Future sea level rise and flood risk in the Chichester District

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Abstract

Future sea-level rise will intensify existing hazards for coastal populations, economies, infrastructure, and ecosystems around the world. The low elevation Chichester region is extraordinarily vulnerable and exposed to sea level rise, fluvial and pluvial flooding. The conflicting aims of meeting housing targets and short-term economic goals versus long-term sustainable management of the environment and communities mean that coastal flooding and erosion are not getting the attention that they merit.

Cautious, stakeholder decision making based on the most up to date science will lead to planning that saves money and protects human lives into the future. To help mitigate against the threat of sea level rise, the following measures are advised:

- Avoid new development in areas at risk of inundation and increase regional standards of protection to levels approximating an annual expected probability of occurrence of 0.01%
- Have alternatives at the ready for when funding is available after focusing events.
- Prepare flexible-adaptive designs that provide pathways for different climate change scenarios, such as methods employed by the Thames Barrier 2100 project.
- Engage with the public when designing and siting infrastructure projects. A local Committee on Climate Change may be formed to engage the public.
- The Chichester Council should consider planning horizons after 2025, ideally to the end of the century.

1 Sea level rise and inundation

As global average temperature increases further into the future, mean sea-level will rise due to runoff from melting mountain glaciers, melting and disintegration of ice sheets, and thermal expansion of warming ocean water (1). Satellite observations from 1993 to 2010 estimate that global sea level is rising by 3.2 mm per year and accelerating rapidly (2), with a recent study attributing around 70 per cent of sea level rise from 1970 to 2005 to human activities (3).

The melting Antarctic and Greenland ice sheets will largely dictate future global mean sea level rise, as together these ice sheets hold enough water to cause mean sea level to rise by 54 m and 7 m respectively (1). Advances in ice-sheet modelling suggest that the West Antarctic ice-sheet, which is particularly sensitivity to climate change as it rests on a reverse slope bed, could contribute 1.7 m to mean sea level by 2100 (4). It is also likely that coastal communities are locked into a range of sea level rise by the year 2050 regardless of whether carbon emissions increase or decrease (5).

Rising mean sea levels are already magnifying the frequency and severity of extreme sea level events and flooding (6). Extreme sea level events, which are driven by storm surges, extreme wave setup and high astronomic tides, that have occurred historically on average once in every 100-years, are expected to occur annually or even more often in many places around the world by 2050 (2). If coastal societies do not adapt, flood risks will increase by 2–3 orders of magnitude reaching catastrophic levels by the 2100, even under the lowest sea-level rise projections (7).

More frequent flooding has a number of economic, environmental, and human costs. Main concerns currently facing low-lying coasts are: (i) permanent submergence of land by mean sea-levels or mean high tides; (ii) more frequent or intense flooding; (iii) severe damages to critical infrastructure; (iv) loss and change of ecosystems; (v) salinization of soils, ground and surface water; (vi) impeded drainage and (vii) enhanced erosion.

Sea level rise additionally raises equity concerns as populations most vulnerable will be disproportionately affected, potentially sparking or compounding conflict. The threat of coastal flooding is evident considering 600 million people currently reside within 10 m of mean sea level (≈2% of the world's land mass), but there has been and continues to be a steady demographic increase through migration to coastal regions (8).

Assuming no upgrade in defensive structures, a sea level rise of only 40 cm is projected to flood more than 100 million people per year globally (9). Sea level rise between 25–123 cm by 2100, if no mitigation or adaptation is employed, will lead to expected annual damages amounting to 0.3–9.3% of global gross domestic product (10). In the UK, current annual damages from coastal flooding are estimated at over £500 million per year, and costs of damage are likely to increase under projections of future sea-level rise. It is almost certain that England will have to adapt to at least 1 m of sea level rise at some point in the near future. As such, sea-level rise presents one of the biggest adaptation challenges to climate change.

2 Risk, vulnerability and exposure

Risk is usually defined as a measure of the probability of an event occurring multiplied by the impact that the event would have (2). In some situations governments are able to directly mitigate the physical event, thus reducing the risk posed to a population. Risk from atmospheric particulate pollution or smog events, as an example, can be mitigated by changes to exhaust systems or by advancing environmental pollution legislation.

Risk = Event + Exposure + Vulnerability - Resilience

Sea level rise, however, is a global phenomena, and the processes that drive sea level rise, once initiated, are highly insensitive to climate mitigation efforts. Climate modelling and paleoclimatic estimates suggest that anthropogenic emissions have already committed the Earth to at least 4 m global mean sea level rise regardless of future carbon emission's or deployment of negative carbon technologies (5; 11). Local and regional efforts to limit carbon emissions will therefore do little to curtail the physical threat from the sea, at least in the near term.

As local and regional communities are extremely limited in their ability to halt or slow sea level rise, they must instead look to ameliorate the risk of rising sea level by limiting the exposure and vulnerability of coastal communities whilst enhancing resilience. Exposure refers to people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses, whilst vulnerability is the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events. Enhancing resilience focuses on improving the ability of a community in absorbing, accommodating and recovering from the effects of an event.

3 Flood risk in the Chichester District

Sea-level rise is not uniform globally, as it is affected by multiple local and non-local factors including gravitational effects, ocean circulation patterns, and vertical land movement. The South Coast of the UK is subject to natural subsidence of land of approximately 1.2 mm per year (12). This regional subsidence is primarily due to the ongoing movement of crust that was once burdened with a huge ice sheet during the last glacial period (a process called Glacial Isostatic Adjustment). Land subsidence in the South Coast therefore enhances local sea level rise (as the land is sinking), thus intensifying coastal hazards and risk.

The most vulnerable regions along the South Coast are low lying flood plains. The Manhood Peninsula is at particularly high risk of flooding as topography in this region is less than 5 m above current mean sea level. Even under moderate carbon emission scenarios (known as the RCP4.5 emission projections), without adaption or wide scale defence infrastructure, by 2050, highly populated areas of the Chichester district will fall below mean sea level ((13); Figure 2 a). By 2100, broader areas inlcuding the Witterings, Bracklesham, Selsey, Birdham, Almodington and Sidlesham will be subject to permanent inundation (Figure 2 b). When the annual flood event is considered, most regions south of Chichester city centre will be inundated regularly by 2100 (Figure 2 c). The main areas at risk are Pagham, Selsey and the Witterings with 20,000 permanent residents, and thousands of visitors each year (14).

Additionally, standards of protection are low in the Chichester region. Under current practice in developed countries, acceptable levels of coastal flood risk are often based upon specific flood return periods, such as the 100-year flood (with 1 % annual expected probability of occurrence [AEP]; (16)). Most developed countries build to protect against an

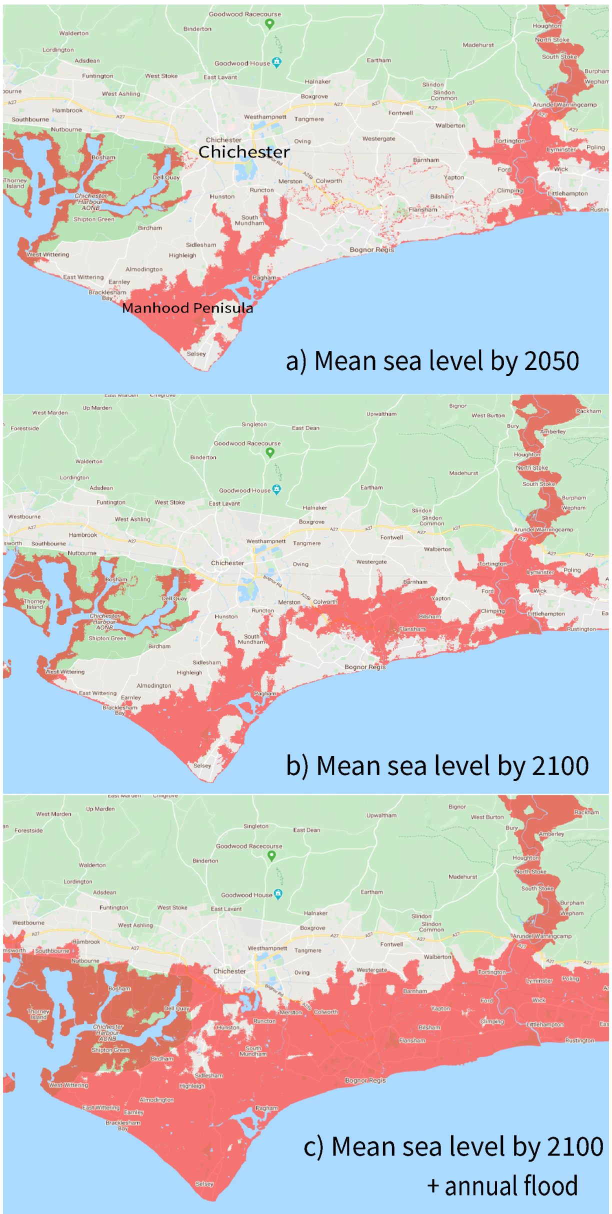

Figure 1: Climate Central sea-level inundation maps (15), based on peer-reviewed science in leading journals. a) Mean sea level by 2050, b) mean sea level by 2100 and c) mean sea level by 2100 with the annual flood level. Annual flood level is used to denote the water level at the shoreline that local coastal floods exceed on average once per year. Projections shown are based on moderate emissions cutting scenario (RCP4.5 emission pathway (1)), consistent with about 2°C of warming, the main target from the Paris Agreement (13).

AEP of 1% (16). The majority of coastal and tidal defences in the Chichester District, however, currently provide a standard of protection against an event with an AEP of 4% or 5% (14). The Netherlands has adopted a much higher standard of protection approximating an AEP of 0.01% (providing protection against a 1-in-10,000 year event; (17)).

Insufficient protection measures in the Chichester District will become even more inadequate in the future due to sea level rise, as flooding becomes more common and flood heights rise (6). Sea level rise of 50 cm, as an example, would increase the AEP of the current 0.1 % annual chance flood to 1 % at London's Thames Barrier (18), meaning the barrier—originally built in the 1970s to protect against the 1 % AEP flood—now faces a premature upgrade to accommodate sea level rise (19).

Some parts of the Chichester District are currently unprepared. The coastline between East Head and Emsworth does not currently have a coastal defence strategy (14). Much of the region south of Chichester has also been categorized in the highest flood risk assessments (flood zone 3) by the Environmental Agency (14). As this region is a popular retirement area, population vulnerability is high. In the Chichester District almost 1 in 4 people are aged 65 or above, which is much higher than the national average (20).

4 Ways forward

The scale and implications of future coastal change should be acknowledged by those with responsibility for the coast and communicated to people who live on the coast. Although the restoration of floodplains is difficult in previously developed areas where development cannot be rolled back, measures can be taken to save human lives and limit loss in the future.

4.1 Coastal protection and planning

If population, economic and environmental resources were not located in potentially dangerous settings, no problem of sea level risk would exist. Land use and territorial planning are therefore key factors in risk reduction. If local governments seek to reduce future impacts from climate change, they should avoid new development in areas at high risk of inundation, while protecting, relocating, or abandoning existing infrastructure and settlements.

It is clear that local protection is low and should be increased, ideally to levels approximating an annual expected probability of occurrence of 0.01%. Allowances for climate change over the lifetime of a proposed development must be made in line with latest guidance for climate change. Chichester District Council's Flood Risk Assessment currently has separate high climate change allowances (referred to as high++) that only apply in assessments for developments that are very sensitive to flood risk, for example large scale energy generating infrastructure, and that have lifetimes beyond the end of the century (14). Chichester District Council should use these high climate change allowances to evaluate developments, such as residential construction on floodplains, that are historically less sensitive to flood risk but will become much higher risk in the future.

Despite strong evidence showing that flood defenses are good long-term investments in developed areas, actual implementation of strategies to reduce flood risks in the UK have been modest. Protection measures such as storm barriers and sea walls are slow to construct, with implementation often occurring only after a focusing event, when damage may have already been inflicted (21). A focusing event refocuses the attention of elected officials and public's on an existing problem. The Thames Barrier, for example, was built following the 1953 storm surge (2).

During a focusing event, a policy window of opportunity opens for a short time period, and advocates often race to push their preferred solutions through before the window closes (21). If no viable solutions are presented while the window is opened, changes are unlikely. Thus, the Chichester Council needs to have alternatives at the ready for when funding is available after a focusing event has occurred. These alternatives may include building surge barriers and other defense measures, options to adapt to coastal floods and sea-level rise such as elevating structures to accommodate extreme water levels and moving populations and the built environment away from the coastline (2).

Many stakeholder plans focus on 2050 or nearer term because that is, for their particular purposes, a rational near-term to medium- term planning horizon (5). The time frame of 20-30 years, is the period when the public thinks about making investments in their homes and when public sector agencies complete long-range master plans for land use or transportation. However, it is important to recognize that land use, transportation, and other infrastructure decisions can have consequences lasting substantially longer than this time frame. Practitioners and legislative entities should therefore identify multi-decadal planning horizons. The Chichester Council climate emergency plan, for example, should be expanded beyond 2025, ideally to the end of the century.

4.2 Community Resilience

Resilience strategies may seek to strengthen coastal protection, provide upgrades to existing buildings and infrastructure, relocate from the most at-risk areas as well as enhance community engagement and preparedness. Due to the uncertainty of sea level rise predictions beyond 2050, it is important for coastal communities to be prepared for different scenarios. Enforcing and deciding on which building and protection frameworks to pursue is particularly difficult due to the uncertainty in sea level rise projection. Flexible/adaptive frameworks, such as methods employed by the Thames Barrier 2100 project (21), have been promoted in recent literature as a way to make decisions under deep uncertainty in sea level rise projection. Flexible/adaptive approaches commit to short-term actions in response to new information (22; 23). They have the advantage of being less dependent on accurate projections of the future. An example could be flexible levee design that allows for heightening over time as risk tolerances change or as new information is learned about future sea-level rise. The use of flexible/adaptable decision-making could also be used to resolve stakeholder disagreements by outlining and visualizing multiple pathways that could lead to the same desired future.

Adaptation strategies to manage long-term coastal changes often conflict with the short term interests of the people who will be most affected by those decisions. The scale and implications of future coastal change should therefore be communicated to people who live on the coast. Resilience can be enhanced by engaging with the public when designing and siting infrastructure projects. Public opinion should also be taken seriously as environmental laws can elevate the power of citizens and non-profits who may view projects as threats to natural resources or have narrower 'not in my backyard' concerns (21). Rather than top-down, state-directed approaches for the siting of controversial facilities, impacted citizens should be directly involved in decision making (21). A local Committee on Climate Change of community stakeholders including local scientists and business owners may be formed to engage the public.

5 Conclusion

The Chichester District is extraordinarily vulnerable and exposed to sea level rise, fluvial and pluvial flooding. Before building on low lying areas, the seriousness of sea level needs to be properly evaluated based on the most up to date sea level science. Sea level rise is both a near and long term danger: today's legislative entities must make choices not just on the behalf of future generations, but also for current populations.

The following measures are advised:

1. Avoid new development in areas at risk of inundation and increase regional standards of protection to levels approximating an annual expected probability of occurrence of 0.01%

2. Have alternatives at the ready for when funding is available after focusing events.

3. Prepare flexible-adaptive designs that provide pathways for different climate change scenarios, such as methods employed by the Thames Barrier 2100 project.

4. Engage with the public when designing and siting infrastructure projects. A local climate change committee of community stakeholders including local scientists and business owners should be formed.

5. Coastal adaptation entails decisions with long time horizons and impacts for people which might involve the permanent loss of their most valuable asset (their home) and threaten the viability of entire communities. The Chichester Council should therefore consider planning horizons after 2050, ideally to the end of the century.

6 About the author

Joe Lockwood is a PhD student at the Department of Geoscience at Princeton University. He was brought up in Chichester and is interested in sea level rise and flooding, hurricanes and climate change and how societies respond to them. Contact at mailme@josephlockwood.co.uk

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