Coastal lowlands; The need for an integrated Response.

By Robert Ware

A thesis into how Europe's coastal lowlands can adapt to potential sea level rises.

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Thesis

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Acknowledgements

This thesis has been a fascinating exploration of a subject which until a couple of years ago, I had little experience of. I have used this study to investigate further a topic I feel is of huge importance, one which I have been continually investigating throughout this year's work and has been incorporated within my project.

With much appreciation and thanks to:

Ian Fisher; my dissertation tutor who guided and helped me through what has been a challenging but exciting year in my life.

The **Environmental Agency** and **European Environmental Agency** for their information supporting my research.

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Finally a special mention to my family and friends for all their support and guidance during this time as well as their continued patience over the past 7 years.

Executive Outline

"In 1992, the Earth Summit of Rio de Janeiro recognised in its Agenda 21 the need for environmental action for oceans and coastlines (Chapter 17) and committed coastal nations to the sustainable development of their coastal areas and implementation of Integrated Coastal Zone Management (ICZM)."[1]

Quite rightly too, with the threat of climate change allegedly fuelling sea level rise, popular statistics that are often stated are that 40% of the global population lives within 100km of the coastline[2] and therefore need protecting. The reason why nothing has been seen or heard about these developments in the past 20 years is that they have not occurred. Perhaps that statement is a little callous, a more accurate unbiased opinion may be that governments within the European Union have not done enough. And why should they? After all, if you look a little more closely at all analysed data relevant to the subject, there is still an ambivalent opinion as to whether we, as a society, are kindling climate change and as a consequence; fuelling sea level rise. Landforms in the form of tectonic plates are constantly shifting, not just laterally, but vertically as well. It has been proven that over the past 50 year's 'edges' of continents have risen and fallen by several centimetres due to these movements, therefore giving the appearance of sea level 'rise' on the areas that are actually slowly subsiding into the waters. In response to the statistic that 40% of the global population lives within 100km of the coastline, this is unarguably true. However, to give the

[1] European Environmental Agency (2006) *The changing faces of Europe's coastal areas*, Copenhagen: European Environmental Agency.
[2] SEDAC (2007) http://sedac.ciesin.columbia.edu/es/papers/Coastal_Zone_Pop_Method.pdf

laymen reader a contextual view of this statement, England is, at its widest point, 520km in width, but on average only 200km. In this respect the majority of England would be considered a coastal population! Along with this, an important figure that should be appreciated when reviewing this subject is that worst case scenario predictions for sea level rises have shown a two meter increase over the next 100 years. Geographically, the landforms around almost all European coastlines increase above two meters within a 5km margin of the coastine; a number far short of the 100km that would be affected in the above 'statistic'. From researching and integrating these figures into my design project this year I have, however, taken into account the effects of storm surges and potential flooding due to precipitation exacerbating coastal flooding and therefore I have raised this figure to five meters to facilitate a 'safety buffer', as it where, within my designs.

The figures that I have produced becomes the underlying defining parameters that focus this dissertation. An expanded title might be *'How can Europe's coastal lowlands adapt to climate change [within the parameters of a predicted two meter sea level rise requiring a coastal management plan to protect all land below five meters]'*.

There are a multitude of problems created by any sort of sea level rise, not only for the populated areas, but for the natural areas of wetlands and marshlands as well. By the conclusion of this work, I hope to have formulated the basis for a *concept* to coastal adaptation that reflects the needs of all 'Anthropocentric' and 'Biocentric' elements in a functional and sustainable way. *Rob Ware.*

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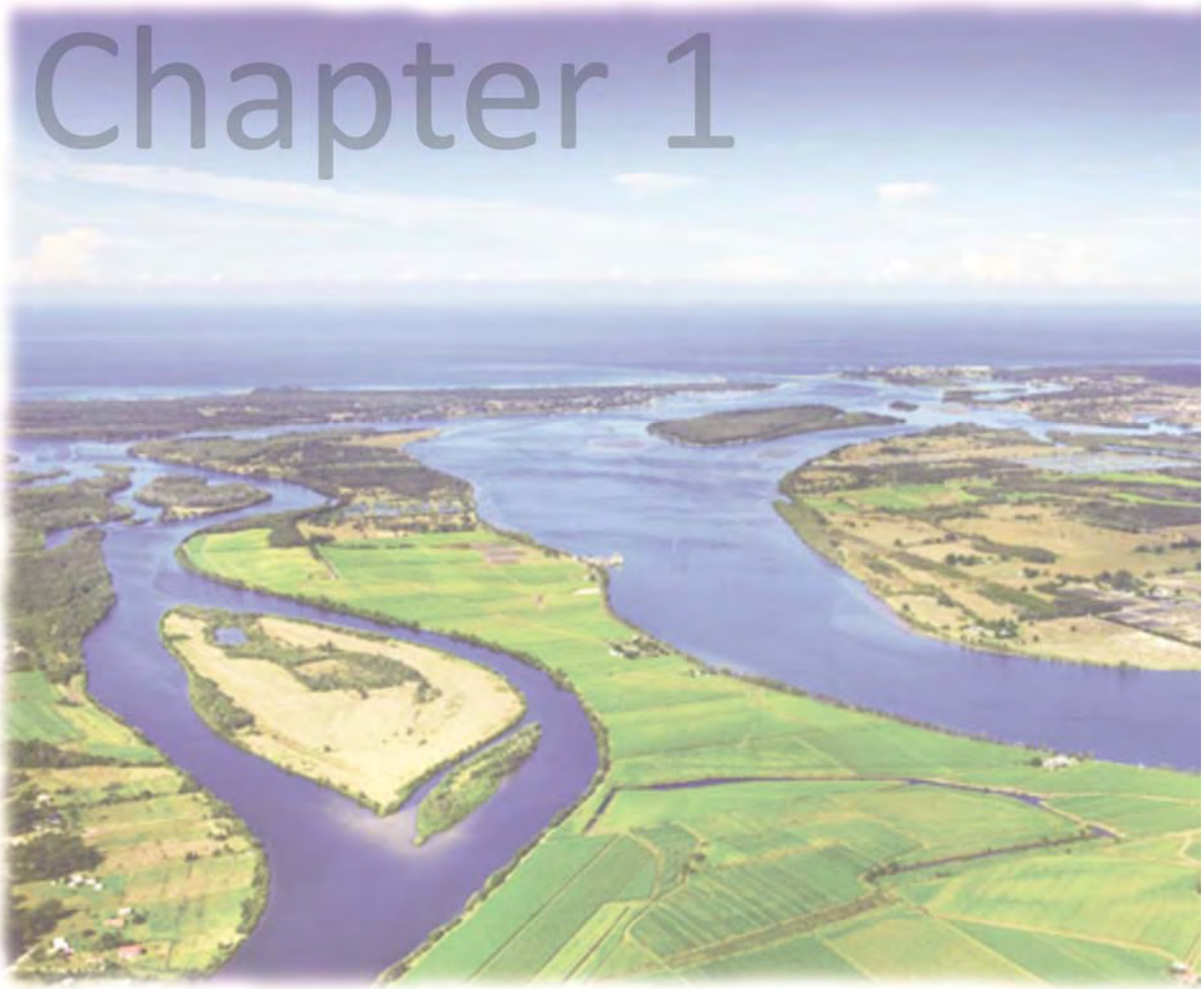


Introduction

The concerns about climate change are known globally. The number of reported natural disasters over the past 30 years has increased significantly; *Figure 1* shows that 133 disasters where reported in 1980 while in the past 10 years it has been commonplace that over 350 are reported annually.

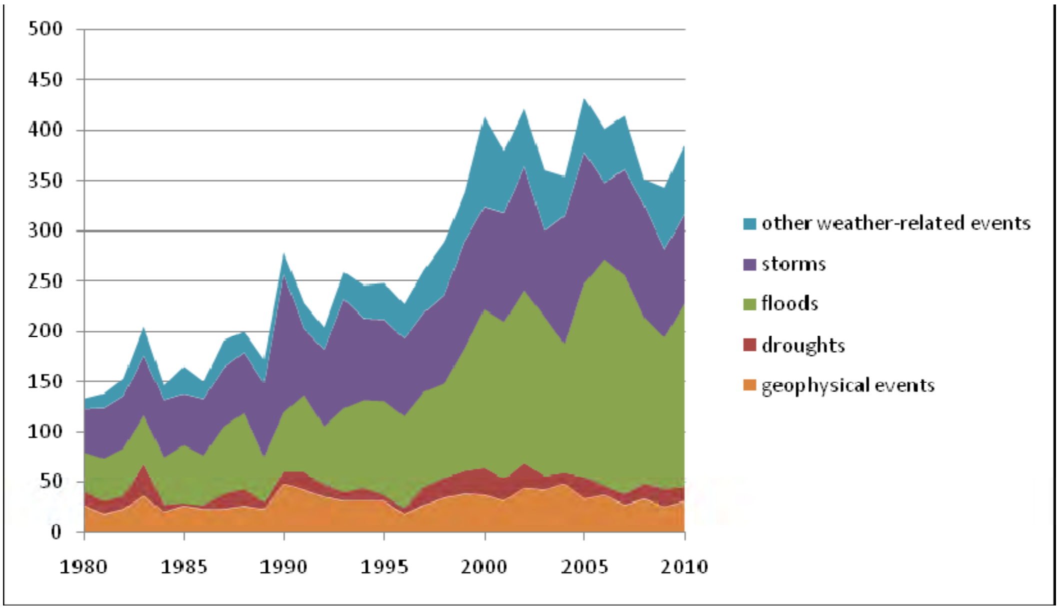


Figure 1: Number of reported global natural disasters. Note: 'Other weather-related events' are wildfires, extreme temperatures, and wet mass movements; geophysical events include earthquakes, volcanic eruptions, and dry mass movements. Source: CRED (2011).

With the increase in sea level rise being exacerbated by climate change, that fuels more intense and more frequent flooding and storms, it is understandable why these figures may be increasing, but it must also be noted that as populations expand towards coastal regions - where land can be more fertile for agricultural purposes and is often more valuable for residential development - we are also increasing our vulnerability by locating ourselves in these exposed regions increasing the likelihood of a 'disaster' occurring. Remember; 'a hazard only becomes a disaster when it coincided with vulnerable people.'[1]

[1] Jennings S. (2011) *Times Bitter Flood.* Oxfam Research Report, Oxford: Oxfam GB

The automotive and construction sectors are two of the key industries thought to be fuelling this problem and although massive advancements in technology and efforts to reduce this impact have been greatly improved in recent times, it is unknown as to whether we are solely responsible for this change or are we just accelerating an existing issue. It is historically proven that the planet has gone through climatic changes previously from ice ages to its current conditions, ergo it is arguable that at some point in the future we may have had to have dealt with such problems anyway as global temperatures gradually increased and inland icecaps melted, if only at a slower rate. Why not use this time to develop something truly sustainable, something for the future that can be as adaptive as required to unpredictable conditions and not potentially waste millions, even billions globally, replacing so called 'defences' every time we realise they are not adequate enough or they fall into disrepair. The Environmental Agency estimates that around £570m is spent every year building and maintaining the defences required to protect 2.4m properties at risk of flooding in England[2].

"...*those of us alive today have a rare privilege that few generations in history have known: the chance to undertake an historic mission worthy of our best efforts. It should be seen as an honour to live in a time when the future of human civilization will be shaped forever by what we do now*."[3]

[*Al Gore*]

[2] Newspaper report (Fri 29.01.10); http://www.guardian.co.uk/environment/2010/jan/29/cost-of-uk-flood-protection. Source: Environmental Agency

[3] Gore A. (2009) *Our Choice, A Plan To Solve The Climate Crisis.* 1st edition, London: Bloomsbury Publishing Plc

Unfortunately, many of the locations most vulnerable to these effects do not have the self-reliance and resources to prepare for such eventualities. Low-lying coastal regions in developing countries such as India, Vietnam and Bangladesh contain many large scale populations living on these at-risk areas on the coast and river deltas [where inland rivers enter the ocean]. Island nations such as the Philippines and Indonesia are at even more of a severe risk as they do not have the physical land elevation to escape the worst sea level rise, meaning an evacuation of these areas and large scale immigration may see nations forced into providing asylum towards the end of the 21st century. That, however, is an entirely different and more complicated issue where political factors will play a huge role in determining an outcome. What is for sure is we cannot wait that long for a resolution. By that time, the full effects of the climate crisis will have taken hold and it will, in all likelihood, be too late to stop a process we have already now put in motion. Future generations that have been condemned to an unpredictable, but catastrophic degradation, will be well within their rights to look back at us as 'a criminal generation that they could curse endlessly as the architects of humanity's destruction' (Gore, 2009: 28).

This dissertation, though, will focus primarily on Western Europe where the threat of sea level rise is just as significant in certain locations [such as Southern parts of France like Marseille, Eastern Spain and lowland agricultural areas around England's coasts such as Cockerham in Lancashire as well as the entire Netherlands coastline], but where if there is action now, a sustainable, effective and potentially lifesaving design can be implemented. The first issue that needs to be understood when considering this investigation is that it is not the entirety of Europe's coastline that is in danger, much of it is above the pre-defined 5m 'safe' elevation level. Therefore the first point of investigation, and the second chapter of this work, is an in-depth look at where these 'at-risk' locations are within the designated survey area. *Figure 2* shows a map of Europe highlighting all the locations below a 5m elevation.

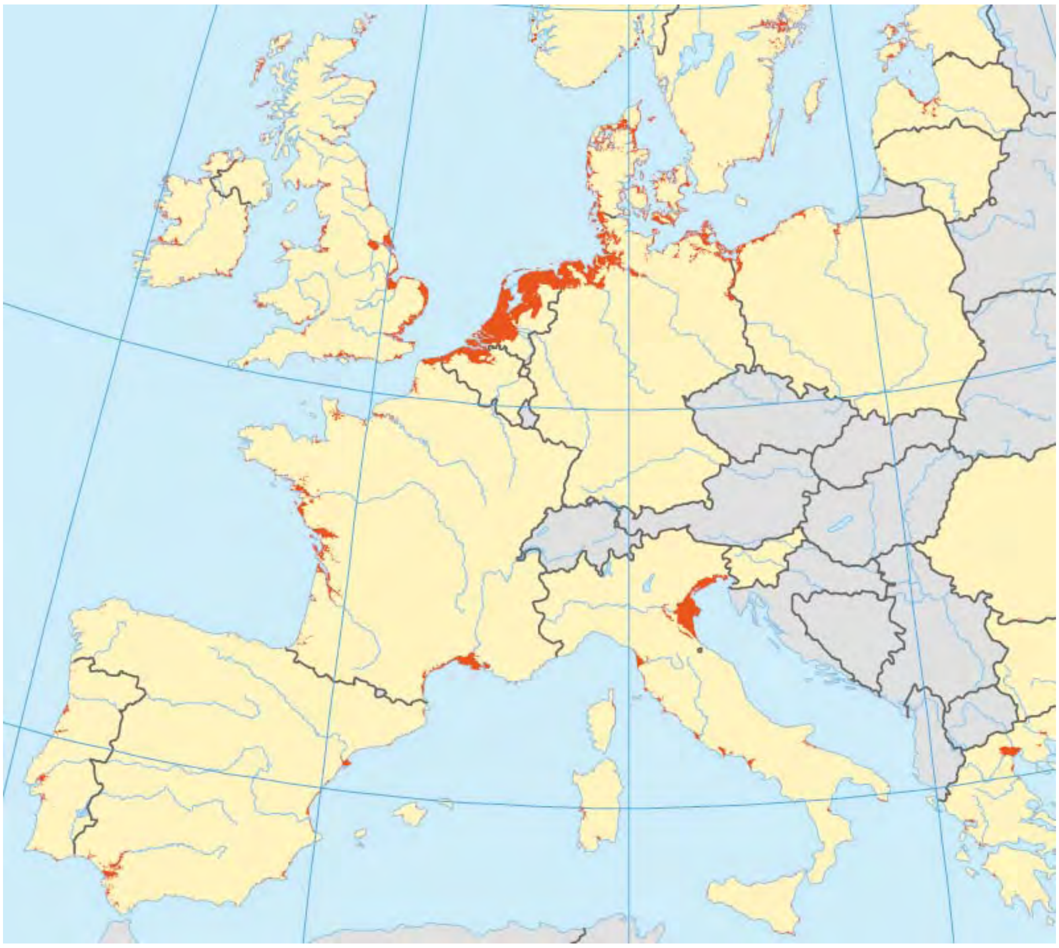


Figure 2: Map of Western Europe Highlighting Areas below 5m elevation

To understand how best to adapt these areas against sea level rise, it is important to know, amongst other things, the primary land use for these areas as this will shape the response required. The European Environmental Agency undertook a European wide investigation, in 2006, of land-use as part of their on-going research into climate change; *Figure 3* shows the results of this study. The mass of information makes it hard to appreciate at anything more than a local scale and unfortunately does not distinguish between coastal and inland areas in its data. However, overlaying *figure 3* on top of *figure 2* provided me with the land use data relevant in the ‘at-risk’ areas and will be covered individually in a greater level of detail for each case study in the following chapter.

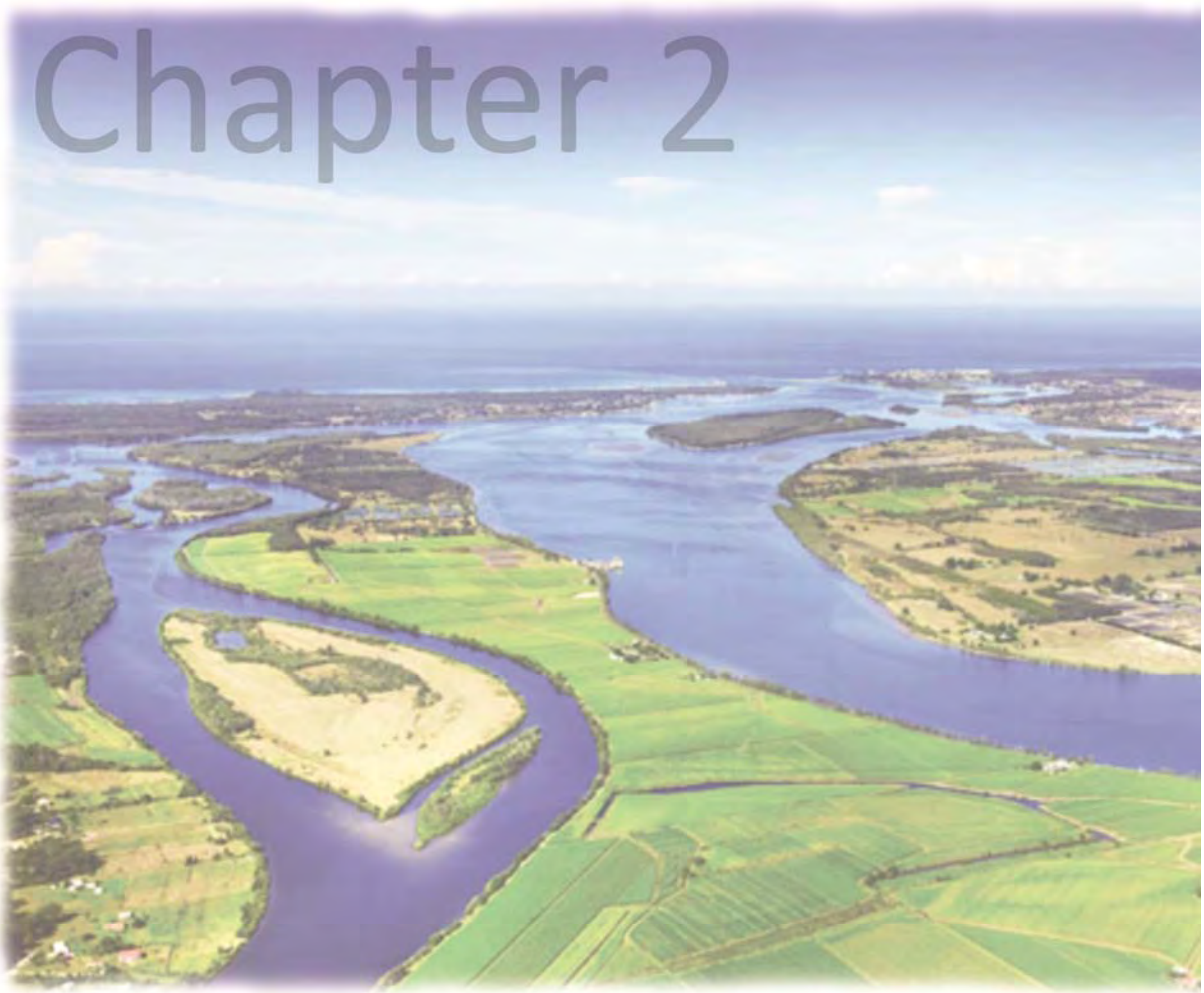
Figure 3: Map highlighting land use of Europe in 2000

Combined with these two primary elements [land elevation and land use] there are other important factors that must be investigated and incorporated to any potential solution. In brief these are; population of location, tourism and access to coast, existing habitats for bio-diversity including coastal shelf ecosystems, economic and industrial uses and potential contamination of these areas.

With the growth of the population, people are more and more residing within areas below flood plain levels and on low-lying coastal areas. Often it is not the increased physical magnitude of climatic events that cause problems and destruction, but our increased vulnerability by locating ourselves within these areas. It would obviously not be a sensible option to intensify the density within inland urban areas in an attempt to avoid the coast, but it is important that these 'seaside' urban developments are integrated within any coastal design solution to maximise effectiveness. Results of the EEA (European Environmental Agency) report also shows that the European coast is made up of a diverse range of landscapes and cultural contexts, while natural ecosystems have also proven effective in increasing coastal resilience to protect coastlines during storm surges. All of this information must be maintained within design responses to avoid oversimplifying the defences of these coastal areas, while the knowledge that a regional, or even local, location driven solution must be implemented that meets the needs of that specific site means a development can be constructed at any time via individual government decisions as opposed to waiting for a global resolution.

In the next chapter I will review case studies of lowland coastal locations around Europe that are most in need of a solution to sea level rise and all associated problems with it. This will underline in detail the specific data related to what I have briefly touched on in this introduction, which in turn will highlight the generic requirements to defend against sea level rise that will form a conceptual basis for any location specific solution.

Chapter 2



‘At risk’ location studies

The location studies chapter is a way to highlight the predominant issues, related to sea level rise, around coastal locations below the 5m elevation threshold. As explained briefly in the introduction, one of the key problems for mobilization of an integrated, sustainable strategy to defend against sea level rise is that it takes a long time to formulate a plan on the European scale with so many people and governments involved. By producing this analysis at the location scale, as opposed to the European scale, for just a handful of areas, I will aim to show that there are generic issues that can be addressed and utilised to formulate a basis for the concept of a solution that can be taken to any site of similar context and provide a homogenous, sustainable defence to rising sea levels. This will allow location specific governments or councils to take action quickly in an effective and well informed way without the need to wait for a wider governing body to pass legislation.

Location Study 1 – *The Netherlands*

Figure 4: Map of Western Europe with Areas below 5m elevation – Netherlands highlighted area

I will start with the Netherlands as it is the most well known problem area when it comes to flooding from to the sea, via storms or sea level rise. The country is unique in that much of the land is reclaimed from the sea and is therefore near or below sea level, protected by a number of natural and man made defences that include sand dunes (*figure 5*) and dikes, while at the same time is it one of the most densely populated areas on the planet.

Land Usage

The country can be divided into two distinct parts; the southern and eastern inland areas are flat, but are higher than 5m above sea level due to the risen landform areas and minor hills. The north and west coastal areas are low lying (less than 1m above sea level) and are completely flat. Stretching from the coast to further inland, these areas cover approximately half of the total land area of the Netherlands with much of it actually below sea level. The entirety of this half of the country is susceptible to flooding and sea level rise and encapsulates every category of urban and suburban anthropocentric and biocentric elements that need to be protected. As such the country is an extreme case for sea defence and faces issues now that other European countries, potentially facing the same threats, have not even started planning for. It does, then, represent a testing bed for these issues due to its immediate predicament and has been implementing different solutions for many years, some successful, some not, which we can learn from and utilise when necessary. These will be investigated more in the next chapter when 'existing solutions' are discussed. Over 60%[1] of the floodable landscape is made up of arable land, permanent crops and pastures or woodland. This is important to note as it is something that must be integrated into future sea defence, making it more adaptable and integrated with the biocentric elements as opposed to most of the current solutions which are based on and defend only the urban usage. No consideration is accounted for the natural organisms and ecosystems inhabiting these coastal areas and how they are destroyed by permanent, concrete sea walls that disrupt the fluvial process, many of which actually naturally absorb the affects of flooding and flood water.

[1] Corine Land Cover Map 2011, http://www.eea.europa.eu/themes/landuse/interactive/clc-viewer, European Environmental Agency.

Figure 5: Aerial view of the Dutch Coast, Netherlands, highlights how flat the low lying land is sat in close proximity behind the sand dunes

Figure 6: Aerial view of a dense urban area along the Dutch Coast, Netherlands. The land is at or below sea level meaning any substantial sea defence would enclose the area off from the sea

Potential Sea Level Rise

+0m (Existing Sea Levels)

The low lying land is already vulnerable to coastal flooding during storm surges, but will remain safe behind existing systems should sea levels cease to rise further.

+1m Sea Level Rise

As the land is so low lying and existing defences on the verge of breaching, a mere 1m rise in sea level would see a large part of the country flooded.

[2]

+2m Sea Level Rise

A 2m sea level rise would place a large amount of people in direct danger. Without adaption of large sea defences, the only viable response would be an evacuation of the region.

[2] Predicted data from http://geology.com/sea-level-rise/

Summary

The area of the Netherlands threatened by floods is essentially an alluvial plain - a relatively flat landform created by the deposition of sediment over long periods of time. Originally this would have been an entire flood plain, but as settlements developed and the first dikes put in place to protect agricultural lands, the location of the flood plain was altered to remain along the coast. As sea levels rise, these manmade defences became insufficient and the entire developed low-lying areas in danger of becoming part of the tidal process once more. As the entire Dutch coastline is a sand dune, it has become a very popular destination for tourists and regularly receives thousands of visitors. As this contributes to a large income in terms of the country’s economy, the loss of this space is often considered a much more significant driving factor in the defence of sea level rise. A document released by the *Ministerie van Verkeer en Waterstaat* back in 2005 highlights all the investigated issues and problems as well as this extract:

> *“Sea level rise. 3 scenario’s:*
>
> *•20 cm per century: for decisions with short design life (low investment or high degree of flexibility) (sand nourishments)*
>
> *•60 cm per century: for decisions with design life of 50-100 years (dikes and storm surge barriers).*
>
> *•85 cm per century + 10% increase of wind speed per century”*

Throughout my research, initiatives from the Netherlands were the only strategies that incorporated variable possible future scenarios for sea level rise.[3]

[3] ‘*Coastline management in the Netherlands*’. Ministerie van Verkeer en Waterstaat, 2005

Location Study 2 – *Southern France; Marseille to Montpellier*

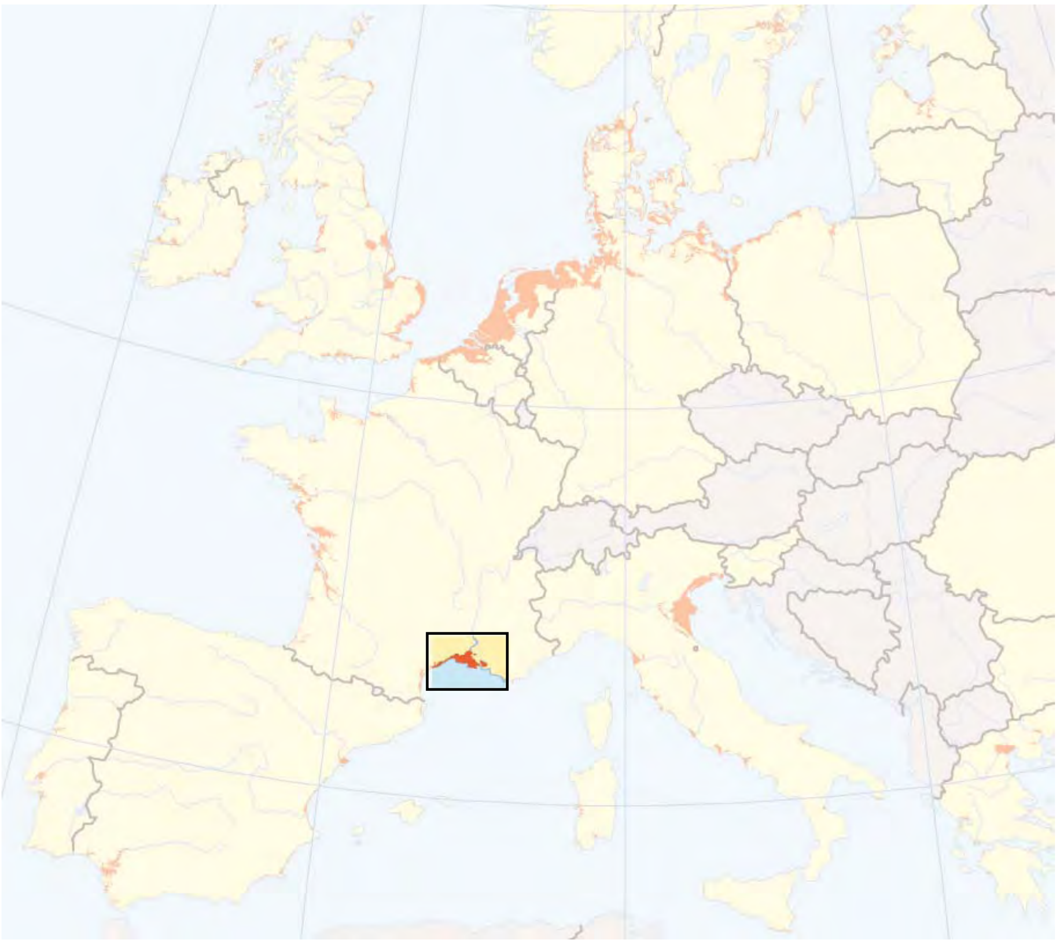


Figure 7: Map of Western Europe with Areas below 5m elevation – South France highlighted area

The south of France has some of the lowest lying land of the entire Mediterranean coastline, except for Venice in Northern Italy. This has been highlighted in recent years with the increase in sea levels spurring more floods within the area. It was only June of last year (2010) that floods caused havoc and took 25 lives in an area just west of Marseille. Some of the lower, flatter lands lie between Marseille and Montpellier (*Figure 8*) and will be more susceptible to the increasing sea levels.

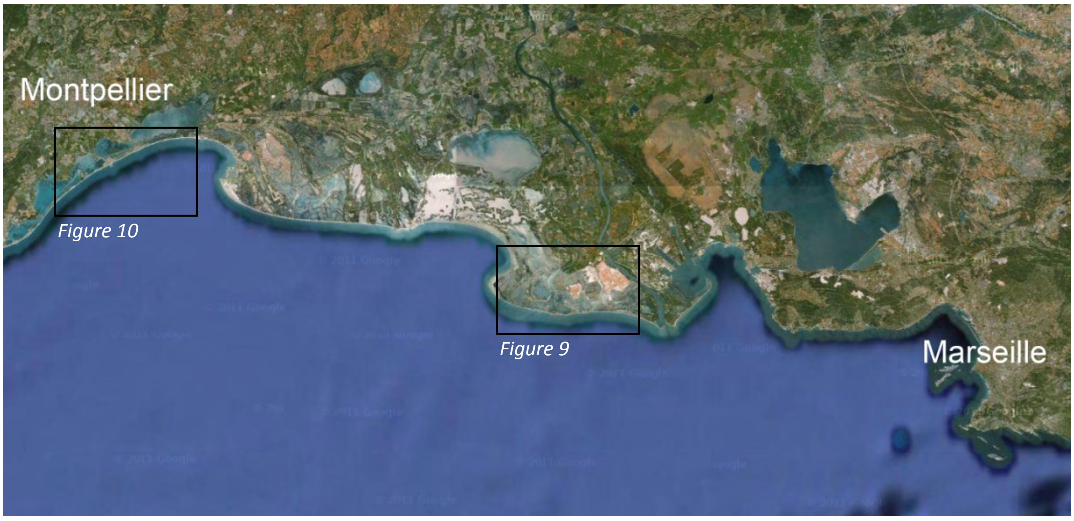


Figure 8: Map of Southern France between Marseille and Montpellier

Figure 9: Map showing one of several large agricultural areas between Marseille and Montpellier

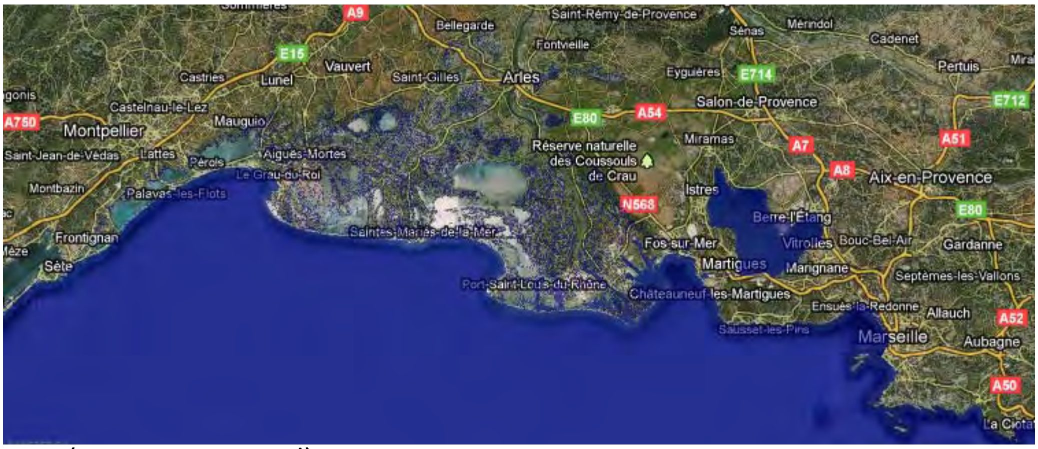
Figure 10: Map showing the man made coastline road protecting the Montpellier coastal areas

Land Usage

Apart from a few sporadic smaller settlements, most of this coastline is agricultural land or wild parkland and wetlands (*figure 9*). Approximately 9%[4] of the coastline below 5m is urban usage, meaning 91% is susceptible biocentric wetlands predominantly made up of coastal lagoons and salt marshes. Not only is this location vulnerable to rising sea levels along the coast of the Mediterranean sea, it is also the exit point of the River Rhone which is already prone to flooding. Starting from the peaks of the Swiss Alps, the Rhone collates several large river along its journey towards the Sea while also has to control the ever increasing water load from the melting ice within the mountain ranges themselves, meaning the deltas that make up the wetlands at the mouth of the Rhone are continuously flooded already. Further along the coast towards Montpellier, a man made road acts as a sea defence and creates artificial lagoons between it and the dense urban areas of Montpellier (*figure 10*). This shows that the local governments has made a conscious effort to protect these obvious low lying lands from a potentially serious issue, but unfortunately I feel this will not be enough if sea levels rise by 2m. Merely adding an extension to the inadequate concrete construction is not a sustainable and adaptable solution for the future. A more homogenous and environmentally sensitive solution can almost certainly be achieved and this is something I have been researching and incorporating into my university project this year.

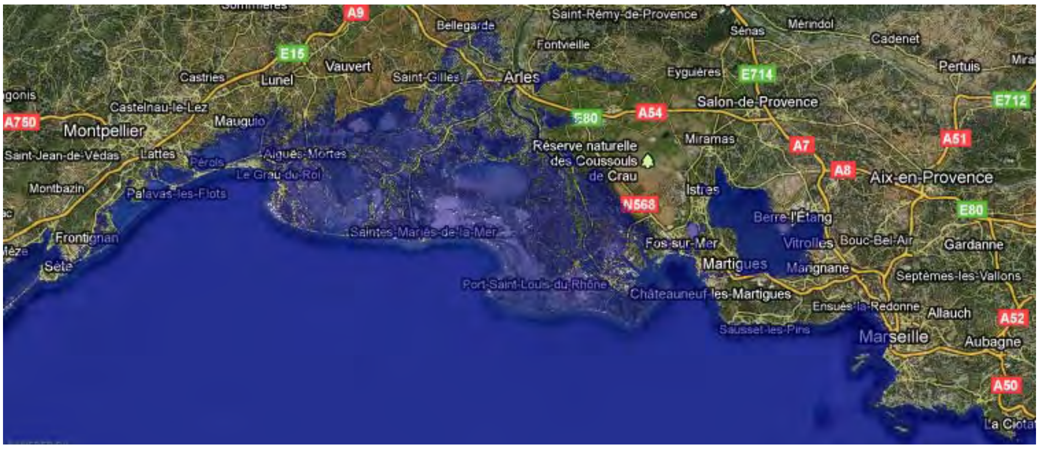
[4] Corine Land Cover Map 2011, http://www.eea.europa.eu/themes/landuse/interactive/clc-viewer, European Environmental Agency.

Potential Sea Level Rise



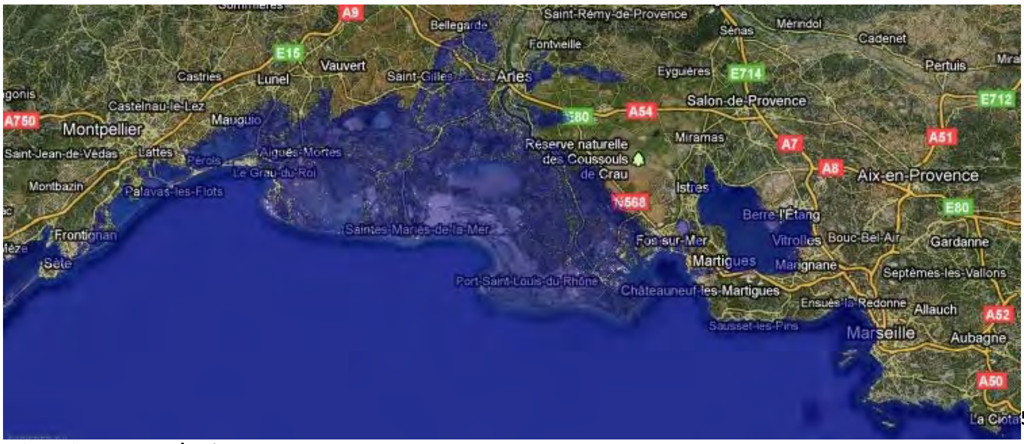
+0m (Current Sea Level)

The wetland delta at the mouth of the river can easily be seen at the centre of this aerial photograph and if left to its own evolution, it would adapt naturally without any problems to sea level rise. The addition of sea walls to protect urban and agricultural areas jeopardises these spaces as they concentrate the issues at these unprotected areas, meaning the land cannot adapt quick enough to the change, resulting in the loss of ecosystems.



+1m Sea Level Rise

A 1m rise in sea level would swamp the low lying wetland areas and some agricultural areas as the surrounding sea walls focus the water on them. Most urban areas would be protected, but a lot of natural resources would be lost.



[5]
+2m Sea Level Rise

A 2m sea level rise would see a complete reshaping of this coastline; all agricultural land utilising the naturally nutritious soil within the delta area would be lost. Existing sea defences would be useless meaning the loss of any settlements along the entire coast between Marseille and Montpellier.

Settlements further inland surrounding the delta and river Rhone would also become affected due to their proximity.

Summary

For this case study, the very defences that are in position to defend the urban and agricultural uses are only accelerating the problems in other coastal locations. This is one of the primary consequences that can happen with such engineered sea walls, as discussed later in this dissertation. Sea level rise must not be solved by looking at the issues at hand and how we can 'save ourselves', but our response must look at the coastline as a whole and form strategies that can adapt to all scenarios for the future, especially where there is a large percentage of natural resources available.

[5] Predicted data from http://geology.com/sea-level-rise/

Location Study 3 – *Eastern England; Between Norfolk and Lincolnshire Districts*

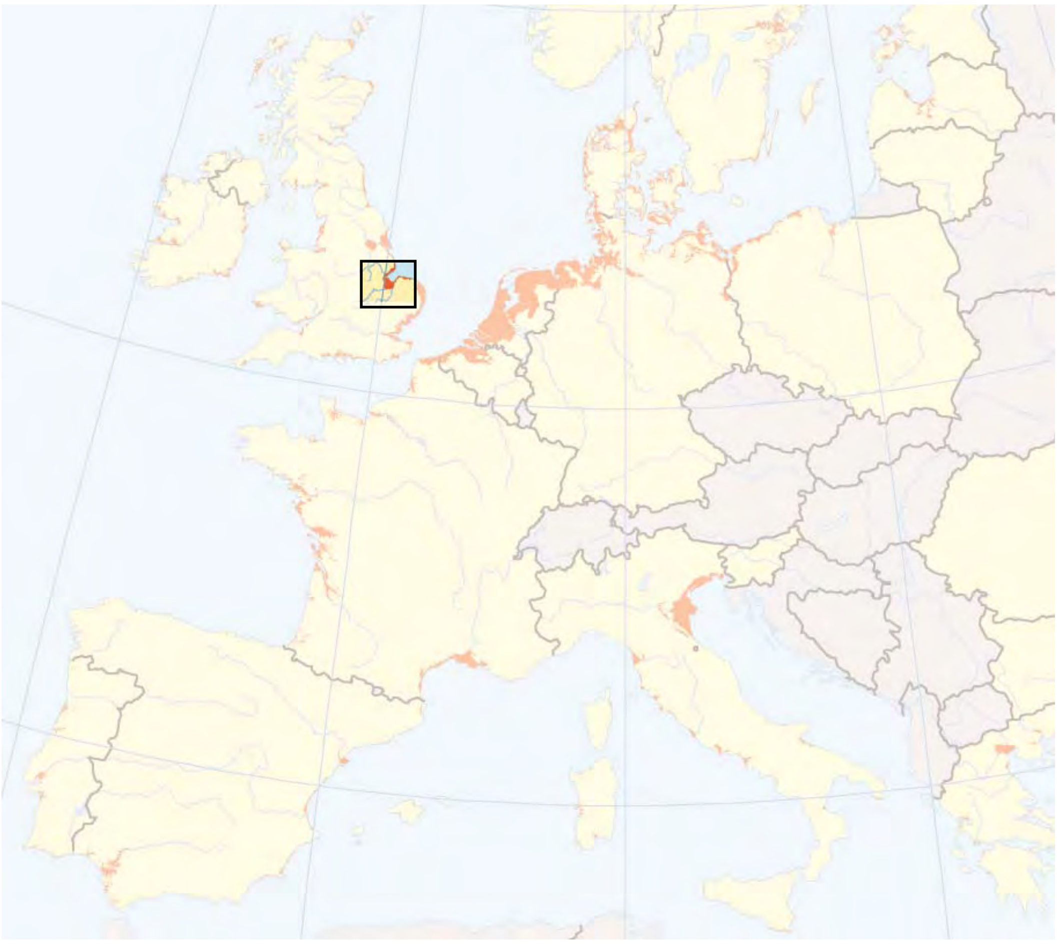


Figure 11: Map of Western Europe with Areas below 5m elevation –East England highlighted area

England has several low lying coastal regions, the majority of which are located along the east coast, off the North Sea. The region highlighted in the map above is a bay called 'The Wash' (*figure 12*) sitting between Norfolk and Lincolnshire. It is one of the largest estuaries in the UK and is fed by four large rivers; the Witham, Welland, Nene and Great Ouse. Similar to the case study in Southern France, this makes the location more vulnerable to flooding as it deals with rising water levels of not only the sea, but of the rivers that run through it. When flooding occurs it is less noticeable as there are very few settlements within it.

Figure 12: Map showing the agricultural lands on the east coast between Norfolk and Lincolnshire

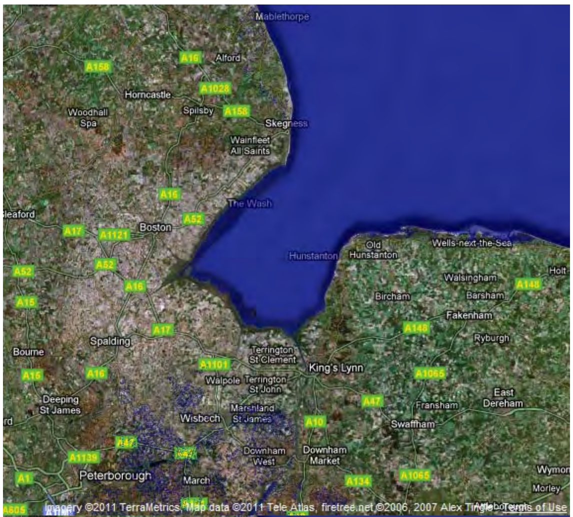
Figure 13: Aerial view highlighting the pattern created by continuously divided agricultural land

Land Usage

The Wash coastline is located at the heart of an area called 'The Fens', or 'Fenlands'. The fens are naturally marshy regions containing large quantities of dissolved minerals, but few other plant nutrients due it its saline environment. Most of the area was drained several centuries ago to provide low-lying, flat, moist agricultural areas lying within a few meters of sea level, but would originally have consisted of a combination of fresh and salt water wetlands. To protect these rich and fertile agricultural areas (*figure 13*), they are sat behind drainage banks and are continually artificially drained through pumps. Without this the Fens would be subject to cyclical flooding, significantly in the winter months when the surrounding rivers struggle to contain the large quantity of water flowing down from the higher surrounding lands. Through this process the Fens have become one of the biggest arable agricultural regions in Britain and contain approximately half of the grade 1 agricultural land in England. Much of the Fenland has similar problems to the Netherlands case study, where the majority of the land has been claimed from the sea and are now trying to defend it from the increasing sea levels as it pushes to reclaim the land. Most of the region is 1 or 2m above sea level, but some areas do fall below reaching as low as -2.75m. Further inland, towards the edges of the Fens, the land levels rise quickly towards 10m+ and a safer altitude from flooding, but this still leaves the majority of the land susceptible to risk. As mentioned previously, very few settlements are located within this region, due to its agricultural nature, with approximately only 4.3%[6] of the surveyed land classified as urban domain. This would influence heavily the design of an integrated sea defence for the future.

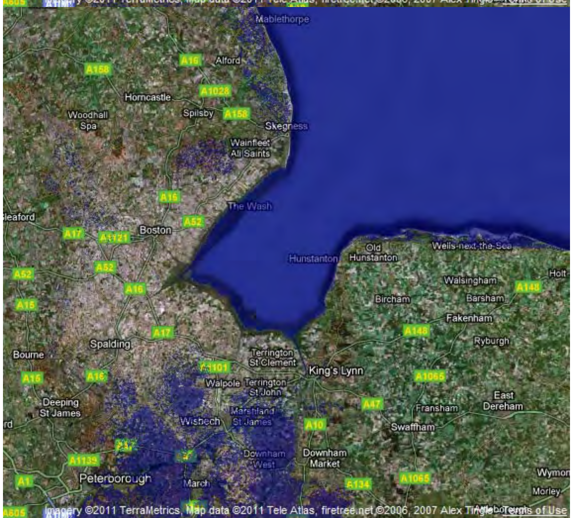
[6] Corine Land Cover Map 2011, http://www.eea.europa.eu/themes/landuse/interactive/clc-viewer, European Environmental Agency.

Potential Sea Level Rise



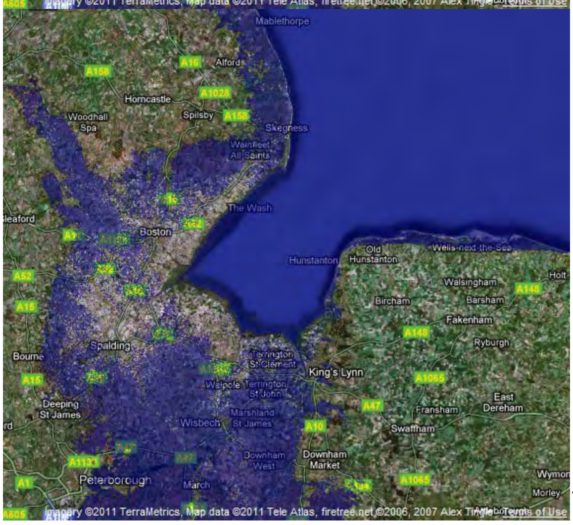
+0m (Existing Sea Levels)

Most of the land is still protected by the drainage banks in place and the natural marshes and wetlands that have formed behind the along the coast. Inland flooding is still a threat though due to close proximity of floodable rivers.



+1m Sea Level Rise

A 1m rise in sea level would still see the existing manmade and natural defences in place cope sufficiently to coastal problems, but due to the low lying nature of the region, inland flooding from storms and river swelling may cause problems.



[7]

+2m Sea Level Rise

A 2m rise in seal level would see a lot of the coastline enveloped tidally and as can be seen on the map, a large quantity of agricultural land would be lost. Almost 80% of the land would be reconverted to wetlands as it originally stood.

[7] Predicted data from http://geology.com/sea-level-rise/

Summary

The wash is designated as an SPA (Special Protection Area) due to its extensive number of salt marshes, inter-tidal mud flats and sand banks that provide habitats for numerous birds, waders and even shellfish in the more confined areas of the coast. The broad variety of vegetation that grows within the vast salt marshes and flats help dissipate energy from the incoming tides and therefore provide an element of protection to the lands behind the marshes. Recent studies into this process had led to several intentional breaches being made into the existing sea defences in an attempt to widen this marshland and provide a larger, natural defence to flood water from rising sea levels. This appears to be a highly effective and sustainable solution to this problem, while also provides much needed protection and extension to existing wetland habitats.

A final important element to note is the accessibility of the coastline and beachfront to locals and tourists, allowing magnificent views and appreciation of such an area. This should be an important element in any consideration for a response to rising sea levels as enjoyment within locations raises awareness of potential problems and enables a response to be integrated with human interaction in mind, but more importantly not a dominating factor.

Location Study 4 – *North West England; Cockerham Flats*

Figure 14: Map of Western Europe with Areas below 5m elevation –N.W England highlighted Area

Morecambe Bay (*figure 15 and highlighted above*) is also one of the largest bays in England and contains the largest area of intertidal mudflats anywhere in the UK. It is also the study location for this year's design module (MA LanArch; M.M.U., 2010/11) for which I based my project on how the coastal lowlands can adapt to sea level rise, subsequently influencing this thesis. Unlike the previous case study, 'The Wash', Morecambe bay contains several large coastal settlements, *figure 15*, along with its numerous large agricultural areas. The focal area for this case study, however, is the area highlighted in *figure 16*.

Figure 15: Map of Morecambe Bay

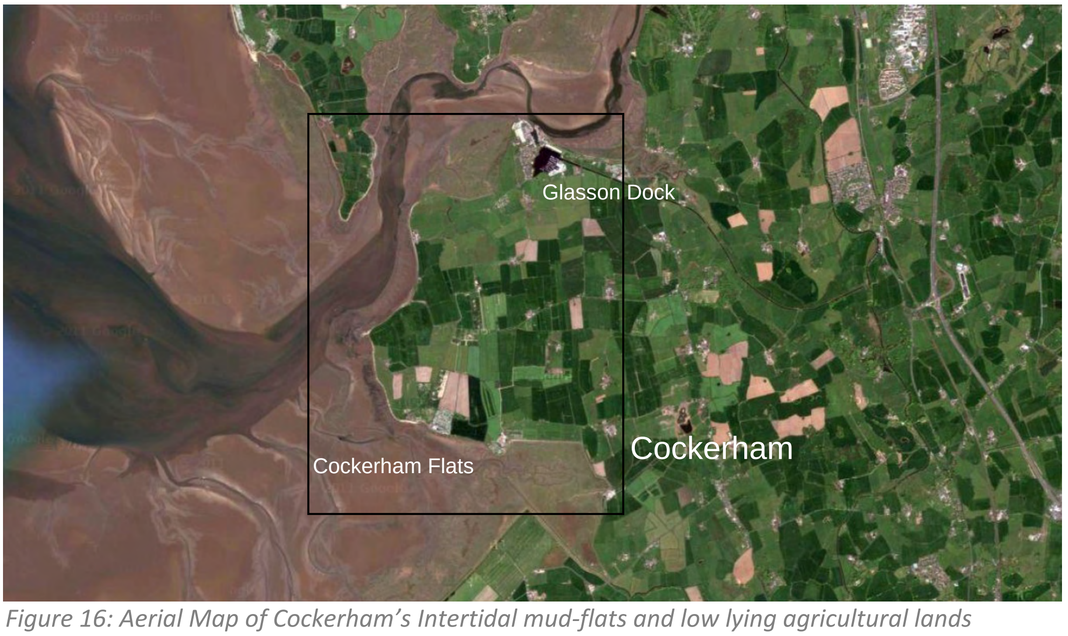


Figure 16: Aerial Map of Cockerham's Intertidal mud-flats and low lying agricultural lands

Land Usage

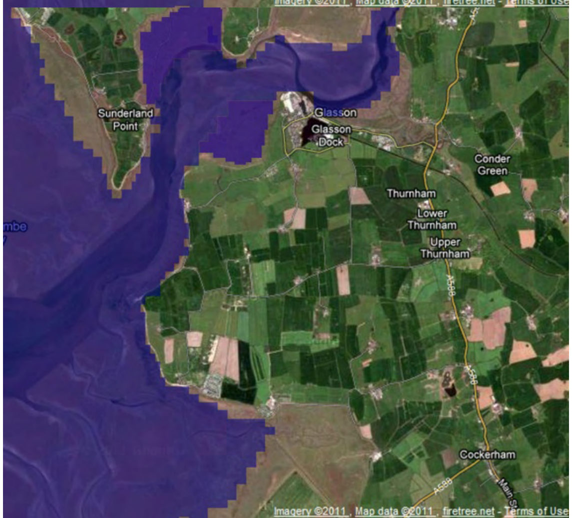
Barring Glasson Dock, a small village within the Thurnham district, containing approximately 600 residents, the entirety of the area highlighted in *figure 16* is agricultural land. Like many coastal agricultural areas of this nature, the land is claimed from the sea, meaning it is at, or below, sea level and defended by a series of manmade engineered sea walls. A trench drainage system running intrusively between each field, controls floods during storm surges and heavy rainfall, but unlike the Fens at 'The Wash Bay' the land has not retained any natural nutrients that are necessary for successful arable lands. As such it is in desperate need of natural replenishment that is obtained during tidal deposits that create nutrient rich marshland. Beyond the sea walls, the inter-tidal mudflats are some of the most important in the UK providing an abundance of natural habitats for many species of wildlife. Their significance is proven by the SPA (Special Protection Area), SAC (Special Area of Conservation) and SSSI (Site of Special Scientific Interest) designations. Construction of more sea walls or defences in an attempt to counteract the effects of sea level rise, that do not accommodate these areas in a sensitive and sustainable way, will result in loss of vegetation, habitation and natural diversity, weakening the ecosystem as whole.

Unlike the previous case study which maintains a successful tourist beach front, it is almost impossible to access the coastline at this location, meaning the area receives little recognition for its significance. It is important that any coastal defence integrates a human interaction to provide a value on the location.

Potential Sea Level Rise

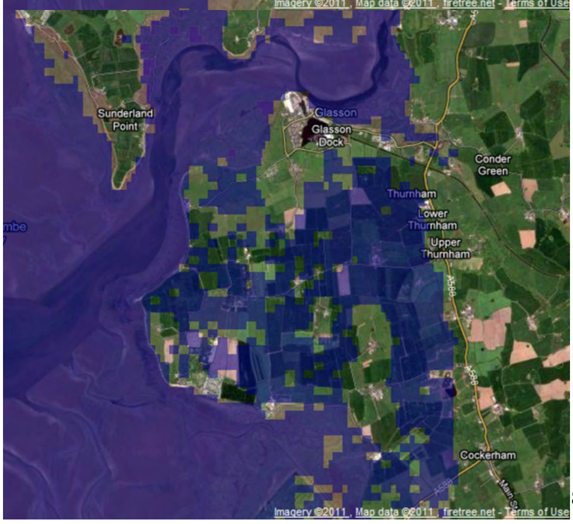
+0m (Existing Sea Levels)

Current sea levels place high tide at the boundary of the agricultural land. A 2m retaining sea wall defends any tidal surges, while the intricate system of drainage channels within the land disperse flood water back out to sea.



+1m (Sea level rise)

A 1m rise in sea level would not directly affect the location as it will be sufficiently protected behind the existing engineered sea wall. However, flooding will occur further along the coast and up the river as the water is forced elsewhere.



[8]

+2m (Sea level rise)

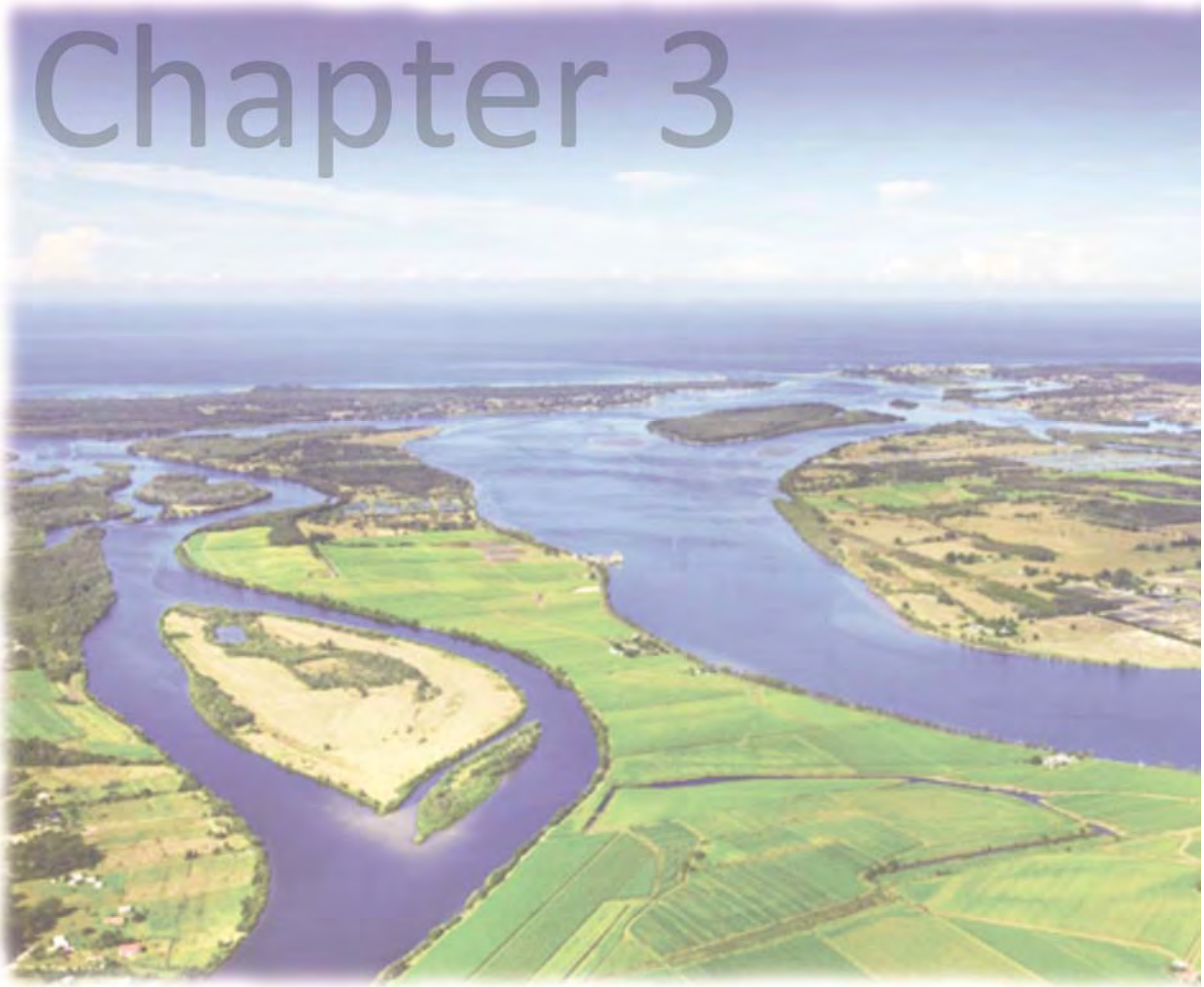
Without adaptation to the existing sea wall, a 2m rise in sea level would see the agricultural land almost completely flooded by the tide twice a day meaning any resources or settlements would be lost.

[8] Predicted data from http://geology.com/sea-level-rise/

Summary

As the land is in much need of remediation, that would take years to naturally resolve before it was usable again, it seems pointless to maintain the land for urban or agricultural use, when there is little output being reaped. It seems an ideal location where the land value is low enough to enable it to be consumed by the sea, at a much higher value result of protection for the inland settlements. Just as importantly, the regions further along the coast that are feeling the effects of sea level rise accelerated - due to the engineered sea walls at this location focusing the water elsewhere - will be better protected. It is this style of strategy that will be most significant for the design of future defences as it looks at the effects of the response at a regional level and not only for location specific areas. This should in itself prove that a more biocentrically driven response would be much more successful than that of any engineered response, but unfortunately it will be very much determined on the value of the land anthropocentrically, as to what will happen, and not what is necessary for the greater good from both a human and natural perspective. Our society has built itself on unsustainable foundations and in a world where economy and speed overpowers any responsibility for factors that cannot naturally keep up with our accelerated evolution, anything left behind will perish. Unfortunately that is a battle we will never win as the natural resources we are leaving behind are the elements that support all human life, but we will choose to ignore that fact as long as possible, even though it may lead to our own detriment.

Chapter 3



Existing Strategies

Originally this chapter was to be entitled 'Existing Solutions', but this would imply that current approaches for the defence of sea level rise are, to a certain extent, successful as the word *solution* is principally utilised when a problem is solved. This chapter intends to give an overview of the current strategies and planning policies towards sea level rise and a brief analysis of how they should influence a potentially successful response to rising sea levels for coastal lowland locations. In a way, some existing responses to the problems, that low lying coastal areas face, have been successful as they have accomplished what they intended to do when constructed. It is only our understanding of the problems that has altered our interpretation of what the actual problems are and therefore the solutions required. For example; pre 1950's phrases coined for the problems associated with coastal areas were the need for a 'sea defence' and 'coastal protection'. When low lying lands were flooded due to tidal storms, concrete *sea defences* (*figures 17 and 18*) were erected that solved this problem, protecting the land from future floods. Concurrently, *coastal protection* was a way to avoid the effects of coastal erosion via similarly designed dense structures. What wasn't taken into account was the existing biodiversity located along the coasts that were subsequently destroyed by these infrastructures and the ecosystems, which help support human life, deteriorated in an irreversible way. 'Between 1990 and 2000, Europe lost more coastal wetlands despite an already high wetland conversion rate during the previous decades'.[1]

[1] European Environmental Agency (2006) *The changing faces of Europe's coastal areas*, Copenhagen: European Environmental Agency.

Figure 17: The Sea Wall at Robin Hoods Bay, North Yorkshire, North East England – notice the lack of any form of nature as the intrusive sea wall destroys any potential ecosystem environment

Figure 18: The Sea Wall at Saint Jean de Luz Bay, South West France.

The most significantly underappreciated issue was the lack of understanding for the potential change in these problems and conditions; change not just in the increase or worsening of these affects, but an unpredictable change dependent of factors primarily out of our control requiring an *adaptable* and sustainable response. According to basic principles of sustainable development, the three dimensions of development - economic, social and environmental - need to be treated simultaneously in a considered and holistic approach. After the 1950's, techniques were developed that attempted to replicate the characteristics of natural coastal systems in the creation of artificial beaches and structured dunes (*figure 19*). This engineered approach was a much more economically viable method and it was thought to be much more environmentally sensitive than the previous hard structures.

Figure 19: The man made beach dunes of Chesil Beach, Portland, south coast of England

Unfortunately, due to a lack of knowledge regarding the fluvial process – coastal sediment transportation influencing land structure and natural systems via erosion or deposition – this method of coastal engineering often resulted in moderate success for the direct location affected, but was outweighed severely by the consequences of the effects it exacerbated or created further along the coast and up rivers, often kilometres away.

Currently, there are five generic strategies the European Union has in place for coastal management;

'*Do nothing'*: the most environmentally friendly option, the *do nothing* option involves abandonment of any residences and facilities located on an undefended coastline, that is subjected to coastal erosion, and allows the coast to take care of itself, slowly consuming the land it needs. The only cost and pollution produced is the resettlement process for any persons evacuated from the region.

'*Managed realignment'*: this process usually involves an area of land that has been reclaimed from the sea and is protected by current sea defence structures. The idea is to breach or remove these defences and allow the land to flood, becoming absorbed by the sea, converting it to new inter-tidal and salt marsh habitats. This will happen over a period of several years, until natural stability along the coastline is resumed. Similar to the *do nothing* strategy, this technique will require the relocation of any existing settlements and is therefore only executed if the land to be flooded is of low human value.

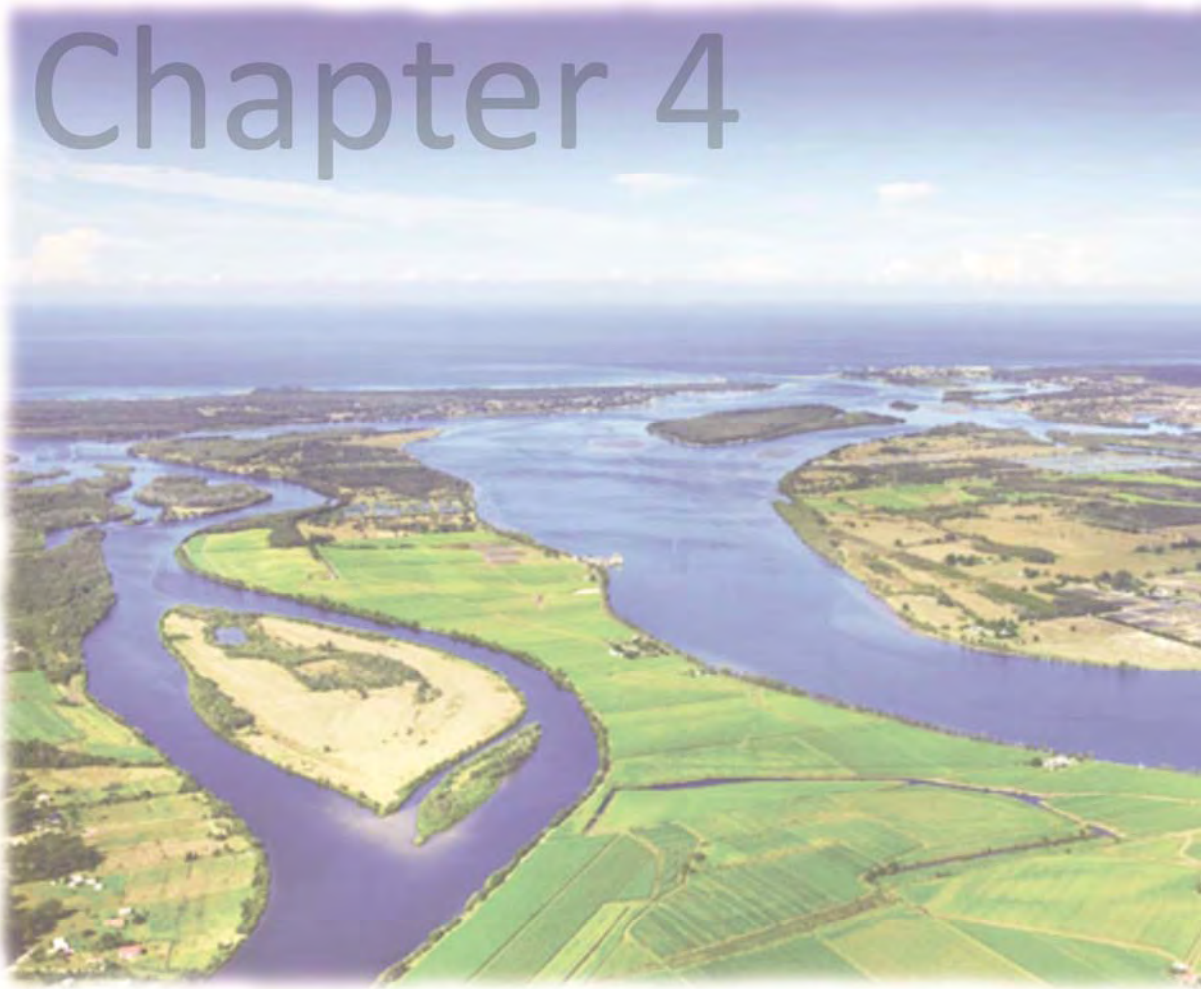
'*Hold the line'*: Unfortunately, as a society that has advanced at exponential proportions, often without great consideration for the environment surrounding us, we have developed large areas of coastal location as prime retail estate. The urban settlements of many major coastal European cities expand close to the edges of the coastline and have subsequently required great engineering of landscape formation and defensive structures to keep them protected. With the increase in sea level rise, the only genuine response, to continue their protection, is the upgrade of these structural defences and keep the sea at bay.

'Advance seaward': It is often considered that even the worst case scenario for sea level rise is possible to be predicted to a certain extent understanding now how we as a civilisation are contributing to climate change and how to counteract the effects. Knowing this, a move forward towards the sea would be theoretically possible; whether by hard defensive structures expanding the coastal settlement areas, or beach nourishment of soft engineering techniques replicating dunes and wetland marshes to absorb sea level rise. The obvious advantage to some of these is the potential for creation of a high land value that could offset the probable high cost of employing such techniques.

Limited intervention: this system is only primarily used where the existing land is of low economic significance and, more importantly, there is enough space to employ the technique. By its very nature, limited intervention only goes someway to aiding in the protection of certain low level lands and does not by any means solve the problem. The encouragement for the land to halosere – to convert into a saline thriving landscape – via man made influences, allows the land to naturally form salt marshes, mud flats or sand dunes. The force of the tides and rising sea levels becomes absorbed by the accumulated sediment areas and expanding vegetation. A positive for this style of system is the creation of additional habitats formed by this natural process; however it does not provide adequate protection where a greater level of threat is occurring.

In a lot of cases these strategies do not fit a singular location, with confusion and frustration ensuing for many local governments or regional councils dealing with the problem at a local level. Often an amalgamation of responses is required, but attempts to provide such 'unorthodox' systems are not supported by the central governments who oversee the issue and, more importantly, provide the funding for their construction, therefore nothing is done. If there are to be generic strategies for different locations, they need to be varied to a much greater extent and incorporate infinitely more information to an almost impossible status. One of the main reasons for the current simplicity of the strategies is their lack of adaptability. They are all based on a solution that looks at the current level of the problem and attempts to solve it in either an engineered approach or semi-natural system. Human strategies for the coast have been always been based on a static engineered response, whereas the coast is a dynamic equilibrium. If we are to learn from these ideas and advance our defensive resources, we must provide a system that, although may not be entirely natural in the form of salt marshes or protective dunes, it must employ the same results. An anthropocentrically designed halosere system would allow varying degrees of change for usage and defence of the land regardless of location and future change. It would be an integrated system along the coastline of any vulnerable, low lying land that would not only avoid disruption of existing ecosystems, but would allow an expansion of them within an engineered landscape. There would be an element of managed realignment, as sections of land are given up for the expansion of such ecosystems, but it would by no means incorporate an evacuation, nor does it provide a ‘hold the line’ engineered structure that simultaneously destroys coastal habitats and disconnects us from the natural coastlines we strive to live by. Such a response has been the centre of my investigations during my final year’s university project (MA LanArch; M.M.U., 2010/11) and the concept for such a system the efforts of my work. Although a refined solution would require scientific incorporation, the culmination of my work, and concurrently this dissertation, is more about highlighting the *generic* problems to sea level rise, along with the weaknesses of the *generic* responses that are currently utilised and how a much simpler concept could be successfully used as a basis for adaption of low lying coastal regions. In the next chapter I will elucidate this concept.

Chapter 4



Potential for a refined solution

This chapter attempts to conclude not only the research undertaken for this dissertation, but summarize the investigation over the course of this year's university project, that instigated the topic for this piece of written work. As briefly explained at the end of the last chapter, the summation of my work and research for this thesis has led me to produce, what I believe to be, an informed concept for the basis of future defences for low lying coastal regions. It is important to note the conceptual nature of this work as without scientific incorporation and testing, probably requiring a large amount of government funding, it cannot be proven that this response would be any more successful than the current strategies in place. What it does attempt to do, however, is respond to current associated problems, in a way the learns from the current failings of existing strategies, while providing an adaptive design that allows for degrees of change in future sea level rise, which from the previous chapter, none of the current strategies provide. At the same time it maintains and often improves the existing biodiversity within the coastline, while facilitating and defending incorporated urban usage. *Figure 20* shows an aerial map of the investigated area chosen to test this concept. *Figure 21* shows the existing sea wall locations, whose concrete structure is the only thing keeping the existing agricultural land behind from flooding. *Figure 22* shows the extent of the land that would be susceptible to flooding where the wall not in place and simultaneously the land that would be flooded should sea levels rise by 2m that would render the existing sea wall useless in the future.

Figure 20: Aerial photograph of Cockerham's Intertidal mud-flats and low lying agricultural lands

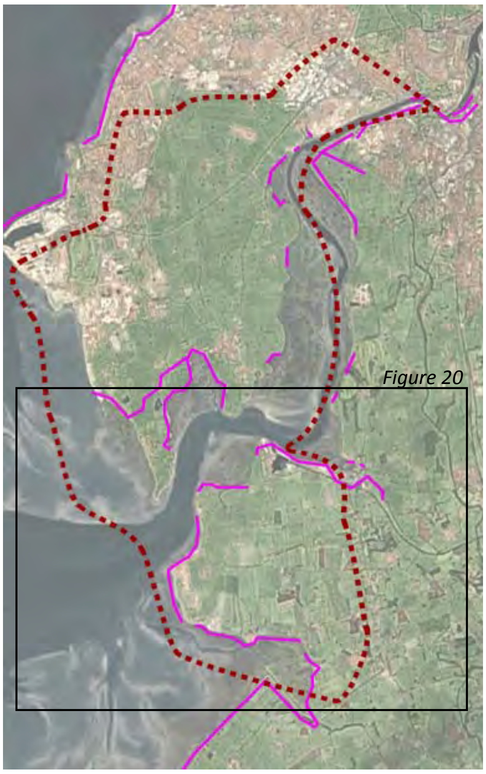


Figure 21: Aerial Map highlighting the existing locations of a sea wall defences between Cockerham's Intertidal mud-flats and low lying agricultural lands

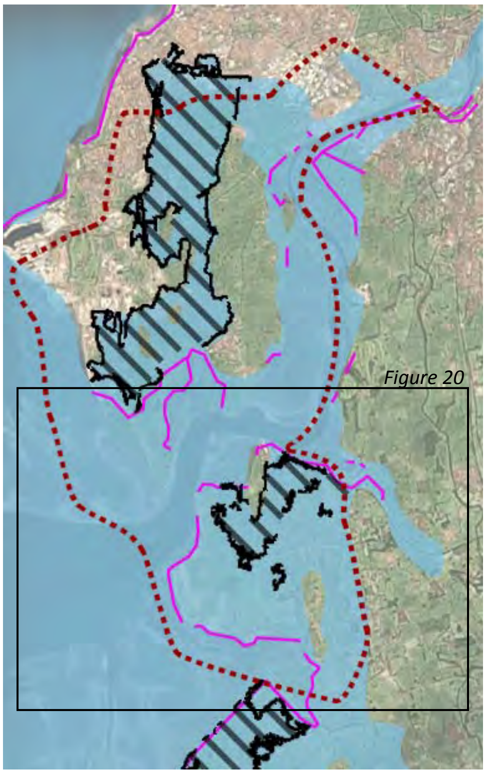


Figure 22: Aerial Map highlighting the existing areas of land that would flood without the current sea wall defences and the areas that would be tidally flooded should sea levels rise by 2m

For too long the coastline has been treated as its namesake suggests, as a *line* - a divide between the urbanised land and the sea. With the increase in population reaching near critical levels, settlements continue to develop and expand outwards. More and more of these developments are being constructed on floodplain levels and coastal lowlands. When this happens, the coast*line* becomes the location for the defensive divide between the two. This instigates the beginning of the problem and it is almost impossible to resolve thereafter. The coast is a margin; a space where nature requires freedom to evolve slowly, to allow ecosystems to adapt and thrive. When we encroach within this space and build our defences, we disrupt this natural process, destroying habitats and placing ourselves in vulnerable situations to the consequences. People like to live by the sea, arguably because they feel it provides a better quality of life, reflected in the elevated real estate values for such locations, therefore from a health or economic point of view this is something that cannot be deprived of. Ironically, a lot of locations similar to that of *figure 20* contain depleted agricultural lands. The very sea defences that are protecting the land from flooding are also the obstructions that stop the land from replenishing its embedded nourishment through tidal deposits. Due to this the land has no value, and is usually sold cheaply for conversion to coastal settlement areas.

In the last few years, governments have begun to appreciate this coastal margin with new strategies being formulated for within the '*coastal zone*'. Often up to 10km in width stretching inland and out to sea it covers salt marshes and mudflats. "The coastal zone is interpreted as the resulting environment from the coexistence of two margins: coastal land defined as the terrestrial edge of continents and coastal waters defined as the littoral section of shelf seas. Together they constitute a whole, which needs a specific methodological approach and dedicated management methods”[1]. The eventual realisation of this has led many European parliaments to investigate what is now called ‘Integrated Coastal Zone Management’ or ICZM for short, that can plan the development of these coastal margins under threat from sea level rise. Although the width of these margins will vary between locations, the basis for this strategy is a move in the right direction, but there is yet to be a physical design for such a strategy and as previously mentioned, it takes too long to advance to that stage on a European scale. Taking that information on board, and combined with my own in-depth research, my strategy appreciates that the coasts can only support a certain amount of activity without suffering environmental degradation; therefore there are minimal engineered defences allowing ecosystems to flourish and actually form a part of the defence, while human settlements remain safe. *Figure 23* shows an aerial photograph of the existing coastal location at Cockerham, next to the proposed strategy developed for the same location. One of the key features developed from my research is the off-set defence line, which does not only protect against sea level rise, it attempts to control it by absorbing the tidal energy, but remains permeable to allow the water to flow through at a safer velocity (*figure 24*). Being off-set from the typical coastline allows surrounding mudflats and salt marshes to continue to thrive within the saline

[1] European Environmental Agency (2006) *The changing faces of Europe’s coastal areas*, Copenhagen: European Environmental Agency.

Figure 23: Existing Aerial (left) next to the potential proposed regional strategy (right)

Figure 24: the proposed wave breaker underneath the coastal promenade absorbs the power of the tide, but allows the water to filter through at a controlled pace to allow the mudflats to thrive

tidal movements. Now that the often violent force of the waves has been removed, the water and rising sea levels will be much more manageable and even exploitable; the often overlooked usefulness of the sea is its predictable tide twice a day. If controlled, tidal deposits provide some of the most nourished land available providing the best natural resource for arable farming. Behind the permeable sea defence, a series of terraced levels provides a variety of activities that can thrive in safety, ranging from the natural ecosystems at the bottom, through controlled salt marshes and agricultural land, to the urban settlements at the top. Each terrace has its own function and more importantly is adaptable to sea level rise. *Figure 25* provides a more detailed explanation of what each terrace contains, but as sea levels rise, each lower terrace can naturally convert to a salt marsh becoming an extension of the defensive strategy, absorbing the water and protecting the urban settlements above, while allowing the ecosystem to thrive unimpeded.

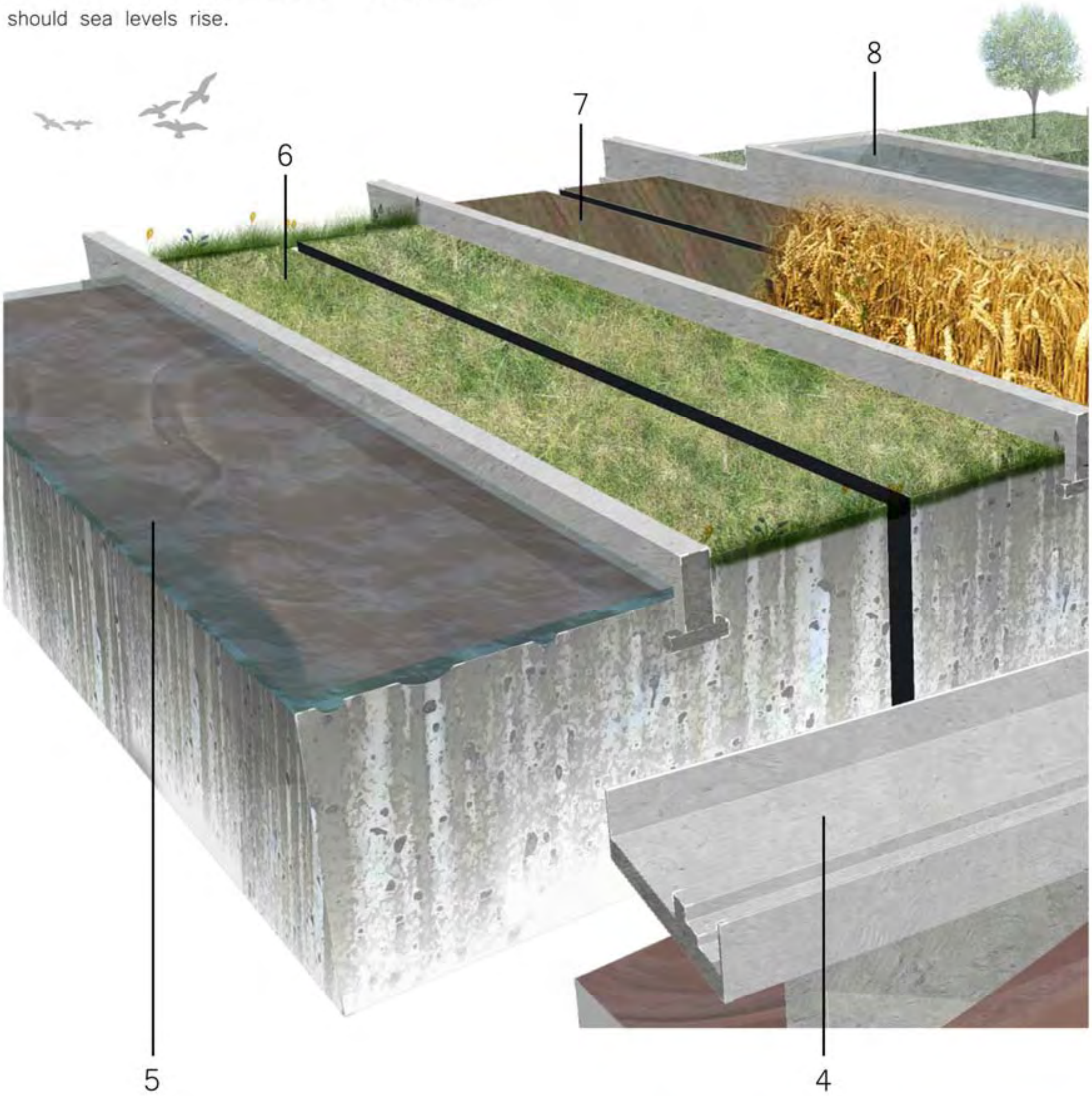
Conclusion

Despite the general recognition for the need of regional sustainable developments, existing environmental policies do not adequately address the spatial and complex requirements within the pre-defined coastal margin, with only a handful facilitating any type of common conceptual framework. Hopefully, the attention being brought to these areas through the increasing disaster rates will enforce an ambitious, but efficient and sustainable response similar to this. Integrated Coastal Zone Management is a step in the right direction, but the key element must be maintained as to how they adapt to specific coastal situations over time and from a human perspective how the strategy counteracts the vulnerability of coastal settlements from a changing climate and more importantly the protection and integration of sea level rise.

06 WILDFLOWER MEADOWS
The meadow terrace is the buffer between the sea and urban areas. It provides boardwalk journeys and jogging routes meandering through wildflower ecosystems, but more importantly can be naturally converted to a saltwater marsh should sea levels rise.

07 AGRICULTURAL TERRACE
Terrace farming takes advantage of recycling surface water run-off and precipitation to irrigate farmland. The terrace retains water well in dryer months, while a narrow width and SUDS drains it efficiently during floods.

08 FRESH WATER FISH FARM
Acting as a form of SUDS it collects fresh water precipitation and surface run-off. The biological water produced by the fish is used to fertilize the agricultural terraces below.



05 EXTENDED MUDFLATS
The mudflats behind the line of the promenade absorb the water filtered through the wave-breakers acting as an 'urban sponge' protecting urban areas around it.

04 PROMENADE
The promenade gives a continuous coastal walkway and provides a physical and visual connection to the views over Morecambe Bay.

09 URBAN AREAS

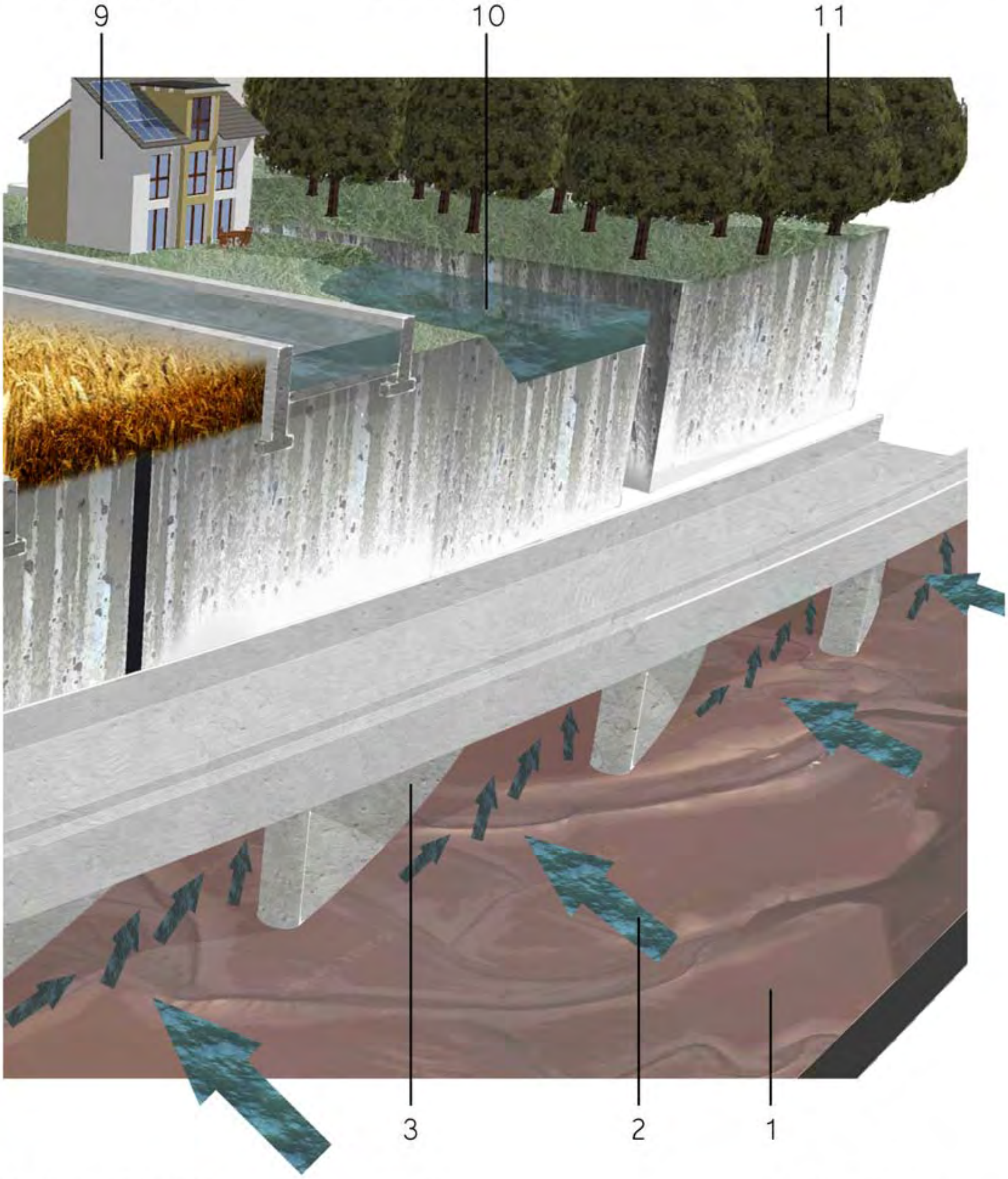
The top terrace provides space for urban usage protected behind the terrace levels from rising sea levels and the coastal wave-breaker during storms.

10 SUDS

A network of SUDS protect the flat terraces from flooding during the most severe storms and controls the filtering of water down the terrace levels.

11 PROTECTIVE WOODLAND

Dense woodland is established around the tip of each urban terrace linear settlement providing protection from harsh coastal winds and salt spray.



03 WAVE BREAKERS

The promenade structures act as a series of wave breakers taking the force of the waves and allows water to filter through at a controlled speed and power.

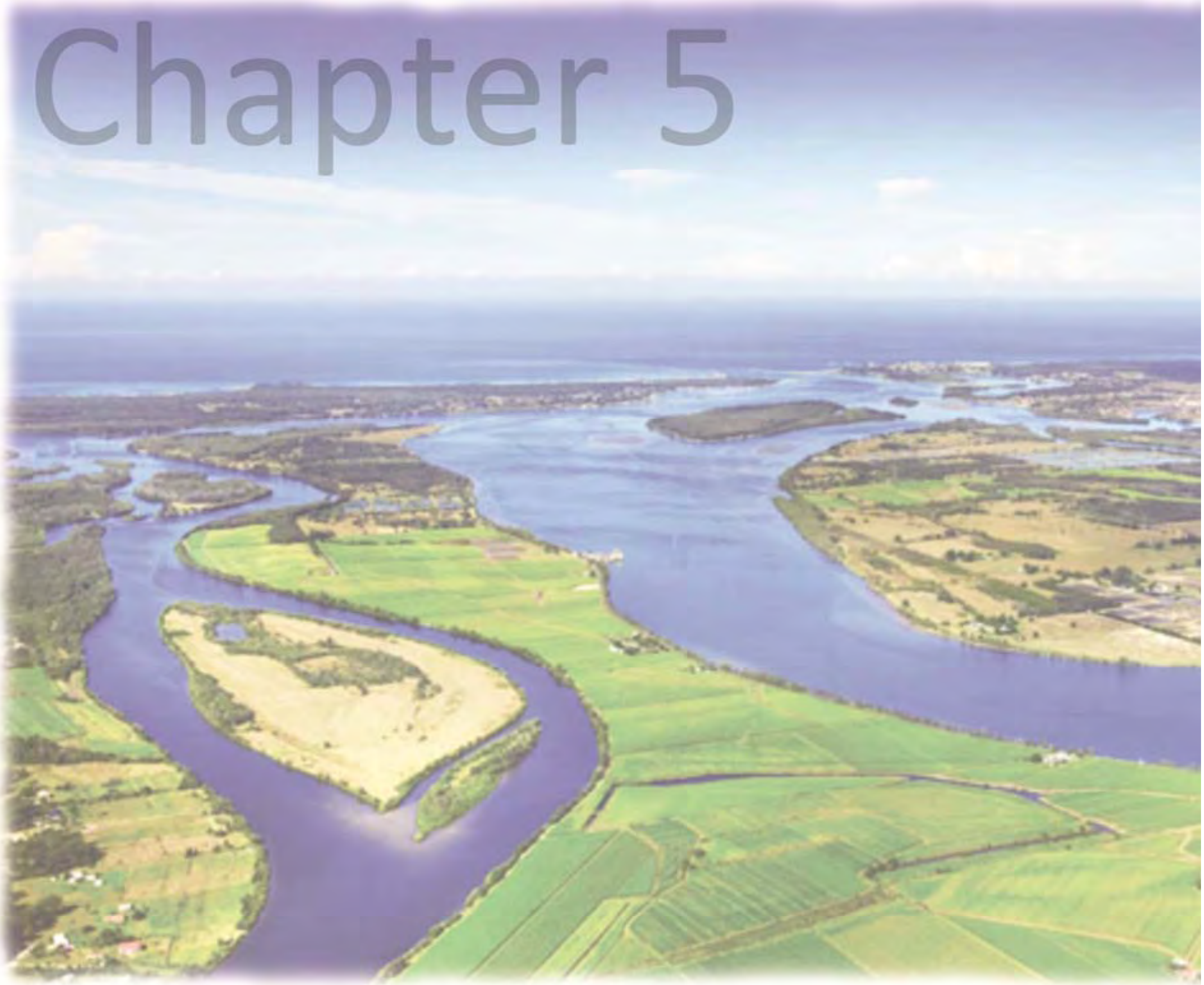
02 SEA

Current high tide level means water will naturally filter through to the extended mud flats. A 1 or 2m sea level rise will provide higher and stronger force waves.

01 TIDAL BEACH

The tidal beach has a fallback of 12km meaning it will always be a tidal beach despite sea rise.

Chapter 5



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