Living with a Changing Coast: Advanced Level learning and teaching programme

The Exe Estuary
Model Research Investigation in Geography
By David Weatherly

Research question: How is the Exe Estuary coastal environment being managed sustainably?

Hypothesis: Non-intervention in natural processes represents the most sustainable management option for the Exe Estuary
Living with a Changing Coast: Advanced Level learning and teaching programme

The Exe Estuary
Model Research Investigation in Geography

By David Weatherly

David Weatherly is a School Improvement Adviser and Curriculum Consultant 3 - 19
Design and illustration by Mike Hughes - www.mikehugheswildlifeart.co.uk
Funded by the Living with a Changing Coast Project www.licco.eu
Contents

About this Resource ................................................................. Page 4

The Exe Estuary ................................................................. Page 9

Model Research Investigation in Geography ................................ Page 9

Line of Enquiry 1: Evaluating the approach taken to researching the Exe Estuary ............................................ Page 15

Line of Enquiry 2: Evaluating the value of the Exe Estuary as a coastal resource ............................................. Page 21

Line of Enquiry 3: Understanding the impact of physical processes and human activity on the coast ....................... Page 26

Line of Enquiry 4: Understanding the 21st century coastal management challenges in and around the Exe Estuary .......... Page 37

Line of Enquiry 5: How should authorities most appropriately manage the risk of flooding and coastal erosion in and around the Exe Estuary? ................................................................. Page 45

Line of Enquiry 6: Understanding the rationale behind different coastal management strategies across the Exe Estuary ........................................................................................................... Page 52

Line of Enquiry 7: Understanding the challenge of managing ‘coastal squeeze’ in and around the Exe Estuary ................. Page 61

Line of Enquiry 8: Bringing it all together – writing up your research investigation ....................................................... Page 68
About this resource

Background

The development and delivery of this education programme has been funded by the Living with a Changing Coast (LiCCo) project. This cross-channel project is part-financed by the Interreg IVA France (Channel) – England programme and is led by the Environment Agency (South West Region). The project started in April 2011 and will end in February 2015. It focuses on the Exe Estuary and Poole Harbour in the South West of England and a further five coastal sites in Normandy, France.

The mission of LiCCo is to help coastal communities to adapt to coastal change and climate change impacts, such as sea level rise and erosion, through:

- Engaging with target audiences in the coastal study sites and supporting their involvement in decision making processes on coastal management;
- Raising awareness of the environmental, social and economic impacts of climate change on coastal communities;
- Considering the challenges and opportunities of climate change in coastal areas and understanding what can be done to prepare and adapt to these.

The UK partners in the project are:

- Environment Agency (lead partner)
- National Trust
- Exe Estuary Management Partnership (hosted by Devon County Council)
- Dorset Coast Forum (hosted by Dorset County Council)

Additional information is available on the project website: www.licco.eu
Aims of the LiCCo education programme

The purpose of the education dimension of the LiCCo project has been to:

- Provide site based educational activities at the Exe Estuary in Devon and Poole Harbour sites in Dorset to teach local children and young people about the ecology, use, management and natural processes affecting their local coast;
- Develop web based information which is specific to the local coastline and freely available;
- Develop an educational package for schools and other audiences with an interest in coastline management, enabling them to explore and better understand coastal ecology; climate change, coastal management issues; the associated conflicts, risks and costs and the options to adapt to future coastal change.

In the summer of 2014 a primary Key Stage 2 and a secondary Key Stage 3-4 LiCCo learning and teaching programme were completed and both have subsequently been introduced to hundreds of teachers across the UK as part of ongoing INSET events. The detailed schemes of work of both the primary and secondary programmes are available to download at http://www.licco.eu/resource/licco-primary-school-learning-pack/ and http://www.licco.eu/resource/licco-secondary-school-learning-pack/ and a DVD containing the learning and teaching resources can be obtained free of charge by contacting exeestua@devon.gov.uk

The Exe Estuary in Devon, South West England covers an area of 3000 hectares and stretches for 11km (8 miles) from just south of the city of Exeter to the open sea of the English Channel just beyond the sand spit of Dawlish Warren. As well as being the home to 294,000 residents the Exe Estuary receives hundreds of thousands of day visitors and holiday makers each year attracted by its beautiful environment and wide range of recreational activities. Protected from the open sea by Dawlish Warren and Pole Sands, the estuary is naturally an ideal environment in which birds can feed and breed. These physical characteristics also make it a perfect open space for shellfish cultivation and a broad variety of other economic activities associated with the sea, residents and visitors.
This A Level Geography resource has been carefully designed to provide continuity and progression with the LiCCo primary and secondary programmes. In one relatively small area of the UK the Exe Estuary exemplifies all of the key geographical issues relating to physical and human coastal processes, the potential impact of climate change and the full spectrum of approaches to managing the environment. It is therefore an ideal case study for students to study and will provide valuable support to A Level teachers in a number of ways.

Firstly, this investigation provides a comprehensive and topical case study which delivers key knowledge and conceptual understanding of core examination specifications across all awarding bodies relating particularly to:

- Assessing the value of coastal areas as a social, economic and environmental resource and the reasons for the growth and development of their associated activities;
- Evaluating how and why conflict may arise between activities competing to exploit the coastal area as a finite resource and the associated management challenges which can arise;
- The impact of both coastal processes and landforms on human activities and of human activities on coastal environments;
- Physical and human causes of coastal flooding and its physical and socio-economic consequences – past, present and future;
- Understanding why some coastal areas need management intervention and the associated methods used to identify and model flooding risk, manage coastal environments through balancing socio-economic and environmental needs and evaluating their effectiveness;
- Issues arising from and the potential impact of climate change on coastal environments – eustatic and isostatic sea level change and the implications of present and projected sea level increases on future management strategy;
- Coastal management strategies – technocentric and ecocentric approaches involving hard and soft engineering and ‘hold the line’, ‘managed realignment’ and ‘no active intervention’ policies - the costs and benefits of both and the potential for sustainable development of coastal environments;
- The role of national and local government, public bodies and European law in determining policy in relation to the management of coastal environments and undertaking the responsibilities and accountability which arise – including the planning process and funding;

Secondly this resource provides an example or model for students regarding undertaking a task involving fieldwork to investigate a geographical argument, assertion, hypothesis, issue or problem that has both a theoretical and locational context.

In line with the Department for Education guidance to examination boards this investigation has been designed to ensure that it fulfils the following requirements which states that an independent investigation at A Level Geography must:

- incorporate field data and/or evidence from field investigations;
- draw on the student’s own research and/or secondary data;
- require the student to independently contextualise, analyse and draw conclusions;
- involve presentation of data and findings, and extended writing.
The Exe Estuary investigation has been designed as a very flexible learning and teaching resource which can be adapted to suit a wide range of learning and teaching contexts. The resource is entirely self-supporting and structured in a way to allow students to use it completely independently. Lines of Enquiry with key geographical aims informed by ancillary questions take students step by step through the enquiry process, ensuring that core knowledge is understood and consolidated before moving on to the next stage. Throughout all of the Lines of Enquiry students are supported in the use of a range of cartographical, graphical and statistical skills to present and interpret data, reach conclusions and make judgements, and to appreciate the significance of attitudes and values. Students are also encouraged at various points in the investigation to reflect on the validity of the information they are handling and to critique perspectives presented. This investigation also offers considerable scope for teachers wishing to use it more formally as a whole group classroom based learning and teaching resource, working alongside students through the Lines of Enquiry. Alternatively some Lines of Enquiry could be accessed by students either as preparation for or follow up to classroom based sessions facilitated by a teacher.

This geographical investigation of the Exe Estuary offers therefore a very flexible learning and teaching resource to support the delivery of core examination specifications as well assisting students to understand the requirements of their individual investigations. The Exe Estuary provides a case study at one location of the full range of coastal processes, strategic planning and environmental management responses together with the implications of climate change and sustainable development. A wealth of resources (many of which have not been publically accessible previously) have been assembled in one place to support teachers to deliver the learning and teaching programme in an engaging and stimulating manner. It is a both a challenging and stimulating resource that we are confident will support students to understand the complexities of coastal change and management and make a valuable addition to learning and teaching at A Level.

David Weatherly
February 2015
**The Exe Estuary**

**Model Research Investigation in Geography**

Research question: *How is the Exe Estuary coastal environment being managed sustainably?*

Hypothesis: *Non-intervention in natural processes represents the most sustainable management option for the Exe Estuary*

Null hypothesis: *Some form of intervention in natural processes is the most sustainable strategy for managing the Exe Estuary*

**Introduction and background**

This research enquiry has been written to support students of geography and their teachers studying specification content relating to coastal environments and their management and/or undertaking an individual geographical research investigation at A Level. It can therefore be used both to deliver core geographical content, concepts and processes and as a model for students of how to approach a personal research investigation at A Level of a geographical argument, assertion, hypothesis, issue or problem that has both a theoretical and locational context involving fieldwork.

**Line of Enquiry 1: Evaluating the approach taken to research the Exe Estuary**

Research is the systematic investigation of a **hypothesis** and consists of:

- Asking a **research question** that nobody has asked before;
- Selecting a **methodology** or approach for your research to help you to discover the answer to the research question;
- Using that answer as the basis for proving or disproving the hypothesis;
- Communicating the knowledge you have acquired to a larger audience.

When undertaking a research investigation it is important for you to understand and to evaluate the approach you have taken to doing the research. This is known as the **research paradigm**. In this research investigation we suggest you follow a particular route (our paradigm) to gathering the information required. But this may not be entirely appropriate or the best approach because of the assumptions we have made. As a result it may not be as effective as we hope in gathering the data required. Your first job then is to critique the approach you are taking to carry out the research. This means considering the accuracy and validity of the assumptions that have been made which is something you will need to do also when carrying out research of your own.
Line of Enquiry 2: Why is the Exe estuary such a valuable coastal resource?

The Exe Estuary in Devon covers an area of 3000 hectares, extends for 11km north to south and its immediate catchment area is home to 294 000 people. Estuaries such as the Exe often have important commercial value and their resources can provide important economic benefits. In addition estuaries also commonly support important public infrastructure and services and possess a rich and diverse range of habitats which in turn can provide a variety of food sources for a wide spectrum of living organisms. This range and variability of living creatures is referred to as biodiversity. The focus of this second line of enquiry is to gain an understanding of how and why the Exe Estuary functions as a valuable economic, social and environmental resource. To achieve this it is important to evaluate the opportunities it provides for human activities and the reasons for their growth and development as well as the estuary’s ecological value. Later you will be investigating some of the ways in which conflict has arisen between some of the different functions of the Exe Estuary so fully understanding their extent at this stage is very important.

Line of Enquiry 3: How has the Exe Estuary coastline been shaped by coastal processes and human activity?

Coastlines are constantly evolving and dynamic environments. They are in a constant state of change. What we see today will not necessarily look the same tomorrow or would necessarily have looked this way in the recent past. Natural coastal processes and landforms impact on human activity along the coast and in turn human activities play an important role in determining both the morphology and function of these environments. Nowhere is this better illustrated than at the Exe Estuary. The Exe Estuary coastline has evolved over thousands of years. Storm waves, high spring tides and gale force winds have battered the coast here resulting in erosion of cliffs and beaches, whilst on-going coastal processes like longshore drift, river and tidal currents move sand and sediments around on a major scale. Human activity including land reclamation, housing development, construction of flood defences and transport infrastructure have also played a very important part in shaping the coastline that we see today at the Exe Estuary. This line of enquiry will enable you to understand the impact of a range of examples of both physical and human processes that have impacted upon the Exe Estuary coastline in the past and also to evaluate some of the costs and benefits that have occurred as a result. Understanding the past is essential to better informing the present and planning for a sustainable future. This line of enquiry will prepare you well for later in the investigation when our attention turns to how best to manage such issues as climate change and increased population growth in and around the Exe Estuary.

Line of Enquiry 4: Understanding the 21st century coastal management challenges in and around the Exe Estuary

This strand of the investigation focuses on both the physical and human pressures which will impact on the Exe Estuary during the remainder of the century and which will require managing in a strategic way. Some time is spent initially looking at the response to flood risk which has occurred in the Exe Estuary in the past – beginning several hundreds of years ago – involving the construction of ‘hard’ sea defences such as sea walls, gabions and rock revetments, evidence of which can still be seen all around the estuary in places such as Dawlish Warren and Exmouth. This very technocentric approach to managing flood and coastal
erosion risk is compared with the more contemporary ecocentric view of working with, rather than in opposition to natural processes, which underpins the principle of sustainable development and modern approaches to shoreline management. The implications of climate change for coastal managers are considerable. It is important that you understand how projections of sea level rise and the frequency and severity of windstorms are generated through mathematical modelling and be able to critique the assumptions upon which conclusions are based as well as reflecting on what the implications of the high emissions scenario might be for the Exe Estuary. As well as planning for projected changes in sea level and windstorm frequency coastal managers will have to put plans in place to deal with another impact of climate change known as coastal squeeze as well as responding to population pressures that are going to build up around the Exe Estuary as housing capacity is increased this century. By the end of this enquiry you will have a thorough understanding of the wide range of (and sometimes conflicting) physical and human issues that coastal managers need to plan for in the most sustainable way in the short (30 years), medium (about 60 years) and long (a 100 years or more) term.

**Line of Enquiry 5: How should authorities most appropriately manage the risk of flooding and coastal erosion in and around the Exe Estuary?**

The Ordnance Survey calculates the length of the mainland coastline of Great Britain to be 11,073 miles (17,820 km) and estimates that upward of 3 million people live on or within 10 km of the coast. No wonder that the government of the UK is anxious to stress that no one has a ‘right’ to be protected from shoreline flooding or coastline erosion – it simply does not have the funds even to think about doing this. Through this line of enquiry you will understand who decides what happens around our coastline – the decision makers – as opposed to those who have to implement the policies created by others. The national government of the United Kingdom through its National flood and coastal erosion risk management strategy drawn up by the Department for Environment, Farming and Rural Affairs (DEFRA) decides the framework of guidance that should be adhered to by those managing the coastline. It doesn’t do the work itself but devolves responsibility (and £500 million a year) to a public body called the Environment Agency to do the work on its behalf. As you investigate the workings of the Environment Agency in collaboration with many partners, you will come to understand the economic, social and environmental criteria that are used to evaluate whether a proposal to protect the coastline should receive the go ahead and be allocated funding. In this process the government is keen for the Environment Agency to involve local community based consultative groups to generate ideas and comment on plans and one such organisation is the Exe Estuary Management Partnership.

**Line of Enquiry 6: Understanding the rationale behind different coastal management strategies across the Exe Estuary**

This line of enquiry focuses on the management of Dawlish Warren spit, the most striking physical feature of the Exe Estuary and which performs such an important sheltering function for communities further inland. The investigation begins by identifying, presenting and interpreting key data from ten sample sites along the spit and then in the context of this considering the likely impact of a 2m storm surge event both for the spit and the estuary as a whole. Based on your analysis and synthesis of data here you will be invited to advise the Environment Agency how they should respond to the coastal management challenges for Dawlish Warren spit in the short, medium and long term. Following this there will be an
opportunity for you to compare your analysis and conclusions with that of the Environment Agency and its partners in terms of determining strategy for the future. Is intervention on economic, social and environmental grounds in fact justified at Dawlish Warren given that national government guidelines to management bodies makes clear that in all instances and wherever possible they should be working with natural coastal processes and not against them. You will be asked to consider for how long it will be practical and economically justifiable to continue to ‘holding the line’ at the distal end of the spit.

**Line of Enquiry 7: Understanding the challenge of managing ‘coastal squeeze’ in and around the Exe Estuary**

One of the implications of allowing natural processes to ultimately determine what happens to Dawlish Warren spit towards the end of this century is that the risk of flooding will increase for communities around the shoreline of the Exe Estuary that are currently protected by it. In this line of enquiry you will be encouraged to look in detail at tidal and overtopping flood risk at the town of Exmouth opposite Dawlish Warren spit on the east bank of the mouth of the estuary. If more ‘hard’ flood defences such as those at Exmouth, are also going to be constructed at communities such as Starcross, Lympstone and Powderham then the Environment Agency estimates that at least 35 Ha of compensatory habitat is going to be needed by 2030. You will be invited to consider why compensatory habitat proposals for the East and West River Clyst proved to be so controversial as well as studying in detail recent plans for the lower Kenn valley. Here you will encouraged to think broadly about why a compensatory habitat proposal may ultimately prove more successful than the plan for the Clyst valley as well as the potential economic benefits of such a scheme for the landowner.

**Line of Enquiry 8: Bringing it all together – writing up your research investigation**

When writing up an investigation at A Level it is very important for students to demonstrate the ability to be reflective and to critique the work they have undertaken. This is not just about identifying and describing ‘what went wrong’ or ‘what I could have done better’ but thinking about your work at a higher critical level. This Line of Enquiry suggests a structure to use when writing up your investigation and you will also see that each section supports you to evaluate the approach you took, the methods you used and the results you obtained. All researchers adopt a particular paradigm or worldview when carrying out investigations and it is important for geographers to recognise this and the assumptions they make before they start gathering data. So the methodology that underpins your research is very different from the methods you use to collect information to test a hypothesis. At A Level it is not enough just to select a range of techniques to present data. You must also critique these techniques by asking the questions – why have I chosen this technique; what does it do well and what are its limitations? The data you collect from primary and secondary data is used eventually to draw conclusions and to make a decision as to whether the hypothesis has been proved or disproved but at A Level you also need to reflect on the validity and trustworthiness of the conclusions you have reached and what you could do to increase the reliability of your judgements. This Line of Enquiry will help you do this.
The Exe Estuary

Line of Enquiry 1: Evaluating the approach taken to researching the Exe Estuary
Ancillary Question 1: Is the hypothesis an effective one?

A hypothesis is simply an assertion or predicted answer to the research question that has been identified and which can be tested through collecting information by researching. In this model investigation a hypothesis has been identified as: Non-intervention in natural processes represents the most sustainable management option for the Exe Estuary. What you need to do now is to evaluate how effective this hypothesis is likely to be as a means of steering the research you are going to undertake.

Consolidating your thinking

Read through the advice and guidance on generating hypotheses at http://www.sciencebuddies.org/blog/2010/02/a-strong-hypothesis.php and http://www.sagepub.com/upm-data/41397_32.pdf

What is your opinion as to whether the hypothesis identified for researching the Exe estuary is an effective one or not? If yes, why and if not how do you think it could be improved?

Ancillary Question 2: Will our research question achieve what we anticipate?

A research question needs to be clear and focused as it will direct the work and efforts of a researcher. If the research question is vague or open to different interpretations then it is unlikely that the researcher will end up collecting the right data to prove or disprove the hypothesis. The research question guides the research process and must be unambiguous. For this model investigation our research question is: Non-intervention in natural processes represents the most sustainable management option for the Exe Estuary. As with a hypothesis it is not sufficient just to accept someone else’s research question or to suggest one of your own without critiquing or justifying it first. It’s a case always of explaining why my question is an effective one and why I think it will achieve what I intend it to achieve.

Consolidating your thinking

Refer to the following guidance to help your thinking here (but remember that the people and organisations offering this advice have made assumptions of their own which you may want to question). Use the following sources to evaluate whether you consider the research question is a good one and suggest how its wording might be improved in order to be more effective:

http://www.socsci.diss.bham.ac.uk/research-question.html
http://www.cliffcollege.ac.uk/documents/cc_document_101_040511213pm22.pdf

Ancillary Question 3: What are the advantages and disadvantages of the research methodology used in the investigation?

A research methodology is the approach that a researcher uses to go about finding out what is required and gather the information needed to answer the research question. There are three research methodologies:

• Quantitative – this involves the collection and analysis of data which is numerical, statistical or involves mathematical or computational modelling and is based on fact not personal opinion or preferences;
• **Qualitative** – this involves the collection and analysis of data such as words (e.g. from interviews), pictures (such as from photographs and film) and objects (such as artefacts) and which generally does not generate numerical data;

• **Mixed** – using quantitative and qualitative research methods together to answer a research question.

In this model investigation a mixed research methodology has been used. It is not enough just to select a research methodology and simply get on with data collecting. A researcher must justify and be seen to critique the approach she is intending to take. For example, if you are using a qualitative approach to test a hypothesis then you will need to justify why you are doing so. This is because many researchers argue that only numerical data collected through a quantitative methodology is appropriate for hypothesis testing. In this example a mixed methodological approach to collecting data has been used.

**Consolidating your thinking**

Before moving on be clear in your mind what the advantages and disadvantages are of both quantitative and qualitative approaches to data collection and also whether you agree or disagree with those that advocate that only ‘hard’ numerical data that is free of subjective human emotion and irrationality can only be used to test a hypothesis. See the following for different points of view:

https://suite.io/martin-bell/1sjc2y6
http://www.palgrave.com/studentstudyskills/page/choosing-appropriate-research-methodologies/
http://www.uk.sagepub.com/upm-data/38123_Chapter2.pdf
http://www.snapsurveys.com/blog/what-is-the-difference-between-qualitative-research-and-quantitative-research/
http://atlasti.com/quantitative-vs-qualitative-research/
http://people.uwec.edu/piercech/researchmethods/data%20collection%20methods/data%20collection%20methods.htm
http://people.uwec.edu/piercech/researchmethods/data%20collection%20methods/data%20collection%20methods.htm
http://archive.learnhigher.ac.uk/analysethis/main/quantitative1.html
http://archive.learnhigher.ac.uk/analysethis/main/quantitative1.html
http://www.southalabama.edu/coe/bset/johnson/oh_master/Ch14/Tab14-01.pdf
http://research-methodology.net/research-methods/
The Exe Estuary

Line of Enquiry 2: Evaluating the value of the Exe Estuary as a coastal resource
Ancillary Question 1: Why are the different habitats of the Exe Estuary of such ecological importance?

The Exe Estuary and its surrounding hinterland (Resource 2.1) is an incredibly rich and diverse area encompassing many different habitat types which support a huge range of biodiversity. Because of their ecological value some of these habitat areas in the Exe Estuary have been designated as requiring protection under British, European and in some instances, international law. Environmental designation of any kind places a responsibility on local and national government (through the agencies which it commissions to work on its behalf, such as the Environment Agency and Natural England and to which it devolves this responsibility) to conserve and enhance these habitats so that wildlife is protected now and into the future. One such responsibility has been to produce a Biodiversity Action Plan (Resource 2.2) for the Exe Estuary which translates the objectives and targets of the UK Biodiversity Action Plan (Resource 2.3) into a local context. The four main targets of this action plan for the Exe Estuary are to:

- Ensure no net loss of intertidal area in the future;
- Support the work of natural processes within the estuary and the creation of saltmarsh;
- At least maintain the extent and distribution of existing eelgrass beds and assess the feasibility of restoring damaged or degraded eelgrass beds in the future.

Consolidating your thinking

Using Chapter 3.1 of the State of the Exe Estuary 2014 Report (Resource 2.4), the aerial photographs (Resource 2.5) and leaflets produced by the Exe Estuary Management Partnership (Resource 2.6) summarise the characteristics and value of the main Exe Estuary habitats and reasons for their national and international designations. More detailed information about the designations placed on the Exe Estuary can be found at English Heritage http://www.english-heritage.org.uk/caring/listing/local/natural-designations/

Ancillary Question 2: What makes the landscape of the Exe Estuary distinctive and special?

Devon’s Landscape Character Assessment (Resource 2.7) identifies 68 distinct landscape areas and records the special qualities that people attach to each. The map of Page 61 of the State of the Exe Estuary 2014 Report shows the landscape character types in and around the Exe Estuary and pages 40 and 41 of Devon’s Landscape Character Assessment provides a description and key characteristics of the environment of the Exe Estuary.

Consolidating your thinking

Read through pages 40 and 41 and reflect on those special qualities of the landscape of the Exe Estuary that people value most. Increasingly the value of landscapes such as the Exe Estuary are being seen in a much more holistic way i.e. recognising the different ways in which such places can benefit people and contribute to their physical, emotional, mental and spiritual wellbeing. Think about how the more intangible qualities of the Exe Estuary such as tranquillity, beauty, a sense of history, the sounds of wildlife and the weather could help to improve the quality of life of people and even improve their physical and mental health. To support your thinking have a look at Natural Devon: Devon Local Nature Partnership
Ancillary Question 3 How is the Exe estuary a valuable resource for both local people and visitors?

Along with its incredibly important habitat designations and landscape value, the Exe Estuary is a rich economic and recreational resource for locals, visitors and tourists who generate tens of millions of pounds a year in income for the area’s economy as well as supporting thousands of full time and part time jobs.

Consolidating your thinking

Read Chapter 4.3 of the State of the Exe Estuary 2014 Report together with the range of leaflets produced by the Exe estuary Partnership and draw a concept or mind map [http://www.wikihow.com/Make-a-Mind-Map](http://www.wikihow.com/Make-a-Mind-Map) to provide an overview of the ways in which the following economic and recreational activities interact with the Exe Estuary:

- Water based functions and harbours/marinas;
- Land and inter-tidal based activities and services;
- Tourism;
- Transport infrastructure;
- Military uses.

Applying your thinking

With nearly 300,000 people living within the catchment area of the Exe Estuary together with hundreds of thousands of visitors and tourists engaging with the locality each year, the likelihood of conflict between different uses and demands is high. Conflict can arise when there are demands to use a finite resource such as the Exe Estuary in different and opposing ways. Consider, for example, the potential conflict that could arise on mudflats and eelgrass beds in the Exe Estuary through the conflicting demands of habitat conservation for feeding migratory birds, commercial and recreational fishing bait digging for crabs, rag and lug worms, windsurfing, dog walking and bird watching. How might this potential conflict be resolved?
The Exe Estuary

Line of Enquiry 3: Understanding the impact of physical processes and human activity on the coast
Ancillary Question 1: How have physical processes and landforms impacted on the coast?

The influence of erosion and the currents of longshore drift and estuarine tidal processes on the Exe Estuary is very well illustrated at Dawlish Warren, a 2 km sand spit which extends north eastwards across the mouth of the estuary (Resources 3.1 and 3.2) and described by Professor Vince May in Volume 28 of the Coastal Geomorphology of Britain http://jncc.defra.gov.uk/pdf/gcrdb/GCRsiteaccount1838.pdf in this way:

The landward side of the spit supports an area of saltmarsh that has developed in its shelter (see set of images Resource 3.3) To seaward, the Inner Warren is a low hummocky area of former sand hillocks resting upon clay (Resource 3.4), whereas the Outer Warren comprises a line of semi-fixed dunes of varying width behind a discontinuous line of sand hills between 25 m and 50 m in width and rising to maximum of about 6 m in height (Resource 3.5). There is a wide intertidal beach, which is connected at low tide to a large sandbank, the Pole Sand (Resource 3.6, Resource 3.7 and 3.8).

Each of these four areas are visible in the aerial video produced by Barrie Jones at http://www.torquayheraldexpress.co.uk/10million-plan-solve-Dawlish-Warren-coastal/story-21282084-detail/story.html which can be paused at various points to ensure correct orientation of the still images and the film. The spit appears to have existed in its present-day position on the western side of the Exe Estuary for at least 400 years. Resource 3.9 is an 1876 painting by Francis Danby showing a view of the spit from Exmouth and Resource 3.10 shows an early navigation chart of the mouth of the estuary. The shape of the spit has constantly been changed over this time when high spring tides are accompanied by south-easterly gales driving high onshore waves (Resource 3.11) As a result the lowest part of the Outer Warren ridge has been breached frequently and consequently the shape of Warren Point has changed considerably over time. Violent storms between 1944 and 1946 washed away all but two buildings of a small community (Resources 3.12 and 3.13) that had settled on Warren Point during the early years of the 20th century and the final traces of the village was lost to the sea in 1962. Resource 3.14 shows in red the location of the properties that were lost to the sea. In 1949 the entire distal end of the spit (Warren Point) was washed away following a series of storms (Resource 3.15). The main London railway line which runs along the coastline at Dawlish Warren has also experienced regular disruption as a result of cliff line erosion as shown by the engraving in Resource 3.16 of the destruction just outside Parson’s Tunnel to the west of Dawlish in 1855. Such breaches in the ridge are subsequently rebuilt as waves from the south and south-west move sand along the spit through longshore drift and extend it. At the same time the face of the beach and dunes is eroded and so the spit retreats. As a consequence of these destructive and constructive coastal processes tending to equal each other out some geographers point to Dawlish Warren as being a good example of dynamic equilibrium – a system in which there is a lack of change over time as inputs and outputs remain in balance. If changes do occur then feedbacks allow for correction and the reestablishment of balance. The continued existence of Dawlish Warren therefore relies on a balance being maintained between the arrival of sediment that travels along the coastline in a south westerly to north easterly direction and the erosion of material on the spit at high tides and during storms (especially easterly storms). However, the
trend during the past century has seen the dominance of erosion of the spit which has not been compensated adequately through deposition and Warren Point has periodically disappeared or even become a detached island. As will be explored later the construction of a granite breakwater to the west of Dawlish Warren at Langstone Rock together with the building of railway embankments at the base of the cliffs further west still between Dawlish and Langstone Rock, are largely responsible for the beaches at Dawlish Warren not being replenished through the longshore drift of sediments. Over the last 250 years the spit has reduced from 250 m to only 50 m wide.

Consolidating your thinking

- Draw an annotated sketch of the photograph in Resource 3.17 to show the four areas of Dawlish Warren spit referred to by Vince May i.e. Saltmarsh; Inner Warren; Outer Warren and Inter-tidal beach. Refer back to his description to ensure you identify the location of the four areas correctly on your sketch.

During the winter of 2013/2014 South West England experienced some of its worst storms for 25 years. During the evening high tide of February 4th and the morning hide tide of February 5th 2014 wind speeds reached 27.3 m/s (Beaufort storm force) at Dawlish Warren. December 2014 was the sixth wettest month in the UK on record. The impact on many places throughout the UK including Dawlish Warren was devastating.

- Read through the 10 key moments in the winter storms as documented by BBC News at http://www.bbc.co.uk/news/uk-26170904 Make a note of an example of storm damage; tidal surge impact; groundwater saturation; coastal flooding and river floods that occurred across the UK during the winter of 2013/2014. Look also at Resource 3.18;

- Events at Dawlish Warren made national and international news headlines. Watch the BBC News report at http://www.bbc.co.uk/news/uk-26042990 and read the accompanying narrative. How was the community at Dawlish and the population of West Devon and Cornwall impacted by the erosion of the coast that occurred overnight?

- The Channel Coast Observatory at http://www.channelcoast.org/ is the website for the National Network of Regional Coastal Monitoring Programmes of England. The site collects coastal monitoring data in a co-ordinated and systematic way and this information is used to inform coastal management programmes around the country. It provides real-time data for wave height and direction, wind strength and direction; water temperature; tide height and other coastal information such as Digital Terrain Models and sediment distribution maps. Resource 3.19 and 3.20 show wave height observations at Dawlish on February 4th and February 5th 2014. Describe the pattern of wave height that occurred over this 24 hour period and provide a reasoned judgement as to what time you consider most coastal erosion at Dawlish is likely to have occurred. What additional data would strengthen the validity of your conclusion?

- Spend time analysing the composite maps of the spit in Resource 3.21 and refer back to Resource 3.11 also. Describe and attempt to explain the way in which the shape of the spit has changed over time using the annotated diagram of patterns of sedimentation movement in Resource 3.22 to assist you.

During the winter storms of 2013-2014 the semi consolidated dunes of the Outer Warren were eroded inland by more than 5 m in places exposing in the process lines of rock filled gabions which coastal engineers had constructed to stabilise the dunes in the 1960s in an
attempt to prevent exactly this kind of thing happening – see the images in Resource 23. The storms also contributed to lowering and steepening the intertidal beach. At many points along the spit erosion has also left parts of the dune face very steep and liable to collapse (Resource 24). Towards the south west of the spit close to the permanent amenity buildings parts of the sea wall were undercut by the waves exposing the steel foundations below (Resource 25) and three of the groynes constructed to help stabilise beach sand in the 1960s were also damaged (Resource 3.26).

At the furthest point to the south west of Dawlish Warren is located Langstone Point a headland of breccia and sandstone, a sedimentary rock, laid down during tropical desert conditions of the Permian period between 250 – 300 million years ago (see Ordnance Survey map Resource 3.27 and geological map Resource 3.28). The headland itself was dissected by the construction of Brunel’s railway in 1846 and is today referred to as Langstone Rock. Over thousands of years abrasion has been occurring at this exposed outcrop during strong wave action associated with storms such as those of the winter of 2013 – 2014.

Consolidating your thinking

• What exactly is breccia and why this sedimentary rock is so liable to erosion – see http://geology.com/rocks/breccia.shtml

• Explain how the process of abrasion occurs and how it has led to the formation of the wave cut notches; caves; natural arch and wave cut platform that are visible in the images of Langstone Rock in Resource 3.29

A very important and dynamic coastal process at the mouth of the Exe Estuary is sediment transport and deposition. Under normal conditions there tends to be a circular movement of sediment in the mouth of the Exe with little in the way of additional sediment being added from adjacent areas of coastline or from offshore. This is mainly explained by the presence of the railway (and of course the coastal defences which support and protect it) to the west of the Exe estuary which prevent the sea from eroding the cliff and providing fresh supplies of sediment via the process of longshore drift. As can be seen in Resource 3.22 the usual pattern of sediment movement is along the shoreline in a north – easterly direction leading to an accumulation at the distal end of the spit and also offshore on the sand bank of Pole Sands (which plays an important role in mitigating the impact on the Exe Estuary of south easterly storms and storm surges). The beach tends to get narrower and more gravelly as new sediment is not introduced from the west because of the granite breakwater at Langstone Rock (Resource 3.30) against which sand accumulates and the railway embankment which prevents erosion of the cliff at Red Rock Beach between Dawlish Warren and Dawlish (Resource 3.31).

Applying your thinking

However, during turbulent storm events such as those during the winter of 2013 – 2014 this usual pattern of sediment movement is often interrupted. Analyse the four maps showing sediment elevation and volume change between February 2014 and April 6th 2012 and November 25th 2011 in Resource 3.32

• What pattern of movement has occurred? What implications do your observations have do you think for the way in which the coastline here might have to be managed in the future? What recommendation would you make? What might the implications be for the Exe Estuary as a whole in the future if no action is taken?
Primary data collection through fieldwork at Dawlish Warren to assess the effectiveness of existing coastal defences

The shoreline at Dawlish Warren provide opportunities to collect primary data which can then contribute to testing the null hypothesis. Data relating to beach width, height and composition can be obtained along the shoreline but please be aware that Dawlish Warren is a highly protected and sensitive site for wildlife. Teignbridge District Council welcomes schools that wish to visit, but would ask that you let them know (01626 863980) to ensure that there are no conflicts with other groups or it management work on site. In particular groups undertaking vegetation transects need to avoid areas of scrub (where birds may be nesting) and must not take any soil samples. The site rangers offer an education service to primary, secondary and university groups studying the site – please contact Dawlish Warren Visitor Centre 01626 863980 or Teignbridge District Council Offices 01626 215884 (Answerphone) or by post: Dawlish Warren Ranger, Green Spaces and Active Leisure, Teignbridge District Council, Forde Road Offices, Forde Road, Newton Abbot, Devon TQ12 4AD.

Possible fieldwork research enquiry 1

The existing groynes at Dawlish Warren are no longer an effective intervention preventing longshore drift and the loss of sediment.

Null hypothesis

The existing groynes at Dawlish Warren effectively control longshore drift and sediment loss.

The null hypothesis will be assumed to be true unless a significant difference is discovered between beach width and height on the north and south sides of the ten groynes positioned along the shoreline at Dawlish Warren). If there is strong enough evidence then the null hypothesis can be rejected. A statistical test such as the Mann Whitney U test can then be used to test for the difference between the medians of sets of data e.g. beach width and height on either side of the groynes using a 5% probability of chance association. The null hypothesis can then be rejected if there is a 95% certainty that the result is statistically significant rather than the result of chance. If the groynes are intervening effectively then there will be a significant difference in the median sets between the north and south sides of the ten groynes.

Possible fieldwork research enquiry 2

No discernible pattern of beach sediment size exists between low water mark and backshore along the coast at Dawlish Warren.

Null hypothesis

Sediment size between low water mark and backshore at Dawlish Warren increases with distance away from the sea.
The null hypothesis here will be assumed to be true unless there is a significant difference between the size of sediments sampled systematically at regular points along the ten transects down the beach e.g. at the edge of the sea, 3, 6, 9, 12 m and so on. If the coastal protection engineering in place at Dawlish Warren – groynes and gabion baskets – are effectively stabilising the beach sediments then a common pattern of sediment size would be anticipated at each of the sample transects. Conversely if despite the groynes and gabions very destructive waves generated by storm surges are impacting negatively on sediment size along the beach and creating a random distribution pattern then the null hypothesis will be proved with a 95% probability if the mean data sets are found to be statistically different.

For additional support and guidance here please refer to:
- http://www.rgs.org/OurWork/Schools/Fieldwork+and+local+learning/Fieldwork+techniques+Sampling+techniques.htm

**Ancillary Question 2: How have human processes and landforms impacted on the coast?**

The impact of human geography on the morphology of the coastline of the Exe Estuary is considerable and its influence spans almost 2000 years. Four aspects of human activity along the estuary – the creation of transport links, land reclamation, housing developments and the construction of flood defences – have been particularly significant.

Railway lines form the coastline along 12 km of the Exe Estuary. The railway line from Exeter to Exmouth along the eastern side of the estuary opened in 1861 and with 1.7 million passengers a year, the *Avocet Line* as it is known locally, is today the busiest branch line in the south west region. See [https://www.youtube.com/watch?v=lDrvols-CZs](https://www.youtube.com/watch?v=lDrvols-CZs) The South Devon Railway running down the western bank of the estuary began operating in 1846. Today it functions as the main First Great Western operated line from London to Plymouth but its most frequent trains are those from Exmouth and Exeter to Paignton along the section of the track marketed as the *Riviera Line*.

**Consolidating your thinking**

*Resources 3.33, 3.34 and 3.35* are matching sets of Ordnance Survey map extracts and aerial photographs of three sections of the Exe estuary coastline at Lympstone, Starcross and Cockwood. Study these and the set of images in *Resource 3.36*. Describe how the construction of the railway routes has shaped the morphology of the coastline and suggest how the alterations to the coastline that occurred could today be both an advantage and disadvantage to the many communities that live behind them.

The Exeter Ship Canal constructed between 1564 - 1567 and further extended in 1676 and 1827 links the west bank of the estuary at Turf to Exeter quay in the centre of the city and allowed passage of ocean going ships that were able to cross the sand bar at Exmouth and sail up the estuary. The canal operated very successfully until the end of the wool trade and the arrival of the railway at Exeter in 1844. In 1939 the canal was still carrying 63,000 tons a year and saw its last commercial use in 1972. Today the canal is widely used as a leisure and
recreational amenity. Constructing the canal with its double tow paths, effectively redesigned
the NW coastline of the Exe Estuary for a length of 3 Km. In the aerial photograph in
Resource 3.37 (taken looking southwards down the estuary) the canal can be seen
forming the right hand bank. The satellite image in Resource 3.38 shows the canal forming
the bank of the estuary to the east of the settlement of Exminster. The photographs in
Resource 3.39 also illustrate how the canal separates the land from the estuary along this
3 km section.

Consolidating your thinking

Until the extension of the Exeter Ship Canal to Turf the land to the east of Exminster (see
map Resource 3.40 and the aerial photograph Resource 3.41) was part of the estuary
i.e. mostly inter-tidal mud banks that were flooded at high tide and left exposed at low tide
as in the photograph Resource 3.42. Completion of the canal created an opportunity for
local land owners to alter this. Look at the photographs in Resource 3.43 as well as the
aerial photograph Resource 3.41. How and why was the landscape between Exminster
and the canal changed? Along with the building of the canal this process of land reclamation is
another very good example of how human activity has impacted on the morphology of the
coastline of the Exe Estuary.

Credit: Sarah Charlesworth

South West Beaches Elevation Change Analysis after the Winter Storms of 2013/2014

Elevation change is derived from a comparison of LiDAR DSM acquired before the storms on 25/11/2011, against LiDAR DSM acquired after the storms on 01/03/2014.

Elevation change is shown for the beaches and intertidal areas, and is overlaid on the hill-shaded image of pre-storm LiDAR DSM.

Credit: Environment Agency
The Exe Estuary

Line of Enquiry 4: Understanding the 21st century coastal management challenges in and around the Exe Estuary
Ancillary Question 1: How effective has the management of physical processes along the Exe Estuary been in the past?

From the construction of the first sea wall at Exmouth in 1841 - 42 which was further extended along the entire seafront in 1870 (see the paintings and engravings by William Spreat 1845 in Resource 4.1) and the completion of the sea wall at Dawlish Warren in 1846 to carry trains from Exeter to Teignmouth (see photographs dating from the 1870s in Resource 4.2 and present day images in Resource 4.3) hard engineering protection from coastal processes has been the typical management approach taken along the Exe Estuary. The improved sea wall and rock armour ‘rip rap’ constructed to protect the village of Dawlish Warren and its associated leisure amenities in the 1990s is another example of this very ‘technocentric’ approach to managing the environment.

Consolidating your thinking

- Before moving on spend some time ensuring that you are aware of the advantages and disadvantages of the range of hard engineering approaches that have been used to date in different locations in and around the Exe Estuary. Many of these including the construction of groynes and breakwaters, sea walls, gabions and rock armour or rip rap you have come across already in this investigation. See:
  - http://www.geography.learnontheinternet.co.uk/topics/coastal_management.html#hard
  - http://sanctuaries.noaa.gov/management/international/pdfs/hard_engineering.pdf and
- Technocentrism is a paradigm or world view held by those who believe that the application of science and technology to control and manipulate the environment is the key to successfully managing change in the future. It places humans in a dominant role over nature. The diametrically opposed view is held by those who believe in ecocentrism as the only approach to managing the environment that will result in a sustainable future for everyone. Ecocentrics respect the natural processes of nature, even if they are potentially destructive, and believe that working in harmony with nature is always more desirable than attempting to control it. It is important for you to reflect here what your personal worldview is about the optimum approach to managing the environment both locally and globally in a world of over 7 billion people. The following article is a good place to begin your thinking:
- Using the two case studies of Dawlish Warren and Exmouth that you have studied to date, how successful do you feel the largely technocentric strategies adopted so far to manage coastal processes along the coastline at the mouth of the Exe Estuary have been?

Ancillary Question 2: What are the implications of projected climate change for the future coastal management of the Exe Estuary?

The most recent UK Climate Projections (UKCPO9) http://ukclimateprojections.metoffice.gov.uk/ were published in 2009 and were arrived at by using a very wide range of complex computer generated Global Climate Models (GCMs). Climate models use a mathematical representation of the climate through simulating the interactions of the atmosphere, oceans, land surface, ice
– and the sun to estimate future trends. Projections can be generated on a 25 km grid square resolution using the UKCPO9 online user interface.

**Consolidating your thinking**

Before moving on to consider what this mathematical modelling suggests for the Exe Estuary it is important to critique the process by which these projections have been arrived at. A mathematical model attempts to represent reality as closely as possible but it can never predict the future because it is formulated on the basis of numerous assumptions – things that are accepted as true or are certain to happen, without proof e.g. the level of greenhouse gas emissions that will occur during the remainder of the century. This, along with a range of other things e.g. computer simulations can only use quantifiable data to generate projections, limit the effectiveness and reliability of the tool and thus the degree of confidence that can be placed in it. Read the Key Findings of the report by Lupo and Kininmonth (2013) Global Climate Models and Their Limitations http://www.nipccreport.org/reports/ccr2a/pdf/Chapter-1-Models.pdf and make a note of the main criticisms of the current use GCMs they raise.

UKCPO9 attempts to deal with uncertainty around the levels of greenhouse gas emissions by presenting three possible emissions scenarios for the remainder of the century – low, medium and high – all of which are assumed to be equally plausible. For each emission scenario, the projections are presented as probability levels for a range of possible outcomes, based on thousands of plausible climate scenarios derived from climate model simulations. In this context the term ‘Very Likely’ is used to describe a change with a 90% statistical certainty for temperature and precipitation and a 95% statistical certainty when referring to Relative Sea Level change.

**Consolidating your thinking**

The current continued rate of build-up of CO2 in the atmosphere is at the level assumed with the high emissions scenario. The ranges of projected climate change in the South West under the high emissions scenario are presented in the table on page 21 of the State of the Exe 2014 Report in Resource 2.4. Using this data make a summary of projected climate and sea level change for the Exe Estuary by the 2080s and consider what the implications of these estimates are likely to be for coastal managers who need to plan now how to respond.

An area of computer modelling of climate change with serious implications for the Exe Estuary has so far demonstrated inconsistent results. Severe windstorms around the UK (such as the one that impacted the UK February 3 – 5th 2014) have become more frequent in the past few decades. The 1990s saw 14 strong wind events, compared to 4, 5 and 8 in the 1960s, 1970s and 1980s respectively. The UKPOC2 report of 2002 suggested an increase in storm event frequency but seven years later UKPOC9 estimated no significant change from present, which highlights the inherent uncertainty in climate modelling. However, as the atmosphere warms up and holds more energy, more frequent and severe storms are predicted by some climate models, although the exact details are still difficult to quantify. In May 2014 Lloyds of London released a Catastrophe Modelling and Climate Change Report. The document provides an overview and examples of the development of catastrophe modelling technology utilized by insurers, reinsurers, governments and other financial entities. This technology is aimed at gauging changes in climate and weather patterns and estimating how risk analysis related to extreme weather events can affect the insurance industry. This report highlighted that despite the differences in various GCM research methodologies, all models agreed, for example with regard to windstorms specifically, that changes in near-surface temperature, baroclinicity and sea-ice will greatly affect the strength and location of cyclone...
activity at mid-latitudes in the northern hemisphere. EQECAT (a catastrophe risk modelling firm) carried out research on windstorm activity in the European mid-latitudes which highlighted the following observations in future climate scenarios:

- Fewer smaller storms but an increase in the frequency of very large storms;
- A shift in the latitude of European windstorms towards central Europe;
- A four-fold increase in the frequency of years with several severe storms.

**Consolidating your thinking**

Refer back to the observations you made about the implications of projected climate change for coastal managers of the Exe Estuary previously. If the scenario for the frequency and strength of windstorms above proves accurate then what additional challenges for the management of the Exe Estuary do you feel this is likely to present?

Mathematical and computational modelling is now used extensively by the Environment Agency and other organisations to assess flood risk through running simulations to demonstrate possible future patterns of both tidal flooding and flooding due to the overtopping of coastal defences. Maps of flood extents based on these simulations using GIS can be generated and subsequently play an important role in the creation of community flood risk plans at a very local and precise level.

**Consolidating your thinking**

Read through the Environment Agency computer modelling guidelines in Resource 4.8. A computer model requires software to be programmed with different data set scenarios. What sources of data do coastal managers use when programming their computers? What possible limitations or challenges could arise through using these data sources?

**Ancillary Question 3: How will ‘coastal squeeze’ impact the natural environment of the Exe Estuary and what response will be required of coastal managers?**

Previous research through Line of Enquiry 2 highlighted the Exe Estuary and its surrounding hinterland (Resource 2.1) as an incredibly rich and diverse area encompassing many different habitat types which support a huge range of biodiversity designated as requiring protection under British, European and in some instances, international law (Resource 4.4). It emphasised also that environmental designation of any kind places a responsibility on local and national government (through the agencies which it commissions to work on its behalf, such as the Environment Agency and Natural England and to which it devolves this responsibility) to conserve and enhance these habitats so that wildlife is protected now and into the future.

As sea levels rise it is probable that large areas of designated inter-tidal habitats which are currently exposed at low tide will be under water for more of the time. Under normal conditions of marine transgression coastal habitats have the ability to migrate landwards as sea level rises (see the top half of the diagram in Resource 4.5). However, where sea walls and embankments have been built (as is the case along so much of the Exe Estuary) to protect communities from the risk of flooding or to support transport infrastructure such as railways, these important habitats will be prevented from migrating up the shore and will be lost permanently under water (see lower half of diagram in Resource 4.5). The loss of these habitats will affect resident and visiting wildlife including many internationally important wading birds.
Consolidating your thinking

Under current law (Resource 4.6) there is a requirement on organisations such as the Environment Agency and local government agencies e.g. town, district and county councils to compensate for any habitat loss resulting from coastal squeeze by creating new areas of suitable replacement habitats of the same size as close as is feasibly possible to the habitat which will be lost. The loss of so much inter-tidal habitat that could not be adequately replaced through compensatory reinstatement locally, was a major factor in the Energy and Climate Change Select Committee’s decision in 2013 to reject proposals to construct a tidal barrage across the Severn Estuary see: http://www.publications.parliament.uk/pa/cm201314/cmselect/cmenergy/194/194.pdf Read the Executive Summary of the report and the section on Inter-Tidal Habitat on pages 20-22. Line of Enquiry 2 referred to over 200,000 residents now living on or close to the Exe Estuary and emphasised the huge range of social, economic and recreational roles that the estuary performs. If and when the time comes to find compensatory habitat for losses resulting from coastal squeeze how easy do you feel this is going to be for coastal managers? What is the reaction likely to be from some residents and ‘consumers’ of the estuary? Read the newspaper article in Resource 4.7 to help structure your thoughts.

Applying your thinking

Responding to the demands of ongoing physical processes such as erosion, transportation and deposition combined with storm waves, high spring tides and gale force winds together with the impending implications of climate change are only one aspect of the management of the Exe Estuary. Equally significant and in many ways related to physical processes and climate change are the implications of the continued growth in population living on and around the estuary. Nearly 900,000 people currently live in Devon and Torbay and of this number 80% live either around, at the mouth or at the head of one of the county’s 13 estuaries. The Draft Regional Spatial Strategy for Devon estimates that the population of the county will increase by 13% by 2026 requiring the construction of 96,000 new homes and the creation of 60,000 new jobs. The number of homes within a 1km distance of the Exe Estuary is therefore set to increase by 20% by 2026. New housing will increase the number of local residents significantly. Consider in what ways the growth in population on and around the estuary could bring benefits to the area e.g. the creation of new jobs, greater expendable purchasing power of local people and the growth of ancillary services such as shops, schools and medical facilities. In what ways will this growth in people present a human management challenge in relation to ensuring the conservation of the Exe Estuary? What kind of pressures and problems might arise?
There are also other protected areas around the estuary that are not shown here.

Habitats include sandbanks and mudflats which are important for breeding waders and ducks. Invertebrates and birds are also important.

Habitats include saltmarsh, sand dune, grassland, heath, scrub and marsh. Rare plants include the Warren Creeper and Custard Apple.

Scientific Interest (SSI)

Special Scientific Interest (SSSI)

Exe Estuary Special Protection Area (SPA)


Dawlish Warren Site of Special Scientific Interest (SSSI)

Dawlish Warren Special Area of Conservation (SAC)

Dawlish Warren and the Exe Estuary are important conservation sites because of the habitats, plants, animals and birds found there. The area is protected by Local, National and International conservation designations.
Line of Enquiry 5: How should authorities most appropriately manage the risk of flooding and coastal erosion in and around the Exe Estuary?
Ancillary Question 1: Who determines how coastal environments should be managed?

In England it is estimated that 25,000 homes will be at risk due to coastal erosion in the next 20 years and it is possible that this could rise to 70,000 by 2065 as a result of the impacts of climate change i.e. sea level rise combined with increasingly severe and more frequent windstorms.

How the risks of flooding and coastal erosion are managed and funded if considered necessary, in places such as the Exe Estuary, is determined nationally by the UK government through its Department for Environment, Food and Rural Affairs (DEFRA). Through its policies and legislation (laws) the UK government provides a framework for those managing the coast to follow. How the coastal environment should be managed in England is set out in the government’s National flood and coastal erosion risk management strategy 2011 (Resource 5.1). This document provides a clear national framework through which the seriousness of all potential sources of flooding and erosion around the coast of England are assessed using a risk – based approach that balances the needs of communities, the economy and the environment.

DEFRA does not do this work itself. Instead it provides over £500 million of Treasury funds (i.e. derived from taxation) a year to a non-departmental public body called The Environment Agency https://www.gov.uk/government/organisations/environment-agency to take the lead operational role on its behalf in England in undertaking flood and coastal erosion risk management (FCERM).

Consolidating your thinking

In its National flood and coastal erosion risk management strategy 2011 the government says this:

Flooding and coastal erosion cannot be entirely prevented and the relevant legislation is largely permissive. This means that there is no general right to be protected from flooding and coastal erosion, and no right to be protected to any particular standard where risk management action is taken.

Why do you think the government has stressed this? Consider the implications of climate change and the estimated numbers of homes likely to be vulnerable to coastal erosion in the next 50 years or so. Why is the government do you think not making a commitment to protect everyone at potential risk?

To ensure an integrated and ‘joined up’ approach to FCERM the Environment Agency collaborates with other risk management authorities, in particular coastal elected local authorities such as County Councils, District Councils, City Councils and Unitary Authorities. District Councils have a key role to play in planning risk management and in making decisions on development in their area as a local planning authority. In developing land-use plans, planning authorities must take flood risk and coastal erosion into account and ensure that the risks are managed and new properties are insurable over their lifetime. Coastal local authorities undertake works to tackle the risk of sea flooding and coastal erosion where they are best placed to do so. Coastal authorities also have powers to protect land against coastal erosion and to control third party activities on the coast. This includes the construction of private defences or the removal of beach material as well as having to assess very carefully what the implications could be of any housing developments it may be proposing through local Structure Plans.
Consolidating your thinking

East Devon District Council (EDDC) covers an area of 314 Km2 that includes the east bank of the Exe Estuary. Because of the designation of the Exe Estuary as both a Special Protection Area (SPA) and RAMSAR site the district council must carry out assessments of the potential impact on the estuary of any aspect of its local strategic plan. For example new housing developments in the vicinity of the estuary will very likely increase visitor pressure on a scarce resource and either create or exacerbate existing problems. The evaluative report in Resource 5.2 was commissioned by EDDC to make an assessment of just this kind. Make a note of both the likely problems that the report identifies as potentially arising from increased visitor numbers and the mitigation actions recommended to reduce their severity or seriousness.

There are many other public bodies that play an important role in supporting the Environment Agency and local authorities in FERCRO. For example Natural England and English Heritage are the Government's advisors on the natural environment and cultural heritage and The Met Office, British Waterways transport and utilities providers all have important expertise and/or infrastructure that may impact on FERCRO.

There are 34 non-government organisations that also contribute to managing flood and coastal erosion risks in England, including the Association of British Insurers, Royal Society for the Protection of Birds, Association of Drainage Authorities, engineering consultants and contractors, National Flood Forum, National Voice for Coastal Communities, Royal National Lifeboat Institution, Red Cross, Salvation Army, the armed forces, professional institutions, universities, Country Land and Business Association and National Farmers Union, River Restoration Centre, as well as land owners and land managers. There are also a number of organisations that own and maintain FERCRO structures and structures that may have other primary functions but which also help to reduce flood risk or coastal erosion. These include ports authorities, the Highways Agency and Network Rail.

Consolidating your thinking

Local partnerships, forums and community groups such as the Exe Estuary Management Partnership also provide valuable local knowledge and insight as well as a focus for involving local people in FERCRO. Engaging more people locally in decision making relating to their own communities forms an important aspect of national government policy when it comes to managing the risks of flooding and coastal erosion in the most sustainable manner as well as adapting to climate change in the future. The Exe Estuary Management Partnership publishes a regular newsletter to update members with news, dates and venues of forthcoming events and invitations to become involved in discussions and consultations relating to the management of the Exe Estuary. Read the newsletter in Resource 5.3. What examples are there here of news updates, events and consultations? How might a publication such as this encourage empowerment (sharing information to encourage people to take the initiative to do things and become involved in decision making) of local people?
Ancillary Question 2: How is government funding for managing coastal environments allocated?

As highlighted earlier the UK government, through national taxation, is the primary funder of coastal flooding and erosion risk management activity, with the majority of funds provided by DEFRA directly to the Environment Agency as Flood Defence Grant-in-Aid – currently over £500 million a year. As a public body (agency spending public tax revenue) the Environment Agency has to ensure that the very best results are achieved with the money made available. Its work is constantly under scrutiny by parliamentary committees to ensure that this happens.

The Environment Agency cannot fund everything. As you have seen, the government has made it clear that people and their property do not have a ‘right’ to be protected from coastal flooding and erosion. Because funding is scarce decisions on the investment of money in management schemes have to be prioritised. This means that when the Environment Agency is asked to consider allocating funds for coastal management programmes – either maintaining existing coastal flooding or erosion defences or constructing new schemes – applications have to be prioritised. Intervention always has to be economically and/or environmentally justified. This means that in most cases either:

- A strong economic case has to be made for investment to prevent the risk of coastal flooding and erosion to people and property. Every £1 of capital investment made by the Environment Agency on behalf of the UK government must provide an average long term benefit in reduced damage of at least £8 for a scheme to be considered for approval;

Or

- A strong environmental legal case is made for investment to ensure that the UK government complies with European and international law to protect internationally designated environmental habitats from the damaging effect of flooding and/or coastal erosion.

Applying your thinking

In Resource 5.4 is a Project Appraisal Report for a proposed £30 million construction project to replace and improve coastal defences at Clacton and Holland-on-Sea in Essex. Tendring District Council used this report in an application to obtain the funding required from the Environment Agency. In your view did their proposal justify funding on the grounds of either of the two criteria above? Explain and justify the decision you would have made if you were part of the project appraisal panel at the Environment Agency.
What happened during the storms at Dawlish Warren?
Dawlish Warren spit 1949 showing removal of distal end by storms

Credit LiCoCo
The Exe Estuary

Line of Enquiry 6: Understanding the rationale behind different coastal management strategies across the Exe Estuary.
Ancillary Question 1: How and why is the coast being managed at Dawlish Warren?

Line of Enquiry 3 focused on how both physical and human processes have impacted on the Exe Estuary coastline over many hundreds of years and how together they have been responsible for shaping the morphology of the coastline we see today. The most striking natural feature of the Exe Estuary is the 2 km long sand spit which stretches in a SW to NE direction across most of the mouth of the ria (see Resources 6.1 – 6.6 to revisit this).

Consolidating your thinking

As you already know from your work in Line of Enquiry 3 the shape and composition of Dawlish Warren spit has changed dramatically over time. For much of historic time it has remained in a state of dynamic equilibrium but more recently the rate of sediment erosion has exceeded that of sediment deposition. Analyse the data in Resource 6.7 very carefully. It shows three sets of information for 20 sample sites at 100 m intervals along the spit (shown on the aerial photograph below the data sets) – beach width, consolidated sand dune width and total spit width. The sampling began at 100 m which is the point where the sea wall and rock armour revetment which protects Dawlish village and the leisure facilities at Dawlish Warren ends and the remainder of the spit is exposed (see annotated aerial photograph in Resource 6.8).

- Using an outline of the aerial photograph showing the location of each sample site (Resource 6.9) construct a located divided proportional bar to present the data in Resource 6.7. Compare your completed graph with those in Resources 6.10 and 6.11 and also the located graphs showing beach width at selected groynes along Dawlish Warren spit in Resource 6.12. How does the pattern of this data correspond to your located divided proportional bars?

- Now look at the graphic in Resources 6.13 which models the possible consequences of a 2 m storm surge event involving a combination of the occurrence of a severe windstorm and a high spring tide in the Exe Estuary. Using Resource 6.14 for additional information consider particularly the location of where coastal and shoreline breaches are projected to occur as a consequence of such an event and the possible consequences for people, property and infrastructure in the communities of Exmouth, Dawlish Warren, Starcross, Topsham and Lympstone;

- Reflect for a moment on what you learned about the rationale of decision making and the criteria of funding provision for coastal management programmes in Line of Enquiry 5. In the role of an independent consultant and using the work you have done in the first two tasks above, provide a short brief to the Environment Agency outlining what you have identified as the main coastal flooding and erosion risk at Dawlish Warren, the scale of that potential problem and what in your view should be done, if anything, to mitigate it.

As has been made clear in Line of Enquiry 5 the UK government through its National Flood and Coastal Management Strategy produced by DEFRA determines the approach that should be taken in identifying and managing the risk of coastal flooding and erosion and the Environment Agency ensures that these government policies are implemented around the coastline on its behalf. In turn and to ensure a co-ordinated approach, the Environment Agency works in partnership with lead local authorities in coastal areas such as publicly elected Unitary Authorities, County, District and Town Councils who all have a duty under the Flood and Water Management Act to ‘develop, maintain and apply a strategy to manage and protect the coastline’. A key requirement is that local coastal authorities should produce a Shoreline
Management Plan and the Environment Agency assists them in doing this and also monitors its implementation and progress over time. Another important requirement on lead coastal authorities is to co-ordinate and support public consultative groups in coastal communities such as the Exe Estuary Partnership which is facilitated by the Exe Estuary Officer https://www.exe-estuary.org/exe_estuary_officer who is hosted by Devon County Council working within the Environment Team at County Hall. Lead coastal local authorities also have powers to undertake coastal works to tackle the risk of sea flooding and coastal erosion where they are best placed to do so and receive funding for this from a range of sources including through local services support grants direct from DEFRA, formula grants from the government Department for Communities and Local Government, capital grants from the Environment Agency and money raised through council tax - a tax levied on households by local authorities in Britain, based on the estimated value of a property and the number of people living in it.

When preparing a Shoreline Management Plan a local authority must adhere to the government directives detailed in the National Flood and Coastal Erosion Risk Management Strategy. This tells local authorities that in their planning for risk management along the coast that unless there are compelling reasons to do otherwise they must:

“In all instances flood and coastal risk management should wherever possible work with natural processes and always seek to provide environmental benefits” (p. 26) and “contribute to the achievement of sustainable development, balancing the needs of society, the economy and the urban, rural and natural environment and taking account of cultural heritage” (p. 34)

Through the National Flood and Coastal Erosion Risk Management Strategy the government also makes it clear that when intervention by local authorities is deemed necessary this should wherever possible be as ‘minimal’ as possible working in conjunction with natural processes as the diagram below from Page 25 of the strategy indicates:

<table>
<thead>
<tr>
<th>Hard engineering</th>
<th>Soft engineering</th>
<th>Mitigated hard engineering</th>
<th>Natural flood-risk management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavily modified river or coastline</td>
<td>Natural Processes</td>
<td>(Semi) natural river or coastline</td>
<td></td>
</tr>
</tbody>
</table>

**Example interventions**

- Flood walls
- Pump drainage, dry washlands (significant intervention)
- Green roofs, permeable paving
- Wet washlands, balancing ponds, regulated tidal exchange swales
- Managed re-alignment, upland grip blocking, re-meandering
- Natural floodplain /coastal zone (minimal intervention)

**Example outcomes**

- Floodplain disconnected from channel/sea, except in exceptional circumstances
- Floodplain connected with channel/sea with high degree of control
- Floodplain connected with channel/sea with high degree of freedom
Consolidating your thinking

The Exe Estuary forms part of the Durlston Head to Rame Head Shoreline Management Plan 2011 (see the Resource 6.15) which covers the coastline of Dorset and South Devon. Based on this plan which sets out only broad coastal management policies the Environment Agency collaborated with key local authorities and stakeholders – Devon County Council, East Devon District Council, Teignbridge District Council, Natural England and Network Rail to prepare a draft Consultative plan for Managing Flood and Coastal Erosion Risk for the Exe Estuary in January 2013 (Resource 6.16). Although this plan set out things which would need to be considered up to 100 years’ time its greatest focus was on 30 years ahead. Because it was a consultative plan people living in communities around the estuary were invited to respond with their views and suggestions during the period January 21st through March 4th 2013. In total 125 responses were received together with two campaign petitions. As a result in the final plan (Resource 6.17) most of the recommendations made in the draft report remained unchanged.

- Read the final plan and identify where changes were made to the original recommendations – identify the bold italic text and refer back to the same pages in Resource 6.17. Why do you think that these original recommendations were so controversial? Read again the newspaper report in Resource 4.7 and see also:

  http://www.savetheclyst.org/index.html


- With regard to Dawlish Warren read the strategy which has been decided upon on Page 15 of Resource 6.17. How does the risk identified and the strategy to be adopted to manage that risk compare with your own analysis? As we will see for approximately the next 30 years or so the plan for Dawlish Warren will be a combination of hold the line and managed realignment. How will this change in the medium to long term i.e. from about 2050 onwards? The plan says that after this the sand spit “will be allowed to evolve naturally”. What in reality will this almost certainly mean and what are the implications for the Exe Estuary as a whole and the communities living around it?

Martin Davies who is FCRM Advisor at the Environment Agency for South West England says this about the coastal management strategy adopted for the next century at Dawlish Warren:

“For students of geography, Dawlish Warren is an ideal case study of coastal management because in such a short stretch of coastline can be seen the entire spectrum of management responses – from highly technocentric ‘hold the line’ utilising hard engineering in some places through to much more ecocentric responses such as the removal of existing defences in other places to allow ‘managed realignment’ of the coastline to take place which reflects a much more ecocentric worldview and utilises soft engineering”.

55
Applying your thinking

• Read through the first ‘brief description of proposal’ for Dawlish Warren spit in Resource 6.18 and then have a look at Slide 4 in Resource 6.19 to remind yourself of the important sheltering function of Dawlish Warren spit for the Exe Estuary. What do you think the potential cost of not intervening here would be? A conservative estimate has identified over £300 million worth of residential, commercial and infrastructural property including the railway, to be at risk from a potential breach of the spit. Watch the film in Resource 6.20 from 04.52 until 05.38. What would be the likely consequence be of doing nothing?

• Slide 7 of Resource 6.19 identifies 6 risk management issues for Dawlish Warren spit. If you were advising the Environment Agency as to the priority it should give to dealing with these issues how would you recommend that it rank orders them 1 – 6?

• Slide 14 of Resource 6.19 provides information about a ‘soft engineering’ and more ecocentric element of the risk management strategy for Dawlish Warren spit – that of beach nourishment or replenishment. What is the rationale for doing this – how will this intervention protect the spit and why can it be argued that this is both ecocentric and sustainable? However, it is very important to reflect that even ecocentric and soft engineering approaches to coastal management will generate potential environmental costs as well as benefits. Although these costs may be outweighed by the potential benefits of a programme they are nevertheless negative impacts which need to be reduced to a minimum. For the beach replenishment scheme at Dawlish Warren what do you consider to be the most serious negative impact (Slide 13)? Another important aspect of beach nourishment schemes with potential negative environmental impacts is the question of where the sand that is going to be used is sourced from? At Dawlish Warren a number of sites have been identified as potential donor locations (Slide 14). Which of these would you consider to be the most sustainable option and why?

• Slide 16 shows how the removal of obsolete coastal defences (rock filled gabion baskets heavily damaged by the winter storms of 2013-2014 – see photographs in Resource 3.23) along one stretch of the shoreline is going to be combined with the construction of a new sea flood wall defence across the middle of the spit (see photographs in Resource 6.21) – to both protect Dawlish village from flooding and to enable managed realignment of the coast to occur as a result of natural processes in the future. Watch the film in Resource 6.20 from 05.38 to the end and also look carefully at the map in Resource 6.22. This map shows how Dawlish Warren could look in ten years’ time at a high spring tide. Describe and explain how and why the coastline could realign itself as a result of not actively intervening to interrupt coastal processes.

• The final aspect of the coastal management strategy for Dawlish Warren spit is to protect its narrow neck to ensure the sequence of events simulated in the images in Resource 6.23 do not occur in the short to medium term – about 60 years. The plan calls for a ‘new hard defence buried under the sand’ to prevent it eroding but does not provide any additional information. How might such a defence be designed to ensure that it ‘holds the line’ at this point along the coast and yet also have minimal environmental impact – visually as well as ecologically?
* Looking beyond the next 60 years the *Managing Flood and Coastal Erosion Risk for the Exe Estuary Strategy* says the following:

“It is predicted that towards 2060 continued engineered control of the sand spit will become too difficult and costly. We also then expect the sand spit will partly lose its sheltering function requiring further defence improvements within the estuary.” (p. 15)

This is an acknowledgement that the new buried hard defence is a short to medium term response and that after about 2060 a policy of ‘no active intervention’ in natural processes will be adopted for the management of the far distal end of the spit. Is the increased risk of flooding this will mean for estuary communities such as Cockwood, Starcross, Topsham, Lympstone and Exmouth reflected in their long term strategy planning in *Resource 6.17*? If so how is the increased risk going to be managed? If you feel that the increased risk has not been adequately addressed in any of the communities then why do you think this may be?
1. Wider, sandier tourist beach
2. Gabions remaining here but will be removed eastward from this point
3. New tidal flood defence wall
4. Proposed location of new visitor/warden centre
5. Position of existing visitor centre
6. New tidal inlet - Greenland Lake
7. Likely breach in dunes here (lowest point)
8. Approximate location of new hard defence structure to strengthen neck
9. ‘Hook’ end accreting with sand
10. Relict sand dunes and golf course
11. Recharge of beach with sand
12. Sand dunes naturally moving back
13. Indicative scouring of sand dunes caused by storms
14. Car park
15. Tourist facilities
16. Sea wall
17. Railway defences
Line of Enquiry 7: Understanding the challenge of managing ‘coastal squeeze’ in and around the Exe Estuary.
Ancillary Question 1: Why is coastal squeeze becoming a serious coastal management issue?

Line of Enquiry 4 provided an opportunity to understand the concept of ‘coastal squeeze’ which is going to become an increasing challenge to coastal managers around the UK as sea levels rise during the remainder of this century. Before moving on revisit Ancillary Question 3 of Line of Enquiry 4 and reacquaint yourself with the main issues and responsibilities facing coastal managers regarding coastal squeeze.

Consolidating your thinking

The Managing Flood and Coastal Erosion Risk for the Exe Estuary strategy in Resource 6.17 provides an overview of the approach to coastal management recommended by the Environment Agency and a wide range of key stakeholders including local government. The strategy identifies 11 coastal and shoreline communities – see map on page 3. Read through the recommendations for each community and make a note of those where the summary of the work to be undertaken in the short (by 2030) and medium term (by approximately 2060) involves aspects of what can be considered ‘hold the line’ flood defences e.g. the construction of new sea walls; raising existing sea walls; ongoing maintenance of embankments; the raising of either canal, railway or harbour defences and or improvements to offshore or shoreline revetments of one kind or another.

You will have observed in this exercise that in fact over two-thirds of the coastal and shoreline communities of the Exe Estuary will have work undertaken by 2060 to increase their flood protection through one or more of the measures listed above. This is because coastal managers in the Exe Estuary have to plan for the implications of the reduced sheltering effect of Dawlish Warren spit after about 2060 and the consequential need for communities around the Exe Estuary to rely on even bigger coastal defences during the second half of this century which may affect their enjoyment of the estuary.

This need to increase flood defences for the majority of communities around the Exe Estuary is of course going to exacerbate the issue of coastal squeeze. Coastal managers have estimated that 35 Ha of inter-tidal habitat is likely to be lost around the Exe Estuary as a consequence of these measures. As you are aware the UK government is required by European agreements to which it is a signatory to compensate in law for this loss of habitat by creating an equal amount of new habitat through controlled tidal flooding as close to the areas where it will be lost as possible.

Consolidating your thinking

The town of Exmouth on the east bank of the mouth of the Exe Estuary opposite Dawlish Warren is one of the coastline communities you will have identified where both renewal of existing flood defences and the construction of new defence works are considered necessary. Resource 7.1 is part of the public information and consultative material that the Environment Agency has produced relating to flood protection in Exmouth.

• Explain the difference between astronomic tide level, surge and actual tide level. On the night of February 4th/5th 2014 how much of the observed tide level was due to surge? What would have been the consequences for Exmouth if the largest surge measured along the south coast during the winter storms of 2014-2015 had coincided with the highest tide of the winter?

• What will now be done to reduce the risk of tidal flooding and wave overtopping at Exmouth?

In its original draft consultation document Managing Flood and Coastal Erosion Risk for the Exe Estuary both the East and West banks of the River Clyst (see the set of location photographs
in **Resource 7.2** and the briefing note in **Resource 7.3**) were identified as potential sites for inter-tidal habitat compensation.

**Consolidating your thinking**

- Read the original proposals for the East and West banks of the River Clyst on pages 16-17 of **Resource 6.16**. How was it intended that the new inter-tidal habitat would be formed and what area of habitat would have been created?

- Environmental management proposals are often controversial and divide opinion and the habitat creation proposals for the East and West banks of the River Clyst illustrating this. Read through the information in the sources below. On what grounds did many of the local landowners oppose the proposals?


  http://www.exmouthjournal.co.uk/news/flood_fears_remain_forcampaigners_1_2218350

In November 2014 the Environment Agency altered its proposals for the west bank of the Clyst river on the grounds that: “investigations show the Clyst site would not work and it would not be able to provide the habitat suitable to meet the legal requirements”.

The Environment Agency’s favoured location for the creation of compensatory inter-tidal habitat is now the lower Kenn Valley in the Powderham Castle estate situated on the west bank of the estuary 1.5 Km east of the village of Kenton and 2 Km north of Starcross – see the location map **Resource 7.4**, the two locational satellite images **Resources 7.5** and **7.6** together with the terrestrial photographs of the site in **Resource 7.7**. If the project goes ahead sea water will be allowed access through weirs and valves onto an area of low lying predominantly rough ground and freshwater marsh. This will create between 35 and 49.8 Ha of habitat (Mudflats, Saltmarsh and Grazing Marsh) to compensate for losses elsewhere around the estuary shoreline.

**Consolidating your thinking**

- How might the fact that the area under consideration for habitat creation in the Kenn valley is of little agricultural value (Grade 4 only) or existing freshwater marsh owned by just one landowner make it more likely perhaps that the Environment Agency will receive a more favourable response here than for its proposals for the east and west banks of the River Clyst?

- The foundations of the castle date from the 1390s and it is interesting that one of the earliest images of the buildings, the 1745 engraving in **Resource 7.7**, shows historic flood and erosion defences along the shoreline with the Exe Estuary. Since it opened to the public in 1959 over 1 million visitors have come to Powderham Castle to enjoy its many attractions – see: http://www.powderham.co.uk/ Currently a 2+2 family ticket ranges in price from £29.00 to £37.50 depending on the time of year. Consider how a new inter-tidal habitat attraction to which thousands of wading birds and geese would be drawn every year (particularly during the winter) could have an economic value for the Powderham Castle estate much greater than that offered by the existing low grade farmland and marsh. Using the aerial photograph in **Resource 7.8** as a template, design a plan for the area which would be particularly attractive to bird watchers and
photographers and people walking the nearby Exe Estuary Way. To assist you in your thinking to inform your design and the possible benefits for the landowner that might accrue visit the Slimbridge Wetland Centre website at http://www.wwt.org.uk/wetland-centres/slimbridge/. This is the most popular and successful centre of its kind in the UK.

- If the proposal to create new inter-tidal habitat at the lower Kenn valley does get the go-ahead then there will be a number of management and engineering challenges associated with it. Study the images in Resource 7.9 together with the map and satellite images in Resources 7.4 – 7.7 carefully. What possible problems relating to the future management of the site can you identify?

- The whole area designated for potential compensatory habitat creation in the lower Kenn valley currently lies behind existing tidal flood defences (a sea wall) upon which both the mainline railway from the South West to London and a road are located. At the moment the River Kenn flows into the estuary via a tunnel through the sea wall and underneath both the road and railway. What do you think may need to be done in the new habitat area to the west of the existing sea wall to ensure that it continues to act as an effective flood defence structure?

**Applying your thinking**

In 2011 the UK government introduced a system called biodiversity offsetting. This means that developers e.g. builders and mining companies must compensate for the loss of habitats and species in one area with the creation of new habitat suitable for the same species in another. It is an approach widely used in the United States and Australia and becoming increasingly common in the UK. It is an approach which is similar in many ways to the compensatory habitat that has to be created as a consequence of coastal squeeze. It is also a very controversial approach about which public and professional opinion is divided. Read the following articles to gain an awareness of the arguments on both sides:

http://www.theecologist.org/News/news_analysis/499256/what_is_biodiversity_offsetting_and_how_would_it_work.html

http://www.theguardian.com/environment/2014/jun/03/conservationists-split-over-biodiversity-offsetting-plans

http://www.wildlifetrusts.org/biodiversityoffsetting

The Exe Estuary

Line of Enquiry 8: Bringing it all together – writing up your research investigation
In terms of writing up a research investigation in Geography at A Level the precise requirements of different examination board specifications will vary to some degree e.g. in relation to the application of precise ICT and statistical skills but the general structure required of a write up is nevertheless much the same. In writing up your Exe Estuary investigation it is important to refer back to Line of Enquiry 1 where time was spent evaluating the approach taken to researching the Exe Estuary and the thinking you did there needs to be incorporated into your write up. Across all of the examination specifications there is a strong emphasis at all stages of a research investigation on students demonstrating the capacity to critique and evaluate and to question both the validity and trustworthiness of data collection methods, presentational and statistical techniques and the conclusions and judgements which are made. During this research investigation you have been encouraged to do this as an ongoing or iterative process. One possible structure for writing up your research investigation is:

**Aim and objectives of the research investigation**

In this section it is important to present and justify your research question and to identify why you consider the investigation to be a valid and worthwhile piece of geographical research to be undertaking. Therefore a link needs to be made to a relevant and geographical issue, concept, theory or topic – in this case investigating the potential impacts of climate change at a coastal location and the associated implications for sustainable management in the future – and how this has underpinned your research. You also need to identify the research hypothesis you are using – the statement you are going to test through research – and also the null hypothesis that you will be using in the statistical testing of primary data collected through fieldwork. Take time to justify why you feel the research question, hypothesis and the null hypothesis are effective mechanisms to be steering the research. An important aspect of this will be to make clear that you are aware of the assumptions you may have made, perhaps unknowingly at the time, when you generated a research question, hypothesis and null hypothesis.

Having explained the aims and objectives of the research it is important that you clearly identify the location of your research using appropriate maps, images and graphical techniques; as well as the risk assessment considerations you made in advance of your investigation. This relates particularly of course to fieldwork elements e.g. carrying out sampling along a beach transect, and you need to identify the main risks and the control measures you put in place to mitigate them as far as what practical and reasonable. It is worthwhile when undertaking risk assessments to discriminate between hazards that have to be avoided and risks that need to be managed through mitigation.

**Methodology**

You need to make clear in this section the approach that you have taken to find out what is required and to gather the information needed to test the hypothesis. These are not your methods e.g. a questionnaire or quadrat analysis but the concepts, theories and general approach that underpin the methods. So, you will need to make it clear whether you have pursued a quantitative, qualitative or mixed methodology approach to your research investigation and to demonstrate that you are aware of the advantages and disadvantages of all three approaches to research e.g. that some geographers feel that only ‘hard’ numerical data that is free from subjective human emotion can be used to test a hypothesis since only this kind of data can be tested for statistical significance. The same geographers will feel that any data likely to be influenced by human irrationality or error is not suitable for an hypothesis testing. Your reading in Line of Enquiry 1 will support your thinking here.
In this section it is also important to describe, explain and justify the sequence of the investigation you undertook and to provide an insight into how you have planned and organised your research. Again, take time to reflect on this with regard to its limitations. For example, accessing the research location may have only been possible at particular times despite your best efforts at planning because the bus service you were using only ran at certain times or you discovered that the beach at Dawlish Warren was closed for two days following damage to the sea wall. All research is limited in these sorts of ways and it is important to demonstrate that you recognise this and can critique what you have done stage by stage.

**Methods**

Now is the time to provide an overview of the precise tools you have used to gather the data you require to test the hypothesis and answer the research question. Take time both to justify why you have selected each of these data collection methods but also make it clear that you are aware of their strengths and limitations as well. For example using a well-designed questionnaire with a relatively small number of relevant questions with multiple choice answers can be a very effective way of easily and rapidly gathering the views of local people and visitors about the long term management of their coast. However, the limitations of this method will certainly include not being able to get either a random sample i.e. each individual in Dawlish Warren has an equal likelihood of being selected to answer the questionnaire or a stratified sample e.g. if 54% of the population of Dawlish Warren is female then 54% of questionnaire responses should be female.

Once again it will be important to demonstrate how well you have organised and thought through your data collection e.g. locations, times, sampling methods, sample sizes used etc. to achieve as much accuracy as possible and to reduce bias to a minimum. As before it will be important to critique and evaluate your approach and demonstrate that you are aware of any glaring limitations or inaccuracies caused by assumptions that you may have made or the weaknesses of particular techniques that you have used. For example, laying out 10 transects along Dawlish Warren beach at 100m intervals and then sampling sediment size along each transect at 0m, 25m, 50m, 75m and 100m provides a very precise stratified sampling method which generates data relatively rapidly which can be statistically tested for significance (important say when time is limited during a one day fieldwork visit to a location such as Dawlish Warren) but there are of course limitations to this method also. For example, because Dawlish Warren is part of a National Nature Reserve and Special Protection Area sediment samples cannot be removed for analysis in a laboratory using a Keck Sand Shaker (which can sort the sample into one of 7 size categories) and so measurement would need to be done using much less sophisticated sieves and ‘best fit’ picture keys which increases the likelihood of human error when estimating size.

**Data Presentation**

Your precise selection of cartographic, graphical, statistical and ICT skills and their complexity to present the data generated during the research phase may be determined by examination specifications but in general terms exactly the same principles of choice, justification and evaluation hold true here as with the selection of methods of data capture. You should therefore look to explain both the strengths and potential weaknesses of each technique you have used as a means of presenting data. For example although choropleth maps give a good visual impression of change over space e.g. average income levels in each local authority of the UK, they provide a false impression of abrupt change at the boundaries of one LA with the next and considerable variations which might exist between incomes within each LA are obscured. A scatter graph is often used to demonstrate with clarity whether a linear...
A relationship exists between two variables e.g. house prices and distance from a town centre but it is limited in value because either a positive or negative correlation does not imply causality e.g. house prices may well be found to increase with distance from town centre but the causal factor may be nothing to do with the perceived unattractiveness of the town centre (an assumption you may have made to begin with) and more to do with access to a newly established country park on the outskirts of the urban area.

**Interpretation and analysis**

In this section it is important to describe and analyse your results as accurately and in as much detail as possible in relation to the original research question and hypothesis. Data analysis is the process of looking at and summarising data to discover useful information which will support you in the next section to develop conclusions make judgements and reach decisions which confirm or falsify your hypothesis. Look particularly to make links between data sets e.g. between the width of the beach at various points along the beach at Dawlish Warren and the sediment profiles. Does their appear, for example, to be an association between those sample points where beach width is narrowest and sample sediment points where no zoning or clear grading is discernible? If so then this may be the location on the beach where the incidence of highly destructive waves during the winter storms of 2014-2015 were most frequent. Is this borne out by any secondary information collected by another agency or organisation or by the observations of local residents who were surveyed?

**Conclusion and evaluation**

The conclusion should summarise your main findings arrived at through the analysis of the data you have collected. This could take the form of a number of summary statements. It is important that you summarise what you have found out and how it has helped to further your understanding of the geographical problem, issue, theory or concept upon which it was based. It is also crucial that you now refer back to the original research question and hypothesis and make a judgement as to whether the null hypothesis has been proved or disproved. If you have been testing a theory for example, it will be important to explain how and why your findings either support or contradict that theory. You will have critiqued your research at each stage of the write up and in the final section it is imperative to offer an overall evaluation of your geographical investigation. For example this might include offering ideas about how the effectiveness of the data collection and presentation methods you used could have been improved and also recognising the assumptions you made at various points which in hindsight have proved erroneous. Evaluation is about identifying problems and difficulties encountered in your research which could have distorted the results e.g. only carrying out a questionnaire on a mid-week afternoon when most people of employment age would have been at work or in education centres. Evaluation is also about reflecting on the validity of your results and conclusions. This is about discussing whether your findings and conclusions from research can be trusted as logical and true. Take time therefore to reflect on the limitations of your research and how these limitations may have resulted in a distorted or biased outcome and subsequent conclusions and decisions. Part of this will be about making suggestions regarding how your research could have been improved and what you would do differently again or extend if you had more time available. This might involve suggested improvements to methods and/or sampling but could also, for example, include ideas about how the validity of your result might be increased by carrying out a another investigation at a similar coastal location to ascertain whether results there support or refute the findings of the original study of the Exe Estuary.