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Field Investigation of the Flood Disaster in South-West Area of Sri Lanka Occurred in May 2003

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SYNOPSIS

A heavy flood occurred on May 17th-18th in 2003 in southern Sri Lanka which caused severe river inundations and landslides across a wide area. About 300 people were killed, and houses, farm products and infrastructures were severely damaged. In order to investigate this flood and sediment disaster from the hydrological and hydraulic aspects, the Committee on Hydroscience and Hydraulic Engineering, Japan Society of Civil Engineers (JSCE) delegated its members whose respective fields are hydrology, hydraulic engineering and river engineering as a flood investigation team by JSCE. Japan is also an island country, and suffers both flood and sediment disasters by heavy rainfall and typhoon. In considering flood and sediment disaster prevention and mitigation, it is quite important to study disasters in foreign countries and to determine countermeasures against future disasters. This field investigation was conducted to clarify the details of the flood disaster in Sri Lanka to learn valuable lessons and ideas for our flood control policies.

Key words: Sri Lanka, heavy rainfall, flood disaster, landslide disaster, field investigation

INTRODUCTION

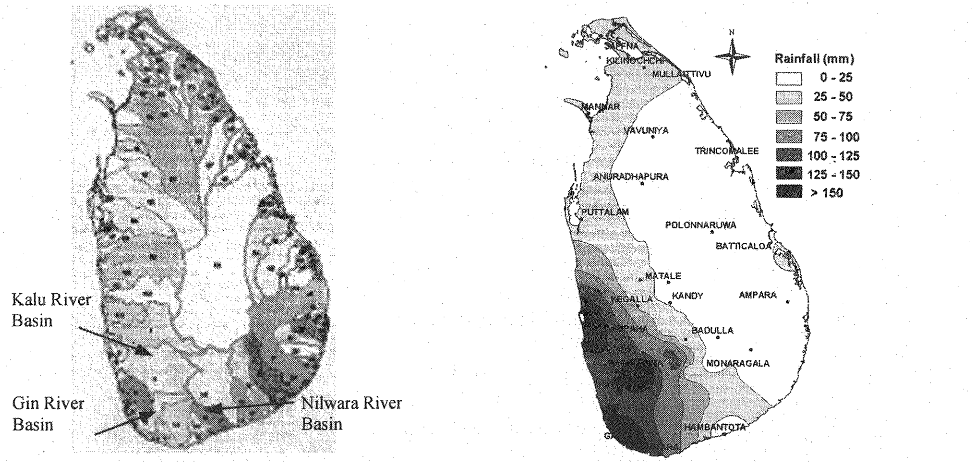
The flood that struck Sri Lanka in May 2003 resulted in approximately 300 deaths and 120,000 affected people. Therefore, the Committee on Hydroscience and Hydraulic Engineering, Japan Society of Civil Engineers planned and executed a field investigation of this flood damage. Given that Sri Lanka is a relatively small country and is also a developing country, the findings and lessons learned through conducting a scientific field investigation of this flood disaster may not necessarily be directly applied to our country. However, this investigation was conducted in the hope that we not only uncover findings that our country can learn through the result of this investigation, but also we demonstrate that Japan is able to provide technical support as well as cooperate and work together with Sri Lanka and many other developing countries as well.

STUDY AREA AND OVERVIEW OF RAINFALL AT THE TIME OF MAY 2003 FLOOD

(1) Study Areas

The areas studied in the present investigation were the basins of Kalu River, Gin River and Nilwala River (**Figure 1(a)**), where damages were heavy. Field investigations were conducted as well as interviews with the central government, local administrative bodies, media and universities to gather information.

The landscape of Sri Lanka can be separated into the central highlands, the plains, and the coastal regions according to their altitudes. The central highland is located in the south-central area of the national land. The plains are 30 – 200m above sea level, and account for majority of the land. Sri Lanka's rivers originate from the central highlands and run down radiating toward the sea. The river channels are often separated into a few segments due to discontinuous topographical features, and many waterfalls and rapids form at cliffs and steep slopes. The current speed of these rivers slows down when they reach the plains, and meander through flood plane and deltas.



(a) Sudy area (b) Rainfall for the week of disaster (after Zubair[1])

Figure 1 Study area and weekly precipitation

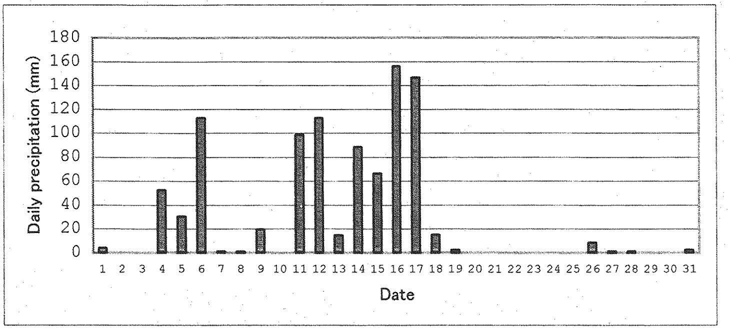


Figure 2 Daily precipitation in Ratnapura (May 2003)

(2) Overview of Rainfall at Time of May 2003 Flood

There three characteristic features of the rainfall that led to flooding and landslide disasters in the southwest region of Sri Lanka in May 2003. They are as follows:

1) Stagnant cyclone, which is rare in the month of May
2) Continuous rainfall due to stagnant cyclone
3) Concentrated rainfall following saturation of soil moisture

Sri Lanka, located in the lower latitudes between latitudes 6 - 10 degrees north, counted less than 20 cyclone landfalls over the past 100 years, most of them occurring in the months of November and December. This time, the cyclone slowly climbed up north over the Bay of Bengal from May 11th-19th in 2003, stimulated the monsoon and brought heavy rainfall over southwest region of Sri Lanka. **Figure 1 (b)** shows the rainfall distribution over the entire area of Sri Lanka for the week from May 6th-13th, before the disaster took place (May 16th-18th). In the southwest region of Sri Lanka over 100mm of rainfall was observed over the period of one week.

In Ratnapura in the river basin of Kalu River, over 600mm of rainfall was observed as shown in **Figure 2** for the period May 1st-15th, one day prior to the disaster. Based on these findings, it is estimated that the soil moisture was already at a saturated level in the area where the disaster occurred. Following this, Ratnapura received 156mm of severe rain on May 16 followed by 146.5mm on May 17th. One continuous rainfall that lasted 18 hours from 3am to 9pm on May 17th brought 366.1mm of rain, in which 99.8mm of rain was observed in the hour between 2pm to 3pm. Thus, it can be concluded that the concentrated rainfall following the saturation in the soil moisture level was the direct cause of landslides and other disasters.

DISASTERS IN KALU RIVER BASIN

(1) Flood Disaster

The Kalu River is located in the central part of Sri Lanka, with the river basin area of 2,690m^2 with a length of approximately 100km. According to Sri Lankan Government (Irrigation Department) documents, the average annual rainfall is 4,000mm and the annual total outflow volume is 7.3 billion m^3, which amounts to approximately twice the average annual rainfall as that of Japan. The Kalu River basin can be divided into the upstream valley region (Ratnapura District) and the downstream low-lying region (Kalutara District), as shown in **Figure 3**. The difference in altitude between the mountainous lands of the headwaters and the mouth of the river is approximately 2,250m, but since the altitude abruptly drops from 2,250m to 14m in the first 36km from the riverhead, much of the river channel has a steepness of only approximately 1/5,000. Furthermore, another characteristic of the basin is that the separation point between the downstream low-lying area and the upstream valley is located where the width of the river channel narrows to approximately 50m, and this was one of the factors that contributed to the flooding and inundations in the upstream area.

Ratnapura, the central city in the upstream valley region, is situated where the rivers from the surrounding mountain lands converge. Since this is also the point where the river slope falls sharply, it is prone to flood disasters. The maximum flood stage in May 2003 reached 23.9MSL, which is the fourth highest ever recorded[2)]. The water level reached over 3m maximum in depth in the urban district, and the ground floors of most houses were flooded. It is estimated that the maximum river discharge in Ratnapura was 1,300m^3/sec, a flooding with the return period of 50 years.

The causes of this flooding are summarized as follows: 1) extremely small river bed slope (1.0ft/1 mile), 2) far too much rainfall, as detailed in the previous section, and 3) disruption of the river flow due to the contraction in Ellagawa.

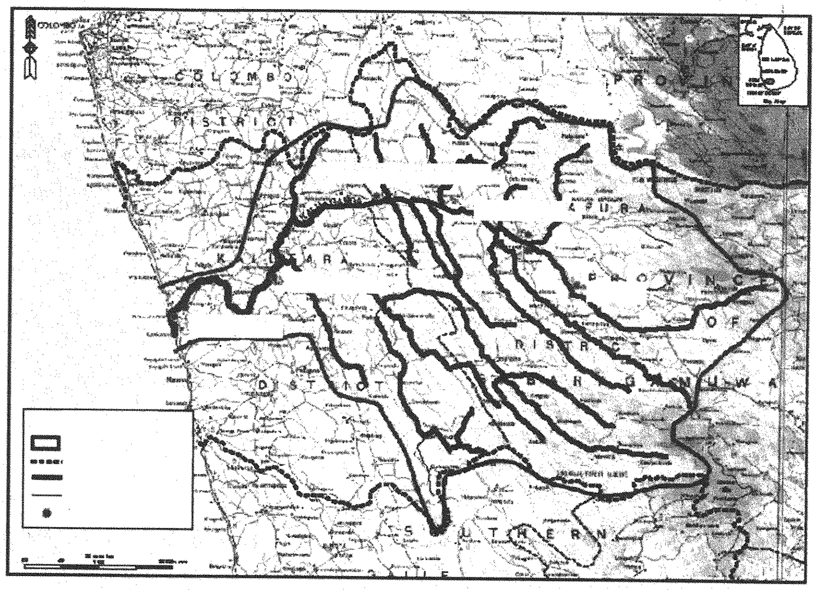


Figure 3 Kalu River basin

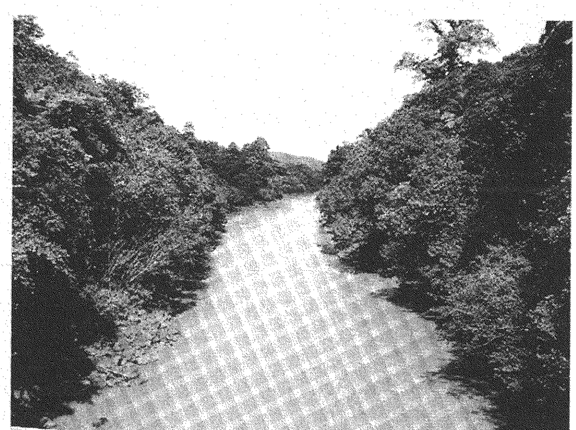
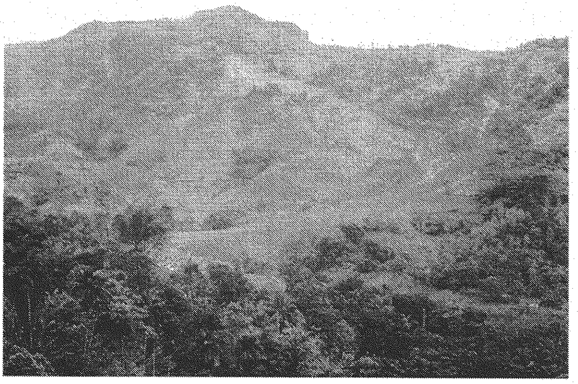


Photo 1 Narrow section in Ellagawa

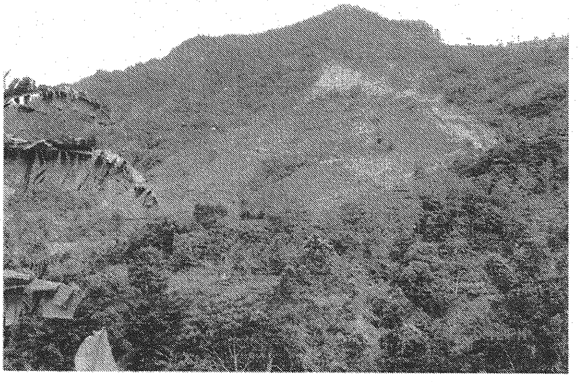
According to residents living in settlements slightly upstream from Ratnapura along Kalu River, the flood water came close to reaching the roof of the building. During the present field observation, its traces were still clearly marked inside the residence above the level of our waists.

Piecing together the stories of the residents, it seems that in Ratnapura and in the nearby villages, the place was gradually flooded rather than undergoing a sweeping torrent, and the residents had plenty of evacuation time. It was concluded again that the cause of the flood was the disruption of river flow in the narrowing river area and that the effect gradually spread to the upstream regions. **Photo 1** shows the throat section in Ellagawa, separating the upstream from the downstream of Kalu River. The width of the river is approximately 50m. Certainly, with this cross section, the river cannot be expected to accommodate a flow discharge over 1,000m^3/s.

Traces of flooding levels were left throughout the downstream low-lying areas around Kalutara. The flooding in this area is said to have taken place gradually similar to the upstream flooding, with no dead or missing persons from the flood. Compared with cases of Japan's inundations by river water, the situation seemed to be not so serious.



(a) Immediately after the landslide



(b) April 21, 2004 (about 1 year after the landslide)
Photo 2 Landslide at Hapugoda in Ratnapura District

(2) Landslide Disaster

Landslides occurred in many places in Ratnapura Province, and 122 lives were lost because of this. Hapugoda had the most number of landslides, resulting in a death toll of eight. **Photos 2(a), (b)** show the largest landslide scar in Hapugoda. **Photo 2(a)** was taken immediately after the landslide, while **Photo 2(b)** was taken in April 2004 during the present field investigation. Here, eight people were buried alive. These photos are insufficient in explaining the process of how the landslide and debris flow occurred, but a landslide scar could be seen near the mountain top as well as traces showing how the sediments flowed downward in two separated routes. Of the two, the route on the right hand side of the photo shows a valley had been created. The trace of the route on the left was created by the sediment moving past the small mountain ridge.

Photo 2(b) taken a year later shows most of the sediments from the landslide had been carried away, with hardly any left behind in the river channel, and the river bed is covered with grain size gravels. Also, the vegetation that had been lost along the sediment routes may be seen substantially restored.

Halfway up the mountainside, there is a private residence. The area around here was developed as tea plantation, and the people built and lived in houses on the risky mountainside for convenience of their operation. This deforestation and the ingression of people's settlements into the forest is thought to be one of the factors that caused spreading of the damage from the landslide. According to the interviews from the field investigation, the government has advised residents to move their houses, but most have not done so.

This landslide in Hapugoda is thought to have naturally formed a temporary dam that banked up Delgoda River. This creation of the natural dam and its destruction is said to have triggered the washout of bridges in the downstream area; however, there have not been any reports of serious human damage from flooding caused by the destruction of the temporary dam.

(3) Countermeasures against Landslide Disaster

In Sri Lanka, creation of landslide hazard map is in progress for sustainable management of long and short term landslide disasters. Furthermore, plans for setting up standards and guidance for selection of residential areas are being made. Ratnapura's hazard map was completed prior to this May 2003 disaster. However, it seems this map was not utilized effectively, and new disaster control measures are being made taking into consideration of this problem.

Actions immediately following the landslide disaster included relocating the houses, land appropriation, restoration work, and monitoring of landslide damaged area.

Future control measures will include for one, the landslide hazard map project. Hazard maps are drawn up in either 1/50000 or 1/10000 scale. These maps indicate risks of four levels based on land use, landscape, slope, soil condition, geological condition, and hydrological information.

Another future control measure is the reinforcement of the building permit process by local governments and municipalities. When drawing up the urban development plan, the potential disaster data must be included, the guidelines for construction in landslide risk areas must be provided, development must be controlled through insurance and special taxes and such, and the construction law must be obeyed. They are also trying to establish self-awareness by disseminating disaster information to promote the formation of community-based volunteer organizations regarding the observations during the rainy season, and are working to equip communities with disaster prevention equipment, to implement an early warning framework, to avoid construction in danger zones, and to avoid settling in danger zones.

DISASTERS IN GIN RIVER BASIN

(1) Overview of Flood

Gin River flows through the Galle Province in southern Sri Lanka with the river basin area of 947km^2 and the length of 112km **(Figure 4)**. By early morning on May 17, 2003, a severe rainstorm occurred with local heavy rainfall over the upstream of the Gin River basin. Flooding occurred in Nelluwa in the upstream of the Gin River, 20km up from the mouth of the river. The inundated flood water flowed down the protected lowland downstream for three to four days. The overflowing water in the protected lowland could not be drained to the waterside even when the floodgate was opened. During the flood, the water flowed rapidly in some places reaching a depth of over 2m, and since the route to the evacuation area became submerged in water, evacuation proved very difficult in certain areas. This flood claimed 17 lives as well as generated extensive damage to the area's infrastructure and agricultural products.

By early morning of May 17, 2003, the forest region in Sinharaja was under torrential rain of more than 350mm. The water level in the river seemed no different from usual at that time, but it rapidly increased by around noon. By night, the Nelluwa District was under water and the water level in Gin River increased to unprecedented levels. A flood broke out in the low grounds in Nelluwa , and the villagers were faced with the violence of flood. The same conditions were seen in Tawalam region on the same night, and transportation networks were was completely shut down. In early morning on May 18, the Nagoda and Niyagama regions were also affected by the flood, and by night, the Baddegama, Elpitiya, Hikkaduwa, and Galle regions as well.

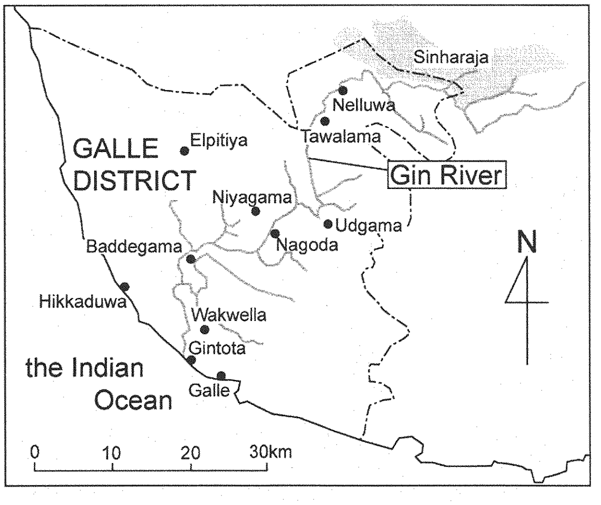


Figure 4 Gin River basin

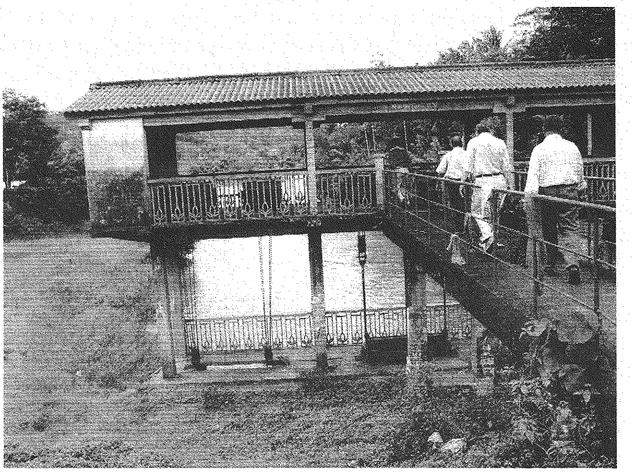


Photo 3 Pumping station coping with inundation by heavy rainfall

The mouth of the Gin River in Gintona was not able to discharge the volume of flood water generated by this flood, and so the water backed up and increased the water level of the river. On a bridge pier located in the outskirts of Galle on the highway connecting Galle and Colombo, the water level rose to 0.6m below the bridge floor. In view of this situation, the Galle Province Government cut out a part of the sand bar that had formed near the bridge pier, and by doing so, managed to avoid flooding in the Galle Province.

By noon of May 19, water levels in the upstream river gradually decreased, and the provincial and local authorities began assessing the damage and assisting victims.

(2) Overview of the Damage

Out of the 17 lives lost in the flood damage, six died from landslides and the remaining drowned in the flood. Compared with other provinces, it should be noted that more died from drowning than the rest. The number of flood-affected households was 32,000, and most severely damaged were Nelluwa, Tawalama, Nagoda, Niyagama, and Galle.

At the time of flooding, the flood waters moved fast in some areas, reaching a depth of over 2m. The route to the evacuation area was also submerged in water, so it seems evacuation was very difficult in some parts of the area. Evacuation centers were schools and public facilities. The residents were informed about the flood conditions through the media such as radios and TVs. The province disseminated evacuation information, and it was conveyed to each village. The information was passed on to each community. Regarding evacuation process, although there were some residents who were late, the evacuation procedure seemed to have been relatively successful. The evacuation and relief activities were energetically performed by the military (navy). Boats for evacuation and relief activities were provided by those involved in the fishing business.

In regards to the flood control structure of Gin River, the embankments are only constructed in the downstream regions up to 12km from the river mouth. The downstream region of Gin River is a low-lying area and receives much rain during the rainy season. Therefore, it seems that emphasis was placed on discharging the water from the protected lowlands. Since the water level of Gin River rises in the rainy season, pumps are used to discharge water from the tributary streams, because they cannot naturally flow down through the mainstream waters of Gin River (**Photo 3**). Flood control measures started in 1975 with help from the Chinese Government. It seems that flood prevention measures for the 5,000ha paddy fields based on precipitation for a ten-year return period was implemented, and pumping stations were set up in 10 locations. There was a diversion channel of an approximate width of 30m near the downstream waters, and the hydraulic design for it was completed under the auspices of the Chinese Government.

There is no flood disaster prevention plans for the entire river basin area of the Gin River. It is highly likely that similar inundation by river water will reoccur if there is another occurrence of heavy rain. The measures against inundation by heavy rainfall are also hardly adequate.

Because of the scale of the flooding and the likelihood of losing human lives, the measures against inundation by river water is extremely important. Extending the length of the embankment would require both time and cost, so they should start by developing an evacuation system that includes a preliminary warning system and information transmission as well as providing disaster prevention education that generates public awareness of the dangers of flood disasters.

It seems the evacuation was carried out smoothly in spite of the large scale of the present flooding. However, it should be noted that the means of communication of disaster information on sites other than the mass media such as TVs and radios was mostly through word of mouth including the use of loud speakers. Promptly conveying accurate information to residents in scattered communities and evacuating them quickly and safely is an important issue. Therefore, it is necessary to build an information communication network from provincial and local authorities to each community, and to prepare and improve a prompt information communication and evacuation framework within each community. Also, it is recommended that actual flooding results be recorded immediately following the disaster and organized for future records as well as for effective utilization as educational materials for disaster prevention.

Furthermore, the development of rescue and relief framework during the flood, and the recovery system following the flood are also key issues. How to quickly and accurately people grasp the extent of damage when flooding occurs across vast areas along the basin, how to rescue residents in isolated communities where roads are severed, how to collect and distribute food and relief supplies, how to support the disaster victims who are forced to live in evacuation centers. These are some issues that became evident as a result of this flood disaster. Coordination between the government (provincial and local authorities), police, and the military are considered vital for rescue and relief activities, and coordination among the government and residents as well as volunteers are considered crucial in the recovery stage. These are some similarities between the present disaster and that occurred in Niigata and Fukui Prefectures caused by the severe rainfall in July 2004 in Japan.

DISASTERS IN NILWARA RIVER BASIN

(1) Overview of Flooding

The Nilwara River is located in southern Sri Lanka in Matara Province between latitude 6°13'to 5°55'north and longitude 20°25'to 80°38'east (**Figure 5**). The riverhead is located in the central mountain region in Daniyaya and Rakwana at altitude 1,050m. The length of the channel is 70km, and it pours into the Indian Ocean at the provincial capital of Matara City. The river basin area is 1,070km^2. The mountainous area around the riverhead is woodland, and it is covered with red-yellow podzol. The hillside area consists of plantations including rubber, tea and spice, and the most of the plains are paddy fields. The riverbed in the mountainous area is rocky with steep slope, whereas the slope in the downstream regions is less steep.

The water level in Bopagoda in the upstream Nilwara River is shown in **Figure 6.** The water level rapidly rose from May 17th to 18th, reaching over 35 ft, (10.7m) at the maximum level. Because the water level surpassed the upper limit of the automated water level gauge, the figure shows the maximum water level based on a flood mark around there. It is estimated that the maximum water depth was reached around 4:30am on May 18th. In Pitabeddara which is located in the upstream region, the maximum flow discharge is estimated from water level to be 2,900m^2 on May 18th.

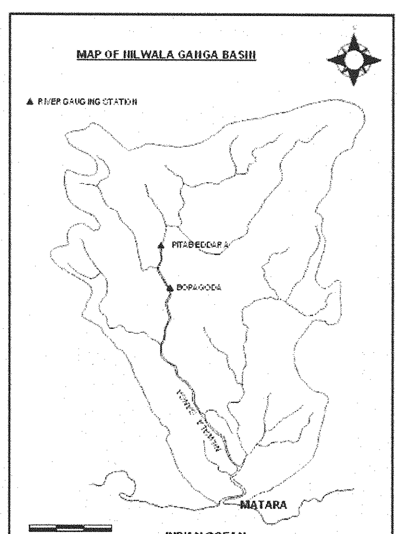


Figure 5 Nilwara River basin

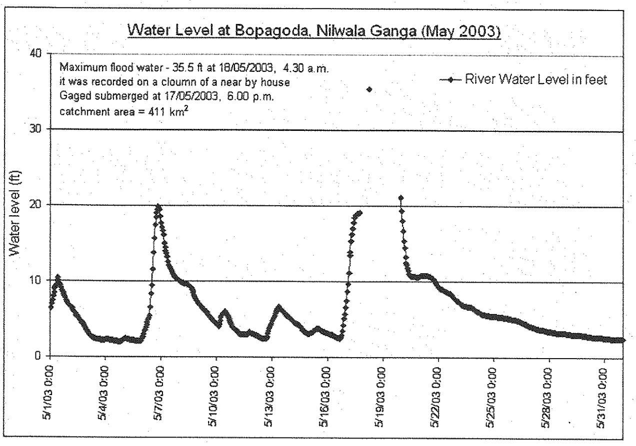


Figure 6 Water level at Bopagoda

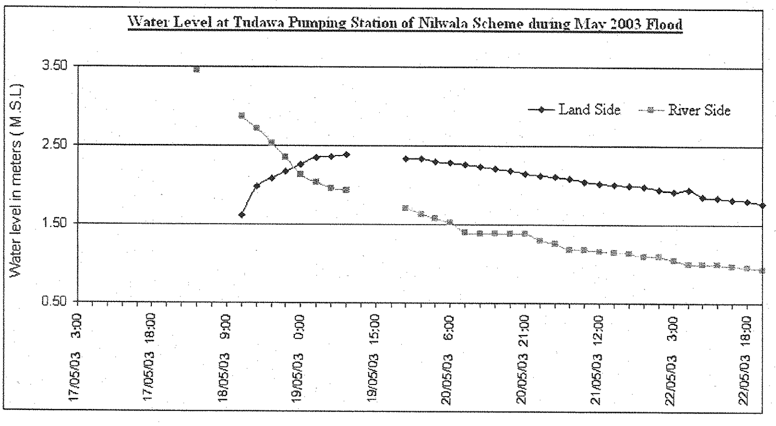


Figure 7 Water level at Tudawa pumping station

At the Talgahagoda pumping station, which is approximately 30km down the river from Bopagoda, the maximum water level was recorded at 3:00am on May 18th. The reason why the time of upstream flood peak came later than the downstream peak may have been because the downstream embankments were cut in the early hours of May 18th, which caused the flood waters to run into the protected lowlands, thereby reducing the peak flood from what it would originally have been. Judging from the reported time of embankment cutting, this presumption seems to be correct. As can be understood from **Figure 7,** the water level in the protected lowlands further down the river in Tudawa increased from May 18th to 19th, and the level inside the protected area rose above the level outside the embankment on May 19. The area protected by embankments has a low altitude in general, so it is prone to inundations. Also, the drainage pump station was not functioning at the time of flood peak, which was another cause of the higher water level inside the embankment. Compared to the size of the river basin, the downstream water level remained high over a long period of time, although it was partly due to the continuing rainfall. The people had to wait for the flood water to naturally drain out through the water channels. The above flood situation applies mainly to the right hand side of the river. On the left side, the above situation did not arise since embankments were not cut. The pumps steadily drained out the water. The Irrigation Department explained that the reason for this was that there were residential houses very close to the embankment on the left, and that it was easy for the local people to predict what damage would be caused by cutting the embankment. On the right side, on the contrary, the protected area close to the place where the embankment was cut was mostly paddy fields with no residential houses, deceptively appearing as a retention reservoir. This was why the residents felt no sense of guilt in cutting the embankment according to the explanation of the Irrigation Department.

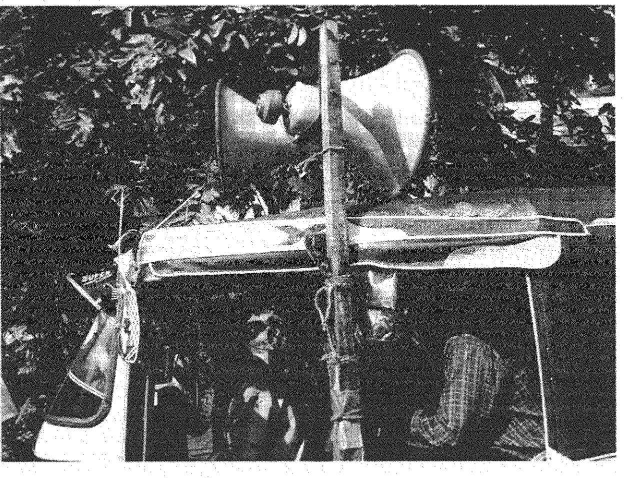


Photo 4 Announcement of disaster information through loud speakers

(2) Overview of the Damage

The Nilwala River had not flooded in over 30 years. Hence, most of the residents had no experience of flooding, which led to the extensive damage. Because of the rainfall that began on May 11, TVs, radios and newspapers reported the risks of landslides and floods. The residents were also aware of these risks. However, concerning the spreading of the flood in the downstream regions on May 18th, the residents did not get any information until it was announced through the loud speakers. The announcements made by loud speakers were only emergency measures from three-wheeler and cars, and there were no permanent disaster speakers placed in the area (**Photo 4**). These speakers were installed in electric stores in big communities, and when the need arose to inform the residents, the announcements are made with the help of the NGO. However, because the spreading of the flood occurred prior to the announcement, it resulted in creating isolated areas where the announcements could not be reached. According to the people living in the area, the water level increased without a known reason, which terrified them.

In many cases, family members or neighbors carried the disadvantaged on their backs when evacuating. Nevertheless, there were no designated places to evacuate to, so they tentatively evacuated to the elevated lands nearby. Victims in the isolated communities were rescued by the military boats and fishing boats owned by Matara fishermen. The Matara District Office requested rescue assistance from the military and the police on May 18th. The military rescued residents in the isolated areas and transported relief goods, and the police led the evacuation and directed traffic. From May 19th and onward, international organizations and NGOs brought in relief goods, medicine and food from Colombo. Some also participated in medical activities. On May 18th and 19th, the helicopters transported relief goods as well. In a few of the communities in the flooded area, they had stocked up on food. These were not stocked for disaster purposes, but rather for the purpose of securing food throughout the year for the local people. This food was distributed to the disaster victims. In some of the communities, small boats usually used for fishing were used for rescue activities.

CONCLUSIONS

Field investigation was conducted for the flood disaster occurred in May 2003 in Sri Lanka, and the following conclusions are obianed:

(1) Stagnation of a cyclone rarely seen in May produced continuous rainfall. The rainfall caused saturation of soil components in its early stages, and then later hit with a torrential rainfall.
(2) Most of Sri Lanka's rivers have steep slope in the upstream regions, but are not nearly as steep in the downstream regions. This created many landslides and avalanches in the upstream regions, and the gentle slope in the downstream regions caused a disruption in the river flow which led to the flooding. Especially along Kalu River, there is a constriction around Ellagawa, which blocked the flow of the river. This kind of geological feature was also cause for aggravating the damage.
(3) Most of the lives lost were due to landslides and debris flow.
(4) Evacuation orders and directing of people to evacuation centers were not always carried out smoothly. Evacuation centers were designated in advance, but since no consideration was given to landslide disasters, they were not necessarily safe.

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