The Management of Mitigation and Reconstruction for the Hazardous Catchment Areas Caused by the 2009 Typhoon Morakot

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***ABSTRACT*:**

Typhoon Morakot accompanied strong southwesterly monsoonal flow brought extreme heavy rain over the southern half region of Taiwan in August 2009. The large extent, high intensity and long duration rainfall caused huge damage. The objectives of this paper are to evaluate the benefit of reconstruction and management for the main disaster catchment areas, to arrange the results of conservation management of the Soil and water Conservation Bureau in sediment-related disaster area and to review and amend those strategy and countermeasures. In response to the post-disaster reconstruction is necessary to grasp the change of the environment state and make a management process to follow the countermeasures and evaluate the risk. Settling basin, flood retaining zone are measures to protect the residents. The balance of sediment transport and the channel stability could be accelerated through dredging of unstable sediment. The recovery process of the disaster catchment areas struck by Typhoon Morakot could be proceed through the management.

KEYWORDS: Typhoon Morakot, Reconstruction, Sediment disaster, Countermeasure.

1. INTRODUCTION

Typhoon Morakot is probably the deadliest typhoon over the past fifty years of Taiwan area. The purpose of this paper is thus to provide an overview of disasters resulted from Typhoon Morakot and the management of reconstruction for the hazardous catchment areas. Different kinds of disasters which include flood, landslides, landslide dams, driftwoods, and water supply disruptions, occurred during the period of Typhoon Morakot. Some of these disasters occurred almost concurrently in certain places. Such disasters are defined as the compound hazard in this paper. In the following sections, the characteristics of the heavy rainfall are first described. Then three major types of disasters, which are the flood, the sediment-related disasters, and the driftwoods, are explained. In response to the post-disaster reconstruction is necessary to grasp the change of the environment state and make a management process to follow the countermeasures and evaluate the risk. Settling basin, flood retaining zone are measures to protect the residents. The balance of sediment transport and the channel stability could be accelerated through dredging of unstable sediment. The recovery process of the disaster catchment areas struck by Typhoon Morakot could be proceed through the management. A possible measure to alleviate the loss of such compound hazard is suggested as the conclusion of this paper.

1.1 Rainfall

The most critical feature of Typhoon Morakot is the rainfall, and the rainfall is generally regarded as the major cause of the disasters. As given in Shieh et al. (2009), the characteristics of the rainfall of Typhoon Morakot are long-duration, large-extent, and high-intensity. For example, the incremental and cumulative rainfall hyetographs (Fig. 1) at the rain gauge Fenchihu show that the duration of the observed rainfall is 118 hours and the cumulative rainfall depth is 2841.5 mm. The greatest 1-hour rainfall intensity is 109.5mm/hour.

The isohyets of cumulative rainfall depth for Taiwan during Typhoon Morakot are depicted in Fig. 1. From Fig. 3, it can be found that the heavy rainfall covered whole Taiwan during Typhoon Morakot. Therefore, it is said that one characteristic of the rainfall of Typhoon Morakot is large-extent.

Storm centers can be observed in the southern area of Taiwan from Fig. 1. The locations of the storm centers have strong connections with the disasters. Most of severe disasters, including landslides and landslide dams, occurred surrounding the storm centers. Flood occurred in the downstream areas of the storm centers as well.

Fig. 1 Isohyets of Taiwan during Typhoon Morakot. Isohyets are in mm depth of total rainfall.

1.2 Flood

During Typhoon Morakot, the torrential rainfall mainly fell on the areas around the storm centers and hence the corresponding downstream areas were flooded. The most severely flood-damaged area is the southwest region of Taiwan. The flood breached levees at some places. The statistics of levee breaches is given in Table 1. Through the breaches, waters of the flood flowed into areas that were originally protected by the levees. In other places, the causes of the flood damages were complex. The causes included the lack of levees, the overtopping of levees, and the unexpected flood discharge of reservoir, etc. In addition, waters that could not be drained in time by drainage systems caused damages. It is one of the causes of the flood damages as well.

Table1 Statistics of levee breaches (Shieh et al., 2009)

Item	Length of breaches (m)	Length of damaged (m)
Levee of major River	36,242	9,590
Levee of drainage system	0	325
Sea wall	520	180

2. SEDIMENT-RELATED DISASTERS

Rainfall is one driven force for landslides and the erosion of slopes. Landslides and the erosion of slopes are sources of sediment yield. A large landslide may block the river channel and may form a landslide dam. Furthermore, the sediment yield may contaminate the water and disrupt the water supply. Landslides, landslide dams and the turbid water are regarded as the sediment-related disasters in this paper. In this section, the information of sediment-related disasters during Typhoon Morakot is given.

2.1 Landslides

During Typhoon Morakot, the torrential rainfall induced many landslides all over Taiwan. One notorious landslide is the one that occurred in Siaolin village. Over four hundred people were killed by the landslide. The location of the deadly landslide was close to the storm centers. The cumulative rainfall depth that was observed in a rain gauge near the landslide is 2,583 mm with the duration of 91 hours. Readers can refer to Shieh et al. (2009) for more information.

Landslides, which occurred during Typhoon Morakot, are recognized using satellite imageries. The result of the recognition is overlaid with the isohyets of cumulative rainfall depth (Fig. 2). It can be observed that numerous landslides occurred within the regions where the cumulative rainfall depths are more than 800 mm.

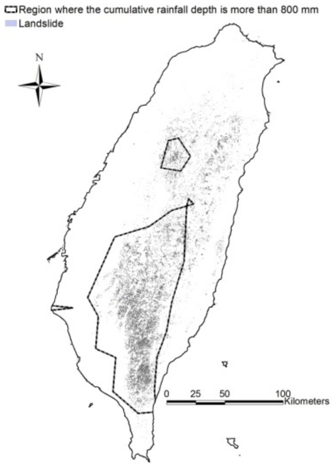

Fig. 2 Landslides within regions where the cumulative rainfall depths are more than 800 mm.

2.2 Landslide dams

Fifteen landslide dams formed during Typhoon Morakot. They were observed using the satellite imageries. The locations of the fifteen landslide dams are illustrated in Fig. 3. Most of these fifteen landslide dams spread around the storm centers. Some of them are located in the downstream areas of the storm centers. Fig. 3 also comparing the locations of the landslide dams with the isohyets. Twelve landslide dams formed in the region within which the cumulative rainfall depth is between 1,000 mm and 2,500 mm.

2.3 Driftwoods

Driftwoods are one source of damages to

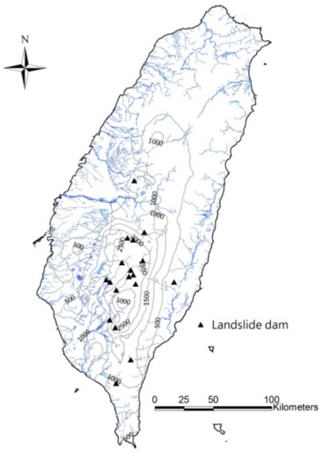

Fig. 3 Locations of landslide dams formed during Typhoon Morakot.

various facilities, such as bridges, levees, and dams. Driftwoods may collide with these facilities, and may cause disablement of them. Driftwoods in river channels may obstruct the water flow and may raise the water level of flood. The increased water level enlarges the damage of flood.

After Typhoon Morakot, many bare lands and landslides can be observed from the satellite imageries. This implies that the vegetation at these places was destroyed during Typhoon Morakot. The resulted driftwoods rolled down river channels or were probably moved to river channels by the strong surface runoff. Then the driftwoods in the river channels were flushed downstream to the sea or stopped by dams, bridges and other facilities.

From our field investigation, the driftwoods were observed in the downstream areas of the storm centers.

3. POST-DISASTERS RESCONSTRUCTION

The extremely heavy rain brought by Typhoon Morakot over the southern region of Taiwan during August 8-10, 2009 due to accompanied strong southwesterly monsoonal flow. The large extent, high intensity and long duration rainfall a caused the most serious disaster in the past 50 years in Taiwan.

Villages, roads and farms were flooded after days of incessant torrential rain. Landslides and mud flow destroyed the memorial scenery.

The characteristics of the rainfall and induced sediment-related disasters are :

(1) Large extent: large disaster area, large amount of unstable sediment.

(2) Many disaster types: different disaster types caused by different conditions.

(3) Serious impact: long period need for recovery and reaching new stability, severe management conditions.

The strategy of watershed conservation and disaster mitigation for the hazardous catchment areas of the Typhoon Morakot are list in Fig. 4. Based on the classes and items of the problems met, we list the refer solutions for the planner of the reconstruction. The phases of the reconstruction are divided into: (1) Safety homeland、(2) Infrastructures protection and (3) Conservation management.

類別 Class	項目 Item	目標 Goal	策略 Strategy	方法 Method	
坡地復育 Sloeland Conservation	土砂 Sediment 水文 Hydrology	平衡 Balance	收支平衡 Sediment Budget Balance 災害抑制 Disasters Mitigation 環境調和 Environement Harmonizing	坡面 Slope • 源頭處理 Erosion Control • 崩塌地處理 Landslide Treatment • 地滑處理 Deep-Seated Landslide countermeasure • 地表水、地下水處理.. Drainage Works	溪流 Channel •清疏 Dredging •滯洪 Detention •分洪 Diversion •沉砂 Deposition •消能...等 Slowing etc.
	生態 Ecology	多樣性 Diversity	棲地環境營造 Habitat Building 物種人工培育 Cultured Species	•棲地環境的恢復與營造 Habitat Recovery and Construction •生物庇護所的營造 Shelter Construction •必要物種的移棲與繁殖...等 Migration and Reproduction	
	景觀 Landscape	自然化 Naturalization	自然復育 Natural Recovery 人工補強 Structural Remedy	•人工植栽 Planting •自然復育...等 Natural Recovery etc.	
坡地管理 Slopeland Management	重災區 Serious Damaged	療養止痛 Healing	土地利用限制 Limitation	•水土保持特定區劃設 Specific Regulation Zoning •遙測影像變異監測 Remote-sensing Monitoring •非法使用查報取締 Illegal-use Discipline •教育宣導...等 Education etc.	
	輕災區 Lightly Damaged	休養生息 Resting	持續性監測 Monitoring		
	未受災 Non-damaged	合理利用 Utilization	常態性管理 Management		

Fig. 4 The strategy for mitigation and reconstruction of the hazardous areas.

3.1 Safety homeland

Typhoon Morakot brought record-breaking rainfall and did great damage. Many homesteads were flooded and struck by huge amount of sediment. In order to ensure life and property, relocating the residents, setting up buffer zones and constructing levees are response strategies to prevent from disaster risks. Disaster training programs are also provided to the public for disaster preparedness. Every endeavor is made to reconstruct a comfortable homestead in harmony with the nature.

The actions of the Soil and Water Conservation Bureau included took instant measures to respond the demand of villages protection and to preserve the community safety. The objectives are to prevent from secondary disaster, increase slope stability and reduce the risk potential of landslides and debris flows.

3.2 Infrastructures protection

The water receded gradually after the disaster. It takes a long time for the heavily damaged disaster area to recovery. Repair of the lifelines and linking road and some urgent works were to be done in this phase. In order to prevent from secondary hazard, further extensive reconstruction work could be done after the environment conditions have become stable.

River channels were dredged, link roads were repaired in the frame of the urgent measures. The slope and the rivers recover the stability. It is ready for homestead reconstruction. Also the time scale and spatial scale involved should be taken account to the plan (Fig. 5). For the different time scale can be considered in the infrastructures protection. In short-term case, only watershed C is considered. But for long-term consideration, A, B and C are all take account.

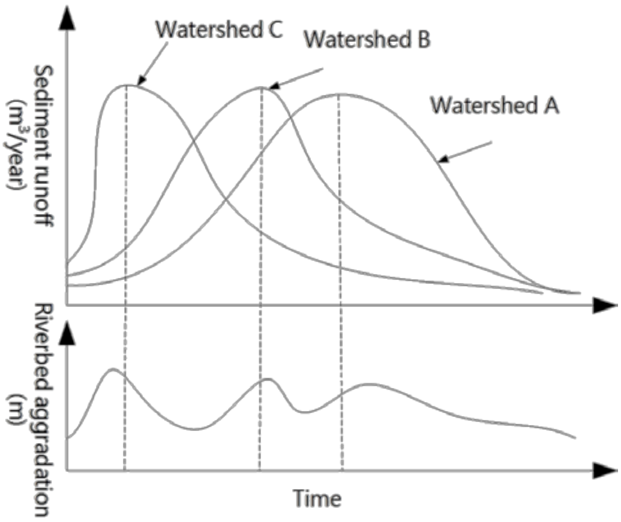

Fig. 5 The time and spatial consideration of the infrastructures protection.

3.3 Conservation management

The recovery status of a watershed could be followed by a regular "health check". According to the results, Reinforced measures should be taken for the watersheds that get worse, and maintain work should be done for improved watersheds.

The disaster area is separated in regions. The reconstruction plan is carried out in stages. The time table is then determined according to the demand of each region under the goal that the disaster area could recover from damages and retrieve its function as soon as possible.

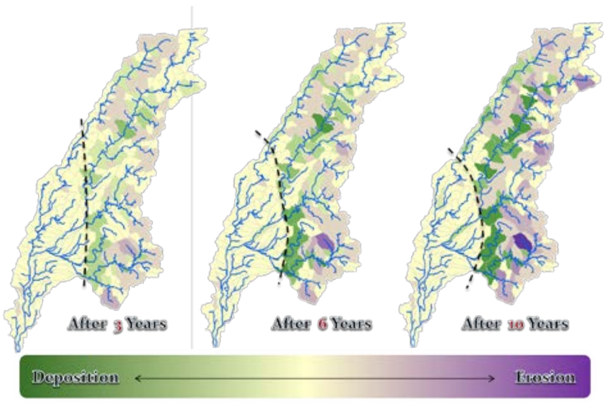

Fig. 6 The long-terms simulation of future profile of the Gaoping river basin.

4. MANAGEMENT OF THE RECONSTRUCTION

4.1 Classification of catchment areas

Based on the environment factors (landslide ratio and riverbed variation) of 88 hazardous villages in Typhoon Morakot, we carry out the characteristic analysis of the hazardous catchment areas. The results are divide into 3 classes (Fig. 7).

(1) Class 1: seriously damaged (landslide ratio＞8 %, riverbed variation＞5 m).

(2) Class 2: lifeline breakage (landslide ratio 2~8 %, riverbed variation 2~5m).

(3) Class 3: safety villages (landslide ratio＜ 2%, riverbed variation＜2m).

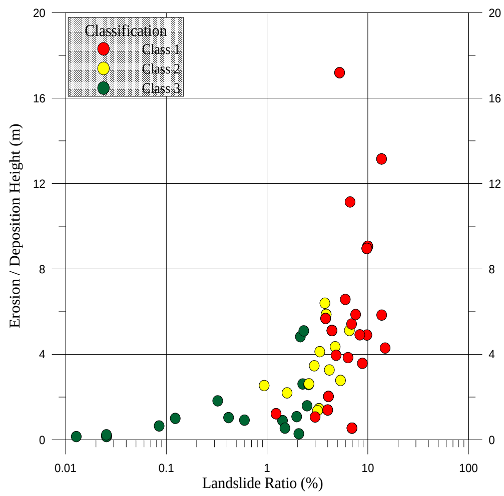

Fig. 7 Characteristic Analysis of the Hazardous Catchment Areas.

Factors	Risk:＜—Low — Moderate — High ＞		
Protection Targets	Ⅲ No village	Ⅱ Village safety/ Lifeline breakage	Ⅰ Village damaged
Landslide Ratio	3 ＜ 2%	2 2% ≦ ， ≦ 8%	1 ＞ 8%
Riverbed Variation	C ＜2 m	B 2m ≦ ， ≦ 5m	A ＞5 m

Fig. 8 Characteristic index of the risk level of the hazardous catchment areas.

4.2 Evaluation of risk level of catchment areas

We apply the seasonal check of the hazardous catchment areas, to check the processes of the recovery or degenerated of each catchment area. Also we recheck the renovation strategy by watershed damage investigation、village damage investigation、village disasters simulation and then determine the management scale for modify of the renovation strategy.

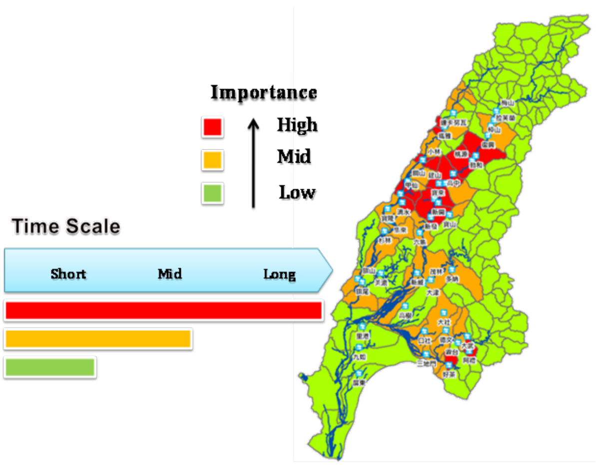

Fig. 9 The result of the evaluation of risk level of catchment areas in the Gaoping river basin.

4.3 Combination of hardware and software disaster prevention measures

Through the combination of hardware and software disaster prevention measures (Debris flow monitoring, investigation, dredging and disasters control works). Target on conservation of watershed, protection of water resources and hazard mitigation. Strategy of watershed conservation and hazard mitigation should be done by structural engineering and risk management methods. Through the PDCA cycle（Walter A. Shewhart，1980），Plan→Do→Check →Act continue to improve the techniques of the risk management.

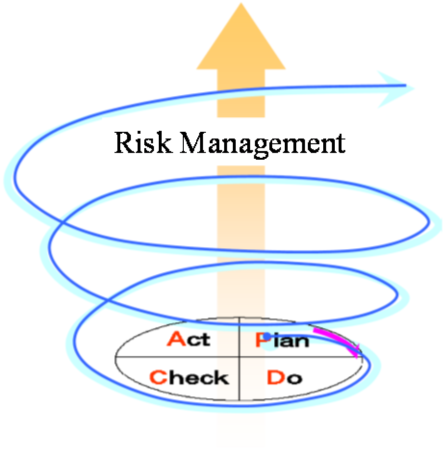

Fig. 10 The PDCA cycle for risk management (MLIT, Transport and Tourism Japan, 2008).

5. CONCLUSION

Climate changes that accompany anthropogenic global warming are a serious issue as they are projected to cause serious, large-scale adverse impacts that may even threaten people' s lives. These impacts will affect a wide range of areas as both the intensity and frequency of sediments disasters are expected to increase due to frequent heavy precipitation events, intensified typhoons.

The framework for procedures to whole watershed conservation should be develop. The strategy and adaptation measures mainly targets practitioners engaged in the basin-based management of the slope land in country.

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