Compounding focusing events as windows of opportunity for flood management policy transitions in Singapore

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Abstract

Urban floods are the result of natural and man-made events, with their economic, social, and environmental impacts reflecting policy and political decisions taken at different times in the history of cities. In this paper, we discuss flood events in Singapore over 2010 and 2011 in Orchard Road, one of the traditionally most important retail and touristic areas in the city-state, as the

compounding focusing events that opened a window of opportunity for flood management policy transitions in the city-state. Using qualitative case study analysis and topic modelling, we evaluate the multi-pronged plans and measures taken by the government to strengthen Singapore's flood resilience, and the lessons learned that were born out of these events. We conclude the Orchard Road floods served as a focusing event that raised the attention to the limitations of flood management in Singapore and reaffirmed the importance of adaptive management in policy making.

Keywords

Flood management, focusing events, qualitative case analysis, topic modelling, Singapore

1. Introduction

Floods reflect the convergence of climatic, demographic, socioeconomic, and political factors. As riparian urban development intensifies, floodplains are increasingly disconnected from river channels (Gober and Wheater, 2015) despite the potential risks this represents. While the issue of flooding has, over the years, often taken on a political dimension, it may not always be defined immediately as a political problem at the point of occurrence (Prater and Lindell, 2000). Rather, it may only be moved from the backseat into the realm of public discussion and political attention through sudden events that cause significant impacts in communities. Such events could create 'policy windows', brief periods when the *status quo* is disrupted to the extent that policy change becomes more likely. In our case study, responses involved major changes in public policies that

have ensured their relevance within a longer-term framework. Specifically, we use the 2010 and 2011 floods in Singapore in a traditionally retail and touristic area, Orchard Road, as exemplars of events that opened a policy window and expanded its agenda — in this case, in terms of flood management. This window allowed policymakers to examine, revise, and even reinvigorate Singapore's approach to urban flood resilience with a greater sense of purpose in the longer-term. We argue that the resulting policy changes were not gradual or incremental; rather, they happened in a highly compressed period of time. We also perform a detailed analysis, and provide in-depth evidence, of how the transition occurred in practice. With our analysis, we aim to contribute to the literature on best practices to improve the mitigation capability and capacity of public agencies in managing flood events in other highly urbanised areas.

2 Focusing events and policy change

A 'focusing event' is a rare, harmful and sudden event that becomes known to the community and policy makers (Birkland, 1997). Such events often highlight policy failure and open policy windows – momentary periods of time when the policy status quo is disrupted and the likelihood of instituting policy change is higher (Kingdon and Stano, 1984). While the mitigation of, adaptation to and responses to natural disasters often taken on a political dimension, they may not always be defined immediately as a political problem at the point of occurrence (Prater and Lindell, 2000). Rather, a pre-existing perception of the problem often exists (Kingdon and Stano, 1984; Farley et al., 2007). However, this may only be moved from the backseat into the realm of public discussion and political attention through a focusing event. This process can be understood by a consideration of the Multiple Streams Approach (MSA) which theorises that potential

changes in the policy agenda are frequently placed on the radar only when the policy stream, politics stream and problem stream converge (Kingdon, 1995; Birkland, 1997). Kingdon and Stano (1984) explain that this happens when public opinion is embraced by the political stream, potential solutions to a problem are embedded within the policy stream and the characteristics of a problem are highlighted in the problem stream through a focusing event.

To date, numerous studies have examined the role of disasters, both natural and man-made, in enacting policy change. For example, Meijerink (2005) used the case of flood policy changes in the Netherlands from 1945 to 2003 to investigate how policy shifts, while influenced by flood events, were catalysed by citizens' environmental awareness and were provided the enabling condition to be brought to the fore by the newly elected national government. Johnson et al. (2005) and Birkland (2006) assert that policy responses to floods are not the result of changes in the values or beliefs of policy makers. Rather, they often increase attention to various policy solutions that were discussed and considered prior to the disasters. For example, Hurricane Katrina that made landfall along the south-eastern coast of the United States in late August 2005 brought to the fore gaps in policies designed to deal with disasters, inequitable resource allocation and cast a spotlight on politicians' ability to demonstrate their understanding of the problem and their ability to push forth accompanying policy solutions (Farley et al., 2007). Although research had already warned of the relationship between climate change, global warming and the resultant impacts on hurricane intensity, it took the tragedy, its impacts on the community and the widespread public unhappiness and discussion to bring natural disasters to the foreground of political discourse.

While floods in Singapore have always garnered a great degree of attention, they were most effective as focusing events that opened up policy windows in the case of the 2010 and 2011 Floods. Several conditions created the enabling environment for the policy windows to bring flood management to the forefront of the policy agenda. In the wake of both flood events, the problem stream emerged with the finding of the limitations of existing drainage infrastructure and provided a glimpse into how the hazardous nature of such events may become a more frequent reality in the face of climate change. The policy stream pointed to the problematic approach towards floods along Orchard Road – largely of a reactive nature in the form of built infrastructure that might not have kept pace with the rapid urbanisation of the area and changes in rainfall pattern over the year while the governing regime or political stream influences the policies to be discussed and the attention paid to them in parliamentary debates.

The rest of our paper proceeds as follows. We first describe our mixed methods approach which combines qualitative case study analysis and topic modelling, a quantitative machine learning approach. We then present the evolution of flood management in Singapore, including flood events, drainage management and institutional responses as backgrounds for the study. This is followed by a review of the development of Orchard Road and its flood events, highlighting the 2010 and 2011 floods as case studies. These accounts are supplemented by policy discussions as reflected in the parliamentary debates; the impacts of the floods; and how to prepare for and mitigate them. We then explore the incremental changes in flood policy and management in

Singapore. Using the concept of focusing events and their role in opening policy windows, we argue that floods can catalyse policy change within a long-term framework. We conclude by summarising the main findings and identifying avenues for future research. Potential limitations of the study, inherent to qualitative case study analysis in the sense that they are case-specific and findings cannot be generalised, are also presented in the conclusion section.

3. Methodology

3.1 Qualitative Case Study Analysis

The first method focuses on the 'how' and 'why' questions pertaining to a contemporary phenomenon in a real-world context (Yin 2017). As a longitudinal approach, it elicits rich details to understand, in this instance, the policy evolution in Singapore's flood management, specifically the milestones and key activities describing the policy shifts and interventions.

Documents reviewed included academic papers, books, policy documents, and the annual reports of PUB (Public Utilities Board, National Water Agency of Singapore) from 1963 to 2020. At appropriate junctures, we supplemented our document review with news reports that provided additional contextual information to the milestones and key activities, such as the public outcry from the environment minister using "ponding" to characterise the Orchard Road floods.

The narratives were particularly relevant in understanding the historical importance of floods in Singapore, and the government's continuous efforts to reduce flood prone areas by first

constructing drainage and flood alleviation schemes as well as water development projects, and subsequently, considering also non-structural measures to strengthen flood resilience and folding flood management into the ambit of climate change. This narrative development came about as a result of the understanding by policymakers of the risks related to climate change.

3.2 Structural Topic Modelling (STM)

Ideally, as it has been done in the qualitative case study analysis part of the study, researchers would also examine and manually annotate all the Hansards (Official Reports on Parliamentary Debates) published by the Singapore Parliament, to understand the political attention accorded to the impacts of floods and associated policy responses. However, since more than 30,000 documents have been published since 1963 when Singapore gained self-government, we used automated content analysis to detect themes within this corpus. Web scraping techniques were applied to retrieve Hansard documents from 1963 to February 2020. Next, NVivo software was used to identify 568 paragraphs in 123 Hansard documents with content related to floods. The resulting dataset contains 54,034 words, with a mean of 95.13 words per paragraph. We then used topic modelling to identify the themes within this dataset.

For the estimation process and to describe and interpret the topics, we used structural topic modelling (STM) (Roberts et al., 2014, 2016). This approach allows the use of covariates such as document source and date in the topic modelling algorithm. In comparison to other probabilistic topic models such as Latent Dirichlet Allocation (LDA), this approach provides improved

153 estimation of the topics and introduces valuable information into the inference procedure
154 (Roberts et al., 2016).
155
156 **3.2.1 Diagnostic Testing**
157 We estimated a series of STM models by varying the number of topics in a series of diagnostic
158 tests, including calculating the held-out likelihood (Wallach et al., 2009) and performing a residual
159 analysis (Taddy, 2012) to assess goodness of fit (Roberts et al., 2014). The small set of models
160 that performed well in the diagnostic tests were further compared using scores of semantic
161 coherence and exclusivity. We estimated the STM models in a series of declining intervals to
162 narrow down the range of appropriate models and to reduce the computation time for the
163 diagnostic tests. Further tests revealed that a model building upon 21 topics gave us the best fit.
164 All substantive findings were verified for small variations in the number of estimated topics and
165 found to be robust. We also elaborated on the tests and sensitivity analysis, including the
166 complete results from the diagnostic tests and estimated topics. These analyses can be found in
167 the online Supplementary Material.
168
169 The results of 21 topic STM model are shown in Figure 1. The topics are collections of words that
170 are ranked according to their prevalence (documents contain topics with varying probabilities).
171 For example, Topic 3, the most prevalent topic in Figure 1, is dominated by words such as “heavy”,
172 “rainfall’’, “floods” and “people” and can be labelled as “heavy rain & affected people”. This
173 indicates that the topic primarily represents discussion of heavy rainfall as one of the main causes
174 of the floods and the groups of people affected by it in Singapore.

175

176 (Insert Figure 1)

177

178 The key inferential task of STM is defining the semantic content of each topic using the
179 distribution of words in each topic and expected topic proportion, which indicates the expected
180 proportion of the corpus that belongs to each topic. When an expected topic proportion value is
181 negative, no proportion of the documents refers to the individual topic in question.

182

183 Once the topics have been identified using STM, the topic proportions can be plotted to examine
184 how flood discourse in the Hansard documents has evolved over time. The negative expected
185 topic proportion values showed in the figures with the results, have been highlighted to mark the
186 years when a particular topic was not discussed in the Hansard documents.

187

188 **3.3 Iterations between the qualitative case analysis (method 1) and the structural topic**
189 **modelling (method 2)**

190 The value of a mixed method approach was how the two methods could offer feedback to each
191 other, thus strengthening the insights and conclusions from the analysis. A longitudinal
192 qualitative case analytic approach (method 1) builds the chronology of events and the "plot"
193 which arranges the events in a loose causal order (Miles and Huberman, 1994). The narratives
194 assembled sensitised and guided us to perform deep reading of the topics generated from STM
195 (method 2), which involved interpreting and making sense of the results extracted in topic
196 modelling to define topic labels (Nelson, 2020). In turn, the topics identified through STM were

also used to further verify and refine the chain of events that led to policy changes in Singapore's urban flood management. This interactive and iterative process served as the devil's advocate, forcing us to seek clarification or offer alternative explanations, thus reducing the likelihood that our analyses might conclude prematurely.

4. Evolution of flood management in Singapore

Singapore is a highly urbanised city-state located near the equator. It has a tropical climate, with abundant rainfall, high and uniform temperatures, and high humidity throughout the year (Meteorological Service Singapore (MSS), n.d.). The combination of small drainage basins, low-lying land (90% is within 15 m above sea level and 30% less than 5 m above sea level), and its location in the tropics render the city-state naturally flood-prone (National Climate Change Secretariat (NCCS), 2021). This has been exacerbated due to climate change. According to the National Climate Change Strategy, annual total rainfall has risen at an average rate of 101 mm per decade between 1980 and 2016; annual mean temperature has increased at an average rate of 0.25^{o}C per decade between 1948 and 2016; and that sea level rise in the Straits of Singapore has risen at the rate of 1.2 mm to 1.7 mm per year between 1975 to 2009 (NCCS, 2021).

Floods' disruptions and destruction in Singapore have been documented for decades (PUB, 2015; Tortajada et al., 2013). Prior to the implementation of flood control measures, sudden downpours tended to cause floods in low-lying areas, especially during high tides. Looking at the overall deliberations in the Hansards using STM, it was clear that related events were discussed in the Parliament over the years. These can be found in Figure 2, figures 2a and 2b, which show

the expected topic proportions of the topics “Heavy Rain” and “High Tide”, respectively within the Hansards. Looking at the figures, we see that the values for “Heavy Rain” peaked in 1970, and “High Tide” peaked in 1973. It is interesting that both terms reached similar peaks again after 2010 after the Orchard Road floods.

(Insert Figure 2)

One can also affirm that flood events have shaped policy discussions in the Parliament. Concerns have shifted with time from trying to understand the reasons for the flood events (Parliament of Singapore, 1967, 1969, 1974) to longer-term flood management and the development of flood alleviation schemes (Parliament of Singapore, 1966, 1968). Since the 1970s, flood protection has incorporated structural and non-structural measures, such as construction and widening of drains and diversion canals, as well as construction of reservoirs in the first case; and flood control guidelines that have included raising the height of low-lying areas and making construction sites do not release silty water into the drains mandatory, in the second one (PUB, 2003).

Among the main flood alleviation schemes is the Bukit Timah Flood Alleviation Scheme. Completed in 1985, it paved the way for other equally important schemes. During that time, in a parliamentary discussion, the minister for environment proposed to accelerate the construction of drainage infrastructure. Two years later, the government earmarked about S$700 million for flood alleviation schemes over the next five years. The new schemes were meant to alleviate flooding in the existing flood-prone areas, and to construct drainage infrastructure for new towns

241 (Parliament of Singapore, 1986, 1987, 1990). A corresponding peak in the expected topic
242 proportion values for the topic on “Flood Alleviation Schemes” in late 1980s can be seen in Figure
243 2c, indicating that it was a topic frequently discussed in the Parliament.
244
245 Another main infrastructure constructed for flood control (in addition to water supply and
246 recreation) is the Marina Barrage (PUB, 2010). Located in central Singapore, its construction
247 started in 2005 and was completed in 2008. It has the capacity to pump out of the reservoir and
248 into the sea, up to 40 m^3/second when high tides coincide with heavy rains (PUB, 2003).
249
250 An innovative flood management initiative that has been implemented is the Active, Beautiful,
251 Clean (ABC) Waters Programme. Launched in 2006, the objective of the PUB programme is to
252 transform drainage infrastructure (e.g., waterways and waterbodies) into a more natural stage,
253 integrating them with the built environment and bring people closer to water (PUB, n.d.).
254
255 Some of the most relevant non-structural measures have been institutional and regulatory in
256 nature. A major institutional milestone was the merger between PUB and Sewage and Drainage
257 Department of the then-Ministry of Environment in 2001. This enabled an integrated
258 management of water by a single agency, including flood alleviation and management (PUB,
259 2001). Regarding regulations, the Code of Practice on Surface Water Drainage specifies the
260 minimum engineering requirements for surface water drainage for new development that should
261 be considered at the planning, design, and implementation stages of development proposals

(PUB, 2018c). This Code is essential to minimise the impacts of numerous new developments in Singapore in the surface water drainage and avoid that its capacity is exceeded.

All the above improvements have resulted in a greater sense of security in the city-state. Even then, floods and flood management have been a constant concern for the parliamentarians. In Figure 2d, for example, the expected topic proportion values for the topic on "Flood Prone Areas" reached peak levels in late 1990s and early 2000s (Parliament of Singapore, 2001). Several years later, in 2004, discussions in Parliament continued to demonstrate concerns that areas above high tide level were still getting flooded during heavy rains (Parliament of Singapore, 2004).

The structural and non-structural measures mentioned had been generally effective in coping with the strains of increasing economic and population growth, urbanisation, and industrial development (CLC, 2012). In recent times, however, flood risks have increased due to more intense rains, surface runoff exceeding the capacity of stormwater drains and topographical changes from land use modifications, among others (Chow et al., 2016; Public Utilities Board (PUB), n.d.).

4.1 Urbanisation and flood risks: the case of Orchard Road

Orchard Road is located in central Singapore (Figure 3). Traditionally one of the most important retail and touristic places in the city-state, the highly urbanised area has undergone multiple intensive rejuvenation and redevelopment initiatives. These have included the S$1 billion Tourism Product Development Plan in the 1980s, the 'Tourism 21: Vision of a Tourism Capital'

284 plan in 1997 (Kaw, Lee and Wahba, 2020), and, most recently, the 'Bring Back the Orchard' Plan
285 (URA, n.d.).
286
287 (Insert Figure 3)
288
289 The Orchard Road area sits in a depression on low-lying land, making it highly vulnerable to
290 flooding. During the 1980s, enormous effort was invested in alleviating and reducing flood events
291 in the area. Modifications to the built environment included the deepening and widening of the
292 Stamford Canal (the main stormwater drain of the catchment) to cover a catchment area of 619
293 ha, at a cost of S$56 million; the construction of a 1.2 km canal; and the conversion of an open
294 drain along Orchard Road to a closed drain (Loh and Pante, 2015). One could argue that with the
295 successful implementation of protection measures, the lower frequency of floods could have
296 blurred Singaporeans' 'collective memory' – the 'inherited knowledge' of flood hazards (Viglione
297 et al., 2014; Gober and Wheater, 2015: 4783). People's memory of flood risk is shaped by more
298 complex processes than the length of time since the last flood event. As high-water marks,
299 warning signs, and other visual reminders of flood risk fade from view, the 'memory landscape'
300 of floods also fades, fostering underestimation of future flood risk (Ludy and Kondolf, 2012;
301 Gober and Wheater, 2015; McEwen et al., 2017: 17). For example, in the late 1990s, the Drainage
302 Department remarked that the floods in Orchard Road were 'a thing of the past' (Loh and Pante,
303 2015: 45). Even parliamentary discussions touted that "flooding is no longer a serious problem in
304 Singapore. It is now less frequent and less extensive" (Parliament of Singapore, 1992).
305

306 **4.2 The 2010 and 2011 Orchard Road floods**

307 Despite the many improvements in flood-prevention infrastructure, the events of 2010 and 2011
308 reminded both the community and the policymakers that the geographical profile of the Orchard
309 Road area still rendered it vulnerable to flooding.

310

311 In June 2010, intense rainfall of about 100 mm in two hours generated surface runoff that
312 surpassed the drainage capacity of the Stamford Canal. This situation was aggravated by the
313 blockage of the canal by debris that was flushed into and trapped in the culvert across Orchard
314 Road, resulting in water overflowing onto Orchard Road in the form of a flash flood up to 300
315 mm deep. The flood severely disrupted traffic and inundated the basements of several buildings.
316 The 868 insurance claims from business interruptions, property and motor vehicle damage
317 amounted to approximately S$23 million (PUB, 2012a).

318

319 On 16 June 2011, heavy rain again fell over the central parts of Singapore, including Orchard Road.
320 With 65 mm of rain falling in about half an hour, Stamford Canal overflow covered the road to a
321 depth of 100–300 mm. Like the year before, the flood stalled cars and flooded the basement level
322 of buildings (PUB, 2012a). Several months later, on 23 December 2011, 152.8 mm of rain fell,
323 with more than half of it falling within 30 minutes, causing another flash flood (Chan et al., 2018).
324 Although a S$200,000 barrier system had been installed about a year before, there were
325 buildings that were affected again (Eco-Business, 2010; AsiaOne, 2011). These events showed
326 how a trend of more frequent and intense rainfall events in highly urbanised areas, can
327 overwhelm drainage infrastructure not designed for extreme rainfall (Chow, 2018; PUB, 2012a).

The increased sense of safety among the population living and working in the area, as well as the policymakers, may have resulted in more adverse effects due to the flash floods because to an increase in exposure and vulnerability. This sense of safety is known as the 'safe development paradox' or 'levee effect' (Burby, 2006). In trying to reduce flood risk by enacting proactive strategies on flood protection, the government could have created a false sense of security and indirectly reduced incentives for people and businesses in the affected area to put in place additional autonomous mitigation measures, thereby exacerbating risk by situating assets in a flood-prone area (Haer et al., 2020). As the mitigation measures were only designed to protect against rainfall events of a certain magnitude and scale, the hazardous nature of the area surfaced during the 2010 and 2011 events when these were exceeded.

5. The 2010 – 2011 floods as focusing events: a policy window opens

According to the 'multiple streams' approach, potential changes in policy appear on the radar when the policy stream, the politics stream, and the problem stream converge (Kingdon and Stano, 1984). This happens when public opinion is embraced by the political stream, potential solutions to a problem are embedded in the policy stream, and the characteristics of a problem are highlighted in the problem stream through a focusing event. A focusing event refers to large, sudden, rare, and harmful event that occurred in a specific locale or community of interest that is known to both the public and policymakers (Birkland, 1998). The 2010 and 2011 floods can be considered as examples of focusing events that opened a policy window: they were sudden, taking place within hours of the onset of a rainfall event, and showed that the thinking that floods

of that magnitude, while understood to be rare in Singapore, were still possible and could lead to significant destruction. Because these events represent "sudden shocks to polity systems that rapidly increase attention to a suddenly revealed problem" (Birkland, 2016), they allow communities (e.g., the public, subject matter experts, and politically disadvantaged groups) to champion their messages and push for policy change (Birkland 1998). Recent research on rarity of floods as aggregate focusing events (compounded disasters such as repetitive floods) has also shown to trigger policy change (O'Donovan, 2017). In fact, given the right conditions, such as the extent of 'shock' triggered by the focusing events, policymakers might even over-react for a limited period of time to insulate themselves from political repercussions (e.g., election loss) (Maor, Tosun & Jordan, 2017).

The occurrence of three flash floods along Orchard Road within 18 months galvanised social and political attention. Thus, opportunities for the authorities to push flood risk management onto the policy agenda came through the political stream. This could be seen when the then Ministry of Environment and Water Resources (MEWR, renamed the Ministry of Sustainability and the Environment in July 2020) appointed an Expert Panel on Drainage Design and Flood Protection Measures to review the events. The panel also assessed the flood protection and risk management measures that were slated for implementation in Singapore over the next decade (PUB, 2012a, c).

A key difference between the damage brought about by the floods in earlier decades and the 2010 and 2011 ones lies in the intangible damages caused by the latter. The expert panel's report

highlighted that Singapore's reputation as a safe, "well-organised and well-engineered city" could have been marred (PUB, 2012a). Most Singaporeans learned about the floods through the mass media than first-hand experience. Unlike the more traditional media (such as television, radio, and newspapers) through which information on floods was disseminated in earlier decades, information conveyed on social media tends to be less credible, as its accuracy is not validated before it is disseminated (Ismail et al., 2019). Therefore, people's response via social media could also have amplified the perception of risk from floods (Kasperson, 1992; Pidgeon et al., 2013). Although flooding events have been a preoccupation of the city-state since the 1960s and 1970s, the response of Singaporean society to the 2010 and 2011 events made the now Ministry of Sustainability and the Environment and PUB to concentrate on longer-term flood risk management. In response to the policy window created by the Orchard Road floods, various efforts were taken to increase resilience to future events, and new benchmarks were set. The main strategies and formal responses were as follows:

1. Carrying out event-based learning to elucidate the causes of the 2010 and 2011 floods and the compounding factors that led to their impacts.
2. Harnessing the potential of digital, green, and built infrastructure, implementing comprehensive solutions, and building new capabilities.
3. Improving public understanding of flood events.

These are discussed in the next sub-sections.

5.1 Event-based learning

Until 2010, floods were discussed in general terms, with only specific events being emphasised by policymakers. However, the floods of 2010 and 2011 were so severe that they became a self-contained discussion topic in the Hansards with its own policy implications. This can be seen In Figure 4a, where the expected topic proportion values for the topic on "Orchard Road Floods" turned positive only after 2010 and continued to rise all the way to 2019.

(Insert Figure 4)

An effective public bureaucracy created an enabling environment for an in-house investigation team to be brought together. PUB convened an Inter-Agency Review Committee, gathering key public development agencies to evaluate drainage design standards and the capacity of major drains and canals. This exercise provided a valuable forum for the exchange of perspectives, identifying both problems and avenues for improvement. To ensure that the recommendations were judicious, an independent review was also conducted by an external panel. The panel brought together local and overseas experts across disciplines, including hydraulic engineering, climate change, hydrology, and flood management, to review PUB's drainage planning assumptions and parameters, identify innovative and practical solutions, and develop ways to improve people understanding of floods (PUB, 2012a).

Before the 2010 and 2011 floods, the design return period in Singapore for all outlet drains and secondary drainage facilities was 5–10 years; for major rivers, 50–100 years; and for

developments, 50 years. In December 2011, drainage design standards were revised with the potential to carry up to 45% higher rainfall intensity (Parliament of Singapore, 2018; PUB, 2012a). The design return periods for drain capacity were also revised. They increased from 5 to 10-25 years for local drainage and residential areas; 5 to 25 years for commercial/industrial areas and regional systems; and 50 to 100 years for critical infrastructure and major rivers (PUB, 2012a).

PUB also showed that policy change is far from a linear process by making a commitment to review its drainage master plan every three years, and to make the first one available to the public by the end of 2013 (PUB, 2012b), which the agency did. This exemplifies the iterative nature of policy learning, which can be understood as using experiences and new information to better actualise or reformulate policies (Hall, 1993; Dovers and Hezri, 2010).

5.2 **Harnessing the potential of built, green and digital infrastructure**

In the wake of the 2010 and 2011 floods, PUB announced plans for 20 drainage improvement projects (at a total cost of S$750 million) to improve flood protection. Direct infrastructural developments included the Stamford Diversion Canal and Stamford Detention Tank that became operational in 2018. The 2 km canal diverts stormwater from the upstream of Stamford Catchment into the Singapore River and eventually into the Marina Reservoir. The Stamford Detention Tank can temporarily store up to 38,000 m^3 of excess stormwater from the drains upstream of the Stamford Canal. After heavy rains subside, water is pumped back into the drains for subsequent discharge (PUB, 2012a, 2019). The infrastructure cost S$227 million, including more than two million man-hours across four years of construction, to protect Orchard Road

438 from future rainfall events of the same intensity as the ones in 2010 and 2011 (Straits Times, 28
439 September 2018).
440
441 Overall, from 2011 to 2020, the investment in flood mitigation measures was on the order of S$2
442 billion. Another S$190 million was expected to be invested in 2020 to improve flood resilience
443 (MEWR, 2020). However, in line with Singapore government's long-standing policy, while limiting
444 flood events is critical, resources and administrative attention need to be balanced with financial
445 prudence. The government has been candid about the near impossibility of complete flood
446 elimination. While heavy rain in a short period coupled with urbanisation can contribute to
447 flooding, the infrastructure is not and will not be built for worst-case scenarios, as it is financially
448 prohibitive and not space-effective in land-scarce Singapore.
449
450 In 2012, to maximise the ability of infrastructural measures to protect Singapore's urban areas,
451 the expert panel recommended that PUB consider a broader range of drainage interventions.
452 This would involve ensuring that there are no 'silos' in the various components of the drainage
453 system. This is, drainage channels, green spaces, streetscapes and other built and green
454 infrastructures would have to be integrated holistically. Specifically, the panel proposed going
455 beyond the traditional 'pathway' approach (such as expanding drains and canals) to developing
456 solutions at 'source' (e.g., local storage tanks, rain gardens and bioretention swales) to regulate
457 stormwater runoff, and providing 'receptors' (e.g., flood barriers and raised platforms) to protect
458 local infrastructure (PUB, 2012a, b). This comprehensive 'source-pathway-receptor' approach
459 has been implemented by PUB: runoff pathways have been expanded, and previous work to

460 naturalise previously concretised channels as part of the ABC programme, has been continued to
461 include more green and blue spaces, in addition to rooftops when possible (PUB, 2018a). Finally,
462 new developments are required to incorporate receptor solutions in their design to minimise
463 flood risk (PUB, 2018b; Wang et al., 2018). This strategy has helped water engineers, planners
464 and decision makers make more prudent decisions on land use changes and drainage
465 requirements (Chan et al., 2018; PUB, 2013b). In addition, despite its land scarcity, Singapore
466 has managed to set aside approximately 8 m^2/person of public open space that are meant to be
467 impermeable to ensure that land surfaces are not unnecessarily made impermeable and
468 stormwater can infiltrate, reducing runoff (Henderson, 2013).

469

470 Knowledge of and/or information about a flood does not necessarily translate to action with
471 regard to public response or policy making. However, they provide policymakers with the
472 elements needed to predict the outcomes of available policy alternatives to adaptively manage
473 appropriate strategies. In line with the expert panel's recommendation, Singapore move to a
474 more risk-based approach to flooding events based on 'dynamic modelling and comprehensive
475 monitoring' (PUB, 2012a: ii; PUB, 2012c). For example, to strengthen the real-time monitoring of
476 site conditions during intense rainfall, about 210 water level sensors have been installed at
477 various locations around Singapore (PUB, 2018b). Although the additional rain gauges, water
478 level sensors and flow meters that were installed along the Stamford Canal following the 2010
479 floods did not lower the flood risk in the 2011 events, they did enable PUB to conduct a more
480 thorough assessment of the events as they occurred (PUB, 2012a).

481

Effective inter-agency collaboration was also demonstrated through PUB's partnership with various agencies. This included working with the Singapore Land Transport Authority, which was already developing a national digital elevation map for whole-of-government applications, and the Institute for Infocomm Research (part of the Agency for Science, Technology and Research) to create a smarter flood detection system that uses image analytics technology to scan real-time footage from PUB's CCTVs and detect images of floodwaters (PUB, 2012b; Smart Nation and Digital Government Office, 2019; Today, 18 November 2015). In 2014, a network of 142 CCTV cameras was installed to monitor road conditions in real time, mostly in low-lying areas and at hotspots. The public can view CCTV images of 49 locations around the island and be updated on the latest flood situations via PUB's website and the MyWaters smartphone application (PUB, 2014). Hence, it is argued that it is a myth that science can serve as a basis for effective policymaking (Baker, 2007), the measures taken by policymakers in Singapore in response to the floods demonstrate that while knowledge by itself, does not cause change, ideas that float around in a 'policy primeval soup' can accumulate and influence public policy (Penning-Rowsell et al., 2017: 10).

Social resilience has emerged as a particularly conspicuous policy narrative. As part of its comprehensive action plan to strengthen Singapore's flood resilience, PUB has committed itself to working with stakeholders to improve preparedness (Parliament of Singapore, 2012b). One way to increase public participation and thus preparedness is through the development of a free mobile text alert service for individuals who want to receive notifications of imminent heavy rain, flood risk, and water levels in specific major waterways (Chan et al., 2018). In August 2011, the

National Environment Agency and PUB jointly launched the Integrated Heavy Rain and Water Level Alert Service. It facilitates more timely public updates on potential flash floods. The Drainage Operations Unit at PUB also alerts the public of flash flood locations through Facebook and Twitter and aids the affected premises. To better connect with the community, the MyWaters application also features a dedicated feedback channel so users can send their suggestions to PUB (PUB, 2012c).

These participatory approaches demonstrate that public participation is embedded in Singapore's flood management and governance frameworks. However, the modest attention given to them in comparison to the vast resources allocated to technical measures for flood protection suggests that more can be done to cultivate public participation as a best practice to enhance social resilience.

5.3 Improving public understanding of flood events

Far from being passive consumers of policy, citizens are actively involved in the development, adoption and adaptation of policy (Prater and Lindell, 2000). More than ever, public involvement in decision-making processes is indispensable for the effective application of flood risk management policies (Krasovskaia et al., 2001). Singaporeans today have far higher expectations of the government than in the past (The Straits Times, 4 May 2017). A reasonable criticism of PUB in the aftermath of the 2010 and 2011 floods was in terms of communication. In the aftermath of the floods on 23 December 2011, the flood event was called ponding, which resulted in a strong public reaction. On 9 January 2012, this was discussed by the then Minister of Environment

and Water Resources in the Parliament, when he emphasised that the flood should not have been describe as 'ponding' but as a flood. During that session, the Minister also mentioned that the Stamford Canal capacity would have to be increased by 30% to reduce risk of floods along Orchard Road, as the flood events were part of a larger pattern of rainfall change over the pass decades (Parliament of Singapore, 2012a).

Another reasonable criticism is that PUB did not successfully convey to the public 'the scientific and economic philosophy underpinning its flood management practices' (Biswas, 2012). Failing to understand the concept of cumulative probability, citizens had considered the floods to be events that only happened 'once every 50 years' (Yong, 2013). It is likely that very few would be cognisant that this probability is defined by scientists and engineers based on historical records of rainfall and may thus be redefined based on future events that contribute to the historical record and tweak the averages. This misperception of risk could have been coupled with the false sense of security people had, given the effectiveness of drainage control and flood-prevention measures that have been put in place in Singapore over the years. Identified as one of the 'nine fallacies' of floods, the notion that flooding is regular and predictable should thus be quashed, and greater effort must be made by policymakers to improve public education on this topic. Specifically, more precise use of language must be adopted when communicating the causes of flood events and accurate description of their magnitude would reduce the confusion that can lead to anger towards and distrust of policymakers in the aftermath of such events (Pielke, 1999: 413).

Parliamentarians not directly involved with the then MEWR were concerned with Marina Barrage and whether it had played any role in the Orchard Road flooding. In Figure 4b, it can be seen that the expected topic proportion values for the topic on “Marina Barrage” turned positive only after 2010 and continued to rise until 2020. The trend seen is similar to the one in Figure 4a on Orchard road floods. In retrospect, the ministry could have better qualified its earlier statements that the barrage would contribute to flood-prone areas being ‘reduced to less than 100 ha’ and that the drainage programme would ‘manage unprecedented flash floods’. This led population to believe that Singapore was safe from flash floods from then on (Singapore Budget, 2008).

The 2010 and 2011 floods also brought other topics of discussion in the Parliament such as the importance of maintenance and improvement of public drains (Parliament of Singapore, 2013). Discussions on improving the existing infrastructure also increased after 2010. Figures 4c shows a sustained rise in the expected topic proportion values for the topic on “Public drains” after 2010 (Parliament of Singapore, 2009), while Figure 4d shows a steep increase in the expected topic proportion values for the topic on “Improvement works” after 2010. This increasing trend continues until 2019.

In Figure 4e, we can see that the expected topic proportion values for the topic on “Emergency response” drop down drastically after 2010. This reflects a shift in the parliamentary discussions from the immediate response provided by PUB to flood events towards setting up early warning systems to better prepare the public for the possibility of floods. After Orchard Road floods, PUB

focused on devising a more holistic response strategy that included early warning systems and the "Source-Pathway-Receptor" approach, in addition to existing emergency response protocols.

Earlier generations of Singaporeans were inadvertently socialised to keep the memory of floods out of sight through the integration of drainage control measures with the built environment. Similarly, the present generation may also be socialised to underestimate flood risk. Therefore, even though the shifts in mindset and organisational culture around flood risks in PUB are critical and commendable, there is a need to improve social awareness and expectations about flood risks and their management to increase acceptance of the inevitability of flood events and empower individuals to make fully informed decisions about the risks.

6. Conclusions

The Singaporean Government, through the PUB, has demonstrated an iterative approach to policy making in addressing the recurring and dynamic problem of floods. The presence of flood management on the political agenda shortly after independence, and especially in the wake of the 2010 and 2011 floods, best exemplify this. Not all focusing events lead to major policy changes, but the Orchard Road floods catalysed changes in flood-risk management for three reasons. First, the floods were so much more severe than what many Singaporeans were accustomed so they could not be considered routine. Second, the short time that policy windows are typically opened for was taken advantage of to identify solutions. Finally, appropriate solutions were implemented. These were in turn the result of institutional strength and flexibility. As Singapore's National Water Agency, the PUB, led the charge in convening experts from both

591 within and external to the organisation, this ensured that investigations could yield peer-
592 reviewed lessons to inform recommendations and decision-making in flood management. Next,
593 innovation was at the heart of improvements to augment the infrastructural capacity of the
594 country's drainage system. Although Singapore has had a long history of continual upgrading and
595 construction of drainage infrastructure, the 2010 and 2011 floods provided the impetus to
596 construct large-scale infrastructure in the form of the SDC and SDT without requiring extensive
597 land surface in a land-scarce country. An effective framework to enable an adaptive approach to
598 policy making is also key and is demonstrated through PUB's engagement of business owner's
599 public participation to scrutinise the processes and outcomes of each strategy and enhance
600 education in flood risk reduction.
601
602 It is also worth noting that as new developments and measures have been put in place in
603 Singapore, the questions raised by MPs in parliamentary debates have also evolved. These
604 questions have been key in providing a direction for future development. Still, the threat of
605 climate change calls for more comprehensive contemplation of urban development and flood
606 management policies, to balance development and its impacts on the environment under
607 changing conditions. The Orchard Road floods resulted in adaptive policy learning and
608 collaborative governance arrangements and demonstrated how the range of policy options for
609 flood management can expand from traditional infrastructure options to include more robust
610 non-structural measures. The challenge is to continually strive to consider multiple pathways for
611 flood adaptation. The hope is that future policy advances arise as a result of flood management
612 having a permanent place on the policy agenda in anticipation of climate change and rainfall

scenarios rather than being pushed into the spotlight as a reaction to focusing events after they occur. Singapore has invested heavily in flood management. Future progress is contingent on the capacity of policymakers to ensure robust and continuous adaptive governance, and of the population to be more aware of the inevitable changes that will result from climate change.

Finally, while a case study approach offers robust internal validity, there will be questions surrounding its external validity, specifically the extent to which it is generalisable to other focusing events. Our study inadvertently suffers from this limitation that plaques in-depth case studies that focus on a concentrated series of events. Further research should be conducted to explore the applicability of our insights: focusing events, especially when its rarity is magnified, not only could lead to policy change in its immediate domain (i.e., flood management), but also in its global domain (i.e., climate change). Future studies should test and develop theories around this proposition, thus expanding the "theoretic" and external validity of our explanations to un-studied parts of Singapore's experience in building climate change resilience, as well as other cases of focusing or extreme events.

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10. Competing interest statement

635 The authors have no competing interests to declare.

636

637 **11. References**

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Supplementary material

Diagnostic Testing

Models are examined for variations in the Held-out likelihood, Residuals, Lower Bound and Semantic Coherence (Roberts, et al., 2016; Taddy, 2012). In calculating held-out likelihood and residuals the dataset is divided into a training set and test set. First, Held-out likelihood tests the accuracy and recall of the codes marked in the training set. Second, Residuals tests the difference between the training set and the test set for topic predictions. Third, Lower Bound calculates the lower bound of the marginal log likelihood and finally, Semantic Coherence tests the cooccurrence of words in each topic. Figure 3A shows that topic-models 18, 19, 20 and 21 produce high held-out likelihood values, minimal residuals, high semantic coherence, and a maximised lower bound. It is noted in Roberts et al. (2014) that topics with fewer models have high semantic coherence as they are dominated by very common words. Hence, the topic-models 18, 19, 20 and 21 are examined further to measure topic quality through acombination of cohesiveness and exclusivity of topics. Figure 4A shows that the 21-topic model achieves a good balance of values for both tests i.e., average scores are towards the upper right side of the plot.

1. Models between 10 and 110 are considered in increments of 10. The testing range is reduced to 25 to 65 based on the results of the diagnostic test (See Figure 1A)
2. Models between 25 and 65 are considered in increments of 5. The testing range is further reduced to 15 to 45 based on the results of the diagnostic test (See Figure 2A)

3. All models between 15 and 45 are considered. (See Figure 3A)

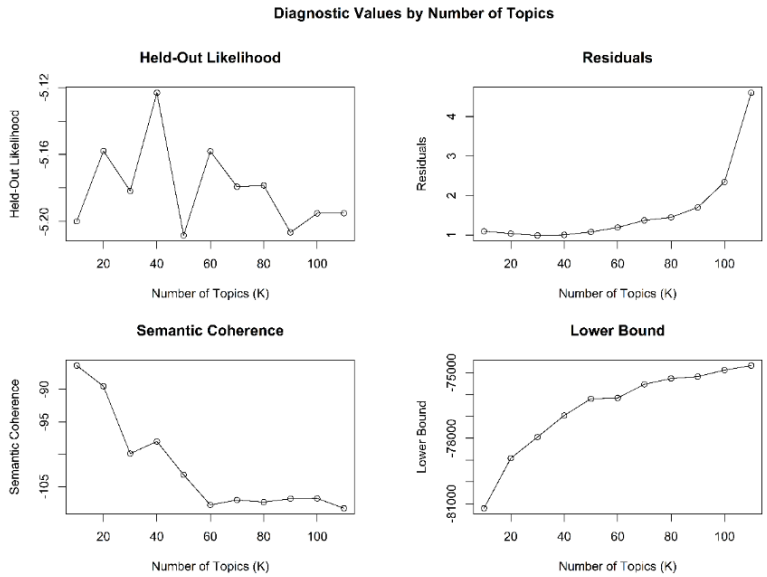

Figure 1A. Model Selection: Diagnostic values by the number of topics (a) held-out likelihood; (b) residuals; (c) semantic coherence; (d) exclusivity. (diagnostic testing is done in increments of 10)

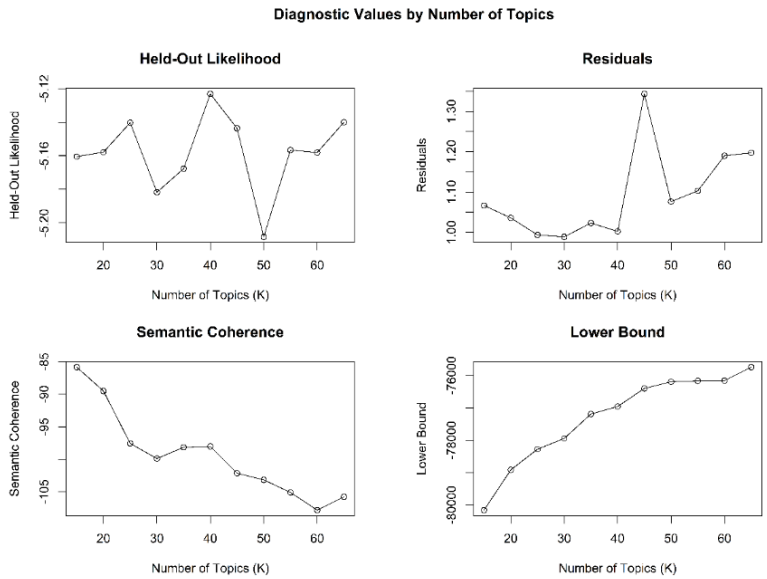

Figure 2A. Model Selection: Diagnostic values by the number of topics (a) held-out likelihood; (b) residuals; (c) semantic coherence; (d) exclusivity. (diagnostic testing is done in increments of 5)

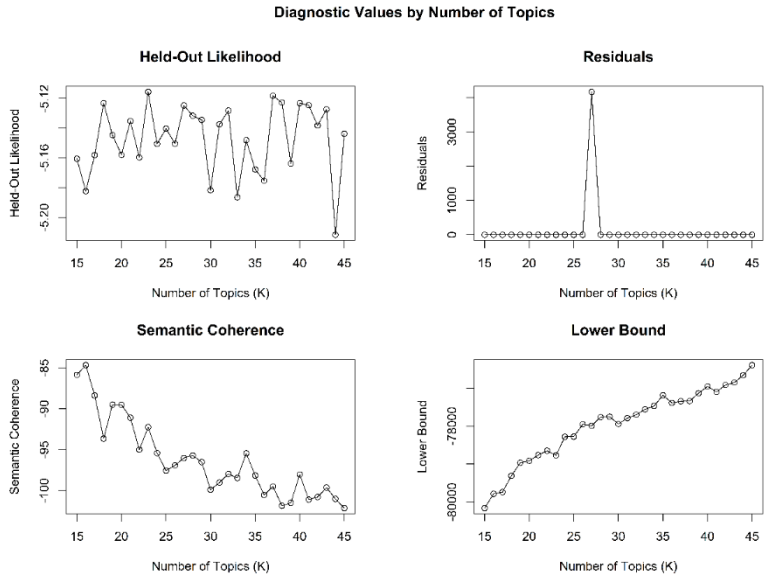

Figure 3A. Model Selection: Diagnostic values by the number of topics (a) held-out likelihood; (b) residuals; (c) semantic coherence; (d) exclusivity. (diagnostic testing is done in increments of 1)

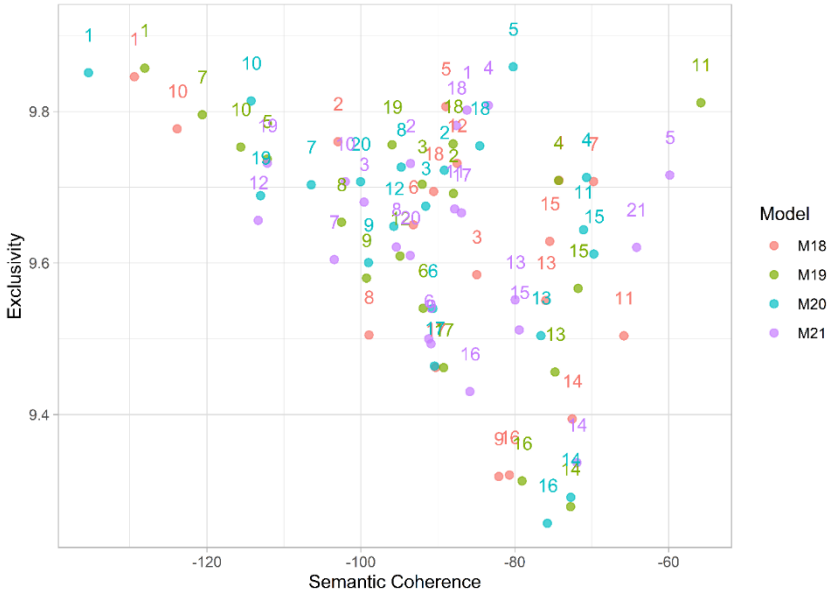

Figure 4A. Model selection: semantic coherence and exclusivity in 18-topic model, 19-topic model, 20-topic model and 21-topic model. The numbers represent the topic specific scores.

2.2 Estimated Topics and Correlations (STM)

The results of the STM model are identified in Table 1A along with the following measures (Roberts, et al. 2014):

1. Highest Prob: words within each topic with the highest probability
2. FREX: words that are both frequent and exclusive to each topic
3. Lift: words that are more common within each topic than they are across the dataset
4. Score: same as lift except the calculation is done using log frequency of words instead of frequency of words

While the intuitive fit of using the word measures to define cohesive topic labels is clear for majority of topics, all topics labels can be logically defined after checking the examples of text highly associated with each topic (Table 2A).

Topic correlation of the estimated topics is also analysed through calculating topic correlates (Schwemmer, 2018). The co-occurrence of topics correlates at the document level are examined to understand how a single document is associated with a given set of topics. Figure 5A shows a network of positive topic correlations from the 21-topic model. In the figure a shorter distance between the nodes and the presence of connections indicates a higher chance that the given set of topics will be discussed in the same document. Larger topic font indicates a higher topic proportion and thicker links indicate stronger level of correlation between the topics. Isolated nodes are not included in the visualisation.

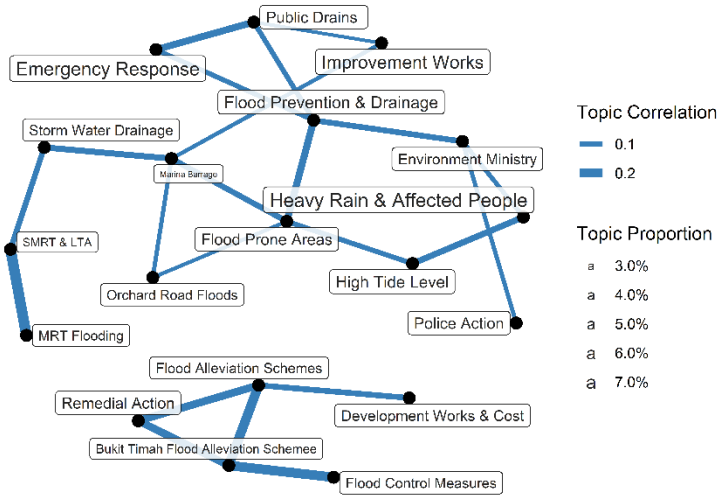

Figure 5A. Positive Topic Correlations.

Table 1A. Topics estimated for 21-topic model.

Topic	Label	Topic Proportion (%)	Top Words
1	Bukit Timah Flood Alleviation Scheme	3.126649	Highest Prob: bukit, timah, flood, scheme, alleviation, phase, areas FREX: bukit, timah, phase, scheme, steps, alleviation, construction Lift: steps, phase, bukit, timah, scheme, alleviation, construction Score: bukit, timah, steps, scheme, phase, alleviation, improvement
2	Public Drains	4.672907	Highest Prob: public, drains, flash, pub, also, members, drain FREX: public, flash, drains, increased, members, free, contractors

			Lift: increased, contractors, public, free, debris, source, flash Score: increased, public, drains, flash, maintenance, debris, pub
3	Heavy Rain & Affected People	7.626658	Highest Prob: floods, heavy, singapore, rainfall, many, rain, people FREX: floods, many, heavy, made, people, rainfall, per Lift: per, floods, small, made, many, experienced, far Score: per, floods, heavy, rainfall, people, flash, singapore
4	Flood Prone Areas	4.750404	Highest Prob: areas, flood, hectares, flood-prone, prone, singapore, years FREX: hectares, flood-prone, areas, prone, used, reduce, years Lift: used, flood-prone, hectares, prone, less, areas, reduce Score: used, hectares, flood-prone, areas, prone, reduce, less
5	SMRT & LTA	2.829575	Highest Prob: maintenance, lta, smrt, pump, pumps, bishan, system FREX: smrt, lta, pump, maintenance, pumps, bishan, systems

			Lift: smrt, pump, pumps, lta, maintenance, bishan, incident Score: smrt, lta, maintenance, bishan, pumps, pump, incident
6	Flood Protection Measures	6.35132	Highest Prob: will, can, take, work, second, just, done FREX: second, take, make, done, think, just, need Lift: second, sure, going, let, make, take, go Score: second, let, make, take, need, owners, question
7	Orchard Road Floods	3.590041	Highest Prob: road, orchard, area, canal, june, rain, mm FREX: orchard, road, june, mm, estate, caused, avenue Lift: orchard, mm, june, estate, avenue, road, jalan Score: mm, orchard, road, june, stamford, canal, estate
8	Environment Ministry	4.279674	Highest Prob: ministry, whether, flood, know, will, plans, environment FREX: ministry, know, plans, environment, whether, national, see Lift: national, ministry, environment, know, plans, see, run Score: national, ministry, whether, environment, development, know, plans

9	The Role of the Police Force	4.690523	Highest Prob: traffic, police, areas, flood, roads, will, situation FREX: police, traffic, roads, motorists, situation, flooded, plan Lift: police, motorists, traffic, morning, situation, roads, alexandra Score: motorists, police, traffic, roads, flooded, areas, Alexandra
10	Storm Water Drainage	4.174823	Highest Prob: water, storm, even, drains, also, much, one FREX: water, storm, even, third, sump, much, built Lift: sump, storm, third, water, metres, even, built Score: sump, water, storm, even, metres, third, drains
11	Flood Alleviation Schemes	3.728419	Highest Prob: completed, drainage, will, project, catchment, drain, area FREX: project, completed, catchment, tanjong, katong, drain, changi Lift: katong, changi, project, tanjong, expected, completed, alexandra Score: katong, project, completed, changi, scheme, tanjong, catchment
12	Marina Barrage	2.4447	Highest Prob: stamford, marina, pub, barrage, level, will, ha

			FREX: marina, barrage, stamford, ha, detention, reduced, increase Lift: barrage, ha, marina, detention, stamford, reduced, 1970s Score: barrage, marina, stamford, ha, detention, 1970s, pub
13	Flood Prevention & Drainage	5.365981	Highest Prob: system, drainage, measures, flooding, can, prevent, ensure FREX: system, drainage, prevent, rainwater, measures, ensure, view Lift: rainwater, system, prevention, incidents, adequate, prevent, view Score: rainwater, system, drainage, ensure, weather, early, incidents
14	High Tide Level	5.128865	Highest Prob: high, tide, will, level, flooding, flooded, area FREX: tide, high, flooded, came, parts, tides, level Lift: came, tide, high, tides, parts, quite, flooded Score: came, tide, high, flooded, level, tides, reclamation
15	Improvement Works	6.665833	Highest Prob: drainage, will, works, improvement, flood, year, pub FREX: improvement, locations, works, drainage, design, concrete, developments

			Lift: concrete, enhance, improvement, locations, design, standards, across Score: concrete, drainage, improvement, works, locations, enhance, design
16	Emergency Response	7.094456	Highest Prob: pub, flood, water, levels, also, level, measures FREX: levels, alert, sensors, residents, sms, provide, platform Lift: sensors, alert, additional, sms, buildings, platform, available Score: additional, pub, sensors, levels, sms, alert, platform
17	Climate Change	7.062572	Highest Prob: climate, change, singapore, rainfall, intense, infrastructure, weather FREX: climate, change, panel, report, intense, urbanisation, weather Lift: change, report, climate, urbanisation, panel, potential, extreme Score: change, climate, report, panel, intense, urbanisation, extreme
18	Development Works & Cost	4.283558	Highest Prob: million, alleviation, schemes, flood, cost, projects, development

			FREX: million, cost, schemes, rural, alleviation, projects, total Lift: total, rural, million, spent, cost, schemes, four Score: total, million, schemes, rural, alleviation, cost, development
19	MRT Flooding	3.520818	Highest Prob: flooding, whether, mrt, stations, risk, tunnel, due FREX: mrt, stations, risk, tunnel, train, whether, due Lift: mrt, stations, train, tunnel, risk, braddell, services Score: mrt, stations, train, tunnel, bishan, braddell, risk
20	Remedial Action	4.693905	Highest Prob: road, area, flooding, sungei, along, kampong, kallang FREX: kampong, sungei, thomson, pasir, kallang, potong, along Lift: pasir, potong, kampong, thomson, temporary, feet, aware Score: potong, road, kampong, sungei, pasir, thomson, braddell
21	Flood Control Measures	3.918321	Highest Prob: canal, timah, diversion, bukit, will, pandan, road FREX: canal, diversion, pandan, ulu, timah, sungei, kallang

			Lift: pandan, ulu, diversion, canal, divert, widening, waters Score: ulu, canal, pandan, timah, bukit, diversion, sungei

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1020 Table 2A. Example of highly associated paragraph for each topic.

Topic	Document Title and Date	Example
1	Budget, Ministry of the Environment 21-03-1986 (Parliament of Singapore (1986). Budget, Ministry of the Environment, 21-03-1986, Vol:47. https://sprs.parl.gov.sg/search/to	First, I will give a reply to the Member for Kaki Bukit who has touched on the Ministry's Bukit Timah Flood Alleviation Scheme Phase II, involving the construction of a diversion canal at Swiss Cottage. I think, if I got him correctly, he wants to know whether this scheme would solve the problem of flooding, particularly in Bukit Timah area.

	pic?reportid=013_19860321_S0002_T0003)	
2	Early Warning Systems for Better Management of Flash Floods 06-02-2017 (Parliament of Singapore (2017). Early Warning Systems for Better Management of Flash Floods, 06-02-2017, Vol:94. https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-1607)	Keeping our drains free flowing is the joint responsibility of all stakeholders? be they public agencies, private developers and contractors, and members of the public. PUB works closely with NEA's Department of Public Cleanliness (DPC) to regularly remove debris, litter and leaves from the drains. It also encourages the public to keep our environment litter-free and give feedback on drain conditions.

3	Floods (Relief to victims) 29-12-1969 (Parliament of Singapore (1969). Floods (Relief to victims), 29-12-1969, Vol:29. https://sprs.parl.gov.sg/search/topic?reportid=01019691229_S0004_T0012)	Pig farmers are eligible for a loan of up to $1,000 at 3 per cent interest repayable in one year. In addition to this loan, small pig farmers who lost pigs in the floods are given $160 worth of feeding stuff.
4	Budget, Ministry of the Environment 19-03-2003 (Parliament of Singapore (2003). Budget, Ministry of the	what about water? Water, obviously is clean and clear from the tap that you have and in the reservoirs. But, more importantly, I also want to highlight that even the amount of ""brown"" water that we have in Singapore has declined. I am referring to floods. In 1992, about 10 years ago, we had about 335 hectares of flood-prone areas in Singapore. Over the last ten years, we have been able to reduce the flood-prone areas by 50% to 172 hectares today. And, over the next five years, we intend to further reduce the areas by

	Environment, 19-03-2003, Vol:76. https://sprs.parl.gov.sg/search/topic?reportid=00220030319_S0002_T0003)	one third to 110 hectares. In fact, Members will notice that, in the last three years, there was not a single case of a major flood in Singapore. There was no flood that was more than 0.5 metre deep with a duration of more than one hour and with a flooded area of one hectare, which is about 1.5 times the size of a football field. Even minor floods, which are less than 0.3 metre and short duration, have also come down from 10 in 2000 to 7 last year.
5	Review of MOT and LTA Senior Staff Remuneration and Bonuses 06-11-2017 (Parliament of Singapore (2017). Review of MOT and LTA Senior Staff Remuneration and Bonuses, 06-11-2017, Vol:94. https://sprs.parl.	Nonetheless, on 29 September 2017, in accordance with its regulatory role, LTA did expressly highlight to SMRT the importance of regular and diligent maintenance of tunnel pump systems and to surface a list of pumps requiring replacement to LTA. Unfortunately, the remedial actions instructed by LTA were not taken in time. The flooding incident occurred before the replacement programme could be completed. There is no evidence of shortcomings or lapses in regulatory oversight by LTA or MOT staff.

	gov.sg/search/topic?reportid=00220030319_S0002_T0003)	
6	Recent Flash Floods in Singapore 19-07-2010 (Parliament of Singapore (2010). Recent Flash Floods in Singapore, 19-07-2010, Vol:87. https://sprs.parl.gov.sg/search/topic?reportid=00620100719_S0006_T0003).	As I mentioned in my reply, where it is possible to accelerate, we will do so and, in fact, the Bukit Timah canal and the diversion canal is one of the top priority areas. So I would like to assure the hon. Member that the PUB is paying close attention and will work as fast as possible to get this job done. To the second question as to whether we can continue to work with the management of the condominiums, we would do so, as per my reply to the earlier question. In fact, after the last three incidents, we contacted all the management of the condominiums and advised them on what can be done. These are all older condominiums. The new condominiums are all subjected to the new platform levels in which PUB has stipulated. For those who were built before the new law came into effect, the best thing for the management to do is really to work together with the PUB and find measures in which they can incorporate. Some have already done so. Some, I think, are considering that. And, in fact, Sir, I would like to add that we are also prepared to work with home owners because, in some areas, it may be difficult for us to expand or enlarge the drain because of

		limited land availability, but what we can do is to advise the home owners on the necessary actions to take. So the PUB is prepared to work with the home owners on what are the measures they can take to prevent flooding in their homes.
7	Flash Floods in Orchard Road 09-01-2012 (Parliament of Singapore (2012). Flash Floods in Orchard Road, 09-01-2012, Vol:88. https://sprs.parl.gov.sg/search/topic?reportid=006_20120109_S0007_T0003)	There have been three episodes of flooding in the Orchard Road area over the past 18 months. On 16 June 2010, some 100 millimetres (mm) of rain fell in the area over two hours. This resulted in the stretch of Orchard Road between Cuscaden Road and Cairnhill Road being flooded to a depth of up to 300 mm. On 5 June 2011, a few days after I moved to the Ministry, some 124 mm of rain fell on those areas over about four hours, and caused the Tanglin area to be flooded to a depth of some 100 mm. Most recently, on 23 December 2011, even heavier rainfall occurred - this time, some 153 mm of rain over three hours was recorded over the same catchment area.
8	Jalan Eunos (Flood control measures)	asked the Minister for the Environment (a) whether his Ministry had anticipated the recent floodings at Jalan Eunos in the vicinity of the Pan-Island Expressway flyover, and, if so, why the flood

	15-05-1979 (Parliament of Singapore (1979). Jalan Eunos (Flood control measures), 15-05-1979, Vol:39. https://sprs.parl.gov.sg/search/topic?reportid=010_19790515_S0006_T0025)	control measures were not effective; (b) what steps are being taken to remedy the flooding problem; how effective those measures will be; and, if they are not effective, whether he will recommend that the families affected by the floodings be resettled immediately; and (c) whether draining flood water into the Siglap Canal will cause overloading of the Canal thereby aggravating the floodings in Pachitan, Changi Road and Frankel Estate; and, if so, whether his Ministry will revise its plans by diverting flood waters elsewhere or into new drainage networks instead of into the Siglap Canal. the piece of land between Jalan Eunos and the Pan-Island Expressway flyover now under construction is a part of the low-lying area of Geylang Serai, and it is always prone to floods. There are 20 squatter huts there. The residents there do know that this area is very prone to floods and so out of the 20 huts, 10 are on stilts. The Ministry does not run a weather bureau, but it does know that this area is prone to floods. Part of this low-lying area has been filled up to build the Pan-Island Expressway and, as a result, the rest of the area has become more prone to floods.
9	Budget, Ministry of Home Affairs 14-03-1984	The plan is implemented in phases. The flood situation is first monitored. If necessary, the Police will request SBC to broadcast at regular intervals the areas affected by flood so that the motoring public can avoid these areas. If the flood situation gets worse, the

	(Parliament of Singapore (1984). Budget, Ministry of Home Affairs, 14-03-1984, Vol:43. https://sprs.parl.gov.sg/search/topic?reportid=01019840314_S0002_T0003)	plan for road diversions and, if necessary, for evacuation of flood victims, will be implemented. Should floods occur during hours of restrictive entry into the Central Business District, the Police will also lift the restriction to enable the motorists to go through the gantry points and thus avoid flood areas.
10	7 October 2017 SMRT Flooding Incident and Related Issues 07-11-2017 (Parliament of Singapore (2017). 7 October 2017 SMRT Flooding Incident and Related	Specifically, the Bishan storm water sump pit has a capacity of over 5,000 cubic metres. This is roughly the size of two Olympic-sized swimming pools. In comparison, the total rainfall which was cleared from the tunnels was only about 640 cubic metres, not even 700, not even a thousand cubic metres, much less than the 5,000-cubic-metre capacity. This would have filled 13% of the pit's capacity even if all the three pumps were not working. There is plenty of buffer.

	Issues, 07-11-2017, Vol:94. https://sprs.parl.gov.sg/search/sprs3topic?reportid=ministerial-statement-1013)	
11	Budget, Ministry of the Environment 19-03-1990 Parliament of Singapore (1990). Budget, Ministry of the Environment, 19-03-1990, Vol:55. https://sprs.parl.gov.sg/search/topic?reportid=006_19900319_S0002_T0003)	The main work under the Tanjong Katong Flood Alleviation Scheme comprises the re-construction and upgrading of two drainage pumping stations serving the low-lying catchment of Tanjong Katong. This project is expected to be completed by the end of this year. When completed, flooding in Tanjong Katong catchment will be alleviated substantially.

12	Recent Flash Floods in Singapore 19-07-2010 (Parliament of Singapore (2010). Recent Flash Floods in Singapore, 19-07-2010, Vol:87. https://sprs.parl.gov.sg/search/topic?reportid=00620100719_S0006_T0003).	To alleviate the risk of flooding in low lying areas in the city, the Marina Barrage has been in operation since 2008. It has served to remove tidal influence at the Stamford Canal outlet. During heavy rain, up to nine gates and six pumps at the barrage will be operated to discharge excess storm-water to the sea.
13	Public Utilities Bill 16-03-2001 (Parliament of Singapore (2001). Public Utilities Bill, 16-	This Public Utilities Bill is to respond to the changes in the water industry. Allow me to explain. In the early days, drainage systems were meant to drain away rainwater quickly to prevent flooding. At the same time, sewerage systems were put in place to control pollution in order to protect public health. Hence the Drainage and Sewerage Departments come under ENV.

	03-2001, Vol:73. https://sprs.parl.gov.sg/search/topic?reportid=00820010316_S0002_T0009).	
14	Budget, Ministry of the Environment 20-03-1974 (Parliament of Singapore (1974). Budget, Ministry of the Environment, 20-03-1974, Vol:33. https://sprs.parl.gov.sg/search/topic?reportid=01419740320_S0003_T0005)	The tide that he mentioned was a freak tide, which is not normal. The freak tide was the highest recorded in 20 years. It was two feet higher than normal, and high tides usually occur around that time of the year. We have the spring tide around the Chinese New Year and, as far as I can remember, very high tides usually occur on the 3rd day and on the 18th day of the Chinese Moon. On these occasions a large part of that part of the town is flooded because it is just a few inches above high water level. But the freak tide that the Member referred to was so high that it even covered the breakwater. Those Members who were observant enough on that day would have noticed that it even covered the breakwater. So the freak flood that had occurred was not the result of land reclamation. It has got nothing to do with it. It is the result of some special conjunction of the moon, the sun and the earth.

15	Early Warning Systems for Better Management of Flash Floods 06-02-2017 (Parliament of Singapore (2017). Early Warning Systems for Better Management of Flash Floods, 06-02-2017, Vol:94. https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-1607)	First, the pathways. Since 2011, PUB has raised drainage design standards for new developments and redevelopments, which would increase their drainage systems' capacity by up to 50%. PUB has also been carrying out improvement works to progressively increase the capacity of existing drains and canals, and rehabilitate older drains. In the last three years, drainage improvement works at 192 locations have been completed and there are on-going projects at 90 other locations.
16	Singapore's Flood Resilience Plans	At the ""receptor"" level, PUB has raised the requirement levels for platform and crest levels for all new developments and re-developments since 2011. This is to provide an additional safeguard

	20-01-2015 (Parliament of Singapore (2015). Singapore's Flood Resilience Plans, 20-01-2015, Vol:93. https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-799)	against future sea level rises. PUB has also been working with specific building owners to provide technical advice on relevant receptor solutions such as flood barriers and road crests where necessary.
17	Enhancing Commitment to Climate Change 14-04-2014 (Parliament of Singapore (2014). Enhancing Commitment to	what development plans and past strategies need to be reviewed as a ""whole-of-Government"" approach to ensure that the recommended solutions of the UN Intergovernmental Panel on Climate Change are heeded and our commitment strengthened in dealing with climate change. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), global warming could increase risks of flooding, food insecurity, insufficient access to drinking water, heat-related mortality, breakdown of infrastructure networks and

	Climate Change, 14-04-2014, Vol:91. https://sprs.parl.gov.sg/search/sprs3topic?reportid=written-answer-na-1957)	services from extreme weather events, and loss of biodiversity. The report highlights the importance of countries taking action to reduce greenhouse gas emissions while enhancing their resilience to climate change. It is an authoritative document based on the collective assessment of scientists worldwide.
18	Annual Budget Statement 28-11-1963 (Parliament of Singapore (1963). Annual Budget Statement, 28-11-1963, Vol:22. https://sprs.parl.gov.sg/search/topic?reportid=025_19631128_S0005_T0021)	Under Land and Agricultural Development [Table III], the performance was well below the average for the economic development sector. The main projects consist of Flood Alleviation Schemes, Rural Development Schemes, Purchase of Land, Animal Husbandry and Station, and equipment for public works. General Rural Development Schemes are progressing on schedule, $1.6 million to be spent as against $1.64 million in the plan estimate. These schemes have provided more than 250 rural streets and kampongs with lights and extension of electric supply. 239 stand-pipes have been installed for rural dwellers. Farmers and fishermen have received extension services in agricultural, fishing and other veterinary services from seven centres. Fertilisers, technical advice and other services are also given to farmers and fishermen at little or no cost to increase their farming or fishing productivity and

		lower the cost of production, thereby increasing their incomes. Purchase of land exceeds the plan estimates, being $10 million as against $8.8 million. As against these successes, the swamp reclamation schemes hardly got off the ground, $0.24 million being spent as against $2.7 million ear-marked for these schemes. Flood Alleviation is also well behind schedule, $1.7 million being spent as against the plan estimate of $9.0 million. This lack of progress is mainly due to the obstruction by squatters which was engineered and encouraged by pro-Communist groups as part of their deliberate policy to frustrate development in the State.
19	7 October 2017 SMRT Flooding Incident and Related Issues 07-11-2017 (Parliament of Singapore (2017). 7 October 2017 SMRT Flooding Incident and Related Issues, 07-11-	in an unrelated but concurrent incident, train services were suspended in both directions between Marina South Pier and Newton MRT stations from about 5.50 pm, when the same train captain who reported the flooding, spotted electrical arcing at the trackside between Raffles Place and Marina Bay MRT stations. Electrical arcing occurred because accumulated debris caused a short circuit between an electrified baseplate and a bolt in the ground. The bolt had been left in place after some renewal works many years ago in 2003. It should have been removed but it was not. The short circuit generated sparks and heat, causing the debris to smoulder.

	2017, Vol:94. https://sprs.parl.gov.sg/search/sprs3topic?reportid=ministerial-statement-1013)	
20	Lorong Kinchir (Flood alleviation measures) 15-05-1979 (Parliament of Singapore (1979). Lorong Kinchir (Flood alleviation measures), 15-05-1979, Vol:39. https://sprs.parl.gov.sg/search/topic?reportid=016_19790515_S0006_T0026)	This brings out the point that I was trying to make earlier on to the hon. Member for Kampong Kembangan who asked about the flooding at the junction of Jalan Eunos and the Pan-Island Expressway. Here is a case where it is unwise to spend money on something temporary. It is only after completing the deepening and widening of Sungei Kallang that we should begin to widen and deepen the six canals which drain water from Ang Mo Kio through the Kampong along Lorong Kinchir to Sungei Kallang. This is the sequence to be followed to finalise the drainage for the area.

21	Upgrading of Bukit Timah Canal and Maple Avenue Tributary Canal 07-07-2014 (Parliament of Singapore (2014). Upgrading of Bukit Timah Canal and Maple Avenue Tributary Canal, 07-07-2014, Vol:92. https://sprs.parl.gov.sg/search/sprs3topic?reportid=written-answer-2029)	The First Diversion Canal branches off from the main Bukit Timah Canal at Maple Avenue and helps to divert stormwater from the upstream section of Bukit Timah Canal into Sungei Ulu Pandan. Since 2012, PUB has commenced upgrading the 3.2-km diversion canal in phases. Works are ongoing for a 280-m stretch underneath Ulu Pandan Road near the Pine Grove condominium and a longer 1.5-km stretch between Maple Avenue to Holland Green. Both stretches will be completed in 2015 and 2016 respectively, and the rest of the First Diversion Canal will be enhanced subsequently.

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