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1. Introduction

Asia is one of the world's most flood-prone regions by many metrics: high flood magnitudes, frequency, severity; the number countries affected, the area of inundation; the number of people at risk; and importantly, flood-related fatalities (AIR, 2014; Luo, Maddoks, Iceland, Ward, & Winsemius, 2015; Table 1). With respect to mortality, nearly all the countries with more than 5,000 flood-related deaths since 1985 are from Asia (11 of 13; Table 1; Figure 1). As we write this commentary, flooding associated with tropical storm Nangka has caused more than 40 deaths in Laos, Cambodia, and Vietnam (Floodlist, 2020).

Elevated mortality in Asia results, in part, from the extreme nature of the storms that trigger floods in most locations. The bulk of the staggering death toll in some countries occurred during a single catastrophic event: for example, Bangladesh, Myanmar, and Thailand (Table 1). High mortality is also related to the substantial exposure of people living near rivers and the coasts (Bangalore et al., 2019; Chen et al., 2020). The World Resources Institute (Luo et al., 2015) lists India, Bangladesh, China, Vietnam, Pakistan, and Indonesia as the top six countries with the greatest number of people exposed to river floods in the world (635,000–4,835,000). Urban exposure in SE Asia stems from the historical affinity and necessity to build close to the water, then rapidly urbanize around these areas in recent times (Hill, Chean, & Hicks, 2017; Ng, Wood, & Ziegler, 2015). Jakarta and Bangkok are two examples of low-elevation coastal cities suffering from flooding due to uncontrolled urban development on deltaic floodplains of large rivers. The Indonesian government's proposed migration of its administrative functions from Jakarta to Borneo, in response to recurrent flooding, land subsidence, and crowding, will cost approximately USD31.5 billion (Figure 2a; Indonesia announces site of capital city to replace sinking Jakarta). Recent political discourse hints that Bangkok may address its flooding issues by following Jakarta's lead of moving elsewhere. One response to reduce flood risk and its impacts has been the heavy investment in flood defence infrastructure (dams, levees, barrages, canal systems). However, this approach has resulted in limited success. Classic examples include recurrent flooding on the modified Chao Phraya River in Thailand and the tributaries of the Ganga river system draining from Nepal to India (Singh, 2015; Ziegler, Lim, Tantasarin, Jachowski, & Wasson, 2012). Jakarta still floods despite the vast number of policies and projects aimed at flood mitigation (van Voorst, 2016). Even the huge investments in Singapore and Hong Kong have not cured all flooding, though mortality is practically nonexistent because floods tend to be localized and small (Chan et al., 2018). For very large floods, engineering alone has rarely been an effective approach to eliminating impacts and risk. These are contemporary problems that are common in other large coastal Asian cities, including Hong Kong and Ho Chi Minh City, and that require attention given that urban development will certainly continue. We explore the idea that flood-related mortality from river overbank flows in the SE Asian region could be reduced by incorporating evidence from the past to foster a better understanding of the realm of plausible flood regimes, and hopefully guide improved flood hazard management practices in the future (Lebel, Manuta, & Garden, 2011).

1.1 Estimating flood magnitude and frequency

Flood frequency analysis (FFA) is an empirical technique to predict the probability of river flows based on a probability density function fit to a dataset of flood magnitudes. The degree of fit is evidence of model veracity, despite a lack of knowledge of causal meteorological phenomena and their interactions with hydrological processes that

TABLE 1 Countries worldwide with more than 5000 flood-related deaths (1985-2020); number of people exposed to flooding; and exposure rank

Country	Region	Estimated deaths	Number of floods	Exposed population (millions) | World rank in ()	Note regarding deaths
Thailand	SE Asia	163,893	75	0.25 (12)	160,000 during 2004 tsunami
Bangladesh	South Asia	150,871	96	3.48 (2)	138,000 during 1991 cyclone
Myanmar	SE Asia	100,382	27	0.39 (8)	100,000 during 2008 tropical storm Nargis
India	South Asia	53,680	269	4.84 (1)	Multiple storms and cyclones
China	East Asia	32,219	361	3.28 (3)	Heavy rains
Venezuela	South America	20,336	27	0.02 (67)	20 006 during a 1996 storm
Philippines	SE Asia	19,974	193	0.18 (16)	Tropical cyclones dominate
Honduras	Central America	11,411	19	0.01 (84)	11,000 during 1996 storm
Japan	East Asia	11,099	71	0.09 (31)	10,000 during 2011 tsunami
Pakistan	South Asia	10,823	74	0.71 (5)	Heavy monsoon rains
Vietnam	SE Asia	5,870	119	0.93 (4)	Multiple storms and cyclones
Indonesia	SE Asia	5,233	215	0.64 (6)	1,173 during tsunamis in 2011 and 2018
Afghanistan	South Asia	5,032	79	0.33 (9)	3,000 during 1992 storm

Note: Mortality and flood number data (until 19 October 2020) are from the Dartmouth Flood Observatory (https://floodobservatory.colorado.edu/). Exposure data are from the World Resource Institute Aqueduct project (https://www.wri.org/blog/2015/03/world-s-15-countries-most-people-exposed-river-floods). Deaths for Cambodia and Laos (both not listed), Thailand, and Vietnam are some what uncertain as a flood affecting more than one country is assigned to one primary country in the database; the same is true for Myanmar and India.

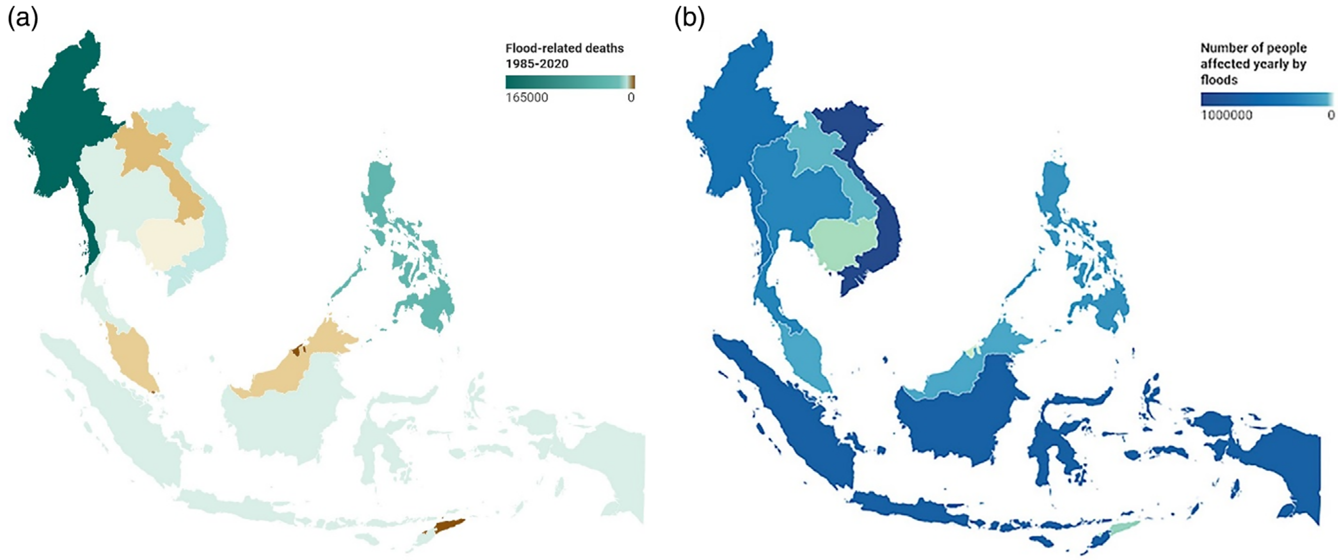

FIGURE 1 Country-wide comparison of flood exposure in SE Asia. (a) Deaths from floods excluding tsunamis (data from the Dartmouth Flood Observatory, 2020); (b) number of people ‘affected’ by floods yearly (data from the WRI Aqueduct project, 2015)

control flood size and frequency (Hubert, Tchiguirinskaia, Schertzer, Bendjoudi, & Lovejoy, 2007; Wasson, 2016). A complicating issue is that the clustering of flood events negates the statistical stationarity assumptions behind traditional FFA (Milly et al., 2008). Hydrologists are currently examining the effects of non-stationarity on flood magnitude estimates (e.g., Machado et al., 2015; Šraj, Viglione, Parajka, & Blöschl, 2016) and finding new ways of dealing with it in FFA, for example by using mixed distributions (e.g., Li et al., 2018). Further, FFA is fundamentally hindered because it is often based on short hydrological records that cannot take into account the full range of floods that are plausible on a river system as evidenced by the past (Parkes & Demeritt, 2016). Most gauging stations in developing countries have records between atmost 30 and 90 years in length, resulting in very uncertain flow magnitude estimates for large floods (Lim & Boochabun, 2012; Loebis, 2002).

In SE Asia, river floods are triggered by anomalous extreme monsoon rainfall patterns as well as intense tropical storms that originate from the South China Sea and the Indian Ocean (Lim &

FIGURE 2 (a) Flooding on the Ciliwung River in Jakarta; (b) Palaeoflood slackwater couplets on the Zanskar River, Ladakh, between 13 and 9 ka BP (Sharma et al., unpublished); (c) contemporary photo of the historical Khmer capital Ang Kor, which is believed to have fallen, in part, because of inability of the water infrastructure to cope with water-related hazards including floods and droughts (Buckley, Fletcher, Wang, Zottoli, & Pottier, 2014; Day et al., 2012; Penny et al., 2018); (d) ruins of the former Lanna capital city Wiang Kum Kam, in northern Thailand. The city was eventually abandoned completely sometime between 1,477 CE and 1,512 CE following a catastrophic flood that caused the Ping River to change its course (Ng et al., 2015). Photo credits: (a) # 168352391 Runvillage | Dreamstime.com. All other photos belong to one of the authors

Boochabun, 2012). Nearly 25% of the floods occurring in SE Asia between 1985 and 2018 were associated with tropical storms; these types of floods tend to have higher mortality than those generated by other mechanisms (Chen et al., 2020; Table 1). The largest contemporary flooding mortality in the region was an estimated 100,000 deaths in Myanmar when tropical storm Nargis made landfall in 2008. For comparison, casualties totalling 160,000 in Thailand in 2004 resulted from storm surges during the Great Indian Ocean tsunami (Table 1). We view tsunami-induced floods as exceptional types of deadly maritime events that are not the focus of our argument.

The phases of ENSO, the Indian Ocean Dipole (IOD), and the Pacific Decadal Oscillation (PDO) all influence the strength and occurrence of the monsoons and tropical storms in SE Asia. In a recent analysis, the reconstruction of 800 years of streamflow in several rivers by Nguyen, Turner, Buckley, and Galelli (2020) was useful in showing that streamflow in Monsoon Asia is spatially coherent, with concurrent high/low flow episodes in adjacent basins because ENSO, IOD, PDO, and tropical Atlantic sea-surface temperatures are common drivers. Collectively, the effect of these phenomena, often in tandem, vary in location, magnitude and timing, such that extremes are not likely captured in short flow records. The importance of accurate flood prediction is made clear by simulations indicating that large floods of 100-year return periods could increase in probability from 1% to 2–20% throughout the SE Asia region in the future (Hirabayashi, Mahendran, Koirala, et al., 2013). While informative for planning, the analysis has inherent uncertainty because the magnitudes of most floods of 1% probability were determined from short data records.

To extend the hydrological record for FFA, non-traditional sources of information such as palaeohydrological and historical records are increasingly used in other parts of the world, including Europe and the United States, through programmes such as

FLOODRISK and SPHERE (Brázdil et al., 2006; Kjeldsen et al., 2014). Studies have often determined that at least some of the palaeofloods in the study areas had higher flood magnitudes than those in the modern gauged record. Further, the inclusion of these data improved flood estimates, reduced uncertainty, and allowed for better estimates of flood risk (e.g., Lam, Thompson, Croke, Sharma, & Macklin, 2017; St. George & Muldelsee, 2018). For example, after extending gauged flow records for the River Ouse (UK) with information from historical maps and epigraphic markings, MacDonald and Black (2010) showed that five of the 11 new flood events were larger than the most extreme event in the modern gauged record. Similarly, Zawada, Hattingh, and Van Bladeren (1996) used palaeoflood deposits to show that the largest gauged flood on the Orange River in South Africa had been exceeded by floods in the past 5,500 years by as much as 2.7 fold. To our knowledge, these types of approaches have rarely been applied in Southeast Asia, despite knowledge of large past floods.

1.2 | Palaeo-historical information

Palaeohydrological information refers to physical evidence left in the landscape by floods (Figure 2b), including sedimentary archives in lakes/reservoirs, floodplains, and slackwater deposits in stable river sections that provide information on flow velocities/energy of past flood events (Patton, 2013; St. George, Hefner, & Avila, 2020). This information is used in hydraulic models to estimate the extent of flood inundation. Other useful indicators include tree rings, lichens and speleothems, which when dated allows the reconstruction of past wetness regimes and provides clues about the frequency and magnitude of ancient floods (Benito & Díez-Herrero, 2015). Historical documents include newspapers, field reports, correspondence, photographs, oral histories and ancient texts that supply information including the magnitude and timing of flood events, damages, aid provided, as well as the physical and socio-economic context (Brázdil et al., 2006). Together, a variety of palaeo-historical records can extend the hydrological flood record, allowing comparison between the largest gauged floods and those from the past.

The wealth of historical documents and ancient chronicles from the SE Asian region have been useful for revealing the dates of some past floods. For example, historical documents indicate severe, pre-record floods occurred twice in Malaysia (1847 and 1926) and in Singapore in 1846, 1855, 1881, 1884, 1892, 1899, and 1925 (Williamson, 2016). In Thailand, the Prime Minister's office record collection at the National Archives preserves documents relating to some of the city's worst floods of the twentieth century, including in 1917, 1933, 1939, and 1942 (Vinasandhi, unpublished). Some of the oldest SE Asian examples are the passages in the *Chiang Mai Chronicle* and the *Lanna Chronicle* describing recurrent floods in the ancient capital Wiang Kum Kam, ca. AD 1283/84 (Ng et al., 2015). Other historical texts include the *Cambodian Royal Chronicles*, *Đại Việt sử ký toàn thư* (The Dai Viet History Full Book), *Đại Nam Thực Lục* (Chronicle of Greater Vietnam), and the *Kengtung Yazawin* (Padaeng Chronicle and the Jengtung State Chronicle).

The palaeo-historical record in SE Asia has shown that the success and failure of some ancient civilisations have been tied to regional wetness regimes (Lieberman & Buckley, 2012). In the case of Ang Kor in Cambodia (Figure 2c), failure to maintain and manage an ageing water management infrastructure, affected by floods and droughts, was a major factor in the demise of the great Khmer civilisation (Buckley et al., 2014; Day et al., 2012; Penny et al., 2018). Elsewhere, sedimentary records, combined with archaeology and historical documents, show that an avulsion of the Ping River during an extreme flood influenced the abandonment of Wiang Kum Kam between 1477 and 1512 AD, even though the city was likely well-equipped to cope with floods via architectural and societal adaptations (Ng et al., 2015; Figure 2d). Investigations show that other Thai rivers (Mekong, Mun, and Yom) have avulsed or migrated laterally during extreme flood events in response energy regimes that have not occurred for floods in the contemporary record (Bishop & Godley, 1994; Kidson, Richards, & Carling, 2006; Wood, Ziegler, & Bundarnsin, 2008; Yang, Grote, & Zhang, 2019). Flood deposits on a tributary of the Ping indicated a flow volume greatly exceeding any discharge value measured on the main channel (Kidson et al. (2006). This historical information foreshadows that future migrations/avulsions would likely be catastrophic because of recent floodplain development and flow pathway modification that influences the extent and time floodwaters impact an area (Wood & Ziegler, 2008).

Palaeo-studies have provided information that increases our understanding of the drivers of past SE Asian floods, including ENSO, IOD, and PDO (D'Arrigo et al., 2011; Ummenhofer, D'Arrigo, Anchukaitis, Brendan, & Cook, 2013). For example, Nguyen and Galelli (2018) reconstructed annual streamflow for the Ping River using the Monsoon Asia Drought Atlas gridded PDSI dataset to identify several prolonged historical 'pluvials' and droughts in Thailand. Xu et al. (2019) used a 202-year tree ring record to determine that ENSO and the PDO interacted to create periods when extreme events, including floods, occurred on the Chao Phraya River in Thailand. Sediment deposits from a small lake in East Java (Indonesia) revealed a linkage between ENSO and 50 major flood events in the past 1,000 years (Rodysill et al. (2019). The results of these reconstructions portend a potential increase in flood events in the future, depending on how these large-scale climate phenomena are affected by climate change (Cai, Sullivan, & Cowan, 2009; Perry, Mcgregor, Gupta, & England, 2017; Zhang & Delworth, 2016). Further, the streamflow reconstructions provide an extended flow dataset ranging from 247 to 800 years in length to test and improve FFA methods (D'Arrigo et al., 2011; Nguyen et al., 2020; Nguyen & Galelli, 2018). Finally, New research on the Ping River in northern Thailand, however, has revealed that a flood in 1,831 CE enlarged the channel with a bankfull discharge (not including overflows) of 11,000 m^3/s, a rate that is larger than the maximum flow ever gauged in Chiang Mai by more than an order of magnitude (Wasson, unpublished). We argue that more palaeo-historical data of this nature should be incorporated into FFA to reduce loss of lives and the economic burden of flooding in the region.

1.3 | The dam problem

One contemporary concern relates to how over-reliance on flood defence infrastructure may amplify flood magnitudes (Lebel et al., 2012). In the United States, for example, flood defence structures on the Lower Mississippi River increased the 100-year flood by 20% over the pre-1800 period when human impacts on the landscape were small (Munoz et al., 2018). In SE Asia, dam building on many rivers has reduced the risk of floods, yet dams potentially create a false sense of security that catastrophic flood risk is eliminated (Lempérière, 2017; Newell & Wasson, 2002; Ziegler, Lim, Jachowski, & Wasson, 2012; Ziegler, Lim, Tantasarin, et al., 2012). The case of the dam and reservoir built in Mozambique on the Cahora Bossa, the third largest river system in Africa, provides some insight on the dangers of making this type of assumption (Isaacman, 2005). The somewhat predictable large floods that occurred prior to the construction of the dam were eventually replaced by disastrous floods triggered when water was released during large floods to prevent the dam from overtopping. In Asia, the 2005 floods in Chiang Mai were exacerbated by the inability to release enough water from upstream reservoirs prior to extreme rainfall events associated with Typhoon Damrey that tracked over the continent (Wood & Ziegler, 2008).

The most deadly recorded flood in Laos resulted from a dam failure in 2018, killing more than 70 (International Rivers, 2019). A largely unknown disaster – the third most deadly flood in history – occurred in 1975 when the Banqiao Dam in Henan China failed, killing 85,000 people during the initial breach; ultimately as many as 230,000 perished through flooding, famine and disease (Xu, Zhang, & Jia, 2008). The flood trigger was the blocking of typhoon Nina by a cold front, an extreme phenomenon that produced a year's total of rainfall in 24 hr (Higginbottom, 2019). A similar consequence nearly came to fruition in 2020 when Three Gorges Dam reservoir was on the verge of breaching (Figure 3). Critical in the discussion of the role of dams in mitigating/exacerbating floods is that the design storage limits of reservoirs/dams likely prevent them from being able to hold the waters of enormous floods resulting from extreme, widespread rainfall (Lempérière, 2017). Dams and reservoirs must therefore be designed to withstand extreme flows from upstream flooding: palaeo-historical flood information of past flood discharges is useful in this process, again by augmenting short gauged flow records.

Although, some of these examples are from outside the region, they are relevant to our message given the momentum to increase hydropower generation by building dams on large SE Asian rivers including the Mekong, Salween, and Ayerawaddi (Hecht, Lacombe, Arias, Dang, & Piman, 2018; Middleton, Scott, & Lamb, 2019; Taft Linda, 2016). Despite the alteration of natural flows, we argue that new knowledge of past floods on dammed rivers is still important for understanding the magnitude of plausible catastrophic floods.

FIGURE 3 The Three Gorges Dam Reservoir approached maximum storage in August 2020 after receiving near-continuous inflow of 75,000 m^3/s for about 1/3 a day (CGTN, 2020). The high flows were the result of flooding in the upper reaches of the Yangtze River. The widespread flooding was described as the worst in about 40 years. Extreme discharges on the Yangtze at Yichang of $\sim$71,000 m^3/s were recorded in 1896 and 1981. Part of the motivation to build this dam was the flood of 1954 where 33,000 people died, many perishing from disease. Photo: 10724842 Kun Yang | Dreamstime.com

Improved estimates of flood magnitudes will aid flood mitigation and adaptation work, including the design of safe dams and the accurate delineation of flood risk areas. The result should be fewer lives lost and lower financial burden.

2 | CONCLUSION

We believe that Southeast Asia should look more to the past in an effort to prevent unnecessary casualties during future floods. We argue for the incorporation of palaeoflood information, palaeoclimate reconstructions, and historical information with modern gauged data to improve FFA to guide flood risk reduction policy and actions. The inclusion of palaeo-historical information allows for more robust estimates of flood magnitudes with lower uncertainties to use in a multitude of applications including the design of flood defence infrastructure, urban planning design and governance for flood-risk reduction. This comprehensive approach will increase the region's resilience to changing flood risks related to uncontrolled urbanization, the unpredictability of tropical storms, and the influence of climate change. Looking to the distant past allows for better flood forecasting when extreme rainfall can be tied to the somewhat predictable phases of large-scale climate phenomena.

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REFERENCES

AIR. (2014). Flood: Mapping flood-prone areas in SE Asia. Retrieved from https://www.asiainsurancereview.com/Magazine/ReadMagazineArticle?aid=34926

Bangalore, M., et al. (2019). Exposure to floods, climate change, and poverty in Vietnam. *Economics of Disasters and Climate Change*, *3*, 79–99.

Benito, G., & Díez-Herrero, A. (2015). Chapter 3, Palaeoflood hydrology: Reconstructing rare events and extreme flood discharges. In J. F. Shroder, P. Paron & G. D. Baldassarre (Eds.), Hydro-meteorological hazards, risks, and disasters, (pp. 65–104). Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-394846-5.00003-5.

Bishop, P., & Godley, D. (1994). Holocene palaeochannels at SiSatchanalai, north-Central Thailand: Ages significance and palaeoenvironmental indicators. *The Holocene*, *4*, 32–41.

Brázdil, R., et al. (2006). Historical hydrology for studying flood risk in Europe. *Hydrological Sciences Journal*, *51*, 739–764.

Buckley, B. M., Fletcher, R., Wang, S. Y. S., Zottoli, B., & Pottier, C. (2014). Monsoon extremes and society over the past millennium on mainland Southeast Asia. *Quaternary Science Reviews*, *95*, 1–19.

Cai, W., Sullivan, A., & Cowan, T. (2009). Climate change contributes to more frequent consecutive positive Indian Ocean Dipole events. *Geophysical Research Letters*, *36*(L23704), 1–5. https://doi.org/10.1029/2009GL040163.

CGTN. (2020). World's largest hydroelectric dam ushers in largest flood peak. Retrieved from https://news.cgtn.com/news/2020-08-20/China-s-Three-Gorges-Dam-ushers-in-largest-flood-peak--T6vmjnCdNe/index.html

Chan, F., et al. (2018). Towards resilient flood risk management for Asian coastal cities: Lessons learned from Hong Kong and Singapore. *Journal of Cleaner Production*, *187*, 576–589.

Chen, A., et al. (2020). Flood impact on mainland Southeast Asia between 1985-2018—The role of tropical cyclones. *Journal of Flood Risk Management*, *13*, e12598.

D'Arrigo, R., et al. (2011). Reconstructed streamflow for Citarum River, Java, Indonesia: Linkages to tropical climate dynamics. *Climate Dynamics*, *36*, 451–462.

Day, M. B., Hodell, D. A., Brenner, M., Chapman, H. J., Curtis, J. H., Kenney, W. F., Kolata, A. L., & Peterson, L. C. (2012). Palaeoenvironmental history of the West Baray, Angkor (Cambodia). *Proceedings of the National Academy of Sciences of the United States of America*, *109*, 1046–1051.

Floodlist (2020). *Laos, Cambodia and Vietnam – Floods leave over 40 dead, dozens missing as storm 'Nangka' approaches*. Retrieved from http://floodlist.com/asia/laos-cambodia-and-vietnam-floods-october-2020. Cyberspace: Floodlist. http://floodlist.com/.

Hecht, J., Lacombe, G., Arias, M., Dang, T., & Piman, T. (2018). Hydropower dams of the Mekong River Basin: A review of their hydrological impacts. *Journal of Hydrology*, *568*, 285–300.

Hirabayashi, Y., Mahendran, R., Koirala, S., et al. (2013). Global flood risk under climate change. *Nature Climate Change 3*, 816–821. https://doi.org/10.1038/nclimate1911

Higginbottom, J. (2019). 230,000 died in a dam collapse that China kept secret for years. Retrieved from https://www.ozy.com/true-and-stories/230000-died-in-a-dam-collapse-that-china-kept-secret-for-years/91699/

Hill, T., Chean, J., & Hicks, R. (2017). *Flood controls in Southeast Asia*, 1 Retrieved from https://www.preventionweb.net/files/54679_grundfoswhitepaper.pdf–45. Singapore: Eco-Business Pte Ltd.

Hubert, P., Tchiguirinskaia, I., Schertzer, D., Bendjoudi, H., & Lovejoy, S. (2007). Predetermination of floods: Extreme hydrological events: New concepts for security. In O. F. Vasiliev, P. H. A. J. M. van Gelder, E. J. Plate, & M. V. Bolgov (Eds.), NATO Science Series book series (NAIV), (Vol. 78, pp. 185–198). Switzerland: Springer.

Indonesia announces site of capital city to replace sinking Jakarta. The Guardian. Retrieved from https://www.theguardian.com/world/2019/aug/27/why-is-indonesia-moving-its-capital-city-everything-you-need-to-know

International Rivers. (2019). Reckless endangerment assessing responsibility for the Xe Pian-Xe Namnoy dam collapse. Retrieved from https://www.internationalrivers.org/wp-content/uploads/sites/86/2020/06/reckless_endangerment_final_for_web-compressed.pdf

Isaacman, A. (2005). Displaced people, displaced energy, and displaced memories: The case of Cahora Bassa, 1970-2004. *The International Journal of African Historical Studies*, *38*, 201–238.

Kidson, R., Richards, K. S., & Carling, P. A. (2006). Power-law extreme flood frequency. In G. Cello & B. D. Malamud (Eds.), *Fractal analysis for natural hazards* (Vol. 261, pp. 141–153). London, England: The Geological Society.

Kjeldsen, T. R., MacDonald, N., Lang, M., Mediero, L., Albuquerque, T., Boganowicz, E., Brázdil, R., Castellarin, A., David, V., Fleig, A., Gul, G. O., Kriauciuniene, J., Kohnova, S., Merz, B., Nicholson, O., Roald, L. A., Salinas, J. L., Sarauskiene, D., Šraj, M., … Wilson, D. (2014). Documentary evidence of past floods in Europe and their utility in flood frequency estimation. *Journal of Hydrology*, *517*, 963–973.

Lam, D., Thompson, C., Croke, J., Sharma, A., & Macklin, M. (2017). Reducing uncertainty with flood frequency analysis: The contribution of palaeoflood and historical information. *Water Resources Research*, *53*, 2312–2327. https://doi.org/10.1002/2016WR019959.

Lebel, L., Manuta, J., & Garden, P. (2011). Institutional traps and vulnerability to changes in climate and flood regimes in Thailand. *Regional Environmental Change*, *11*, 45–58.

Lebel, L., Sinh, B. T., Garden, P., Seng, S., Tuan, L. A., & Truc, D. (2012). The promise of flood protection: Dikes and dams, drains and diversions. In F. Molle (Ed.), *Contested waterscapes in the Mekong region* *hydropower, livelihoods and governance* (pp. 283–306). Taylor and Francis Group.

Lempérière, F. (2017). Dams and floods. *Engineering*, *3*, 144–149.

Li, J., Zheng, Y., Wang, Y., Zhang, T., Feng, P., & Engel, B. A. (2018). Improved mixed distribution model considering historical extraordinary floods under changing environment. *Water*, *10*, 1016.

Lieberman, V., & Buckley, B. (2012). The impact of climate on Southeast Asia circa 950-1820: New findings. *Modern Asian Studies*, *46*, 1049–1096.

Lim, H. S., Boochabun, K, & Ziegler, A. D. (2012). Modifiers and amplifiers of high and low flows on the Ping River in northern Thailand (1921–2009): The roles of climatic events and anthropogenic activity. *Water Resources Management 26*: 4203–4224. https://doi.org/10.1007/s11269-012-0140-z

Loebis, J. (2002). Frequency analysis models for long hydrological time series in Southeast Asia and the Pacific region. *IAHS Publication*, *274*, 213–219.

Luo, T, Maddoks, A, Iceland, C, Ward, P, Winsemius, H. (2015). World's 15 Countries with the Most People Exposed to River Floods: Retrieved from https://www.wri.org/blog/2015/03/world-s-15-countries-most-people-exposed-river-floods

MacDonald, N., & Black, A. R. (2010). Reassessment of flood frequency using historical information for the River Ouse at York, UK (1200–2000). *Hydrological Sciences Journal*, *55*, 1152–1162.

Machado, M. J., Botero, B. A., Lopez, J., Frances, F., Diez-Herrero, A., & Benito, G. (2015). Flood frequency analysis of historical flood data under stationary and non-stationary modelling. *Hydrological and Earth System Sciences*, *19*, 2561–2576.

Middleton, C, Scott, A, Lamb, V. (2019). Hydropower politics and conflict on the Salween River. Knowing the Salween River: Resource politics of a contested transboundary river. In *The Anthropocene: Politik—economics—society—science*, vol 27, Middleton, C, Lamb, V. (eds). Springer: Cham.

Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., & Stouffer, R. J. (2008). Stationarity is dead: Whither water management? *Science*, *319*, 573–574.

Munoz, S. E., Giosan, L., Therrell, M. D., Remo, J. W. F., Shen, Z., Sullivan, R. M., Wiman, C., O'Donnell, M., & Donnelly, J. P. (2018). Climatic control of Mississippi River flood hazard amplified by river engineering. *Nature*, *556*, 95–98.

Newell, B., & Wasson, R. (2002). Social system vs. solar system: Why policy makers need history. In S. Castelein & A. Otte (Eds.), *Conflict and cooperation related to international water resources: Historical perspectives* (pp. 3–17). Grenoble: UNESCO.

Ng, S., Wood, S. H., & Ziegler, A. D. (2015). Ancient floods, modern hazards: The Ping River, palaeofloods and the 'lost city' of Wiang Kum Kam. *Natural Hazards*, *75*, 2247–2263.

Nguyen, H. T. T., & Galelli, S. (2018). A linear dynamical systems approach to streamflow reconstruction reveals history of regime shifts in northern Thailand. *Water Resources Research*, *54*, 2057–2077.

Nguyen, H. T. T., Turner, S. W. D., Buckley, B. M., & Galelli, S. (2020). Coherent streamflow variability in Monsoon Asia over the past eight centuries- links to oceanic drivers. *Water Resources Research*, *56*(12), e2020WR027883. https://doi.org/10.31223/osf.io/5tg68

Parkes, B., & Demeritt, D. (2016). Defining the hundred year flood: A Bayesian approach for using historic data to reduce uncertainty in flood frequency estimates. *Journal of Hydrology*, *540*, 1189–1208.

Patton, P. (2013). Measuring the Rivers of the past: A history of fluvial palaeohydrology. In C. S. Gillmor, E. R. Landa, S. Ince, & W. Back (Eds.), History of geophysics, 3, 55–67. https://doi.org/10.1029/HG003p0055. Malden MA (USA): American Geophysical Union. https://agupubs.onlinelibrary.wiley.com/hub/contact-us.

Penny, D., Zachreson, C., Fletcher, R., Lau, D., Lizier, J. T., Fischer, N., Evans, D., Pottier, C., & Prokopenko, M. (2018). The demise of Angkor: Systemic vulnerability of urban infrastructure to climatic variations. *Science Advances*, *4*, eaau4029.

Perry, S., Mcgregor, S., Gupta, A., & England, M. (2017). Future changes to El Niño-southern oscillation temperature and precipitation teleconnections: Future changes to ENSO teleconnections. *Geophysical Research Letters*, *44*, 10608–10616.

Rodysill, J. R., Russell, J. M., Vuille, M., Dee, S., Lunghino, B., & Bijaksana, S. (2019). La Niña-driven flooding in the IndPacific warm pool during the past millennium. *Quaternary Science Reviews*, *225*, 106020.

Singh, D. (2015). Climatically induced levee break and flood risk management of the Gorakhpur Region, Rapti River Basin, Ganga Plain, India. *Journal of the Geological Society of India*, *85*, 79–86.

Šraj, M., Viglione, A., Parajka, J., & Blöschl, G. (2016). The influence of non-stationarity in extreme hydrological events on flood frequency estimation. *Journal of Hydrology and Hydromechanics*, *64*(4), 426–437.

St. George, S., Hefner, A. M., & Avila, J. (2020). Paleofloods stage a comeback. *Nature Geoscience*, *13*, 766–768. https://doi.org/10.1038/s41561-020-00664-2

St. George, S., & Muldelsee, M. (2018). The weight of the flood-of-record in flood frequency analysis. *The Journal of Flood Risk Management*, *12*. https://doi.org/10.1111/jfr3.12512(Suppl 1), e12512.

Taft Linda, E. M. (2016). A review of current and possible future human-water dynamics in Myanmar's river basins. *Hydrology and Earth System Sciences*, *20*, 4913–4928.

Ummenhofer, C. C., D'Arrigo, R. D., Anchukaitis, K. J., Brendan, B. M., & Cook, E. R. (2013). Links between indo-Pacific climate variability and drought in the Monsoon Asia Drought Atlas. *Climate Dynamics*, *40*, 1319–1334.

van Voorst, R. (2016). Formal and informal flood governance in Jakarta, Indonesia. *Habitat International*, *52*, 5–10.

Wasson, R. J. (2016). Uncertainty, ambiguity and adaptive flood forecasting. *Policy and Society*, *35*, 125–136.

Williamson, F. (2016). The great flood of 1926: Environmental change and disaster governance in British Malaya. *Journal Ecosystem Health and Sustainability Environmental Impact of Disasters*, *2*, 11.

Wood, S. H., & Ziegler, A. D. (2008). Floodplain sediment from a 100-year-recurrence flood in 2005 of the Ping River in northern Thailand. *Hydrology and Earth System Sciences*, *12*, 959–973.

Wood, S. H., Ziegler, A. D., & Bundarnsin, T. (2008). Floodplain sedimentation, channel changes and riverbank stratigraphy of the Mekong River area, Chiang Saen, northern Thailand. *Geomorphology*, *101*, 510–523.

Xu, C., Buckley, B. M., Promchote, P., Wang, S.-Y. S., Pumijumnong, N., Ann, W., Sano, M., Nakatsuka, T., & Guo, Z. (2019). Increased variability of Thailand's Chao Phraya River peak season flow and its association with ENSO variability: Evidence from tree ring δ18O. *Geophysical Research Letters*, *46*, 4863–4872.

Xu, Y., Zhang, L., & Jia, J. (2008). Lessons from catastrophic dam failures in August 1975 in Zhumadian, China. *GeoCongress 2008: Geosustainability and Geohazard Mitigation GSP*, *178*, 162–169.

Yang, F. C., Grote, P. J., & Zhang, S. T. (2019). The evolution of Mun River in Southeast Asia, and its relationship with the environmental changes in the late Middle Pleistocene, based on sedimentologic and palynological evidences. *Quarternary International*, *519*, 50–57.

Zawada, P. K., Hattingh, J., & Van Bladeren, D. (1996). *Palaeoflood hydrological analysis of selected South African rivers*. WRC Report No 509/1/96, Water Research Council by the Council for Geoscience (Pretoria); 209. Retrieved from http://www.wrc.org.za/wp-content/uploads/mdocs/509-1-96.pdf

Zhang, L., & Delworth, T. L. (2016). Simulated response of the Pacific decadal oscillation to climate change. *Journal of Climate*, *29*, 5999–6018.

Ziegler, A. D., Lim, H. S., Jachowski, N. R., & Wasson, R. J. (2012). Reduce urban flood vulnerability. *Nature*, *481*, 145–145.

Ziegler, A. D., Lim, H. S., Tantasarin, C., Jachowski, N. R., & Wasson, R. (2012). Floods, false hope, and the future. *Hydrological Processes*, *26*, 1748–1750.