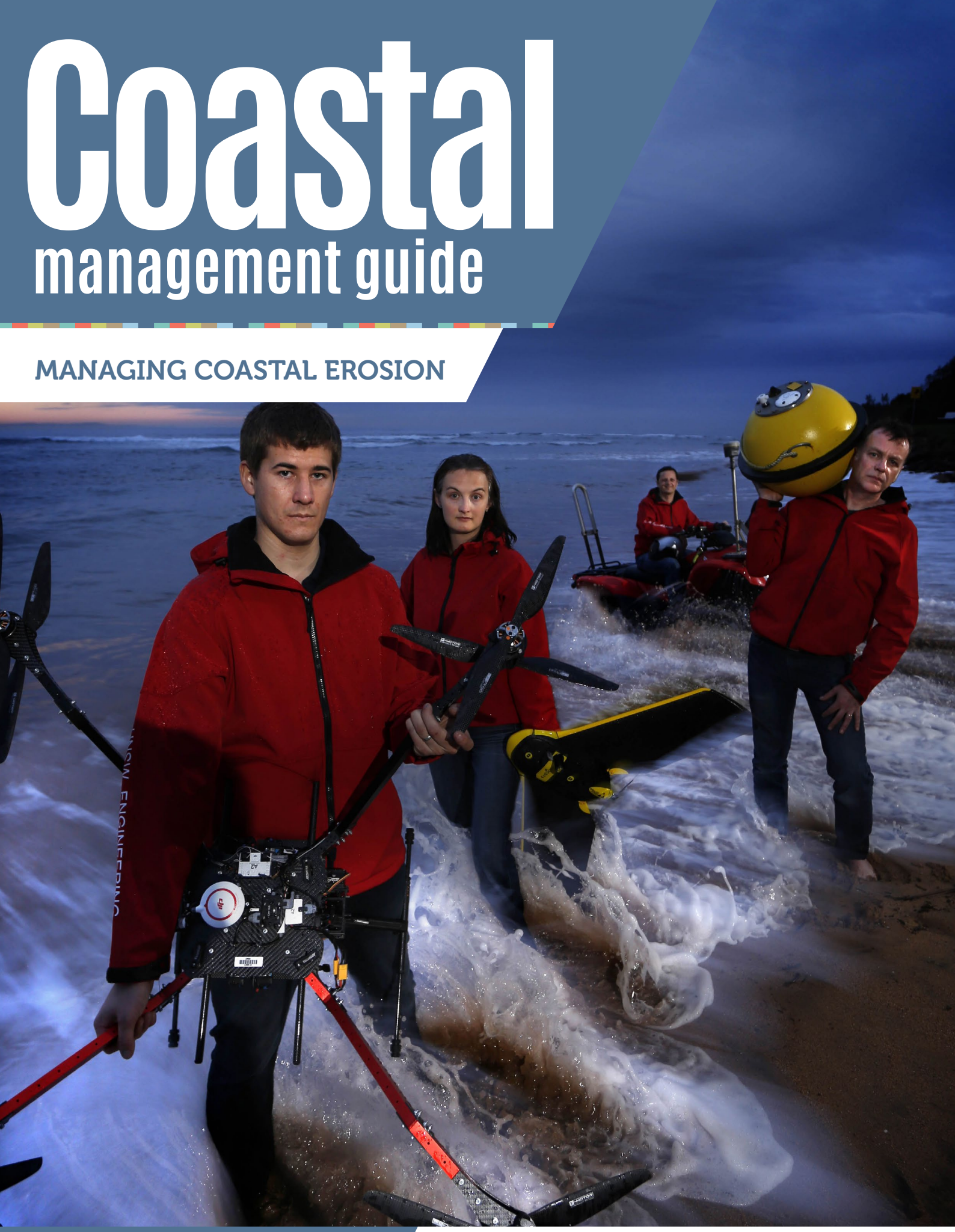
Coastal management guide

MANAGING COASTAL EROSION



TEACHER RESOURCE GUIDE FOR YEARS 7-10

REFRACTION MEDIA
NSW GOVERNMENT Office of Environment & Heritage
UNSW SYDNEY

Introduction

THIS COASTAL Management High School Study Guide is an educational resource that targets Australian curriculum areas of Physical Sciences, Human Society and its Environment (HSIE), Geography, Earth and Environmental Sciences and Maths for Years 7–10.

This guide is designed to assist high school teachers to engage students in the complex issue of coastal management in Australia. The guide will encourage students to explore issues in their locality, and will cover coastal management as the key underlying issue with coastal erosion as the "attractor" to the core topic, and relating themes including the risks to Australian beaches and researching coastal change.

HOW TO USE THE GUIDE

The notes in this study guide offer both variety and flexibility of use for the classroom. You and your students can choose to use all or any of the five sections – although it is recommended to use them in sequence, along with all or a few of the activities within each section.

"FIVE Es" MODEL

This resource employs the "Five Es" instructional model designed by Biological Sciences Curriculum Study, an educational research group in the US state of Colorado. It has been found to be extremely effective in engaging students in learning science and technology. It follows a constructivist or inquiry-based approach to learning, in which students build new ideas on top of the information they have acquired through previous experience. Its components are:

ENGAGE

Students are asked to make connections between past and present learning experiences and become fully engaged in the topic to be learned.

EXPLORE

Students actively explore the concept or topic being taught. It is an informal process where the students should have fun manipulating ideas or equipment and discovering things about the topic.

EXPLAIN

This is a more formal phase where the theory behind the concept is taught. Terms are defined and explanations are given about the models and theories.

ELABORATE

Students have the opportunity to develop a deeper understanding of sections of the topic.

EVALUATE

Both the teacher and the students evaluate what they have learned in each section.

UNSW/OEH project team: Ian Turner, Mitchell Harley, David Hanslow, Michael Kinsela, Kristen Splinter, Heather Stevens.

This resource was developed through the NSW Adaptation Research Hub's Coastal Processes and Responses Node, NSW Office of Environment and Heritage.

This Coastal Management High School Study Guide is produced by Refraction Media for the NSW Office of Environment and Heritage and School of Civil and Environmental Engineering, UNSW Sydney.

UNSW SYDNEY Water Research Laboratory School of Civil and Environmental Engineering

Curriculum links

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
SCIENCE					
Year 9					
Science Understanding					
Biological sciences Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (ACSSU176)					
Physical sciences Energy transfer through different mediums can be explained using wave and particle models (ACSSU182)					
Year 10					
Science Understanding					
Earth and space sciences Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189)					
Physical science The motion of objects can be described and predicted using the laws of physics (ACSSU229)					
Years 7–8					
Science as a Human Endeavour					
Nature and development of science					
Scientific knowledge has changed people's understanding of the world and is refined as new evidence becomes available (ACSHE119) (ACSHE134)					

CURRICULUM LINKS

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures (ACSHE223) (ACSHE226)					
Use and influence of science					
Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120) (ACSHE135)					
People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE121) (ACSHE136)					
Years 9–10					
Nature and development of science					
Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE157) (ACSHE191)					
Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (ACSHE158) (ACSHE192)					
Use and influence of science					
People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE160) (ACSHE194)					
Values and needs of contemporary society can influence the focus of scientific research (ACSHE228) (ACSHE230)					

CURRICULUM LINKS

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
Science Inquiry Skills					
Years 7–8					
Questioning and predicting					
Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124) (ACSIS139)					
Planning and conducting					
Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125) (ACSIS140)					
Measure and control variables, select equipment appropriate to the task and collect data with accuracy (ACSIS126) (ACSIS141)					
Processing and analysing data and information					
Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships in data using digital technologies as appropriate (ACSIS129) (ACSIS144)					
Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions based on evidence (ACSIS130) (ACSIS145)					
Evaluating					
Use scientific knowledge and findings from investigations to evaluate claims based on evidence (ACSIS132) (ACSIS234)					
Communicating					
Communicate ideas, findings and evidence-based solutions to problems using scientific language, and representations, using digital technologies as appropriate (ACSIS133) (ACSIS148)					

CURRICULUM LINKS

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
Years 9–10					
Questioning and predicting					
Formulate questions or hypotheses that can be investigated scientifically (ACSIS164) (ACSIS198)					
Planning and conducting					
Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165) (ACSIS199)					
Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately (ACSIS166) (ACSIS200)					
Processing and analysing data and information					
Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170) (ACSIS204)					
Evaluating					
Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems (ACSIS172) (ACSIS206)					
Communicating					
Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174) (ACSIS208)					

CURRICULUM LINKS

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
GEOGRAPHY					
Geographic Knowledge and Understanding					
Year 8 Unit 1: Landforms and landscapes					
Different types of landscapes and their distinctive landform features (ACHGK051)					
Spiritual, aesthetic and cultural value of landscapes and landforms for people, including Aboriginal and Torres Strait Islander Peoples (ACHGK049)					
Geomorphic processes that produce landforms, including a case study of at least one landform (ACHGK050)					
Human causes and effects of landscape degradation (ACHGK051)					
Ways of protecting significant landscapes (ACHGK052)					
Causes, impacts and responses to a geomorphological hazard (ACHGK053)					
Year 10 Unit 1: Environmental change and management					
Human-induced environmental changes that challenge sustainability (ACHGK070)					
Environmental world views of people and their implications for environmental management (ACHGK071)					
The Aboriginal and Torres Strait Islander Peoples' approaches to custodial responsibility and environmental management in different regions of Australia (ACHGK072)					
The application of systems thinking to understanding the causes and likely consequences of the environmental change being investigated (ACHGK073)					
The application of geographical concepts and methods to the management of the environmental change being investigated (ACHGK074)					

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
The application of environmental, economic and social criteria in evaluating management responses to the change (ACHGK075)					
Years 7–8					
Geographical Inquiry and Skills					
Observing, questioning and planning					
Develop geographically significant questions and plan an inquiry using appropriate geographical methodologies and concepts (ACHGS047) (ACHGS055)					
Collecting, recording, evaluating, representing					
Evaluate sources for their reliability and usefulness and select, collect and record relevant geographical data and information, using ethical protocols, from appropriate primary and secondary sources (ACHGS048) (ACHGS056)					
Represent data in a range of appropriate forms, for example, climate graphs, compound column graphs, population pyramids, tables, field sketches and annotated diagrams, with and without the use of digital and spatial technologies (ACHGS049) (ACHGS057)					
Interpreting, analysing and concluding					
Interpret geographical data and other information using qualitative and quantitative methods, and digital and spatial technologies as appropriate, to identify and propose explanations for spatial distributions, patterns and trends, and infer relationships (ACHGS051) (ACHGS059)					
Apply geographical concepts to draw conclusions based on the analysis of data and information collected (ACHGS052) (ACHGS060)					

CURRICULUM LINKS

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
Communicating					
Present findings, arguments and ideas in a range of communication forms selected to suit a particular audience and purpose; using geographical terminology and digital technologies as appropriate (ACHGS053) (ACHGS061)					
Reflecting and responding					
Reflect on their learning to propose individual and collective action in response to a contemporary geographical challenge, taking account of environmental, economic and social considerations, and predict the expected outcomes of their proposal (ACHGS054) (ACHGS062)					
Years 9–10					
Observing, questioning and planning					
Develop geographically significant questions and plan an inquiry that identifies and applies appropriate geographical methodologies and concepts (ACHGS063) (ACHGS072)					
Collecting, recording, evaluating, representing					
Evaluate sources for their reliability, bias and usefulness and select, collect, record and organise relevant geographical data and information, using ethical protocols, from a range of appropriate primary and secondary sources (ACHGS064) (ACHGS073)					
Represent multi-variable data in a range of appropriate forms, for example scatter plots, tables, field sketches and annotated diagrams, with and without the use of digital and spatial technologies (ACHGS065) (ACHGS074)					

CURRICULUM LINKS

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
Interpreting, analysing and concluding					
Interpret and analyse multi-variable data and other geographical information using qualitative and quantitative methods, and digital and spatial technologies as appropriate, to make generalisations and inferences, propose explanations for patterns, trends, relationships and anomalies, and predict outcomes (ACHGS067) (ACHGS076)					
Apply geographical concepts to synthesise information from various sources and draw conclusions based on the analysis of data and information, taking into account alternative points of view (ACHGS068) (ACHGS077)					
Communicating					
Present findings, arguments and explanations in a range of appropriate communication forms, selected for their effectiveness and to suit audience and purpose; using relevant geographical terminology and digital technologies as appropriate (ACHGS070) (ACHGS079)					
Reflecting and responding					
Reflect on and evaluate findings of an inquiry to propose individual and collective action in response to a contemporary geographical challenge, taking account of environmental, economic, political and social considerations; and explain the predicted outcomes and consequences of their proposal (ACHGS071) (ACHGS080)					
Year 7					
Maths					
Linear and non-linear relationships					
Investigate, interpret and analyse graphs from authentic data (ACMNA180)					

CURRICULUM LINKS

Australian Curriculum Link	Engage	Explore	Explain	Elaborate	Evaluate
Statistics and probability / Chance					
Assign probabilities to the outcomes of events and determine probabilities for events (ACMSP168)					
Data representation and interpretation					
Identify and investigate issues involving numerical data collected from primary and secondary sources (ACMSP169)					
Year 8					
Statistics and probability / Chance					
Represent events in two-way tables and Venn diagrams and solve related problems (ACMSP292)					
Data representation and interpretation					
Investigate techniques for collecting data, including census, sampling and observation (ACMSP284)					
Explore the practicalities and implications of obtaining data through sampling using a variety of investigative processes (ACMSP206)					
Year 9					
Measurements and Geometry / Using units of measurement					
Calculate areas of composite shapes (ACMMG216)					
Investigate very small and very large timescales and intervals (ACMMG219)					
Data representation and interpretation					
Identify everyday questions and issues involving at least one numerical and at least one categorical variable, and collect data directly and from secondary sources (ACMSP228)					

Our changing coastline

AS AN island, Australia has more than its fair share of coastline – about 34,000 km of it. Many Australians live within 50 km of the shoreline and beaches are places of special significance to many Australians.

Coastlines are complex, dynamic systems with many components. Coastal areas and estuaries form a transition zone between the land and the sea, and within this zone there are many different types of environments. In this guide we focus on the open coastline. Estuaries, which are a connected part of the coastal system and where many of us live, are very important and have their own unique hazards and management challenges. For more, see Estuaries and climate change.

THE DYNAMIC COAST

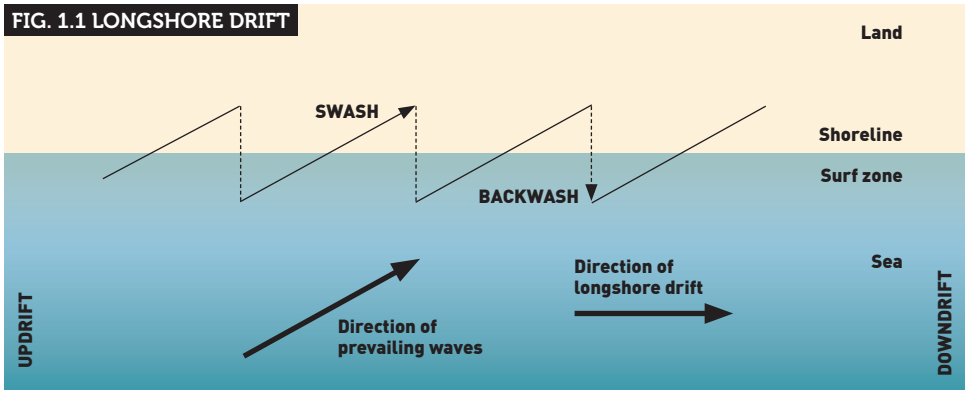
Coastal geomorphology

Coasts are dynamic zones that involve complex and continual interactions between the ocean, land and atmosphere. Among the many factors that form and shape coasts are ocean waves, tides, currents and wind.

These natural factors and processes result in constant changes taking place over long periods of time. Australian Aboriginal stories from several mainland locations are understood to recall the effects of post-glacial sea-level rise more than 7,000 years ago. Changes that take place over shorter periods of time, such as those resulting from severe weather events, also occur.

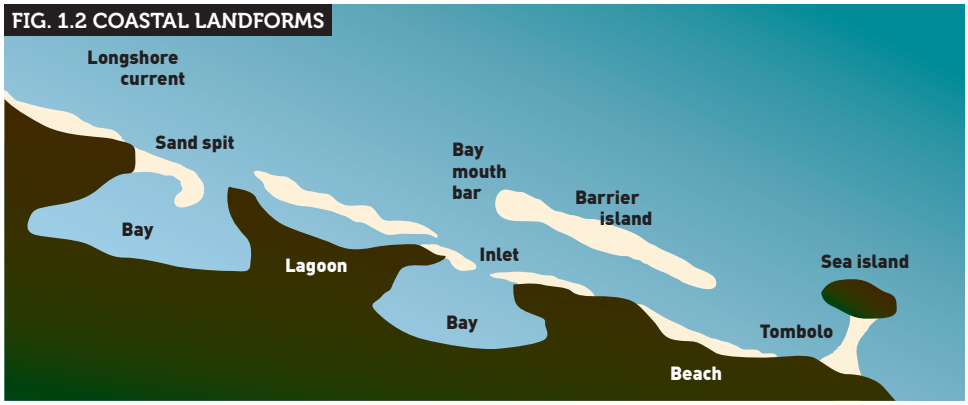
Australian beaches are subject to ongoing processes of sediment (sand) transport by ocean currents, waves and wind, as well as sediment supply from rivers and adjacent beaches. **Cross-shore transport** is the cumulative movement of beach and nearshore sand perpendicular to the shore by the combined action of tides, wind and waves. One of the strongest influences shaping the coastline is the constant impact of waves, which may cause longshore drift. **Longshore drift** is a geophysical process that consists of the transportation of sediments (e.g. clay, silt, sand and shingle) along a coast and leads to the creation of many types of landforms including sand spits, bay beaches and barrier islands.

FIG. 1.1 LONGSHORE DRIFT



Waves approaching the beach at an angle cause a longshore current to form parallel to the shoreline. This longshore current can transport sand along the beach, from the updrift to downdrift direction. Figure adapted from the website page bit.ly/2r00Qnd

FIG. 1.2 COASTAL LANDFORMS



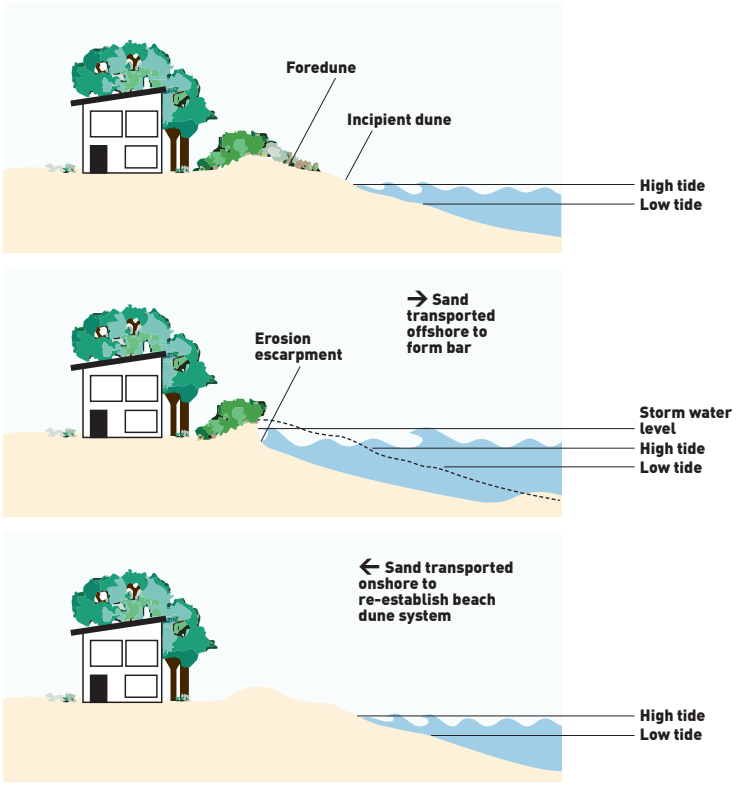
Longshore drift causes sediment to be transported in the direction of the prevailing current and helps to shape the coastline over many years. Figure adapted from The British Geographer website: bit.ly/2qYnx6J
For a map of Australia's coastal landform types, beach geomorphic models and more, visit the OzCoasts website.

Coastal erosion – a natural process

A beach functions as a natural system. Over time, beach sediments continuously build up (accrete) and drift away (erode) again and again. There are two main types of sand movement on beaches:

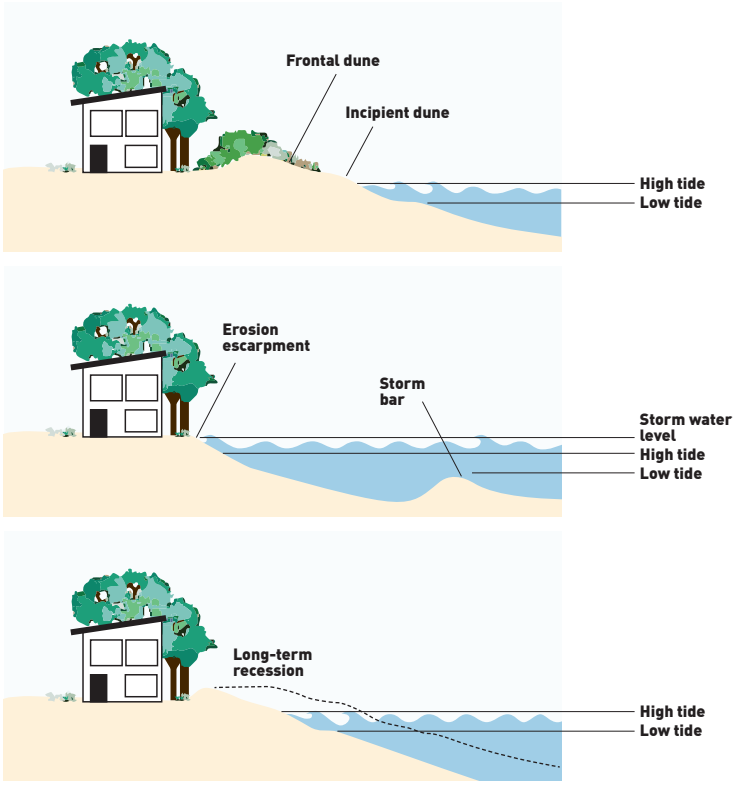
- **Short-term storm erosion-recovery:** occurs when, during storms, sand is rapidly removed – sometimes 20 m or more of beach can be lost overnight. The sand then comes back over a period of weeks, months or even years, resulting in no net loss of sediment in the long term.

FIG. 2.1 BEACH EROSION / ACCRETION CYCLE



Short-term storm erosion-recovery. Figure adapted from the following website: www.newcastle.nsw.gov.au/Living/Environment/Coast-River/Coastline-Hazards

FIG. 2.2 LONG-TERM COASTAL RECESSION / ACCRETION



Long-term coastal recession/accretion. Figure adapted from the following website: www.newcastle.nsw.gov.au/Living/Environment/Coast-River/Coastline-Hazards

- **Long-term coastal recession / accretion:** occurs when sand removed by a storm or by longshore drift does not all return to the beach, or is not replaced by new sediment from the updrift direction. This results in a net loss of sediment from the system (a sediment deficit). Alternatively, there may be a slow net increase of sediment into the system.

Coastal erosion is part of the natural response of a beach to changing wave and water level conditions. In a natural setting, beaches are quite resilient to erosion, largely because sand dunes form a natural buffer and work to use up the wave energy before it reaches the coastal hinterland (the area extending landwards of the coast). Stable and well-vegetated dunes also help stop sand from being blown inland by the wind. However, many areas of Australian coastline are no longer in a natural state and erosion has become a significant management challenge.

WHAT ARE THE PROBLEMS?

Mounting pressures

Human activity can fundamentally alter beach systems. Coastal areas are being increasingly developed for a range of purposes, particularly urbanisation and tourism, which are placing enormous pressure on our beaches.

About 85% of Australia's population lives in coastal centres. For many others, beaches are extremely popular places to visit. Development along certain parts of the coastline has occurred too close to the shore, placing it at risk of coastal erosion. With the population growing, pressures on the Australian coastline will continue to increase.

In some locations, human intervention has worsened the problem of coastal erosion.

Coastal protection measures such as sea walls – usually built to guard against erosion – have the effect of hardening the coast. This can reduce its ability to adjust naturally.

The loss of protective vegetation by stock grazing, fires or walking tracks, is a major influence on dune erosion and can worsen beach erosion. Damming of rivers has also probably contributed to the problem by reducing the amount of sediment delivered to the coast.

Climate change is another major threat to coastlines. Current models indicate extreme rain events and tropical cyclones will become more intense, likely increasing the risk of inundation and erosion in coastal areas. Sea-level rise is also likely to lead to the recession of shorelines and the permanent loss of beaches.

Changing boundaries between water and land are set to challenge non-Indigenous notions of land ownership.

Legacy of mistakes

Mistakes of the past – such as building too close to the shoreline – have created major modern-day management problems. These can only be expected to get worse as beaches recede and sea levels rise.

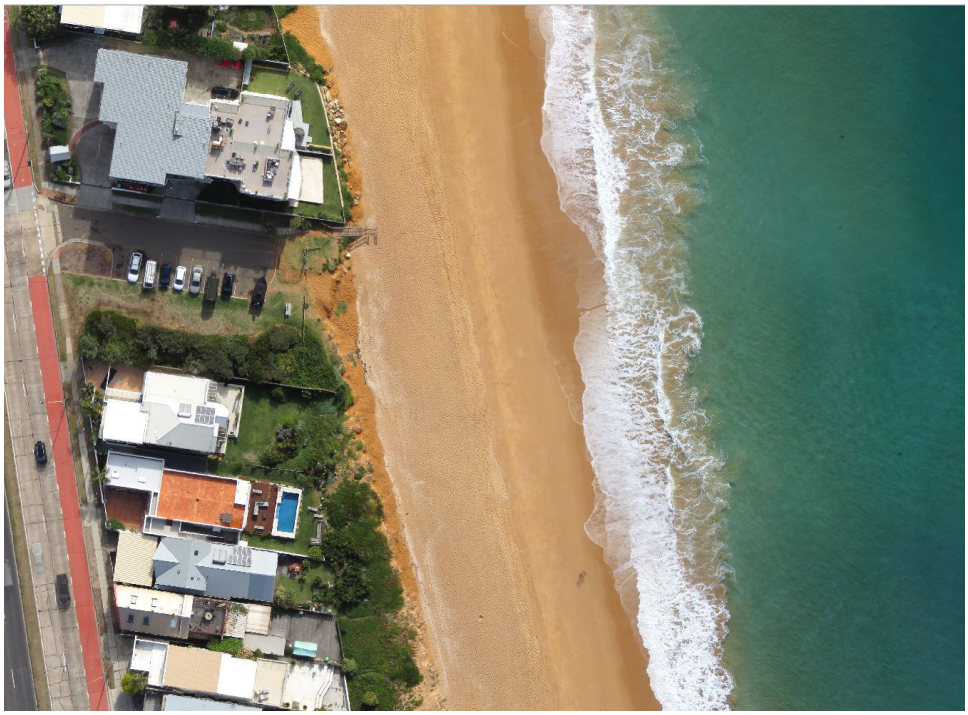
Collaroy Beach in Sydney is a classic example, where shoreline subdivision more than 100 years ago has lead to a series of costly property damage over the years.

Inflexible planning and development add to the difficulty of responding to changing coastal environments. Today's challenge is to plan effectively for changes, so we don't create new legacy problems for other generations to deal with.

MANAGING FOR THE FUTURE

A wide range of issues affect the management of coastlines. Social, economic, aesthetic, recreational and ecological factors all need to be considered. Because the issues involved are complex and interrelated, an integrated and long-term approach is needed.

Coastal management seeks to balance all of these factors in a way that is sustainable for the future. Ideally, techniques are adopted that work with nature and maintain the coast's natural ability to adapt to change.



Collaroy Beach, NSW, just prior to a large storm in June 2016. The swimming pool in the lower part of the picture collapsed as a result of storm erosion.

Management strategies

Management strategies to address coastal risks fall into five broad categories:

1. **Avoidance** – e.g. ensure that new developments are not permitted in vulnerable areas
2. **Retreat** – e.g. relocate structures at risk
3. **Accommodation** – e.g. modify buildings to deal with rising waters
4. **Hold the line** – e.g. capital works such as sea walls and levees
5. **Do nothing** – a temporary measure; adaptation action will need be taken in future

People often have conflicting views about how the coast should be used and managed. Multiple stakeholders are involved in coastal management including governments, businesses, landowners, community groups and the public. When management options are being weighed up, an important consideration is who the beneficiaries will be; for example, property owners or beach visitors? The cost and who will pay for the coastal management is another major consideration.

While all levels of government have some responsibility for coastal management, there are often opportunities for local communities to be involved (see BeachCare in the Gold Coast).

For more on management strategies, see CoastAdapt.

Hard and soft management options

Options aimed at protecting our coastline from further erosion are often referred to as "hard" or "soft".

Hard options include the construction of engineering structures such as groynes, sea walls, artificial reefs, offshore breakwaters, revetments, rock armouring and gabions.

Hard structures generally have large initial costs, but are designed to protect vulnerable coastal locations for many decades (often 50 years or more). Soft options such as beach nourishment and dune management typically have lower initial costs, but may require regular upkeep to maintain the desired level of coastal protection.

A key aspect to deciding appropriate management options is their impact on beach amenity (the overall quality of the experience when visiting a beach).

Soft options are often preferred to maintain beach amenity, as they aim to restore the coastline to a more natural state. Hard options, meanwhile, can improve beach amenity through better beach access and facilities, such as walking promenades, steps for sitting and relaxing, or enhanced surf quality. In many locations, a combination of hard and soft options is the most appropriate management strategy.

Top: Coastal imaging cameras capture images of the beach every half hour at Broadbeach, Queensland.

Above: Dune revegetation is an example of a "soft" management option.

HOW DO WE MEASURE COASTAL CHANGE?

Monitoring "in the field" is key to understanding beaches, allowing us to better predict and manage change along coastlines.
A beach survey program at Narrabeen, on Sydney's Northern Beaches, is one of a limited number of sites globally where beach monitoring now spans decades. Emerging survey technologies and techniques have been progressively implemented at the site. Today, these include:

- **RTK (real time kinematic) GPS technology used to measure beach profiles, and to produce monthly 3D surveys of the entire subaerial beach using an all-terrain vehicle**
- **Coastal imaging stations – installed at each end of the beach to collect regular daylight images from several cameras**
- **LiDAR (light detection and ranging) systems – a permanent fixed LiDAR system to scan a single profile line day and night, and airborne LiDAR surveys of the entire beach and dune systems pre- and post-storm**
- **Unmanned aerial vehicles (drones) – to conduct pre- and post-storm 3D surveys of the entire beach and dune systems**
- **Bathymetric (hydrographic) surveys – to measure water depth in the surf zone and offshore.**

For more information visit
www.narrabeen.wrl.unsw.edu.au/background/

Dr Kristen Splinter

AS a child, I was always fascinated with water – be it swimming, boating or just playing. I grew up in Ontario, Canada, near Lake Ontario, and summered at our family cottage or the local pool. My first experience with the ocean was when my family moved to Nova Scotia on Canada's east coast. I remember playing with jellyfish on Prince Edward Island and the saltiness of the water and waves. As I grew older, I had a fascination with corals and dolphins (and perhaps warmer tropical islands).

When it came time to apply for university I looked at marine biology and engineering programs. Ultimately, I chose to do my undergrad in Civil and Environmental Engineering at Queen's University (Canada), but was always pulled back to the water and geology courses.

Upon graduation my interest in water continued and I pursued a Master of Science in Coastal and Oceanographic Engineering at University of Florida (USA). While my research focused on numerical modelling of surf zone currents, I was also able to help in field experiments. Being involved in a multi-institutional field experiment in San Diego, California, might have been my game changer. I got to be outside, and my experiences with the nearshore broadened.

But I wanted to learn more about the ocean. This ultimately led me to Oregon State University, also in the USA, where I did a PhD in geological oceanography. I learned about ocean chemistry, the tiny shelled creatures called forams, seafloor sediments, ocean currents and more. I got to take part in research cruises out in the Pacific. It was great. It made me a better scientist and "engineer", with this new (broader) perspective.

Now, seven years beyond the completion of my PhD, I still find myself blurring the lines of engineering and oceanography as I establish my career in a male-dominated field.

I'm lucky to be part of such a great team at the Water Research Laboratory at UNSW. My research interests focus on coastal change: specifically understanding how coastlines change due to changing wave heights and water levels. This includes the captivating coastal storms that can cause significant damage and erosion in a very short period, but also the lesser-studied processes on how beaches recover.

I have recently been involved in research examining the impact of storms on coastal reef lagoons, as well as developing real-time erosion forecasting systems.

Dr Kristen Splinter
Senior Lecturer, Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney.

When there's opportunity, I get involved in field research as well. The best way to understand a rip current is to be stuck in one! Every day I ask the question: "Why do we see the things we see?" and "Can we explain it?". I live within walking distance of the beach and spend most mornings down there, either walking, swimming or surfing. Every day I learn or observe something about how this water world works. The beach is never the same twice. I love it.

As a new mum, the challenges ahead of family and work are inevitable. Professionally, I'm embarking on larger teaching role and advising PhD and Honours students. While all of this is challenging, I'm enjoying being able to share my love of the ocean with the next generation.

Engage

The following newspaper articles cover the impact that storms have had on Australia's East Coast in recent years.

The role of climate change in eastern Australia's wild storms

AUSTRALIA'S EAST coast is recovering from a weekend of wild winds, waves and flooding, caused by a weather pattern known as an East Coast Low. Tragically, several people have died in flooding.

Parts of NSW have received more than 400 mm of rain since Friday morning. Places such as Canberra and Forster had their wettest June day on record. Waves have also caused severe coastal erosion and damaged property.

East Coast Lows are a type of low-pressure system or cyclone that occur on the Australian east coast. They are not uncommon, with about seven to eight lows a year causing widespread rainfall along the east coast, particularly during late autumn and winter. An East Coast Low in April last year caused similar damage.

But whenever they happen they raise the question: did climate change play a role?

Read the full story here | bit.ly/2LJo60Q
The role of climate change in eastern Australia's wild storms, The Conversation, published June 6, 2016.

IMAGES AND COVERAGE OF STORM DAMAGE

"IN 2002, A PROTEST SUCCESSFULLY PRESSURED THE THEN WARRINGAH COUNCIL TO KNOCK BACK THE BUILDING OF PROTECTIVE WALLS."
– THE DAILY TELEGRAPH

Sydney storm: Massive 2002 protest stopped sea wall being built, but at what cost?

THESE are the pictures that have come back to haunt opponents to Northern Beaches sea defenses.

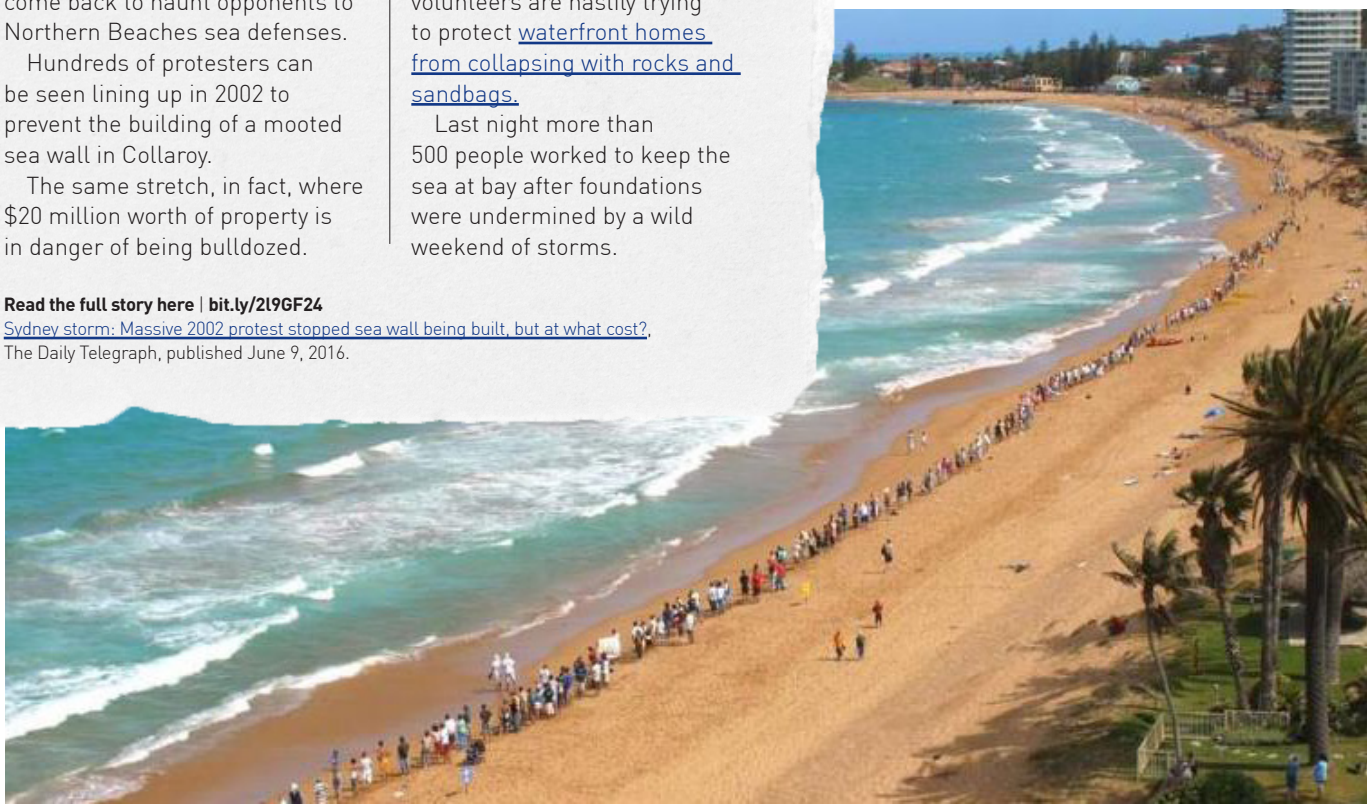
Hundreds of protesters can be seen lining up in 2002 to prevent the building of a mooted sea wall in Collaroy.

The same stretch, in fact, where $20 million worth of property is in danger of being bulldozed.

Emergency crews and volunteers are hastily trying to protect waterfront homes from collapsing with rocks and sandbags.

Last night more than 500 people worked to keep the sea at bay after foundations were undermined by a wild weekend of storms.

Read the full story here | bit.ly/2l9GF24
Sydney storm: Massive 2002 protest stopped sea wall being built, but at what cost?, The Daily Telegraph, published June 9, 2016.



Sydney wild weather: Residents called for pavilion on site of Waverley landslip

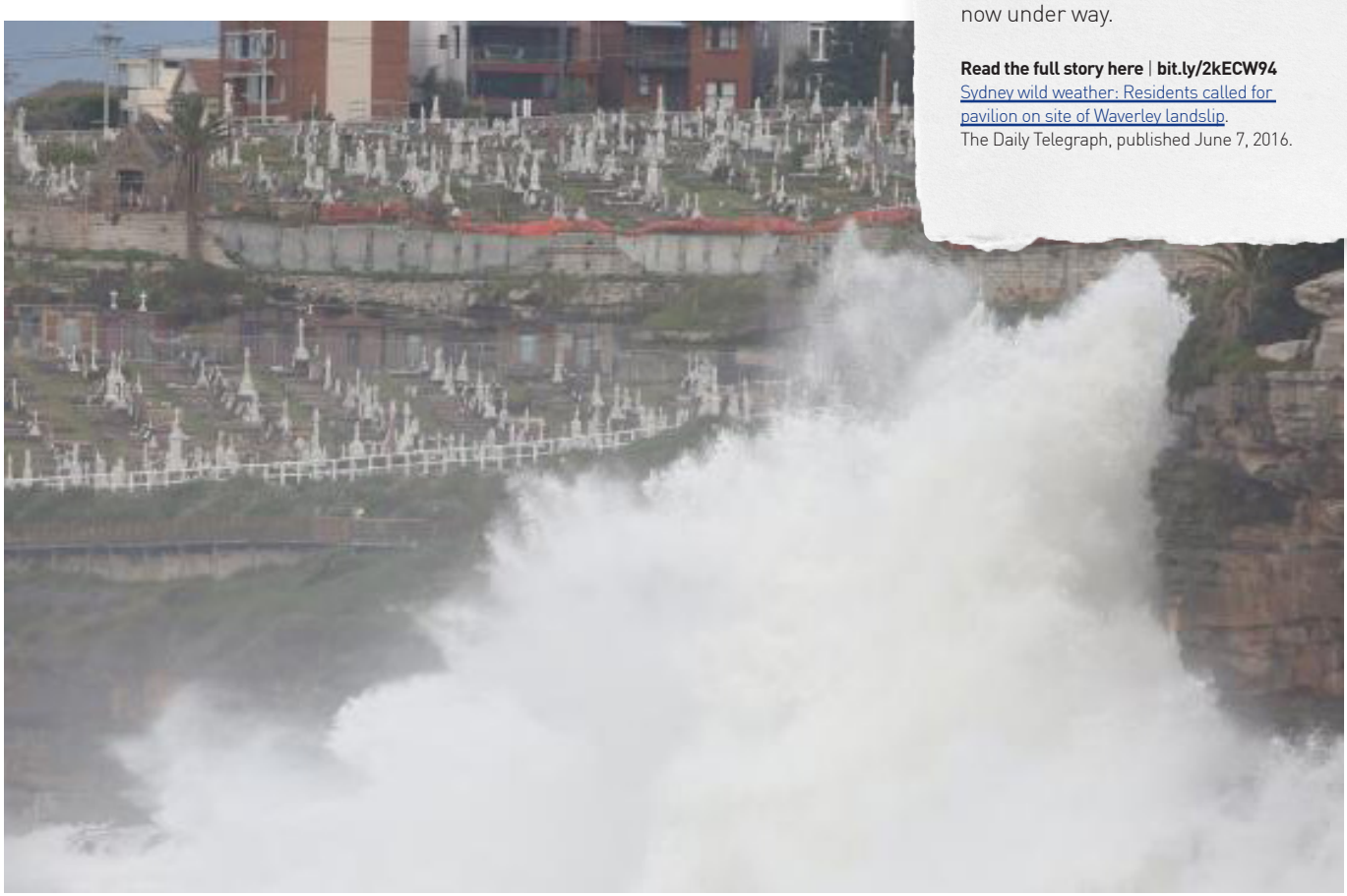
IT'S ONE of Sydney's most historic graveyards and a spectacular sight from the air.

But Waverley Cemetery wasn't spared by the weekend's wild weather which smashed the east coast of NSW.

Two days of heavy rain and rough conditions caused the landslip at the clifftop Waverley Cemetery, sending huge boulders and debris crashing down onto the beach below.

Waverley Council has roped off a section around the adjacent walking track and repair work is now under way.

Read the full story here | bit.ly/2kECW94
Sydney wild weather: Residents called for pavilion on site of Waverley landslip.
The Daily Telegraph, published June 7, 2016.



Gold Coast beach erosion plan: Is the plan on the right track?

AS THE 2015 summer storm season approaches, has the Gold Coast City Council got the right plan in place to protect the beaches luring the 11.5 million tourists, residents and investors to Australia's playground each year?

Two years ago – in June 2013 after three years of storms – Gold Coast City Council launched its "Three-Point Plan for Coastal Protection", part of its high-profile 10-year Ocean Beaches Strategy.

The "Three-Point Plan" promised $30 million over two years until June 2015 to build a mix of new sea walls and dredging sand from locations off the beach to re-nourish Gold Coast beaches.

In a nutshell it wanted to bring forward two to three decades of beach protection work; with $15 million from the Gold Coast City Council and $15 million from the previous State Government. However, the state government never provided money to the plan.

Read the full story here | bit.ly/2kEHVGK
Gold Coast beach erosion plan: Is the plan on the right track?
brisbanetimes.com.au, published July 5, 2016.

Teacher information

THE AIM of the *Explore* section is for students to investigate some of the scientific theory behind coastal erosion. It is intended that students make their own discoveries as they work around the stations in the room; they should be encouraged to record their questions as they ask them. When they learn the theory in the *Explain* section about coastal erosion, they can refer back to these activities.

The table below lists the equipment and preparation required for each of the workstations. Stations can be completed in any order.

Station	Equipment
1 Coastlines on Google Earth Engine	You will need a computer with internet access to the following website: earthengine.google.com Note: you need to have a Google account and sign in to Google Earth Engine to use it in full. If students cannot do this on their own computers, we recommend you set up a computer at this station. The time-lapse section is accessible without signing in.
2 Comparing storm damage using coastal imaging from the UNSW Water Research Lab	You will need a computer with internet access to the following website: http://ci.wrl.unsw.edu.au/current-projects/narrabeen-collaroy-beach/image-archive/
3 Sea walls	You will need: • paper towel • one plastic tray • sand • water • flat Perspex wave maker • building blocks Prepare one or more model coastlines, each inside a plastic tray. Use sand to make a beach and water to represent the sea. A wave maker, such as a piece of Perspex, can be pushed back and forth to create water waves onto the sand. If one model is made, the sea wall must be removable so students can compare the effect of waves on the sand with and without the sea wall. Otherwise, it will be necessary to make two identical models, one with a sea wall and another without a sea wall.
4 Sand nourishment	You will need: • paper towel • one model coastline • sand • plastic metric ruler Prepare a model coastline inside a plastic tray using sand, water and a flat piece of Perspex that can be pushed back and forth to make waves onto the sand. Slope the sand against one inside edge of the plastic tray as steeply as possible without it collapsing. Use enough water so that the tidal mark is halfway up the slope.

Station	Equipment
5 Who should pay for the damage?	Images of various photos of coastal erosion – supplied.
6 What would you do	Image of a beach front house – supplied.
7 Our beaches and how we interact with them	You will need: data projector computer video or series of images of a local or iconic beach most likely to be known by the students

STATION ONE

COASTLINES ON GOOGLE EARTH ENGINE

1 Go to earthengine.google.com and scroll down to the time-lapse section.

2
Choose a beach near you, or one of your favourite beaches, and watch a time-lapse video of it. What are the changes you notice over time?

3 What kind of information could coastal management teams gain from using a tool like Google Earth Engine?

STATION TWO

COMPARING STORM DAMAGE USING COASTAL IMAGING FROM THE UNSW WATER RESEARCH LAB

1 Go to the UNSW Water Research Lab Narrabeen-Collaroy webpage and click on "2015".

2 Use the navigation tool at the bottom right to compare the Narabeen-Collaroy beaches at the beginning of April and the end of April. Note: not all days have images of the beaches, so you should select a range of days to compare. Use the images to make observations on the following:
a The condition of the beach and its surrounds before the storm.
b The condition of the beach and its surrounds after the storm.
c Evidence of storm damage.

3 Record all observations in the table below.

Storm date	Observations of beach and surrounds before the storm. Actual dates used:	Observations of beach and surrounds after the storm. Actual dates used:	Evidence of storm damage
April 2015			
June 2016			

4 Look at images taken in June 2016 to locate the date of the storm. Make the same observations pre-storm and post-storm as you did for the April 2015 storm. Record all your observations to complete the table above.

5 Which storm had the greatest impact? Use your recorded observational evidence to justify your response.

6 What might be some consequences of storm damage? Look at the storm photographs again. Think broadly across all aspects, for example societal, physical, geomorphic and economic factors, and include ideas about possible future impacts.

STATION THREE

SEA WALLS

1 Being careful not splash any water, use the wave maker to create gentle and even waves that break onto the model sandy beach.

2 Record the effect of the waves on the distribution and movement of the sand in Column A.

Observations of sand	A Effect of waves on model beach with no sea wall	B Effect of waves on model beach with sea wall in place	C Effect of waves on model beach with sea wall in a changed position
Distribution			
Movement			

3 Repeat steps 1 and 2 above, but use a sea wall between the generation of the waves and the model sandy beach.

4 What is the effect of the sea wall on the distribution and movement of the sand? Record your observations in Column B.

5 If you have a removable sea wall, set it up differently to steps 3 and 4 above.

6 Does the new position of the sea wall have a different effect on the distribution and movement of the sand? Record any new results in Column C.

7 Clean up any spilt water.

8 What is the general effect of the sea wall on coastal erosion in this model?

9 Identify one strength and one limitation of this model, to predict the effect of a real sea wall on a real coastline.

Strength	Limitation

10 What is the function of a sea wall and what is it supposed to do?

11 Sea walls can be costly so who should pay for them, and why?

Note to student | Please leave this station as you found it with the model(s) "restored" to "starting" position and any mess cleaned up.

STATION FOUR

SAND NOURISHMENT

1 Measure the width of the model beach from the inside edge of the container to the water edge and record your measurement here:

2 Measure the height of the sand from the bottom of the plastic container and record your measurement here:

3 Complete in pairs. Student 1 makes regular, gentle waves by pushing the Perspex back and forth in the water. Student 2 uses the extra sand to maintain the width and height of the beach.

4 What effect did the waves have on the width and height of the sand on the model beach?

5 Estimate how much extra sand (in litres) you needed to keep the beach replenished:

6 Where did you have to place the extra sand to best restore the beach width and height? Provide a sand replenishment strategy for your model coastline.

7 What is the general effect of sand nourishment on this model?

8 Identify one strength and one limitation of this model to predict the effect of sand nourishment on a real coastline.

Strength	Limitation

9 What is the function of a sand nourishment; what is it supposed to do?

10 Who should pay for a sand nourishment, and why?

Note to student | Please leave this station as you found it with the model(s) "restored" to its "starting" position and any mess cleaned up.

STATION FIVE

WHO SHOULD PAY?

Look at each photograph showing storm damage and decide who should be responsible for covering the cost of repair. If you decide it should be a combined responsibility (such as the local council and residents), state a percentage of responsibility each one should take.

EXAMPLES OF STORM DAMAGE

Damaged houses along Collaroy Beach in NSW after the June 2016 storm

Collaroy's Beach Club was heavily damaged in Australia's worst storms for 40 years. Extreme weather saw flooding, evacuations and property lost to the sea

STATION SIX

WHAT WOULD YOU DO?

1 Examine the following image.

Houses along Collaroy Beach, NSW

2 Would you like to buy one of these houses? Why, or why not?

3 If you did own one of these houses, what actions, if any would you take to protect it from natural forces?

STATION SEVEN

OUR BEACHES AND HOW WE INTERACT WITH THEM

Examine the images shown by the data projector.

1 List the many ways that humans interact with, and impact on, this section of coastline

2 How do you think the sand stays on the beach and doesn't wash away?

3 How might this coastline change in the future? Justify your answer using current evidence

Teacher's instructions

In this section, we explain the science of coastal erosion by getting students to read articles about storm damage, particularly erosion and the effects on infrastructure.
Before reading the articles, students can complete the Brainstorm Flowchart to elicit what they already know and ideas they may already have related to the science and management of coastal erosion.
For each of the three articles related to coastal erosion there are linked literacy activities. These are:

- Comprehension and summary – to help students engage directly with the content and ideas communicated
- Questioning toolkit – to probe the issues and science beyond
- Glossary of terms/reflection questions – to help bring the themes of all three articles together

ARTICLES

1 Part A: Sydney's Wild Weather [page 34]
This news article introduces us to coastal erosion through the challenging personal and social issues it instigates. The aim is for students to realise the importance of a sound scientific and geographical understanding of coastal erosion to make better informed decisions to reduce the impact of coastal erosion in the future.

Part A and Part B of Article 1 consider personal experiences of coastal erosion.

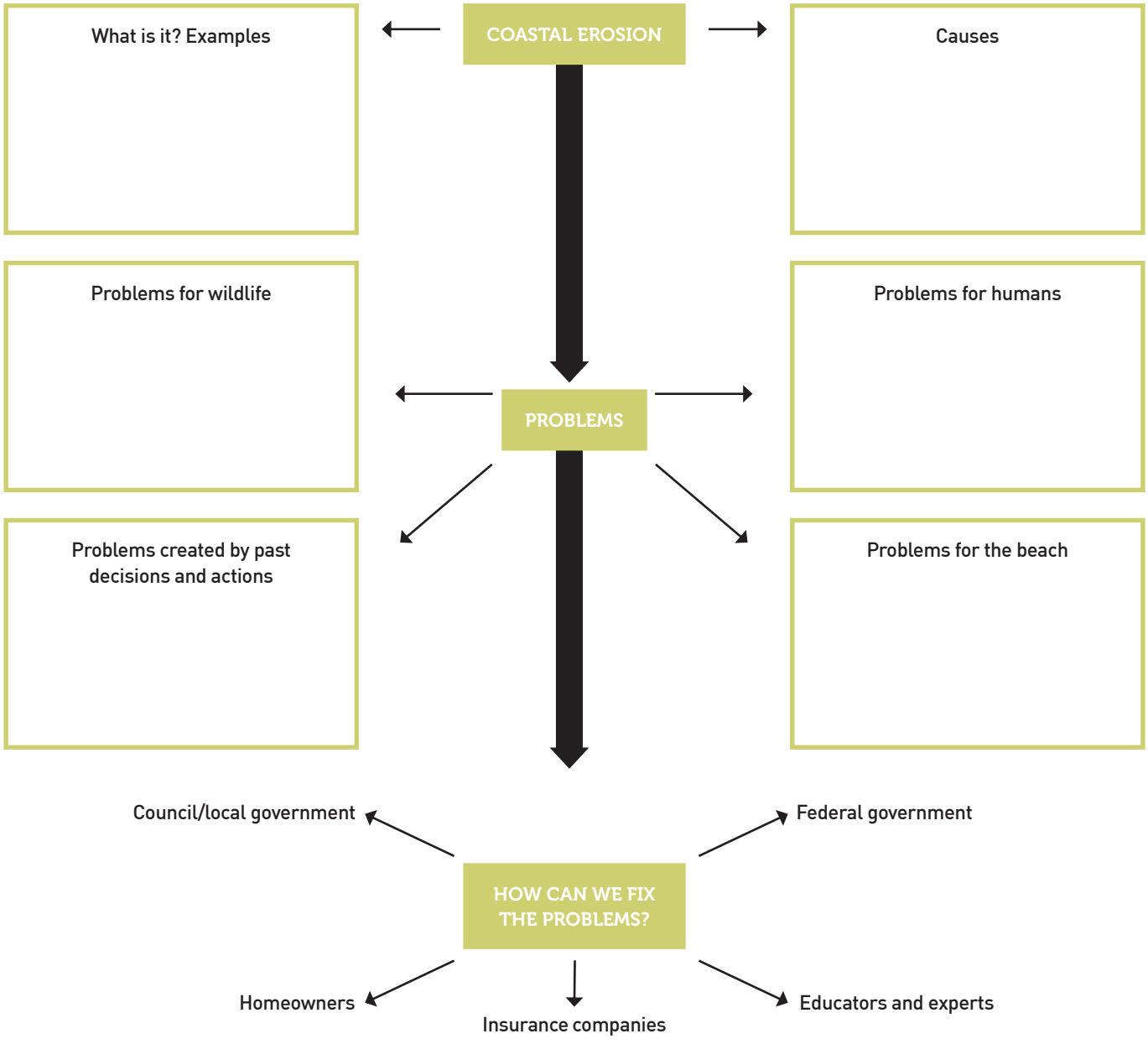
Part B: Kai'Mia – The Gymea Lily [page 36]
A D'harawal Dreaming Story called Kai'Mia The Gymea Lily – related by a D'harawal Elder named Frances Bodkin who heard it from her mother – describes the changes at Sydney's Botany Bay.

2 The Secret Life Of Coasts [page 40]
In this article, we discuss the influences of a range of factors that affect coastal erosion.

3 Coastal Erosion Management [page 45]
In this article, we discuss the various strategies and approaches to the integrated management of vulnerable coastal ecosystems.

Brainstorm Flowchart

What do you already know about coastal erosion? What ideas do you have about coastal erosion? Make notes, write questions and/or draw pictures in the boxes provided. Do this on your own before sharing your ideas with the rest of the class. If you wish, you can add more headings to the flowchart.



PART A:

Sydney's wild weather shows homeowners are increasingly at risk

Damage to homes after June 2016 storm in Collaroy, NSW

Eastern Australia's wild weather has left coastal homes teetering on the brink of collapse, and has eroded beaches by up to 50 m in parts of Sydney.

Now the attention turns to the clean-up. There are several legal issues for owners of damaged properties, particularly the question of if, and how, they can be compensated.

While the recent events cannot be attributed directly to climate change, they are certainly consistent with a warming world. Our institutions are ill-prepared for a potential increase in the frequency and severity of such events.

Time-lapse movie of extreme coastal erosion at Collaroy

INSURANCE

Unfortunately, the success of insurance claims for damaged homes in Sydney will depend entirely on the terms of their policies. Some policies don't cover erosion. Some only cover erosion if it occurs in a proximity to another insured event (for example, within 48 hours of a storm). What's more, while insurance will cover damage to buildings, policies do not cover damage to, or loss of, land. This is especially problematic in the case of damage caused by waves and storms.

LEGAL PROCEEDINGS

Another potential avenue for home owners to pursue is proceedings against local government for negligent approval of development. The success of this type of proceeding is highly speculative – much will hinge upon when the development was approved and how much information on the coastal hazards was available at that time. Where development was approved decades ago, it may be difficult to prove that a local government was negligent because of the limited state of knowledge at the time. In the case of more recent development approvals, there may be an argument that a local government had a high level of knowledge of the risk and control of risk information. These are the type of factors a court will look at in assessing negligence.

DISASTER ASSISTANCE

Where insurance is not available and there are no legal rights against government, landholders may request disaster relief or assistance from the government. Despite the lack of any legal compulsion to do so, Australian governments have a long history of providing disaster relief to citizens when an extreme weather event causes property damage. A recent Productivity Commission report estimated that, over the past decade, the federal government spent $8 billion on post-disaster relief and recovery. State governments spent a further $5.6 billion. However, the availability and amount of a payment are not guaranteed. This may depend upon the number of other claims for assistance, and any other demands on government resources.

WHAT SHOULD WE LEARN FROM THIS EVENT FOR THE FUTURE?

While the pictures of houses being lost to the sea are confronting, these images may become more commonplace. The most recent scientific report from the Intergovernmental Panel on Climate Change suggests that, a global sea-level rise in the range of 0.53–0.97 m by 2100 is likely. This will be especially problematic in Australia, with an estimated 711,000 residential addresses located within 3 km of the shore and less than 6 m above sea level – not to mention the billions of dollars' worth of government infrastructure also located in these regions. If these events continue to attract disaster relief, the financial burden will become too great for governments to bear. Furthermore, government disaster assistance does not solve the more intractable problem of land being lost to the sea. These pictures should therefore prompt a discussion about how we, as a society, can deal with the potential impacts of coastal hazards on existing developments.

The above text is extracted from an article published by The Conversation on June 7, 2016.
Read the full article here.

PART B:

Kai'Mia – The Gymea Lily

Botany Bay, Sydney NSW

The story of Kai'Mia describes how Botany Bay once consisted of swamps, and the river Kai'eemah (now known as the Georges River) and the Goolay'yari river (now Cooks River) joined together and flowed through one of these swamps and out through Kurunulla (Cronulla).

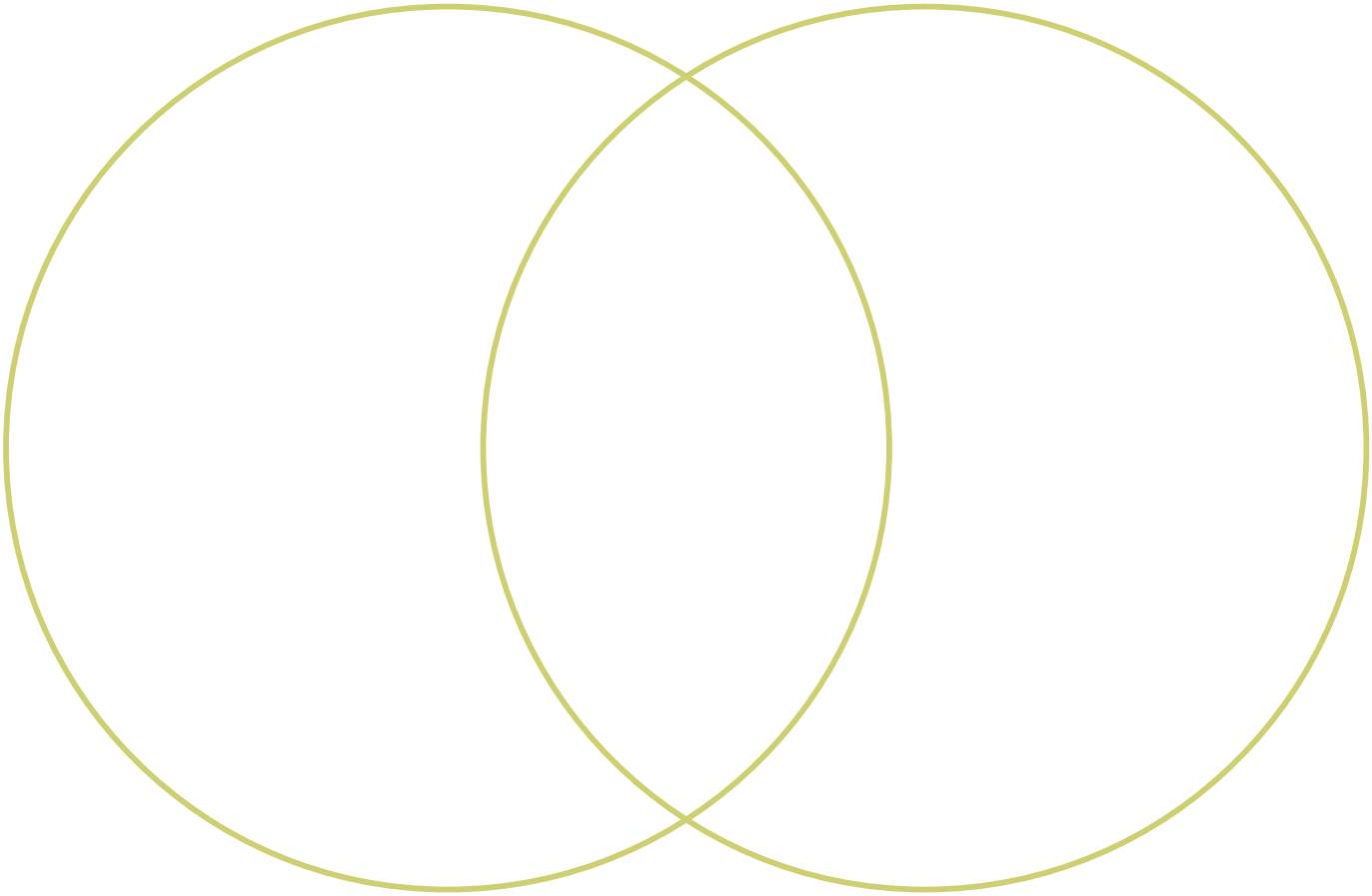
It goes on to say that "a great storm came up and huge waves washed into the Kai'eemah, destroying much of the swampland that they used for their food gathering. The waves crashed into the shore so fiercely that they washed over the land." The people fled inland to escape the flood; when they returned, the story says they found "that what they once known was no longer. Instead of the swamps, there was a great bay, and where the Kai'eemah had met the sea there was high mountains of sand. The two rivers now no longer joined together, but ran into the sea separately."

The coast is still changing today – sea levels are rising and storms are predicted to get stronger (both as a result of climate change), and beaches and dunes, particularly in built-up areas, are being eroded. A storm that struck Sydney on June 3, 2016, for example, is estimated to have stripped 65 million cubic metres of sand from beaches and dunes along NSW's 990 km of sandy coastline. While the sand will gradually return, this erosion can damage houses and other buildings on the coast or even cause them to collapse.

Activity 1
Comprehension and Summary

Summarise the information in Article 1 by responding to the following questions:

1 Using the Venn diagram below, write the differences in the stories (Part A and Part B) in the large parts of the circles and the similarities in the overlapping central part.



2 Do you think each article was written for the same reason? Suggest why each article was written.

3 For Part A:

a Why might people with damage to their property due to coastal erosion not be able to use their insurance to cover the cost of the damage?

b For residents who can't use their insurance to cover the cost of the damage, how else might they get financial compensation?

c How can the federal government assist home owners who have suffered storm damage to their homes?

d What type of information is considered in a legal case to help find who is financially responsible for damage caused by coastal erosion?

4 For Part B:
What can scientists learn from this Indigenous story that has been handed down throughout history and is a memory of the physical geography of the area?

Activity 2
Questioning Toolkit

Complete the Questioning Toolkit below.

Write your ideas and opinions relating to each of the different types of questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Questions** What did people do in the past (without insurance) when storms damaged their property? Why is coastal erosion difficult to insure against? What processes or activities other than storms cause property erosion?	
Subsidiary questions These questions help us to manage our information by finding the most relevant details. **Questions** What is the International Panel on Climate Change, and what does it do? What research should be conducted to help us learn about coastal erosion? How can predicting storms help us?	
Hypothetical questions Questions designed to explore the possibilities – the what-ifs. They are useful when we want to test our hunches. **Questions** If you were an expert on coastal erosion, what advice would you give to homeowners thinking of buying a property on the forefront of a beach? What advice would you give to local council representatives? What if insurance was no longer an option? What are the options against storm damage?	
Provocative questions Questions to challenge convention. **Questions** Do you think it is fair that many insurance companies don't insure against erosion? Who do you think should pay for the sorts of damage shown in the photos? Would you buy a house on the coast, and why or why not? Should it be national policy to incorporate Indigenous knowledge of areas into urban planning?	

The secret life of coasts

Coastlines are dynamic, complex systems that are made up of different habitats, such as beaches, cliffs, dunes, estuaries, headlands, lagoons and rock platforms. They have evolved over millions of years and are subject to natural processes, such as waves, ocean currents and sea levels, which cause them to constantly change.

Some of the changes take hundreds or even thousands of years. For example, 20,000 years ago, sea levels were 120 m lower than they are today, with islands like Rottnest Island in WA joined to the mainland. Other changes can happen over a few days or even hours, when storms and the powerful waves they create erode coastlines and move large amounts of sediments offshore.

This can also cause buildings next to the coast to be damaged or destroyed by the waves.

WHAT CAUSES COASTAL EROSION?

Coastal erosion is a natural process that takes place when waves wash sand, other sediments and rocks away from the shoreline. This often happens during storms, as the stronger waves generated during rough weather conditions can wash away large amounts of sediments, causing beaches and dunes to erode.

WHY DO SOME STORMS CAUSE MORE EROSION THAN OTHERS?

The storm that hit Sydney on June 3, 2016, was an East Coast Low (ECL), which is a weather system that can form off Australia's eastern coast at any time of the year, and can cause extensive damage to coastal areas. ECLs are areas of low pressure that cause air to swirl around their centre. When located over water, these weather systems can draw up large amounts of moisture, creating heavy rainfall. Strong winds on the water surface can also cause large waves.

One of the most important factors determining the amount of coastal erosion caused by storms like ECLs is the height of the waves generated. Larger waves contain more energy to wash away sediments and undermine dunes and any coastal developments located too close to shore. Smaller waves, meanwhile, do not contain as much energy and generally move less amounts of sediment.

WHAT ROLE DO TIDES HAVE ON COASTAL EROSION?

ECLs can also cause storm surges, which are an increase in the sea level caused by the strong winds and/or the lower air pressure. When combined with tides, storm surges affect how much erosion and other damage waves cause on the coast. If a storm surge takes place during a high tide, the damage can be much greater because the waves can travel higher and further and reach areas that would have been safe during a low tide.

The storm that hit Sydney on June 3, 2016, arrived at the same time as a king tide – a higher than average tide that happens a few times a year as a natural part of the tidal cycle – and waves up to 12 m in height were reported along the coast, smashing against cliffs that had previously been thought to be unreachable.

WHAT EFFECT IS CLIMATE CHANGE AND A RISING SEA LEVEL HAVING ON COASTAL EROSION?

After the end of the last ice age, temperatures warmed and sea levels began to rise, reaching somewhere close to their present levels about 8000 years ago. They remained relatively stable, with few variations over thousands of years; however, global temperatures have begun to rise, increasing by about 0.8°C between 1850–2012.This rate of warming sped up in the mid-1970s and climate change projections are indicating a much warmer future. By 2090, Australia could warm by as much as 2.8°C to 5.1°C above the climate of 1986–2005.

These warmer conditions will have a significant impact on coasts as sea levels rise and weather cycles potentially alter. Observations show that sea levels have already risen about 20 cm since the mid-19th century and could continue to increase in the range of approximately 30 cm and 1 m by 2100 (from 2000 levels).

Scientists are also studying what effect a warmer, moister atmosphere will have on Earth's climate – some predictions indicate that while there will be fewer storms in future, the more severe storms will become stronger and produce heavier rainfall, increasing the risk of erosion and flooding during these events. "There are many reports indicating that storm intensity will change, but it's currently too difficult to say with a lot of certainty how they will alter because of climate change," says UNSW Senior Research Associate Dr Mitchell Harley.

Harley says that rising sea levels combined with changing storm patterns will mean that coastal managers will need to think extra carefully about the most appropriate combination of solutions to managing our sandy coastlines. "At some locations, options such as beach nourishment (placing millions of cubic metres of sand on the beach) and the construction of sea walls are likely to be necessary to prevent our beaches from disappearing over time and houses from being undermined."

He adds that without this natural sand buffer or hard structures to protect us from storm waves, the impacts of coastal storms are likely to be much more severe in the future. Another impact of higher sea levels is that waves from future storms will be able to travel further inland, increasing the risk of damage and erosion.

FUTURE PROJECTIONS

"In order to understand how our coasts are changing into the future we need to first have a good understanding of how they are changing now," says Harley. He and the other coastal engineers from the UNSW Water Research Laboratory monitor sites such as Narrabeen, one of only a few sites worldwide that has more than 40 years of coastal change measurements. These measurements allow researchers to observe the cycles of erosion from major storm events and beach recovery over the short term, and look at changes that take place over longer periods of time due to other climate processes such as the El Niño Southern Oscillation.

"As sea levels continue to rise into the future, the Narrabeen dataset will be one of the best records to document these impacts and provide crucial information as to how we can adapt to such changes," explains Harley.

Dr Mitchell Harley

Drone captures footage of Collaroy destruction

After the June 3, 2016, storm battered Sydney, the UNSW Water Research Laboratory's coastal monitoring team used a drone to capture footage of the extensive coastal erosion and damage to waterfront properties at Collaroy from the huge waves and the king tide.

Drone captures footage of North Head collapse

Coastal erosion can also lead to parts of cliffs, headlands and other coastal rock formations collapsing, such as a section of North Head near Manly in August 2016. UNSW Water Research Laboratory's coastal monitoring team captured footage of the damage with a drone.

Activity 1
Comprehension and Summary

Summarise the information in Article 1 by responding to the following questions:

1 Name seven types of habitat that can exist along a coastline.

2 What is coastal erosion and when is it most likely to happen?

3 What are some short-term (days or hours) changes that can take place along a coast?

4 What are some long-term (years or decades) changes that can take place along a coastline?

5 Complete the following table to summarise how each phenomena affects coastal erosion

	Effect on coastal erosion
Tides	
Rising seas level	
Waves	

Activity 2
Questioning Toolkit

Complete the Questioning Toolkit below.

Write your ideas and opinions relating to each of the different types of questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Questions** What are the main factors leading to coastal erosion?	
Subsidiary questions These questions help us to manage our information by finding the most relevant details. **Questions** Are drones more useful than helicopters for monitoring the coastline?	
Hypothetical questions Questions designed to explore the possibilities – the what-ifs. They are useful when we want to test our hunches. **Questions** If there weren't so many people living on the coast, would we still be concerned about coastal erosion?	
Provocative questions Questions to challenge convention. **Questions** If we know that coastal areas are unstable due to possible storm damage, why do we keep building on the coast?	

Coastal Erosion Management

Coastal communities and local councils today face difficult issues associated with the management of coastal erosion around Australia. This is not new: records from the early 1900s show coastal properties being affected by erosion. Many coastal areas experience recurring shoreline erosion problems due to natural coastal processes and the dynamic nature of coastlines, while severe weather such as cyclones and big storms can acutely damage the coasts.

Managing these dynamic and changing coasts often requires adaptation, which involves balancing the perspectives of many different groups to achieve the most appropriate management strategy. For more information about coastal adaptation, visit Coast Adapt.

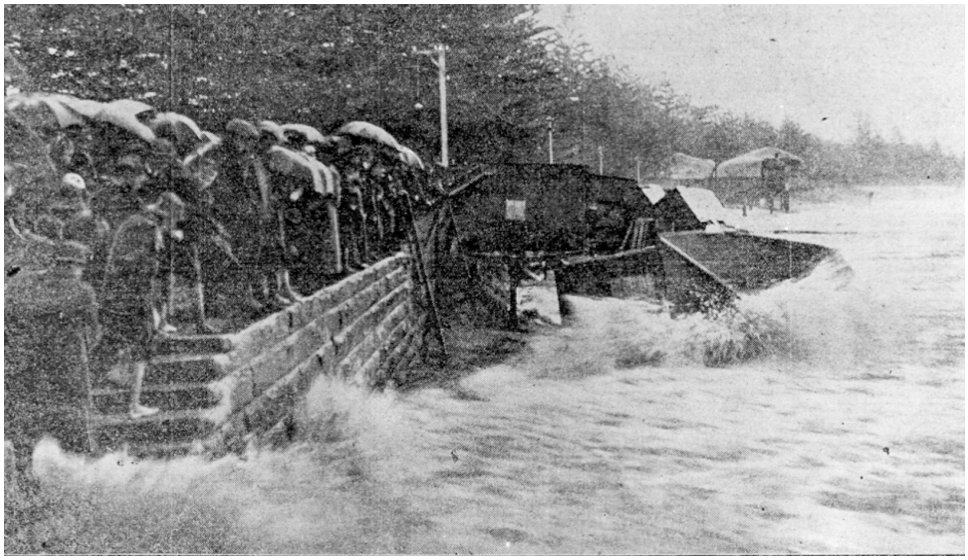
WHO IS RESPONSIBLE?

Coastal communities today need a modern, integrated framework that takes into account all relevant environmental, social and economic coastal values, and works towards a long-term solution where strategies are site-specific in relation to the scientific understanding of the area being managed. For example, management strategies will vary depending on whether the coastal area is a tourist hotspot, a residential area or a national park.

Most state governments have a framework for managing coastal erosion. It involves local councils, with financial and technical support from the state, undertaking coastal hazard studies and developing management plans that inform land-use planning, development controls and coastal activities. These plans contain management strategies to inform communities about how coastal erosion will be dealt with.

EXAMPLES OF HISTORIC SEA WALLS

First stone breakwater, Coffs Harbour, 1914



Elevated tide and sea wall, Manly, 1913

MANAGING COASTAL EROSION AT THE COMMUNITY LEVEL

Local councils can carry out activities to reduce the impacts of coastal erosion on property and infrastructure. These may include dune restoration and beach nourishment, and constructing protection, such as sea walls and groynes (structures built across a beach). Activities could also include dredging, sand bypass pumping and the extension of sea walls. Beachfront property owners in coastal erosion-prone areas can place sand or sandbags on the beach to halt the advancing ocean to reduce the impact of coastal erosion on their property during small storm events. However, they need to abide by strict conditions.

EXAMPLES OF WHAT IS BEING DONE

The Tweed River Entrance Sand Bypass Project is an example of what is being done to adapt to and reduce the effects of coastal erosion. It is a joint initiative of the Queensland and NSW governments to maintain a navigable entrance to the Tweed River and supply of sand to southern Gold Coast beaches. Management strategies include dredging and sand bypassing. A video detailing the methods use can be viewed at the following here.

For more information on the Tweed River Entrance Sand Bypassing Project, visit:
www.qld.gov.au/environment/coasts-waterways/beach/restoration/tweed-river/

Activity 1
Comprehension and Summary

Summarise the information in Article 3 by responding to the following questions:

1 What is integrated management?

2 Who is involved in the integrated management of coastal erosion?

3 What is the aim of integrated coastal erosion management?

4 Identify and classify the different types of coastal erosion management interventions mentioned in the article into the following table. A few have been done for you.

Type of engineering	Definition	Examples
Hard engineering	Rigid coastal structures to prevent erosion landward of a fixed line	**1** Sea walls **2** Artificial reefs
Soft engineering	Actions that work with nature to maintain or enhance natural coastal protection	Beach nourishment, dune management

5 Identify the types of information and knowledge that is used to make decisions about how to manage a coastline.

Activity 2
Questioning Toolkit

Complete the Questioning Toolkit below.

Write your ideas and opinions relating to each of the different types of questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Questions** What are the advantages and disadvantages of a specific type of coastal management technique?	
Subsidiary questions These questions help us to manage our information by finding the most relevant details. **Questions** Which management techniques work well in combinations?	
Hypothetical questions Questions designed to explore the possibilities – the what-ifs. They are useful when we want to test our hunches. **Questions** If you were head of the integrated coastal management team at your local beach, what would you recommend be done to avoid erosion?	
Provocative questions Questions to challenge convention. **Questions** Are the erosion management techniques at your local beach (or a beach you have been to recently) effective?	

Bringing it all together

1 Complete this glossary of terms as you read the different articles.

	Word	Definition
Article 1	Erosion	
	Climate change	
Article 2	Estuary	
	Sediment	
	Coastal erosion	
	ECL	
	Weather system	
	Air pressure	
	Storm surge	
	King tide	
	Tidal cycle	
	Ice age	
	Greenhouse gas emissions	
	El Niño	
	Southern oscillation	
	Dataset	
Article 3	Integrated framework	
	Tide marks	
	Indigenous knowledge	
	Digital terrain models	
	Dune restoration	
	Sand nourishment	
	Groynes	
	Dredging	

2 When it comes to coastal management, do you think it is ever possible to find the right balance between what beach users want and the impact of nature? Discuss your ideas.

3 After reading the articles, go back to the brainstorm flowchart on page 33 and use a different coloured pen to add in your new knowledge. What have you learned?

Teacher's notes

What do the row headings mean?

First-hand investigations	Hands-on activities that follow scientific method. Includes experiments and surveys. Great for kinaesthetic and logical learners, as well as budding scientists.
Maker space activities	Hands-on building, troubleshooting and reviewing a design of their own.
Ethical thinking	Students learn to recognise and explore ethical concepts. They examine reasons supporting ethical decisions, consider consequences of ethical decisions and reflect on ethical actions. Students examine values, rights, responsibilities and points of view.
ICT	Students use searches to locate, access and generate digital data and information. Students generate ideas, plans and processes, and communicate these via ICT. They select and use software, manage data, understand social and ethical protocols, and understand the impacts of ICT.
Personal and social capabilities	Students recognise emotions, personal qualities and achievements in themselves and diverse perspectives and relationships with and between others. They learn self-management through working independently and learning how to express emotions appropriately. Students work collaboratively, make decisions, negotiate, resolve conflict and develop leadership skills.
Creative and critical thinking	Models the inquiry process. Students question, identify, clarify, organise and process information. They generate ideas, possibilities and actions, connect ideas, consider alternatives and seek solutions. Students also reflect on thinking (metacognition) and processes, apply logic and reasoning, draw conclusions and evaluate procedures. Knowledge is transferred into new contexts.
Time travel	Here students consider scientific and technological development as a linear process by travelling back in time or creatively into the future.

	Coastal Erosion Learning Matrix	
	Developing	**Extending**
First hand investigations	Practical activity to look at the use of vegetation cover to reduce erosion of sand dunes. See Linked Activity 1 on page 54. www.griffith.edu.au/engineering-information-technology/griffith-centre-coastal-management/community-projects/beachcare	Use a local beach to investigate and collect original data related to sea level (use an existing sea wall or a post as a measuring stick) or sand movement. Use photos to document your findings and write them up in a full scientific report. Summarise your results and post them on social media.
Maker space activities	Build a model of a coastline that explains one or more causes of erosion or the management of erosion. Use the information in the articles, images and your own research for ideas.	Research the Tweed River Entrance Sand Bypass Project and then design your own sand pumping system. You can model the one at Tweed River or design one of your own, but it must move sand from one place to another. Create drawings of your proposed model before you begin, and comment on the troubleshooting as you go, e.g. what difficulties did you have and how did you overcome them? The following links will be helpful: www.youtube.com/watch?v=18Q8RLiLZEw www.qld.gov.au/environment/coasts-waterways/beach/restoration/tweed-river/
Ethical thinking	There are many different coastal erosion management projects taking place around Australia and although they can learn from each other, each needs its own management plan unique to that area. The development of a plan starts with asking good questions to help probe relevant issues and opinions. The plan needs to consider a range of positive and negative impacts. Choose a coastal erosion media article and investigate it by developing a series of questions and examining the positive and negative impacts. See Linked Activity 2 on page 58.	Not everyone has the same ideas about the management of coastal erosion, and this can create tensions that also require management. Prepare a role-play that demonstrates a variety of opinions around a specific coastal erosion management plan including: **1** An Indigenous perspective. **2** A local government perspective (include interview with local government personnel). **3** At least two different perspectives of residents (e.g. a ratepayer beachfront owner versus a ratepayer who is not beachfront owner). Your script should compare and contrast different viewpoints and touch on some of the political issues surrounding coastal management.
ICT	Use a map app (see examples below), or any other app you wish, to measure the distance or shape of a sea wall at a local beach. **iMapIt** www.youtube.com/watch?v=0nBPq9E30bM **Google Earth Pro** www.youtube.com/watch?v=C1bU6hap-Gc	Go to the Australian shorelines interactive map from the CoastAdapt website and explore its features (see link below). Write a classroom activity where students collect information using the following interactive features: (1) both base map types and (2) at least two Layers (e.g. the Smartline basic interactive and the Sediment Compartments). Swap your activity with a partner to see how user-friendly and educational it is for coastal management. coastadapt.com.au/coastadapt-interactive-map

	Coastal Erosion Learning Matrix	
	Developing	**Extending**
Personal and social capabilities	Find out about volunteering at your local beach. Many beaches have days for clean-up, sand dune restoration or tree planting. It's a great way to learn about your local beach environment. Report your experiences back to the class. Visit the following website for ideas: www.griffith.edu.au/engineering-information-technology/griffith-centre-coastal-management/community-projects/beachcare	Research at least two case studies of Indigenous knowledge about specific coastal areas and then use this information to propose ways in which Indigenous knowledge can be integrated with Western knowledge to improve the management of specific examples of coastal erosion. The following links will be helpful: www.topendcoasts.org.au/saltwater_country www.ozcoasts.gov.au/pdf/CRC/24-indigenous_coastal_management.pdf www.tandfonline.com/doi/full/10.1080/00049182.2015.1077539
Creative and critical thinking	Write a conversation between the Earth, the Sun and the Moon where they discuss their influence on Earth's tides. Who has the greater influence? How do they work together to create tides? The dialogue should be engaging. Make sure it is scientifically correct by conducting some thorough research beforehand. Include a full explanation on the definition and causes of neap and king tides.	One complaint by residents about sea walls is that they are ugly and ruin the look of the beach. Design a wave buffering sea wall, or a series of sea walls, that mixes art and science to create something that will be both functional and effective at preventing erosion, as well as something people may consider a tourist attraction and come from miles around to interact with or simply enjoy looking at. Be as imaginative as you like, but don't forget the engineering!
Time travel	Ask a grandparent about a local or family holiday beach that is familiar to you both. How is the beach different today compared to when your grandparent was your age? Do they have any photographs to compare then and now? Present what you have learned to the rest of the class. Predict any further changes your grandchildren may witness.	Prepare a timeline of a case study of coastal erosion management. Explain the area and its uses and issues before outlining the history of management. Include images to make your timeline visually appealing. Use your local beach or the following video to gather the relevant information: www.youtube.com/watch?v=18Q8RLiLZEw

Linked Activity 1

THE EFFECT OF VEGETATION ON EROSION

In this investigation, you will prepare samples of ground cover with different amounts of vegetation then test them for their resistance to erosion.

Aim

To find out whether the amount of ground cover affects sand erosion.

Materials

- Grass seeds
- 3 shallow trays (or plastic containers)
- Sticky labels and pencil for labelling
- 1 drinking straw
- Sandy soil (all from the same source)
- Water
- 1 block of wood
- Beakers to measure 50 ml and 100 ml of water
- 1 metre ruler

Risk Analysis:

Complete the following risk analysis table before you conduct this experiment.

Risk	Hazard	Precaution
Slipping on water spilt on the floor		

Method

1 Place identical amounts of the sandy soil from the same source into each of the three shallow trays.
2 Leave one tray with nothing planted in it. Label this tray "Sample A".
3 Plant a thin cover of seeds in the second tray, so that the seeds are spaced apart from each other. Label this tray "Thin cover".
4 Plant a thick cover of seeds, where the seeds are very close to each other, in the third tray. Label this tray "Thick cover".
5 Place the trays together in the sun, and water the samples each day for a few weeks, until the grass has grown a few centimetres.
6 Allow the samples to dry out a little so the top layer of sandy soil is dry, but the grass is in no danger of drying out.
7 Once the samples are ready for testing, take a drinking straw and blow air as hard as you can over the surface of each sample. This is Test 1, and represents the wind blowing over the sand dunes. In the data table below, record whether the top of the sandy soil is disrupted – i.e. eroded – in any of the samples by the force of the moving air.
8 Clean up any sand that may have blown out of the shallow containers.
9 Place the shallow trays on the floor.
10 Drip 50 ml of water on the sandy soil and grass in each tray from a height of 1 m. This is Test 2 and represents the effect of rain.
11 Observe any disruption to the surface soil. Is any soil eroded away? Are imprints of the water drops left in the samples? Record all observations in the data table provided.
12 Clean up any splashed water or sand from the floor.
13 Tilt the shallow trays 30–40 degrees by resting one edge on a block of wood.
14 Pour 100 ml water into the shallow tray from the highest end of the sample, so that it runs down to the lowest end of the sample. Pour the water at the same rate and the same height for all three samples. This is Test 3 and represents water running off the area (e.g. a flood or waves).
15 Was any sandy soil moved from the high end to the low end of the sample? Record your observations in the data table below.
16 Clean up any mess made by the water.

Results

Results table: Observations made on various weather simulation tests made on soil with varying amounts of vegetation growing in it.

Sample	TEST 1 Effect of wind (blowing in sample)	TEST 2 Effect of rain (falling on sample)	TEST 3 Effect of runoff (sample on a slope)
Sandy soil only			
Sandy soil with thin cover of grass			
Sandy soil with thick cover of grass			

Discussion

1 Use your observations (collected in the above data table) to identify which sample had the greatest amount of sandy soil and/or grass disrupted under the various test conditions. Suggest why this was the case.

2 Use your observations (collected in the above data table) to identify which sample had the least disruption of sandy soil and grass under the various test conditions. Suggest why this was the case.

3 Suggest whether your findings support the planting of vegetation to help prevent erosion of sand dunes.

4 Identify at least one limitation and one strength of this investigation as a model of what might happen at a beach where vegetation is present or not.

5 Look at the community engagement initiative BeachCare – facilitated by the Griffith Centre for Coastal Management in partnership with the City of Gold Coast – and summarise some of the activities volunteers are undertaking in the area.

Conclusion

Write a conclusion to summarise your results and respond to your aim.

Linked Activity 2

COASTAL EROSIONS IN THE MEDIA

What to do

- Find an interesting coastal erosion media article that has been published in the media.
- Read the article carefully so that you have a solid grasp of its contents.
- Complete the following questions in relation to your article.
- Present your article and discussion questions (see Question 8 below) to the class.

Things to think about

1 What is the title of your chosen article?
2 Who wrote the article, and where and on what date was it published?
3 Why did you choose the article?
4 Write a brief summary of the article.
5 What did you learn from reading the article?
6 List a range of positive impacts raised in the article. Think broadly by including social, political, future and environmental impacts.
7 List a range of negative impacts raised in the article.
8 What questions do you think would have needed to be asked before and during the initiation of coastal erosion management in this area?
9 Suggest two questions that could be raised in relation to current and future management that could be used to promote discussion.
10 Present a summary of the article and questions to the rest of the class.
11 Identify anything new you learned or new questions that were raised during the class discussion.
12 Suggest how group discussion and asking questions can help create new knowledge or ideas.

Letter for the Minister for the Environment

Dear Sir or Madam,

Please find below a copy of the letter prepared for the Minister for the Environment from Sandybeach Council members.

Proposal to build a barrier wall at Sandybeach

To: The Honourable Marian Norfolk
Minister for the Environment

May 27, 2017

Dear Ms Norfolk,

We are writing to you to request a barrier wall be constructed along the foreshore of Sandybeach between the pedestrian path and the actual beach itself. After witnessing recent photos and video footage of devastating storm damage at multiple locations around Australia, we feel we need to act to prevent similar damage to our local infrastructure as well as help preserve the natural environment, both for the continued recreational enjoyment of beachgoers as well as for the wildlife that lives there.

Our proposal is to build a sea wall at the edge of Sandybeach running from its most northern point at Sandybeach School, past the post office and delicatessen and children's playground, and ending at the last of the five private residences on the southern side of the beach.

With your approval, the construction of the 1.5m-high, 30cm-thick and 3km-long concrete wall can commence immediately.

Yours sincerely,
Sandybeach Council

CC: Principal Bligh
Sandybeach School
Sandybeach Rd
Sandybeach

CONFIDENTIAL

Disclaimer: This is letter has been sent to all participants and stakeholders that have already sent an RSVP to attend the next council meeting held at 5.30pm on June 7. Please note the venue of the meeting will be in the staff room of Sandybeach school. This letter, in whole or part, is not to be copied or given in any format to any persons other than those named within this letter.

WHAT TO DO

As well as being sent to your principal, a copy of the above document was found crunched up in a waste paper bin close to the offices of the Minister for the Environment. What does this document mean for the residents, business owners, school community and users of Sandybeach? Your principal knows you have been studying coastal erosion and would like a full report to help inform him of all issues in preparation for the next council meeting to be held on June 7.

The class will be divided up into groups of stakeholders, including:

1 Local council member
2 State government official
3 Home owner with a seafront home
4 Environmentalist
5 Engineer
6 Concerned school parent
7 Volunteer coastguard

Each stakeholder group must present their view on the proposed sea wall for Sandybeach and the surrounding suburbs. You must decide if your group is for or against the proposed development.

AS A GROUP, YOU MUST:

1 Complete some general research and answer the stakeholder focus questions below to gather information into the effectiveness of sea walls to prevent coastal erosion. If possible, add some of your own focus questions to research and include in your presentation. Summarise your findings in an Annotated Bibliography (template provided on page 62) and Research Table (template provided on page 63).
2 Verbally communicate the viewpoint of your group on coastal erosion and sea walls in a talk no longer than 3–4 minutes. You will need to construct a PowerPoint or Prezi presentation to complement your talk with visuals. Include the background information found in your research to help introduce your group's position.
3 Supplement your presentation with any of the other products below.

Which product would you like to use to present your learning?	Tick (√) your choice
Advertisement	
Brochure	
Cartoon strip	
Computer program	
Magazine	
Play	
Report	
Story	
TV documentary	
Webpage	

4 Be dressed appropriately and in character.
5 Be passionate about your stakeholders' views.

INDIVIDUALLY, YOU MUST:

6 Complete a reflection (see questions on page 64).

STAKEHOLDER FOCUS QUESTIONS:

1 Local council member – Why do we need a wall? What is the history of coastal damage? How do locals use the beach?
2 State government official – How much is the wall going to cost? When will building commence and finish? How long will the wall take to build? Will there be an impact on beach use during the building of the wall?
3 Home owner with a seafront home – Will the wall devalue my property? Will the wall block my view of the beach? Will the wall protect my property?
4 Environmentalist – Will the wildlife that lives on and around the beach be affected during building? How can habitats be protected? Will we lose plants and trees?
5 Engineer – How strong will the wall have to be? Are the dimensions mentioned in the letter suitable? What material will be used? If the wall doesn't work, will our reputation be at stake?
6 Concerned school parent – Will we still be able to use the beach after school and have easy access to the beach? Will I be able to see my children playing on the beach while I grab a coffee from the deli? Will I still be able to park at the beach?
7 Volunteer coastguard – Will we have to move our viewing station? Will we still be able to get vehicles and large equipment such as boats onto the beach easily? Will we be able to access the deli to buy our lunch?

REMEMBER!

- You will need to decide how you will communicate your group's point of view to the other stakeholders.
- The presentations need to be engaging and should be used to convince the other class members that they need to support your side of the argument either for or against the sea wall at Sandybeach.
- Your teacher will let you know the date and time of the presentations.
- The presentations will be marked using the rubric marking scheme attached.
- Be "in character" and be passionate about your point of view.

Annotated bibliography

Question/Answer	Source	Annotation (Summary of the information on the website. Is it reliable? Would you recommend it to others?)
Q: How do you construct an annotated bibliography? **A:** Each reference is followed by an explanation containing a brief descriptive summary of its contents.	**SAMPLE ANNOTATED BIBLIOGRAPHY** – Olin and Uris Libraries. (2016). How to Prepare an Annotated Bibliography. Ithaca, New York: Cornell University Library. Available from www.library.cornell.edu/olinuris/ref/research/skill28.htm [Accessed on August 30, 2017].	A good explanation of the process involved and the difference between annotations and abstracts, but not as much helpful information about what to include as the Williams website. Samples are aimed much more at the university level.
1		
2		
3		

Research table

Complete more research surrounding the specific issues that concern your stakeholder group. Use the questions provided to help you. Complete the table below showing the resources you used. If you come up with additional questions, you can add them to the table.

Research question	Source	Annotation (summary)

Project reflection

1 Project description – Give a short summary on the views of your stakeholders about the proposed sea wall.

2 What are the main issues your group are exploring and addressing in your project?

3 What is your opinion about the feasibility of a sea wall at Sandybeach? Do you think it should go ahead?

EVALUATE

4 Which group's argument was the most convincing and why?

5 In your opinion, what were the most successful elements of your presentation and why? What part of the project worked best and why? What was the most effective thing you did in the project? What did you enjoy the most about this project?

6 What other environmental or social problems, either locally or globally, do you think might be related to the issues you researched? Think hard about this one. Try to imagine how other problems may be connected to your issue. What things couldn't you do anything about? What are the bigger issues related to this project?

7 Why do you think this issue is important to Australian society?

Evaluation of group members' contribution

Use this form to assess yourself and other members of the group regarding behaviour and contributions towards the team's goals. Do this seriously. Whatever you record will be kept confidential. Give each team member a grade, to the scale below, and record the grades for each skill listed in the table.

GRADES

0 = Never | 1 = Hardly ever | 2 = Sometimes | 3 = Often

Skill	Your name	Other group member names
Discussed and negotiated the allocation of roles		
Encouraged others		
Carried out their allocated role in the group		
Helped others		
Willing to receive help from others within the group		
Willing to listen to others in the group		
All contributed equally		
Accepted the responsibility for completing the work properly		
TOTAL		