EMERGENT CHALLENGES ADAPTING COASTAL STORMWATER AND DRAINAGE SYSTEMS

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ABSTRACT

Background

The asset value of stormwater and wastewater assets in New Zealand is well over $20 billion, which includes over 17,000 km of stormwater network (White et al., 2017). Historically, infrastructure in coastal areas was designed assuming a static mean sea level (MSL). The so-called local MSL datums still in use are a case in point, where the zero datum was set several decades ago, but MSL is now considerably higher. Consequently, any freeboard (intended or not) built into legacy stormwater and drainage systems has largely disappeared as sea level continues to rise; by around 18-24 cm since 1900.

Building floor levels are generally higher than road networks (and associated stormwater assets) and secondary overland flowpaths. This means that in low-lying coastal areas, flooding of local road networks and decreasing levels of service for stormwater and drainage systems are already emerging as the first signal of significant impacts from sea-level rise (SLR).

A recent risk census for coastal areas for the Parliamentary Commissioner for the Environment (PCE, 2015) shows substantial exposure throughout New Zealand even for modest rises in sea level. It was based on counts of buildings, roads, rail, airports and land-use – but most of these assets are associated or co-located with stormwater networks or drainage schemes, so act as a proxy for their considerable exposure.

Combined indirect effects of SLR and other climate change effects on waves, storms, groundwater, rainfall and river flows will compound the impacts on stormwater and drainage networks. In time, this will alter the type and design of systems that can be used in low-lying coastal areas (e.g., from gravity to vacuum or pressure/pumped systems, or green infrastructure or distributed systems and eventually relocation inland).

The presentation will provide a synthesis of the compounding and cascading impacts from SLR and changes to coastal processes on stormwater and drainage networks, which can inform their consideration in decision making in coastal areas and; how dynamic adaptive pathway planning, with signals and triggers to guide implementation of adaptation options or pathways. Signals (which give early warning) and triggers (defined as the decision point for switching pathways) most relevant to stormwater systems could relate to the changing frequency of coastal flooding (in terms of coping capacity of council services or the community) e.g. number of nuisance floods as the derived indicator of impacts from a rising sea.

Dynamic adaptive pathways planning approach

Adaptation of stormwater and drainage networks in coastal areas will be more effective if the complex mix of compound changes are addressed. Adaptation of such engineering lifelines needs to be undertaken in the context of adaptation of coastal communities and those activities that these systems service.

Adaptation in coastal areas is driven by statutory requirements primarily through the NZ Coastal Policy Statement (NZCPS) and supported by forthcoming implementation guidance on managing the changing coastal hazards by the Department of Conservation. More comprehensive coastal guidance by the Ministry for the Environment or MfE (draft at time of writing) and summarized by Bell et al. (2017), is underpinned by the dynamic adaptive pathways planning (DAPP) approach. This adaptive approach differs from previous versions of the coastal guidance and from current coastal management practice by: a) its focused treatment of uncertainty (e.g. in matching type of decision to appropriate level of hazard/risk assessment – Stephens et al., 2017); b) the centrality of community and stakeholder engagement in the decision-making process; and c) the explicit assessment of community values and related vulnerability assessment and use of scenarios to reflect uncertainties (e.g., Haasnoot & Middlekoop, 2012). The coastal guidance shifts from a linear approach to hazard risk management to a focus on 'testing' adaptation options against a range of scenarios before making decisions on pathways or actions to reduce or avoid risk or to maintain levels of service.

Accordingly, the DAPP approach can accommodate changes in the future without locking in investments that make adjustments difficult or costly, when agreed objectives fail to be met at trigger or decision points (Haasnoot et al., 2013; Lawrence & Haasnoot, 2017). It also enables decisions to be made in the short-term that do not create path dependency, such as not precluding re-routing or greening of areas. Such an approach is nimble in dealing with the widening uncertainty bounds on SLR and other coastal-hazard drivers. However, for effective adaptation to be implemented, it requires: a) motivation by stormwater professionals to employ a DAPP process; b) considerable community and stakeholder engagement; and c) a commitment to monitoring the timing of signals and triggers and regular reviews. Use of DAPP reduces the risk of dependencies in stormwater systems that are not sufficiently robust or flexible (adaptable) to meet different coastal futures and enable surprises at both ends of the range for SLR projections to be accommodated.

Compounding climate-change impacts on stormwater and drainage systems

In addition to the ongoing rise in sea level, several compounding factors, associated with climate change, will impact on stormwater and drainage systems, exacerbating pressure on these systems from intensification of coastal urban and peri-urban areas and land-use change. These include changes in intensity of rainfall (and hence flows in rivers/streams), waves, storm surge, vertical land movement (subsidence), rising groundwater levels, low-flows in rivers (which enable storm-tides to encroach further upstream) and salinization of lowland freshwater systems. One of the more pertinent compounding impacts is the combination of increasing intensity of rainfall and seawater flooding of low-lying coastal areas during storm-tide and wave overtopping events. Projected changes from climate change in waves and storm surge for New Zealand will be relatively small (1-10% change) compared to the background SLR. Nevertheless, even minor changes in waves and storm surge in the near term will further erode the buffer that exists presently between the rising spring high tide and any present-day extreme storm-tide flood level (to which existing development and systems are attuned to). As the SLR continues these compounding effects will intensify to the point they become permanent inundation or groundwater levels. Areas with smaller tide ranges, such as the central east coast areas from Timaru to East Cape, will also experience increased occurrences of both spring high tide inundation (hence the term "fair-weather" flooding) and coastal storm flooding relative to other areas with higher tide ranges (e.g. west coast).

Since many of our gravity driven drainage systems are tailored towards discharges at the coast or to lowland river, these compounding impacts of climate change on the back of SLR, will be one of the first emerging challenges in coastal margins to deal with increasing tail water levels and flood and wave overtopping volumes at the coast. For example, we observe this in the lower Avon River area after the sudden subsidence (effective step change in SLR) following the Canterbury earthquake sequence.

Changing frequency of coastal flooding

Existing development in low-lying coastal areas that is exposed to coastal climate change, can be defined as those areas subject to flooding by a present-day 1% AEP event (or a 63% chance of flooding in 100 years). Ongoing rise in MSL, and therefore the ordinary spring tide, erodes the additional height increase needed to exceed that coastal flood level. Therefore, ever-decreasing storm surge heights and/or wave heights will be all that are needed to cause similar flooding until annual and then fortnightly spring tide inundation. In New Zealand, because our storm surges are physically limited, the range between the present 1% AEP (which existing development is based on) and spring high tide, is only a few decimeters. This buffer disappears when that same equivalent SLR occurs locally. That leaves coastal areas further exposed to deeper flooding and substantial damage for future 1% AEP events.

To support the anticipatory DAPP approach for adaptation of coastal assets prior to an adaptation threshold being reached (e.g. level of service deterioration), early warning signals and triggers can indicate when switching to other adaptation actions and pathways is needed. This work is underway in the Deep South Science Challenge. SLR is the underlying cause of increasing risk exposure in coastal areas, but is not a very useful or timely indicator for New Zealand, because of the difficulty of identifying a change or acceleration in SLR from the noise of climate variability -in which case it is would be too late to act. Rather, we found that the number of coastal flooding events in a 10-year period can provide a more timely signal of an impending adaptation threshold. For example, if stakeholders and the community agreed on an adaptation threshold of 5 $\times$ 1% AEP events in a 10-year period, then a timely early signal or trigger can be derived as a certain number of moderate 20% AEP flooding events in the same 10-year period. Such a derived signal would reduce the chance of the adaptation threshold being reached before adaptation is signalled, otherwise it reverts to a reactive response. The sobering result from this work is that coastal areas currently exposed to infrequent 1% AEP coastal flooding, will reach such a signal in the next two to three decades, irrespective of the climate-change emissions scenario. Consequently, the time to implement adaptation options for say stormwater networks may be relatively short.

Conclusions

Due to ongoing SLR, decreased levels of service of stormwater and drainage systems, along with disruptive roadway flooding will be the first signs heralding more substantial impacts on residential housing and businesses in lower coastal areas. The DAPP approach provides an adaptive planning tool that enables uncertainties in SLR projections to be addressed for avoiding and reducing path dependency from inflexible or premature adaptation actions. Early signals and triggers for the DAPP process derived from a set number of moderate coastal flooding events are likely to occur before an agreed adaptation threshold (e.g. a reduced level of service or number of extreme flood events in a 10-year period), and can be used to trigger adaptation decisions before the threshold is reached. Adaptation planning and monitoring of signals and decision triggers for coastal stormwater and drainage systems needs to start in earnest in areas already exposed to 1% AEP coastal flooding events, because of the rapid increase in the frequency of coastal flooding even for a modest rise in sea level across New Zealand of 30-45 cm. Adaptation of piped systems to more flexible systems will also need consideration for addressing more permanent coastal inundation that will occur routinely at spring high tides and increased erosion of coastal or harbour shorelines.

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KEYWORDS

Climate change, adaptation, stormwater, coastal flooding, sea-level rise

SESSION

Future Ready: Resilience and Climate Change