Submission
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INQUIRY INTO PLANNING SYSTEM AND THE IMPACTS OF CLIMATE CHANGE ON THE ENVIRONMENT AND COMMUNITIES

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Submission to the Inquiry into the planning system and the impacts of climate change on the environment and communities

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Coastal and water engineer and coastal zone and flood zone manager for over 50 years, undertaken projects in all States of Australia and overseas in Brunei, Dubai, Kuwait, Indonesia, Hong Kong and NZ. 90 technical papers published Nationally and Internationally including a number on climate change and adaption, numerous other publications including on climate change such as a chapter in the CSIRO's book Greenhouse 87 (1988) and Engineers Australia's 1991 Guidelines for climate change in the coastal zone. A member of the Australian delegation involved in developing the first IPCC report on climate change. Involved in the preparation of the 1979 Coastal Protection Act and a member of the specialist Committee who developed the 2016 Coastal Management Act. In addition, 9 years as GM (CEO) Pittwater Council prior to retirement and hence a working knowledge of the planning system in action.

Opening remarks:

Planning is a complex issue with different stakeholders having often very different expectations. Unfortunately, experience has demonstrated that planning instruments, through their lengthy development process with extensive consultation often raise community expectations regarding expected outcomes, that are not achieved. DCP's are an illustrative case in point in that they are often aspirational place-based instruments that are, in the minds of the community aimed at ensuring the desired outcome established during their development. But, in reality they are readily set aside far too often resulting in a loss of confidence in the process of planning. Experience dictates this inherent unreliability of application not only generates slow processing times by councils but also results in delays caused by developers seeking to "game" the lack of robustness of the system.

Climate change adds further uncertainty into planning as the potential outcomes are based on scenarios, not scientific predictions and are therefore open to debate, particularly as the information on natural climate variability is not as robust as would be helpful. For example, there is the El Nino/La Nina instability with generally a 3 to 5 year timeframe, then there is the Inter-decadal Pacific oscillation with possibly a 30 to 50 episodic existence and there is 800 year "wobble of the earth around the sun along with volcanic clouds of dust in the atmosphere. These can all combine from time to time to produce unstable weather, regardless of whether the earth is warming due to anthropogenic effects, or not. Currently, for example we are experiencing a natural warming cycle that commenced at the end of the little ice age, which itself was preceded by an extended warm period. Basically, there is yet a great deal to learn about the weather. However, it is noted that the natural phenomena do not discount anthropogenic warming, just complicate the ability to plan for likely outcomes. Timeframes become very important as dose an emphasis on adaptability and "no regrets" solutions to deal with planning for the likely uncertain future climatic conditions.

A basic problem with the current Planning Instruments.

The Planning Act was a farsighted document in its day (1979) but what has become apparent is that it did not appreciate the importance of hazard management and the need to separate two very different issues. One is what I will refer to as “discretional” planning matters which are generally aimed at satisfactory outcomes for “place-based” desires such as set-backs, heights of buildings, walkable neighborhoods etc,. The other is related to the management of natural hazards. It is this second aspect that requires a very different approach and strictures given that **life and property** are at risk, and there is the potential for significant adverse Government and private economic impacts, particularly with an uncertain future climate.

Recent events such as devastating bushfires and flooding has made it apparent that natural hazards need to be more than “matters for consideration” in determining development applications. There are already several tens of thousands of properties in potentially flood effected areas, particularly in the Hawkesbury and Hunter River valleys with Lismore demonstrating just how much economic strain that can be placed on public and private resources when severe flooding takes place. Basically, a Lismore type scenario for the Hawkesbury would be likely to economically and socially cripple NSW for years. The Federal Governments Productivity Commission enquiry into the economic and social impacts resulting from the 2011 cyclones and flooding in Queensland presents an insight into the potential impacts on development, and infrastructure, that has been poorly sited and/or constructed.

The principal hazards that are likely to change in frequency and intensity with climate change (or even the current uncertain climate variability) include: flooding, both depth and velocity: bushfire, coastal erosion and recession, including cliff collapse and coastal inundation; and landslip. The later being an often-overlooked hazard that was brought to the fore by the Thredbo disaster, and the loss of houses at Newport NSW but has since been forgotten it seems. Unfortunately, this is a characteristic of most natural hazard situations, they are “front of mind” during events but with time are forgotten or set aside until the next event. This reactive form of hazard management is reflected in the haphazard planning documents that are a “feature” of the current system, some hazards are recognised by individual, but inconsistent Acts, while others are not subject to separate Acts, such as flooding and landslip.

There is no consistent and robust approach and even within the instruments dealing with identified hazards such as the seven listed in the Coastal Management ACT as applying to the coastal zone and the EP and A Act. Further, there is a complete disconnect between the Act and the SEPP. For example, the CM Act emphasises the need for integrated adaptive solutions for entire embayments for the benefit of the wider community and the environment whereas the mechanisms of the SEPP encourage individual development applications for private protective works. Importantly the SEPP overlooks any need for consideration of the Objects of the CM Act (including an uncertain future climate) and is therefore counterproductive, producing “planning” results that demonstrably leave non-adaptive coastal experiences for future generations and hence an inability to cope with climate change let alone current hazard impacts.

While it is possible to go through issues in detail perhaps it is more effective to simply provide some pictorial evidence of the outcomes relating to hazard management as produced by the current EP and A Act and foreshadow likely future outcomes with this current approach as climate change/variability progresses.

These are photos of Collaroy on Sydney's northern beaches taken in 1907, just over 100 years ago:

Here is what Northern Beaches Council has "achieved" through their implementation of the EP and A Act, and their independent, but non-expert Planning Panel in the last 5 years…and a recent Panel of non-experts in coastal matters have just voted to approve a further northern extension. This isdespite of the Coastal Management Act having as its first Object:

> "to protect and enhance natural coastal processes and coastal environmental values including natural character, scenic value, biological diversity and ecosystem integrity and resilience ",

Further, the Act goes on to emphasises the need for on-going beach access amongst a number of other matters including the uncertain climate future. However, Council has determined to totally overlook the CM Act to produce this result.

Again, Council, their consultants and their "independent" Planning Panel, which has no one with coastal expertise sees this glimpse into the future as being acceptable."

Clearly at Collaroy the Council's interpretation of the EP and A Act and the Coastal Act has produced an outcome that defies the Objects of the CM Act and produces a non-sustainable result that fails to effectively manage the hazards to achieve a balance between property protection, the community and the environment. There were other solutions which would have solved the threat to private property while still retaining the communities' beach asset and the coastal environment, but the Council lacked the competence to see any other way forward than the brutalist engineering approach that had been traditionally used last century. If ever there was an obvious demonstration of the failure of the EP and A Act to produce responsible sustainable outcomes for hazard management now and into the future the Collaroy vertical concrete wall has to be an unquestionably prime example of failure.

But it does not stop there. There are many examples of the failure of the EP and A Act to manage natural hazards including flooding bushfires and landslip in particular those emerging with climate change. Take for example Queenscliff headland where the cliffs on which the buildings are located are being progressively undercut. Contrast this to the second photo which is that of a recent collapse at North Head in the same type of strata and same scale:

The ad hoc current planning instruments for hazard management clearly require integration and a common structure with SEPPs that produce the required **outcomes**, not simply ones that seek to ensure consistent processes are followed and that “quick fixes” replace sound planning that manages hazards to **minimise harm**.

An interesting anomaly that has recently taken form is an abortive and confused attempt to manage natural and man-made hazards through the 2021 Resilience and Hazard SEPP which picks up the previous Coastal SEPP but not management of the other natural hazards. It also demonstrates the lack of understanding of recognising the significant differences between managing the adverse impacts of natural phenomenon as compared to the need to manage man-made hazard. These are two entirely different matters and, particularly when considering climate change require very different legislation.

What is needed:

An Outcome focussed approach aimed at development of planning instruments that manage NATURAL hazards to minimise harm (environmental, social and economic) in a world with an uncertain climate future.

The problem is that the current potpourri of planning approaches to manage hazards is demonstratively not delivering sensible outcomes for management of existing natural hazards let alone the potential exacerbation of adverse hazard impacts due to climate change or even for likely climate variability.

There is a need for a recognition that the identified natural hazards be managed in a different manner than in the past. A consistent approach built into the planning system for the structured management of natural hazards, and the associated Acts and SEPPS to achieve robust, sustainable and adaptive outcomes.

By the way:

In managing natural hazards there is an interesting problem that arises through ignorance. A 1 in 100 year event is a very misleading term. In fact, it is meant to signify an event that has a 1% probability of occurring each year which translates to a 46% probability of being equalled or exceeded during a design life of say 60 years. However It is only valid to use this statistical criteria if dealing with a statistically stationary series….but with climate change such criteria are clearly meaningless as the "series" is, by definition, not stationary so, for example the so called 1% event soon becomes an apparent 2% event with climate change. However, a better understanding of natural events and hazards indicates severe events tend to be "grouped" and episodic rather than cyclic so the whole approach of using % events is fatally flawed. It seems that those choosing to use statistical criteria for natural hazard behaviour have a poor understanding of statistics…and natural system behaviour! There is a great deal more I could write on this topic and have produced papers for engineering conferences on this topic.

Postscript:

Not wishing this submission to be simply a negative criticism of the EP and A Act, and the demonstratively now defunct 2016 CM Act (well, councils don't think the Objects need to be considered) I have included a copy of one of my papers on planning for adaption. This paper was published in a USA journal last year (2022). It is not a "fix all" but rather some practical thoughts on how development, albeit of coastal villages, can be planned to be adaptive to natural hazards. I include it as an example of the fact there are practical ways forward to manage natural hazards to achieve outcomes that enable development to co-exist with hazards. Clearly the matter becomes more complex with development intensification however, the current planning instruments are not well attuned to achieve robust results for anything involving natural hazards.

Disposable or readily relocatable infrastructure to aid managed coastal retreat.

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ABSTRACT

Infrastructure can become a major determinant as to whether a defence or a retreat strategy is adopted at a coastal location. A significant investment in expensive networks of roads, water supply, and sewerage systems, along with power and telecommunications distribution infrastructure, can tip the defence/retreat debate and the associated cost-benefit analysis in favour of a defence approach. Often the increasingly expensive and sophisticated infrastructure servicing a coastal community has evolved over time, from simple beginnings. However, with upgrades and expansions coastal communities have become totally dependent on complex centralized systems that are vulnerable to disruption by erosion, shoreline recession, and/or oceanic overwash. For a strategy of managed retreat to be practical and achievable at any location, a policy which encourages self-sufficient or low-cost infrastructure that can be readily abandoned or relocated is desirable. There is also a need to re-think the forms of coastal subdivision layout and infrastructure provision that are most amenable to progressive retreat.

INTRODUCTION

At many locations throughout the world, early residential development of the coast understandably took the form of a linear coast-parallel row of houses, sometimes in and on the natural dunes, so that residents could best enjoy the ocean views, the beach, the surf, and fishing. Many of these residences were initially relatively low-cost lightweight timber-framed clapboard buildings serving as weekend retreats, fishing shacks, and holiday getaways. Access to these residences was usually in the form of a poorly constructed track on the landward side, though sometimes it was directly along the beach in regions where the back beach area was low and swampy. Most of the buildings had self- contained infrastructure such as water tanks, pit toilets, and kerosene lights and stoves. Perishable food was kept in evaporation-cooled “meat safes” or ice boxes. Some even had fridges driven by the combustion of kerosene, an apparent contradiction in terms, but an interesting study in thermodynamics.

Over time, the value of the properties increased and many progressively became permanent residences. This has resulted in many of the original “shacks” being knocked down and rebuilt as larger residences; in some cases, the lightweight form of structure has been replaced by substantial masonry buildings. This transformation has driven a demand for the relevant local authorities to upgrade the infrastructure to achieve “normal” suburban living expectations. Original access tracks have been upgraded, as have provision of water supply, sewer, power, and telecommunications infrastructure. So an initial low-cost investment in infra- structure by individuals has progressively evolved, often in a poorly planned and haphazard manner, into full suburban residential services provided through centralized authorities, to the standards that might be expected in suburbs of a well-developed city.

As the “front row” of available beach- back land at any one beach or cliff top was exhausted, the coast-parallel, linear layout of houses and infrastructure tended to be replicated landward in a grid-like structure, as required to satisfy the demand for coastal real estate. Increasingly the trend towards permanent residency and investment in the private assets produced the driving force for the upgrading and protection of the infrastructure servicing them.

Much of this development took place without the current knowledge of the dynamic nature of the coast and of historically ambulatory shoreline trends, let alone the future projections associated with climate change. Some of the recent development, including intensification and upgrading of existing dwellings, is still taking place in ignorance of the potential long-term coastal processes and climate change impacts — or worse, in denial of these potential threats.

Experience dictates that some of the confusion and poor decisions occur because the words erosion and recession have often been confusingly used interchangeably. Erosion is part of the beach fluctuation cycle and usually takes place as a result of storm-wave attack. In the aftermath of the storm cut, accretion takes place to naturally restore the beach. Shoreline recession takes place when there is a time-averaged negative net imbalance of the sediment involved in the coastal processes of a beach and when relative sea level rise occurs. Where erosion is the prevailing coastal process, the use of appropriate setbacks for buildings and infrastructure in the relevant planning instruments provides a straightforward land-use planning solution to cope with the likely range of beach fluctuations. However, if coastal recession is occurring, or will occur due to climate change, coastal buildings and infrastructure will progressively fall into harm’s way. Hence the need to ensure the difference between the two terms "erosion" and "recession" is clearly communicated to coastal communities, managers, and planners so there is no confusion in regard to the future outlook.

This paper is relevant to coastal properties located on beaches, dunes, bluffs and to a lesser extent coastal cliffs experiencing recession, albeit at a generally slower rate. It does not directly address development in low lying "back-barrier" areas that may be subjected to wash- over and oceanic or terrestrial flooding inundation, though many of the principal suggestions/recommendations are equally applicable.

THE CONUNDRUM: DEFEND OR RETREAT

Clearly, the most vulnerable location for residential coastal development, and its associated infrastructure, is in the immediate vicinity of the active beach zone. Storm waves or oceanic overwash can causes very localized erosion that can disrupt infrastructure provision to individual buildings. However, because often the overall pattern of coastal development is shore-parallel, many properties can experience disconnection for a time as a result of even a minor breach in one location. If more widespread erosion, overwash, or net shoreline recession impacts a greater length of the shore- parallel infrastructure, significant disruption can occur for not only the front row of dwellings but also for an entire area. The historical trend for vulnerable coast- parallel development means that with the likely future impacts of climate change the quantum of infrastructure in harm's way is only likely to significantly increase.

While this paper focusses on small- scale infrastructure servicing residential developments, it is recognized that in regard to larger-scale infrastructure the natural geography of some coastal locations with steep hinterlands has historically led to the construction of main roads, railways and other infrastructure immediately behind the beach. In regions experiencing long-term shoreline recession, or likely to do so due to climate change, this critical, major infrastructure will become increasingly vulnerable and may eventually have to be relocated.

Defend

Given the potentially expansive im- pacts from even a minor breach of the infrastructure servicing dwellings, and the likely disruption caused by a major breach, often the initial reaction by authorities and communities is to protect the vulnerable or damaged area. But this can itself cause propagation of the threat due to the end effects of any hard protective structure on the adjacent beach (McDougal *et al.* 1987). Hence, over time there is a tendency for defence works to become the accepted response as they incrementally "chase" the adverse impacts of end effects. This reaction progressively, and sometimes unwittingly, commits the affected coastal community to adopt a defence strategy, by default. While it is recognized that where the historic siting and the associated investment in major, critical infrastructure now in harm's way means that infrastructure can become a major determinant as to whether a defence or a retreat strategy is likely to be adopted in a coastal region. However, it is important to recognize the role small- scale infrastructure servicing individual residential dwellings can also have on strategic coastal management decisions in regarding to the adoption of a defence strategy.

Defence works can be "hard" in the form of seawalls and revetments, or "soft" such as a program of beach nourishment. Often a defence strategy combines both hard and soft options. By their very nature defence works involve significant capital, upgrading, and maintenance costs. This in turn produces an incentive to intensify the development in order to generate the necessary funding base, which then drives the need for the existing infrastructure to be upgraded, thereby increasing the value of infrastructure in harm's way -- a contradiction in logic but a trap many communities, and governments, fall into. Once caught in this trap it becomes very difficult socially, emotionally, economically, and politically to abandon a defence strategy and gain agreement for a retreat approach. Unfortunately, over time the necessary resources to sustain a defence strategy, including offshore and onshore sources of sand for nourishment, can become exhausted and/or the seawalls can no longer be upgraded, or the funding base becomes inadequate for needed maintenance. At such a point in time buildings, and infrastructure, are lost and retreat occurs anyway, often as a haphazard process, as evidenced at Norfolk in England (Brennan 2007). It is instructive to recognize that on a receding coast re- treat is actually inevitable and so defence works simply postpone the timing of the eventuality.

Retreat

Uncertainty is a key factor to be considered in developing an acceptable managed retreat strategy. The recurrence of storm events and the likely impacts of climate change provide projections of potential future coastal impacts and shoreline responses, not predictions. The social, economic, and political reality of projections rather than predictions is the uncertainty of when management actions may need to be taken and when individual dwellings may become untenable. This dictates the need for an adaptable and flexible approach to both the form and the management of coastal development and in particular coastal infrastructure. Unmanaged retreat can result in not only a significant loss to the individuals whose dwellings are affected but also to the broader community. It is after all the broader community who funded the lost infrastructure in the first place and who now find they may have to fund the actions required to ensure there are ongoing services to the remaining dwellings, as well as making-up the rates and taxes the lost dwellings used to provide.

For managed retreat to be more readily implemented as a planned process it would be far better if open coast beach suburbs were based on local road and infrastructure layouts that were perpendicular to the coast. That is, the central spine of critical infrastructure should desirably be located well inland and the overall layout servicing the residences being in the form of shore-normal “fingers” rather than shore-parallel strips. With that form there would only be two dwellings at the end of each road that may be vulnerable at any one point in time, hence a localized erosion or overwash event would only impact the dwelling(s) and infrastructure in the immediate vicinity. Further, as shoreline recession proceeded, properties at the ends of the effected roads could be abandoned without disruption to the social fabric and the infrastructure servicing the still viable remaining com- munity, thereby facilitating a managed roll-back; the concept of “rolling easements” (Titus 1998, Titus and Neumann 2009). This pattern of development means coastal regions do not have to suffer un- necessary sterilization by attempts to take into account the uncertainties of future climate and/or storm erosion. It also has the less socially disruptive advantage over the shore-parallel suburban layouts which can result in individual dwellings increasingly being surrounded by abandoned buildings or allotments and unserviceable infrastructure.

Importantly, managed retreat becomes more viable, regardless of the land use development pattern, if the societal investment in infrastructure is minimized. So, a return to the historical situation where each dwelling is as self-sufficient as possible has merit. That is not to say a re- turn to the beach-side shacks of the past, but rather the philosophy behind them. There is no reason why a well-designed dwelling cannot enjoy a high standard of presentation, liveability, and infrastructure provision but at the same time be as self-sufficient as possible. The challenge is for building designers to make the residences suitably attractive while also seeking to minimize the requirements for external infrastructure. Ideally, the resulting buildings can also be designed to be demountable and hence relocatable, along with their infrastructure, when it becomes apparent that they will be coming under threat. Hence the adaptability of coastal residential settlements can be facilitated, maximizing developed usage of the coastal zone.

TOWARDS MODERN SELF- SUFFICIENT INFRASTRUCTURE

For individual dwellings to achieve as great an independence of infrastructure as possible, options for each of the infrastructure requirements need to be considered in terms of how requirements can be reasonably met without having to heavily rely on back-up from centralized systems. It is also desirable that as much of the infrastructure as possible can be readily abandoned, or desirably recover- able, and reusable when dwellings are adversely impacted by coastal recession. To achieve this requires an innovative approach to both infrastructure and land use planning controls for development.

Complex issues are often best approached by breaking them down into their component parts. Applying this philosophy to the provision of adaptable infrastructure for dwellings that will potentially be impacted by coastal recession, it is convenient to break down the issues under the following infrastructure classes: roads, water supply, wastewater management, stormwater management, electricity, and telecommunications. Potential options for providing these infrastructure requirements are discussed below as a catalyst, and to stimulate further consideration of means to minimize the reliance on centralized systems.

Roads

Road networks generally establish the overall infrastructure layout as they provide the potential services corridors. A shore-normal, rather than shore-parallel, road layout encourages infrastructure provision that can be more easily rolled back as shoreline retreat takes place. Local access roads to service coastal developments can be constructed to a suitable standard according to their expected life. Given that often the back beach area is a sandy substrate, it may be desirable to provide at least a gravel if not a sealed pavement to ensure vehicles don't become bogged. In doing so, it is noted that experience dictates much, if not all, of the materials used in suburban type road construction, including the pavement and the subgrade, is potentially recyclable.

The width of the trafficable road sur- face can be varied in accordance with traffic loads as the pavement approaches the beach, to minimize the amount of material that may require removal in the future. Hard surfaces promote rainwater runoff, and management of this is often reliant on curb and guttering, and the associated drainage lines. Unfortunately, this generally results in outfalls being constructed that erode the beach. A more satisfactory treatment of runoff from roads in sandy areas is to create grass-stabilized swales on either side of the pavement (MAPC 2010) instead of curb and guttering. These swales can be designed to capture the runoff and allow it to be infiltrated into the underlying sand. They also have the added benefit of collecting any sediment in the runoff and improving aquifer water quality through natural filtration as the runoff is absorbed into the ground (MAPC 2010).

Water supply

The water requirements of dwellings can be met in various ways, the simplest being rainwater tanks of adequate capacity capturing runoff from all available roof areas. The internal distribution of water within a dwelling can be achieved by a commercially available on-site pump arrangement that can provide the necessary domestic water pressure requirements for the dwelling. Where water quality management is required, there are again commercially available units which can be inserted into the system. To this end, there is advantage in separating drinking water from that required for general use, as usually only the drinking-water component needs to be treated to achieve acceptable human health standards. Such systems are not unusual in many remote communities. It is important to be aware that contamination can enter the system through bird and other animal life defecating on the roofs, or through agricultural sprays and other airborne contaminates, and hence the need for treatment systems. Even general-use water may still require passage through a filter to remove sediments. In areas where the rainfall is nearly (but not quite) sufficient, the tanks can be topped up from time to time, as required, by commercial tanker truck services.

There are however some locations where rainfall is seasonal and/or there can be extended dry periods, which require a different approach. In such cases, water can be imported via small- diameter low-pressure pipes connected to a low-pressure main located inland in the spinal core of critical infrastructure. This low-pressure "trickle" supply can top up any residential tank on the individual "fingers," as required, on a 24 hour a day standby, facilitated by a ball valve shutoff at each tank, not unlike the "automatic" refilling of toilet flushing systems. The "trickle" supply line can be constructed as a disposable piece of infrastructure that can be easily disconnected from each dwelling on a "finger" once that dwelling became unacceptably impacted by shoreline retreat. Being a low-pressure distribution system, there are potentially significant cost savings in the provision and maintenance of the overall distribution infrastructure. The individual dwelling systems including the tanks, pumps, and water quality management systems can be designed to be recoverable.

At many beach-side locations, the dwellings are sited on a sandy substrate that typically has an associated under- ground freshwater aquifer. Even where there is saltwater penetration into the aquifer, there is often a freshwater lens "floating" on top of the salt or brackish zone. There is understandably a temptation to utilize ground water to supplement the tank, or imported, water sources. This should be subject to careful consideration and management for a number of reasons. Importantly, there can be serious health implications due to contamination of groundwater. This is particularly the case where sewerage disposal systems discharge into the ground and/or animal waste can contaminate the water table as rainwater runoff makes its way into the ground. Excessive pumping from underground water can also draw down the aquifer for an extended distance, resulting in adverse impacts on vegetation and consolidation of the ground formation thereby producing land settlement. Hence, the use of water from aquifer harvesting should be care- fully managed and monitored. The use of this water should generally be confined to activities such as garden watering and possibly toilet flushing. In most beach- side locations it is not wise to utilize shallow underground water sources for drinking purposes at all. If it becomes a necessity, it should receive a high level of treatment, and its quality be carefully monitored to ensure adequate health standards are met.

If there are also "deep" aquifers in the area, it is possible to achieve a relatively reliable supply by "harvesting" the aquifer during dry periods but then actively recharging it during wet periods. This is referred to as "water banking." Practical experience regarding this technique has been summarized by Dillon (2019). The quality and usability of the water from deep aquifers is site-dependent but can yield a ready supply of water that can be treated to drinking standards.

Wastewater management

Wastewater management is often the most complex and expensive challenge in providing suitably risk managed domestic infrastructure to coastal communities. Wastewater includes "black water" or sewage that comes from the use of toilets and bidets, and "greywater" coming from the use of kitchen sinks, dishwashers, baths, showers, and washing machines. Both black and grey water contain pathogens (including viruses) and therefore can pose a health risk. They also contain nutrients which can overload natural environmental systems.

There are a variety of treatment methods for wastewater generated by individual dwellings. Traditionally many of the "coastal shack" type dwellings in low density areas had toilets consisting of a hole in the ground enclosed by an "out- house" located separate to the residence. Apart from the inconvenience and odours associated with this type of toilet, contamination of the groundwater aquifer is a potential health risk. In these rudimentary situations grey water is usually discharged directly onto the ground or used to water the gardens and allowed to evaporate or to infiltrate into the underly- ing aquifer. Again, this poses a potential health risk which is generally dependent on the density of the development, the number of people in the dwellings and their relationship to one another. Family members tend to share their pathogens; however, visitors can introduce new varieties into the household.

As development densities increased the simple hole in the ground was superseded by "septic tank" technology (WaterNSW 2020a) which remains a common onsite wastewater system for coastal communities that are remote from municipal infrastructure. How- ever, septic tanks achieve only primary treatment through a two-chamber system with the initial chamber providing anaerobic conditions and the second chamber offering limited aerobic conditions before the partially clarified liquid is then discharged into absorption beds which tend to become clogged over time and therefore need to be regularly relocated. Effluent from septic tanks is not suitable for surface watering of gardens and lawns. An often-overlooked issue is that because septic tank systems do not remove nutrients, the absorption beds cause shallow aquifers to become overloaded with nutrients which can have adverse implications for the sur- rounding vegetation. During wet weather, rainfall runoff can result in the pathogens and nutrients trapped in the absorption beds being brought to the surface and transported to receiving waters. As with a low-cost centrally supported "trickle" water supply, it is possible to connect the septic tanks of individual dwellings to a centralized system via a low-cost pipe network, whereby the effluent from the tanks is pumped by the individual residences to a collecting main on the spinal core of critical infrastructure. The individual dwellings are responsible for their pumping requirements and the connecting pipes. The piping and pumping infrastructure can be readily abandoned or recovered as shoreline recession takes place. Alternatively, the effluent can be stored and removed by tanker trucks; an often-expensive alternative which can suffer from limited reliability. Both arrangements potentially reduce, but do not eliminate, the treatment requirements, and therefore cost, of a central Sewerage Treatment Plant (STP). Apart from the health and odour issues, septic tanks require regular desludging to remove the fats and solids, a most unpleasant operation. So, it is not surprising that as coastal communities develop and evolve, they seek access to standard suburban reticulated sewer infrastructure that conveys all wastewater to a central STP. Unlike water-supply infrastructure that can be pressurized, sewer infrastructure relies mainly on gravity-driven flows, or in some cases vacuum lines. This means the collection infrastructure is complex and usually involves expensive and vulnerable networks of pumping stations.

A recent alternative self-sufficient form of onsite wastewater treatment is referred to as the "composting toilet" (WaterNSW 2020b). There are two types of composting toilets — dry and wet. Dry composting toilets collect and treat only blackwater and can achieve a similar standard as septic tanks. The collected material needs to be removed from time to time, and grey water from the bath- room and laundry needs to be treated separately. Wet composting systems can be used in conjunction with flushing toilets. Bacteria breaks down the solids in a similar manner to biological filter systems; however, in this application the aeration is via a design that promotes air flow through the collected material. Wet composting systems treat all the waste- water from the house and do not need separate grey-water management. While relatively inexpensive to establish and operate, there is a significant investment in time required for the ongoing management of the system. Further there are sometimes odour issues and the potential for health hazards if persons other than the immediate household occupy the premises and introduce new pathogens.

Because wastewater management infrastructure is potentially the most complex and expensive of all infrastructure servicing coastal communities, and can significantly affect community health, it requires special attention. If a conventional centralized system is employed, it can also potentially be the most vulnerable aspect of infrastructure associated with coastal developments. The required network of pipes and pumps in a conventional centralized system generally involves greater establishment, maintenance and operating cost than that of any other infrastructure type. Importantly, any break in the system due to an erosion or overwash event can result in major disruptions and health hazards for the surrounding community. Hence, the opportunity to achieve acceptable levels of wastewater management using stand-alone systems for individual dwellings provides a practical solution where a managed retreat strategy has been adopted, and it is desirable that the infrastructure can be recovered for reuse elsewhere should a property be subsequently adversely impacted by shoreline erosion and recession.

Stormwater

Conventional design tends to emphasize the collection of stormwaters into pipes and channels that divert it away as efficiently as possible into systems that convey it to remote discharge points at convenient locations such as creeks or beaches, thereby wasting a potential resource. Stormwater provides an opportunity, where possible, to directly replenish fresh water supplies and/or aquifer recharge (Dillon *et al.* 2019, Kretschmer 2017). Harvesting to supplement freshwater supplies can be achieved by directing rainfall runoff from roofs into water tanks. For unroofed areas of allotments and for excess roof runoff, provision can be made to create temporary pond- age through the design and treatment of landscaping (Gordon 2011). Given that back-of-beach developments are generally founded on a sandy substrate, experience dictates that such ponding may be a little inconvenient for a short period during heavy rain; however, the collected water will be rapidly absorbed into the ground as infiltration takes place. The advantage of this approach is that it directly recharges the ground water aquifer thereby providing water to the roots of garden plants and lawns. Where the aquifer is of adequate quality this stored resource can be used during dry periods (Dillon *et al.* 2019), as discussed in the section on "water supply."

Stormwater runoff from public areas such as roads can similarly be directed into absorption areas for example, as formed swales in dunes, or contoured depression areas in beach-side parkland. Again, this provides the opportunity for aquifer recharge and hence vegetation resilience. This approach has been successfully applied at a number of locations throughout the world as summarized by Dillon *et al.* (2019), with examples of specific applications by Kretschmer (2017) and Gordon (2011).

Apart from utilizing stormwater to support water supply and aquifer re- charge, its capture also reduces, or eliminates, the need for outfalls on beaches. Stormwater outfalls on beaches, whether formal or informal, concentrate flows across the beach causing a local scour channel to develop across the beach berm. This scoured channel allows storm wave energy to penetrate to the back of the beach, resulting in localized attack on the dunes and nearby properties. After the storm conditions have passed, the scoured channel starts to infill from the seaward end creating a small landlocked water body which can be an attractive play area for small children and therefore can pose a health risk as the water body often contains contaminants such as pathogens sourced from the stormwater drains.

There have been many attempts to design beach-side stormwater outfalls that minimize their impacts (Gordon, 2011). Experience dictates that the most environmentally sound approach is to di- vert the stormwater into aquifer recharge rather than discharge across the beach, particularly since the hard surfaces of dwellings and associated infrastructure, along with rainwater harvesting for water supply, acts to reduce the volume of water otherwise available to the aquifer under natural, undeveloped conditions.

Electricity

Worldwide, there has been an increasingly rapid take-up of self-sufficient power supply systems for individual dwellings. Solar and wind power, connected to on-site storage batteries, is allowing individual dwellings to be in- dependent of network grid distribution of power by central organizations – the corollary being that the "poles and wires" or underground cabling infrastructure as- sociated with such conventional networks is unnecessary. All self-sufficient power infrastructure components are recover- able if a dwelling becomes untenable due to coastal impacts and therefore provide a cost-effective solution that makes grid-type infrastructure redundant. It also means that managed retreat of one or more dwellings is practical as shoreline movement causes dwellings to be in harm's way. Again, the flexibility of this approach means coastal areas do not have to be sterilized, and that timely decisions can be implemented in accordance with what is a difficult to predict and uncertain future.

Telecommunications

This is arguably the easiest infrastructure issue to address. With the growing predominance of mobile phone and data services, there is increasingly little dependence on "hard wiring" to individual dwellings. Adequate provision of mobile transceiving towers, associated with the spinal core of critical infrastructure can provide suitable connections achieving adaptability. As communities become independent from hard wired networks, managed retreat can take place without adverse impacts on individuals or com- munities.

CONCLUSION

Conventional infrastructure servicing dwellings to acceptable suburban standards involves a significant investment of government and community funds but is potentially vulnerable in regions of the coast experiencing shoreline recession, which can include both sandy and rocky coastlines. As a result of this vulnerability, defence rather than retreat options often dominate management strategies in these areas, particularly if they are rocky and hence much slower to erode. Importantly, as defence works propagate there often becomes a counterintuitive need to escalate the intensity and investment in the potentially vulnerable development, and associated infrastructure, so as to provide the funding base needed for building, upgrading and maintaining the defence works.

The alternative is to accept natural shoreline recessional trends and retreat development including its associated infrastructure. However, for managed retreat to be a practical and more accept- able option, it is desirable that the overall land use layout of coastal development be made adaptable, and that infrastructure be designed to be readily withdrawn. Hence, rather than having vulnerable critical core infrastructure located in hazardous areas in the immediate vicinity of the beach/shoreline, it is better to locate any shore-parallel infrastructure spine as far inland as possible with the local road network and infrastructure being shore- normal "fingers". The aim of such a layout being that the loss of any one property, or group of properties will not necessarily adversely impact on the rest of the village or suburb. That is, where possible configure or, where it already exists, reconfigure urban development and infrastructure for resilience by adopting an underlying philosophy of shore-normal rather than shore-parallel layouts and infrastructure provision.

To enhance this adaptability, where possible each dwelling in a coastal area that is potentially vulnerable to shoreline recession should be as independently serviced as possible, and any infrastructure servicing that dwelling be either recoverable for later relocation or be disposable. Importantly, to encourage adoption of this approach the aim should be to best mimic the service and liveability outcomes which would be expected by residents in a "normal" quality suburban setting. For example, water supply can take the form of rainwater tanks pressurized by on-site pump for individual dwellings with provisions for topping-up the tanks if required, resulting in a water supply outcome that is of a similar standard to that expected from a centralized connected system. Similarly, wastewater management can include an on-site extended aeration plant producing treated effluent that can be used to water the gardens and flush the toilets. Solar panels and wind generators connected to batteries can provide a practical source of electrical energy. Mobile phone and data networks, along with satellite technology has removed the need for wires and cables. It is therefore becoming increasingly possible to minimize the need for expensive centralized networks of infrastructure in vulnerable areas. While this approach can be adopted for any suburban community wishing to be self-reliant, it is particularly applicable to coastal developments where the use of self-reliant services for individual dwellings facilitates the implementation of a managed retreat strategy by allowing buildings and infrastructure to be readily abandoned or preferably relocated as retreat takes place.

As natural imbalances in sediment budgets develop and climate change threatens a defence approach, there may come a time when a defence strategy turns into forced retreat as, for example, beach nourishment becomes non-feasible due to a diminishing offshore or onshore resource or seawalls become uneconomic to maintain or upgrade to meet the changed design requirements dictated by climate change. The move towards the self-sufficiency of dwellings facilitates the implementation of a retreat strategy, however there is no reason for not applying similar principles to areas that have currently adopted a defence approach.

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