THINKING BIG - DEFINING RESOURCES FOR MAJOR COASTAL DEFENCE PROJECTS

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ABSTRACT

The UK's coastline holds a special place in the nations psyche, but in many places requires significant and ongoing engineering effort to maintain its integrity. A 'soft' coastline and strong hydrodynamic regime around the UK, combined with the effects of climate change, contributes to high levels of erosion and sediment transport. Accordingly high volumes of sand and gravel are required for coastal defences, beach recharge and land reclamation every year.

The British Geological Survey (BGS), in a project commissioned by The Crown Estate, has been identifying offshore resources which can be used for these applications with the aim of understanding the UK's capacity for supplying major coastal defence projects. Research has been undertaken using industry and legacy sample data in association with modern high resolution bathymetry. This has allowed the volume of material in significant seabed features, such as sandbanks, to quickly be calculated and their properties defined. Results from this research will help to ensure that materials are sourced from the most cost-effective areas and that supply is not restricted.

Understanding the volumes and properties of offshore sea bed features opens up the possibility of new types of coastal management, linking defence with amenity. Large scale coastal engineering schemes, such as the 'Sand Engine' on the Dutch coast, shows how these types of projects can both protect the coastline and promote public amenity if the large volumes of suitable material required can be economically and environmentally sourced.

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INTRODUCTION

There are two methods for the construction of coastal defences. One is the construction of permanent solid structures, such as groynes and sea walls, known as 'hard defences' and the other involves working with natural coastal processes and sediment movement, often referred to as 'soft defences'. Soft coastal defence mechanisms consist of beach recharge or beach nourishment. These can consume very large volumes of marine sand and gravel. In recent years, between 8 and 11 percent of all marine dredged aggregates, which totalled 10.2 million tonnes in 2012, have been consumed by beach recharge projects (The Crown Estate, 2013).

Beach recharge is essentially the process of placing significant volumes of material on, or near, the foreshore to raise the profile of a section of coastline. This may be undertaken by pumping material directly from a vessel, either a barge or dredger, on to the foreshore, or pumping via pipeline from fixed points offshore. In some cases material can be placed in close proximity to the foreshore and natural processes are used to distribute the sediment. Material is then often re-distributed and landscaped onshore into the desired profile.

There are several reasons why beach recharge is an effective method of coastal defence. By building up the profile of a beach a natural barrier is created against coastal flooding, which also acts to dissipate wave energy, thus providing significant flood defences and reducing coastal erosion. Also, unlike hard defences, beach recharge does not block long shore sediment transport paths and as a result does not result in sediment starvation along the adjacent coastline.

As well as the engineering and geomorphological benefits of creating larger, more easily accessible beaches, additional public and amenity space is created. This, in turn, brings associated economic benefits and the potential for the development of important coastal habitats.

The need for coastal defences is widely accepted in the UK, being an island nation with a soft, often rapidly eroding coastline. Also the 'seaside' seems to hold a special place in the nation's consciousness which means there is often great pressure to ensure it is well protected. The high value we place upon coastal environments means that very careful consideration is required when implementing coastal defence projects as changes can easily cause significant resistance from the public. An example of this effect can be seen from Bournemouth Beach when, during a replenishment scheme, pebbles appeared on a normally sandy stretch of beach. Even though this could have been a natural seasonal effect the public outcry reached the national papers (Daily Mail Online, 2007). This importance that society places on the coast and beaches means that beach recharge has a significant advantage over other hard forms of coastal defence due to the creation of a wide and healthy beach.

Despite the advantages, beach recharge is a far less popular means of coastal defence now than it was predicted it would be. A major study looking into future trends and demands of beach recharge materials completed in 1996 (Humphreys et al., 1996), predicted that over a 20 year period, from 1995 onwards, the UK would require between 60 and 130 million tonnes of sand and gravel for beach recharge. In reality, actual demand has been just above 40 million tonnes.

Figure 1 shows, despite a few major schemes causing peaks, that demand for beach recharge material has been on a gradual decreasing trend since 1995. As a result of low implementation of beach recharge schemes coastal communities are losing out on the benefits associated with these projects and the extractive industry is losing out on potential business opportunities.

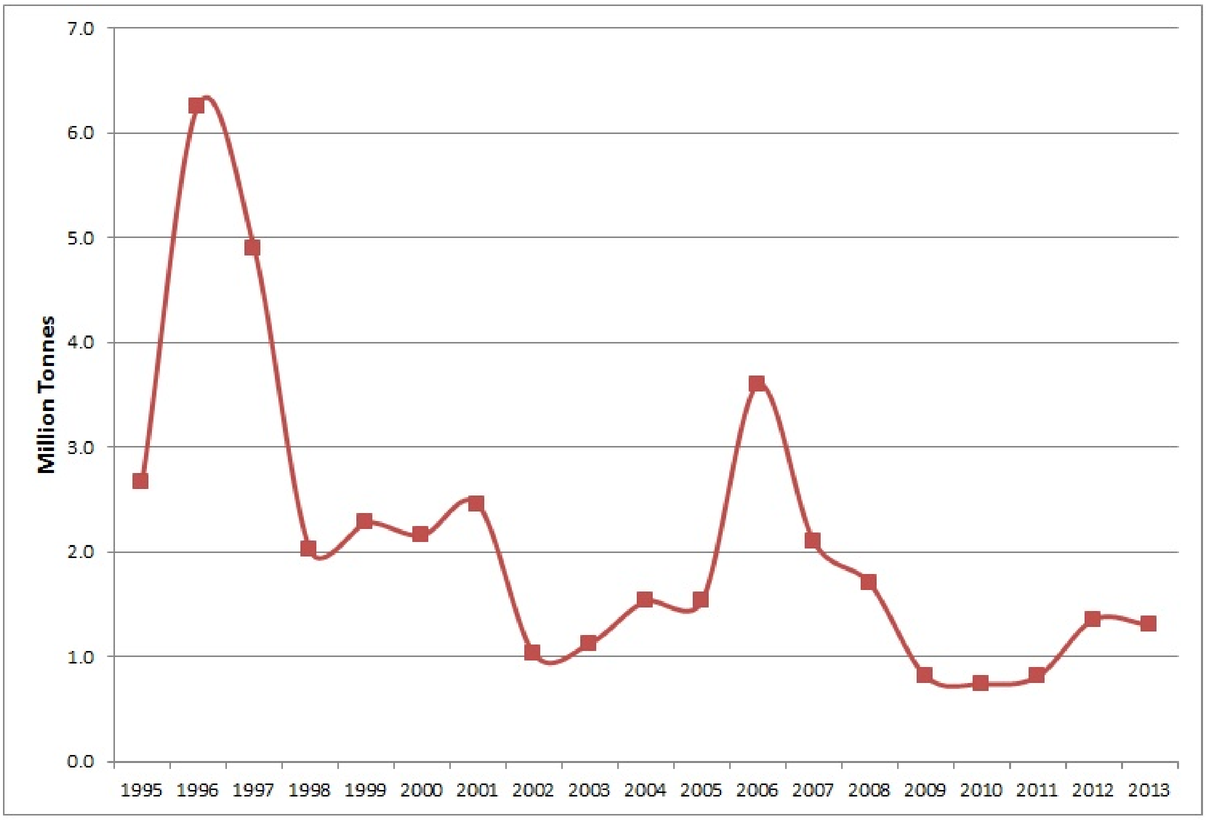

Figure 1. *Consumption of material for beach recharge from 1995-2013 for the UK. Source: The Crown Estate Marine Aggregate Statistics..*

The unpredicted lack of demand for materials and fewer than expected beach recharge schemes are considered to be due to a combination of the high cost of these types of projects (the largest cost being raw materials) combined with a lack of funding and a lack of available, affordable and suitable raw materials.

As a result of these issues, The Crown Estate commissioned the BGS to undertake a study looking at the location and properties of proposed sources of material for use in coastal defence and beach recharge. If beach recharge is to be increased as a method of coastal defence, cost reduction is required in the sourcing of raw materials. This could be achieved by locating appropriate resources and ascertaining their properties; this information is essential to improve cost efficiency. For example savings could be made, as a result of reduced transport costs, by utilising resources of material closer to scheme locations where possible. An efficient and cost effective system for coastal defence is predicted to become increasingly important in the UK due to the possible effects of climate change.

The identification of resources suitable for beach recharge is also important due to the changes being made in UK marine planning. The UK is currently compiling its first marine spatial plans and this presents a unique opportunity to ensure that marine sand and gravels are properly represented in this process. If important natural resources are not considered in these plans there is a risk that development could sterilise them for future generations.

An additional component of the study was to consider the potential for ‘mega nourishment’ type projects. In this type of project very large volumes of material (tens of millions of tonnes) are placed at a single point on the coast and natural processes are left to distribute it over a long timescale (tens of years). This type of sea defence has been implemented on the Dutch coast in a project termed ‘The Sand Engine’ (Stive, 2013). The Sand Engine was produced by placing 32 million tonnes of sand along the coast, creating a peninsular 2km wide extending 1km into the sea. The material was sourced from relatively close by, 10km offshore, and the scheme has created 35 hectares of new beaches and dunes. It is predicted to be 20 years before this stretch of coast needs defending again (Stive, 2013); previously nourishment was required every 5 years. The Sand Engine has widely been considered a success in terms of long term costal protection, the creation of public amenity space and boosting tourism to the area by the establishment of a larger, healthier beach. The data collected by the current study has considered if this type of mega nourishment could be applied to parts of the UK coastline in suitable locations where there is a long linear coastline in need of coastal defence and also potential coastal regeneration opportunities. Also, if such locations exist, are the required volumes of suitable material actually present to supply such a scheme?

METHODOLOGY

The first step to identify sources of material for beach recharge involved compiling a dataset, on a national scale, of areas containing potentially suitable resources. This was made considerably easier by previous work the BGS has undertaken for The Crown Estate which defined areas of marine aggregate resources (Bide et al., 2013) (Figure 2). The data created as part of the marine aggregates resources study was used as a basis for this study. Additional data relevant to beach recharge applications, such as the average grain size of the whole sediment type was added to the dataset. The volume of contained sand and gravel was also calculated for each area of resource. These volumes have been calculated using estimates of sediment thickness, based upon cores and BGS mapping data; and the composition of sediments, as indicated by seabed sediment samples.

The combination of volume and property data allows for the linking of resources of material suitable for beach recharge to potential coastal defence projects, and to assess if suitable volumes of material are present. Linking such data with the location of current beach recharge schemes, where material is sourced from distant areas, also allows for the identification of potential areas of suitable resources closer by.

It is important to note that these maps have not taken into account existing designations of the seabed and other uses of marine space. If these areas are taken into account, areas of available resource are drastically reduced. All areas defined indicate the total available geological resource.

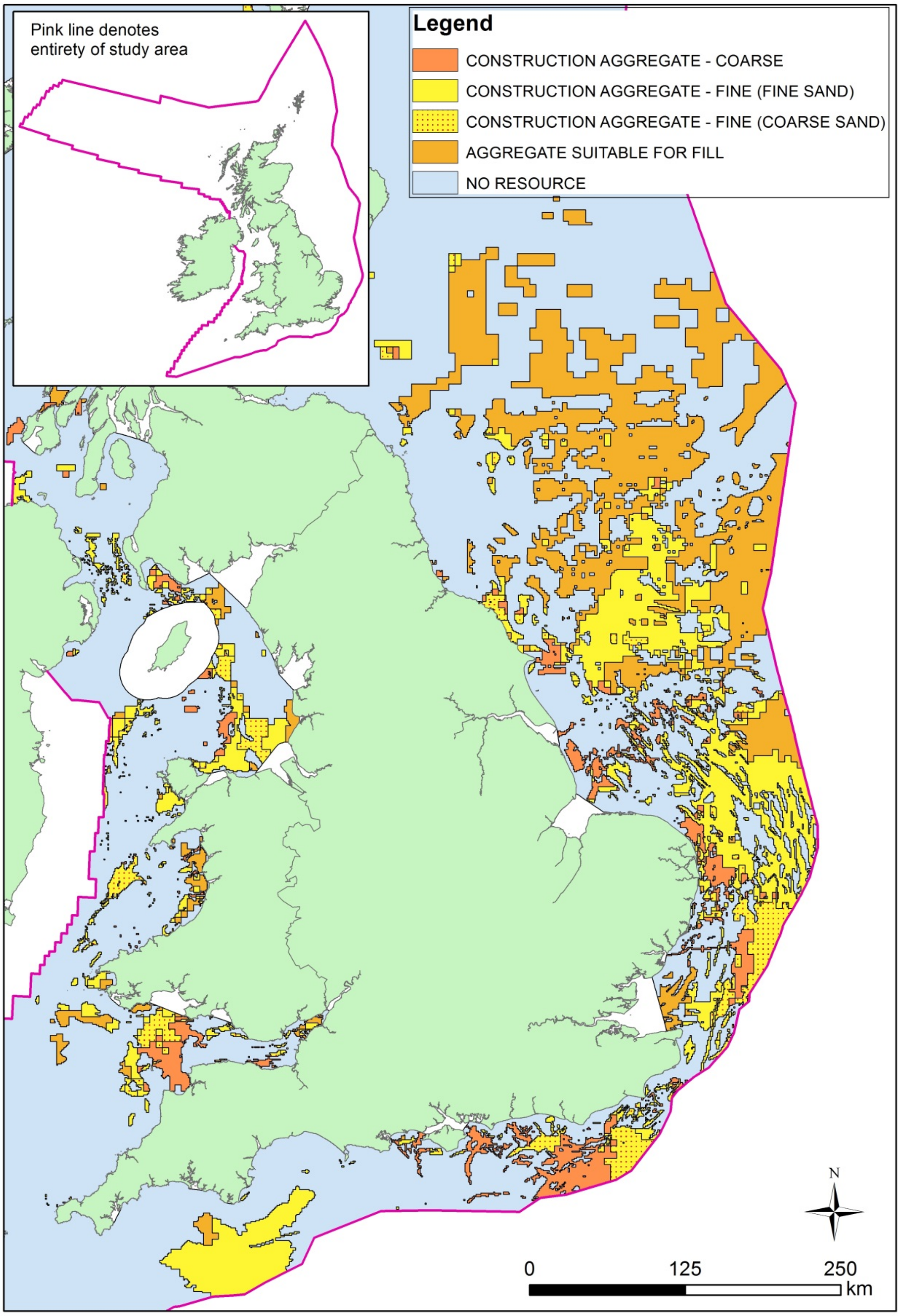

Figure 2. *Data from the UK marine sand and gravel map (Bide et al., 2013).*

After the completion of a national assessment identifying the locations of resources suitable for beach recharge material, this study also looked at several case study areas in more detail. For these areas the specific supply/demand situation was considered and the properties and volumes of suitable material for beach recharge applications were more accurately estimated than was possible for the national study.

NORTH EAST NORFOLK - A CASE STUDY

The coastline of north east Norfolk (Figure 3) is potentially a suitable site for a sand engine mega nourishment type scheme. It consists of a long linear sandy coastline which is heavily eroding thus requiring coastal defence, and major works have been undertaken here. The area does have a tourism industry associated with these beaches but there is scope to build upon this existing infrastructure. All beach recharge schemes that have been undertaken here to date have been sourced from offshore aggregate licences that predominantly produce high specification material for the construction market. The aggregate licence areas used for existing schemes are all located in a cluster offshore Great Yarmouth. Production for all licences in the area is just over 4 million tonnes from a permitted maximum of 9.7 million in 2013 (The Crown Estate, 2014). Utilisation of such construction grade material can both push up prices for beach recharge schemes and also may not be the most sustainable use of these resources. However, large volumes of sand contained within sandbanks closer to the coastline than the currently utilised sources present a potentially suitable alternative source of material.

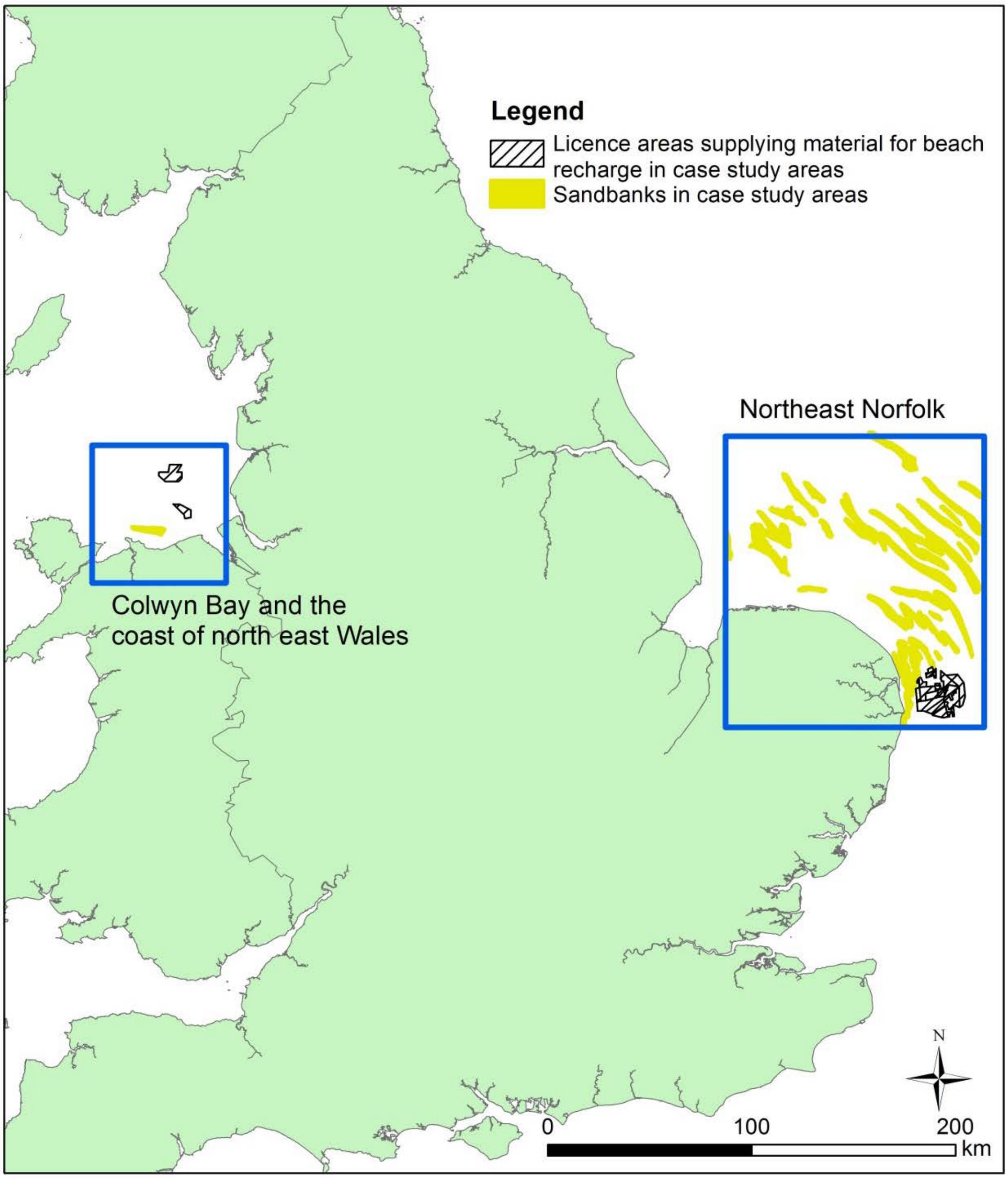

Figure 3. *Case study areas.*

The study calculated the volume of material contained within this sandbank system to be 15 billion tonnes of sand. Volumes for individual banks, such as those relatively near to potential schemes at 5-10 km from the shore, have been calculated to be approximately one billion tonnes. Any extraction of material for beach recharge would, therefore represent a small percentage of the total bank volume. Considerations such as this may make these features potentially more environmentally and economically feasible for exploitation. Available volumes would be much less once environmental and operational constraints are considered. Despite this, however, there remains considerably more material than would be required for any current scenario of potential demand for a sand engine.

Volume calculation was a key part of this study and access to regional bathymetric datasets enabled more accurate results for bedforms, such as sandbanks, than had been previously possible. Volumes were calculated in GIS (Geographic Information System) software by modelling the bottom surface of the seabed features of interest using the bathymetric profile of the sea bed just outside the sandbank and interpreting a plane between these points. The top surface of the sandbank being already defined by the bathymetry,. Using the average depth between the bottom surface and the top of the feature it is then comparatively quick and straightforward to calculate a figure for the total volume of the feature, as shown in Figure 4. This methodology can be applied anywhere for resources that sit on top of the seabed (generally sandbanks and sand waves) where adequate bathymetric data exists.

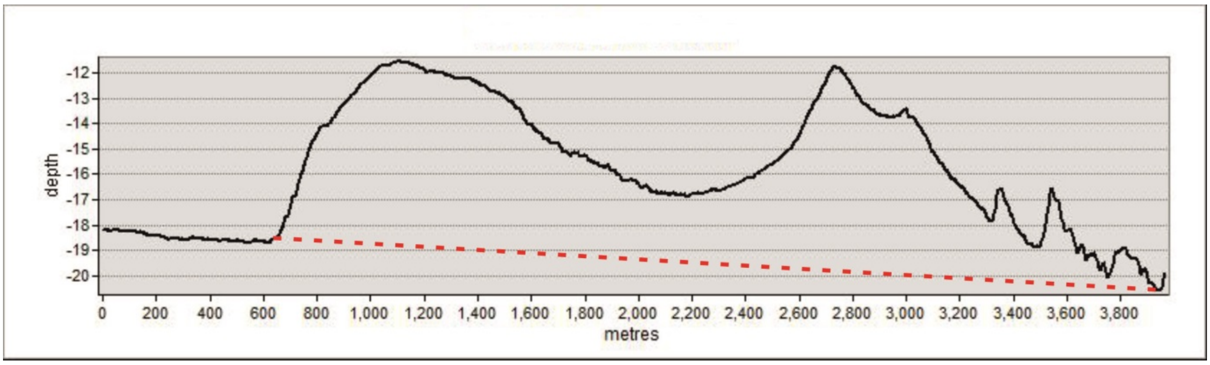

Figure 4. *The cross section profile of a sandbank based on bathymetric data and its inferred bottom bounding surface (in red).*

NORTH WALES - A CASE STUDY

Another case study area where resources for coastal defences have been investigated in more detail is the coast of North Wales (Figure 3). Like that of north east Norfolk, this is another long linear stretch of sandy coastline with problems resulting from coastal flooding and erosion with some beaches being notably damaged or degrading. There already is a large tourism industry here, but there remains great potential for coastal regeneration especially around some urban centres, such as Rhyl. As this section of coastline is host to major infrastructure, such as the A55 trunk road, a link to the port of Holyhead, as well as many urban conurbations, coastal protection is a priority (McCue et al., 2010).

All recharge material to date has been supplied from two licenced areas offshore North Wales and in the Liverpool Bay area. However the permitted output is less than 1 million tonnes per year, insufficient to supply a major new scheme. This area does, however, have large quantities of potentially suitable material from several other sources. Large sandbanks are present 5-10km offshore. The area also contains large volumes of material contained within older sediments, although these are geologically complex and not well defined. There is also potential for beneficial use of material from ongoing port improvement works in Liverpool Bay. Here very large quantities of fine-medium sand are being dredged to deepen and widen navigation channels, although any beach recharge scheme using this material would need to be contemporaneous with port improvement works. Another important issue in the area is significant offshore windfarm development. If resources need to be safeguarded for future extraction it is important that they are considered now and included in future plans regarding use of the seabed.

ISSUES

Although the principle of 'mega nourishment' has worked very well for the Netherlands via the Sand Engine project, problems are associated with trying to implement this type of scheme in the UK.

By mapping sand and gravel resources suitable for beach recharge schemes and calculating associated volumes it can be established that large quantities of sand are available close to existing and potential locations requiring defence. This is mainly contained in sandbanks, however, these features are rarely used for this purpose. This highlights another current issue with beach recharge materials used in the UK. The specifications for material used for recharge can be incredibly stringent, often more so than for construction material, with narrow grading envelopes frequently required. Also, it is normal practice to specify material coarser than that of the current composition of the beach that requires nourishment. In theory, the coarser the material is, the longer it will take to wash away, as higher energy is required for sediment transport of larger particles. This requirement can cause issues in terms of material availability and increased cost, as generally it will result in a medium-coarse sand being specified, which is already in high demand for concreting applications. An example of this is shown by the particle size distribution curves of sediment in Colwyn Bay compared to that specified for a beach recharge scheme in the area (Figure 5). Here the similarity between sandbank and beach sediments can be noted, however, the material required for the scheme is coarser, with a median grain size of around 0.5 mm, compared to 0.2-0.3 mm for that of the sandbank and beach.

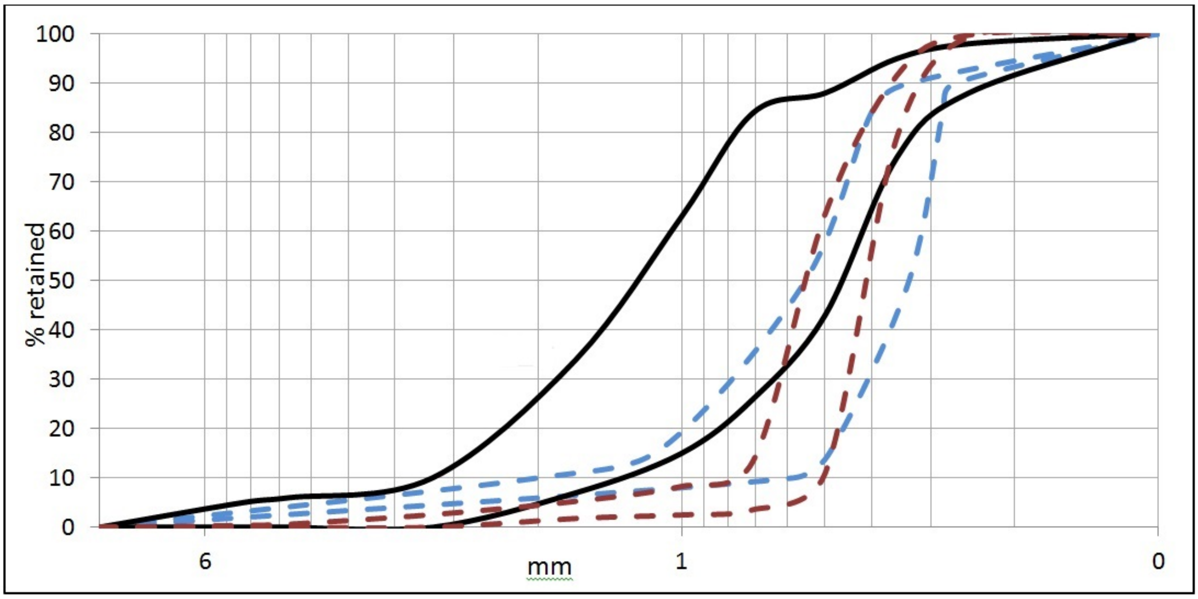

Figure 5. *Particle size analysis for sediments from the North Welsh Coast. Black lines represent a grading envelope of material specified for beach recharge schemes in the area (Coastal Engineering UK Ltd, 2012), dashed red lines indicated sediment composition of sandbanks (CMACS, 2005) and dashed blue lines represent sediment composition of the sandy foreshore.*

A potential solution to this issue may be to use material of the same or slightly finer grain size, i.e. fine-medium sands that generally comprise sandbanks. For this sediment fraction a potentially much greater volume of material could be easily sourced at a much reduced cost when compared to coarse sand. This cost saving may make the higher volumes required to offset higher sediment losses acceptable. In this type of scenario these sandbanks are a very attractive target as they contain very large volumes of material in well-defined locations, often near to potential, or existing, recharge schemes. However further work would be required to investigate the balance of sediment losses compared to the cost of sourcing material.

The demand for coarser grain sizes from current coastal defence schemes also means material for coastal defence directly competes with the demand from construction aggregates, which both commands a higher price and forms the core business of the extractive sector. It is rare for an aggregate dredging company to hold a specific licence for supplying material for coastal defence schemes and infrastructure projects due to the time and effort involved in securing a licence and the associated costs. As a result of these factors the price of material for beach recharge can be increased and the provision of this material is a secondary priority for the majority of the dredging industry. A better solution in terms of the cost benefit of individual schemes and also to preserve high specification material for construction purposes may be for other bodies, such as the EA (Environment Agency) or local authorities, to hold licences for extraction which then can be exclusively used for coastal defences. This split between aggregates for construction and material for national infrastructure and coastal defence schemes results in better utilisation of available resources.

Funding for coastal defence work is also a key concern. The EA, which has historically managed and provided the majority of funding for beach recharge projects, is now devolving more of the responsibility for these activities to local authorities. These bodies may have difficulty raising funding for large schemes, requiring a complex funding model with finance sourced from various bodies and commitment from local communities, central and regional government. However, this type of funding model is possible and is how many major inland flood defence projects are now managed, so this is not an insurmountable barrier.

CONCLUSIONS

Beach recharge projects in the UK are being restricted, principally due to high costs, which can adversely affect coastal defences and can deprive coastal communities of the other benefits associated with these schemes. However, there is potential for savings, by more efficient use of materials and by sourcing materials from locations closer to coastal defence schemes. The example from the Dutch coast has shown how a different approach using 'mega nourishment' from local sources can be greatly beneficial to both coastal defence and local amenity. To create these efficiencies increased knowledge of the location of resources for beach recharge material in the UK and the properties of these resources must be known. Such information, as has been produced by this study, can enable beach recharge schemes to be supplied more efficiently and aid with the planning of new larger schemes, by ensuring material is sourced from the most suitable locations and comprises sediment with correct specifications.

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