ESCAP/WMO
Typhoon Committee

REPORT ON MOUNTAINOUS FLASH FLOOD FORECAST SYSTEM MANUAL

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WMO

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REPORT ON MOUNTAINOUS FLASH FLOOD FORECAST SYSTEM MANUAL

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FOREWORD

The ESCAP/WMO Typhoon Committee (TC) is an intergovernmental body established in 1968 under the auspices of United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and the World Meteorological Organization (WMO) in order to promote and coordinate the planning and implementation of measures required for minimizing the loss of life and material damage caused by typhoons.

Despite being the most recent working group of the Committee, given that it was created in 2005, the Working Group on Disaster Risk Reduction (WGDRR) intends to work closely with the Working Group on Meteorology (WGM) and the Working Group on Hydrology (WGH), and contribute for an enhanced integration of all WMO observing systems through the establishment of a comprehensive, coordinated and sustainable structure ensuring the interoperability of its component observing systems, as it was recommended by the Fifteenth World Meteorological Congress (Geneva,7-25 May 2007).

It is hoped that this publication of the Working Group on Disaster Risk Reduction will contribute to greater participation of this working group in planning and implementing the new warning system for disaster risk reduction. The Flash Flood Forecast System (FFFS) has been pursuing the sharing of information in a timely and integrative way and should be managed in both top-down way via standardization and bottom-up way via implementation of each project under a specific purpose and target. The FFFS manual will be one of the best examples from the members of Typhoon Committee to allow for an integrated warning system of systems designed to improve the capability of Members to effectively provide a widening range of services and to better serve WGDRR research programme.

I am confident that this publication will be useful not only for the members of Typhoon Committee but also for the other regional bodies of the Tropical Cyclone Programme of the World Meteorological Organization and for other members of WMO, in particular to their decision-makers, financial experts and emergency response managers, currently in the process of implementing and upgrading their respective observing systems, especially the end-to-end flash flood early warning systems, and educational institutions for training disaster awareness.

I congratulate the authors of this publication, expecting that the manual will be updated sooner or later following the improvement of FFFS. Meanwhile this manual will help the members of the TC to understand all the related information including data on flash flood, statistics and other information and knowledge. I would like to thank Dr. Jeong and other DRR experts for building the FFFS and giving all the basic material for this publication.

Waon-Ho Yi
(Chairman of Working Group on
Disaster Risk Reduction)
December 2010

EXECUTIVE SUMMARY

Sudden violent storms and localized heavy rain frequently occur in Korea, especially recently, leading to serious disasters in mountain areas. These rainfall patterns are a direct cause of flash floods which leave large-scale damages in both urban and mountainous areas. Furthermore the impact of damages caused by flash floods show the magnitude of disasters has increased over time.

In urban areas, the number of casualties lost due to flash flooding is not as serious as that of rural areas, but property damage is high. Whereas flash floods that occur in mountainous regions have a huge impact on residents' lives. So the National Institute for Disaster Prevention (NIDP) established a plan to minimize damages and causalities in the valley of these regions by estimating flash floods in three hours and issuing an early warning within 20 to 40 minutes.

For this, the Flash Flood Forecasting System (FFFS) was established, with 4272 units in which 3 hours of rainfall are predicted using the McGill Algorithm for Precipitation nowcasting and Lagrangian Extrapolation (MAPLE). Among these, a total of 345 stations, including existing stations, were selected for the warning system. In the existing stations, rainfall is monitored and checked for warnings according to the Flash Flood Guidance Rainfall. New warning stations estimate rainfall by using AWS and MAPLE and then warn if the amount of rainfall has passed the limit line. Accuracy is determined by a separate expert system which predicts rainfall and compares it with measured data and the properties of the warning criteria are checking continuously.

This can be used for educational purposes of disaster risk reduction and international responses to climate changes and related flash flood events, as there are valuable examples and concrete figures of systems. Regardless of the competence of information technology and network environment, this FFPS with a proper manual will help each country understand the disaster behavior itself and the disaster mitigation strategy based on the statistics and reports.

I. INTRODUCTION

Recently, due to climate abnormality brought on by global climate change, severe, short-duration, sporadic and localized rainfalls occur frequently, resulting in considerable damage. In particular, flash floods in steep mountainous areas have caused fatalities and property damages. This is because 67% of the Korean peninsula is made-up of mountainous areas and because the country is affected by monsoon season. Also, the peninsula is located in the path of typhoons during the rainy season, resulting in heavy rainfalls frequently. Thus, flash flood occurrence will increase during the rainy season. For example, concentrated rainfall that took place between July 23 and 26, 2008 claimed eight lives and left about 0.3 billion USD of property damage in Bonghwa province, Kyungbook. Unfortunately, the Korean Meteorological Agency (KMA) and other government agencies were uninformed before this happened so they could not carry out any emergency procedures. Eventually, more damages occurred. Therefore, to minimize the damage by flash floods, there was the need to build a flash flood forecast system specifically for mountainous areas. To improve the accuracy of the flash flood prediction capability, the system should be integrated with the weather forecasting system operated by KMA. Based on those requirements, a flash flood forecast system for mountainous areas was developed.

II. THE COMPONENTS OF THE FLASH FLOOD FORECAST SYSTEM FOR MOUNTAINOUS AREAS

1. Archiving geographical data for flash flood risk areas

In this system, collected rainfall data which are used to explore the disaster mitigation information are then integrated with the geographical data to create the geographical data for high flash flood risk areas. The point rainfall data at the rainfall gage stations and the warning stations are collected from the reports which are made by the NIDP and the local governments. The locations of the rainfall gage stations are provided in the form of TM or Longitude and Latitude. Thus, the general information of the rainfall gage stations and the warning stations are arranged by the database standard. In accordance with the database standard, each station is assigned to a unique serial number and the data format associated with a station is modified to standardize the information. Also, the locations of the stations are converted into a GIS dataset. Finally, the serial numbers of the database and the GIS symbol codes are synchronized.

In general, a basin with mountainous flash flood risk should be a mountainous and steep area, resulting in a short travel time to the basin. In this system, using the standard basin map provided by Water Management Information System (WAMIS), the following two criteria are applied to select target basins. First, to consider the fact that it should be a mountainous area, basins whose highest elevation is less than 500m are excluded. Among the basins whose highest elevation is higher than 500m, any basin whose average slope is less than 0.1 is also excluded because it is assumed that a basin of gentle slope may not be subject to flash flood. After these assumptions are applied, basins which are subject to flash flood are selected. Then, if a dam is located in the basin, the basin is divided into "upper basin" and "lower basin" from the dam. From this procedure, the 48 basins are selected to evaluate the flash flood risk. Table 1 shows the name of the selected mid-size basins.

To delineate a sub-basin in the selected mid-size basins, which is the fundamental unit basin for the evaluation of flash flood risk, appropriate procedures are taken into account. First, "Flow Direction" and "Flow Accumulation" are performed on a selected mid-size basin and then channels are defined with the proper threshold size. The determination of the threshold size depends on the minimum area of a sub-basin. In this system, it is set to 1,000ha (10km^2). The delineated sub-basins are shown in the Figure 1.

Table 1 The selected mid-size basins to evaluate the flash flood risk

No.	basins	No.	basins	No.	basins	No.	basins
1	ansengchen	13	gapshen	25	mankyunggang	37	sumjin
2	bochengchen	14	hapchendam	26	milyanggang	38	sumjingangdam
3	chengpengdam	15	hongcheongnag	27	mujunamdae	39	sumjinharue
4	chogang	16	hyungsangang	28	nakdong	40	suyeunggang
5	chunchendam	17	imjingang	29	nakdongang_1	41	taewhagang
6	chungjudam	18	jejudo	30	namgangdam	42	uiamdam
7	daechen	19	juanmdam	31	namhangang_1	43	wangpichen
8	daejongchen	20	junranamdo	32	sabkyochen	44	whoiyagang
9	dalchen	21	jurangetc	33	samchek	45	yangyangnam
10	dalcheon	22	kongjuetc	34	soyangdam	46	yongdamdam
11	dongjingang	23	kyunganchen	35	suachen	47	yongdamdam
12	gangreungnam	24	kyungbook	36	sumgang	48	yongduk

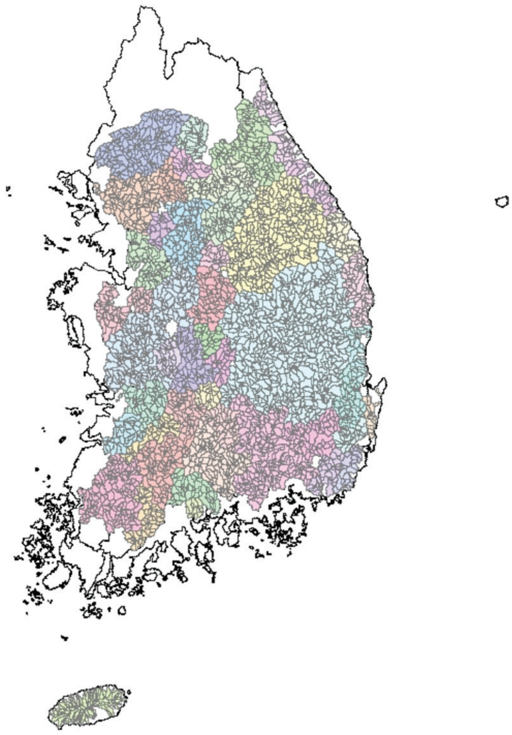


Figure 1 The delineated sub-basins

In this system, channels including streams for the entire Korea Peninsula are defined and the characteristic velocity for a grid is estimated. Also, a grid's Curve Number (CN) of Soil Conservation Service (SCS) is determined based on the land use and soil map provided by WAMIS. To determine the Horton's Ratio for a channel, the channel order is analyzed for all channels. From these procedures, parameters can be estimated for a sub-basin to apply Geomorphic-Climatic Instantaneous Unit Hydrograph (GCIUH). Figure 2 shows the parameters for 76 sub-basins in the Anseong-cheun mid-size basin.

2. Development of a rainfall forecasting system based on the rainfall adjustment method

One of the difficulties involved in the flash flood forecast is to accurately forecast the amount and duration of rainfall in the area. However, to forecast

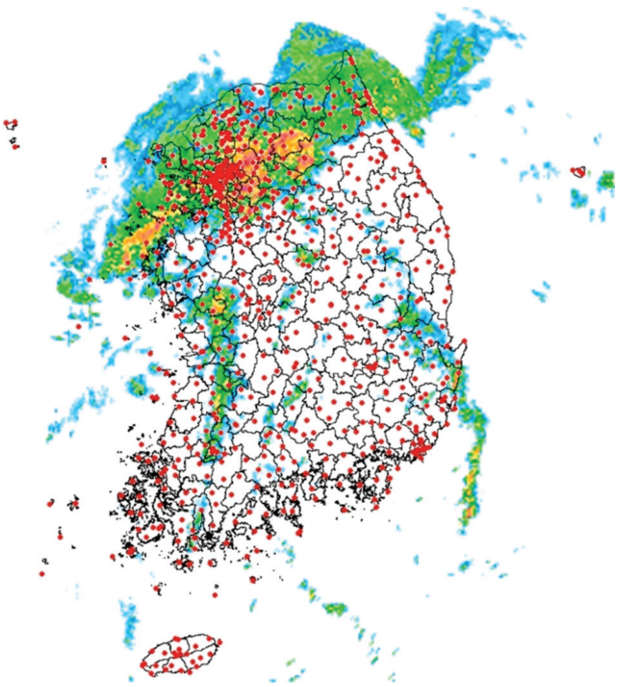
유역	최고차하천	유역면적	최고차하천의길이	하폭	유역경사	면적비	길이비	분기비	CN	특성속도	위락시설	관광휴게시설	하도경사
1	3	2842.02	545.084193	9.6109	17.3675	1.394257368	1.588067608	1.664100589	73.094757	63.849742	5	0	0.4551
2	3	1019.88	732.3315333	5.1966	20.3696	1.450901144	1.442431066	1.354006401	74.053924	58.96207	1	0	0.3560
3	4	3813.93	469.8857121	11.466	5.3167	1.114600308	1.473393256	1.62598983	81.129165	173.347518	3	0	0.1521
4	4	2798.64	9.292090212	9.5227	8.9725	0.051092172	0.76811874	2.839276598	76.506614	92.954116	7	0	0.2075
5	4	2660.04	6.799114544	9.2368	13.0268	0.046973009	0.628141819	2.49218942	74.976257	106.084556	12	0	0.6480
6	4	4705.92	378.2400865	13.007	9.4127	1.088134914	1.347764912	1.56267737	79.799499	106.851753	24	2	0.2025
7	4	7520.76	925.1474861	17.2324	3.879	0.934598534	1.235751066	1.617290615	82.533653	190.041946	0	0	0.1748
8	4	7910.37	612.6444572	17.7627	4.5357	0.938225252	1.155491764	1.572666204	82.939849	109.902084	0	0	0.1371
9	4	1482.75	6.799114544	6.5047	26.6073	0.043972964	0.614368953	2.462288827	70.105148	59.450382	5	0	1.0013
10	4	2149.65	192.1653188	8.1285	29.7181	0.047905581	1.898094768	2.623829401	70.871231	66.839027	10	0	0.8836
11	4	8056.44	728.3423562	17.9587	15.2151	0.844725571	1.383721329	1.921180893	75.192817	162.555419	13	47	0.3331
12	3	1419.57	526.109199	6.337	18.188	0.812055993	1.235801731	1.258305739	72.493095	58.948005	0	0	0.5741
13	4	2057.22	498.4909168	7.917	13.3097	1.223935981	1.652015964	1.889059452	78.597274	73.62664	0	0	0.0704
14	5	18659.79	461.9991836	29.7258	9.1495	0.782276268	1.073299327	1.865525431	80.934272	216.672348	1	15	0.3380
15	4	6992.19	649.2269719	16.4952	20.1875	0.626785416	1.058826473	1.478384633	75.416252	127.125289	4	1	0.3211
16	3	1166.94	728.8696059	5.634	15.8345	1.217847921	1.69015469	1.61245155	74.436035	59.677639	0	0	0.6194
17	3	2280.69	655.6594362	8.4223	24.4781	0.634777701	1.208084698	1.341640786	73.494682	131.608566	0	0	0.2396
18	4	12357.18	1400.278905	23.2135	8.0985	0.818101787	1.086804745	1.532669325	83.331291	143.611511	0	0	0.5101
19	4	1963.98	30.47715932	7.6997	19.4582	0.048581708	0.971333317	2.466447908	75.93029	69.426475	7	1	1.0626
20	4	10332.9	955.3211399	20.8508	20.6988	0.61402656	1.001684061	1.51022255	77.43534	140.40097	3	0	0.2113
21	4	13785.3	1578.357016	24.7879	11.266	0.757442222	0.988793666	1.521472847	78.167655	146.049072	0	0	0.2516
22	4	1056.78	14.56133994	5.3086	25.3342	0.04973281	0.894201089	2.393628033	74.409217	49.658958	0	0	0.1702
23	4	17050.23	1876.138074	28.1597	14.9012	0.749651619	0.979913049	1.513711906	79.453689	159.061889	1	0	0.1168
24	3	1210.41	688.1091039	5.759	16.6095	1.019206962	1.501772009	1.511857892	76.129821	64.6651	0	0	0.8154
25	4	14647.14	1236.71917	25.7064	9.5302	0.819275196	1.265329206	1.714562764	81.960144	209.24208	0	0	0.0961
26	4	19632.33	2261.839434	30.6459	9.0325	0.752565899	0.971937195	1.483743397	81.25634	176.005828	0	0	0.3803
27	5	24730.65	932.3014291	35.1991	7.0162	0.791873321	1.06954263	1.706824137	82.069335	252.802444	0	0	0.0771
28	5	36844.11	425.5729481	44.7106	5.8072	0.7303518	0.964881086	2.148308815	82.291404	230.77893	0	0	0.0881
29	3	1356.93	619.8719811	6.1677	9.6666	0.648360345	1.431405891	1.527525232	79.196655	77.172065	0	0	0.1000
30	6	62029.89	726.1175658	61.1154	1.409	1.151032219	1.279780433	2.614450775	85.126068	260.083801	0	0	0.1000
31	4	7761.3296	388.5431423	17.5611	19.883	1.023862988	1.37072661	1.536314009	74.945365	166.832672	4	1	0.5281
32	4	2550.69	426.6368253	9.0071	12.5626	1.217712594	1.55882661	1.678917325	76.772415	119.466117	0	0	0.1811
33	3	1114.11	462.9113864	5.4796	18.0448	0.481606133	1.087764408	1.369306394	75.244392	54.50872	0	0	0.1227
34	5	11469.4196	459.5085329	22.198	12.6677	1.007611046	1.221985375	1.736708647	77.228454	186.291061	0	0	0.7279
35	6	64668.51	1339.473996	62.6622	3.1881	1.005047302	1.153151987	2.193871808	85.028015	278.842498	0	0	0.0403
36	3	3000.33	551.0674874	9.9287	9.0668	0.704961686	1.132374103	1.210076739	80.17649	123.076087	0	0	0.2138
37	3	2990.7	405.9576011	9.9095	19.9276	0.555356927	0.971497996	1.164964745	75.674468	97.594535	0	0	0.6014
38	4	5402.79	960.6998614	14.1306	11.6668	1.087492969	1.423522427	1.776675102	77.537239	88.554649	0	0	0.1000
39	6	69744.51	1715.043849	65.5686	3.217	0.981310238	1.088163958	2.037838781	83.907608	294.456024	0	0	0.2404

Figure 2 The estimated parameters for 76 sub-basins in the Anseong-cheun mid-size basin

the amount and duration of rainfall many tasks are required including the observation of meteorological data. Currently, the weather radar is widely used to observe temporal and spatial distribution of rainfall and yet, from a single observation, sufficient data may not be obtained to forecast the convective rainfall. Since localized flash floods have caused severe damages, the weather radar is used to try forecasting short term rainfall.

To accomplish the accurate forecast of rainfall, the McGill Algorithm for Precipitation nowcasting and Lagrangian Extrapolation (MAPLE) is used to develop the rainfall forecast system for this system. MAPLE was developed by the National Institute of Meteorological Research (NIMR) and McGill University, Canada and shows its capability to forecast rainfall characteristics in less than 3 hours. Although MAPLE may forecast the rainfall characteristics precisely in less than 3 hours, there is still need to adjust its forecast result using the data integration between MAPLE and Auto Weather System (AWS) as shown in Figure 3.

Figure 3 MAPLE data and AWS stations and data integration



To carry out the real-time rainfall adjustment, MAPLE data are obtained from the FTP server of the NIMR and the AWS data are then converted into the required input data for the analysis through National Disaster Management System (NDMS).

Meanwhile, data measured from the ground rainfall stations and obtained by the weather radar are shown in the system.

From the two data sets, MAPLE and the AWS connected in the system, the data measured by a ground rainfall station should fall into a grid of the weather radar. This process is necessary to determine the number and location of AWS which is used for the adjustment of data and rainfall information of a station located within the standard range (30km x 30km).

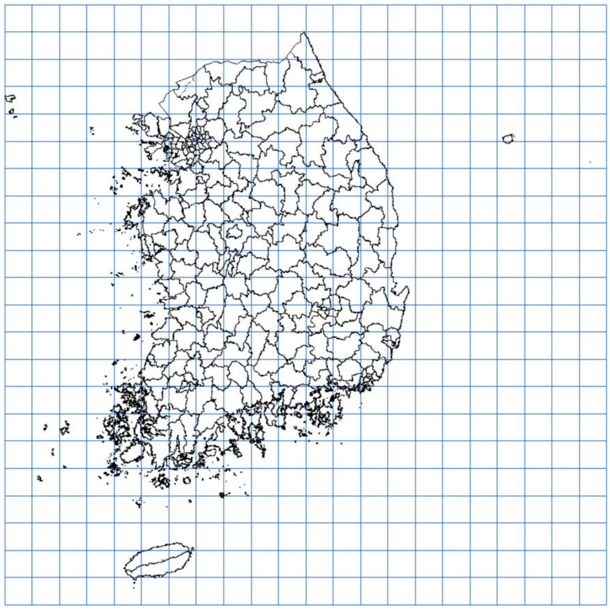


Figure 4 Grids for the rainfall adjustment in the system

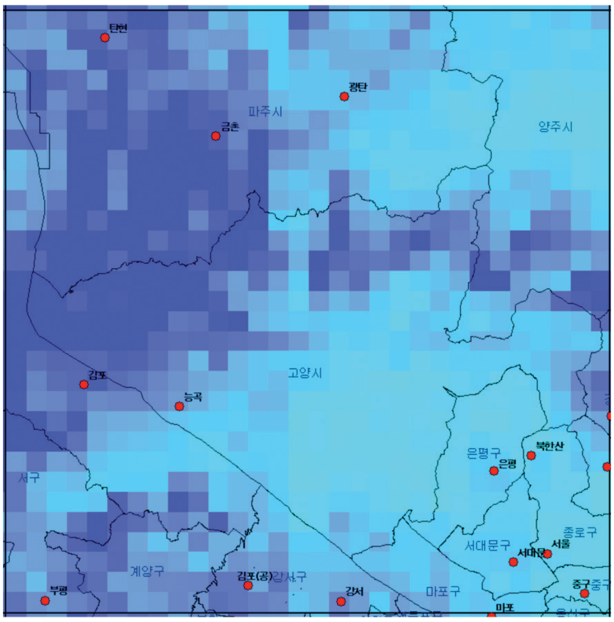
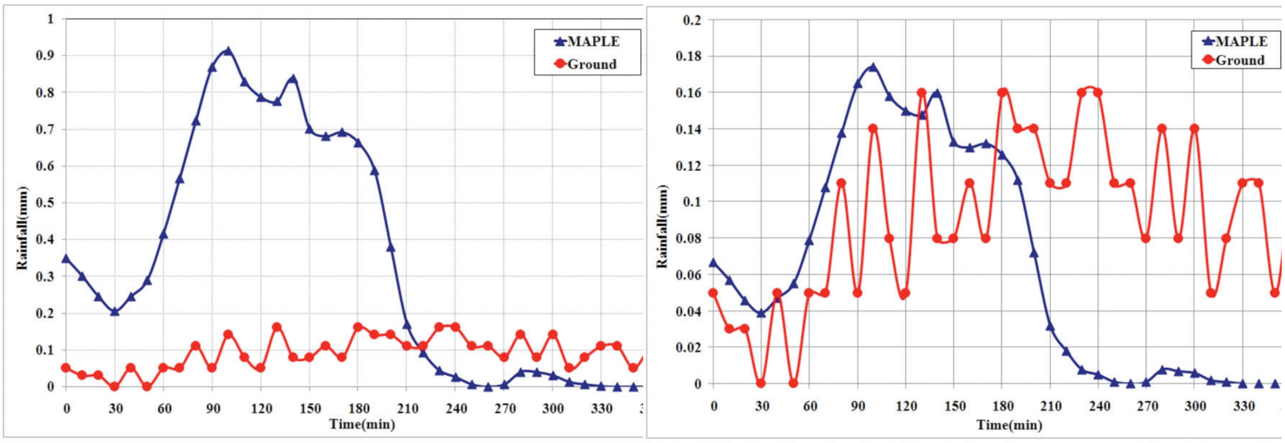


Figure 5 Displaying AWSs located within an unit grid

Through this process, the number and locations of an AWS which is in the standard range can be changed depending on which AWS is selected as the central grid. To resolve this problem, as shown in Figure 4, the AWS information for each unit grid is pre-determined after the country is divided into 30km x 30km grids. Since the number of AWSs will vary depending on where the start location was set, the system is forced to determine the start location to make the 77 rainfall stations distributed as evenly as possible. Figure 5 shows the locations of AWSs within a unit grid.

Once a ground rainfall station is selected, a radar grid and its number where the ground rainfall station is located, is identified and the average adjustment is carried out based on the ratio of ground-radar ratio (G/R; Figure 6). In case of the selected rainfall data which are estimated by each unit grid, it is possible that a couple of grids are located in the same district if it is a big district. It is also possible that more than two districts are located within a same grid. In this case, the system calculates the ratio of the area of each district within the grid and the ratio is then used to calculate the amount of rainfall for each district which will be displayed on the screen of the developed system.



(a) Before the adjustment (b) After the adjustment

Figure 6 Monitoring results at a high flash flood risk area before and after the adjustment

III. DEVELOPMENT OF A REAL-TIME WARNING DELIVERY SYSTEM

The development of a real-time flash flood warning delivery system for the country is explained in this chapter. Current flash flood risk areas and other areas where flash floods may occur within 3 hours are identified based on rainfall data collected in real-time. The flash flood warning messages are “Caution”, “Warning”, and “Evacuation”, and the warning criterion for each message is pre-defined at each warning station. If the appearance of a flash flood risk area is noticed, a SMS message and Email are automatically sent to pre-designed persons working for National Emergency Management Agency (NEMA) and NIDP. As shown in Figure 7, a person who is designated by NEMA and NIDP should register his/her information such as name, affiliation, email address, and contact phone number in the system. Also, he/she should choose the warning cycle and type of message they wish to receive (SMS or email).

As mentioned before, if the appearance of a flash flood risk area is noticed or it is predicted that a flash flood is expected to occur within 3 hours, all registered persons in the system will be informed via SMS or email. Currently, the Email warning system shown in Figure 8 is working and the SMS warning system is being set up. Warning information delivered through SMS will be concise and include the warning time and current situation for each district. More detailed information will be sent via Email.

Through email, the following information will be included (i) Type of the warning: “Caution”, “Warning”, and “Evacuation”; (ii) Data of the area: Province, District, and Town; (iii) Trend of rainfall recorded in the previous analysis: rise, descent, or constant.

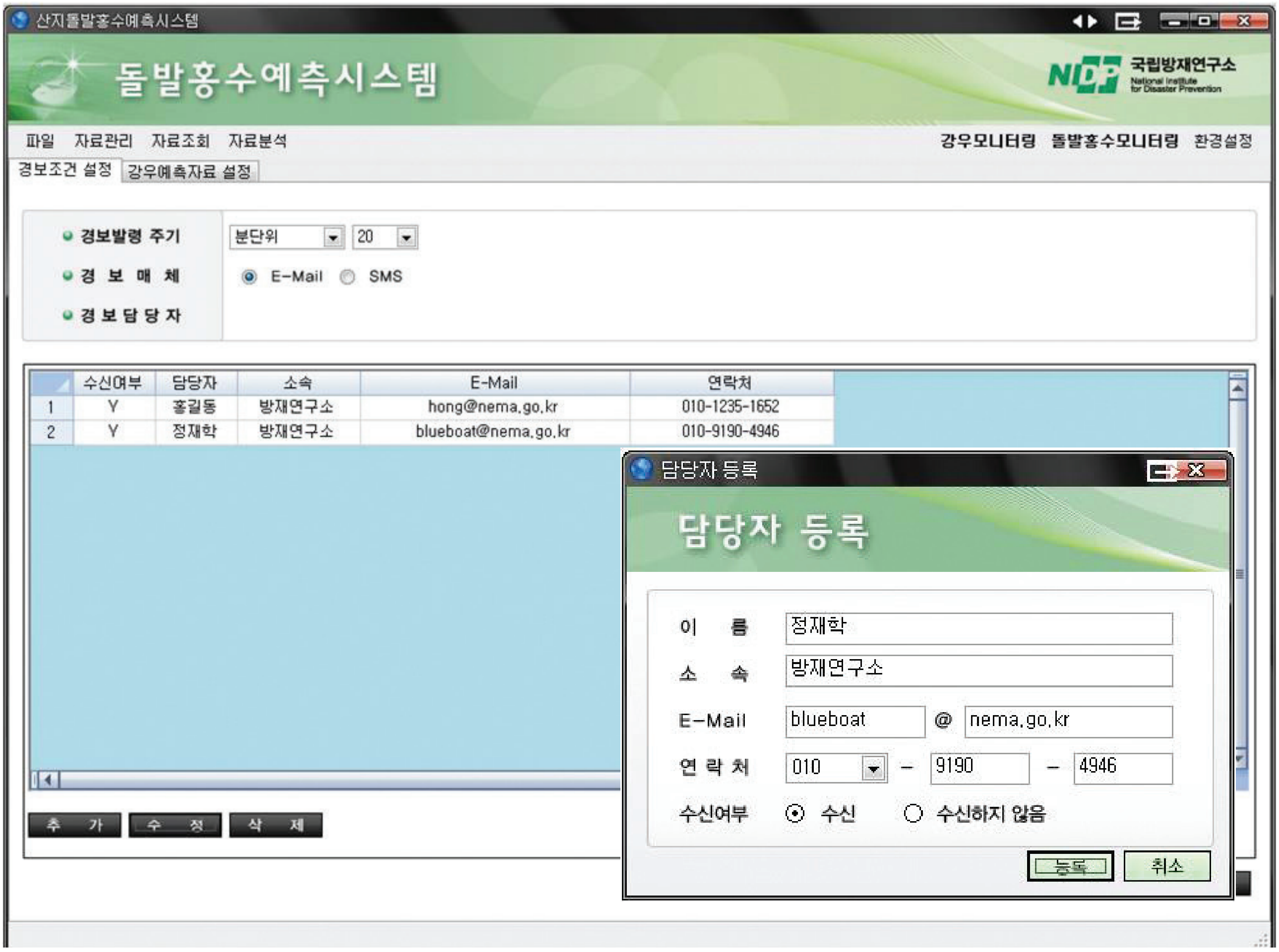


Figure 7 Screen capture of System Environment Setting window

돌발홍수 위험지역 정보(2009년07월16일 08시00분) 받은편지함

모두 인쇄

보낸사람 "alarmmasterff@gmail.com" <alarmmasterff@gmail.com>
받는사람 woonss@gmail.com
날짜 2009. 12. 9. 13:58
제목 돌발홍수 위험지역 정보(2009년07월16일 08시00분)
서명한 사람 gmail.com
메일발송 도메인 gmail.com

< 2009년07월16일 08시00분 현재 위험지역 >

경보종류	시도명	시군구명	읍면동명	경향	현재강우량 (mm/hr)	누적강우량 (mm/hr)
대피	전라남도	순천시		▲	19.32	
대피	전라남도	순천시		-	14.31	

< 2009년07월16일 08시00분 3시간 예측 위험지역 >

경보종류	시도명	시군구명	읍면동명	경향	3시간예측강우량 (mm/3hr)
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대피	울산광역시	울주군		-	123.42
대피	울산광역시	울주군		-	84.19
대피	울산광역시	울주군		-	104.6

경보종류	시도명	시군구명	읍면동명	경향	3시간예측강우량 (mm/3hr)
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대피	울산광역시	울주군		-	123.42
대피	울산광역시	울주군		-	84.19
대피	울산광역시	울주군		-	104.6
대피	울산광역시	울주군		-	125.39
대피	부산광역시	기장군		-	187.07

첨부파일 2 개 — 모든 첨부파일 다운로드 모든 이미지 보기

현재위험지역.jpg
79K 보기 다운로드

Figure 8 Email warning system

For sub-basins where flash floods are expected within 3 hours, all information provided for the sub-basins where flash floods are about to occur is provided as well. In addition, forecasted rainfall data within 3 hours are provided for the sub-basins. Personnel in charge of dealing with flash floods in NEMA and NIDP are also provided with that information making it possible to integrate the control center and the decision support system of NEMA with the developed mountainous flash flood forecast system.

IV. FLASH FLOOD FORECAST SYSTEM

1. Main window of the Flash Flood Forecast System

In the main window of the Flash Flood Forecast System shown in Figure 9, the user can login the system. With his/her authorized ID, the user types the username (1) and the PW (2) and then clicks the login button 5) to start the system. To terminate the session, clicks the cancel button (6). Also, the user can save his/her ID (click 3) and PW (4) to not retype the ID and PW for the next session.

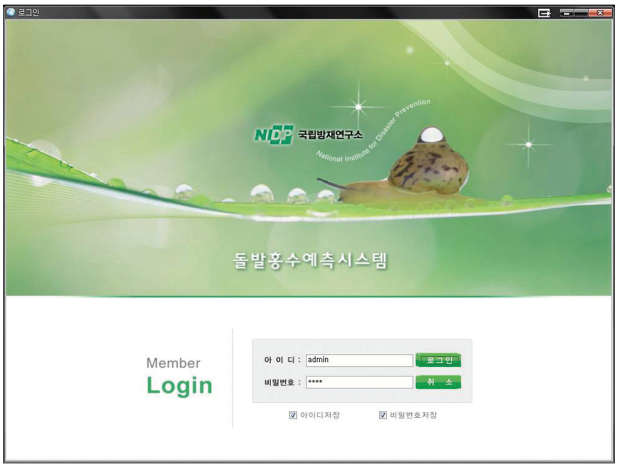


Figure 9 Main window of the Flash Flood Forecast System

The initial window of the system is shown in Figure 10. The window consists of 5 sub-windows. The radar image window (3) shows the very short-term rainfall data and current flash flood areas which are determined by analyzing the current rainfall data that are then shown in window 4. The areas where the occurrence of flash floods is expected within 3 hours are shown in window 5. As mentioned before, these areas are determined by the forecast rainfall data using MAPLE.

- The radar image window: every 20 minutes, the very short-term forecast rainfall data is collected and shown in the window. The time and date of the collected data are displayed in the excel sheet (1).
- The flash flood risk area window: flash flood risk areas are determined by the short-term forecast rainfall data and the flash flood warning degree (“Caution”, “Warning” and “Evacuation”) for the area. After the areas are determined, an appropriate warning degree will be issued. Measured rainfall data are displayed in the excel sheet of window 2.

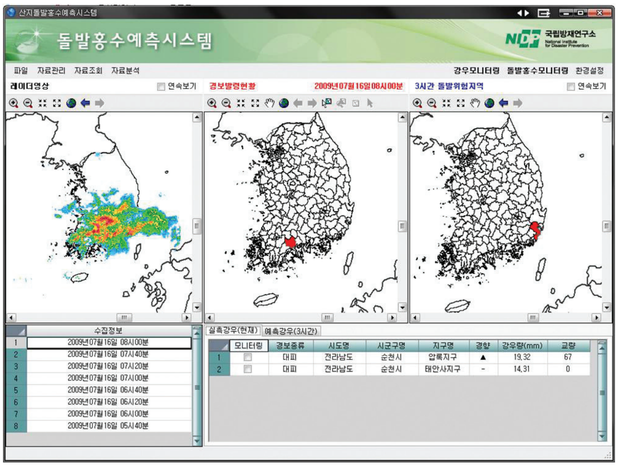


Figure 10 The initial window of the system

Figure 11 shows 3-hour flash flood risk areas. Based on the forecast rainfall data obtained from the very short term rainfall data, the warning will be issued if a 20-minute duration rainfall is expected to pass the warning criteria within 3 hours. After analyzing the collected information and if any warning degree such as “Caution”, “Warning” or “Evacuation” is to be expected, the regional information will be displayed in the excel sheet (1) for each type of information along with the warning degree.

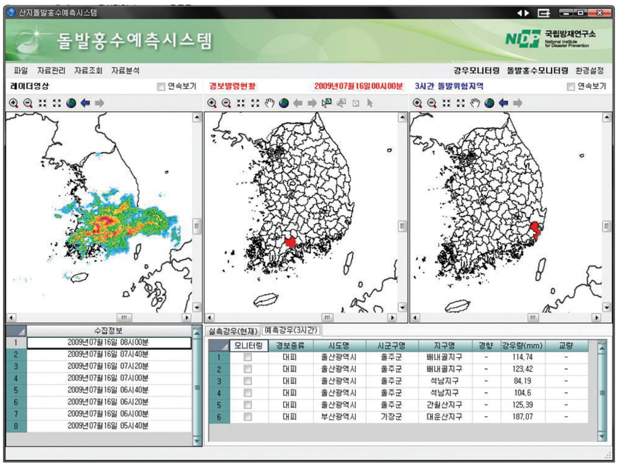


Figure 11 The windows for 3-hour flash flood risk areas

When the flash flood risk area is identified, the warning message will be delivered to pre-designated persons via SMS or Email as shown in Figure 12. Warning information delivered via

SMS will be concise and include warning time and current situation of each district. More detailed information will be delivered via Email. Window 1 is for SMS delivery (being installed) and 2 is the Email delivery windows.

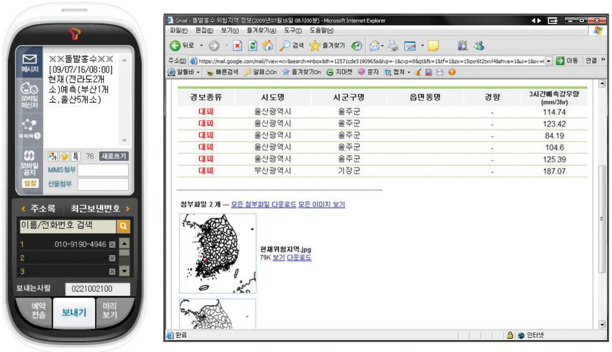
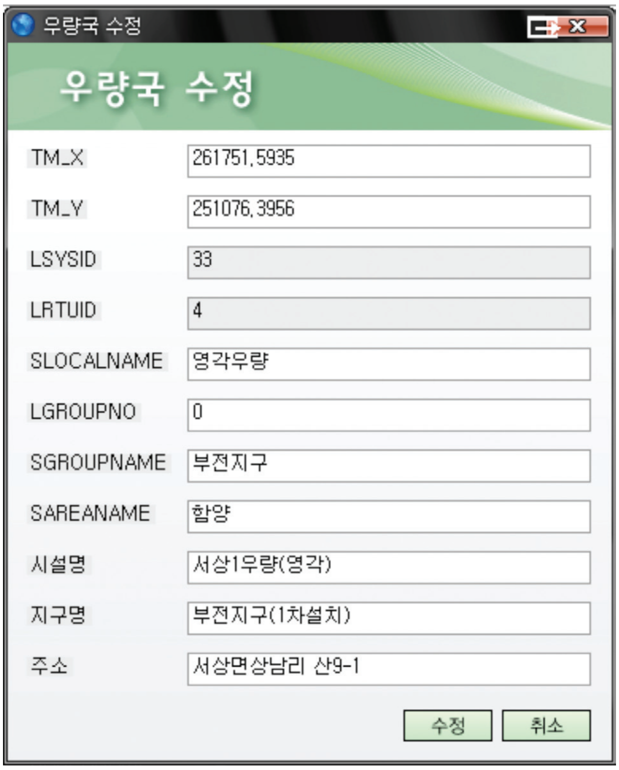


Figure 12 Delivering the warning degree via SMS or Email

Figure 13 is the rainfall station window. Data of the rainfall stations located in the flash flood area is shown in window 1. The user can add a new rainfall station by clicking the "add" button (2) or modify the data of a rainfall station by selecting from the excel sheet. Also, the user can remove a rainfall station by clicking the "remove" button (4) after selecting the station.

(a) Data management of rainfall stations

(b) Add a new rainfall station



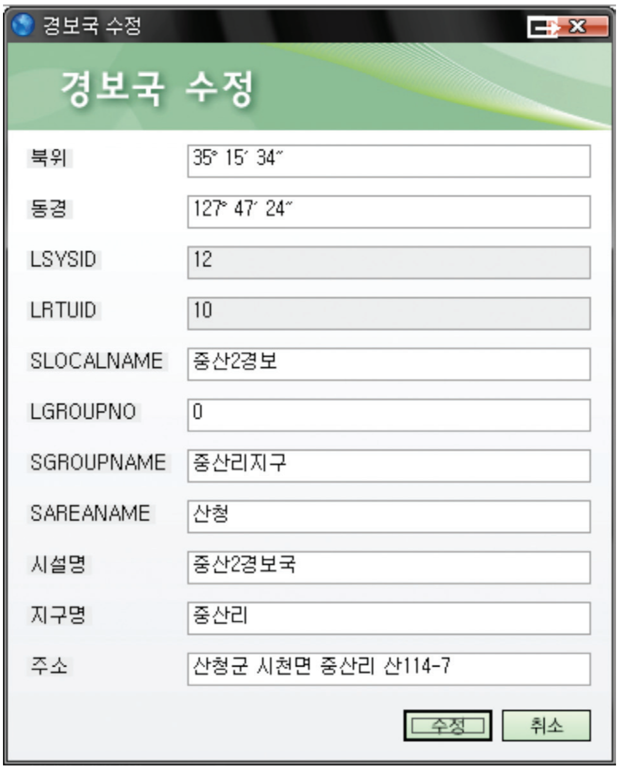
(c) Remove a rainfall station

Figure 13 Management of the data associated with rainfall stations located in the flash flood risk area

Figure 14 is the warning station window. Data of the warning stations located in the flash flood area are shown in window 1. The user can add a new warning station by clicking the “add” button (2) or modify the data of a warning station by selecting from the excel sheet. Also can remove a warning station by clicking the “remove” button (4) after selecting the station.

(a) Data management of the warning stations

(b) Add a new warning station



(c) Remove a warning station

Figure 14 Management of the data associated with warning stations located in the flash flood risk area

Figure 15 is the attribute window for rainfall stations located in the flash flood risk area. The user can find the attribute associated with a rainfall station located in the flash flood risk area and it is possible to obtain information of the accumulated rainfall every hour during the period assigned by the user as shown in Figure 16. All the information associated with a rainfall station located in the flash flood risk area is displayed in the excel sheet (1). Once a rainfall station for which the user wants to know the rainfall data, click the “rainfall data reference” button (2) which then opens the “hourly and accumulated rainfall” window.

Figure 15 Attribute window for rainfall stations located in the flash flood risk area

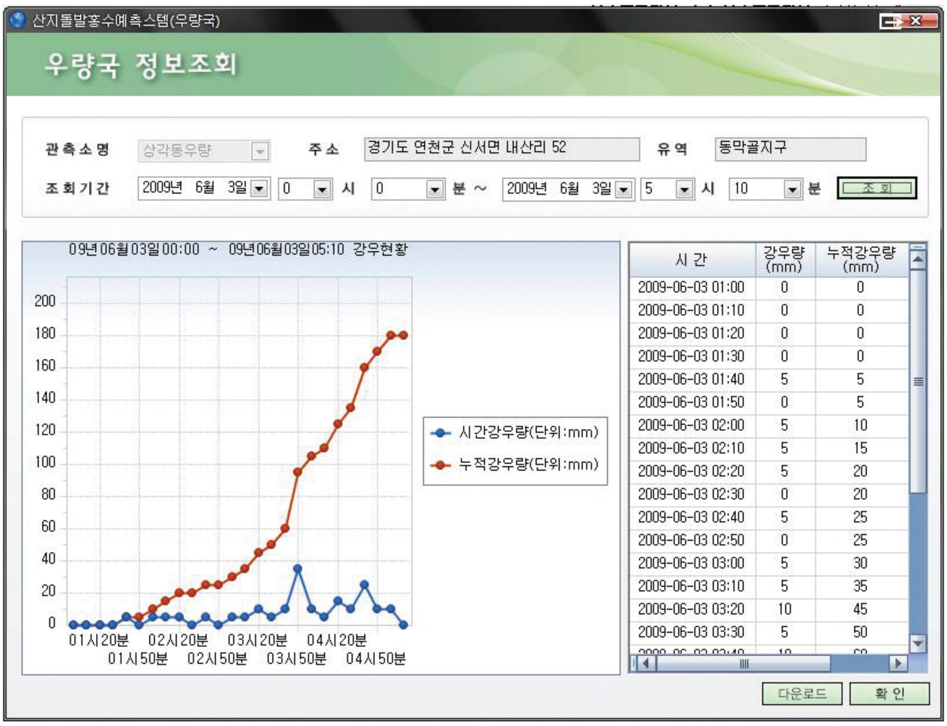


Figure 16 The hourly and accumulated rainfall window

Figure 17 is the attribute window for warning stations located in the flash flood risk area. The user can find the attribute associated with a warning station located in the flash flood risk area and all the information associated with a warning station located in the flash flood risk area will be saved in the excel sheet (1).

Figure 17 Attribute window for warning stations located in the flash flood risk area

Figure 18 is the attribute window for rainfall observation areas located in the flash flood risk area. The user can find the attribute associated with a rainfall observation area located in the flash flood risk area and it is possible to obtain hourly and accumulated rainfall information during the period assigned by the user as shown in Fig. 19. All the information associated with a rainfall observation areas located in the flash flood risk area is displayed in the excel sheet (1). Once a rainfall observation location for which the user wants to know the rainfall data, click the "rainfall data reference" button (2) which then opens the "hourly and accumulated rainfall" window (Figure 19).

Figure 18 Rainfall observation areas located in the flash flood risk area

Figure 19. The hourly and accumulated rainfall window

Figure 20 is the data analysis window. The user can select the combo box assigned as the observed rainfall event and click "Analysis" button (4). Then all of the warning records in accordance with sub-basins' names and the warning degrees during the selected period will be displayed.

Figure 20. Data analysis window

Once the user clicks on a row of the excel sheet to select a period and clicks the “Display chart” button (2), the window shown in Figure 21 opens. The line charts in the window show the number of the warning degree of the flash flood warnings during the selected period.

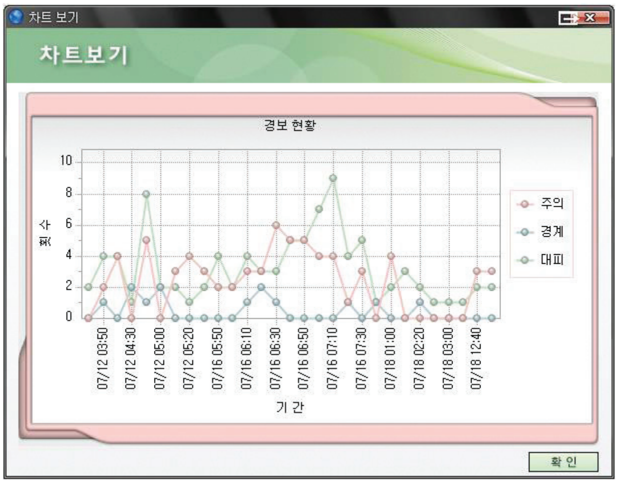


Figure 21 The number of the warning degree of the flash flood warnings during the selected period

Figure 22 shows the region where the flash flood warnings are issued during the selected period. The region is shown in different colors depending on the warning degree namely “Caution”, “Warning” or “Evacuation”.

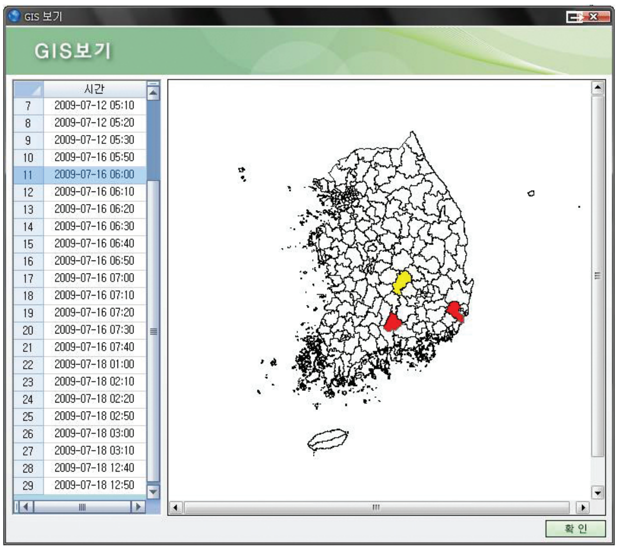


Figure 22. Displaying regions in accordance with the warning degree issued

The window in Fig. 23 is the system environment setting. In the window, all of the designated persons information can be found in the excel sheet (1) and their information can be managed with “add” (2), “modify” (3), and “remove” (4). If “reception” is set to “Y” in the information of the designated person, he/she will receive the warning message via Email. In the window to register a designated person (5), new information is added to the system. With this window, the following information can be set and managed.

- The types of the very short-term rainfall data (CAPPI10, CAPPI20, CMAX20, CMERGE10, CMERGE20)
- Warning period
- Warning device (SMS or Email)

With the “initial setting” button (6) the warning period is set to the initial value which is of 20 minutes.

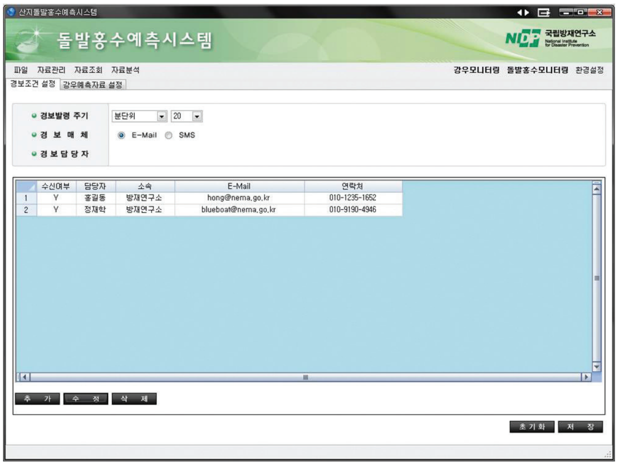


Figure 23. System environment setting window

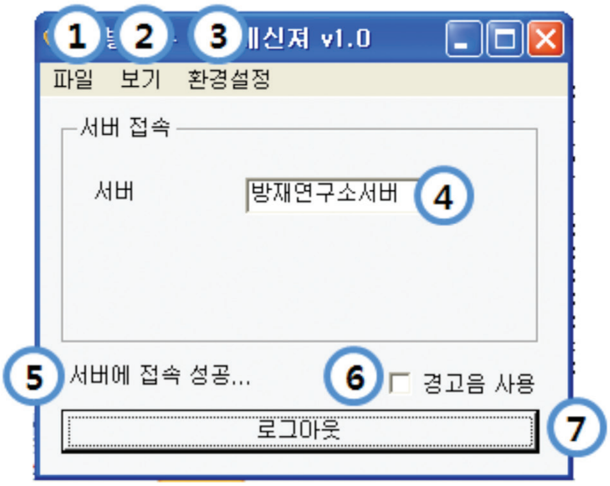


Figure 24 Flash flood warning messenger client

2. Messenger client

The messenger client is developed to quickly spread the current regional conditions which are collected and expected by the developed flash flood forecast system to all authorized persons to handle the situation properly. Figure 24 is the login window for the messenger client. It is automatically connected to the mountainous flash flood server and performs the initial and idle tasks to receive the circumstance report message from the server. “File” (1) includes the type of program and log-out functions and “See” (2) shows all the information related to the previous warnings. “Environmental setting” (3) allows us to set the environmental setting of the messenger client. The name of the server in 4 refers to which server is connected to the messenger client and 5 indicates the communication condition. 6 lets the user make choose whether he/she wants to use the device notification or not. 7 is the log-in and log-out button and is used to connect and disconnect from the server.

Figure 25 is the circumstance reporting window that pops up after messenger client is activated. It shows an expected circumstance which is required to issue a flash flood warning based on the 3-hour forecast rainfall. The warning degree is set to “Caution”, “Warning”, and “Evacuation” depending on the severity. In the window, 1 is used to hide the window and the color of the window (2) will automatically change to inform a warning was issued. “Regional Information” (3) shows the information of the region where the warning was issued. If the user clicks this button, as shown in Figure 26, the user obtains “Full extent” (1) for the region, “Contact” (2), “Address and photos of the region” (3). 4 shows the warning messages which were issued earlier and saved in the system. 5 displays the time of the warning message issued and with 6 the user can obtain the warning degree, the name of the region, the amount of rainfall, 3-hour forecast rainfall and more. “Suspension of warning” (7) button is used to stop the device notification and the number of the warning messages which have been issued till now can be found by clicking 8.

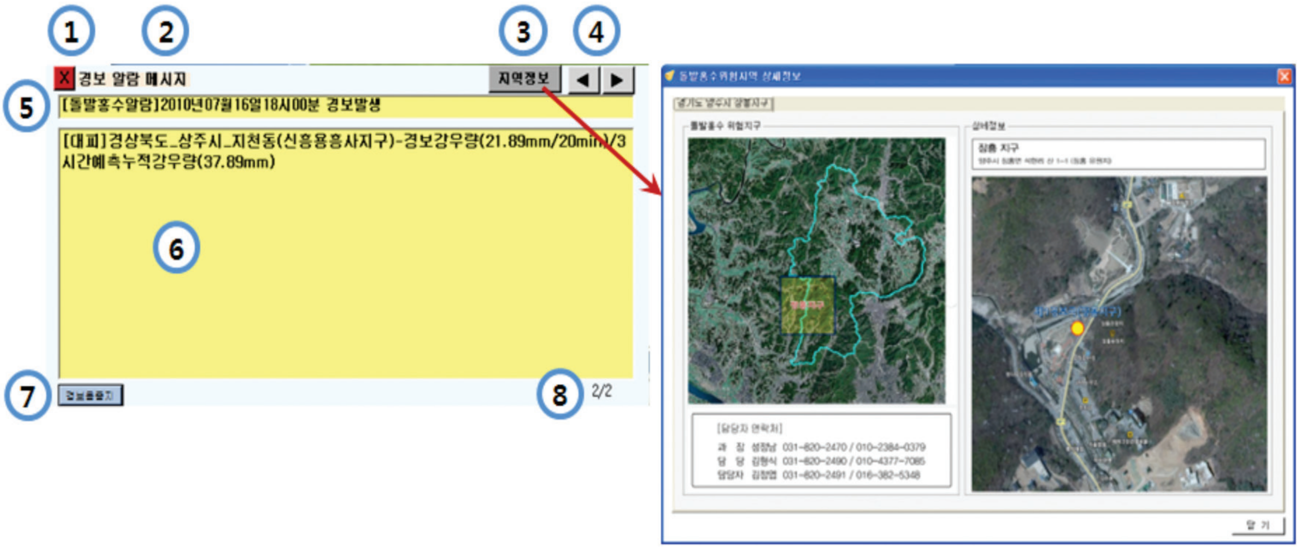


Figure 25. Circumstance reporting pop-up window

Figure 26. Regional Information where a flash flood warning has been issued

When an immediate flash flood incident is expected, the following procedures should be performed as shown in Figure 27.

- Flash flood warning issued after the circumstance has been analyzed
- Check-out the regional information and perform according emergency actions
- Notify the circumstance to the region and identify critical factors
- Identification of critical factors, performing emergency actions and reporting to on-duty employees in the region

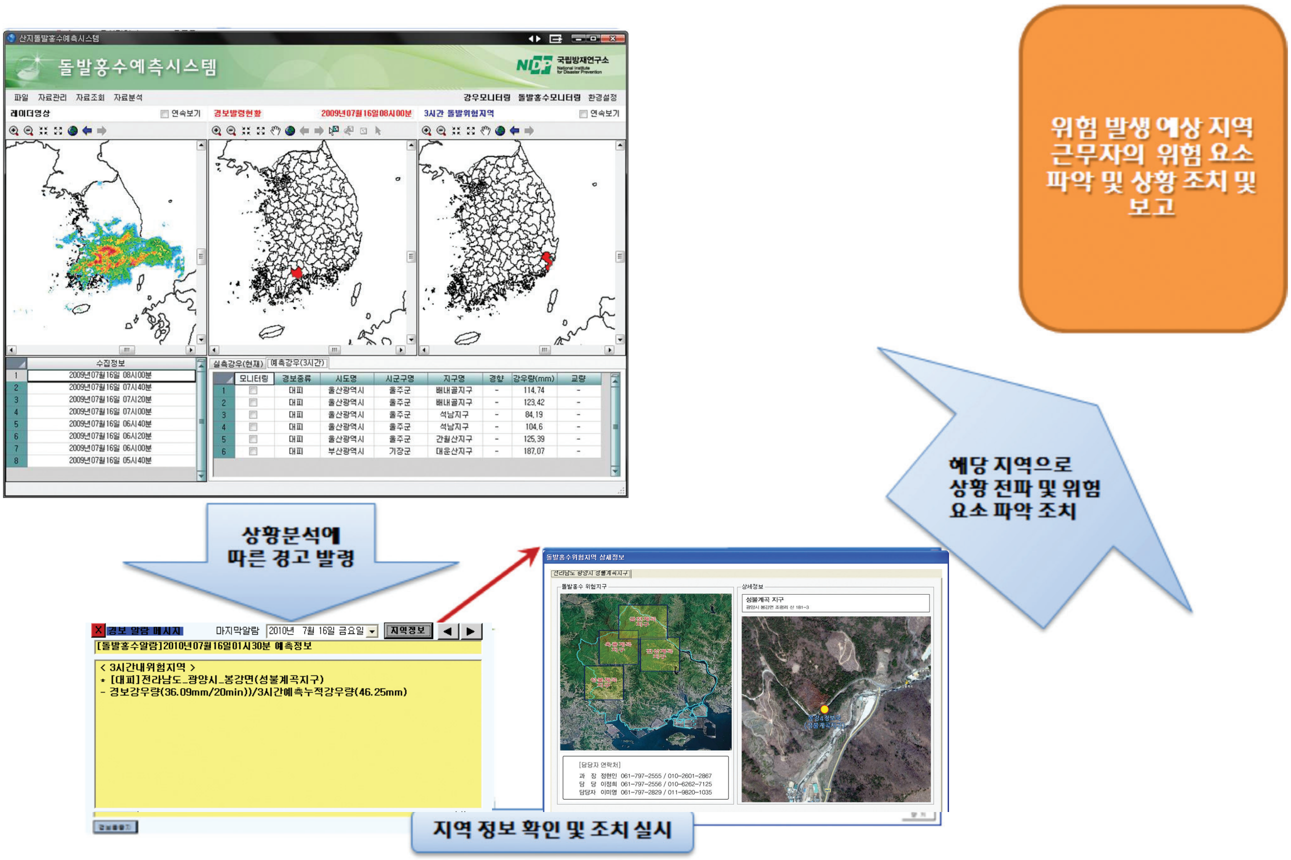


Figure 27. Flow chart of performing emergency procedures

3. Flash flood forecast system for professionals

Figure 28 is the initial window of the flash flood forecast system for professionals. This window consists of

- Rainfall data collection window (1) on the left side of the window
- Toolbar (2) and Menubar (3) on the upper-right of the window
- Map (4) and Legend (5) on the lower-right of the window

In the rainfall data collection window, rainfall data analyzed by the user is displayed after the searched data in “C:\Compress”. Once the user can select any rainfall data from the list (1), the observed rainfall phase and other 36 phases of the forecasted rainfall are displayed on the map (4) and from the legend (5), the user can find the rainfall intensity. Using the period button in the toolbar (2), the relevant information of both the observed and forecasted rainfall phases corresponding to the selected period will be displayed on the map (4). By clicking the “System End” button (6), the system is completed.

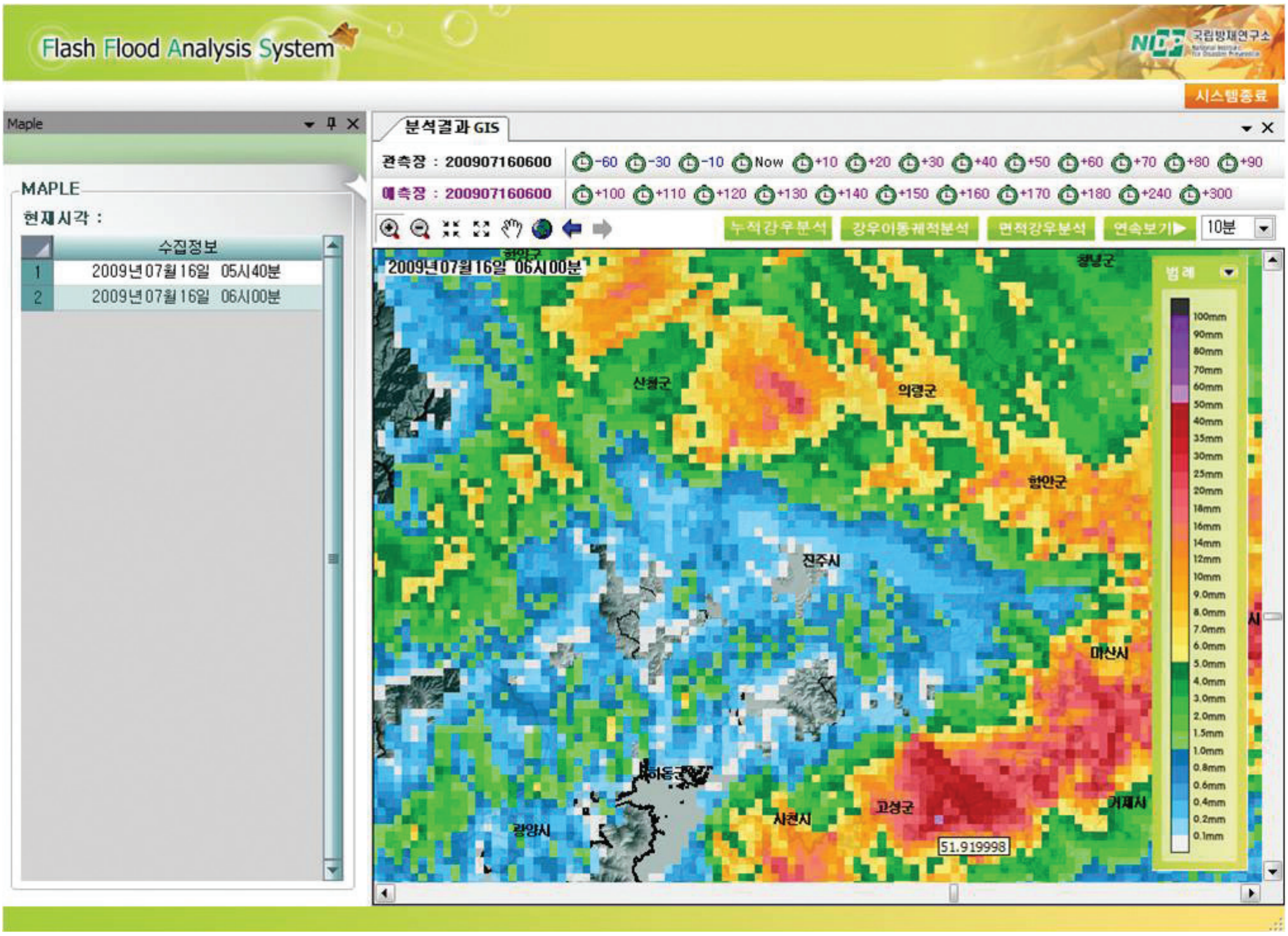


Figure 28 The initial window of the flash flood forecast system for professionals

Figure 29 is the screen for the analysis of the areal rainfall. First, select very short-term rainfall data in the list window (1) and click “Analyze the areal rainfall” (3). A message window (2) will then pop up explaining the functions of the analysis of the areal rainfall. Clicking the “Yes” button performs the analysis of the areal rainfall. If “No” button is clicked, the task is finished. After the user selects a target range on the map by dragging a mouse, he/she double-clicks to open the window showing the rainfall analysis results 4). The min, max, and average rainfall, and standard deviation, and the total amount of rainfall are obtained.

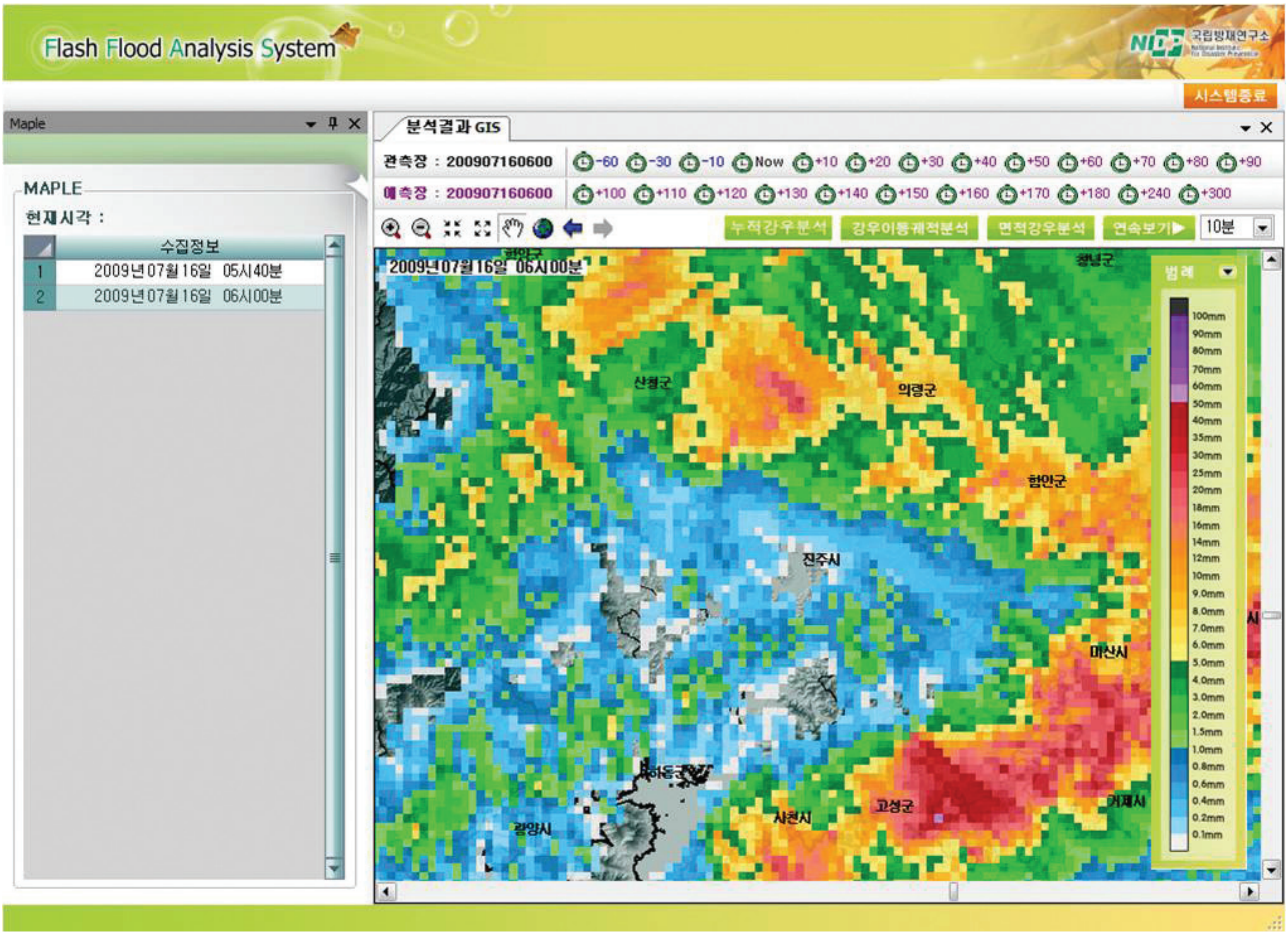


Figure 29 The screen for the analysis of the areal rainfall

The rainfall movement speed can be estimated by clicking the “Rainfall trace analysis” button of the toolbar as shown in Figure 30. If the user sets the start time and location to analyze the rainfall movement velocity in the combo box (1), the radar image corresponding to the time the user set is displayed in the map on the left (7). The user clicks “Start location set” button (3) and clicks again on the location to be analyzed on the map. To set the end time and location for the analysis, repeat the same procedures but using the “End location set” button (4) instead of the “Start location set” button.

“Redraw” button (5) allows the user to restart the analysis. After clicking the “Movement velocity analysis” button (6), the user finds results on the upper-right corner of the window (8). The speed in the window is calculated by using the distance which is set by the user. The analyzed distance is shown on the map and by clicking the “Download” button (9), the screen containing the information related to the analyzed distance can be saved. “End” button (10) finishes the analysis.

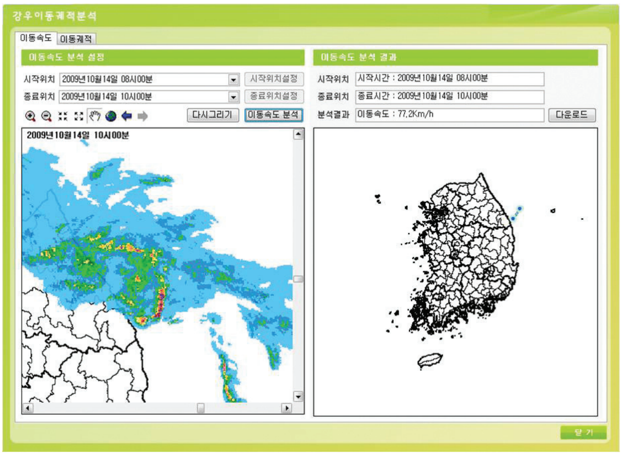


Figure 30 The window for the analysis of the rainfall movement velocity

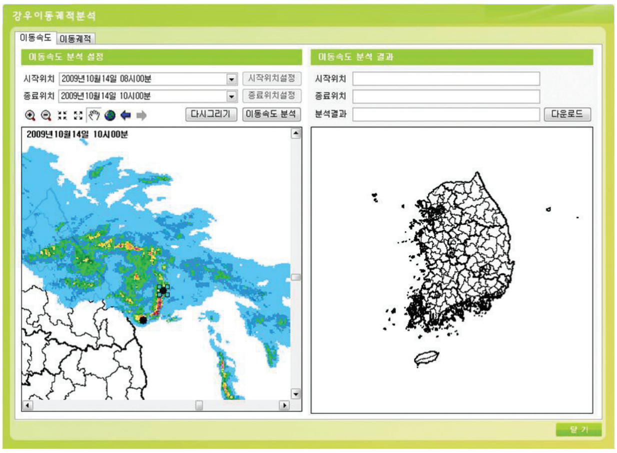


Figure 31 Analysis of the rainfall movement velocity (1)

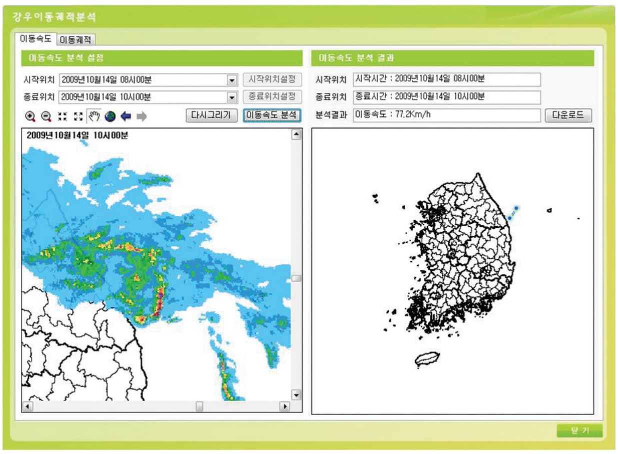


Figure 31 (cont') Analysis of the rainfall movement velocity (2)

By clicking the "Rainfall movement trace analysis" button of the toolbar, the window of the rainfall movement trace analysis opens as shown in Figure 32. Once the user selects the time that he/she wants to analyze in the combo box (1), the radar image corresponding to the time the user set is displayed in the map bellow (7). After clicking the "Display the rainfall movement trace" button (3), the user clicks again on the location to be analyzed on the map to perform the analysis. The time information for the analysis is displayed in the combo box of the rainfall movement trace (2). The rainfall movement trace for other time periods can be performed by following the same procedure.

"Redraw" button (5) allows the user to restart the analysis.

The analyzed rainfall movement trace is shown on the map and by clicking the "Download" button (7), the screen containing the information related to the analyzed rainfall movement trace can be saved. "End" button (9) finishes the analysis.

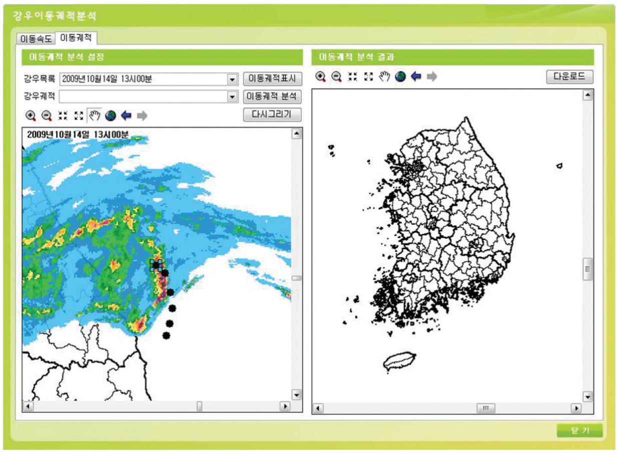


Figure 32. Analysis of the rainfall movement trace (1)

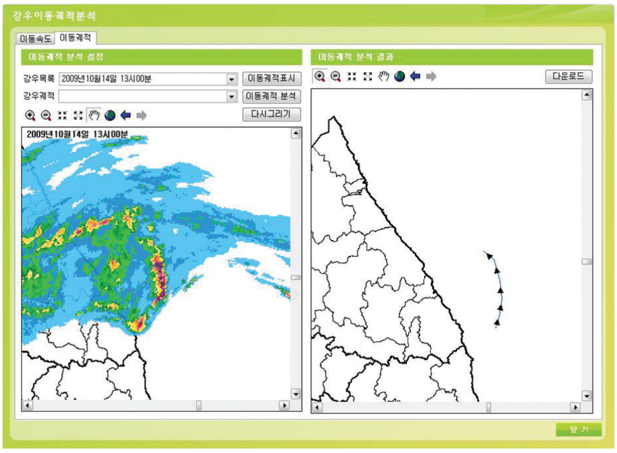


Figure 32 (cont'). Analysis of the rainfall movement trace (2)

By clicking the "Accumulated rainfall" button in the toolbar, the window for the analysis of accumulated rainfall opens. Once the user selects the time of rainfall to be analyzed on the "Set the analyzed data" (1), the list of observed rainfall phases will be displayed in the combo box and the analyzed accumulated rainfall data corresponding to the observed rainfall selected will be displayed on the map. From the legend 5), the rainfall intensity data will be identified. At the same time, if the "Analyze the areal rainfall" button (3) is clicked, it will perform the same analysis as the analysis of the areal rainfall. The user can save the analysis results shown in the window by clicking "Download" (5). "End" button (6) finishes the analysis.

V. CONCLUSION

In this system the flash flood forecast system based on GIS is developed to predict flash flooding from occurring in mountainous areas. With the system, basin data can be obtained and sub-basins are delineated from the Korea Peninsula to identify which are the mountainous flash floods risk areas. The data associated with each sub-basin such as the characteristics of velocity, length of channel, area slope, and channel slope are estimated. These data are needed to obtain the hydrographs. Also, the rainfall adjustment method is built to improve the reliability of forecasted rainfall. To issue a flash flood warning promptly, an emailing system has been developed and an SMS service system is being developed. To obtain the flash flood warning time, a very short-term rainfall forecast model is selected and a methodology to adjust forecasted results from the model is developed.

Since Republic of Korea, where this forecast system is being applied, is vulnerable to flash floods due to its geographical characteristics as well as climate change, it will be a constant concern to keep the country safer from mountainous flash flood. For this purpose, IT and hydrological methodologies are integrated to develop the scientific disaster mitigation technology and to advance the current system based on this technology. With the developed technology and the system, it is possible to obtain the pre-disaster mitigation capability which is a sociological and academic demand for this era. This is the main reason that led us to carry out this system.

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