NATIONAL MARINE SCIENCE COMMITTEE

National Marine Science Plan Infrastructure Theme White Paper

Australian National Coastline Observatory Facility

Abstract

A recurring theme that cross-cuts the six MN2025 'grand challenges' is the importance of our coastlines. This unique land-ocean interface is where we live; it is the focus of our international trade and built infrastructure; with natural coastline features such as beaches delivering enormous ecosystem services to our society's economic and environmental wealth and security. At the present time there is a paucity of sustained observation currently underway around Australia's coastline to underpin the necessary scientific advances that are the foundation for coastal risk assessment, climate change shoreline forecasting and now-casting of coastal erosion and inundation warning systems. The rapid realisation of a National Coastline Observatory Facility is relatively straightforward to achieve, pending the allocation of a suitable and sustained funding source to support this priority research initiative.

Background

Marine Nation 2025 [1] details a framework and solutions for marine science to support Australia's Blue Economy. To achieve this, *MN2025* outlines a coordinated plan for investment in the three traditional pillars of science:

(1) **sustained observing systems**
(2) experimentation, and
(3) modelling

To address the critical need to understand and quantify the present and future state of our marine estate, OPSAG[1] proposes the expansion of existing observing systems and identifies it as **a priority that new National Facilities be established to address critical knowledge gaps**.

A recurring theme that cross-cuts the six 'grand challenges' outlined in *MN2025* is **the importance of our coastlines**. This unique land-ocean interface is where we live; it is the focus of our international trade and built infrastructure; with natural coastline features such as beaches delivering enormous ecosystem services to our society's economic and environmental wealth and security.

So it will come as a surprise to many that, at the present time, there is a paucity of sustained observation currently underway around Australia's coastline. Australian Marine Science is lagging far behind in basic observations and infrastructure, compared to other developed nations throughout Europe and in North America. Clearly and explicitly identifying the need to address this knowledge gap, *MN2025* states that:

- "*long term commitment is required to develop a national operation oceanographic and geohazard forecasting capability with* ***an enhanced coastal component***" (p.13)
- "*To provide real benefit to the Australian community… will* ***need to focus on… shoreline conditions****…* ***supported by a wide range of observations, collected both remotely and in situ****".* (p.14)
- "*Projected increases in storm severity resulting from climate change will* ***intensify shoreline erosion***" (p.18)
- "*New remote and in situ observation technologies allow the development of* ***cost-effective and sustained observations systems and monitoring programs*** *that can be deployed from inshore coastal to deep oceanic waters. These* ***provide critical data for determining baseline condition, function and variability***" (p.20)

The existing *Integrated Marine Observing System - IMOS* and *Terrestrial Environment Research Network - TERN* observing networks are providing invaluable and unprecedented data-streams of real significance and application to the wider coastal zone – *IMOS* principally seaward of the 50 m depth contour, and *TERN's* primary focus inland of the open coastline at estuaries and coastal catchments.

The critical missing gap between these two existing observation programs is rigorous and sustained observations of the littoral zone specifically encompassing the land-ocean boundary, which also represents the region of the ocean with which the great majority of society directly interacts. Nominally spanning water depths of 20 – 0 m along open coastlines and extending landward to include frontal dunes, this critical region where the land meets the ocean currently falls outside any nationally-coordinated monitoring effort.

At the present time rigorous observations and resulting data-streams of shoreline conditions, variability and trends around the Australian continent are sparse, ad-hoc, uncoordinated and largely depends upon the motivation of individuals (and often volunteers). As a result, the coverage and sustainability of these observations is unsecured, incomplete and inadequate to support marine science at a national scale. The contributors to this White Paper represent a cross-section nationally of research institutions and governments that have contributed to and use coastline observations, and each will increasingly rely upon the expanded availability of sustained coastline data-streams to support coastal research, management and policy

[1] *Ocean Policy Science Advisory Group*

development. While this document is primarily focused on open coast beaches that dominate the most populous and developed regions of our coastlines and where the present coastal pressures are greatest, it is also recognised that there is a diverse range of coastlines types around Australia; from temperate open ocean beaches, to muddy-mangrove coasts, rocky coasts, and coasts associated with coral reefs.

Funding (where it has existed) to support past and present coastline monitoring efforts is most often site-specific, project-specific and short-term, with very few examples where this has enabled ongoing data-streams of coastline conditions to be collected regularly beyond the time-scale of a year or two. Recently, the *Australian Research Council* through the Linkages Project Scheme signalled the importance nationally of the establishment of a National Coastline Observatory, through the funding of a targeted 3-year pilot project[2]. The lessons learnt from this pilot project undertaken by a NSW partnership including universities, industry, state and local government, are now available to guide and inform the establishment of a national and sustained approach to coastline observation around Australia.

Relevance

Australia is a distinctly coastal-focused nation. Half of Australia's open coastline is sandy, comprising 10,685 individual beaches [2]. Over 85% of Australians live in the narrow coastal strip and this will increase [3]. Population growth and the need for a corresponding expansion in infrastructure and services go hand-in-hand, placing immense pressure at the land-ocean boundary [4]. Long term, continuous monitoring of the coastal zone will become increasingly important in the face of climate change, and mitigating the effects of inundation and coastal erosion will continue to be a focus of coastal councils and communities for the foreseeable future.

The economic value of existing built assets at risk to coastal erosion is substantial. Various attempts have been made to assess national assets currently at risk: roads - $46-$60 billion; commercial buildings - $58-$81 billion; residential property - $41-$63 billion [5]. No less significantly, the cultural and economic value of natural coastal assets, including coastal ecosystems, marine parks and beaches, has also been recognised. For example, beaches are ranked by the NSW government as one of the four most valuable natural resources in the entire State [6]. **The specific amenity and storm protection provided by beaches nationally is estimated to be in the range of $3.8-$13 million for each and every kilometre of the shoreline** [7]. In Australia, The federal government's *National Climate Change Adaptation Research Facility (Settlements and Infrastructure)* has identified 'Vulnerable Coastal Communities' as one of five top research priorities [8].

Coastal erosion is a first-order challenge to society and the natural environment in Australia, as it is internationally. In December 2013 the peak scientific journal 'Nature' devoted a special supplement (natureINSIGHT 'Coastal Regions', vol. 504, no. 7478) to the current science focused on better quantifying present and future pressures impacting on coastline 'ecosystem services'; in other words, those natural coastal features such as beaches that provide measurable economic and environmental benefit to societies world-wide. The Editors concluded that the best solution to mitigate the coastal erosion hazard is the design of coastal defences based on the adaptive use of natural coastal ecosystems. Crucially, along beached coastlines this equates to the maintenance (or creation) of a sufficient 'sand buffer' contained within the beach and dunes to accommodate rapid sand losses that occur during storms.

In this context, the goal of coastline numerical modelling is to:

- provide reliable and risk-based predictions of the erosion and recovery of beaches during and after a single or cluster of storms;
- inform coastal policy, planning and management at all three levels of local, state and federal government; and
- provide the basis for present and future risk assessment and real-time geohazard forecasting.

[2] LP100200348 '*Australian Coastal Observation Network: monitoring and forecasting coastal erosion in a changing climate. 2010 - 2013* (Host Institution: UNSW Australia)

Fundamentally, and irrespective of the coastline modelling approach used, sustained observations of present-day coastline variability and trends at selected 'representative' coastal settings around the Australian continent are a fundamental pre-requisite to develop, calibrate, test and further improve the practical tools that will be relied upon be used to predict and forecast coastline hazards (shoreline erosion, shoreline retreat, coastal inundation and flooding, coastal hazard lines, coastal infrastructure at risk, etc, etc).

Internationally, sustained observations of beach and coastal dune systems are widely sought to support model development and forecasting capabilities [9]. In Australia, long-term observational datasets of this type are virtually non-existent. **In 2014 there is just one site located in southeast Australia (Collaroy-Narrabeen Beach) where a current, frequently sampled (minimum monthly), long-term (multi-decadal) dataset of shoreline variability and trends is available to the Australian and international coastal modelling community** [10]. Other notable past and present monitoring efforts in Australia include the 4-decades of beach profiling at Moruya in southern NSW [11] that continues to be maintained outside any endorsed program which currently limits its wider availability; and significant State programs including in SA (e.g. Adelaide Beaches) and QLD (e.g. Gold Coast) where sustained but infrequent (typically annual or less) snapshots of beach, nearshore and offshore conditions have been collected primarily to support recreational beach asset management.

The significance and timeliness for the proposed establishment of a National Coastline Observatory Facility was signalled several years ago by the release of the Parliament of Australia House of Representatives landmark report '*Managing Our Coastal Zone in a Changing Climate*' [12]. Based upon an exhaustive 18 month inquiry comprising over 100 written submissions and 28 public hearings, the Parliamentary Committee (representing all major political parties) explicitly identified the need for further research in Australia to examine how waves interact with coasts, and to better understand and predict the range of responses expected. The recent *CSIRO* monograph '*Sustainable Coastal Management and Climate Adaptation*' reinforces the particular significance of this area of research, identifying the threat to our coasts this century as *"...one of the most pressing, yet difficult, issues to be dealt with in Australia*" [13].

Science needs

The ability to quantify and model contemporary and future coastline variability and change, at a range of time-scales spanning now-casting (**Coastal Hazard Early Warning Systems**), extreme storm erosion (**Coastal Erosion Risk Assessment**) and decadal-scale shoreline evolution (**Forecasting Impacts of Climate Change**), offers the very real potential to inform and guide emergency preparedness, coastal planning and management decisions at all levels of government.

The significance to Australia of enhancing our national coastline monitoring and forecasting capabilities was signalled by the *CSIRO Wealth from Oceans National Research Flagship* [14] and *Australian Greenhouse Office* [15]. Both these benchmark reports stress the high priority in Australia for the rapid establishment of a network of sustained coastline observation sites, to be used as a basis for modelling and forecasting the contemporary and potential future coastal impacts of climate variability and trends in coming decades. The Australian Government has invested $117 million (2008 to 2012) in climate adaptation policies through the Department of Climate Change, coordinated through the National Climate Change Adaptation Research Facility (www.nccarf.edu.au). Yet at the coast, significant and fundamental knowledge gaps persist.

Gap:

- Continuous and sustained observations spanning a network of regionally-representative Coastline Reference Stations throughout Australia, including shoreline, beach volume and nearshore bathymetry.

Needs:

- Real-time data-streams to underpin coastal erosion emergency preparedness (Early Warning Systems).

- Coastal erosion-recovery data-streams to underpin risk-based storm erosion modelling (Coastal Hazard Erosion Risk Assessment).
- Longer-term shoreline data-streams to underpin medium-long range shoreline forecasting (Impacts of Climate Change).

Challenges

- Predicting morphological change along the open coast requires predicting sediment transport and deposition under the combined effects of vary water-levels, waves and wave-driven currents. Significant theoretical and model development is needed to reduce the level of empiricism that is currently used to simulate observed morphological changes.

Outcomes

- Reliable process models, combined with the observed forcing and initial conditions including water-levels, waves and bathymetry, to be used as part of an early warning system in known erosion hotspots or vulnerable low lying coastal regions.
- Rigorously calibrated coastal erosion predictions, for quantitative and risk-based coastal erosion hazard assessment.
- A next generation of long-range forecasting tools to provide the basis for coastal erosion hazard forecasting extending in to the next several decades and beyond.

Key advances in Australian Marine Science that will be facilitated by the establishment of a National Coastline Observatory Facility include:

- the ability to quantify contemporary and future coastline variability, erosion hazard and change
- make available 'standard' community data-streams for coastal sites encompassing regional differences around Australia's open coastlines
- underpin 'real-time' model – data assimilation and coastline geohazard forecasting (storm erosion)
- baseline geo-coastal data-streams for testing and improving the next generation of longer-range coastal change forecasting tools (climate change)
- coordinated network of coastline laboratories nationally, co-located (where possible) to established National Reference Stations, to support the next advances in fundamental and applied process-based marine science research.

Science Perspective

5 year horizon – Coastal processes and short-term forecasting

Natural beaches never reach a stable equilibrium but are continually changing in response to changing wave and water-level conditions. During storms elevated sea-level leads to erosion of the upper beach face and dunes. During subsequent periods of low waves there is a net onshore movement of sand and, given sufficient time, the beach may recover to something close to the pre-storm profile. Beach profiles may also change significantly between seasons. During a stormier period of the year, a beach will be observed to erode often exposing rocks which were previously covered by sand. During a following more quiescent period the sand will return. Furthermore, changes in the beach profile are not confined to the upper beach but extend seaward across the surf zone and beyond manifested in the formation of sandbars and rip channels. Medium term (months) video observations have revealed complex spatial and temporal variability of the nearshore morphology over time scales of days to months.

The underlying processes driving this variability involve complex coupling between the incident wave field, bathymetry, wave-driven currents and associated sediment transport and, while present models include all of these components, the level of skill in predicting nearshore morphological change over time-scales of several days to weeks is still very low. Significant theoretical and model development is needed to reduce the level of empiricism that is currently used to simulate observed morphological changes. Improved understanding of the underlying processes is essential for improving the predictive skill of these process based models in complex, real world applications.

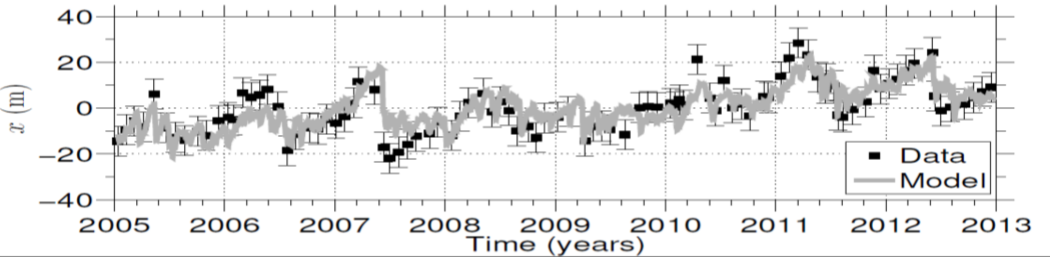
Data assimilation has been widely used in atmospheric and ocean models to improve forecast skill but is not widely used in the nearshore due to the lack of suitable assimilation data sets, in particular bathymetry. Given the beach and nearshore morphology changes on daily time-scales, conventional hydrographic survey methods are not suitable. Recent advances in image analysis techniques [16] have shown nearshore bathymetry can be derived from video observations of the nearshore wave field providing the potential to be able to assimilate daily observations of bathymetry. Reliable process models, combined with observed initial conditions including waves and bathymetry, could then be used as part of an early warning system [17] in known erosion hotspots or vulnerable low lying coastal regions.

Recent research lead by Australian university researchers has begun to rigorously examine the application of process-based coastal models to provide estimates of extreme storm erosion within a probabilistic risk framework [e.g. 18,19]. Encouragingly, this work suggests that existing models can predict extreme storm erosion with a reasonable degree of accuracy, when carefully calibrated using real-world coastline observations spanning multiple storms.

Importantly, this significant body of work also highlights a number of substantial knowledge gaps that presently exist. With no alternative datasets currently available, monthly surveys only have been used to underpin this research to-date, which leaves open the unanswered question of whether the 'initial' beach conditions inferred were sufficiently close in time to the actual onset of storms, to provide a realistic representation of the pre-storm coastline? And perhaps even more importantly, the 'post-storm' profiles were actually the available observations recorded up to several weeks after each storm event (i.e., monthly surveys), by which time a significant (but unknown) portion of the non-linear beach recovery process had likely already occurred. And crucially, for all the storms simulated the calibration data used was necessarily restricted to just one beach profile obtained at one location within one embayment on the Australian coast (Collaroy-Narrabeen), the only site where suitable data is presently available.

10 year horizon – New approaches to medium-range coastline forecasting

Given the stochastic nature of the forcing and response, process-based models are unlikely to produce reliable predictions of morphological change and alternative approaches are required. The challenge of developing new quantitative medium-range forecasting tools to predict the response of coastlines to changing wave and sea-level conditions spanning multiple years is in its relative infancy both in Australian and Internationally. Australian researchers are currently at the forefront of this field, working alongside their international collaborators to develop new modelling tools that begin to address this gap [20,21].



Medium-range model-data comparison of shoreline movement at Collaroy-Narrabeen [21]

Encouraging results are being obtained to hindcast the movement and fluctuations of the shoreline spanning daily to multiple years.

But once again, the ability to extend this new research to other coastal settings around the Australian coastline to predict regional shoreline variability and trends, is presently limited by the lack of suitable data-streams for model calibration and model-data evaluation.

20+ year horizon – Forecasting coastal impacts of climate change

Long-term, continuous monitoring of the coastline will become increasingly important in the face of climate change, and mitigating the potential effects of inundation and coastal erosion will continue to be a focus of coastal councils and communities for the foreseeable future. This is because gradual changes to the coast in response to climate change can be difficult to isolate in short data records (e.g. less than a decade) due to the strong signals also imposed by normal seasonal and inter-annual variability responses of coastlines to vary incident wave conditions.

Projected acceleration of global sea level rise will have the significant effect of progressively extending the impacts of storm wave erosion further landward. The resulting horizontal retreat of the soft shoreline is expected to be many times the vertical extent of seal level rise [22]. But for at least the next several decades (30 – 50 years), recent international research [e.g. 23,24] points toward shifting regional storm wave climates continuing to be the primary driver of coastline vulnerability along wave-dominated beaches. As increasingly reliable and high-resolution forecast data for future wave climatologies and sea level become available (through other research priority areas outlined in *MN2025*), the next generation of long-range forecasting tools will provide the basis for coastal erosion hazard forecasting extending in to the next several decades and beyond.

Sea level and waves are the major climate drivers affecting the coastal zone and in turn are affected by changes in the magnitude and frequency of storm events at a range of space and time scales. Monitoring and predicting the morphological adaptation, erosion and accretion, of our coasts to the combined effects of rising sea level and changing wave climate presents considerable challenges. Significant changes at the coastline are driven by short, extreme events followed by relatively prolonged, quieter periods and slower, but still significant, morphological adjustment. A monitoring system must be able to capture the response before, during and after extreme events over periods of hours to decades.

At the local scale, changing regional weather trends superimposed on a rising sea-level will result in altered exposure to wave energy at the shoreline, causing the erosion and/or redistribution of unconsolidated sediments within and between coastal embayments around Australia's coast. Whether wave climate change will exacerbate or partially offset the sea-level rise impacts is presently a key and as yet unanswered knowledge gap.

Will future coastal adjustment to climate change be relatively modest and within the range of current-day variability, or is there some future tipping point where dramatic coastal changes are triggered? The collection of sustained and targeted observations from regionally-representative coastal sites around the continent and placing these new data-streams in the context of more detailed analyses of the exiting geo-historical record, will be crucial to the further extension and refinement of this research both in Australia and internationally.

Realisation

Australian Marine Science is in the fortunate position that the technological solutions to underpin sustained coastline and nearshore observing are well established, and there is existing expertise within Australia to coordinate, run, maintained and immediately utilise the data-streams that can be delivered.

Rapid realisation of a National Coastline Research Facility is relatively straightforward to achieve, pending the allocation of a suitable and sustained funding source to support this priority research initiative.

Proactive National Planning

In recognition of the inadequacy of the present status of coastline observing around the Australian continent, and more specifically the growing need for sustained observations focussed at the critical shoreline land-ocean boundary along open beached coastlines, in the past 5 years the community has self-organised, to now be in a position to present a coordinated voice for the establishment of a National Coastline Observatory Facility.

In 2009, this proactive response resulted in the bringing together in Sydney of twenty representatives from across Australia with research expertise in the coastal geosciences and engineering plus key personnel from state governments extending from the west to east coasts, to workshop the key attributes of a National Coastline Observatory Facility.

At subsequent workshops hosted by the NSW government, *IMOS* and *OPSAG* at the *Sydney Institute for Marine Science*, and again at the *Coast2Coast* National Conference in Adelaide, coastal practitioners from across Australia have met to discuss and scope the needs for a National Observatory Facility focussed at the coastline. These efforts mirror other sources of guidance that are also available. For example '*Research Priorities for Coastal and Ocean Engineering in Australia'* produced by the *Engineers Australia National Committee for Coastal and Ocean Engineering* [25] documents the urgent need and applications for a national-scale coastline data collection program.

Regionally-representative monitoring sites

Australia's' coastline is vast, and it is neither feasible nor necessary to obtain observations at many coastal sites around the continent. A more strategic approach is proposed.

A key conclusion of the research and government community is the need to establish sufficient monitoring sites nationally so as to adequately capture regional coastline variability and trends.

The ***Coastal Compartment Project*** recently completed for the federal *Department of the Environment* [26] provides a **national framework for the regionalisation of Australia's open coastlines**, based on offshore forcing (waves and tides), coastal landforms and regional sediment processes. Additional refinement for observation site selection can be achieved by co-locating to existing records of where the long-term (multi-decadal to centennial) history of coastal evolution, wave climate change and sediment transport variability is available [27]. This regional approach mirrors international best practice. For example, in the UK coastal compartments are used by regional coastal groups in conjunction with the *UK Environment Agency* as the basis for the design and implementation of regional coastal management plans.

Evaluation of this approach to guide the selection of regionally-representative sites as the focus of sustained observation effort – rather than more modest and less sustainable effort directed at many more coastal sites – is provided by the results of recent research presently being completed within the context of an *ARC*-funded project [28]. In this pilot study that specifically focused on planning for a National Coastline Observatory in Australia, 10 coastal sites extending along the NSW coastline have demonstrated that by careful selection of a relatively small number of representative locations for sustained coastline monitoring, the variability and trends observed at other locations along extensive lengths of the coastline can be adequately captured and quantified.

Based upon this new research, for the NSW coastline a network comprising of the order of 3 regionally-representative observation sites are sufficient to capture the board-scale coastline variability and trends that are presently occurring, extending along coastal compartments from the south to north coast of NSW. On this basis, it is currently envisaged that of the order of 15 core sites nationally are required to initiate a National Facility. The precise locations and numbers will require further refinement.

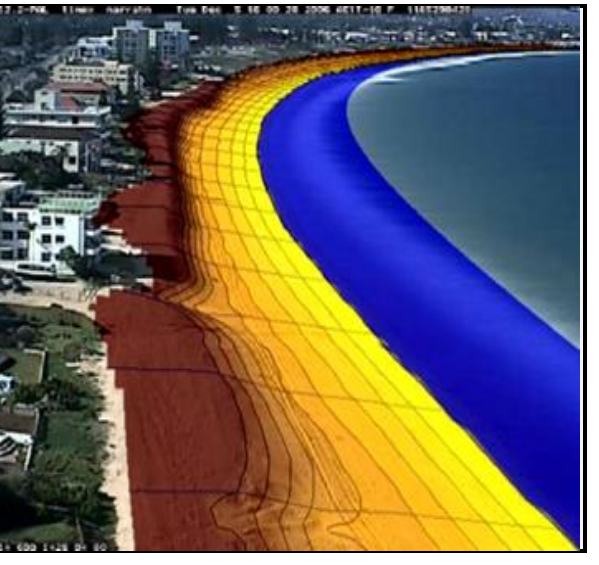
Practical considerations for the final choice of each regionally-located Coastal Reference Station include;

(i) New and existing infrastructure - wave buoys, tide gauges, IMOS National reference stations and the Australian Coastal Radar Network
(ii) Previous studies – beach surveys, in situ observations
(iii) Logistics – access, power and local support.

Observations and infrastructure

The following core baseline coastline data and associated data-streams are required:

- continious imaging of the nearshore, surfzone, shoreline and subaerial beach
- periodic beach profile surveys
- co-located to waves, water-level and wind measurements (existing or new)
- shelf-to-shore bathymetry
- beach and nearshore sediment characteristics
- time-series of paleo-coastline evolution
- water quality
- baseline ecology
- beach usage and hazards



ARGUS Coastal Imaging [29] is internationally acknowledged as currently the leading remote-sensing platform delivering automated, routine, high-resolution, cost-effective, long-term monitoring and quantification of site-based coastline and nearshore conditions. This proven technology has the capability to deliver a broad range of the required data-streams, including: nearshore waves and currents, surfzone bathymetry (cBathy), shorelines, beachface profiling and sand volumes, nearshore morphology and bar position, dune line, beach user counts, and surfzone hazards. Data-streams can also be obtained in real-time to obtain a detailed snapshot of the current coastal state, or be used in retrospective mode to quantify information about past extreme events. The active international ARGUS user community that includes researchers in Australia continues to develop new analyses routines that will further enhance ARGUS system capabilities in to the future.

As the critical natural driver of coastline variability and change, it is crucial that the National Coastline Observatory Faculty be supported by a suitable network of wave measurements. At the present time adequate infrastructure exits for the NSW and QLD coasts and more limited parts of WA, but for much of the rest of the country is inadequate, and insufficient to support broader scale understanding of key coastal processes. The solution is an increased, openly accessible and nationally coordinated network of waverider buoys, or an expanded network of wave capable HF radar systems co-located to regional Coastline Observatory sites.

The use of coastal imaging-based coastline monitoring around the world and its proven value in Australia to research & applied coastal management & engineering is well established. The ARGUS coastal imaging system is now the primary observation platform currently deployed at the Collaroy-Narrabeen coastal monitoring site located in NSW, and was the core observation infrastructure deployed at CSIRO's Secret Harbour *Nearshore Research Facility* located in SW Western Australia, that ran successfully for three years (2011 – 2014) until shut down due to lack of sustained funding.

Coastal imaging can be supplemented with one or more of the following data streams dependant on the resources available at each site:

- RTK-GPS ATV surveys of the subaerial beach and dunes
- RTK-GPS/Sonar surveys of the surfzone and nearshore
- satellite altimetry of dune, beach and nearshore
- regional Airborne Lidar
- Fixed/scanning Lidar of dune, beach and nearshore
- UAV photogrammetry
- Radar detection of beach & nearshore wave conditions

Recent Australian research provides rigorous guidance regarding the required sampling frequency of key coastline data-streams [30]. Demonstrating that these sampling requirements are in part a function of the regional coastal setting, this work will inform the detailed design and scheduling of observations across the National Facility.

Following the establishment of a National Coastline Observatory Faculty at key regional sites nationally, there is the future potential for opportunistic use of existing 'surfcam' networks to compliment and extend the monitoring effort beyond the coverage of core regional monitoring sites [31].

List of contributors and affiliations

CONVENORS	**INSTITUTION**	**STATE**
Ian Turner	Water Research Laboratory, UNSW Australia	NSW
Graham Symonds	CSIRO	WA
CONTRIBUTORS		
Tom Baldock	University of Queensland	QLD
Ron Cox	Australian Climate Change Adaptation Research Network - Settlements and Infrastructure	NATIONAL
Peter Cummings	National Committee for Coastal and Ocean Engineering (Chair), Engineers Australia	NATIONAL
Ian Goodwin	Macquarie University	NSW
Jeff Hansen	University of Western Australia	WA
Mark Hemmer	CSIRO	TAS
Darren James	VIC Department of Sustainability and Environment	VIC
Ryan Lowe	University of Western Australia	WA
Kathleen McInnes	CSIRO	VIC
Tim Pritchard	NSW Office of Environment and Heritage	NSW
Andy Stephens	CSIRO	QLD
Bruce Thom	Wentworth Group of Concerned Scientists Australian Coastal Society	NATIONAL
Murray Townsend	SA Department of Environment and Natural Resources	SA
Colin Woodroffe	University of Wollongong	NSW

Selected references

[1] OPSAG, 2013. Marine Nation 2025: Marine Science to Support Australia's Blue Economy. Australian Government.

[2] Short AD & Woodroffe CD, 2009. '*The Coast of Australia*.' Cambridge University Press, Melbourne, 288p

[3] ABS, 2002. *Regional Population Growth, Australia and New Zealand*. Australian Bureau of Statistics, cat. No. 3218.0.

[4] NCCARF, 2012. '*The Economic Value of Natural and Build Coastal Assets – Part 2: Built Coastal Assets'*. ACCARNSI Discussion Paper P, 32p

[5] DCCEE, 2011. '*Climate change risks to coastal buildings and infrastructure'*, Commonwealth of Australia.

[6] NSW Government, 2006. '*Economic values of Natural Resources and Natural Environment on the NSW Coast'*. Sum. Sheet CCA 22a.

[7] Blackwell BD, 2005. *Proceedings, Australia and New Zealand Society of Ecological Economics Conference*. Palmerston North, NZ.

[8] NCCARF, *2010'National Climate Change Adaptation Research Plan – Settlements and Infrastructure'*. Thom BG et al, NCCARF, 60p

[9] Coco G, et al, 2014. *Geomorphology*, doi: 10.1016/j.geomorph.2013.08.028.

[10] Harley, MD et al. 2011. Assessment and integration of conventional, RTK-GPS and image-derived beach survey methods for daily to decadal coastal monitoring. *Coastal Engineering*, 58(2), 194-205.

[11] McLean, R and Shen, J-S, 2006. Journal of Coastal Research, 22(1), 28-36.

[12] House of Representatives, 2009. '*Managing our coastline in a changing climate'*, Canberra, 368p

[13] CSIRO, 2012. '*Sustainable coastal management and climate adaptation: global lessons from regional approaches in Australia'*, CSIRO

[14] Hemer, MA, et al, 2008. *Variability and trends in the Australian wave climate and consequent coastal vulnerability*. Report to Department Climate Change Surface Ocean Wave Variability Project, CSIRO.

[15] Voice, M, et al 2006. *Vulnerability to climate change of Australia's coastal zone: analysis of gaps I methods, data and system thresholds*. Report to Australian Greenhouse Office, Department of Environment and Heritage.

[16] Holman, RA, Plant, N, Holand, T., 2013. cBathy: A robust algorithm for estimating nearshore bathymetry. *Journal of Geophysical Research*, 115(5), 2595-2609.

[17] Basher, R., 2006. Global early warning systems for natural hazards: systematic and people-centred. *Phil. Tans. R. Soc*., 364, 2167-2182.

[18] Callighan DP, et al, 2008. *Coastal Engineering*, 55:375-390

[19] Callighan DP, et al, 2013. *Coastal Engineering*, 82:64-75

[20] Davidson MA, et al, 2013. *Coastal Engineering*, 73:191-202

[21] Splinter, KD et al, 2014. A generalized equilibrium model for predicting daily to inter-annual shoreline response. *Journal of Geophysical Research*, DOI: 10.1002/2014JF003106

[22] Ranasinghe, et al, 2012. *Climate Change*, 110:561-574.

[23]]Brunel C & Sabatier F, 2009. *Geomorphology*, 107:47-57.

[24] Ruggerio P, 2013. *Journal of waterway, Port, Coastal, Ocean Engineering*, 139(2):88-97.

[25] NCCOE, Research Priorities for Coastal and Ocean Engineering in Australia, Engineers Australia. Available at: http://www.engineersaustralia.org.au/coastal-ocean-engineering/publications

[26] Thom, BG, 2014. *Coastal Compartment Project – Summary for Policy Makers*. Australian Government Department of the Environment. Available at: http://www.environment.gov.au/climate-change/adaptation/australias-coasts/coastal-compartments

[27] Goodwin, ID et al. 2006. Marine Geology 226, 127-144

[28] Turner, IL et al, 2011. Planning for an Australian National Coastline Observatory: monitoring and forecasting coastal erosion in a changing climate. *Coasts & Ports 2011*, Engineers Australia.

[29] Holman, RA and Stanley J, 2007. The history and technical capabilities of Argus. *Coastal Engineering*, 54(6–7), 477–491.

[30] Splinter, KD, 2013. How much data is enough? The importance of morphological sampling interval and duration for calibration of empirical shoreline models. *Coastal Engineering*, 77, 14-27.

[31] Mole, MA, et al, 2013. Capitalizing on the surfcam phenomenon: a pilot study in regional-scale shoreline and inshore monitoring utilizing existing camera infrastructure, 2013. *Journal of Coastal Research*, SI65 (ICS2013), 1433-1438.

ATTACHMENT:

LETTER OF SUPPORT - *EA NATIONAL COMMITTEE FOR COASTAL AND OCEAN ENGINEERING*

ENGINEERS
AUSTRALIA

23rd September 2014

National Marine Science Committee (NMSC)

Australian Institute of Marine Science (AIMS)

PMB 3, TOWNSVILLE, QLD, 4810

RE: MARINE NATION 2025: WHITE PAPER:
ESTABLISHMENT OF A NATIONAL COASTLINE OBSERVATORY FACILITY
LETTER OF SUPPORT

Dear Madam / Sir,

In my capacity as the current chair of the Engineers Australia (EA) National Committee for Coastal and Ocean Engineering (NCCOE), I wish to advise NMSC of the NCCOE's contribution to, and endorsement for the aims and goals of Marine Nation 2015 and in particular the White Paper Marine Nation 2025: "Establishment of a National Coastline Observatory Facility".
Please direct future communications to NCCOE via Ian Turner at UNSW, who is a current member of NCCOE and our contributor to the White Paper.

Yours Sincerely,

Peter Cummings,
Chair, NCCOE

Engineering House
11 National Circuit, Barton ACT 2600
Phone: +61 2 6270 6555 Facsimile: +61 2 6273 1488
www.engineersaustralia.org.au