Emergency Investigation and Assessment 2022 Pakistan Flood

Investigation Briefing

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The Disaster-causing Factor in the Alluvial Plain along the Lower Indus River of Southern Pakistan — Topography

Pakistan is located at the junction of the Eurasian and Indian plates and the western Himalayan tectonic knot and the intersection of the three major mountain system(i.e., Himalayas, Hindu Kush and Karakoram). Due to plate collision and the gradual uplift of the Tibetan Plateau, Pakistan is characterized by extremely high mountains in the north, alpines in the west, plains and hills in the central and deserts in the south. The special topography superimposed with the Indian monsoon climate has led to the recent high frequency and extreme rainfall in Pakistan. The large-scale floods from the northern mountainous areas that rushed into the downstream alluvial plain were the decisive factors for this catastrophic flood disaster.

1. Under the abnormal monsoon climate, the extreme rainfall and special topography result in excessive flooding

The warm-wet currents controled by South Asian summer moonson from the Indian Ocean gradually move northward. Due to the special topography, the airflow density increases and the subsidence effect occurs due to the radiation cooling effect in the northward process, forming a subtropical high-pressure

area at the junction of Sindh and Baluchistan. Therefore, southern Pakistan has more rainfall with the cooling and sinking of warm-wet airflows and increasing of density. Near the subsurface, the sinking airflow gradually flows northward under the horizontal pressure gradient. With the rapid uplift of topography from south to north, some piedmont zones are featured with topographic rain. And this flood in Pakistan, in the text of the continuous high temperature and drought in the same latitude area of the world, results from the abnormal Indian Ocean summer monsoon, which carries a large amount of vapor to the north, causing extreme heavy rain in the southern plains and forming storm centers in the central and northern parts. To sum up, it is the abnormal monsoon climate and "trumpet mouth" topography that has caused this prolonged and massive rainfall of more than 500mm from July to August 2022, more than five times the average annual precipitation in southern Pakistan.

2. The topographic feature of the lower Indus floodplain is high in the east and low in the west, and the meandering channel wandering aggravates floods.

The lower Indus River is an alluvial plain with gentle topography, where hyper-concentrated flow is easy to have sediment accumulation. It led to meandering channle wanderings and poor flooding capacity. The extreme rainfall caused widespread flash floods in the northern mountainous regions, which in turn caused extraordnary floods along the Indus River, resulting in a flow surge and making the downstream wide and shallow wandering channels extremely vulnerable to flood. The LARKANA floodplain is the worstest flooded area. Satellite images from 25 August to 31 reveal that the western flooded area (black area) of the LARKANA floodplain accounts for a larger area than the eastern one, while the eastern region with slightly higher topography (green background) accounts for a smaller flooded area, with an east-west slope of about 1-1.5% and a north-south slope of 0.2‰ (Figure 1).

The three cross sections reflect the topographic characteristics of lowland terrain: high in the east and low in the west. At the same time, the low-lying areas in the west have been significantly lower than the Indus River channel, with a suspended driver development process and trends, which is very likely to cause the river to lose the banks' impediments and flood. Take the Sukkur to Larkana as an example. As shown in Figure 2, there were abandoned channels of the Indus River before the floods, but these channels were submerged after the river level rose. During the flood peak, the river reached the widest state. It formed point bar deposits in meander channels, further aggravated the wide shallow lower Indus River valleys and river wandering and increased the potential disaster risk during major floods. It can be concluded that the suspended river in the alluvial plain of the lower Indus River and the meandering channel wanderings aggravated the floods in Sindh province, southern Pakistan.

In summary, this catastrophic flood disaster in Pakistan was formed by a combination of extreme rainfall triggered by abnormal southern Asian summer monsoon, the special topography of northern Pakistan, and the wide and shallow wandering valley of the lower Indus River.

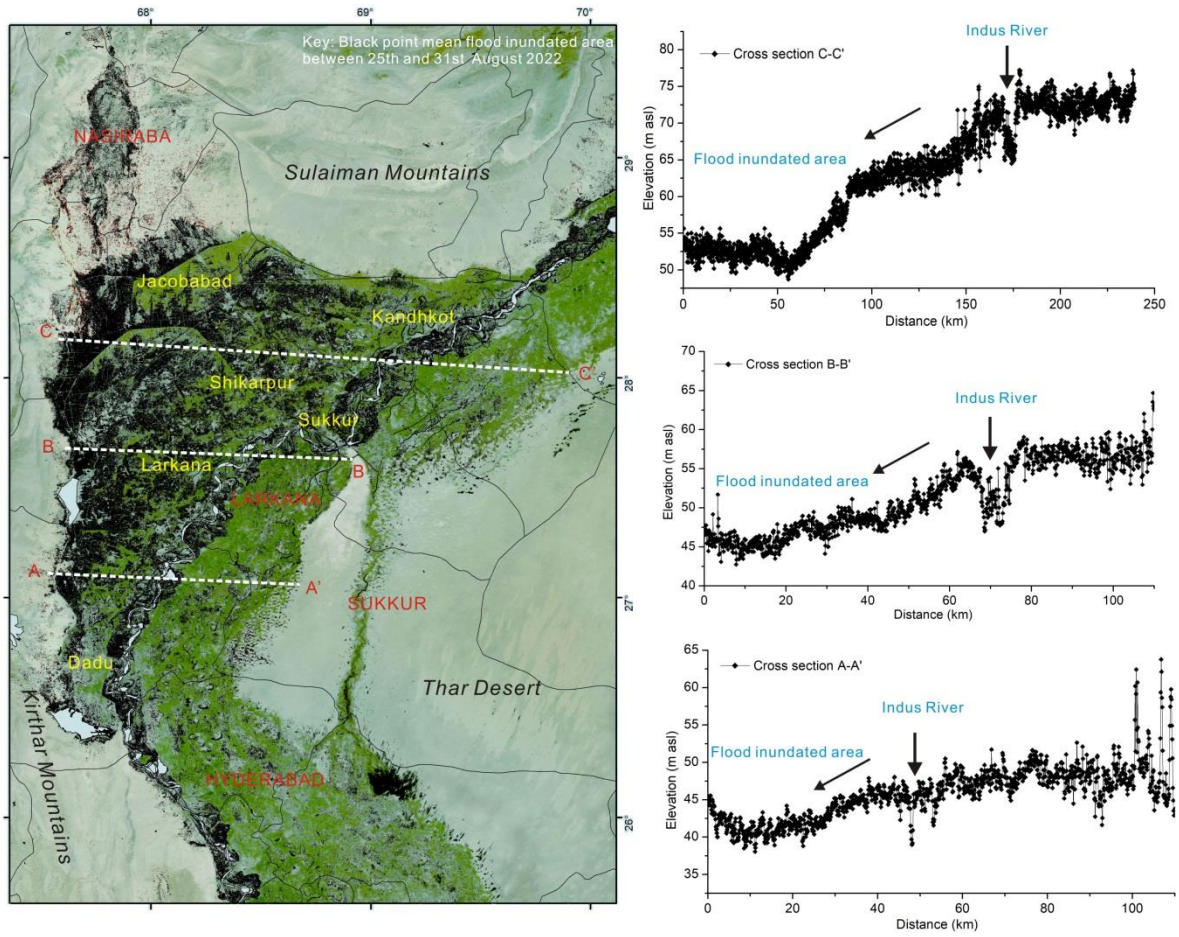

Figure 1. Topographic features of the 'high east and low west' of the lower Indus River （LARKANA floodplain）in southern Pakistan

Figure 2. Meander channels wanderings and floodplain deposits in the Sukkur-Larkana Section (pre-flood, 4 and 28 August; images from USGS and NASA)

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