Submission No 362

INQUIRY INTO PROPOSAL TO RAISE THE WARRAGAMBA DAM WALL

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Preamble

For fourteen years between 1990 and 2004 I was employed by the New South Wales State Emergency Service, firstly as its State Planning Co-ordinator and later as Deputy Director General (Deputy Commissioner). In those roles, and later as a floodplain management consultant and researcher undertaking projects in Queensland, New South Wales, Victoria and South Australia, I developed expertise in flood response management, in planning for the occurrence of floods, in comprehending the contexts in which floodplain management and flood mitigation decisions are undertaken and in coming to grips with the benefits and disadvantages of proposals for development on floodplains. I liaised frequently during my career with personnel from the Australian Government Bureau of Meteorology, the various water agencies (the New South Wales departments of Public Works and Water Resources and their successor organisations), the state's Department of Planning, councils of local government, dam owners and the Dams Safety Committee and the volunteers of local State Emergency Service units. I learned about flood forecasting and warning practices, land use management regulations and the many aspects of flood preparation (such as community education and organisational planning) and real-time flood responses including evacuation management and the undertaking of resupply operations.

As a result of this work, I believe I came to understand well the strengths and weaknesses of flood management as it is practised in New South Wales and other parts of Australia. I also led in the development of a number of best-practice national flood management manuals on flood warning, flood preparedness, flood response and planning for releases from storage dams (both intended and as a result of dam failure). These manuals were published in 1995 and 1998, and they were reviewed and updated by multi-state committees I oversaw in 2007-09.

In my work I became a strong supporter of the tools of flood mitigation as means of reducing community vulnerability to flooding, one of the most costly and most life-threatening agents of natural disaster in Australia (Gissing et al, 2019). I accepted, for example, the benefits of levees in protecting towns from floods, and I understood the need at the beginning of the 1990s to raise Warragamba Dam after it had been discovered that the dam as it then existed would not be able to withstand and safely pass a flood of much lesser proportions than the Probable Maximum Flood (the PMF). At that time it had become clear that the dam, built between the late 1940s and 1960 and without today's detailed knowledge of the potential for extreme floods and their probable consequences, would be likely to fail in a flood whose average recurrence interval was of the order of 1500 years. The consequences of failure for downstream communities (including large-scale loss of life and crippling economic costs for individuals and in terms of rectifying infrastructure damage, and for the very viability of the Sydney metropolitan area in the context of water supply) were, it was widely accepted, untenable. To make the dam safe its crest was raised

in concrete by five metres, with some environmental damage upstream a regrettable but necessary price to pay to ensure that big floods did not become utterly disastrous. The later construction of a large auxiliary spillway at the side of the dam, with associated fuse plugs, I also accepted as a legitimate flood mitigation initiative.

During my career I also noted a tendency for investment in flood mitigation to promote development in ways that necessitated further mitigation investment to be undertaken. There is a perverse sense here that in important ways such investment can actually **exacerbate** the problem that it is intended to address. Many examples exist in Australia and around the world of what is known as the 'levee paradox', and it behoves governments to take good care to ensure that the trap that the paradox signals is avoided as far as possible.

The Current Proposal to Raise the Dam Wall

In 2019 I find myself unable to support the state government's proposal to raise once more the level of Warragamba Dam ostensibly for the purpose of mitigating the effects of future floods downstream. There is a strong likelihood that the proposal if put into practice will undermine its own stated flood mitigation goal. It will do this because it will create a climate that will facilitate further urban development in the areas it is intended to protect, thereby increasing community vulnerability to big floods which the raising of the dam wall will not be able to prevent (or even mitigate). Furthermore, it will place an additional burden on the State Emergency Service as the agency responsible for the real-time management of floods and therefore as the organisation that will coordinate and undertake evacuation and rescue operations. The scale of the evacuation required under today's conditions is considerable and the task complex, and substantial population growth in areas that are liable to be inundated in big floods will increase both the scale and the complexity. While some mitigative capacity will be provided against the smaller and more frequent flood events, this result is likely not to be achieved in larger, inherently more devastating floods which, already very difficult to manage, will be rendered even more so. The consequences for community safety should not be under-estimated.

A rethinking of the proposal is required to ensure that the unintended and self-defeating consequences of the proposal do not occur. If the Warragamba Dam wall is raised as a means of mitigating the flood risk downstream it is very likely that the internal logical contradictions embodied by the proposal will have the effect of increasing, not reducing, community vulnerability in times of severe floods.

The Levee Paradox

The levee paradox is a well-known phenomenon around the world (Smith, 1998) and there is much evidence of its applicability in areas that are liable to flooding. It works as follows. A community, having experienced repeated flooding and the damage that accompanies it, petitions local or higher levels of government to invest in flood mitigation (typically by building levees). The mitigation works duly provided, the community and business interests come to think they have been granted total flood immunity or a large measure of it, and pressures arise to intensify development in the areas that are protected. This often takes the form of more housing in such areas, but other forms of community investment (for example in commerce and industry) can also occur. The community is spared from some

floods that would previously have invaded it, but because levees can virtually never provide absolute protection, the time comes when they are overwhelmed by an event which is larger than they were designed for. The levees are thus overtopped or fail and the community experiences flooding once again. Now, though, because of the intensified or added development, the damage done is greater than would have been sustained under the conditions that prevailed before the levees were built. In essence the mitigation device has prevented small floods from entering the now-protected areas but big ones are not kept out and the extra development means a higher capacity for damage to be suffered.

The term 'levee paradox' has become by usage a broad one which covers other forms of flood mitigation provision. Dams built to reduce flooding by storing floodwaters (flood mitigation dams, or dams whose design incorporates an element of mitigation capacity beyond full supply for other purposes) are also covered by the concept: they too can have the effect of creating the circumstances in which additional development is encouraged downstream and becomes vulnerable when the mitigation capacity of the dam is exceeded.

Probably the best recent Australian example of the paradox is that of Brisbane. After a devastating flood in 1974, the state government built Wivenhoe Dam upstream of the city as a water supply and flood mitigation structure. It was touted as a measure which would, by impounding big floods, create flood immunity downstream of the dam. One result was a push for further development in areas near the river within Brisbane, and developers with strong city council support constructed thousands of new houses on the floodplain (Cook, 2018). In 2011 there was another flood, which peaked a metre **lower** than the level reached in 1974 at the key stream gauge within the city (the Post Office gauge) but led to many more houses being inundated over their floors than had been the case in 1974. The operation of the dam during the 2011 flood was controversial and may have been sub-optimal, but it was later credited with having lowered the downstream peaks of the 2011 flood by about a metre compared with what would have occurred had the dam not been there (Queensland Floods Commission of Inquiry, 2012). The 'additional' damage was attributed unequivocally to the further development on the floodplain since the construction of the dam.

There are examples of the operation of the paradox in New South Wales in the past, and indeed it is clear that in some areas the paradox is likely to be demonstrated again in the future. Maitland, in the Hunter Valley, provides evidence of both the levee paradox having been demonstrated in times gone by and the likelihood of its applying in times to come. In the nineteenth century a portion of the floodplain at Oakhampton, on Maitland's outskirts, was given over to extensive grazing. The area was then 'protected' by levees, and an intensification of land use occurred when the grazing was replaced by orchards and market gardens. The orchards and gardens were destroyed in a big flood in 1893 which caused the levees to be overtopped and then to fail, and the economic losses were greater than they would have been had grazing remained the dominant land use in the area. The community's response was to rebuild the levees higher and stronger, thereby enhancing the protection provided downstream where housing was then constructed in a street which crossed the floodplain. But during the great flood of 1955, which was substantially bigger than the 1893 flood, 21 of the houses in this street (Mount Pleasant St) were washed away with loss of life when the 'improved' levees gave way.

After the 1955 flood there was further investment, by the state government, in the levees of Maitland which were built to considerably augmented engineering standards. For many

years development in the areas that had been affected in 1955 was limited by stringent state regulations on building in flood-liable areas, but over time the Maitland City Council chafed increasingly at the restrictions and eventually sought to have them diluted as a means of bolstering the Central Business District which was suffering from a decline in population in its market area (the adjacent residential areas which had been flooded in 1955 and in earlier years). Maitland's CBD has much architectural and heritage merit but declining trade was seeing retail businesses close and graffiti and antisocial behaviour becoming common with attendant negative impacts on the amenity of the precinct.

The Council reacted by commissioning a study (City Plan Urban Design, 2009) which recommended that it seek to increase the population of the inner city from a total of about 1800 in 2009 to 5500 by 2030. Coincidentally, the larger number was the population of the area at the time of the 1955 flood.

The council accepted the advice provided, but over the past decade there has been little interest from developers. This is in part because of the state government's policy on floor levels in flood-liable areas which requires that new dwellings have their floors built above the level of the 1% Annual Exceedence Probability flood (the so-called one-in-100-years flood) plus half a metre freeboard. The council sought in 2016 to have this restriction diluted by stipulating that only a **majority** of a dwelling's flooring, not all of it, be required to meet the state standard. Potentially, this could have meant that almost half of the flooring of new dwellings would have been of slab-on-ground construction, and this in areas that saw flooding more than three metres deep over ground level in 1955. The council petitioned the state Minister for Planning to relax the floor level standard, but the minister rejected the proposition.

The council still seeks to increase the residential population of low-lying, flood prone residential areas near the CBD. Given that the ring levee that was built during the 1970s to the immediate south of the built-up area of central Maitland is designed to be overtopped in a flood little larger than the 2% AEP (so-called once-in-50-years) event, the areas in which the additional population is intended to be housed have not been rendered free of flooding. It follows that community flood vulnerability will be increased if the population grows to the intended pre-1955 level. Had the proposal to allow lower floors been accepted, susceptibility to floods would have been increased even further given that dwellings would have been invaded by floods reaching levels substantially lower than those in the 1% AEP event.

What might be called 'the psychology of development' in flood-prone locations is instructive in all this. In the Brisbane case, senior state politicians including the premier of the day were relentless during the building of Wivenhoe Dam in claiming a high level of achievement in reducing the city's flood problem. In effect the message they transmitted during the building process was that the problem had been overcome. After completion, the same message was the one that cut through to the community: the dam was cast in the community's consciousness as the solution to the city's flood problem.

Something similar seems to apply in Maitland. There, councillors appear to be placing a very large store in the levees and the fact that they have kept all Hunter River floods out of the town for more than half a century. Yet the design standard of the ring levee, noted in council's own engineering reports, makes it certain that big floods, albeit floods

substantially smaller than what was visited upon the city in 1955, will invade large tracts of residential land. If the council's plans come to fruition, these areas will contain many more residents than is currently the case.

In Brisbane, development was talked up as a result of flood mitigation, and the same appears to be true today in Maitland. In both cases the discussion appears to have been conducted with little concern for the inevitability of future flooding which on occasions will be severe. Community safety was shown in Brisbane in 2011 to have been compromised, and in Maitland the same result should be expected at some stage. Probably, the councillors in the two cities have confused floods that will occur only rarely with floods that will not occur at all: metaphorically, it might be said, they placed bets that a big flood would not be experienced in their areas during their time in office.

In this context it should be noted that engineering reports on the mitigation devices developed in both Brisbane and Maitland noted that rare large floods could still inundate the 'protected' areas. In all likelihood there is a subconscious tendency among decision-makers in councils and in governments to discount the potential impacts of such floods because they can be expected to occur only rarely. The problem here is that while they are infrequent they are also inevitable, as the experiences of Brisbane in 2011 and Maitland in 1955 demonstrated.

All this has relevance for the floodplains below Warragamba Dam, both along the main stem of the Nepean-Hawkesbury River (in the Penrith and Hawkesbury council areas) and along Eastern and South creeks largely within the Blacktown council area. The raising of the dam wall will reduce the threat of flooding for the lesser, more frequent floods in these areas but will according to the government's own investigations achieve little mitigation in the bigger events. For one thing, Warragamba commands only about half of the catchment of the river system: floods on the Nepean and Grose rivers (both of which enter the Nepean-Hawkesbury river below the dam)[1]. Secondly, the raising of the dam will only mitigate, not eliminate, flooding emanating from the dam as the Wivenhoe experience indicates. It is always thus: floods can be tamed to a degree but never overcome entirely. Yet mitigation is talked up, often carelessly, and it becomes the equivalent in the public mind of 'elimination'. People are thus encouraged in effect to play a form of 'Russian roulette' with the flood hazard by seeking the amenity (for example river views and level building sites) of the floodplain which the river is bound at some stage to reclaim.

Not surprisingly residents react angrily, as was seen in Brisbane after the 2011 flood, when their assumption that their properties were flood-free is shown to have been false. Sooner or later, this same scenario is likely to be demonstrated in Maitland too.

The psychology unleashed by constructing flood mitigation devices like levees and raised dam walls can only be overcome if the inevitability that one day the levee paradox will be demonstrated is recognised and acted upon in public discourse and in decision making. This

[1] Much of the great flood of 1867, the largest experienced on the Nepean-Hawkesbury River since European settlement, came from the catchment of the Grose. That flood at Penrith, upstream of the confluence of the Nepean and Grose rivers, has been assessed as approximating the 1% Annual Exceedence Probability (so called one-in-100-years) event, while at Windsor it has been variously assessed as being of an AEP of 0.4% (once-in-250 years) or less. Such a large difference over a short distance is very likely to be the result of substantial inflows from an intervening tributary.

means that the temptation to promote land use intensification in the 'protected areas' needs to be resisted or, alternatively, that additional mitigation efforts are undertaken – for example by building up evacuation routes (which means admitting the problem and investing further in its rectification). This is difficult, of course, given the additional expenses that will be required and when development interests (including insurance companies and property developers) are strongly supportive of the original mitigation proposal and hungry for investment opportunities in areas where the risk of flooding can be palliated but not eliminated.

The conclusion here must be that the probability of flood damage being wrought is reduced in the first instance by investment in flood mitigation, but it does not disappear entirely and may be increased over the longer term. Sooner or later, a generation of residents learns this harsh lesson, as the 2011 generation in Brisbane did and as did the 1955 one in Maitland when the levees of the day were breached in several places with loss of life and great property damage occurring.

The logic of all this is that individual mitigation projects by themselves are often less effective than their proponents in governments anticipate, and therefore additional efforts are required which adds to the total cost of protection. There is a sense here that flood mitigation can end up by 'chasing its own tail'; that is by being forced to add further mitigation to counter the inevitable demonstration of the levee paradox instituted by earlier rounds of investment. Moreover, increasing the population living in flood-liable areas can overwhelm investment in things like evacuation routes: thus the big viaduct built between Windsor and Mulgrave early this century at a cost of $126 million in the dollar value of the time (Keys, 2008, p130) may one day be at risk of having its traffic flow capacity overwhelmed by increases in the numbers of people having to utilise it when big floods are developing. More bridge lanes might be required, or additional escape routes constructed elsewhere.

A stronger effort to educate people about the inevitability of occasional big floods should also be considered: to date, the investment in flood education in the state has been paltry and there is little evidence that it has substantially improved people's understanding of the flood threat they may have to face and what they can do to keep themselves safe and protect items of their property. What has been done by the SES by way of community flood education so far appears to have had limited impact: in 2015, as part of the commemoration of the 1955 flood in Maitland, the SES organised a series of three workshops in which residents could learn about their flood risk and what they should do to manage it. The take-up was poor and in the end only one workshop was held. Nine people attended, only two of whom lived on floodplain land. The population of floodplain Maitland (including central Maitland, Horseshoe Bend, South Maitland, Lorn, part of East Maitland and various rural localities) is of the order of 4000 (Keys, in preparation). To say the least the penetration of the educational initiative was poor in this case.

It may be that part of the problem here is that people tend not take seriously the risk implied by rare, very big floods that are outside their own experiences. Possibly this leads them to deny the potential for harm that educational campaigns seek to publicise. Sadly, there is little evidence that such campaigns genuinely increase the level of recognition that very big floods are bound to occur on occasions. Their very rarity encourages people to take the view that they will not have to confront them: the risk, therefore, is classified as being

worth taking. Current residents, when appraised of a risk they had not previously been aware of, may react angrily to new information which they see as unwelcome, while potential residents are likely to note that the return periods being discussed are long (or may be convinced by real estate interests that they are so long as to be merely 'theoretical'. Educational campaigns in this context may in fact be self-defeating; at the very least they have some difficult psychology to break through. They will also not be welcomed by the proponents of development in areas that are prone to flooding, especially if the risk is likely to be seen only rarely.

In this context it should be noted that the 1867 flood on the Hawkesbury River has at times been referred to in local council discourse as the "alleged" 1867 flood. Thus a well-documented event is undermined and a repeat of it probably is rendered less credible in people's minds. The use of the word 'freak' to describe rare events likely has the same effect.

Flood mitigation, it is clear, needs to be more effectively multi-faceted than we tend to consider it to be, in part because individual mitigation initiatives themselves carry what might be seen as elements of internal contradiction. Mitigation can incorporate investment in levees, flood mitigation dams, improved evacuation routes and community education along with flood warning services, the use of flood-resistant building materials and restrictions on building at low levels on floodplains. This multi-faceted character makes mitigation expensive, and it raises the question as to whether we should be making stronger efforts to restrict the amount of development in areas that will inevitably be flooded at some stage. The alternative is to utilise a suite of measures rather than to rely principally or largely on individual strategies involving such things as raising dam walls alone.

Population growth is inevitable in western Sydney so long as Australia maintains a policy designed to achieve rapid population increases. The national population has grown in recent times by about 1% per annum, or about 250,000, from the excess of immigration over emigration alone (Australian Bureau of Statistics, 2015). Both major parties at the federal level appear to take the view that rapid population growth, well above the average in the countries of the Organisation for Economic Co-operation and Development (OECD) with which Australia compares itself, is in the national interest. Most immigrants, it is clear, choose to live in a major city, especially Sydney or Melbourne. This means more pressure on housing markets and increased demand for new housing at the urban fringes and elsewhere. It also means that care should be taken in our land use planning and in our flood mitigation investment if community vulnerability is to be kept in check. In my view the case of the Nepean-Hawkesbury Valley demonstrates on a number of levels that New South Wales has not done enough on these scores despite having spent large sums of money in palliating the problems that will one day have to be borne.

We need to recognise the fundamental reality that floods cannot be eliminated and that the community must not be misled into thinking that mitigation will completely solve the problems that floods pose. Ideally, they should not be encouraged to build or buy houses on floodplains, but in fact the opposite is the case: state governments and councils plan large-scale growth in such areas and rely on floor-level restrictions, flood mitigation measures and the real-time activity of the emergency services to contain the damage that will one day be wrought. On that day, in the valley of the Nepean-Hawkesbury River, there may be deaths in large numbers and there will certainly be massive payouts in terms of flood relief and

reconstruction. The development that has been promoted will be seen by many in the community as having been mistaken.

The Impact on the Emergency Services of Increased Population Growth Below Warragamba Dam

The SES, an organisation made up largely of unpaid volunteers attached to local units in the various council areas of New South Wales, has the legislated responsibility of co-ordinating community responses to floods. Since the passage of the State Emergency Service Act (1989), this has been taken to mean that the SES will plan for floods and co-ordinate the many different sorts of response activity that are required. A particular difficulty in the valley below Warragamba Dam is that the task load for the SES and the other emergency service organisations (including the Police, the fire services, the Ambulance Service, councils and welfare agencies among others) is bound to increase as the population grows. For many years it has been appreciated that the challenge of evacuating tens of thousands of people from areas below the dam in a difficult time frame when big floods threaten will be a daunting one, and the fact that the area is on the metropolitan fringe of Sydney, where population growth has been and inevitably will continue to be strong, simply adds to that challenge. Moreover the emergency service agencies will be required to conduct large-scale emergency and rescue operations only very infrequently: they will not be practised on the day their services are required. There have been no flood-related evacuations needed in the Windsor and Richmond areas for 27 years.

Here it should be noted that mass evacuation is by definition difficult to accomplish. People do not wish to be told to leave their homes and many resist the call, in the case of floods, until they can see the floodwaters ─ by which time it is usually too late because evacuation routes are compromised by the floodwaters. The only option in this circumstance will be to leave them in their houses or on their roofs or to attempt to rescue them in often dangerous circumstances. The SES's experience in various parts of New South Wales since about 1990 is that many people simply will not evacuate when asked or told to do so (see Keys, 2015; Yeo et al, 2018). Compliance with evacuation orders during floods has tended in the areas covered by these studies to vary between less than 30% and about 95%, which means that many people have remained unevacuated. Most of these floods, it should be said, have been of return frequencies much greater than that of the 1867 flood on the Hawkesbury River at Windsor.

In the case of occasional very severe floods this is likely be disastrous, given that rescue resources to extract people from danger will inevitably be stretched very thinly. The valley below Warragamba Dam, it should be said, probably constitutes one of the two most problematic areas in Australia when big floods are developing: the other is Queensland's Gold Coast. Both have very large populations at risk and on rare occasions the emergency services will face the need to evacuate them against very difficult time constraints.

There are signs that the SES is being asked in its flood management role to cover increasingly for poor land use and transport decisions. Two cases in the Hunter Valley can be cited, one in the Maitland City Council area (Gillieston Heights) and one in Port Stephens (Wallalong), but there are others around the state. Gillieston Heights is a recently-developed dormitory suburb of more than 3000 residents located immediately south of the

main urban centre of Maitland: the one road in and out was closed due to flooding for five days in 2015. The community was completely cut off from the outside world, its normal functioning severely impaired for the duration. Several things happened which became severely problematic when the area was cut off: there were two cases of babies with breathing difficulties needing hospital treatment, a woman had a heart attack, a man broke a hip in a fall and there were a number of emergencies involving pets. None of them could be taken by road for treatment, and the SES was obliged to ferry them to hospital by floodboat (sometimes under dangerous conditions) or to organise helicopter assistance. The assistance rendered was inevitably slower than would have been ideal, and the 'Golden Hour' which is often said to be vital in attending to serious medical emergencies was sometimes infringed upon. Moreover policing was made difficult in the isolated community, which contains no police station; nor does it meet the threshold population for a fire station. A fire breaking out, or a police emergency, would have been very difficult to manage on this occasion.

Wallalong is a village of about 1000 people in the west of the Port Stephens council area. For a decade it has been council policy to develop it as a larger centre, and a proposal to expand its population to 10,000 was recently rejected by the Land and Environment Court. Wallalong in floods that are frequent and that fall far short of being extreme events is cut off for several days by roads covered in floodwaters for hundreds of metres in all directions. The potential for the Gillieston Heights experience to be repeated on a larger scale is clear. While the development has been rejected so far, its principal proponent still has it on its books and a revised proposal can be expected to be submitted in due course. Developers, it is often said, "play a long game" in these matters, and the popularity of the lower Hunter as an area in which to live probably means that an expanded Wallalong can be expected to develop at some stage.

What these Hunter and Nepean-Hawkesbury cases show is that the SES and the other emergency services, largely volunteer based, face a future of being asked increasingly to 'band-aid' the problems of flood isolation and inundation which are being made more serious by our efforts to accommodate larger and larger populations in areas that ideally should not be developed. Ever-larger populations will need more and more help, in severe and life-threatening floods, to be safe.

It must be asked whether placing a larger load on volunteers in maintaining community safety in such situations is ethically sound. It must also be asked whether our urban planning should be doing more to identify areas which can become isolated by floods and to invest more in their road provision than has been the norm to date.

Discussion

I am not confident that raising the wall of Warragamba Dam is an appropriate central strategy for flood mitigation in western Sydney. Not only will it have a destructive effect on the environment and Aboriginal sites of heritage significance around Lake Burragorang, it will virtually certainly create yet another demonstration of the levee paradox in the area below the dam. The flood problem in that area is well known to be a severe one, and continued strong population growth will make it even more severe from a management point of view. The ideal would be to restrict further growth, but I recognise that the

pressures are such that this will be difficult to achieve to the optimal degree. Much better in this circumstance, surely, is to focus attention on improving evacuation routes as the prime infrastructural strategy interests: this will buy time for evacuation operations and without compromising environmental or cultural values. We must also intensify our efforts to ensure that the people who live in flood prone areas understand the flood problem they will occasionally have to face and know how to deal with it in their own best interests. This will be difficult, however, and one should not naively assume that it will have high levels of success.

In New South Wales we continue to develop large amounts of flood liable land for urban purposes, a result perhaps of governments, and councils and development interests prioritising economic growth over community safety. We are thus condemned to the creation and augmentation of inefficient, indeed dangerous patterns of settlement. This is nowhere more clearly demonstrated in New South Wales than in the valley of the Nepean-Hawkesbury River below Warragamba Dam where the internal contradictions embodied in development on floodplains have become ever clearer over recent decades. Indeed they continue to do so. We encourage further inappropriate development in flood-liable areas, magnifying the problem we have inherited from the past, and follow our error up with incomplete, partial efforts to mitigate the threat we have created. This has the effect of encouraging further inappropriate development and thus increases the demand for further investment in flood mitigation, a perverse and contradictory outcome.

One final point should be made about the potential for future severe flooding. For some time the scientific consensus has been that within a generally drier future in temperate latitudes including New South Wales there will be both longer and more frequent droughts and more frequent large floods while small floods will become somewhat less common (Hennessy et al, 2005; Pittock, 2012). What is now taken to be the 1% AEP flood, if this is so, will have a reduced return frequency. Very severe and extreme floods, in other words, are likely to be experienced increasingly often.

The proposal to raise the Warragamba Dam wall is flawed on several counts and should not be proceeded with. It promises mitigative benefits but may actually exacerbate the problems created by severe flooding. Other mitigative measures are likely to be more effective and will have fewer harmful consequences, but some of them too will be difficult to institute as far as rare and severe flooding is concerned. But we also need to note that spending on mitigation tends to beget more spending on mitigation and that despite the investment in it the outcome can be more and more inefficient settlement patterns which on rare occasions will carry danger for communities. This is the fundamental problem underlying the development of low-lying land in the Nepean-Hawkesbury, and successive governments have not faced it squarely.

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