Information Note 25/2022 **November 2022**

Climate Change and Extreme Landslide Events

Key Message: **In recent years, extreme weather exacerbated by climate change has brought about many disasters worldwide, causing significant casualties and economic losses. Given its hilly terrain and densely populated development, there is a risk that landslides with multiple fatalities and serious consequences may occur should Hong Kong be hit by an extreme rainfall event. Concerted efforts of the Government and the public are crucial in enhancing the community's resilience against landslide disasters and reducing the potential loss of life and damage to property.**

Introduction

After years of effort, the Hong Kong Slope Safety System is world-acclaimed and has successfully brought about a significant reduction in landslide risk in Hong Kong. However, landslide risk would progressively increase with time due to slope degradation, population growth and effects of climate change. Hong Kong is still vulnerable to severe landslides under its hilly terrain setting particularly during extreme rainfall. Therefore, the Government is sustaining its efforts on getting prepared for extreme rainfall events through taking suitable measures.

Extreme Weather Events near Hong Kong

In recent years, extreme weather events have caused significant casualties and economic losses worldwide. Annex 1 gives a list of recent extreme weather events in places near Hong Kong.

In Hong Kong, the last rainstorm that triggered landslides and resulted in fatalities occurred over ten years ago in June 2008. The record-breaking rainstorm triggering a landslide caused two fatalities. The rainstorm also resulted in more than 2 400 natural terrain landslides on Lantau Island and havoc in western Lantau. Since then, Hong Kong has not been directly hit by extreme rainfall events. Although Hong Kong was hit by two super typhoons in 2017 and 2018 respectively, which resulted in widespread damage due to flooding and tree falls, there were relatively few landslides occurred. It was by chance that the severe rain associated with these two super typhoons did not fall within the landmass of Hong Kong and thus did not bring extreme rainfall to the territory.

None of the rainstorms that prompted Landslip Warnings since 2008 had reached a landslide risk level of "Extremely high" according to the Landslide Potential Index (LPI) [1] classification. Nonetheless, the Hong Kong Observatory (HKO) has predicted that climate change would render extreme rainfall events more frequent, as well as more intense. The hourly rainfall record in Hong Kong has been broken for several times in the last few decades, whereas it used to take several decades to break the record in the past.

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[1] More information on Landslide Potential Index (LPI) can be found in GEO Information Note No. 15/2022.

Impact of Climate Change on Landslide Risk

To face the unprecedented challenge brought about by climate change and extreme rainfall, the GEO has been proactively undertaking studies to shed light on the impact of extreme rainfall on landslide risk. For this purpose, the GEO has evaluated the likely impact of credible extreme rainfall scenarios, including the June 2008 record-breaking rainstorm had it struck the densely urbanized area of Hong Kong.

Despite that the Hong Kong Slope Safety System has successfully reduced the overall risk of landslides in Hong Kong to an "as low as reasonably practicable" level, the results of the study indicate that if the June 2008 rainstorm is to come again and strike the densely urbanized area of Hong Kong, several hundred severe landslides particularly debris flows on natural hillside would occur. The landslides could block roads, damage buildings and affect other important facilities, and the occurrence of large-scale and severe landslides resulting in multiple casualties and significant economic losses could not be ruled out. Even worse, if an extreme rainfall event like those that affected other parts of the world in recent years hits Hong Kong (e.g. Typhoon Morakot that hit Taiwan in 2009), several thousand severe landslides would occur.

Although the landslide threat brought about by extreme rainfall cannot be entirely avoided, it is imperative that Hong Kong maintains highly vigilant, learns from the past and gets prepared to deal with the challenge in order to minimize the potential loss of life and damage of property to the lowest possible.

Preparedness for Increasing Landslide Risk Due to Climate Change

The Government has formulated strategies to prepare Hong Kong for the ever-increasing threat of extreme landslide events brought about by climate change. In this regard, the GEO has adopted a multi-pronged approach in managing the landslide risk associated with extreme rainfall events due to climate change. The approaches include:

(i) Enhancement of Robustness of Slopes

(ii) Upgrading Emergency Response Capability

(iii) Improving the Community's Resilience

Enhancement of Robustness of Slopes against Extreme Rainfall

The GEO launched the Landslip Prevention and Mitigation Programme (LPMitP) in 2010 to manage the landslide risk of both natural hillside and man-made slopes in a more holistic manner. Natural terrain landslide hazards are usually dealt with by risk mitigation measures such as construction of concrete rigid barriers or steel flexible barriers at the hill toes to prevent debris from impacting on house or roads and resulting in casualties. The GEO also endeavours to enhance the prevailing slope engineering design standard and practice to strengthen the slope robustness against extreme rainfall events, in order to reduce the probability of occurrence of severe landslides. Examples are use of soil nails to enhance the ductility of slope, improvement of slope drainage to cater for the increased precipitation due

to extreme rainfall events, and use of innovative technology to regulate the regional groundwater.

Upgrading Emergency Response Capability to Cope with Extreme Landslide Events

Given that the forecast of climate change effects bears many uncertainties, it is neither practical nor cost-effective to rely solely on engineering solutions to manage the risk of extreme rainfall events. Thus, enhancement of the Government's emergency response capability is essential. The Government has put in place a Contingency Plan for Natural Disasters to ensure that all departments concerned will respond quickly and effectively in a coordinated manner to deal with emergency situations. If needed, the Emergency Command System will be triggered to pool together all emergency works resources within the Government to allow a well-coordinated effective and prompt response to deal with extreme landslide scenarios. The GEO also assists in developing and managing the "Common Operation Picture" to facilitate real-time sharing of emergency information (such as on landslide, flooding, etc.) among various departments. Training events and operational drills are conducted to ensure adequacy and effectiveness of the Plan.

The GEO maintains a 24-hour year-round landslide emergency service to advise Government departments on actions to be taken in case of danger arising from landslides. The landslide emergency service has played a significant role in keeping public away from landslide danger and thereby reducing landslide risk. When the Landslip Warning is in force, the GEO operates an Emergency Control Centre and keeps vigilant of the weather condition. When it is predicted that many landslides will occur based on recorded and forecast rainfall, the GEO will put in place the contingency provision which include deployment of additional dedicated teams to conduct follow up inspection of major landslide events. The GEO has introduced virtual reality training to further enable their geotechnical engineers to deal with severe landslide incidents.

The GEO has also explored using new technology to strengthen its emergency response capability. For example, a landslide detection system, namely "Smart Barrier", has been developed using novel Internet of Things technology to monitor the condition of landslide debris-resisting barriers. The Smart Barriers could continuously monitor the condition of the barriers and provide alerts to the GEO via mobile application in the event of any accumulation of landslide debris, which may forewarn the occurrence of major debris flow and hence allow a timely emergency evacuation of nearby people to minimize any possible casualties.

Improving the Community's Resilience against Extreme Weather

Despite the enhancements made to landslide emergency preparedness, there is still a limit to the Government's emergency capacity. It is therefore paramount for the general public to work with the Government in emergency situations by taking necessary personal precautionary measures. When natural disaster occurs and before the arrival of responders, the public may follow simple and pragmatic self-help tips to protect themselves and minimize damages and avoid casualty.

The key messages to the public are simple and effective. The public should always remain vigilant about the warnings and advice issued by the Government during severe rainstorms. When the Landslip Warning is in force, or during heavy rainfall, the public should stay away

from slopes and watch out and report to the police for signs of landslide danger. Pedestrians should avoid walking along or standing close to steep slopes. Motorists should avoid driving in hilly areas or along roads with landslip warning signs, or parking their vehicles in front of slopes. For buildings close to slopes, residents should stay in rooms on higher floors and/or furthest away from slopes. It is essential for citizens to follow the instructions of the rescue personnel strictly and act promptly. If asked to evacuate, the public should leave immediately and should not re-enter those areas that have been cordoned off.

Although severe landslides arising from extreme rainfall events cannot be precluded, the concerted efforts of the Government and the public could enhance our resilience against landslide disasters and reduce loss of life and damage to property to the lowest possible level.

Geotechnical Engineering Office
Civil Engineering and Development Department
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Annex I: Extreme weather events near Hong Kong in recent years

Event 1 - Typhoon Morakot struck Taiwan in August 2009

Typhoon Morakot made landfall in Taiwan around midnight on 8 August 2009. Almost the entire southern region of Taiwan and parts of Taitung County and Nantou County were flooded by record-breaking heavy rain. The rainfall in Pingtung County exceeded 2 600 mm, breaking all rainfall records of any single place in Taiwan induced by a single typhoon. The entire village of Xiaolin was buried in the southern county of Kaohsiung killing 439 people. Airlines were affected and seaports were closed. Electricity supplies to approximately 25 000 homes were cut. The reported death toll exceeded 600 and economic loss amounted to about HK$3,500 million.

Event 2 - Torrential rain struck South Korea in July 2011

Torrential rain hit Seoul, South Korea on 27 July 2011. The rainstorm, which was estimated to have a 100-year return period, had brought about 500 mm rainfall within three days, resulted in widespread flooding and landslides. Significant traffic disruptions also resulted. There were more than 30 reported fatalities and about HK$1,600 million economic loss.

Event 3 - Typhoon Usagi struck Guangdong, China in September 2013

When Typhoon Usagi was approaching southern China, heading direct to Hong Kong, it was described as being the region's most dangerous storms in three decades. It made landfall at Shanwei, Guangdong on 22 September 2013, passing Hong Kong to its north as it weakened. Throughout Guangdong, at least 15 000 homes were destroyed, 152 000 hectares of crops were lost and more than 30 fatalities were reported. Total economic loss in the province reached HK$22,300 million.

Event 4 - Typhoon Wipha struck Japan in October 2013

Typhoon Wipha dumped very heavy rain in many areas of eastern Japan, when it traversed in a north to northeasterly direction on 15 October 2013. An hourly rainfall of 100 mm and a 24-hour rainfall of 824 mm were recorded. Heavy rain spawned a massive landslide on the island of Izu Ōshima, killing at least 31 persons and leaving 13 others missing. At least 350 homes were destroyed throughout Japan. Total reported death toll exceeded 40 and economic loss amounted to about HK$800 million.

Event 5 - Typhoon Haiyan struck the Philippines in November 2013

Typhoon Haiyan brought disastrous damages to the Philippines on 7 November 2013. It made landfall in Guiuan, Eastern Samar at peak intensity with sustained winds of about 230 km/h with storm surges reaching about six metres. Haiyan was one of the most powerful storms to strike land. The typhoon and storm devastated the middle Philippines as it passed. It destroyed tens of thousands of houses, brought a reported death toll of more than 6 000 and an economic loss of about HK$6,900 million.

Event 6 – Torrential rain struck Japan in August 2014

Torrential rain slammed into the outskirts of Hiroshima, Japan on 20 August 2014. The high intensity and short duration rainstorm (over 200 mm of rain in three hours, which was exceeding twice the monthly-average for the area) triggered widespread landslides and debris flows leading to a total death toll of 74 and havoc in Hiroshima and the evacuation of up to 100 000 people.

Event 7 – Typhoon Hato struck Guangdong in August 2017

Typhoon Hato passed Hong Kong to its south and made landfall near Zhuhai city, Guangdong on 23 August 2017. Hato caused severe storm surge to the coast of Pearl River estuary and widespread flooding, blackouts and destruction in Guangdong and Macao. At least 25 fatalities were reported, over 6 500 homes were destroyed and about HK$40,000 million economic loss was amounted in Guangdong and Macao.

Event 8 – Torrential rain struck Japan in July 2018

The record-breaking rainfall caused by a seasonal rain front with about 1 000 km stretch from west to central Japan and remained stagnant between June 28 and July 8 resulted in widespread and devastating floods, landslides and debris flows. The total reported death toll exceeds 225 across 15 prefectures. More than eight million people were advised to evacuate across 23 prefectures and the economic loss amounted to about HK$160,000 million.

Event 9 – Typhoon Mangkhut struck Philippines and Guangdong in September 2018

Typhoon Mangkhut made the first landfall in the northern part of Luzon of Philippines on 14 September 2018 and weakened after crossing. Mangkhut continued to track northwestwards towards the coast of Guangdong, and made another landfall in the vicinity of Taishan of Guangdong on 16 September 2018, passing Hong Kong to its southwest. Torrential rains and squalls to Luzon caused at least 82 fatalities and destroyed about 15 000 homes. Mangkhut brought damaging winds and severe storm surge to the coast of Pearl River estuary, resulting in damages of many structures along coastal areas and serious inundation of low-lying areas.

Event 10 – Torrential rain struck Japan in July 2020

The record-breaking rainfall struck west Japan, covering Kyushu, Shikoku and Honshu, and remained stagnant between July 3 and 31, resulting in widespread and devastating floods, landslides and debris flows. The total reported death toll exceeded 86 across 33 prefectures.

Event 11 – Torrential rain struck Henan in July 2021

The record-breaking extreme rainfall struck Henan province, including Zhengzhou, between July 17 and 23 resulted in widespread and devastating floods, landslides and debris flows. More than 14 million were affected across 150 cities / districts. The total reported death toll and missing exceeded 398 and the economic loss amounted to about HK$ 147 billion.