DEVELOPMENT OF A STRATEGIC COASTAL MONITORING PROGRAMME FOR SOUTHEAST ENGLAND

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ABSTRACT

The development of a new strategic regional coastal monitoring programme (SRCMP) for the south east of England is summarised. Benefits arising from existing best practice local programmes are highlighted, together with problems, which have arisen due to a previous lack of high quality data. A risk based approach to development of programme design, implementation and analysis is discussed.

INTRODUCTION

The exposed coastline of southeast England is characterised by soft sedimentary geology that is vulnerable to erosion, and extensive areas of low lying land and high coastal urbanisation that are vulnerable to flooding. The coastline of England and Wales is subdivided into coastal cells for the purposes of shoreline management planning (Motyka and Brampton, 1993); this paper examines the management of the frontage of Coastal Cells 4 and 5 (Figure 1), which totals approximately 1000km.

Approximately 10% of the population and billions of pounds of infrastructure are at risk from flooding in south east England, within a vulnerable area that exceeds 480km^2. Annual damages averted by maintaining present levels of coastal protection and sea defence are estimated at £203m per year (Burgess *et al* 2000), whilst capital project investment on defences within the region exceeds an average of £30 million per year and annual maintenance costs exceed £4.3m.

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Shoreline management methods have altered significantly during the past 10 years. Most sea defence and coastal protection schemes are now developed around dynamic elements, such as beach recharge or recycling often in conjunction with beach control structures. The departure from hard engineering presents a complex risk management scenario that requires high quality information to support effective management; it relies heavily on an understanding of coastal processes and the effects that these processes have on shoreline evolution.

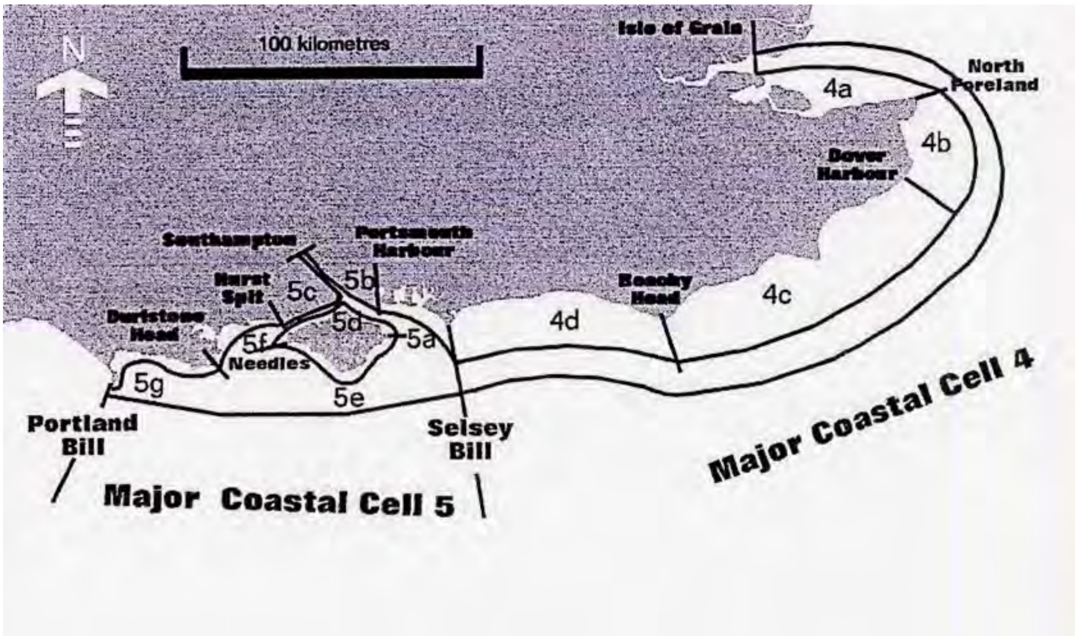

Figure 1 Major Coastal Cell and Sub cell boundaries

A conceptual model of coastal evolution (Stive *et al* 1990) is adapted and applied to shoreline management. The need for data to allow realistic assessments of midscale coastal evolution (MSCE), and large scale coastal evolution (LSCE) (Figure 1) is increasing with the goals of strategic management programme such as Shoreline Management Plans (SMPs). The current inability to carry out robust assessments at either side of these scales has been criticised within the recent SMP review, which has highlighted the need for a strategic approach to regional monitoring. LSCE is relevant to strategic shoreline management, since it includes morphodynamic spatial scales of the order of tens to hundreds of kilometres ie sediment process cells, and temporal scales of the order of decades. The needs for better prediction of MSCE and LSCE are high, particularly given the impending problems arising from sea level and wave climate changes, in context with the need for substantial SMP policies. LSCE studies can provide information concerning shoreline trends and identify fluctuations from these trends. This is essential to the assessment of risk from coastal flooding and erosion. At present the ability to predict LSCE is limited by the general lack of long term (decadel) strategic coastal monitoring data. This short fall severely limits the accuracy and validity of existing LSCE prediction techniques.

In order to make adequate predictions for future LSCE at longer time scales and a range of spatial scales, knowledge of past evolution and the forcing factors that cause the changes are required. Such knowledge enables an empirical assessment and prediction of future changes. Without reliable historical data at the various temporal and spatial scales, prediction of future responses becomes extremely difficult and relies on unproven assumptions; this approach provides limited confidence in planning methods.

TEMPORAL SCALE

Decades			Large scale coastal evolution
Years		Mid scale coastal evolution	
Days	Small scale coastal evolution		
	100s metres operational management	Kilometres beach management plans	10s kilometres Shoreline management plans

SPATIAL SCALE

Figure 2 Scales of coastal evolution (based on Stive *et al*, 1990)

2 CURRENT PROBLEMS

A number of existing beach management projects have performed contrary to predictions provided by physical- and numerical- models. Nearshore wave climate prediction, sediment transport modelling and performance of beach control structures have often been unreliable. Inadequate field data has often been available, to provide calibration or validation of these models. Any data that is available is generally very localised, and focused at those sites where there is significant intervention on the beach. Adjacent undefended stretches of shoreline are infrequently monitored, despite the potential for local interaction with managed sites.

The recent approach to coastal monitoring has been both ad hoc and unsatisfactory within the southeast of England, and elsewhere in the UK; this is evident at both regional- and local- scales. Data collection- and analysis methodologies have been inconsistent, and coordination has been poor. Region wide monitoring costs have been estimated at between £700,000 and £1.4m per year however. Although several region wide monitoring programmes have been managed in isolation, results have not been integrated; either in context with each other, or with relation to regional aspects of shoreline management; this is contrary to best practice shoreline management principles.

SMPs have provided the management framework for development of Coastal Defence schemes; these have consistently recognised the need for a cohesive coastal monitoring strategy. Current UK practice in coastal monitoring is widely varying however, both locally within individual coastal groups, and regionally. Existing initiatives need to be coordinated and integrated within regional frameworks, to provide best value and maximise the use of data.

3 BEST PRACTICE EXAMPLES

Well established and evolved coastal monitoring programmes have formed the basis for decision making at a number of sites within the southeast of England; these have formed the basis for design of the SRCMP. Complex management of problems have similarly been resolved at sites where long term, high quality beach monitoring programmes are in place eg Bournemouth (since 1974), North Kent (since 1974) and Christchurch Bay (since 1987). Extensive monitoring at these sites has provided the design framework for timely and cost effective management.

An example is presented for a site where monitoring has demonstrated that earlier intervention is required than was originally anticipated. Analysis of beach monitoring at Bournemouth (Dorset) demonstrates details of beach and bathymetric changes since 1974 (Harlow, 1999). Recharge schemes are phased on the basis of scheme monitoring. Recent programme analysis indicates that recharge will be required at a more frequent rate in the future to maintain the standard of service, on the basis of an increasing trend of beach erosion. Whilst these results do not identify a saving in cost as a result of the monitoring, they enable works phases to be programmed optimally; this approach provides considerable savings by averting losses, due to damage arising from a scheme that is below its required standard of service.

A long term local monitoring programme at Herne Bay (North Kent) has been used to calibrate sediment transport rate predictions, examine the performance of a breakwater and recommend appropriate recharge volumes to maintain balance down drift of the breakwater. The monitoring programme has provided timely intervention and optimised the quantity of recharge required to maintain longshore balance within a natural system that has been artificially interrupted.

The Hurst Spit (Hampshire) beach management plan is based upon extensive pre- and post-scheme monitoring. Beach surveys are used to determine intervention dates for beach recycling and recharge based upon detailed analysis of critical profiles. Projections have been derived from a combination of field measurements, physical- and numerical – modelling. Current beach performance is better than originally predicted (Figure 3), but under worse conditions than originally anticipated (Figure 4). These data may enable improved scheme phasing and provide cost savings , by deferring intervention.

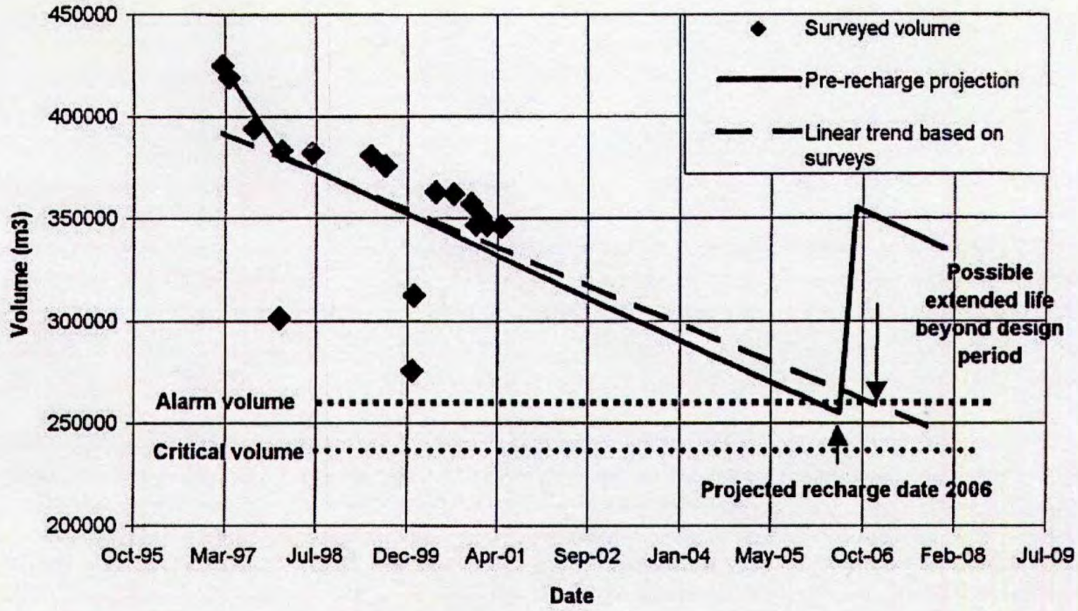

Figure 3. Comparisons of surveyed and projected beach volume change at Hurst Spit

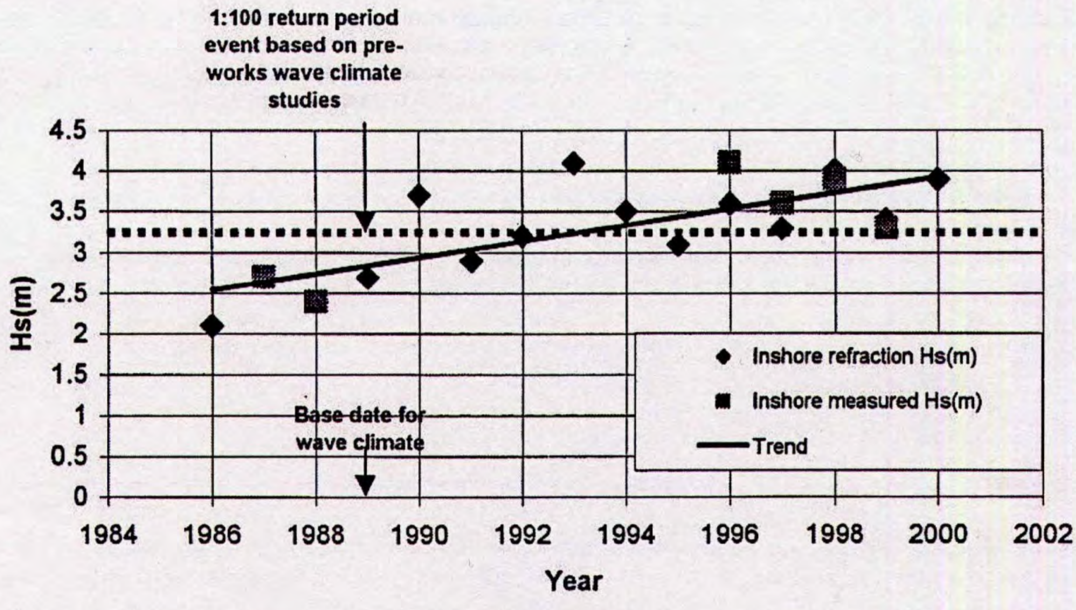

Figure 4. Annual significant wave height maxima at Milford-on-Sea

Elsewhere within the region there are few examples of long-term programmes that have reached the necessary maturity to enable robust predictions to be made.

4 PRE PROGRAMME REVIEW

A scoping study (Bradbury, 2000) has identified a framework for development of a coordinated regional hierarchy of coastal data collection, to inform regional overviews; SMPs; coastal strategies; and individual schemes. This includes analysis and regional definitions of monitoring cells; types of data collected within the coastal zone; appropriateness of current operational survey techniques; current and best practice methods for data management, analysis and dissemination; maintaining the continuity and quality of monitoring programmes and extension of regional initiatives to a national level.

5 BARRIERS TO PROGRAMME DEVELOPMENT

Although the benefits of coastal process monitoring are widely recognised, limited financial returns can be expected initially. Examples of best practice benefits arising from local programmes have been extremely important in establishing a precedent for funding of a large scale regional programme. Long term local programmes have demonstrated considerable cost savings, allowing greater confidence in efficient programming and design of coastal works. Recent evidence from private public partnership initiatives emphasises the importance of high quality data, upon which risk based assessments may be made.

The organisational structure of a region wide approach to shoreline monitoring presents a further barrier, requiring cooperation between many local government organisations, which do not normally operate across administrative boundaries in a coordinated manner (Bradbury *et al* 2001). The new programme is unique within the UK, having 31 Local Authority and Environment Agency partners; this is highly significant, demonstrating that there is considerable local political support for the programme as well as vision from the funding government department (DEFRA).

6 RISK BASED PROGRAMME DESIGN

A risk based design approach has been adopted for the regional programme (Bradbury *et al* 2001), in order to optimise expenditure. Coastal characteristics including geomorphology, shoreline composition and defence type, management strategy, exposure to wave attack and tidal range have all been considered within a weighted design framework. For example, three sample subdivisions have been determined for the exposure analysis category.

Table 1 Coastal Exposure Risk Criteria

	Risk Criteria for Exposure
High	Open coast, design Hs typically >1.5m or sediment transport rate >10000m3/year
Medium	Design nearshore Hs <1.5m, or sediment transport rate <10000m3/year eg Solent
Low	Design Hs <1.0m, typically tidal inlets eg Chichester Harbour

Four basic shoreline management policies are used to define coastal sites in England and Wales; hold the line; managed retreat; do nothing and advance the line. Although all categories of sites need some monitoring, detailed data is needed for a further category defined as "beach management plan" sites; these are characterised by: (a) sites with a formally agreed management plan, usually associated with capital projects such as beach recharge schemes and (b) sites with informal beach management plans, associated with any form of beach interventions, such as: beach recharge, by passing, scraping or recycling.

Sites currently being considered as sources for beach recycling, which may normally be considered within the "do nothing" category, have also been assigned to the beach management plan category. Beach recycling impacts on local natural processes and also usually on sediment transport within adjoining coastal units. Detailed surveys will provide general improvements in understanding of beach performance as these sites. Local hydrodynamic data is also extremely valuable close to these sites. Synthetic data is adequate if the approach bathymetry to the site is simple, but measured data is needed in cases where the bathymetry is complex and modelling methods unreliable: previous reliance upon synthetic data has provided problems at some sites. Monitoring must also include full records of deposit and excavation sites (including in- and out- surveys), dates of activities, methods used and quantities. Additional data is needed to evaluate the beach performance during the first 2-3 years following beach recharge, with or without control structures. Beach measurements are desirable at least quarterly and also following storm events. Thereafter the monitoring intensity can generally be reduced. In addition to sampled profiles, the risk model shows the need for annual detailed spot height surveys, to determine the beach volume, identify erosion hot spots and provide operational detail for maintenance. Post storm surveys are of considerable value. A mixture of profile- and detailed spot height- surveys will provide a balance of information at reasonable cost.

A series of generic geomorphological categories have been determined for each stretch of shoreline. Outputs from recent national and regional geomorphological investigations (Burgess, 2002; Halcrow, 2001) have been used to define the appropriate categories and associated vulnerability indices; these are necessarily simplified at this stage and will be refined for later phases of the programme.

GIS mapping of management-, exposure-, defence type-, and geomorphology- categories has formed the basis for the programme design process. An attempt has been made to provide an objective appraisal of the relative need for monitoring data by a simplistic risk assessment based primarily on the key fields and associated weightings, for each of the categories discussed above. When considered together, the risk categories can be analysed in various combinations to determine the required level of monitoring for each characteristic frontage, using numerical indices and thresholds determined for each index category.

A more objective vulnerability index which can be linked with standard of service, will be determined at a later stage during the programme; this will be used to assess the value of the programme and revisions of data collection needs for future phases. In essence, this approach makes provision for more monitoring at the higher risk sites, but also ensures that an appropriate strategic understanding of each coastal cell is developed. Examples for the topographic survey category are presented below.

Table 2 Typical Risk Based Spatial Intervals For Profile Surveys

Typical risk criteria – categories shown are indicative but not exhaustive	Profile spacing	Total frontage
• Barrier beaches fronting hold the line frontage, high exposure • Beach with coastal structures, high risk hold the line beach management plan sites	100m	21km
• Beach with structures, hold the line, retreat or beach management plan, high exposure sites • Beach with cliffs – hold the line, high exposure sites	200m	239km
• Beach with coastal structures – hold the line, retreat or beach management plan, medium exposure sites • Beach with cliffs – hold the line, medium exposure sites	300m	91km
• All do nothing sites with accessible beaches • All managed low risk sites, accessible beaches, low exposure	500m	92km
• Hard rock cliffs with no beach • Cliffs with inaccessible beach • Inaccessible military or industrial sites • Estuarine mudflats, tidal inlets and saltmarshes • Harbours	Remote sensing only	530km

The temporal interval between surveys has been determined in a similar manner to the spatial interval. The risk framework indicates the following broad categories of temporal coverage.

Table 3 Typical temporal intervals for topographic surveys

Frontage category	1:5000 aerial survey	Land based topographic surveys	Detailed spot height survey	Post storm survey (1:1 year threshold event)
High risk beach management plan sites	Annual	Biannual	Annual	Provisional
Hold line, managed retreat, high exposure	Annual	Biannual	None	Provisional
Low-exposure hold line	Annual	Annual	None	Provisional
Do nothing accessible beach	Annual	Annual	None	Provisional
Do nothing inaccessible cliff site	Annual	LIDAR survey every 5 years	None	None

The programme includes extensive baseline topographic and hydrographic surveys, aerial surveys and also a regular programme of shoreline, bathymetry, wave and tidal measurements. The principle monitoring included within the five year (2002/03 – 2006/07) Phase I programme includes:

- Baseline topographic surveys of the whole region
- Baseline hydrographic surveys of the whole region
- GPS control network
- Annual 1:5000 aerial surveys and photogrammetric profiling
- Production of digital orthophotos in years one and five
- LIDAR surveys of cliffed, estuarine and inaccessible beach coastlines
- Regular (annual or biannual) beach profile surveys
- Spot height surveys and digital terrain models at beach management plan sites
- Post storm surveys at selected sites
- Annual bathymetric profile surveys at selected hold the line sites
- Low level aerial surveys at selected sites
- Met office offshore hindcast wave data at 15 sites and wave transformation of offshore time-series to 35 nearshore sites
- Wave time series of Hs and Tz from 8 existing and new nearshore wave recorders
- Tidal time series from 16 local tide gauges and five “Class A” stations

7 DATA MANAGEMENT AND EXCHANGE

Meta data standards, GIS, databases and data exchange procedures form an integral part of the programme, together with analysis routines; these are used to inform development of strategic plans and also operational beach management. A coordinated approach to data management has been developed, to meet varying regional data requirements. Data will be held both locally and at a regional centre (Channel Coastal Observatory, University of Southampton). Data management will include:

- Data storage system, including a searchable metadata base and managed archives of raw data sets
- Development of SANDS database archives of processed and analysed data
- Development of a regional GIS
- Internet data dissemination
- Region wide coastal trend analysis
- Process cell wide coastal trend analysis
- Annual reporting
- Programme performance review

8 ECONOMIC JUSTIFICATION

Economic analysis has demonstrated expectations of benefits and associated costs of several alternative programmes; these include programmes designed to provide detailed and consistent coverage across the region and also risk based programmes with spatially and temporally varying detail. Considerable differences in economic benefits have been identified according to expenditure and measurement composition. The following options were considered within the economic appraisal.

- Do minimum (previous ad hoc programme)
- Risk based programme with data storage and analysis (actual new programme)
- Risk based programme, without hydrodynamic or bathymetric data
- Risk based programme without hydrodynamic or bathymetric data and no analysis
- High resolution data rich programme, applied spatially consistently across the region

Economic analysis has determined expected savings to projected region wide cost estimates of delivery of flood defence and coast protection, over a 50 year period, for each option. Justified assumptions are made relating to potential efficiency savings in capital and revenue programme costs over this period.

Consideration is given to a number of benefit categories within the economic analysis. Improved phasing of schemes will arise as a result of improved accuracy of the prediction of residual life of existing defence systems; this will result in reduced finance costs when schemes are deferred, or will avert damage when triggering the need for urgent works. Strategic planning will benefit from long term data of assured quality and will aid the development of scheme option choices. Design and construction costs will be refined as design conditions and expected performance patterns emerge, providing greater confidence in designs. High quality data will enable appropriate sites to be identified for capital recharge, related to maintenance dredging. Similarly, operational beach management will benefit by identification of suitable sites for recycling of beach materials, quantification of needs for materials and post project assessment of scheme performance. The regional programme will also provide economies of scale through procurement, contract management and preservation of data in a consistent form.

As well established and managed monitoring programmes are not widely present within the UK, precise figures are not available for direct assessment of benefits at most sites. Few local programmes have been able to provide this level of information. Samples drawn from the few well established programmes have been used to project and extrapolate potential benefits across the region to sites of similar character, to demonstrate clear quantifiable benefits. Upper, lower and most likely case benefits were calculated for each benefit calculation, based upon best available data and judgement of validity. The risk based approach to programme design provides a consistent basis for categorisation of the region, by type of frontage and management strategy.

Cumulative benefit cost ratios (BCR) are presented for each programme option (Figure 5). The curve for the preferred (actual) programme demonstrates the best overall economic performance. The discounted benefit cost analysis provides an estimate of the development of programme maturity and the cumulative BCR on a year to year basis, as well as over a 50 year period. This suggests that the programme will start to become cost effective in year two and will reach an estimated BCR of

2.7:1 by the end of the first 5 year phase of the programme. Some of the benefits arise at an early stage, as a result of maturity of existing programmes. Benefits are expected to increase dramatically with subsequent phases of the programme, reaching a BCR of 6.9:1 after 40 years. The annual incremental increase in BCR demonstrates the need to monitor over the long term. There are limited benefits in establishing the programme for a short time period. Calculations of benefits include only tangible financial criteria, while this monitoring programme delivers several undisputable additional management benefits. The BCRs are considered to be conservative therefore.

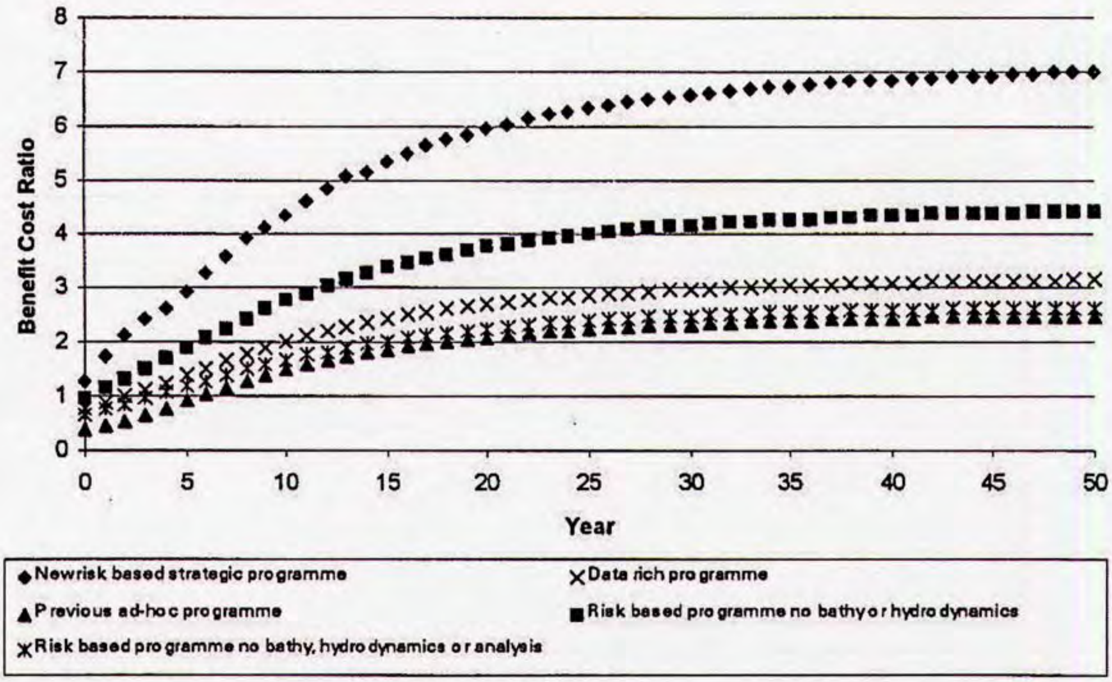

Figure 5. Cumulative benefit cost ratio for monitoring programme

9 CONCLUSIONS

Future improvement in understanding of long term coastal evolution is critically dependent upon the development and enhancement of a strategic approach to coastal data collection and management.

Comprehensive monitoring programmes provide an improved understanding of coastal processes and enable informed strategic decision making, within shoreline management planning and formulation of coastal defence strategies.

Long term planning and projection of needs for operational beach management schemes are enabled by focused monitoring programmes, which may also be used to develop and validate other modelling tools.

The design framework for development of a new integrated regional coastal monitoring programme for south east England is discussed, including a risk based programme design methodology, and a framework for data storage, exchange, analysis and programme review.

The content and design of the monitoring programme has been reviewed on a risk basis, taking into consideration: management strategy; exposure; geomorphology and management type.

Major benefits that will be delivered by the Strategic Regional Monitoring Programme include: (a) the availability of data and information to inform high level strategic initiatives; including Shoreline management plans, Strategic studies, Coastal habitat management plans and Beach management plans and (b) provision of relevant and increasingly useful data sets to inform feasibility studies, scheme specific proposals and operational management.

Sensitivity testing of the programme benefits and costs indicates a conservative average benefit cost ratio of 2.6:1 will be achieved for the first five years of the programme. The annual incremental increase in BCR demonstrates the need to view the programme over the long term. Programme benefits are maximised after approximately 50 years when the BCR is expected to reach 7:1.

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