Large-scale multi-agency strategic beach monitoring of the South-East Coast of England – provision of data and analytical tools.

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Abstract
Beach monitoring projects within the UK have often been confined to short stretches of coastline, usually established in conjunction with individual beach recharge schemes; they often omit to investigate entire coastal process behavioural systems, and the impacts of engineering works on a wider spatial scale. Effective planning and implementation of shoreline management requires high quality, long-term, time-series data sets, at appropriate spatial and temporal resolution, to predict long-term coastal evolution and to determine design conditions for coastal protection and flood defence projects.

A large-scale strategic monitoring and analysis programme has been established for the coastline of southeast England, to provide beach managers with both strategic and operational information (Bradbury et al 2001). Beach management is undertaken by a wide range of agencies within this region (31), each having responsibilities for short sections of coastline. The strategic initiative includes all of these agencies working in partnership. The programme comprises a risk based regional approach to beach monitoring for approximately 1000km of coast (Bradbury et al 2002).

This paper discusses development of data management and analytical tools used in the programme, with particular emphasis on beach profiles and wave data. Analytical databases, GIS and web delivery aspects of the programme are highlighted and demonstrated.

1 Introduction
Until recently, the approach to coastal monitoring within southeast England has been inconsistent, making informed development of strategic plans and operational beach management difficult. There has been considerable and justifiable criticism of this approach within strategic shoreline management plans. The coastline of southeast England is generally comprised of soft erodible sedimentary geology, with extensive areas of low-lying land that are susceptible to flooding. Foreshore material is variable; including sand, gravel, mud and bed-rock. Risks to loss of land, property and life are high.

A regional coastal monitoring programme has been designed with consideration of these risks, and comprises an extensive combination of measurements, including: beach surveys, post-storm surveys, bathymetric surveys, tidal elevation, wave data and aerial photographs. The programme provides detailed baseline surveys of the whole region, in each survey category. Thereafter the temporal and spatial frequency of data collection is determined on the basis of risk based sampling, using the local geomorphology, exposure to wave climate and management strategy, to determine data requirements (Bradbury et al 2002). Essentially, those areas that present high risks of erosion or flooding or are heavily managed, for example beach recharge sites, are served with a higher density of data collection than stretches of unmanaged coast. The whole of the coast is monitored (sampled) at an appropriate level of detail to provide a strategic region wide overview of coastal change. Measurements are complemented by data derived from a range of models, including: sediment transport, wave hindcasting and wave transformation models. A wide range of technology is used to capture data, including wave buoys, tide gauges, numerical models, kinematic GPS, remote sensing, ground based laser scanning, photogrammetry and LIDAR. Consistent survey specifications have been developed for each programme element and these have been adopted across the entire region.

Management and analysis of data for such a programme requires a robust, powerful and, ideally, simple system. Data and analysis is needed in both real time and at periodic intervals. The paper focuses on the data delivery, analytical techniques and software used to provide the beach manager with data. Presentation tools are considered to enable both technical and non-technical decision makers to benefit from the data collection and analysis programme, with a view to provision of decision-making tools for both operational and strategic shoreline management.

Data from the programme are routinely used to examine region wide issues, for validation of coastal simulation models and for development of the design and management of flood and coastal defence schemes. The regional approach provides considerable benefits to the multi-agency management, through provision of widely available information. This approach has enabled linkage of coastal problems to be placed in perspective and promotes the cooperation of the large number of coastal agencies. Although the programme is founded on the basis of sound scientific data, the main aim is to provide a basic framework of data that enables robust decision making. The programme also offers the opportunity to fine tune intervention on the coastline, with particular benefits to beach recycling and beach recharge schemes.

A wide range of practical applications of the data has already arisen, as a direct result of the programme. Practical applications of the data will be presented including:

- Planning for emergency intervention on beaches
- Planning for long term management of beaches, including recycling and recharge
- Validation and calibration of predictive models
- Assessment of the impacts of nearshore aggregate dredging
- Derivation of design conditions for new beach management schemes
- Performance of beach recharge schemes

2 Data Management

The large-scale regional programme presents serious data management challenges, to provide a robust and consistent system. The data management programme must deal adequately with the following data types (Table 1). A detailed data management and analysis flow chart is shown in Figure 1.

Generic data form	**Specific data types**
Time series point data	Wave, tides, currents
Time series profile data	Beach profiles, bathymetric profiles
Time series 3d spatial data	Beach surveys, Bathymetric surveys, terrain models
Time series 2d tiled spatial data	Aerial photographs, LIDAR, isopachyte plots, maps
Raw unprocessed data	All data sets
Point control data	Static GPS network observations

Table 1 Data types produced within the coastal monitoring programme (from Bradbury *et al* 2004)

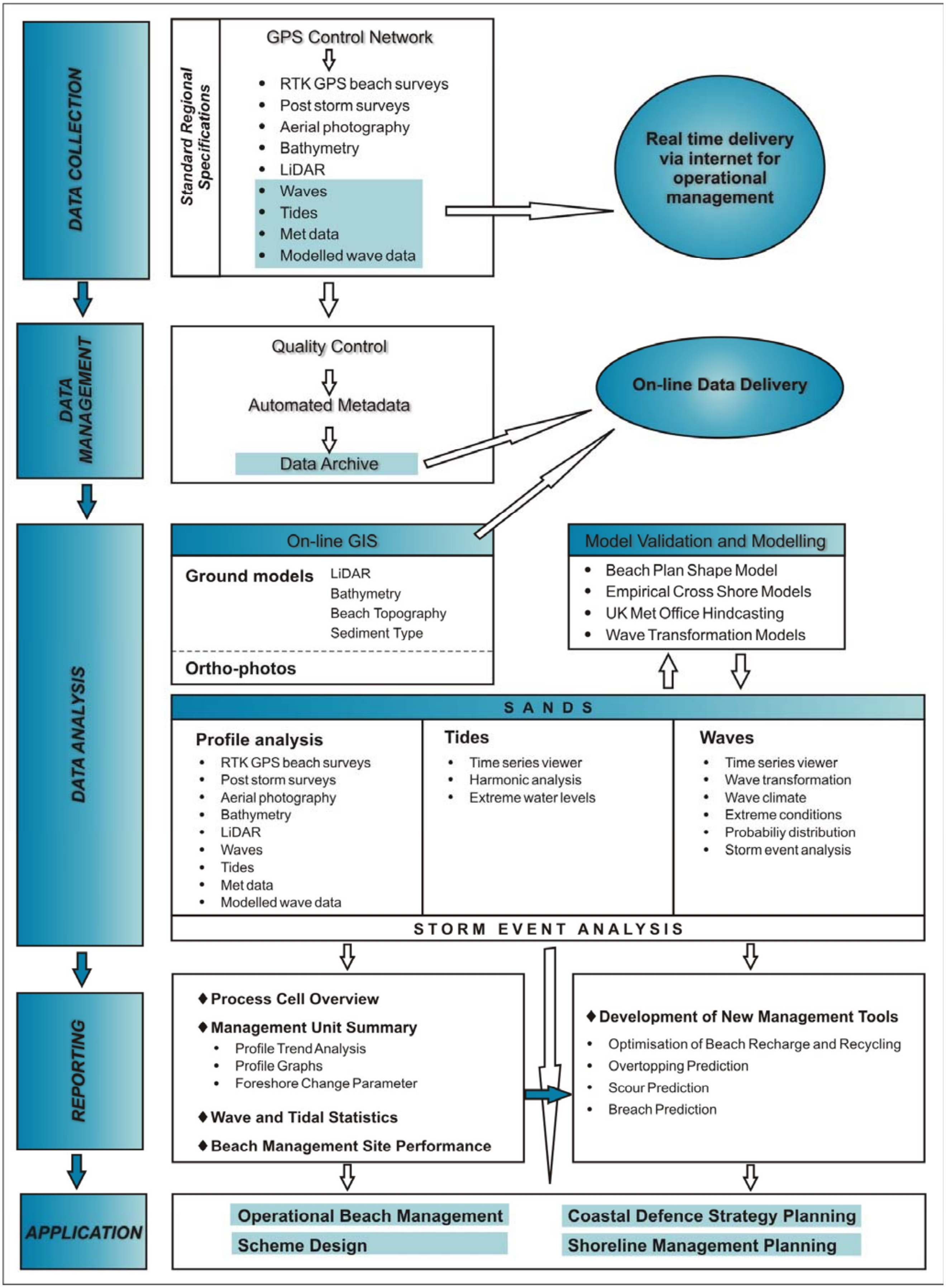


Figure 1 **Data management flow chart**

Standard survey specifications have been established for each data type collected, and rigorous quality assurance procedures established to ensure compliance with these specifications; this minimises variability of data quality across the region, and also with time. Data quality control procedures have been introduced, for each data type. Once the data have successfully passed the quality assurance, it can then be loaded into an archive for storage. This archive is driven by a comprehensive meta-database (Bradbury et al 2004a).

Legacy data sets have been considered at the programme design stage and, where appropriate, new measurement programmes co-located to extend the length of historical time series. These sites often present a problem however, as the historical standards of data collection and management may be somewhat different to the new programme specification. Analysis of legacy data sets has identified that many of these sets are not wholly compatible with each other, for analytical purposes, because of variations in: accuracy, precision, datum, transformation and measurement techniques. It is crucial therefore that adequate description of these variables is presented within the metadata, to enable informed decisions to be made of the appropriateness of the data for each possible application.

The meta-database has been developed as an on-line tool, designed using the FGDC Standard, which comprises a comprehensive set of pre-defined fields; this links seamlessly with the new ISO19115 standard and the next generation of the meta-database will be modified to be compliant with this standard. The raw format of the FGDC metadata standard comprises a total of about 200 pre-defined fields, of which 22 are compulsory. Filling these fields for many thousands of data sets presents a laborious task, yet the majority of fields provide valuable information for one user or another. Given the scale of the metadata forms some practical measures are necessary to encourage effective and efficient use of the system. The approach adopted provides the opportunity for auto filling of a significant proportion of the fields; this is dealt with by the XML metadata code. As a series of key data sets are to be collected on a regular basis, and to a common quality controlled specification, many of the fields can be filled automatically, on the basis of the specification standards. A series of part filled templates have been prepared therefore, for each principle data type e.g. for topographic surveys, wave data, bathymetric surveys etc. This provides a manageable number of fields to be filled manually and ensures that no valuable information about the data set is lost.

Many of the fields are common to the project specification and can be automatically filled on the basis of a single template, for example all data is recorded to a common datum and geo-referencing system. Certain fields are auto-filled by automatic software interrogation of standard format files. For example, the geographical extent fields are automatically extracted from the files; this particular process is particularly useful since each of the thousands of files will vary. There is particular advantage in automating this process, since manual input of numeric coordinate data is often subject to human error. This approach has enabled a series of template forms to be developed that require minimal end user input. Although considerable programming effort has been required to develop the meta-database, it provides a robust and simple to use application. The application has been developed, by using XML to build all elements of the meta-database; this presents many advantages over alternative programming approaches, particularly by reducing the amount of programming code to be written. Importantly, XML schema are used to validate each entry for each field; this ensures that appropriate entries are entered in all relevant fields. A simple front end provides the end user with an easy to use interface for bulk file uploading and metadata entry. The user has to fill in one metadata form for each uploaded data set. The metadata information provided by the user is stored together with the data.

The automated approach to completion of metadata records for programme standard specification data sets works extremely efficiently. Legacy data sets present a significant problem however. In many instances no metadata exists and in other instances the data collection standards are very different. In such instances the only option is to customise metadata forms for each data set; this is inevitably very time consuming. Provision has been made for development of template forms for these historical records, but the process of loading metadata-attributed data from legacy data sets is considerably more cumbersome than for standardised data sets.

The user is able to browse the on-line meta-database via a simple GIS map based search front end (Figure 2) and a number of keyword queries, e.g. the type of data set, location and date of data collection. A list of available data sets and full metadata records provides the user with a selection of data sets, which can be downloaded straight from the archive.

In addition to the main project meta-database a series of proprietary GIS and database tools (SANDS shoreline and near shore data system) are use for data management and analysis (see section 4).

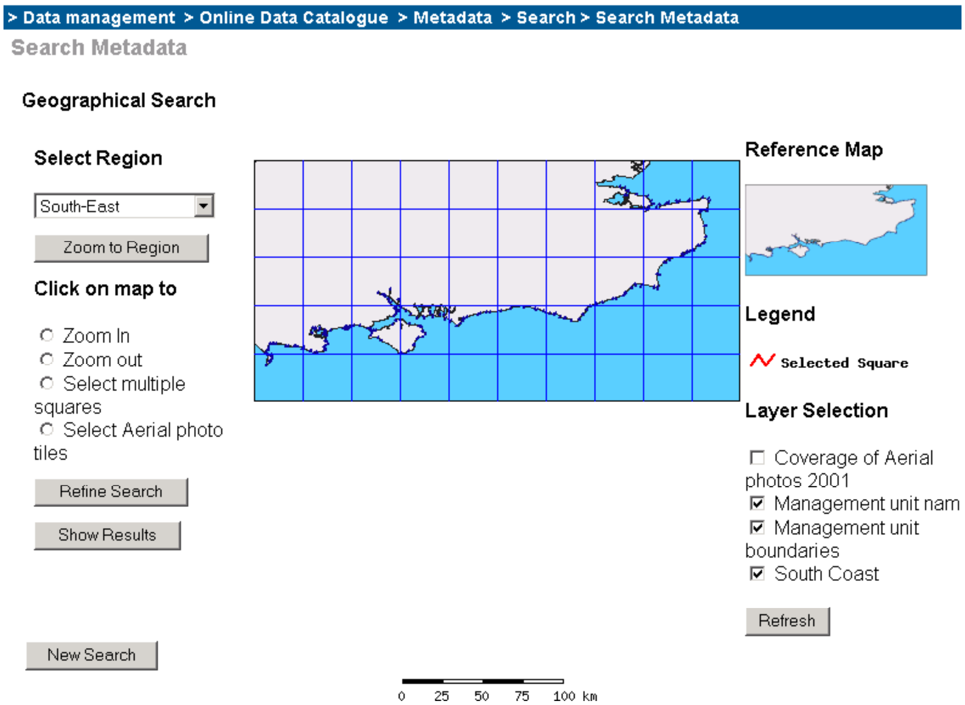


Figure 2 Meta-database search facility

3 Data delivery

3.1 On-line GIS archive

Archive data is made freely and widely available via the Internet. A GIS browser within a Mapserver environment (Figure 3) enables the delivery of a wide range of geographical data. For example, the baseline low water aerial survey of the southeast coast has been completed and orthorectified using LiDAR and photogrammetric ground models derived from the aerial photography. Data has been coordinated by reference to an extensive ground control network of measured photo-control, fast-static GPS observations and using standard geoid models to transform the data from the GPS ellipsoid to national grid coordinates. High resolution digital orthophotos are produced at a ground resolution of 25cm and are produced as 500m square tiles. Wavelet compression enables rapid on-the-fly delivery of the high-resolution imagery, which is held in a layer comprising 4GB of imagery. Basic navigation tools enable the user to zoom, pan and save images, but the tool kit is being rapidly expanded to provide more functionality.

Additional layers will soon be added to the online GIS, e.g. location of beach profiles, Shoreline Management Unit boundaries, defence type, management strategy and geomorphology. Layers related to ongoing surveys are currently under preparation; these will include ground modelled plots of beach topography derived from detailed baseline beach surveys, sediment type, LiDAR surveys of soft cliffs and estuaries and also bathymetric surveys of the nearshore zone. The beach surveys include separate layers for elevation and also feature coded sediment type. As the programme develops, difference models will be produced, showing changes to beach volume and identifying the location and extent of erosion and accretion between surveys.

The on-line GIS is linked to the meta-database enabling the user to download aerial photo tiles on-line, together with supporting metadata information for each photo tile.

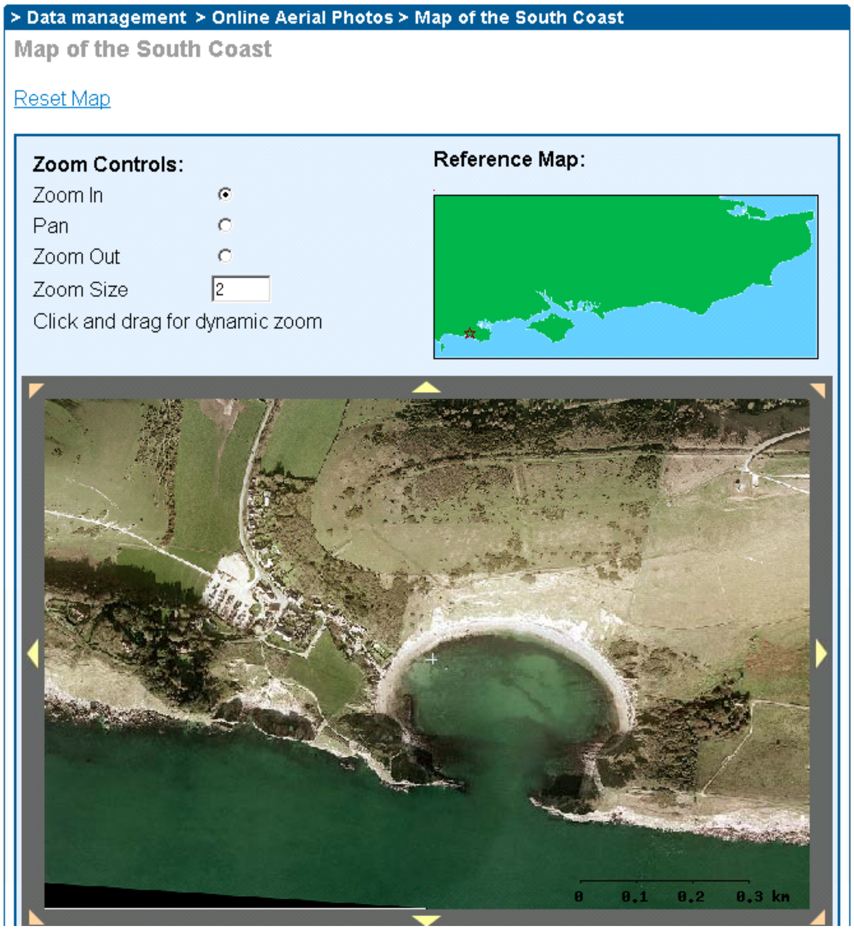


Figure 3 On-line digital orthophoto browser

3.2 Real time data

Real time data is provided for a range of data types, including wave buoys, tide gauges and anemometers. A network of near-shore tide gauges, wave buoys, pressure, and step gauges provides real time wave and tidal data at shallow water sites. Measured time series data are telemetered from the logging sites to shore based stations and forwarded, via ftp link on a broad band connection, for immediate broadcast on the project website. A simple GIS map driven front end enables the end user to navigate quickly to the real time data (Figure 4). Wave statistics (H_s, H_{max}, T_m, T_p, direction and spreading) are calculated and non-quality controlled updates provided every 30 minutes (Figure 5). Tidal data is updated every 10 minutes. The real time web link provides a valuable programme management tool, with the opportunity to track the position of the buoys via a GPS position signal that forms part of the buoy system and the analysis record.

Figure 4 Location of wave measurement sites – website GIS front end

A new position is broadcast every 30 minutes and departures from a defined bounding box result in email and text alerts, triggered by the website software; this enables rapid mobilisation of search and retrieval vessels in the event that a buoy breaks loose from its mooring.

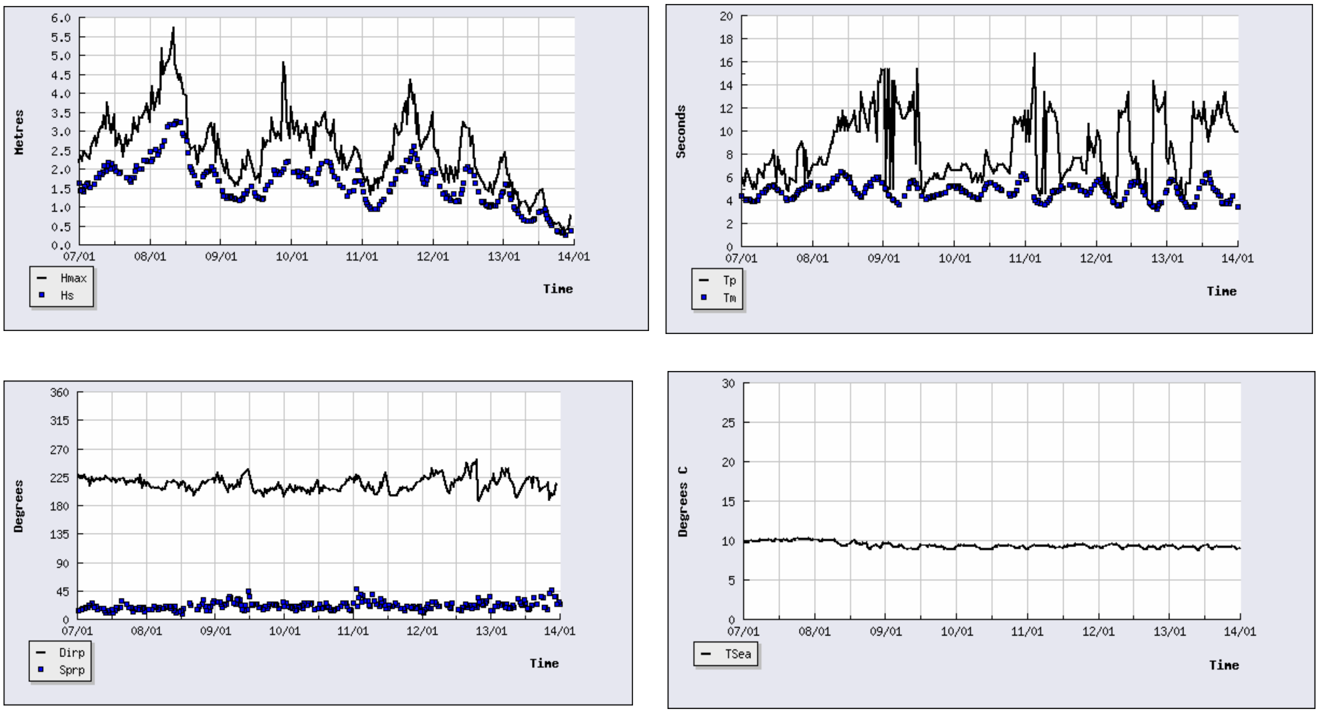
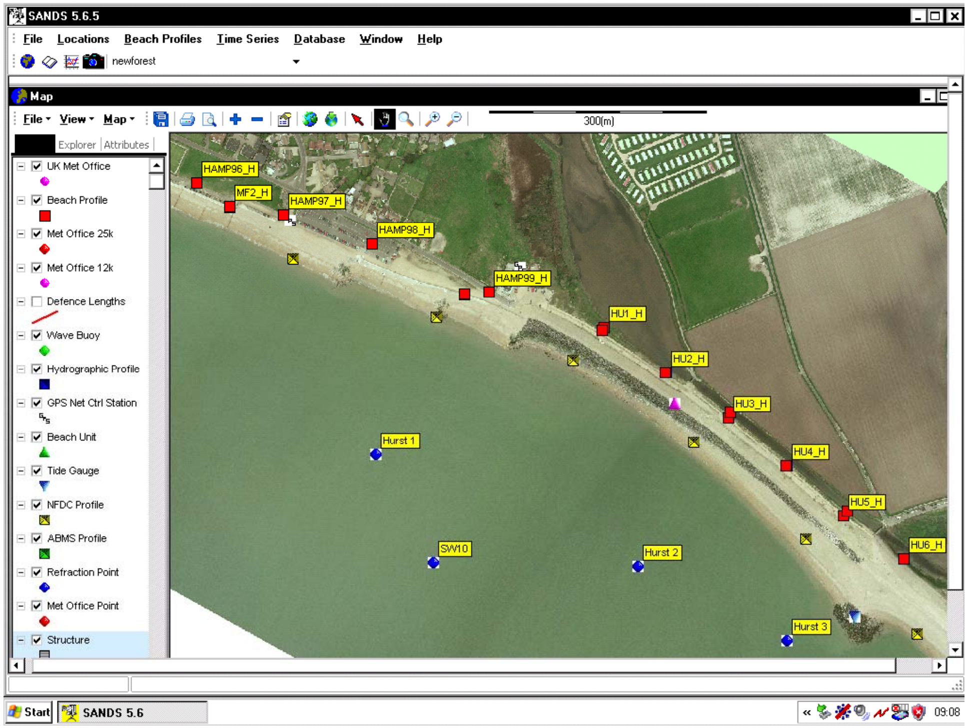


**Figure 5	Example near real-time directional wave data, from the project web site.**

Real time wave data are used for a variety of applications, including determination of threshold conditions for post-storm topographic surveys, identification of trigger levels for maintenance, warning thresholds for flood forecasting systems, management of floating delivery plant for coastal engineering schemes and even for identification of suitable conditions for surfing. Data may also be used in conjunction with post storm beach profile surveys and empirical models, to assess the risk or increased vulnerability of a coastal defence following a major storm event.

4 Data analysis

The analysis programme presents a requirement for a range of techniques, primarily to examine morphological changes to beaches in conjunction with wave and tidal forcing conditions. The level of analytical detail required is dependant on the beach management strategy for each site. A considerable proportion of the routine regional analysis focuses on wave, tide and beach interactions and is conducted within a proprietary analytical database SANDS (Shoreline And Nearshore Data System). The software has been developed by Halcrow Group Ltd and refined in conjunction with the Channel Coastal Observatory to meet programme requirements. Considerable recent modifications have been made to improve the end-user interface and to increase functionality. Databases have been established for each section of the coastline and local databases are held by many of the partner Local Authorities. The geographical front end has been populated with a series of data layers (Figure 6). The graphical front end and use of digital orthophoto backdrops enables beach profile and structure performance analysis to be placed in context with the local geomorphology and structure plan layout. Beach-, bathymetric-, LiDAR-, and photogrammetric- profiles, tidal time series, wave time series, modelled wave data and coastal-defence structure details are all stored and analysed within the system. The database provides complex tools that allow both temporal and spatial analysis of time series data.



Although a wide range of analyses are conducted within the programme, selected analysis tools are examined further in this paper for (a) wave time series and (b) beach profile data.

Figure 6 SANDS database GIS front end

4.1 Wave climate analysis

Region-wide analysis of wave climate is required to conduct coastal flooding and erosion risk assessments, to provide design conditions for new coastal engineering schemes and to provide input to simulation models of sediment transport. Ideally, all data would be derived from measured sources at shallow water sites, but the costs of adopting this approach alone are prohibitive.

The measured wave data archive is updated on a monthly basis, following a series of rigorous quality checks. This is supplemented by a region-wide and regularly updated wave hindcast, provided from the UK met office, UK Waters model; this provides a dense network of synthetic wave data on a 12km grid The hindcast time series archive dates back to 1986. Transfer functions have been determined for each of 42 near-shore sites (Figure 7), for a range of water levels at each site, using shallow water wave transformation models. The transfer function coefficients have subsequently been loaded to SANDS to enable rapid and regular updates of the near shore wave climate, based on powerful algorithms built into the database. On completion of wave transformation, the wave climate statistics can be updated rapidly and joint probability distributions of wave height, period and direction are updated annually for the whole time series and for each calendar year.

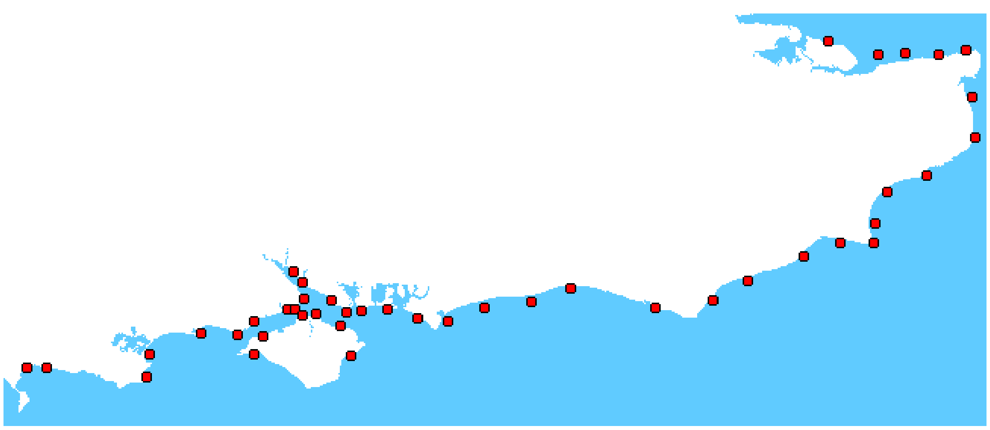
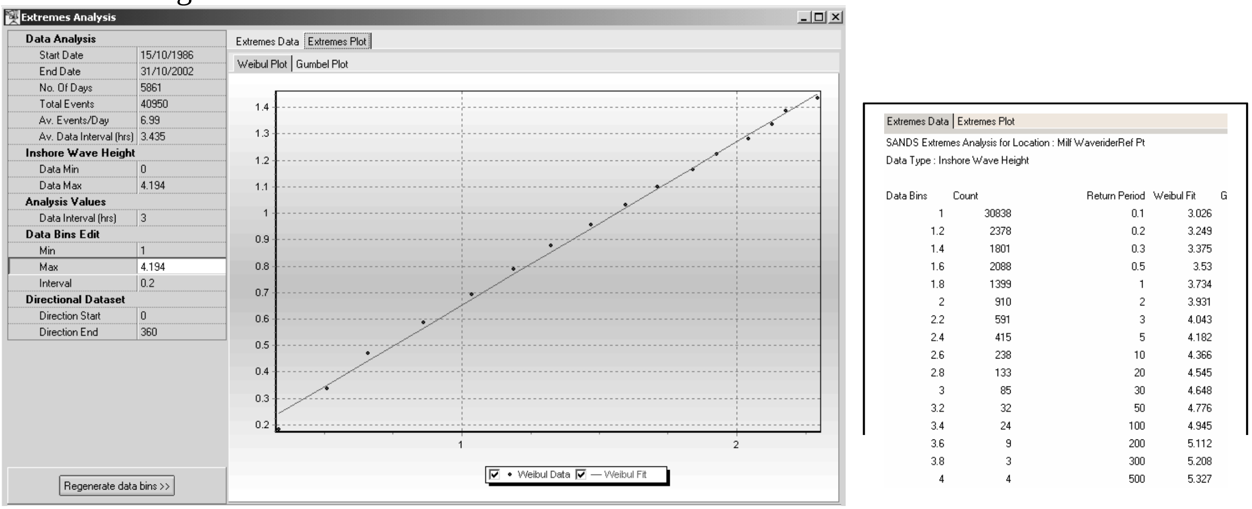


Figure 7 Region-wide wave transformation points in southeast England

Determination of extreme wave conditions is conducted within SANDS, by fitting data to both extrapolated 2-parameter Weibull and Gumbell distributions (Figure 8). Such data is typically used for determination of design conditions for new coastal engineering works and to reassess risk assessments for overtopping, structure stability and potential for breaching. Clearly the data sets need to be of suitable length (typically at least 10-20 years), before such an extreme analysis can be conducted with a reasonable degree of success.



Data Bins	Count	Return Period	Weibul Fit
1	30838	0.1	3.026
1.2	2378	0.2	3.249
1.4	1801	0.3	3.375
1.6	2088	0.5	3.53
1.8	1399	1	3.734
2	910	2	3.931
2.2	591	3	4.043
2.4	415	5	4.182
2.6	238	10	4.366
2.8	133	20	4.545
3	85	30	4.648
3.2	32	50	4.776
3.4	24	100	4.945
3.6	9	200	5.112
3.8	3	300	5.208
4	4	500	5.327

Figure 8 Example of extremes analysis of time series wave data derived from SANDS

Validation tests have been conducted of the numerical hindcasting- and transformation- models, by comparing output from these with the measured wave data at selected co-located sites (Bradbury *et al* 2004b). This exercise has already highlighted some significant, and regionally consistent, discrepancies between modelled and measured data (Figures 9 and 10). Region-wide differences between modelled and measured extreme wave heights are highlighted, with the model constantly under-predicting extreme wave heights. By contrast, the model appears to over-predict wave heights for conditions in the range H_s=1-2m (Figure 10); this has a significant impact on prediction of sediment transport rates in beach plan shape models. Similarly, the model appears to provide a significant over prediction, and provides poor frequency resolution, of wave period. Measured wave steepness is consequently significantly higher at the measurement sites than is suggested by the model (Figure 9).

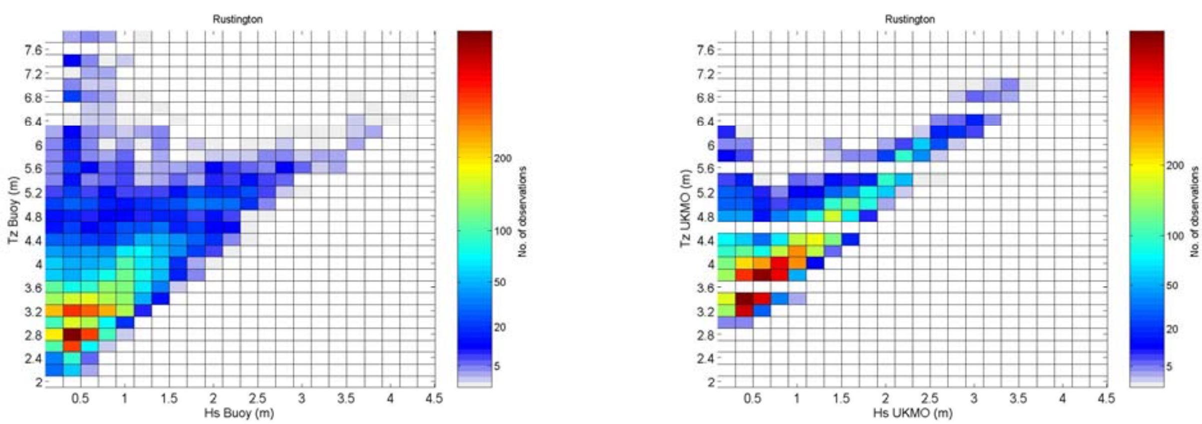


Figure 9 Scatter intensity plots of wave height and period distributions for a collocated wave buoy and UK waters model site (from Bradbury et al, 2004b)

Although wave direction is reasonably well represented, there are significant phase differences, with the model reacting more slowly to changes in wind direction than wave measurements would suggest. These collective differences may have significant management implications, particularly with relation to wave run-up, rock armour stability and sediment transport. This particular comparison exercise has demonstrated region wide benefits of the integrated measurement programme, and the need for improved hindcast modelling within the English Channel. Whilst comparisons at a single site may have identified some variability between modelled data and measurements, this could easily have been attributed to local bathymetric variation (for example). The systematic region wide comparison has shown that this cannot be the case.

Data from both measured and modelled time series data sets are regularly used in coastal process investigations, typically to drive numerical models of sediment transport, which are subsequently validated with measured beach profile and plan shape data. The regional monitoring programme wave data comparisons have now produced additional complications and further uncertainty to a methodology which is already fraught with technical difficulties. It is anticipated that further refinement of the numerical models will be conducted, with a further validation exercise to follow.

The time series data is particularly valuable for the assessment of storm events (Figure 10), usually in conjunction with beach profile data, tidal data and empirical cross shore models. Similarly, individual storm events can be analysed and compared rapidly with beach response data. Rapid comparisons of storm surge elevation and wave condition profiles can be examined quickly within the database.

Measured wave data is currently being used to calibrate a near-shore real-time wave forecasting model, based on the UK met office model, run in forecasting mode. This provides estimates of wave conditions for the period five days ahead. Whilst the model currently suffers from the same difficulties as the hindcasting model, the accuracy of prediction is perhaps less significant for operational planning purposes, when timing and the general magnitude of the event is more significant. The predicted timing of the storm peaks appears to be extremely well represented by the model (Figure 10). This enables reliable planning of any operational activities.

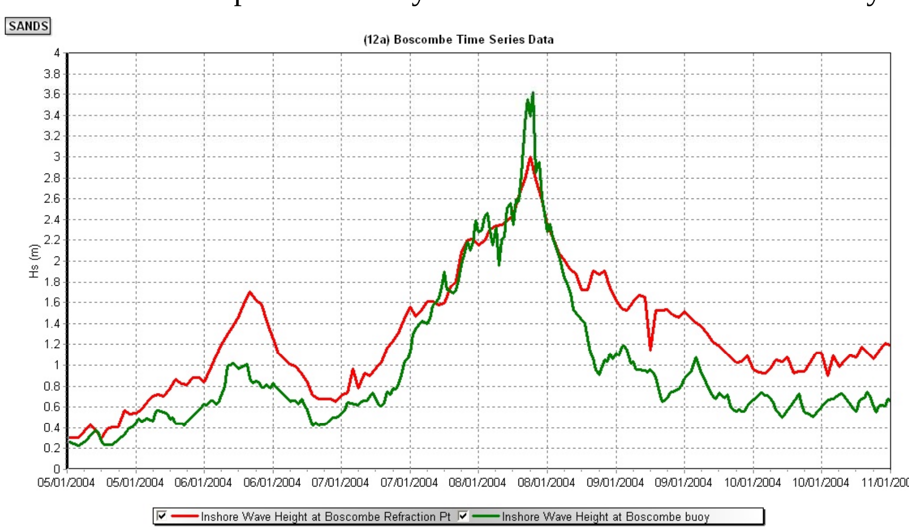


Figure 10 Time series comparison of modelled and measured near-shore wave height data for an extreme event in the English Channel

The wave data is used in parallel with a real time tide gauge network. Where suitable time series have been collected (typically one year per site) harmonic analyses of data sets have been conducted to provide predictions of tidal elevations. The modelled predictions are broadcast simultaneously with measured data and can be used to identify the magnitude of surges. Propagation of tidal elevations can be followed in real time along the English Channel and data used to provide flood-forecasting predictions (Bradbury et al, 2004a). The storm surge prediction model currently operated for the

Environment Agency flood forecasting service is less well developed for the Channel Coast than for some other parts of the country - the Solent is very poorly represented at present within these models. Real time measurements are therefore of considerable value in tracking surges. Data can also be used for validation of flood forecasting models and it is anticipated that the data will be used for development of the next generation of higher resolution (1km) surge prediction models. Real time data and predictions are presented for the Herne Bay tide gauge (Figure 11). Note the storm surge event on 12 November 2004.

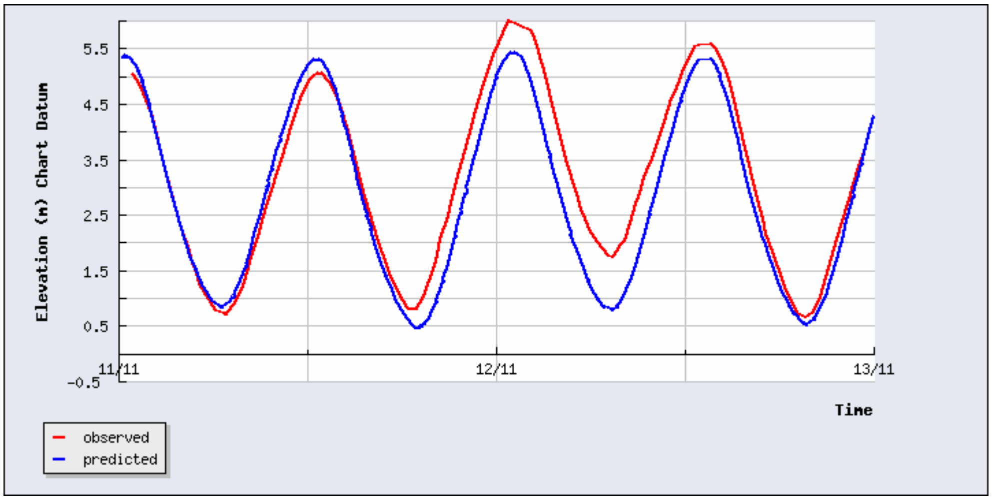


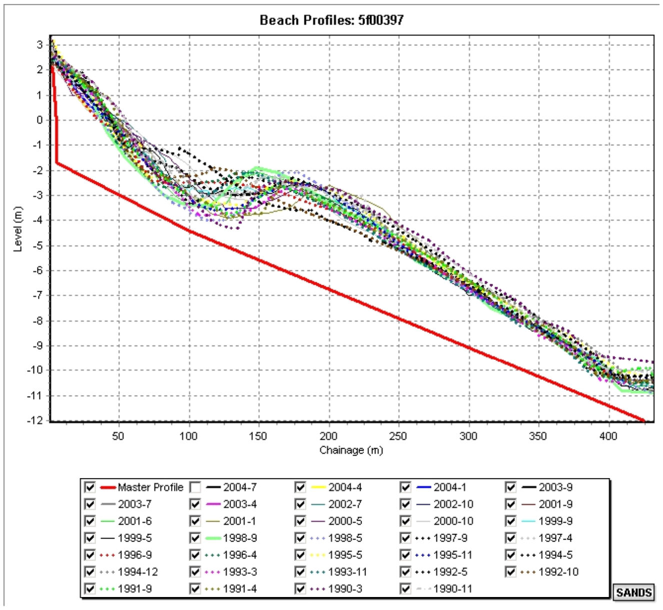
Figure 11 Real-time comparison of measured tidal data with tidal harmonic predictions

4.2 Beach profile analysis

A variety of analytical techniques used for beach profile data are examined and practical data collection and management problems highlighted. The analysis focuses on production of repeatable field and analytical techniques, and on presentation of the results in a form that can be used by non-technical decision makers. Analysis procedures are routinely used to examine seasonal and annual changes to beach cross section, relative to a master profile, and changes in foreshore gradient and intertidal beach width. Post storm data are compared with predictive empirical models of cross-shore profile response, to determine residual life or factors of safety of the existing beach system. Data are further summarised to present the beach manager with a simple overview of shoreline behaviour assessment using GIS to present broad scale coastal process unit behavioural summaries.

Data is subsequently used to refine and calibrate beach plan shape models and to assess actual performance against predicted beach performance. A series of management tools are being developed to assist with determination of the impacts of undermining, beach scour, overtopping of shore parallel structures and breaching of barrier systems. These provide inputs to derive critical thresholds and alarm conditions for each of the survey sites.

Basic comparisons are initially made within simple plotting routines that show changes in beach geometry with time. Examples are presented relative to a master profile (Figure 12) and the mean profile shown relative to the full envelope of change (Figure 13). Data are shown for a 30 year long data set of combined bathymetric and topographic profiles (Harlow and Cooper, 1996). The value of bathymetric data is highlighted by the large scale changes observed in the dynamic sub-tidal zone (below approximately -1m). The master profile is an important variable used for calculation purposes: all cross section areas are calculated relative to this boundary condition (see 4.2.1). In the examples shown, the master profile denotes the seawall and hard substrate geology, and has been determined on the basis of trial pits and boreholes. Use of the bed rock geometry within the master profile provides the opportunity to examine actual mobile sediment changes as opposed to relative changes. Regrettably this level of detail is not normally available at most sites.



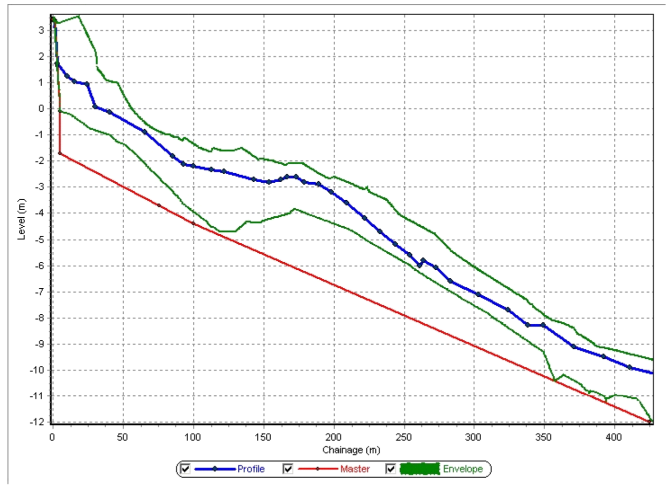


Figure 12 Time series of profiles shown relative to to the master profile.

Figure 13 Mean profile shown relative to the profile envelope.

4.2.1 Definition of the master profile

In order that calculations of beach change can be made in a systematic and repeatable manner, beach cross section areas must be calculated relative to fixed boundary conditions (the master profile). This presents difficulties in terms of (a) definition of the master profile and (b) field data collection procedures, to ensure that each profile survey "closes" on the master profile at both ends. The master profile includes three basic elements (Figure 14): (A) the landward boundary; (B) the lower boundary and (C) the seaward boundary. Once these elements have been defined, other features can be added to define the profile shape.

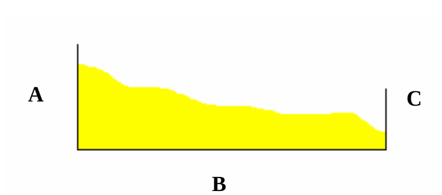


Figure 14 Key elements of the master profile

The landward boundary can be either dynamic *i.e.* unconstrained or static *i.e.* constrained. Static boundaries may include permanent structures *e.g.* sea walls or stable hard cliffs. Unconstrained boundaries may include, for example, dune systems, soft cliffs or barrier beaches. The lower boundary acts as a vertical cut-off for the profile calculations, and may be defined by a level e.g. Mean Low Water Springs (MLWS), or the bedrock level: if this is known it enables a more accurate calculation of actual beach volume. The seaward boundary may be defined by either a seaward chainage, or an elevation at which the calculation is cut. It is important to ensure that any survey data extends at least as far as the seaward boundary to avoid misleading area calculations (see Figure 15).

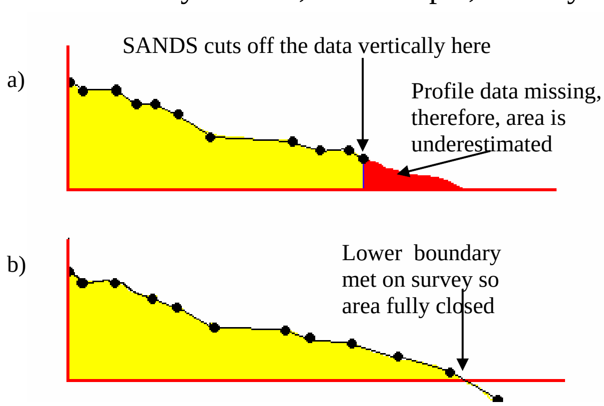
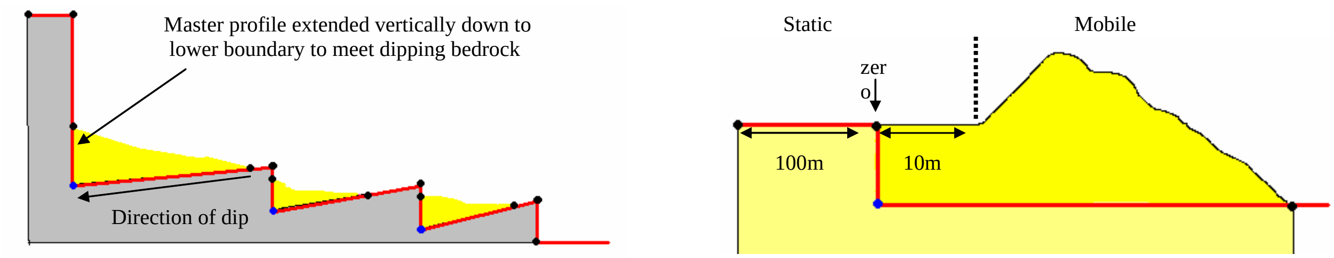


Figure 15 Implications of non-closure of the profile survey on calculations based on the master profile

Cross shore features such as: sea defence structures, slipways, channels and bedrock should form an integral part of the profile and can influence area calculations (see examples in Figure 16). The most frequently occurring problems arise with unconstrained profiles, when closure is difficult to achieve at the landward extent, due to, for instance, movement of dune systems, roll-back of barriers or intersection of beach systems with water bodies such as lagoons. Rigorous survey procedures are required to ensure closure at both limits of the profile. Further guidance for a wide range of beach configurations is presented by Pert *et al* (2004).



16a Landward dipping multiple bedrock exposure

16b Unconstrained barrier beach

Figure 16 Example master profiles for constrained and unconstrained profiles

4.2.2 Consideration of beach management techniques

Whilst analysis of profile changes is a straightforward process, it is often necessary to place measured changes in context with beach management techniques. For instance, beach recycling and sediment control structure construction can have a significant influence on natural evolution patterns. Without data relating to these activities, beach change analysis can be very misleading. Consequently performance assessments of beach management schemes may give a misleading picture. The lack of information often results in analysis that suggests that a scheme is performing somewhat better than it is in reality. Although major beach recharge schemes are usually well documented, with surveys that identify the quantity and location of beach material, many smaller scale maintenance related beach management activities do not seem to be well documented. Operational beach management procedures have not historically made provision for documentation of these activities (within the UK). This is complicated when management is conducted by a range of agencies, in an uncoordinated manner, across the region. Standardised documentation procedures have been developed to overcome this issue in conjunction with the southeast regional coastal monitoring programme. Simple forms have been established for on-site operational data collection and the database modified in order to include this information in conjunction with the beach change analysis (Figure 17).

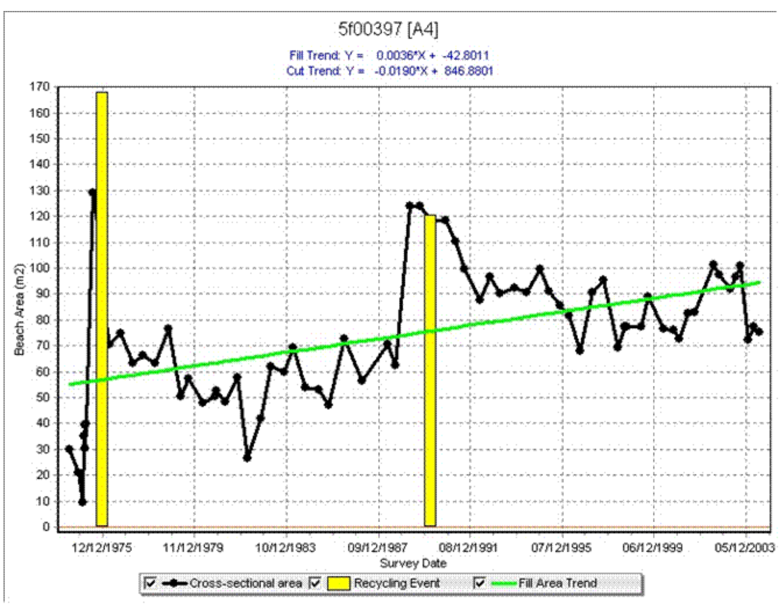


Figure 17 Beach profile trend analysis supported by data identifying beach recharge events.

All operating agencies are asked to fill out simple forms that identify the location and quantity of sediment moved, at excavation or beach fill sites. The system seems to be working reasonably well to date: survey teams are also tasked with identifying notable changes so that the data can be captured from operating authorities retrospectively if necessary. A database diary of beach management events provides the relevant detail to inform analysis of beach performance. The beach profile trend analysis enables beach changes to be put in context with management techniques, with recycling or recharge events highlighted (Figure 17).

4.3.3 The foreshore change parameter (FCP)

The foreshore change parameter (Figure 18) has been developed in conjunction with Futurecoast (Burgess et al, 2002). A single number (ranging from +6 to –6) describes the beach behaviour; it gives an indication of whether the beach is advancing or retreating *and* whether it is steepening or flattening. The rationale is that the most healthy state a beach can be in is to be advancing at both the Mean High Water (MHW) mark and at the Mean Low Water (MLW) level, and for the gradient to be flattening (beach steepening being generally associated with erosive or regressive conditions).There are three components to the FCP:

• Upper beach – can be either advancing, retreating or no change

• Lower beach – can be either advancing, retreating or no change

• Gradient between upper beach and lower beach – can be either steepening, flattening or no change

These three components are derived directly from SANDS (profile analysis by chainage). The beach levels used are MHW and MLW.

FCP	MHW	MLW	Inter-tidal (gradient)	Profile change
+ 6	Advance	Advance	Flattening	
+ 5	Advance	Advance	No rotation	
+ 4	Advance	Advance	Steepening	
+ 3	Advance	No movement	Steepening	
+ 2	Advance	Retreat	Steepening	
+ 1	No movement	Advance	Flattening	
0	No movement	No movement	No rotation	
- 1	No movement	Retreat	Steepening	
- 2	Retreat	Advance	Flattening	
- 3	Retreat	No movement	Flattening	
- 4	Retreat	Retreat	Flattening	
- 5	Retreat	Retreat	No rotation	
- 6	Retreat	Retreat	Steepening	

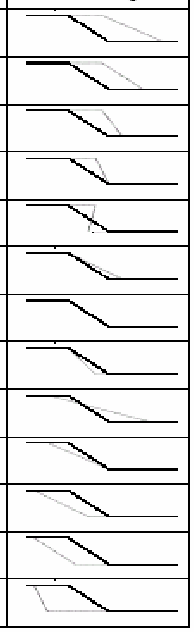


Figure 18 Classification of beach profile - Foreshore change parameter (from Futurecoast, 2000)

A time series of advance or retreat of MHW and MLW can be derived and the gradient between MHW and MLW, and changes in gradient through time calculated. The beach profile is then classified into one of 13 categories (see Figure 18). Note that whilst +6 and –6 are considered the most and least healthy conditions respectively for a beach, some of the intermediate stages are not necessarily a true ranking in order. For most beaches, suitable thresholds to be used in calculation of Foreshore Change Parameter are: change in chainage <= 0.25 m is regarded as no movement and change in gradient <= 0.05 is regarded as no rotation. Results are presented for each profile in the management overview analysis (Figure 19).

4.3 Process unit annual beach change overview

Data are reported on a region wide basis, in an annual overview report. The presentation format enables simple preliminary interpretation. The percentage change in cross section area, actual change in cross section area, and the foreshore change parameter are all presented, for all measured profiles, in a colour coded graphical format, with an aerial photograph backdrop (Figure 19); this enables non-technical end users to quickly identify areas that require further specialist investigation. The location of the survey lines, relative to coastal features, assists the interpretation. Note the long-shore profile response variability arising from the beach-groyne interaction, with erosion typically occurring on the downdrift (right) side of the groynes, and accretion on the updrift side. Further, more detailed supporting information is also provided including full hydrodynamic data sets, beach plan shape changes derived from digital ground models (Figure 20), profile trend analysis, and a strategic overview of beach changes across entire process behaviour units (Figure 21). The focus of this regional presentation style is aimed very much at the strategic level, and at a non technical decision making audience. The overview data identifies areas where further investigation is required for operational purposes.

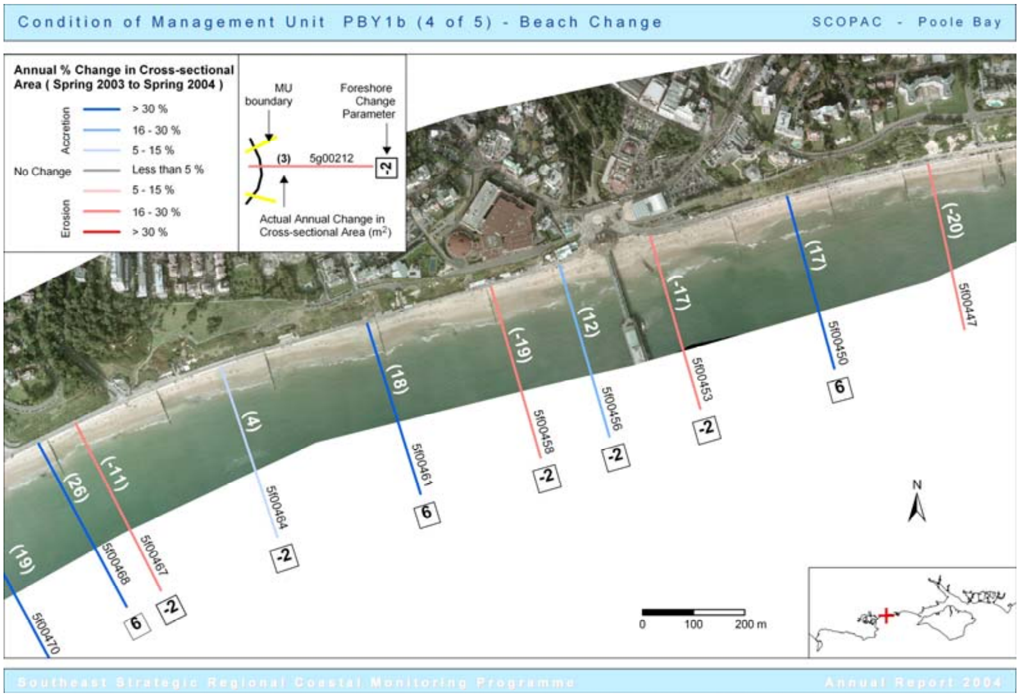


Figure 19 Variable beach changes on the groyned coastline at Bournemouth

Data is subsequently used to assist with the development of management tools, designed to assess the risk of overtopping, toe scour and breaching. A number of empirical techniques are currently either under development or validation.

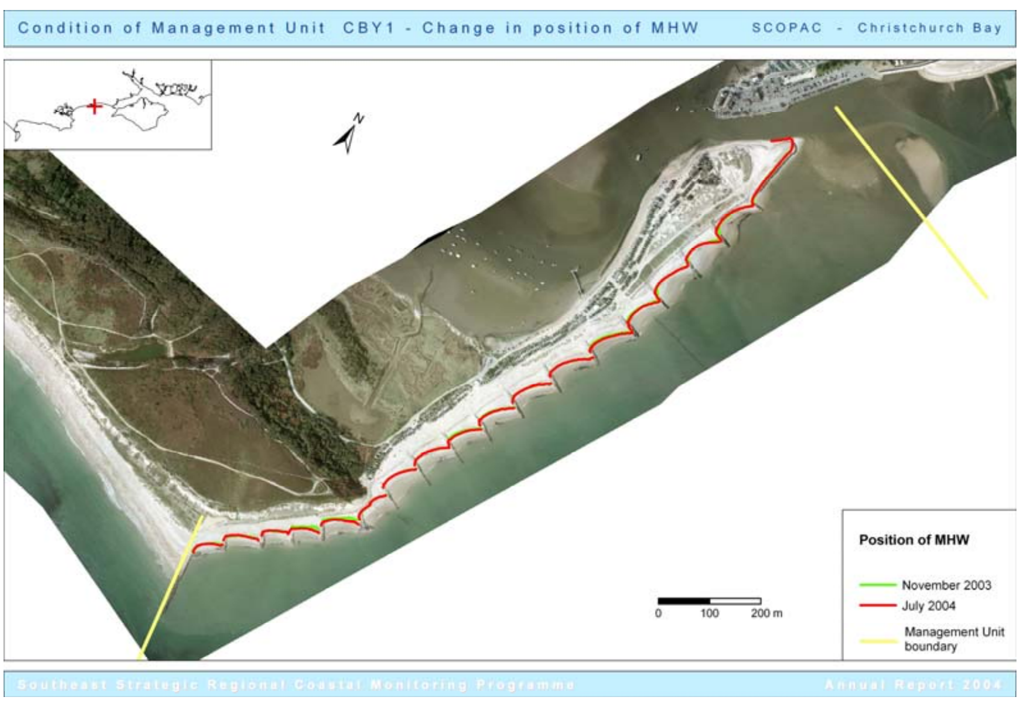


Figure 20 Beach plan shape changes of the mean high water contour, based on ground model

In particular, data is used for the assessment of beach management scheme performance, with comparisons made between performance projection and actual performance. This might typically include validation of numerical beach plan shape or cross shore models, risk assessments of structures and definition of critical or alarm beach levels, based on storm response surveys.

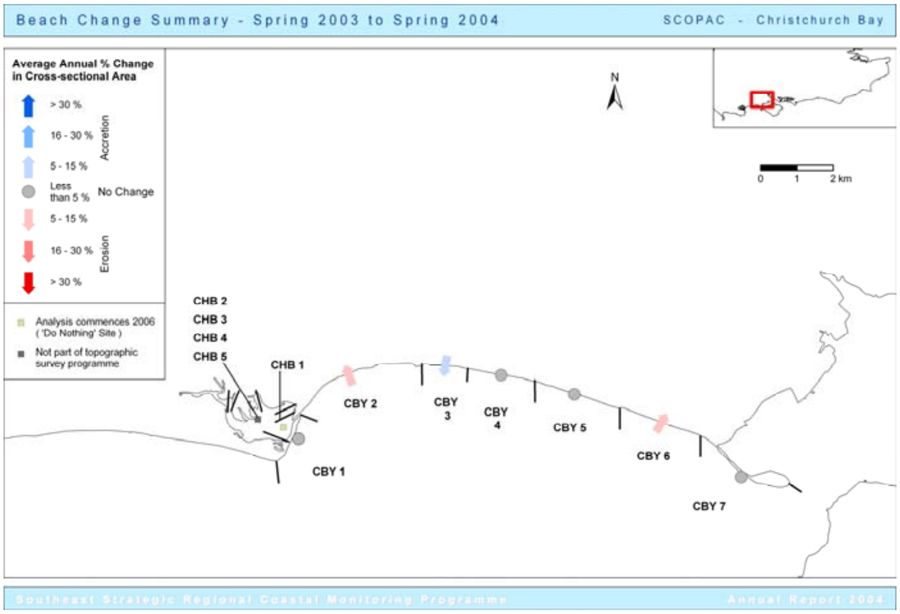


Figure 21 Coastal process behaviour cell performance summary

5 Conclusions

A large-scale regional coastal monitoring network has been established to inform shoreline management planning and operational flood and coastal defence in the UK. Real time web tools have been developed to provide operational real time wave and tidal data via a GIS interface. An operational online GIS and linked meta-database have been constructed. A series of analytical tools have been developed within SANDS, to provide combined analysis of environmental loading conditions and shoreline response. User friendly presentation procedures have been developed.

6 Acknowledgements

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