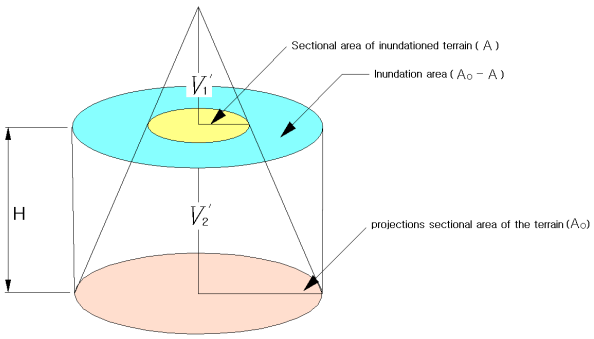

Fig. 8. Determination of inundation level

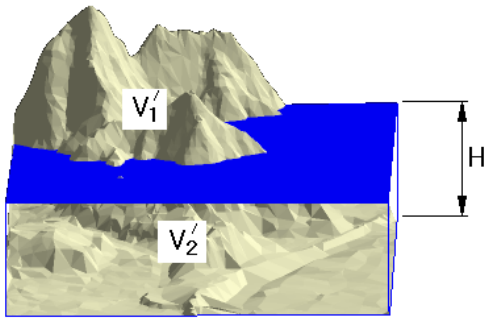

Fig. 9. Inundation level change of train

4 EXAMINATION AND APPLICATION OF FDMS

4.1 Examination of FDMS

4.1.1 Examination basin

Seolma river is a test delta managed by a South Korean construction technology researcher fellow who is situated at the Kyonggido Paju city Juksungmyun which is about 46km up stream from the Imjin river estuary. Seolma river is arborization form to the Imjin river's first tributary and has a river channel length of 11.3km, and basin area of 18.5km^2. Rainfall-runoff data of the Seolma river basin elected as the examination basin was selected as the recorded data of that operation of the examination basin in 2001 and hydrologic characteristics were investigated.

The terrain characteristics factor of the examination basin

The topography characteristics of the basin were investigated by each subwatershed at the inundation level observatory. It is better to use a large scale map for various topography factors of the basin because the whole

basin area is only 8.50km^2. This research used a 1/25,000 digital map. The calculated topography factors are; subwatershed area, channel length, basin average range, shape factor, and basin's center etc.

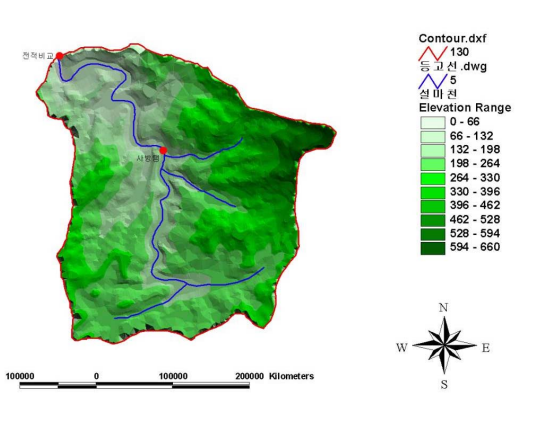

Fig. 10. Examination basin

Analysis of hydrologic observation data

Correct hydrologic analysis of the basin is very important. The survey data is analyzed for the hydrologic factor because it is influenced by the weather distribution and accuracy of hydrological observation data. Rainfall-runoff data for 98.08.05 (16:10) - 98.08.06 (09:20) from the Seolma river basin as the is shown in table 2.

Table 2. Rainfall-runoff of examination basin

Sort	Period	Rainfall (mm)	Peak Time (hr)	Peak Discharge (m^3/sec)
Junguk bridge	98.08.05(16:10)□98.08.06(09:20)	225	1998.08.06 5:30:00 AM	39.996
Sa Bang Dam	98.08.05(16:10)□98.08.06(09:20)	152.5		
Mean area rainfall	98.08.05(16:10)□98.08.06(09:20)	187.82		

CN of examination basin

The results confirm on the 1/25,000 minuteness soil map of Seolma river, surveyed one part the rivers. Therefore, for CN calculation using the SCS method the calculated runoff curve number from table 3 applies the SCS's standard to the characteristics of the forest soil.

4.1.2 Construction of input data

The soil map was inputted digitially to calculate FDMS for the CN value for the Seolma river basin. The input method inputted attribute data into a polygon. Attribute data was inputted inside the polygon after designating the origin point to the bottom left. The system recognizes attribute data by point. If the point exists inside the

polygon, it is possible to join the polygon's space data for analysis(Fig. 11.).

Table 3. CN of examination basin

Sort	Soil Use Situation	Soil type								Area (km^2)	Mean Runoff Curve Number (CN)
		A		B		C		D			
		Area (km^2)	CN	Area (km^2)	CN	Area (km^2)	CN	Area (km^2)	CN		
Number 1 Subwatershed (weir Expectation Place)	Farmland	-	-	0.245	77	-	-	-	-	0.245	77
	Forest	-	-	0.494	75	1.461	86	-	-	1.955	83
	Total	-	-	0.739		1.461		-	-	2.200	83
Number 3 Subwatershed (Junguk brige)	Farmland	-	-	0.245	77	0.041	81	-	-	0.286	78
	Forest	-	-	2.138	75	5.800	86	0.276	91	8.214	83
	Total	-	-	2.383		5.841		0.276		8.500	83

The landuse map of the examination basin is divide into forest, row-cropland and farm area. Data collected was used to construct a landuse map. Data was inputed by vector. As the landuse map is a small part of the polygon's area, there is difficulty to input more attribute data. And the extent of error is large as there is a lot of inputted attribute data. Attribute data was inputted inside the polygon only at origin point(Fig. 12.).

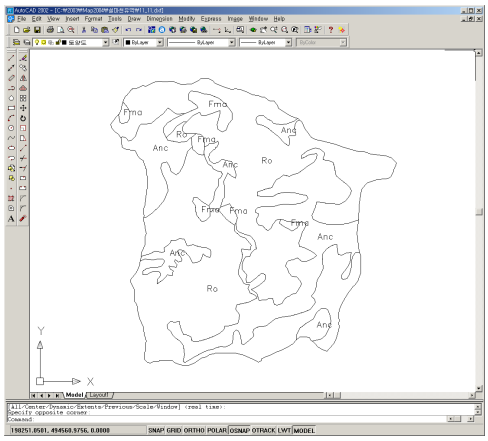

Fig. 11. Draw of soil map

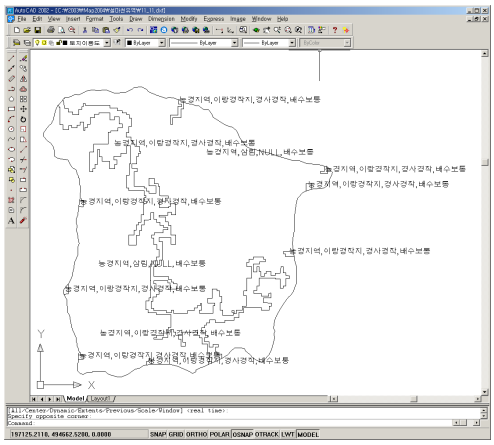

Fig. 12. Draw of landuse

4.1.3 Examination of CN using FDMS

This research, CN of Seolma river basin was calculated using the soil map and landuse map. If data is not inputted accurately using the soil map and landuse map, Then the polygon is not created and there will be error. Therefore, a layer be turned on and off to reduce error so that can examination to "layer on" digital map for the CN result(Fig. 13.). It is as result that calculate CN to examination basin by the FDMS. The AMC-2 condition is 80.36%, therefore 80.36 agrees well comparatively to the interpreted level of confidence of 97% compared with 83 reported in Table 4.

Table 4. CN of examination basin

Soil Use Situation	Total Area	A		B		C		D		Result	
		Area	CN	Area	CN	Area	CN	Area	CN	AMCII	AMCIII
Forest	2.9	0	0	0.75	60	0.12	73	2.03	79	73.82	86.64
Row-Cropland	5.43	0	0	1.56	78	2.69	85	1.18	89	83.86	92.28
Total	8.33	0		2.31		2.81		3.21		80.36	90.4

4.1.4 Construction of input data for runoff analysis system

For execution of runoff analysis system construction input data like a Figure 14. Figure 14 constructs input data about Seolma river examination basin. The level of rivers was inputted using South Korea construction technology researcher's research result data. And number of isochrones maps inputted sequentially from downstream.

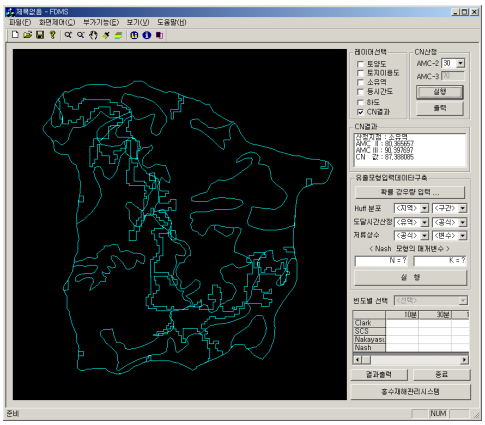

Fig. 13. Calculation of CN

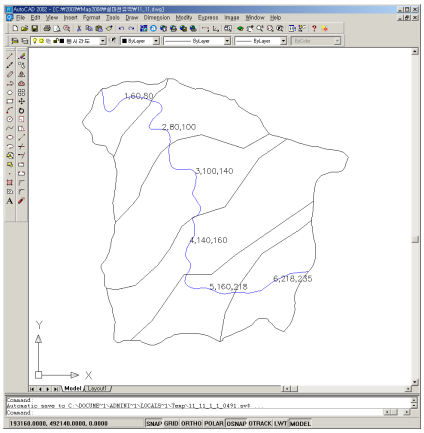

Fig. 14. Input data of runoff analysis system

4.1.5 Examination of discharge analysis system

Each model by FDMS calculated discharge for the data observed in the examination basin as shown Table 5. In the case of the Nash model, n and K were calculated using 1.1. Resulting from the calculation of discharge by FDMS.

The Clark model expressed an error of 1.9% by 39.23m^3/s. The SCS model expressed an error of 5.0% by 37.97m^3/s. The Nakayasu model expressed an error of 2.6% by 41.06m^3/s. and the Nash model expressed an error of 2.2% by 39.11m^3/s and this value could be compared to each model observation value and get a level of confidence of more than 95%.

Table 5. Runoff of FDMS

Runoff Model	Clark	SCS	Nakayasu	Nash	Measured
Runoff (m^3/s)	39.23	37.97	41.06	39.11	39.99
Error Ratio (%)	1.9	5	2.6	2.2	0

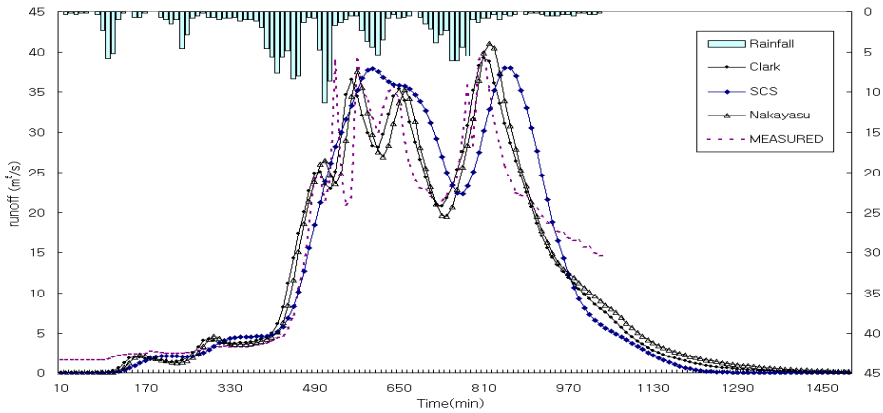

Fig. 15. Examination of runoff model

4.2 Application of FDMS

4.2.1 Application basin

The application basin was the first tributary of west-nakdong river(country river). The West-nakdong river passes farm land of middle·lower basin, forest, and fields of the upper basin. Presently, is used for drainage the low river basin. Because, estuary has no drainage door and internal exclusion equipment, it is an unavoidable condition that there will be inundation damage due to the effect of the drainage level of the west-nakdong river.

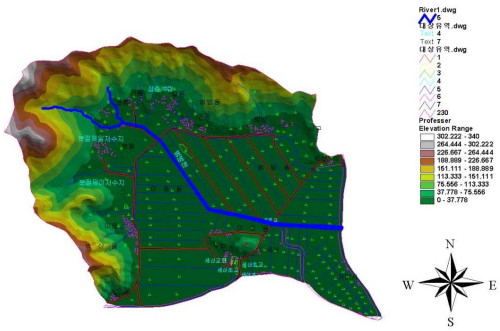

Fig. 16. Application basin

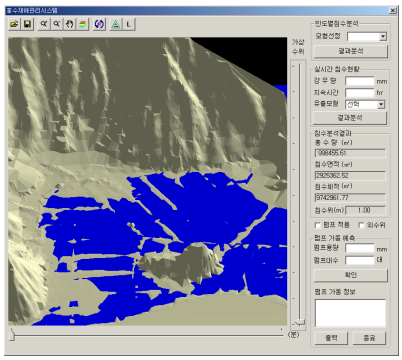

Fig. 17. Application basin in FDMS

4.2.2 Analysis of inundation area and storage

The relationship between the inundation area, inundation volume and the runoff by inundation level of the application basin is shown in Fig. 18. It increases sharply until an inundation level of 2m which can be seen in

the graph, but more than 2m the slope increases gently. More than 2m estimate of the forest area is done using contour surrounding terrain. Also, Figure 18 expresses inundation volume by inundation level. Figure 19 a shows the inundation area three dimensionaly where the inundation level changes by 10cm intervals until it reaches a level of 1m. As a result, Figure 20 can confirm can easily confirm aspects of inundation by terrain.

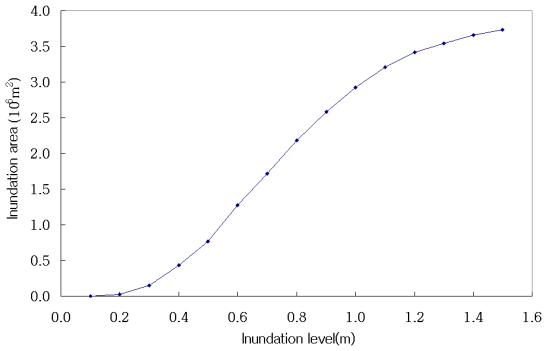

Fig. 18. Inundation level and area

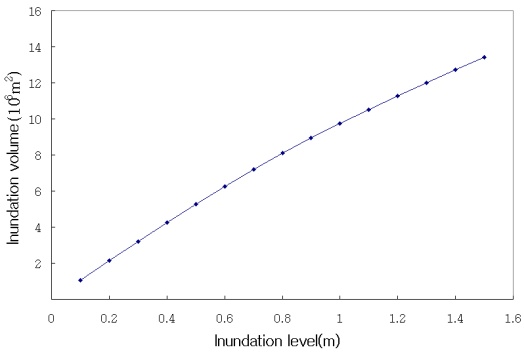

Fig. 19. Inundation level and storage

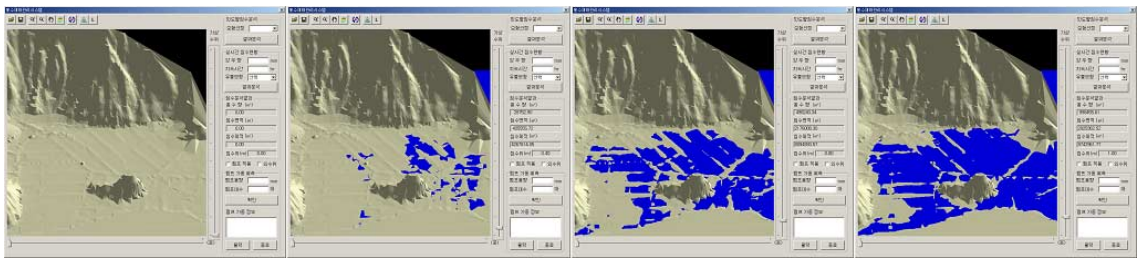

Fig. 20. Reault of FDMS

5 CONCLUSIONS

This research used GIS to control inundation analysis of application area efficiently and to constructed FDMS. We could get following conclusions.

Firstly, we could calculate an objective hydrologic topographical factor by a digital map superimposing system that uses GIS And can save man-power and time by calculating CN rapidly. Also, we can expect a big advantage by connecting the runoff model with GIS. Secondly, creating a runoff model using GIS makes it possible to do recursive hydrologic analysis. Therefore, helping to do the most suitable runoff simulation for the application area. Thirdly, by constructing FDMS it can simulate the runoff model and inundation analysis for an unmeasured basin. Thus diminishing injury to people and property damage from the estimated rainfall. Finally, we are able to develop a rainfall-inundation linked system which analysises the extent of inundation according to time, I will help us to be preparedness for and respond to flood damage.

6 RECOMMENDATION FOR FUTURE WORK

Recommendations for future work of this research include adding a rainfall analysis system and urban runoff model to FDMS. Therefore, by using a digital map for hydrologic analysis, the utility value of this system is expected to rise.

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