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Living with coastal erosion in Europe: Sediment and Space for Sustainability

DATA CONTENTS SPECIFICATIONS

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SCOPE

The scope of this document is to review which datasets will contribute to answer critical questions for coastline management. These critical management questions have already been discussed earlier in this document (introduction) and will continue to be referred to in the next chapter (functional requirements).

On the basis of the review of past and ongoing experiences in coastline management conducted Europe-wide in the framework of EUROSION, such relevant datasets can be organised 26 reference topics that we have organised in 9 topic groups have been identified. These reference topic groups and topics include:

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TOPIC GROUP 1. ADMINISTRATIVE BOUNDARIES

Topic 1.1. Terrestrial boundaries

Abstract: Terrestrial administrative boundaries provide a geographical delineation of administrative units – ranging from national borders to the infra-municipal district. Though the spatial extent of coastal erosion processes has little to do with administration, administrative boundaries are important in the sense that they help identify which local authorities are potentially exposed by coastal erosion and therefore arrange appropriate platforms of dialog and participation. Moreover a number of analysis requiring data of administrative - involving for example demographic data (see *demography*) - administrative

Spatial extent: In the framework of a coastal GIS, terrestrial administrative boundaries should be made available for all municipalities located within 10 km for the coastline. In low-lying areas, it is however recommended to extend the spatial coverage of administrative boundaries landwards up to the contour line corresponding to an elevation of 2 meters.

Format: Information on administrative boundaries should be provided as vector polygons. Each polygon represents an administrative unit ranging from national borders to infra-municipal districts.

Data acquisition and/or production method: Boundaries of administrative units ranging from the national level borders to the municipal level can be found at the level of national mapping agencies and are generally part of digital topographical databases (see *infrastructure*). For the infra-municipal level, EUROSION recommends to adopt the units used for census purposes (e.g. "*enumeration districts*" in the UK, "*îlots*" in France, etc.). The boundaries of these units may be accessible through national statistics office (see also *demography*) but their availability in GIS format varies from one country to another. In case this information on infra-municipal districts is not available in GIS format, the method recommended is to digitize this information from existing plans or textual descriptions obtained from the statistics office. This process is not expected to be time consuming since not all the municipalities are divided into census units (a typical census unit regroups approximately 2000 people, but this varies from one country to another).

Spatial accuracy: The planimetric accuracy of terrestrial administrative boundaries should ideally be better than 5 meters, which is consistent with the existing sources of administrative boundaries in digital format (in general 1:10,000 or better). See the section *infrastructure* for a detailed list of such databases in European countries and their respective scale.

Currency: Administrative boundaries are not expected to change over time. Acquisition of data on administrative boundaries should therefore be considered as a one-shot operation. Should changes occur anyway (e.g. merging of municipalities), it is recommended that this change is immediately reflected in the database.

Availability and costs: As mentioned above, digital databases featuring the terrestrial administrative boundaries – from the national level to the municipal level - exist in all European countries and are distributed by national mapping agencies. These data are copyrighted and subject to licence fees which vary from one country to another. Alternatively, a degraded version of administrative boundaries is also available at scale 1:100,000 - called Seamless Administrative Boundaries of Europe (SABE) – has been produced by the European mapping agencies and is distributed by their European federation, Eurogeographics (**www.eurogeographics.com**). SABE provides the boundaries of European administrative units in a seamless format (no discontinuity) for the whole Europe, at scale 1:100,000, and for fees ranging from a thousand to several thousands euros per country depending on the size of the country. The scale (1:100,000) is however a limitation for the implementation of coastal information system at the local. For more information on infra-municipal units (census units), a detailed list of national statistics offices in Europe is provided under the section *demography*.

Suitability for use: This layer comprises the baseline to which responsibilities may be reach. In order to delineate potential obstacles between natural processes as a continuous system (e.g. coastal sediment cells) and administrative ' irregularities' it is essential to provide *with* other data contents.

Topic 1.2. Maritime boundaries

Abstract: Maritime boundaries are critical elements for the planning of any activity in the ocean realm.. Many activities recognize the growing importance of maritime claim and boundary delimitation. National claims may overlap, creating areas of disputed ownership and jurisdiction that can lead to confrontation and even open conflict. In the assessment, exploration and recovery of petroleum, mineral or fishing resources, a distance of a few hundred meters can have significant economic importance. Trespassing a nation's claims could have serious consequences: arrests, fines, ship confiscation, prison, loss of limb or life. By delimiting areas where specific maritime activities are allowed and others not allowed, maritime boundaries may help delineate the extent of activities which directly or indirectly impact erosion processes, namely sediment extraction (sand and shell), and dredging for navigation. There also helps identifying areas where these activities and associated erosion are conflicting with other activities (fishing for example).

Spatial extent: In the framework of a coastal GIS, the boundaries of all maritime claims for the area considered should be made available.

Format: Information on maritime boundaries should be provided as vector poly-lines. Various types of poly-lines should be provided, namely those corresponding to :
territorial seas;
contiguous, joint development, fishing, and economic zones;
disputed areas

Data acquisition and/or production method: EUROSION has established a Europe-wide database of maritime claims. This database is available for free for any European user.
This database was produced by retrieving the entireness of international conventions and agreements which have been established among European countries to delineate the maritime claims. In practice, maritime claims are defined by a set of points which act as benchmarks. The maritime boundaries are then constructed by joining the points established internationally.

Spatial accuracy: Since the points defining maritime claims are established by law, the accuracy of the maritime claims corresponds to the accuracy of their legal definition.

Currency: Maritime boundaries are not expected to change over time. Acquisition of data on maritime boundaries should therefore be considered as a one-shot operation. Should changes occur anyway, it is recommended that this change is immediately reflected in the database.

Availability and costs: the layer “maritime boundaries” of the EUROSION database is accessible free of charge and should be requested to EUROSTAT.

Suitability for use: This layer comprises the baseline to which responsibilities may be reach. In order to delineate potential obstacles between natural processes as a continuous system (e.g. potential impacts offshore exploitation sites) and administrative ‘ irregularities’ it is essential to provide with other data contents.

TOPIC GROUP 2. TOPOGRAPHY

Topic 2.1. Aerial photographs / ortho-photographs

Abstract: The use of aerial photographs has been a popular method of measuring coastal change. Aerial photographs are taken from cameras embarked on aircrafts flying at variable altitudes. Typical photograph scales vary from 1:30,000 to 1:10,000 depending on the altitude. Aerial photographs provide a reliable picture of the ground at a specific time, including information on the type and position of buildings, infrastructure, vegetated and not vegetated areas. They provide as well the position of "one" interface between land and sea (depending on the tide at the time of photo acquisition). In most cases however, aerial photographs are not usable as such as they have significant geometrical distortions - due to their conic perspective - especially at their edge. A mosaic of geometrically corrected aerial photographs is therefore preferred. These so-called "orthophotographs" are made super-imposable to a map and are more appropriate for further analysis.

Spatial extent:: In the framework of a coastal GIS, aerial photographs should cover a minimal area which extends from 10 km inland to 2 km offshore. In the landward direction, aerial photographs are expected to provide information on urban, industrial, agricultural and natural assets located along the coast and potentially at risk of coastal erosion and flooding. In low-lying areas, it is however recommended to extend the spatial coverage of aerial photographs landwards up to the contour line corresponding to an elevation of 2 meters. Though aerial photographs provide few information on the wave regime near-shore, they can still provide indications on the topography of shallow waters including the locations of rip, flood and ebb currents, especially if aerial photographs are acquired at low tide.

Spatial accuracy: To provide an accurate position of the coastline, the resolution of aerial photographs and ortho-photographs should be sub-metric - ideally between 0,2 to 0,5 metre – which require that the flight scale ranges from 1:10,000 to 1:25,000.

Currency: Because of their high costs, acquisition of aerial photographs and production of ortho-photographs cannot – in general - be renewed every year. In highly dynamic areas, a survey frequency of 5 years should be considered as acceptable. In less dynamic areas, a frequency of 10 years may be considered as sufficient. Between two consecutive aerial surveys, lighter survey methods, like beach profiling on the ground, can be used as a complement (see beach profiling).

Format:: Information on aerial photographs and ortho-photographs should be provided into raster format (pixels). Commonly used raster formats include .bil, .sid, .tif, and .bmp.

Data acquisition and/or production method: Aerial photographs are acquired through analogical or digital cameras embarked on aircrafts specialised equipped for aerial surveys. With analogical cameras, photographs are first developed on silver films with dimension 24 cm x 24 cm before being scanned in order to integrate a GIS. Scanning operations aims at converting an analogical format into a digital format. Different emulsions exist for silver film, namely color emulsion ("natural color"), panchromatic emulsion ("grey scale"), or infrared emulsion, which all have their pros and cons. With digital cameras, photographs are directly acquired in digital format and are ready to use in a GIS, but digital camera. If the time of acquisition can be decided and weather conditions are favourable, it is recommended that aerial surveys takes place at low tide.

Ortho-photographs consist of a mosaic of aerial photographs that aims at correcting the aerial photographs from important internal distortions induced by the camera, and therefore making the information contained on aerial photographs super-imposable to a map. Beyond aerial photographs, production of ortho-photographs requires the accurate coordinates of a number of ground control points (GCP) as well a fair overlap rate between consecutive aerial photographs (i.e. the same ground control points should appear on at least two consecutive aerial photographs) . GCP are details easily identifiable on both the photographs and the ground (e.g. cross-roads, angle of significant buildings, etc.), and their coordinates are measured via GPS techniques.

Availability and costs: Acquisition of aerial photographs and production of ortho-photographs require important skills and equipment. A number of private companies – and in some countries, the national mapping agencies as well - are specialised in the provision of such services. The costs of aerial photograph acquisition ranges from 300 Euros to 500 Euros per square kilometre and depend on: (i) the size of the area to be surveyed (the larger the area to be covered, the lowest the unitary cost), (ii) the type of emulsion (panchromatic emulsion are cheaper, infrared emulsion are more expensive), (iii) the acquisition scale (the higher the aircraft altitude, the less photographs are needed). If the production of ortho-photographs is included in the service, the above mentioned unitary costs are doubled.

Suitability for use: Information extracted from aerial photographs and ortho-photographs are critical to understand coastal processes, monitor coastline evolution and assess the risk of coastal erosion. More precisely, this information include:

the position of the coastline at the time of photo acquisition. Since uncertainties can occur about the level reached by the highest high waters, more practical definition such as the foot of the fore-dune, the cliff toe, or upper limit of beach can be introduced. (see also current and historical coastlines)

the land cover or land use (see also land cover and land use)

Infrastructure including engineered frontage (harbour jetties, breakwaters, groins, seawall) and transport and energy assets (roads, railways, high voltage lines). (see also infrastructure)

Example of aerial photographs - Happisburgh, North Norfolk, United Kingdom

1992 1999 2001

Topic 2.2. Satellite images

Abstract: Recent technological developments in space-borne remote sensing have increased the opportunities offered by satellite images for coastal applications. In the past 5 years, a number of new optical sensors have become operational and routinely provide high resolution images, with a 1 to 5 meter resolution for the most accurate satellites. Even though the resolution of satellite images cannot compete with the resolution of aerial photographs (see aerial photographs), satellite images may provide a cost-effective solution where coastal areas to be monitored are very large, or to derive information which are not needed at a scale better than 1:25,000. Just like aerial photographs, satellite images provide a reliable picture of the ground at a specific time, including information on the type and position of buildings, infrastructure, land use, vegetated and not vegetated areas. In addition, image acquisition can be renewed every month (theoretically), which makes satellite images suitable for six-monthly or yearly monitoring.
However, limitations in the resolution may be an obstacle to monitor the position of the coastlines, since yearly evolution rate exceeds 2-3 meters (the typical resolution of high resolution satellite images) only exceptionally. Best uses of satellite images are therefore in combination with aerial photographs.
Although accurate measurements of water depth can be achieved by using conventional shipboard sounding techniques, such a survey is slow and expensive. To maintain a chart series in an accurate, adequate and up-to-date condition is an immense task to the hydrographers. As a result, investigators have become interested in the application of remotely sensed data for hydrographic charting. The successful application of passive remote sensing techniques to this problem is restricted to shallow, clear water areas with small changes in bottom types and free from atmospheric contamination.

Spatial extent:: Unlike aerial photographs, coverage of satellite images can extend up to 50 km inland. Images are generally provided as “scenes” of square size: typically 90 km x 90 km for LANDSAT images or 60 km x 60 km for SPOT scenes.

Spatial accuracy: The resolution of satellite images varies according to the type of sensors. The table below provides the main characteristics for commonly used optical images.

Currency: The flexible distribution rights policy and the lower acquisition costs of the LANDSAT 7 satellite opened the door to new possibilities for data providers.

Landsat can provide users with coarse scale imagery that covers large areas at a relatively low cost. Costs could be as low as 0 - 600 euros depending on the date of the imagery and if it was previously procured by another agency. If extensive processing is required the costs may be 5,000 euros per frame.

Spot (Level 1A and 1B products), for an area approximately 60 km x 60 km, run upwards from 700 euros for film, 850 euros for print, and 2,000 euros to 2,800 euros for digital. The SPOTView products run from $1,000 on up to about $13,000 depending on the size of the area and the sensor used. Large area coverage is also available and is priced on a cost per square-kilometer basis.

Format:: Satellite images re provided in raster format (pixels). Commonly used raster formats include .bil, .sid, .tif, and .bmp.

Data collection method: Satellite images taken during low tide periods

LANDSAT Image of Sylt, Germany

SPOT 5 image of Eleusis, Greece

Availability: SPOT 4 orbits the earth since March 1998 and is working without problems. Two other satellites of this series, SPOT 1 and SPOT 2 are still operating. The first SPOT satellites have only three bands covering the green, red, and near infrared portion and a panchromatic band. The Short-wave infrared band is the major development for SPOT-4. Since 04.05.02 SPOT 5 is in space
SPOT satellites have a tape onboard able to record data from South Pacific Island Countries and download whenever they fly over a certain area. However, the customer has to pay extra for special acquisition

Suitability for use: The following data types may be collected with a remote sensing system: altitude, bathymetry, morphology, land use and vegetation cover. These data might help to monitor processes like cliff erosion, land use changes, urban development and the change of natural vegetation patterns.

Technical specifications of different sensors – Comparative tables

Sensor	Spatial resolution	Swath width	Spectral features	Visit time period
High Resolution Optical Multispectral sensors				
IKONOS (Space imaging, Commercial)	1m panchromatic 4m multispectral	60 km	4 spectral bands; Range 0.45 – 0.88 µm	5 days
IRS-1C/IRS-1D Pan + LISS	5.8m panchromatic 20m multispectral	70km-140km	4 spectral bands Range 0.59 - 1.70 µm	24 days
Landsat-7, ETM	15m-60m	185km	7 spectral bands; Range 0.45 - 2.35 µm	
SPOT-4 (SPOT Image, Commercial)	10m panchromatic 20m multispectral	60km	4 spectral bands; Range 0.50 - 1.75 µm	26 days
SPOT-5 (SPOT Image, Commercial)	2,5m supermode panchromatic 5m panchromatic 10m multispectral 20m, SWIR	120km	4 spectral bands; Range 0.50 - 1.75 µm	26 days
High Resolution Synthetic Aperture Radar (SAR) sensors				
ENVISAT ASAR (ESA)	6m-100m	50km-500km	C Band HH, VV polarisations	3 days (35 days with the same geometry)
ERS-1 & 2 (ESA)	24m	100km	C Band VV polarisation	3 days (35 days with the same geometry)
JERS-1 SAR (NASDA)	18m	75km	L Band HH polarisation	44 days with the same geometry
RADARSAT-1 (CCRS)	10m-100m	50km-500km	C Band HH polarisation	3 days (34 days with the same geometry)
RADARSAT-2 (CCRS)	6m-100m	50km-500km	C Band HH, VV polarisations	3 days (24 days with the same geometry)
Medium Resolution Optical sensors				
ENVISAT MERIS (ESA)	300m	1150km	15 spectral bands Range 390nm-1040nm	3 days (35 days with the same geometry)
TERRA MODIS (NASA)	250m	2330km	36 spectral bands; Range 0.62 - 16.385 µm	2 days

Topic 2.3. Historical and current coastline position

Abstract: Coastline can be defined as the interface between land, sea and air. However, due to the relentless fluctuations of the sea, its position cannot be precisely defined. To remove ambiguity, the coastline is therefore defined as the level reached by the highest high waters, i.e. the upper limit of the inter-tidal areas. This upper limit is generally easily identifiable on the ground (e.g. foot of the fore-dune) or can be derived from aerial photographs or high resolution satellite images. The current and historical positions of the coastline are key information to understand coastal processes, anticipate future changes and prevent building in highly dynamic areas. In that respect, valuable information is provided by historical topographical maps from the early 1900s.

Spatial extent: The coastline position should be covered for the entire long-shore extent of the area considered in the coastal information system.

Format: The coastline positions over time should be made available as vector poly-lines.

Data acquisition and /or production method collection method: A number of techniques make it possible to delineate the shoreline position (either current or historical). The coastline may be:

Digitised directly from existing ortho-photographs (see *aerial photographs*) using computer-aided photo-identification functions offered by most GIS software, provided the coastline is easily identifiable as, for example, a characteristics feature of the cliff profile, the foot dune, or hard seafront structure.
interpolated from cross-shore profiles (see *cross-shore profiles*), i.e. the “probable” position of the shoreline is deduced from the position of the shoreline accurately known at certain locations along the shore. This method may be particularly efficient if cross-shore profiles are spaced 500 metres or less.
derived by intersecting the highest high water level (excluding storm level) known at a certain location with an accurate elevation model produced from remote sensing technologies (mainly LIDAR or aerial photogrammetry)
In the case of historical coastline position, the coastline may be derived from ancient from old topographical maps (e.g. in France *Carte de l’Etat Major*, 19th century) or old aerial photographs generally available in all Europe since the early 1950’s.

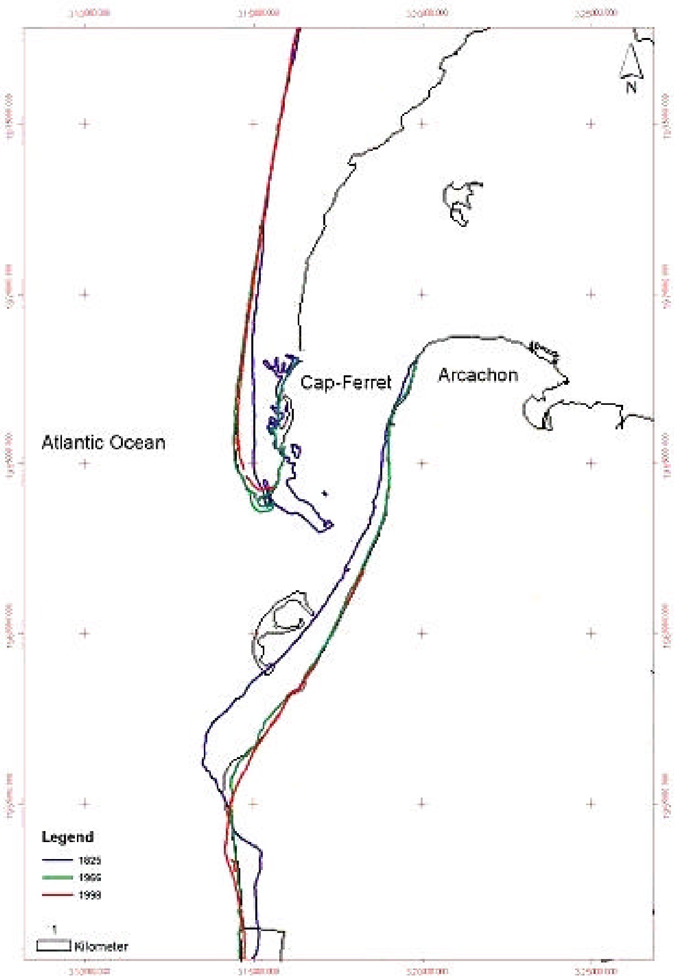
The figure below provides an example of coastline extraction from aerial photographs and old topographic maps in Cap Ferret (France)

Spatial accuracy: The planimetric accuracy of the coastline position should be better than 5 metres.

Currency: Depending on the dynamic of the area (and associated coastline retreat rate), the coastline position should be updated every 3 to 5 years in case of highly dynamic areas or 5-10 years in case of less dynamic area.

Availability and costs: The possibility to derive accurate data on the coastline position depends on the availability of other sources of data, namely aerial photographs, LIDAR surveys or cross-shore profiles. Though the cost of coastline extraction itself is rather low (an experienced photo-identifier can extract 100 km of coastline within one week with adequate documentation), the cost of input data is high: the cost of ortho-photographs range from 100 Euros per km2 (if aerial photographs are already available within national mapping agencies) to 400 Euros per km2. As for a LIDAR survey is about 500 Euros per km2 (if at least 100 km2 are covered). If the coastline length is not too long (less than 50km), cross-shore profiles may be a cost-effective alternative to remotely sensed product with an average of 20,000 to 30,000 Euros of field surveys including GIS treatments.

Suitability for use: A good assessment of historical and current coastline positions is essential when performing a hazard assessment for potential future land or other capital loss near the coastline. This is based on the assumption that processes in the past are the key to processes in the future (at least, when no coastal defence structures are adopted). In the guidance document on coastal hazard assessment (part VII), this is more elaborated.



Evolution of the coastline position in Cap Ferret (France) derived from aerial photographs

Topic 2.4. Infrastructure

Abstract: Spatial data on infrastructure and hydrography constitute the backbone of most land information system. Infrastructure data include a graphical representation of roads, railways, high voltage lines, large jetties, large human constructions (harbours, airport, plants), and remarkable objects (e.g. lighthouse, geodetic benchmarks). In most of European countries, such data exist in digital format at a typical scale of 1:10,000 (in some countries, the scale may reach 1:5,000). They are distributed by the National Mapping Agencies.

Spatial extent: In the framework of a coastal information system, the spatial extent of infrastructure data should encompass all terrestrial areas located within a 10 km land strip from the coastline. In the case of low-lying areas, EUROSION recommends however to extend it to areas located below the 2 metre contour line. Note that in some regions, the 2-metre-contour line may result in extending the spatial extent to more than hundreds of kilometres in land.

Format: The position of infrastructure features shall be made available as vector polylines or polygons. The nature of the infrastructure (road, railway, high voltage lines, jetties, harbour, airport, benchmark, lighthouse, etc.) shall be made available as an attribute of the vector objects.

Data acquisition and/or production method: In case information on infrastructure is routinely distributed by national mapping agencies at a scale 1:10,000 or better (the general case), it is recommended to acquire such a product via those agencies.

In case spatial information does not exist or is not easily accessible, the data production process shall consist in extracting infrastructure features from ortho-photographs using computer aided photo-identification functions offered by commercial GIS.

In practice however, a combination of both method (acquisition of existing datasets and photo-identification) is preferable. Indeed, due to their high production and maintenance cost, digital databases distributed by national mapping agencies are updated with a frequency ranging from 10 to 20 years depending on the country. Recent changes in the infrastructure may therefore not be reflected.

Spatial accuracy: The planimetric accuracy of infrastructure objects should be better than 5 metres. Vertical accuracy should be less than 1 metre. These accuracies are consistent with the accuracy of databases distributed by national mapping agencies.

Currency: Infrastructure objects should be updated with a frequency of 5 to 10 years.

Availability and costs: Infrastructure data are usually part of digital topographical databases generally available as “on-the-shelf” products in all European countries and are distributed by the National Mapping Agencies. They are also copyrighted which restrict their usage to the internal needs of licensed users. Data are provided in vector GIS format compatible with wide range of software (ArcInfo, AutoCAD, MapInfo, etc.). For a typical topographical dataset at a nominal scale of 1:10.000, the expected accuracy is generally about 1-3 meters. At a smaller scale (eg. 1:100.000), the accuracy is about 10-20 meters. The following list summarizes existing topographical databases at the national level :

Providers of GIS topographical data (including infrastructure, hydrography and terrestrial elevation)

Country	***Mapping Agency***	***Product (scale range)***
Belgium	Institut Geographique National/Nationaal Geografisch Instituut	1:10 000 topographic database (1:5000 - 1:10 000)
Denmark	Kort & Matrikelstyrelsen	TOP10DK (1:5000 - 1:10 000)
Finland	Maanmittauslaitos	Topographic Database of Finland (1:10 001 - 1:30 000)
France	Institut Geographique National	BD TOPO (1:10 001 - 1:30 000)
Germany	LandesVermessung + GeoBasisInformation NiederSachsen	Authoritative Topographic-Cartographic Inform. System (1:10 001 - 1:30 000)
	LandesVermessungsAmt Mecklenburg-Vorpommern	Authoritative Topographic-Cartographic Inform. System (1:10 001 - 1:30 000)
	LandesVermessungsAmt Schleswig-Holstein	Authoritative Topographic-Cartographic Information System (1:5000 - 1:10 000)
Great Britain	Ordnance Survey	OSCAR (1:5000 - 1:10 000)
Ireland	Suirbhéireacht Ordanáis na Éireann	Urban Street Vector Database (1:10 001 - 1:30 000) 6 inch RVCS (1:10 001 - 1:30 000)
Italy	Istituto Geografico Militare Italiano	Vector 1:50000 (1:30 001 - 1:75 000)
Netherlands	Topografische Dienst Nederland	Topographic vectordatabase of the Netherlands 1:10 000 (1:5000 - 1:10 000)
Northern Ireland	Ordnance Survey of Northern Ireland	Large Scale Digital Data (Vector) (Larger than 1:5000)
Portugal	Instituto Portugues de Cartografia e Cadastro	1:10 000 Topographic Vector Map (1:5000 - 1:10 000)
Slovenia	Geodetska Uprava Republike Slovenije	Digital Topographic Database (1:5000 - 1:10 000)
Spain	Centro Nacional de Informacion Geografica	Cartographic database 1:25 000 (1:10 001 - 1:30 000)
Sweden	Lantmäteriverket	GSD-Blue Map (1:75 001 - 1:150 000)

All the above mentionned databases are copyrighted. For more information, please refer to Eurographics Web site: http://www.eurogeographics.org/Projects/GDDD/GDDD/lists/sp_54.htm

Suitability for use:
When performing a risk assessment (probability of hazard x potential consequences), georeferenced data on infrastructure works is essential for the assessment of capital at risk (See Cost/Benefit analysis document)

Topic 2.5. Hydrography

Abstract: Hydrographical data include a graphical representation of rivers, canals, lakes and other water bodies. In most of European countries, such data exist in digital format at a typical scale of 1:10,000 (in some countries, the scale may reach 1:5,000). They are distributed by the National Mapping Agencies.

Spatial extent: In the framework of a coastal information system, the spatial extent of hydrographical data should encompass all terrestrial areas located within a 10 km land strip from the coastline. In the case of low-lying areas, EUROSION recommends however to extend it to areas located below the 2 metre contour line. Note that in some regions, the 2-metre-contour line may result in extending the spatial extent to more than hundreds of kilometres in land.

Format: The position of hydrographical objects shall be made available as vector polylines or polygons. The nature of the hydrographical objects (river, canal, lake, etc.) shall be made available as an attribute of the vector objects.

Data acquisition and/or production method: In case information on hydrography is routinely distributed by national mapping agencies at a scale 1:10,000 or better (the general case), it is recommended to acquire such a product via those agencies.

However, should such products not exist or not easily accessible, and contrary to infrastructure, accurate extraction from ortho-photographs may be limited since hydrographical objects are not always easily identifiable from "flat" ortho-photographs. Rather, it is recommended to extract hydrographical objects from "stereo-plotting". Stereo-plotters are devices which can, from two aerial photographs of the same area but taken from 2 different perspectives, reconstruct a three-dimensional view of the area. This 3-D view makes it possible for an operator to "capture" from the aerial photographs a number of terrestrial elements which will be then digitised and structured in a database.

Spatial accuracy: The planimetric accuracy of the hydrography should be better than 5 metres. Vertical accuracy should be less than 1 metre. These accuracies are consistent with the accuracy of databases distributed by national mapping agencies.

Currency: Hydrographical objects do not undergo frequent changes. In addition their updating cost is extremely high. An update frequency of 10 to 20 years is therefore recommended.

Availability and costs: Infrastructure data are usually part of digital topographical databases generally available as "on-the-shelf" products in all European countries and are distributed by the National Mapping Agencies. They are also copyrighted which restrict their usage to the internal needs of licensed users. Data are provided in vector GIS format compatible with wide range of software (ArcInfo, AutoCAD, MapInfo, etc.). For a typical topographical dataset at a nominal scale of 1:10.000, the expected accuracy is generally about 1-3 meters. At a smaller scale (eg. 1:100.000), the accuracy is about 10-20 meters. See infrastructure for a list of existing topographical databases at the national level.

Topic 2.6. Terrestrial elevation

Abstract: Terrestrial elevation is the altitude above sea level. In most of European countries, the altitude "zero" (the so-called vertical datum) corresponds to the mean sea level (MSL), i.e. the average level of the sea as recorded by tide gauges. This "zero" differs from the "zero" of the bathymetry (see *near-shore bathymetry*), which is defined as the mean lowest low water level (MLLW). The difference may reach a few meters. Terrestrial elevation is important to assess the exposure of human assets located along and behind the coastline to the sea processes (mainly storm surges and coastal erosion). This section must be considered in complement to the section *cross-shore profiles*.

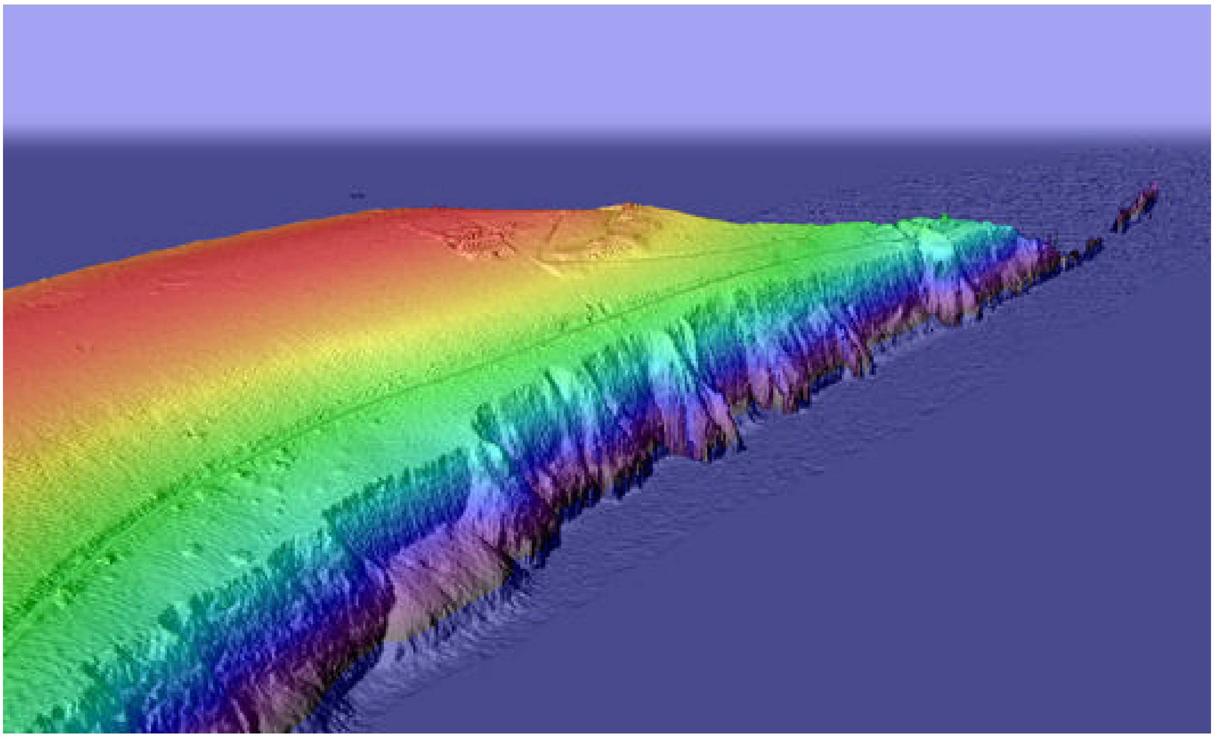
Spatial extent: In the framework of a coastal GIS, terrestrial elevation should preferably be available for all terrestrial areas located within 10km from the coastline. In the case of low-lying areas, it is recommended to expand this spatial extent to areas located below the 2-metre contour line.

Format: Terrestrial elevation should be made available either as vector contour lines, or in a raster grid of elevation points. Key contour lines include
the contour line "zero" corresponding to the mean sea level (MSL).
the contour lines 1m, 2m, 3m, 4m and 5 m above MSL
above 5 metres, all contour lines with 5 metre equidistance (10m, 15m, 20m, 25m, etc.)

Data acquisition and/or production method: A wide range of techniques are available to determine the terrestrial elevation. Major among these techniques are:

Elevation contour lines (vector format) are generally routinely distributed by national mapping agencies as part of digital topographic databases (see *infrastructure* as well). The list of existing digital topographic databases may be found under the section *infrastructure*.

Laser altimetry or LIDAR. LIDAR is an airborne device which send laser pulses downwards. LIDAR is particularly efficient for near-shore areas as it can "sense" the elevation for both terrestrial and underwater areas (see *near-shore bathymetry*). The accuracy of LIDAR survey approximates 15 centimetres and its raster resolution can be one metre. However its extremely high cost limits the possibility to use the technique for the complete coverage of the coastal areas.



LIDAR view of "the Needles" – Isle of Wight (UK)

Alternatively, terrestrial elevation can be extracted from "stereo-plotting". Stereo-plotters are devices which can, from two aerial photographs of the same area but taken from 2 different perspectives, reconstruct a three-dimensional view of the area. This 3-D view makes it possible for an operator to "capture" from the aerial photographs the contour lines which are then digitised and structured in a database. (see also *hydrography*)

Spatial accuracy: The accuracy of terrestrial elevation should be 5 metre for horizontal positioning, and better than 1 metre for vertical accuracy. Note that for very gentle slope, the accuracy may be coarser.

Currency: Elevation data have rather low maintenance costs since within a 1m vertical accuracy, no major changes are expected in areas which are geologically stable. However, if demands on accuracy increase, geomorphologic changes become more and more important.

Availability and costs: Most coarse Elevation models (DEMs) are easily available at low price.

Suitability for use: Collecting information on terrestrial elevation has the main advantage to delineate low-lying areas. This is essential for the assessment of flooding hazards.

Topic 2.7. Nearshore bathymetry

Abstract: Bathymetry is the depth below sea level. In most of European countries, the depth “zero” (the so-called vertical datum) corresponds to the mean lower low water level (MLLW), i.e. the level reached by water at low tide during the period where the tidal range is the highest (spring tides). This “zero” differs from the “zero” defined for terrestrial elevation, which is defined by the mean sea level (MSL). The difference may reach a few meters. Changes in nearshore bathymetry occur as a result of sediment processes or dredging activities. It is an important feature for understanding coastal erosion as erosion processes mainly occurs underwater and affect the sea bottom therefore coastline retreat is effectively observed. The bathymetry plays also an important role for nearshore wave propagation, as waves modifies their courses as soon as they “feel” the sea bottom.

Spatial extent: In the framework of a coastal GIS, bathymetry should preferably be available for a maritime area extending up to the 20 meter water depth. The 20-meter-water depth approximately corresponds to the depth at which shoaling processes start.

Format:: Near-shore bathymetry should be made available as vector contour lines (or “isobath”). The contour line “zero” corresponds to the lowest low water line (LLW).

Data acquisition and/or production method: A wide range of techniques are available to determine the bathymetry. Major among these techniques are:

Waterborne acoustic sensors. Acoustic sensors like multibeam echosounders or sidescan-sonar. are emitters-sensors onboard ships. The sensor sends a signal in the direction of the sea bottom. After it has reached the seabed, the signal is back-scattered to the sensor with a delay which is converted into a distance. Performance of echo-sounding for very shallow waters (0 to 3 metres) is limited since ships cannot get too close from the shore.

CRAB echo-sounding. The technology of CRAB echo-sounding beamers is similar to the technology of waterborne echo-sounding. However, instead of being embarked on a ship, the beamer is mounted on a mobile crane able to move easily on the foreshore and in shallow waters.

Laser altimetry or LIDAR. LIDAR is an airborne device which send laser pulses downwards. Just like SONAR, the laser signal is reflected by the ground and a part is backscattered with a delay to the sensor. LIDAR is particularly efficient for water depths down to 5-10 metres (and with limited turbidity) and for terrestrial elevation (elevation of terrestrial and shallow waters are provided “seamless”). The performance of LIDAR however decreases for deeper waters. Since data recorded by echo-sounding or LIDAR sensors are not easily exploitable by a GIS, they need to be converted into either into raster image or vector contour lines.

Interpolation of cross-shore profiles. Cross-shore profiles (see section *cross-shore profiles*) provide accurate information on the bathymetry of the foreshore at specific location. The bathymetry between these locations can be interpolated using standard GIS functions such as spline.

Spatial accuracy: The accuracy of bathymetric contour lines should be compatible with scale 1:25,000, i.e. 5 metre for horizontal positioning. Note that for very gentle slope, the accuracy may be coarser. Contour lines should ideally have a 1-metre-equidistance, i.e. contour lines should be provided for the following water depths: 1m, 2m, 3m, until 20m. Note that near-shore bathymetry should be far more accurate than for example terrestrial elevation (say, a 5m contourline) or offshore bathymetry, when it comes to coastal dynamics.

Currency: As coastal sediment transport processes primarily occur underwater (in the surf zone, i.e. 5-10m water depth), sediment deficit is first and foremost reflected in bathymetric changes. For that reasons, it is recommended to adopt a 5-year update frequency.

Availability and costs: Compared to national or regional existing digital terrain models, near shore bathymetry is much less available: First, because high-resolution bathymetry is very dynamical because of waves, tidal currents, etc. Second, near shore bathymetry is only relevant when certain accuracy has been reached. Therefore, costs are expected to be high.

Suitability for use: Collecting information on near-shore bathymetry has a threefold objective:
Near-shore bathymetry interacts with waves and alters their propagation patterns, which may result in a modification of near-shore currents.
As coastal sediment transport processes primarily occur underwater (in the surf zone, i.e. 5-10m water depth), sediment deficit is first and foremost reflected in bathymetric changes.
Finally, wind blowing over the coastal waters generates a wind set-up (water elevation due to the wind stress), which is inversely proportional to the water depth. In turn, the wind set-up may transform into a surge during extreme weather conditions.

Topic 2.8. Offshore bathymetry

Abstract: Offshore bathymetry consists of bathymetry for water deeper than 20 metres. Offshore bathymetry complements near-shore bathymetry. But unlike near-shore bathymetry, offshore bathymetry is not significantly altered by sediment transport processes.

Spatial extent:: Offshore bathymetry should preferably be available over the fetch. The fetch corresponds to the extent of waters in front of the coastline.

Format:: Near-shore bathymetry should be made available as vector contour lines (or “isobath”). The contour line “zero” corresponds to the lowest low water line (LLW).

Data acquisition and/or production method: Contrary to nearshore bathymetry, offshore bathymetry may be retrieved from existing sources of data at the national level or at the international level.

Spatial accuracy: The accuracy of off-shore bathymetry is not a strong requirement (see suitability for use). Provision of bathymetric contour lines with a 50 metres equidistance is considered as sufficient..

Currency: Since offshore bathymetry is not significantly altered by sediment transport processes, it is not necessary to update the offshore bathymetry frequently. Updating may occur whenever a new version of the bathymetric charts is issued by hydrographic offices.

Availability and costs: At the international, the GEBCO database provides a coarse representation of bathymetry for about 200 Euros. At the national level, national hydrographic surveys are responsible for building and disseminating digital bathymetric charts. License fees for national bathymetric charts in digital format may range from a few Euros to hundreds of Euros per square kilometre depending on the country.

Suitability for use: The role of offshore bathymetry for coastal applications is restricted to the estimation of the wind set-up, i.e. the water elevation induced by the wind stress. The wind set-up is a function of the fetch, the wind speed, and the water depth. An accurate bathymetry is not needed.

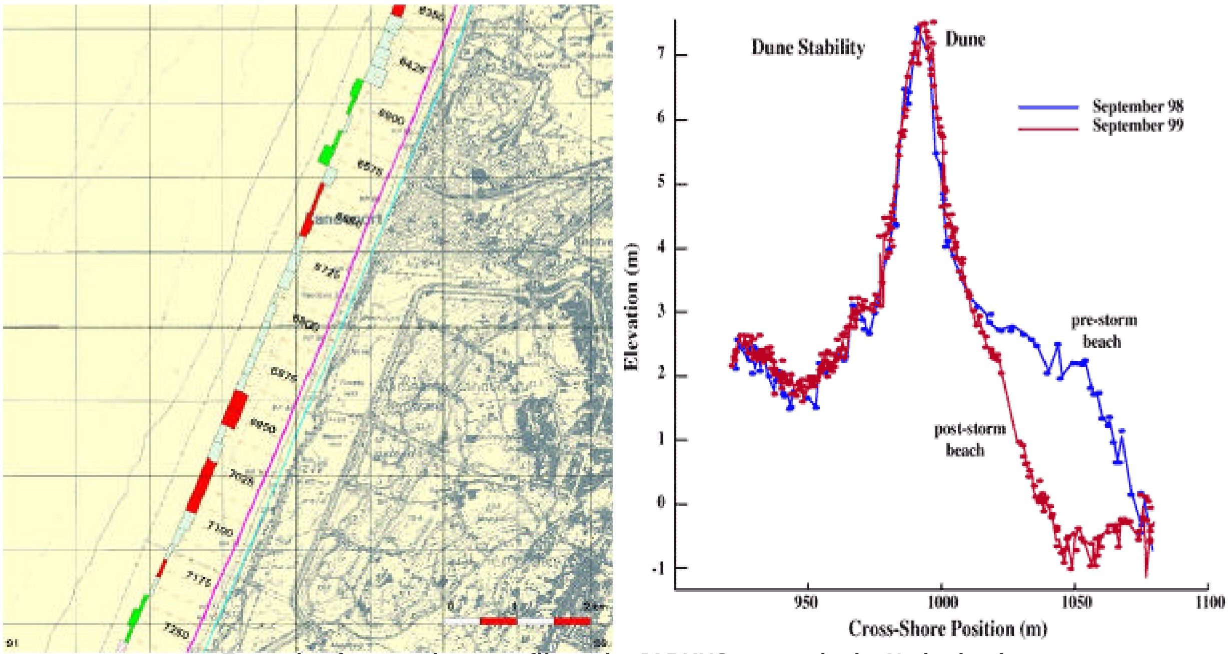
Topic 2.9 Cross-shore profiles

Abstract: Cross-shore profiling aims at providing highly accurate data on foreshore and backshore elevation and other relevant features. Contrary to remotely sensed elevation data which have a limited accuracy (typically 15 cm for LIDAR survey, one metre or more for aerial photogrammetry), coastline monitoring, especially along coast with low erosion rate requires a higher accuracy. Since provision of extensive elevation data is extremely expensive and time-consuming, an alternative solution is to sample the coastline via profiles (or transects) set at right angles to the coastline and along accurate elevation data will be measured. It should be noted that some countries, like the Netherlands (JARKUS system), have been using systematic cross-shore profiling at the core of their coastline monitoring strategy.

Spatial extent: In a framework of a coastal GIS, cross-shore profile data should be made available for the whole coastline. The length of transects must cover both the backshore and the foreshore and should preferably extend to shallow waters (e.g. 2 metre water depth or deeper if surveying equipment makes it possible) and a few hundred meters inland, especially if dunes are present.

Format: Cross-shore profile data should be ideally provided as attributes of vector points. Each vector point correspond to one location along one transect. Profile data include the reference of the location, the elevation and the time of acquisition (or alternatively the reference of the survey campaign).

Data acquisition and/or production method: Cross-shore profiles result from ground surveying techniques.A profile (or transect) is a line of data collection points from a benchmark (or fixed point) located on the coastline, and set at right angle to the coastline (see picture). Profiles are spaced at regular intervals which may range from a few hundreds meters to a few kilometres. In turn the profile is divided into regular points for which the difference of elevation with respect to the benchmark is measured using surveying equipment which may range from traditional leveling equipment to sophisticated laser guided versions.
Profile elevation data collected at a specific time can be represented as a function of the cross-shore position. Comparison with former profile data for the same transect can be done.



Example of cross-shore profiles : the JARKUS system in the Netherlands

It is worth mentioning than in the past 5 years, new video techniques known as ARGUS system have been developed and experimentally adopted in a number of European countries (mainly Netherlands, United Kingdom and Spain). ARGUS system is made of a series of video cameras mounted on high vantage points (tower of cliff), "looking" towards the foreshore, and connected to a computer system via a modem. ARGUS cameras are mounted in such a way that two consecutive cameras may acquire instant images of the same area. Based on photogrammetric techniques, the elevation may be deduced.

Spatial accuracy: To provide an accurate estimation of coastline retreat and sediment losses, the accuracy of cross-shore profile data must have a centimetric accuracy (0.01m) in elevation. Along a specific transect, elevation should be ideally measured every 5 to 50 meters depending on the width of the foreshore. The number of transects needed or the regular interval between consecutive transects may range from a few hundred metres to a few kilometres. Alternatively, the coastline may be divided into different sections with a different interval. Profile interval along sections known as highly dynamic should be smaller (e.g. 500 metres) than profile intervals along sections known as lowly dynamic areas (e.g. 2-3 kilometres).

Availability and costs: Field measurement is extremely expensive in term of staff costs and technical equipement required. For a typical coastline of 100 km and profiles spaced every 500m, surveying costs are expected to reach 40,000 to 50,000 Euros excluding equipment cost but including integration within the GIS.

Suitability for use: Changes in cross shore profiles are essential when assessing coastal hazards near coastal dunes (See hazard assessment document). These profiles are necessary to calculate the resistance from flooding and are an essential tool for monitoring of e.g. coastal nourishments.

TOPIC GROUP 3. GEOLOGY, GEOMORPHOLOGY AND SEDIMENTOLOGY

Topic 3.1. coastline geomorphology

Abstract: Coastline geomorphology is concerned with the present-day landforms at the interface between land and water and the processes operating upon the surface of the Earth and which contribute to shape these forms. Coastline geomorphology determines the type of coastal erosion processes the coastline is susceptible to undergo. Data on coastline geomorphology echo and fine-tune at the local level the data compiled by the EUROSION project at the European level.

Spatial extent:: In the framework of a coastal GIS, coastline geomorphology should be provided for the entire extent of the coastline.

Format: Coastline geomorphology should be provided as an attribute of the vector coastline (see *current and historical coastline*). Each segment of the coastline is assigned a morpho-sedimentologic code according to a standardized classification defined by CORINE Coastal Erosion and fine-tuned by EUROSION. This classification distinguishes 20 different geomorphologic types, grouped in 5 major types: (i) rocky coasts, (ii) beaches, (iii) muddy coasts, (iv) artificial coasts, and (v) estuaries (virtual line).

Data acquisition and/or production method: The initial coastline geomorphology at the local level should be derived from the EUROSION database provided at scale 1:100,000 for the entire European coastline. A 4-step methodology is recommended:

information contained in the EUROSION coastline is transferred to the local coastline. This can be done manually. By default, the geomorphologic code of new segments introduced in the revised shoreline is set to "void".

Update of geomorphologic code of coastline segments is based upon various ancillary data collated at different levels, namely: (i) most recent topographical maps issued by national mapping agencies, (ii) geological data and reports issued by national geological surveys, (iii) if available, any local or regional databases. The update procedure may result in splitting existing segments in two or more new segments. The revised shoreline should be modified accordingly

A boolean attribute for each coastline segment which informs that one attribute (geomorphology, geology, evolutionary trends, or coastal defence works) has changed since the previous version is introduced and should be adequately filled in. By default, the attribute value is set to "0" (no change)

A second boolean attribute for each coastline segment which informs that the attribute values (geomorphology, geology, evolutionary trends, or coastal defence works) are validated (even though no change has occurred) is introduced and should be adequately filled in. By default, the attribute value is set to "0" (not validated)

Former versions of the geomorphologic pattern of the coastline should be adequately archived. Keeping record of former versions makes it possible to analyse changes over time.

Spatial accuracy: The geometrical accuracy of the coastline geomorphology should be compatible with the accuracy of the coastline, i.e. about 5-10 meters. Only morpho-sedimentologic forms which are more than 50-meter-long should be mapped. In case of a morpho-sedimentologic form shorter than 50 meters, the corresponding segment should be aggregated with surrounding segments.

Currency: Since coastline geomorphology is an attribute of the coastline, it should be transferred to the new coastline position whenever this coastline position is updated, i.e. every 3-5 years for highly dynamic areas and 5-10 years for less dynamic areas (see *current and historical coastline*).

Availability and costs: This layer depends on the availability of geo-morphological data

Suitability for use: Coastline geomorphology determines the type of coastal erosion processes the coastline is susceptible to undergo, which is, in turn important when performing a hazard assessment of coastline retreat.

Topic 3.2. coastline geology

Abstract: Coastline geology is concerned with the nature of geological rocks or deposits at the interface between land and water. The geological nature of the coastline determines the natural “resistance” of the coastline to coastal erosion processes. Data on coastline geology echo and fine-tune at the local level the data compiled by the EUROSION project at the European level.

Spatial extent:: In the framework of a coastal GIS, coastline geology should be provided for the entire extent of the coastline.

Format:: Coastline geology should be provided as an attribute of the vector coastline (see *current and historical coastline*). Each segment of the coastline is assigned a geological code according to a standardized classification defined in the framework of EUROSION (such a classification did not exist in the former CORINE Coastal Erosion initiative). This classification distinguishes 25 different geological types, grouped in 2 main classes (substratum or non-cohesive formations) and 7 subclasses: (i) plutonic, (ii() volcanic, (iii) metamorphic, (iv) sediment rocks, (v) marine deposits, (vi) lacustrine deposits, and (v) continental deposits.

Data acquisition and/or production method: The initial coastline geology at the local level should be derived from the EUROSION database provided at scale 1:100,000 for the entire European coastline. A 4-step methodology is recommended:
information contained in the EUROSION coastline is transferred to the local coastline. This can be done manually. By default, the geomorphologic code of new segments introduced in the revised shoreline is set to “void”.
Update of geomorphologic code of coastline segments is based upon various ancillary data collated at different levels, namely: (i) most recent topographical maps issued by national mapping agencies, (ii) geological data and reports issued by national geological surveys, (iii) if available, any local or regional databases. The update procedure may result in splitting existing segments in two or more new segments. The revised shoreline should be modified accordingly
A boolean attribute for each coastline segment which informs that one attribute (geomorphology, geology, evolutionary trends, or coastal defence works) has changed since the previous version is introduced and should be adequately filled in. By default, the attribute value is set to “0” (no change)
A second boolean attribute for each coastline segment which informs that the attribute values (geomorphology, geology, evolutionary trends, or coastal defence works) are validated (even though no change has occurred) is introduced and should be adequately filled in. By default, the attribute value is set to “0” (not validated)
Former versions of the geomorphologic pattern of the coastline should be adequately archived. Keeping record of former versions makes it possible to analyse changes over time.

Spatial accuracy: The geometrical accuracy of the coastline geology should be compatible with the accuracy of the coastline, i.e. about 5-10 meters. Only geological formations which are more than 50-meter-long should be mapped. In case of a geological formation shorter than 50 meters, the corresponding segment should be aggregated with surrounding segments.

Currency: Since coastline geology is an attribute of the coastline, it should be transferred to the new coastline position whenever this coastline position is updated, i.e. every 3-5 years for highly dynamic areas and 5-10 years for less dynamic areas (see *current and historical coastline*).

Availability and costs: This layer depends on the availability of geological data at the local level.

Suitability for use: Coastline geology determines the type of coastal erosion processes the coastline is susceptible to undergo, which is, in turn important when performing a hazard assessment of coastline retreat.

Topic 3.3 Seafloor sedimentology

Abstract: Sediment is defined as fragmented material formed by physical and chemical weathering of rocks. As fragmented materials, sediments are more easily subject to transport by fluids (air and water) than their original rocks. This transport particularly affects the sediments deposited on the sea bottom and is the central element of morphological changes of the coastline. Seafloor sedimentology aims at providing information on the properties and distribution of the sedimentary materials deposited on the sea bottom, and is therefore a key information layer to understand the interaction of seafloor sediments with water. Key properties include: (i) grain sortedness (texture), (ii) grain size and grain size distribution, (iii) grain shapes (roughness), and (iv) grain density. Seafloor sedimentology is complementary to the near-shore bathymetry.

Spatial extent: In the framework of an operational coastal GIS, seafloor sedimentology should ideally be made available for maritime areas extending up to the 20-meter-water depth, i.e. the approximative depth at which wave interactions with the bottom starts.

Format: Information on seafloor sedimentology is made of two elements:
Sediment properties (size, size-distribution, density and roughness) are made available as attribute of points scattered over the nearshore area. Each point represents a location where sediments have been sampled and their properties measured.
Sediment size distribution (zoning) is provided as vector contour lines or vector polygons (see data acquisition and/or production method). Each line marks the boundaries between different sediment composition.

Data acquisition and/or production method: Sediment properties are known through direct measurements. Sediments are collected at a specific location via grab samplers or sediment cores. The oldest, but still widely accepted, method for determining grain-and grain-size distribution uses a nested set of sieves in which the size of the mesh is progressively smaller down the stack. In the case of muddy sediments, pipette analysis shall be conducted. Sediment density and shapes are determined via Rapid Sediment Analysers (RSA). The most popular RSA is a settling tube - a vertical cylinder one to two meters high filled with distilled water. Note that there is no standardized classification for sediment. It is recommended to use the following classification adapted from the Unified Soil Classification System (USCS)

Sediment classification
Adapted from the Unified Soil classification system (USCS)

Sediment type	Sediment size
cobble	greater than 75 mm
gravel	4.75 to 75 mm
sand	
coarse	2.0 - 4.8
medium	0.43 - 2.0
fine	0.075 - 0.43
silt	0.002 - 0.075
clay	less than 0.002 mm

As for sediment zoning, it is can be extrapolated between sample locations using sidescan-sonar surveys (see also *nearshore bathymetry*). Indeed, sidescan-sonar can provide information on surficial geological texture as well as bathymetry (though mulitbeam echosounding provide better result for bathymetry). The geological texture is then photo-identified and digitized on-screen by specialist. Photo-identification procedures is quite similar as the process employed for land cover maps (see also *land cover*)

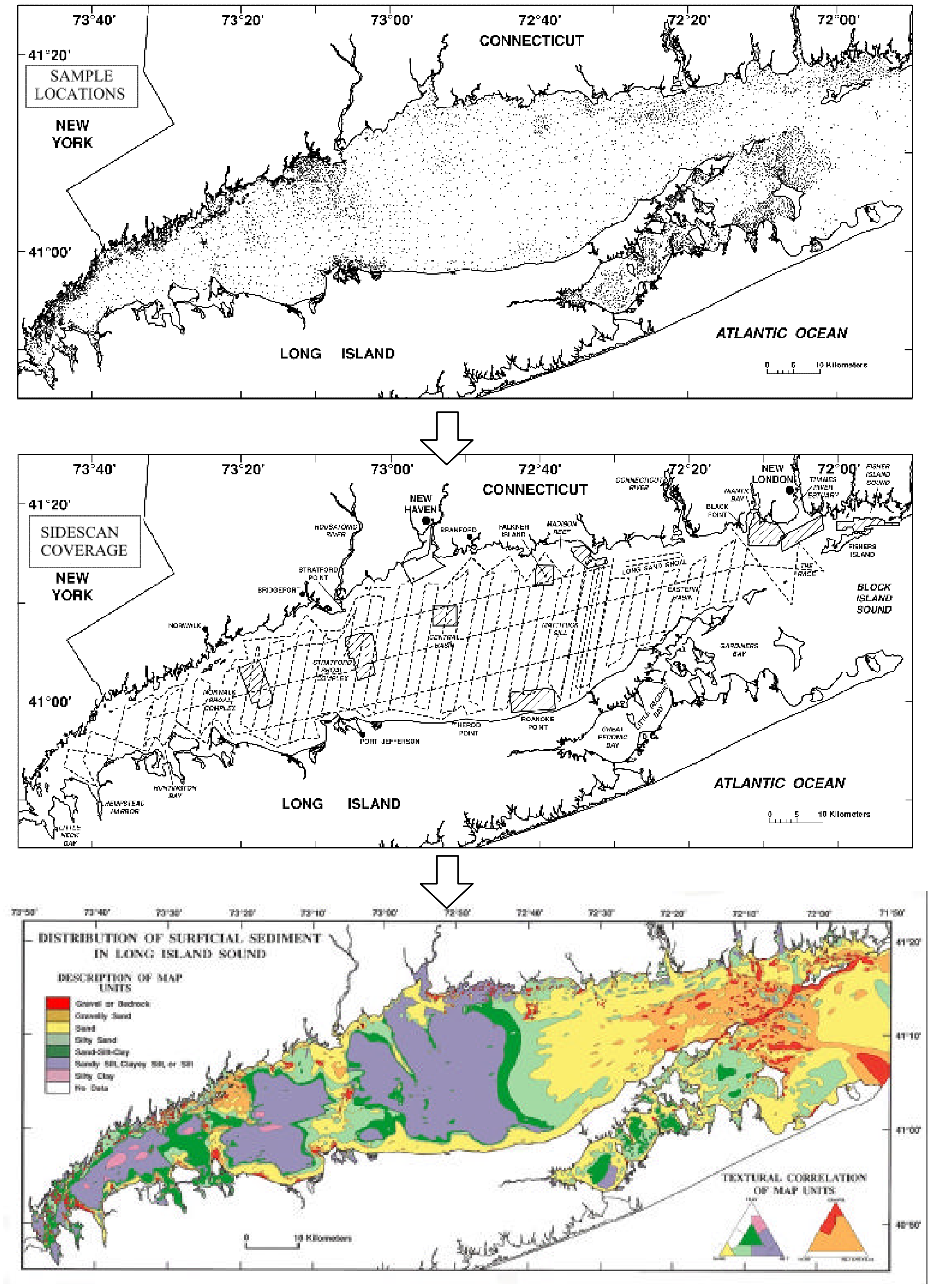
Spatial accuracy: N.A.

Currency: N.A.

Availability and costs: Seafloor sedimentology data are collected during measurement surveys involing adequate instruments. Such instruments include sediment grab samplers or sediment cores, sidescan sonars and Differential GPS (DGPS) for positioning. For a typical area of 100 km2 and sediment sampling density of 1 point per km2, a minimal budget of 100,000 to 120,000 Euros is required including lab analysis of sediment properties, sonar surveying and GIS processing. For larger areas, substantial economies of scale maybe realised on sonar surveys but not on sediment property analysis.

Suitability for use:

Example of process for producing coastal seafloor sedimentology data: Long Island (source: US Geological Survey)



Topic 3.4 Sediment transport

Abstract: sediment transport is among the primary physical process responsible for coastal erosion, in the sense that coastline retreat at a specific location is observed whenever sediments removed and transported from this specific location by nearshore currents are not compensated by new sediments coming from updrift beaches or upstream riverbeds. Sediment transport is expressed in terms of a flux of material through a plane surface perpendicular to the flow of the nearshore currents or the the river.

Spatial extent: In the framework of a coastal information system, information on sediment transport should be provided for different locations throughout the area covered by the coastal information system.

Format: information on sediment transport – namely sediment fluxes (the amount of sediments which passes through a unit of surface per unit of time) - should be made available as attribute of locations. These locations either correspond to direct measurement stations, or estimation derived from modelling.

Data acquisition and/or production method

Step 1. Selection of direct measurement locations

The locations where sediment transport will be observed through direct measurements should be carefully selected. Three

- *locations within the surf zone*: Direct measurement within these locations aims at estimating the sediment transport induced by long-shore transport. Locations should coincide with cross-shore profiles if such cross-shore profiles are available as part of the coastal information system (see cross-shore profiles)

- *locations within the tidal currents*: Direct measurement within these locations aims at estimating the sediment transport induced by tidal currents (both ebb and flood currents). Measurements should be performed when the currents are maximum (approximately 3 hours before/after the high and low waters). In case of semi-enclosed basins, one of the locations should be the tidal inlet.

- *locations at the mouth of rivers*: Studies conducted by EUROSION have demonstrated that shortage of sediment induced by river regulation works contribute significantly to exacerbate coastal erosion processes seawards. Direct measurement at the level of river mouths should therefore be executed as well. To be consistent with the definition adopted by EUROSION, these locations should be selected where the river width is approximately 1 km.

Step 2. Sampling and measurement

Sediment transport is made of two components: bedload transport and suspended load transport. Bedload transport is dominated by a balance of applied stress acting to put particles into motion and gravitational forces acting to keep them in place. Suspended load is dominated by a balance of turbulent forces acting to keep particles in suspension and gravitational settling. Besides this separation by physical mechanisms involved, the two modes of transport are also distinguished by being measured with quite different techniques:

- *Suspended sediment traps*. Sediment traps are cone-shaped or cylindrical collectors that catch materials as they sinks down from the surface sea to the deep sea. They are particularly adapted to measure suspended load transport. The sediment traps are attached to a line that has floats on the surface and a weight at the bottom to keep it vertical. Some sediment traps have subsurface floats and a bottom weight that actually rests on the sea floor. After several days or weeks, oceanographers recover the traps, weigh the particulate material therein, and analyze the material's chemistry. The quantity of material divided by the collection area and the time the traps were deployed gives the particle "flux".

- *Bedload samplers*. There is currently no entirely reliable devices to measure bedload transport as it is a delicate operation. Indeed, the sampler must collect the particles rolling onto the seabed, while in the same time avoiding to disturb the particle flows and to collect sediments deposited on the seabed and not affected by the transport. The most popular sampler is know as the Helley-Smith sampler and is made of an aluminium frame with a water intake. The frame is mounted on the base of a wading rod.

- *Optical sensors*. Oceanographers began to commonly use optical sensors for measuring turbidity or suspended-sediment concentration (SSC) in the 1980s on the continental shelf, in nearshore waters, and in estuaries (Sternberg 1989). Optical sensors transmit a pulse of light and measure the intensity of light transmitted, scattered 90°, or backscattered 180°, depending on sensor design. The sensor processes the signal so that its output is in units of turbidity or is proportional to SSC if the particle size and optical properties of the sediment remain fairly constant. The technique is however still experimental.

Analysis consists then to estimate the flux of sediment, i.e. the amount of sediments which passes through a unit of surface per unit of time.

Step 3. Extrapolation using sediment transport models

A number of sediment transport models have been developed and make it possible to extrapolate sediment transport fluxes observed at specific locations to other locations. Most advanced models are based upon the works of Bijker (1968), Van Rijn (1984), Bailard (1981), Engelund-Hanssen (1971) are nowadays routinely integrated into software packages like MIKE or UNIBEST, commonly used worldwide. These models are generally expressed as a function of sediment size, density, roughness, current velocities, and wave regime.

<u>Spatial accuracy</u>: Given the highly empirical modelling of sediment transport, the accuracy of mapping is not completely relevant. One may think of spatial data on sediment budgets over time. Spatial accuracy may be 1-2 meters for this. Most changes in sediment transport ratios are assessed with the measurement of near shore bathymetry.

<u>Currency</u>: See near shore bathymetry

<u>Suitability for use</u>: See near shore bathymetry

Topic 3.5 Benthic infauna

<u>Abstract</u>: Benthic infauna are bottom-dwelling animals which live in the water for all or most of their life. They have long been used for river, coastal and marine water quality assessments because of their tendency to be more sedentary and thus more reliable site indicators over time compared to fish and plankton. In addition, they are easy to collect, to identify in a laboratory, are good integrators of environmental condition since they are highly reactive to environmental stressors. Benthic infauna includes worms, clams and crustaceans and are an important food source for bottom-feeding fish, shrimp, and birds. Examination of benthic community structure and function is therefore a valuable tool for evaluating the condition of benthic habitats, for monitoring rates of recovery after environmental perturbations and potentially to provide an early warning of developing impacts to the system.

<u>Spatial extent:</u> Information on benthic infauna should be made available for a number of reference sites scattered over the nearshore areas. The location of reference sites should be defined as precisely as possible in order to be re-surveyed unambiguously in later stages. Reference sites should also be located in areas where major investments are planned, for example, beach nourishment, groins or breakwaters.

Format: Information on benthic infauna should ideally be made available as attributes of objects linked to reference site. Each object is a a compound of variables describing the benthic environment and defined hereafter as metrics (see data acquisition and/or production method).

Data acquisition and/or production method: Benthic infaunal data are collected from ground survey and their production process may be divided in three major steps.

Step 1. Identification of reference sites.
Reference sites are areas or variable dimension where benthic community structure and function will be sampled and analyse. These sites should be representative of the most predominant seafloor substrates present in the nearshore (see *Seafloor sedimentology*).

Step 2. Definition of metrics.
Metrics are variables which characterize the benthic community structure. Individual invertebrate species have sensitive life stages that respond to stress and integrate effects of short-term environmental variations, whereas community composition depends on long-term environmental conditions. In addition to taxonomic identification, benthic macroinvertebrate metrics may require knowledge of the feeding group to which a species belongs, for example, suspension feeders and deposit feeders. Potential metrics for estuarine and coastal marine benthos and their respective response to impairment are listed below.

Example of benthic assessment metrics
(source: **Estuaries and Coastal Marine Waters Bioassessment and Biocriteria Technical Guidance (2000) , Environment Protection Agency - EPA-822-B-00-024)**

Metric	***Response to environmental perturbations***
No. of taxa	Reduced
Mean no. of individuals per taxon	Substantially lower or higher
% contribution of dominant taxon	Elevated
Shannon-Wiener diversity	Reduced
Total biomass substantially	Substantially lower or higher
% biomass of opportunistic species	Elevated
% abundance of opportunistic species	Elevated
Equilibrium species biomass	Reduced
Equilibrium species abundance	Reduced
% taxa below 5-cm	Reduced
% biomass below 5-cm	Reduced
% carnivores and omnivores	Elevated
No. of amphipod species	Reduced
% individuals as amphipods	Reduced
% individuals as polychaetes/oligochaetes	Elevated
No. of bivalve species	Reduced
% individuals as molluscs	Reduced
% individuals as deposit feeders	Elevated
Mean size of organism in habitat	Reduced
Proportion of expected no. of species in sample	Reduced
Proportion of expected no. of species at site	Reduced
Mean weight per individual polychaete	Reduced
No. of suspension feeders	Reduced
% individuals as suspension feeders	Reduced
No. of gastropod species	Reduced
No. of Capitellid polychaete species	Elevated

Step 3. Sampling.
A large number of benthic sampling methods and gear are available. The choice of appropriate methods and gear will depend upon the goals of the sampling and the habitat to be sampled.

- In subtidal areas, benthic infauna can be collected using grabs, such as Young, Ponar, or Van Veen; or cores such as box, gravity, or hand-held cores collected by divers. Grab or core size and number of replicates should be sufficient to adequately sample the infaunal community, bearing in mind that distribution is usually spatially clumped rather than random or regular; and

- Intertidal areas may best be sampled at low tide with hand-held cores. For certain infauna it may also be feasible to estimate abundance by counting the number of surface structures within a given area. For example, some polychaete worms build identifiable tube or mound structures, or leave identifiable fecal coils in intertidal areas. If the local infauna has been studied to the extent that identification of such topographic features can be correlated to the presence of a particular organism, crude abundance and presence/absence evaluations may be possible.

Collection of sediments and benthic organisms should be done concurrently in order to reduce the costs of field sampling and to permit sound correlation and multivariate analyses. Therefore, the sampling equipment and procedure should also include sampling the sediment.

Step 4. Analysis
The analysis aims at determining the value of metrics identified during step 2 for the different samples collected in the fields. This analysis should be conducted by specialised laboratories or universities which generally have appropriate equipment to do so. Beside the determination of the metrics' values , two complementary analysis can be conducted, namely: i) a multivariate discriminant model to distinguish impaired sites from unimpaired sites; and ii) a perturbation tolerance index from the species abundance found at a site.

Spatial accuracy: N.A.

Currency: N.A.

Suitability for use: An assessment of recovery rates in terms of species composition and overall biomass, in relation to the timing of reinstatement or recharge; recovery rates related to sediment type; and timescale of community recovery to the pre-damage assemblage in terms of age structure and composition.

TOPIC GROUP 4. HYDRODYNAMICS

Topic 4.1. Nearshore wave regime

Abstract: The wave regime defines the sea state in a specific area. It can be defined as the physical and statistical characteristics of waves propagating over this specific area. Wave regime is characterized by a number of parameters that include wave heights, periods and direction and their remarkable value, such as their mean or their extreme values. More sophisticated parameters exist. Waves are generated by the action of winds over the sea surface. Wave regime is closely related to coastal processes in so far as:
Energy liberated by breaking waves is directly responsible for stirring up sediments deposited on the foreshore or undermining the cliff toe;
Wave run-up and backwash on the foreshore transport sediments in the cross-shore direction and contribute to maintain the foreshore profile to an equilibrium profile.
Waves breaking with an angle generate a current parallel to the shore and responsible for the long-shore transport of sediments
Accurate knowledge on the wave regime, and its changes overtime as a result of seasonal processes or human activities, therefore helps predict sediment movements.

Spatial extent:: In the framework of a coastal GIS, nearshore wave regime should preferably be known for a maritime area extending up to the 20 meter water depth. The 20-meter-water depth approximately corresponds to the depth at which shoaling processes start.

Format: Information on wave regime is provided as attributes of vector point (GIS format) locations disseminated along the European coastline. For each location, the following parameters should be provided as a statistical estimator of values recorded over the previous 15 years:
average wave height
wave height exceeded by 10% of the measurements
wave heights exceeded by 1% of the measurements
average wave period
wave period exceeded by 10% of the measurements
wave period exceeded by 1% of the measurements
These parameters should be provided for each directional sector: 0, 45, 90, 135, 180, 225, 270, and 315 degrees.
In case wave regime is directly measured from wave buoys, locations at which wave attributes are attached coincides with the location of wave buoys. In case, wave regime is measured from HF radars or derived from wave transformation models, wave attributes are estimated over a regular grid of locations.

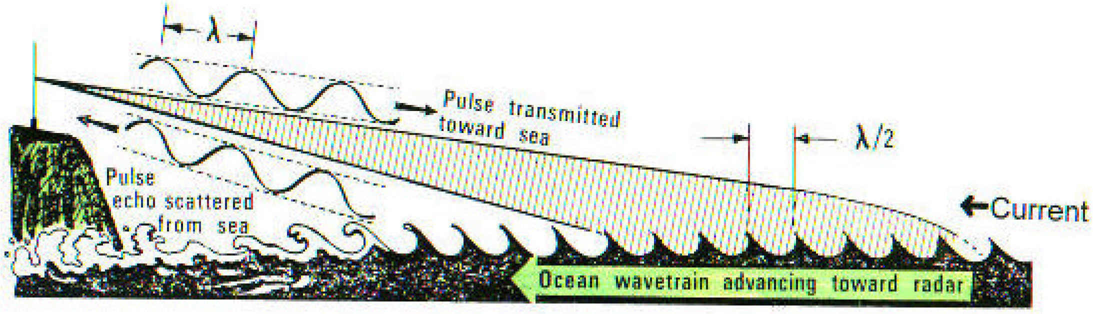
Data acquisition and/or production method: There are two generic way to produce wave data: (i) direct measurement, and (ii) wave modelling.

(i) Direct measurement

Direct measurement consists in determining wave parameters from direct observations of the nearshore sea surface wave via sensors. Two techniques of direct measurement are commonly used in Europe:

Wave gauges are water level sensors that are generally mounted on moored buoys. Devices onboard the buoys measure the vertical displacement of the buoy during a data acquisition time (a few minutes). Fast Fourier Transform (FFT) is then applied to the data by the processor on board the buoy to transform the data from the temporal domain into the frequency domain. From these processed data, information on height and period can be derived. If the gauge is directional, the previous information can be provided for any specified direction.

High Frequency Doppler radars. HF radars use radar technologies to provide information on wave propagation. HF radar can be mounted on a fixed point along the shoreline. Their range can reach 70km in the offshore direction. Because they do not require sea-going operations, HF radar is easier to operate than buoys or gauges and more economical, resulting in a cost per data ten times less than with buoys.



Production of near-shore wave regime via HF Doppler radar

(ii) Wave modelling

Wave modelling consists in deriving nearshore wave regime from offshore wave conditions. In that case, data related to offshore wave regime are needed as well as a wave transformation model. Indeed, as offshore waves propagate over nearshore waters, they interact with the sea bottom (see nearshore bathymetry) and their course is modified. Processes known as shoaling, refraction and reflection are responsible for this modification. A number of wave transformation models have been developed to anticipate the impact of such processes on wave propagation. Commonly used models includes SWAN (Delft Hydraulics), MIKE (DHI), and STWAVE (USACE).

Spatial accuracy: Wave regime attributes should be ideally made available with a density higher than 1 point for every 1 km. These locations should be situated between 1 and 5 km away from the shoreline (or alternatively at locations where water depth is between 5 and 20 meters).

Currency: Near-shore wave regime should be re-evaluated with a periodicity of 5 to 10 years and whenever an important investment is made in the coastal area (e.g. harbour development, dredging activities).

Availability and costs: Wave Buoys, Radar, and other measuring equipment, accompanied by the processing and modelling techniques, may be quite costly depending on the expected accuracy.

Suitability for use: Monitoring of wave statistics is essential to forecast the effects of storms on a short time scale. Accurate knowledge on the wave regime, and its changes overtime as a result of seasonal processes or human activities, therefore helps predict sediment movements.

Topic 4.2. Offshore wave and wind regime

Abstract: Major difference between offshore and nearshore wave regime is that offshore wave propagation patterns are not altered by changes in the bathymetry, but are mainly driven by winds. EUROSION has provided for the entire European coastline statistical data related to offshore wave regime with a resolution of 1 point for 100 km.

Spatial extent: In line with EUROSION database, offshore wave and wind parameters should be statistically estimated over boxes of 200 km x 200 km disseminated along the coast.

Format:: Information on offshore wave regime is provided as attributes of vector point (GIS format) locations disseminated along the European coastline. For each location, the following parameters should be provided as a statistical estimator of values recorded over the previous 15 years:
average wind speed (10 meters above the sea surface)
wind speed exceeded by 10% of the measurements

- wind speed exceeded by 1% of the measurements
- average wave height

wave height exceeded by 10% of the measurements
wave heights exceeded by 1% of the measurements
average wave period
wave period exceeded by 10% of the measurements
wave period exceeded by 1% of the measurements
These parameters should be provided for each directional sector: 0, 45, 90, 135, 180, 225, 270, and 315 degrees.

Data acquisition and/or production method: The update methodology should be based upon the following analysis of satellite images:
Wave height should be derived from altimeters with technical capabilities equal or exceeding those of altimeters carried by ERS-1, ERS-2, Topex/Poseidon and Geosat satellites.
Wind speed and wind direction should be derived from scatterometers with technical capabilities equal or exceeding those of scatterometers carried by ERS-1 and ERS-2.
Wave spectral parameters should be derived from spectra of Synthetic Aperture Radar (SAR) imagettes with technical specifications equal or exceeding those collected by ERS-1 and ERS-2.
Each parameter should be statistically estimated by processing the above mentioned sources of data recorded during the previous 15 years, over «boxes » of 200kmx200km centred on the vector point locations. Former versions of the offshore wave and wind regime should be adequately archived.

Spatial accuracy: Offshore wave parameters should be statistically estimated over boxes of 200 km x 200 km disseminated along the coast (centres of each approximately located at 100 km from the coastline). Successive boxes have approximately of 50% overlap.

Currency: Offshore wave and wind regime should be re-evaluated with a periodicity of 10 to 15 years.

Availability and costs: N.A.

Suitability for use: The relevance of offshore wave and wind and wave is threefold:
when data on nearshore wave regime are not available, offshore wave regime provides the boundary conditions to operate wave transformation models (see nearshore wave regime)
offshore wind regime provides input data for estimating surge level which is a function of the wind speed, the fetch, and the water depth (see also offshore bathymetry), this at a somewhat longer time scale that near shore wave regime.
Finally, significant changes of offshore wave and wind patterns can reflect significant changes induced by climate change, which in turn may result in changes in near-shore wave propogation.

Topic 4.3. Near-shore currents

Abstract: Currents can be defined as movements of fluid particles towards determined directions. In the near-shore, currents occur as the results of tides and waves (see also wave regime). The impact of oceanic (or deepwater) currents can be considered as negligible in shallow water compared to tide and wave generated currents. More precisely:

Tidal currents. Tidal currents are generated by the rising and falling tidal waters. During the rising tide, water flows onshore following specific paths ("flood" streams) along which water velocity is maximal. Current velocity is zero at high tide because the water has reached its highest stage and is about to begin its outward flow. As the water flows offshore, it follows other paths ("ebb" streams) . Tidal currents are more pronounced in places where constrictions such as narrow entrances (inlet) to large bays cause strong flows. Such as the tidal range, tidal currents generated vary widely and consequently, have an effect that can range from strong in shaping the coast to almost no effect on beach processes.

Wave associated currents. In shallow water, the movement of the water particles become very complex in terms of onshore and offshore motions resulting in an excess of water carried to the shoreline. This excess of water is translated to a long-shore movement (long-shore currents) and a cross-shore circulation movement (rip currents).

Spatial extent: Current measurements should take place at different locations of the coastal sediment cell. Fixed measurement stations should be preferably located at key locations such as bay entrances or inlets (where tidal currents are expected to be the highest). Fixed or mobile measurement stations should be considered as well along the surf zone (where wave associated currents occur) and where ebb and flood currents are expected to occur.

Format:: Near-shore current data should be made available as a time series for each measurement station, or as trajectories in the case of drifters. For each measurement station, both the current velocity and direction should be recorded. Velocity should be expressed in m.s-1

Data acquisition and/or production method: A wide range of techniques dedicated to current measurement exist. These techniques include:
Electromagnetic Current Meters are devices which measure the voltage resulting from the motion of a conductor (water flow velocity) through a magnetic field generated by the device. The voltage is then converted into a fluid speed.
Acoustic Doppler Current Profiles (ADCP) are instruments that use ultrasonic pulses to measure the current velocity and direction throughout the water column. ADCP's can be mounted on a boat permanently or temporarily, to a cage on the bottom, or to a buoy system.
GPS difters are free floating current following (Lagrangian) buoys which are released for a few days to a few months. Onboard electronics record a time series of positions using GPS and Lagrangian current data using deep drogues as the drifter moves. Information is telemetered by email to the user anywhere in the world generally the US/French ARGOS system.
Hydraulic tracers are inert substances that are injected in the water system and is subsequently measured in the outflow.. A variety of tracers have been used to study surface water and groundwater flows. Types of hydraulic tracers include ions, dyes, inert gases, stable isotopes, and radioisotopes

Spatial accuracy: The necessary accuracy for currents may be up to 0.1 m.s-1, depending on the accuracy of the necessary information. Near shore currents are essential for both cross-shore and alongshore transport of sediments.

Currency: Near shore currents may be generated by tides, winds and waves and change fast over time. However, to assess the net direction of long shore transport it is more useful to have time averaged data.

Availability and costs: See near shore waves

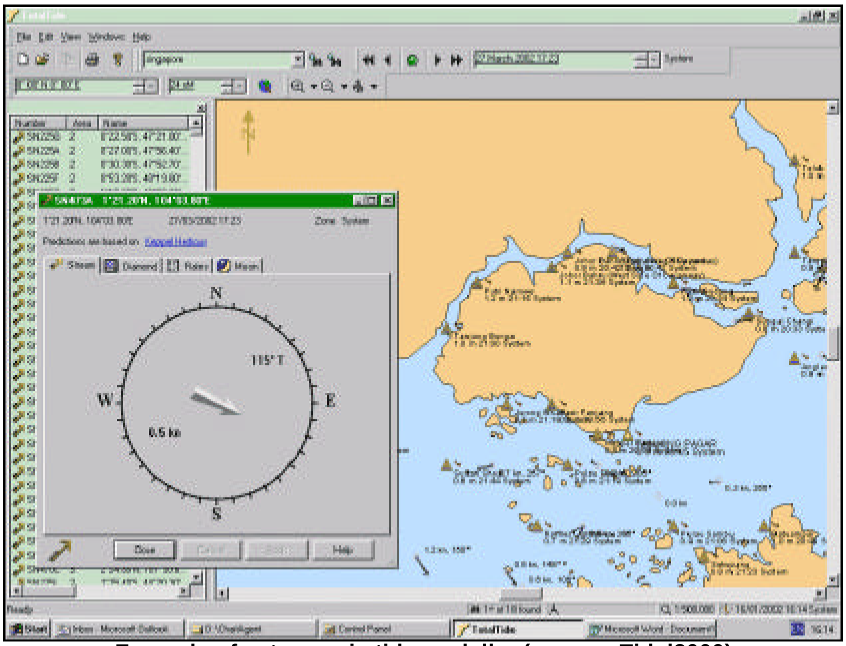
Suitability for use: to assess the net direction of long shore transport it is more useful to have time averaged data.

Topic 4.4. Astronomic tides

Abstract: The tide is the periodic rise and fall of oceanic and coastal waters as a result of the relative positions of the earth, moon and sun. Tidal periodicities vary from semi-diurnal, through diurnal, fortnightly, monthly, seasonal, annual to even longer. The tidal range (i.e. the difference in elevation between consecutive high and low waters) varies from a year centimetres (microtidal) to up to 10 meters (macrotidal) according to the location on earth and the time during the year. Spring tides are associated with higher tidal range. In addition, the tide does not occur at the same tide everywhere: its propagation is governed by the geometry and the bathymetry of the sea basin. A distinction is made between the periodic and non-periodic components of the tides. The periodic component is referred as the astronomic tide and is governed by the relative positions of the earth, moon and sun as well as the geometry of the sea basin. The non-periodic component is referred as the meteorological tide or surge and is governed by weather conditions.

Spatial extent: Astronomic tides have a spatial extent of the size of a geographically determined tidal basin such as the North Sea, or more focused such as the English Channel (macro tidal regime due to funnelling effect). In the Mediterranean however, tidal ranges are smaller so a less accurate prediction is expected.

Format:: Astronomic tide data take two formats. (i) the most commonly used format is the so-called “tide table” which give the daily prediction of the times and heights of high and low waters. They are generally computed at standard locations corresponding to major harbours. Other locations, corresponding to secondary harbours, are given in the form of time and height from standard locations; (ii) alternatively to tide tables, mathematical models of tides can also be implemented directly in a GIS with a few developments: tide data can indeed be mathematically approximated as the sum of a series of sine waves of determined frequency "harmonic constituents". The parameters of each sine wave are called "harmonic constants", and are the amplitude (half the height) of the wave and phase, or time of occurrence, of the maximum.



Example of astronomic tide modeller (source: Tidal2000)

Data collection method: A number of software packages and computer models specialised in the provision of tide data over a great number of locations (more than 7,000 locations worldwide) are available. Analysis of data observed by tide-gauges constitutes the basics for all of these models. Tide-gauges – generally at the locations of harbours – record the hourly fluctuations of sea level which includes both the astronomic tide, the meteorological tide and the wave height. If recordings are available for a sufficiently long period of time, the periodic elements of sea level corresponding to the astronomic tide can be calculated using such methods as least-squares tidal harmonic analysis, the admittance method of Munk and Cartwright (1966) or the Fourier harmonics. The primary role of tides in beach processes is exposure and submergence of the foreshore, and hence changes in how effective incoming waves may be in modifying the foreshore.

Spatial accuracy: Tidal waves and associated tidal currents propagate at a speed of 20-40 km/h in small tidal basins such as the North Sea.

Currency: Many models and tidal gauges have generated clear astronomical tide tables for most of Europe.

Availability and costs: Tide models are generally available at the level of National Hydrographic Offices. Fees may be required. It is worthwhile to mention that the UK Hydrographic Office has developed the package Total Tide 2002 which provide instant tidal predictions for over 7000 ports and 3000 tidal stream stations worldwide.

Suitability for use: For navigational purposes tidal data is essential, but it also used as a basis for the forecasting of stormsurges. If you add astronomical tide with the wave setup predictions (based on wind speed, fetch, wind direction and duration), more accurate forecasting of water levels may be performed.

Topic 4.5. Probability of exceedance of extreme water levels

Abstract: The fluctuations of the sea surface corrected from wave height and tidal range - known as the still water level or the surge - are driven by atmospheric pressure and wind stress which may have either a positive or negative influence on the sea level. The occurrence of a specific water level is difficult to predict long in advance. However, academic research has shown that a specific water level can be associated with an annual probability of exceedance. This probability defines the chances that a specific water level is reached or exceeded at a specific location and within a specific year. It is traditionally expressed in terms of return period (*e.g. 100-year-return period = 1% annual probability of exceedance*).

Spatial extent: The probability of exceedance of extreme water levels should be made available for the entire coastal stretch as a unique function or a set of functions if the coastline length is important or complex (e.g. with tidal basins or embayments).

Format: As an exponential mathematical function of the water level, the probability of exceedance of extreme water levels should be made available as a mathematical formula and its calibration parameters. Since this function is not unique for the entire coastline (the probability of exceedance may vary significantly if the coastline length is long or the coastline shape is complex), several sets of calibration parameters should be provided. Ideally a different set of calibration parameters shall be estimated for each tide gauge location (based on the observation of this specific tide-gauge). Should no tide gauge with exploitable data be available in the area covered by the coastal information system, a set of approximated calibration parameters shall be estimated for a number of locations within the area covered by the coastal information system, by interpolating observations recorded by the nearest exploitable tide gauges (outside the area).

Data acquisition and/or production method: The mathematical function and its calibration parameters needed to determine the probability of exceedance of extreme water levels can be deduced from observations realised by tide-gauges. This is done in three steps.

Step 1. Tide-gauges observations

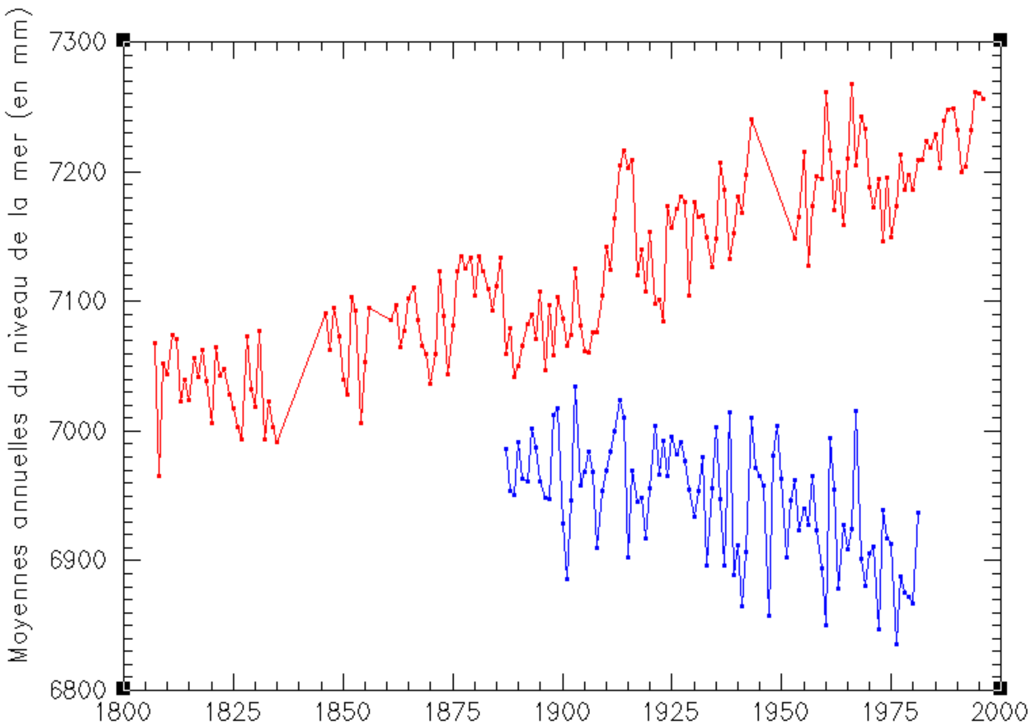
In practice, tide gauges records the “effective” water level above mean sea level (MSL) with a frequency ranging from a few minutes to an hour. It is commonly agreed that this effective water level has four components:

the tidal component, i.e. the water elevation above MSL due to the astronomic tide

the wave height, i.e. the water elevation above MSL due to short period waves

the still water level or surge level, i.e. the water elevation above MSL induced by weather conditions

the relative sea level rise, i.e. the long-term variation of the MSL as a result of global warming and land subsidence



This example shows the annual mean sea level as measured by the tide-gauge of Brest in France (in red) and Varberg in the Baltic (in blue).

Step 2. Correction from tide, wave, and sea level rise effects
Correction of the recorded sea fluctuations from the effects of the tide (de-tiding process) or the effects of the waves is performed by accurate knowledge on the astronomic tides (see astronomic tides) and nearshore wave regime (see nearshore wave regime). The effect of long term relative sea level rise can be modelled by averaging tide gauge data per year and by analysis the evolutionary trends of year-averaged water level through mathematical regression analysis. It is worth mentioning that the Permanent Service for Mean Sea Level (PSMSL) hosted by the Proudman Oceanographic Laboratory has mandated internationally to provide statistics on relative sea level rise worldwide. The results of this correction in the still water level or the surge level.

Step 3. Extrapolation
As mentioned above, academic research has shown that a specific water level can be associated with an annual probability of exceedance. This probability defines the chances that a specific water level is reached or exceeded at a specific location and within a specific year. It is traditionally expressed in terms of return period (e.g. 100-year-return period = 1% annual probability of exceedance). An exponential mathematical function (Generalised Extreme Value - GEV function) is assumed to link the still water levels with their probabilities of exceedance. This mathematical function can be calibrated with the observations derived from the tide gauge observations corrected from the tide, wave and RSLR effects. This method is deemed to be valid for the estimation of water levels associated with return-periods corresponding to three times the time range of tide-gauge observations. For example, 35 years of tide-gauge observations make it possible to estimate the water levels associated with return periods up to 105 years.

However, mathematical functions reflecting the probability of exceedance for extreme water levels are valid only for those locations where tide-gauge records exist. Indeed, the probability of exceedance may vary significantly if the coastline has a considerable length (100 km or more) or if the coastline shape is complex (with tidal basins and embayments). Interpolation is possible but should be restricted to open seas, and provided a sufficient number of tide gauges nearby exist.

<u>Spatial accuracy:</u> The location of tide gauges shall be provided with a geometrical accuracy of 5 metres maximum.

Currency: The need to update the probability of exceedance of extreme water levels is driven by two major consideration:
Over time, the time series of tide-gauge observations get longer and therefore calibration parameters become more accurate.
After 10 years, the effect of relative sea level rise can no longer be ignored and calibration parameters need to be re-adjusted.
However, there is no need to update this information with a frequency less than 10 years.

Availability and costs: Tide gauges are generally associated with ports. Major tide gauges constitute the primary network of tide-gauges which is part of Permanent Service for Mean Sea Level (PSMSL) hosted by the Proudman Oceanographic Laboratory (POL). Their coordinates and annual mean values are available online. However, tide-gauges associated to secondary harbours are not considered by the PSMSL.

Suitability for use: : This probability defines the chances that a specific water level is reached or exceeded at a specific location and within a specific year. It is traditionally expressed in terms of return period (*e.g. 100-year-return period = 1% annual probability of exceedance*). It is used to prioritise low lying coastal hazard areas (see also the guidelines for hazard assessment) for flooding.

TOPIC GROUP 5. LAND COVER

Topic 5.1. Land cover

<u>Abstract</u>: land cover corresponds to a (bio)physical description of the earth's surface. It is that which overlays or currently covers the ground. This description enables various biophysical categories to be distinguished — basically, areas of vegetation (trees, bushes, fields, lawns), bare soil, hard surfaces (rocks, buildings) and wet areas and bodies of water (watercourses, wetlands). As for land use, it can be defined as the socio-economic description (functional dimension) of areas: areas used for residential, industrial or commercial purposes, for farming or forestry, for recreational or conservation purposes, etc. Land cover and land use can be used alternatively since it is possible to infer land use from land cover and conversely. But situations are often complicated and the link is not so evident. Contrary to land cover, land use is difficult to 'observe'. For example, it is often difficult to decide if grasslands are used or not for agricultural purposes. Distinctions between land use and land cover and their definition have impacts on the development of classification systems, data collection and information systems in general (source: EEA glossary).

<u>Spatial extent:</u> In the framework of a coastal GIS, land cover (or land use) data should be available for inter-tidal and terrestrial areas up to 10 km inland. In low-lying areas, it is recommended to extend the spatial coverage of land cover/land use up to the contour line corresponding to an elevation of 2 meters.

<u>Format::</u> Land cover data should be ideally provided as vector polygons, (.shp, or .dxf formats). The following specifications are recommended: (i) polygons should be delineated with a geometrical accuracy of 5 meters, or an equivalent scale of 1:25,000, (ii) polygons should cover a minimum areas of 5 hectares, (iii) each polygon should be assigned a land cover code compliant with CORINE Land Cover classification. CORINE Land Cover classification features 44 land cover classes grouped in 5 major land cover types: (i) urbanized areas, (ii) agricultural areas, (iii) natural and semi-natural areas, (iv) wetlands, and (v) water bodies. The complete CORINE Land Cover classification is provided in Annex. The adoption of CORINE Land Cover classification standards is key to enable comparison between different areas.

<u>Data acquisition and/or production method:</u> The experience of CORINE Land Cover in Europe has demonstrated that most reliable land cover data are obtained from computer-aided photo-identification of satellite images (see satellite images) or aerial photographs (see aerial photographs). Photo-identification consists of a visual recognition and delineation of land cover patterns on-screen (via a GIS) and is facilitated by ancillary data (such as existing maps), discussions with experts and through ground truth surveys.
"Supervised classification" is an alternative methodology for obtaining land cover data. Contrary to computer-aided photo-identification, supervised classification does not require the assistance of an experienced photo-identification specialist. A number of predefined land cover classes are defined as ranges of values that a pixel may take: each pixel of the satellite image or the aerial photograph is given the land cover code corresponding to the range of values it belongs to. Contrary to computer-aided photo-identification, the final product of supervised classification is a raster image.

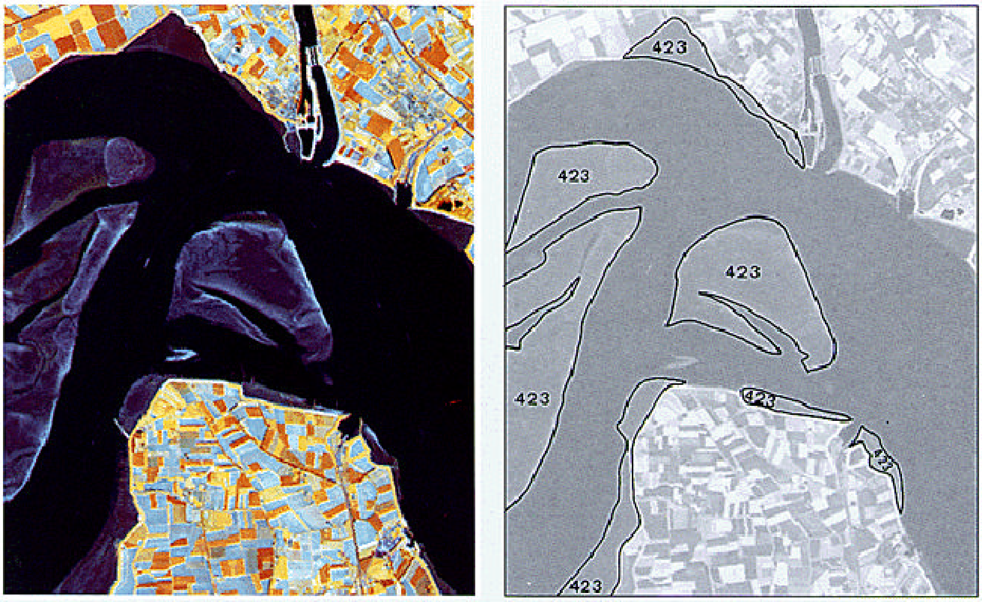
<u>Spatial accuracy:</u> To enable efficient analysis, land cover/land use data should be compatible with scale 1:25,000 (or alternatively with a geometric accuracy of 5 meters). Land parcels smaller than 5 hectares should be neglected (e.g. 5 meters X hich

<u>Currency:</u> Depending on the economic or ecological value of a certain area, Landcover needs to be updated every 3-5 yrs.

<u>Availability and costs:</u> not available

<u>Suitability for use:</u> Land cover and land use can be used alternatively since it is possible to infer land use from land cover and conversely. But situations are often complicated and the link is not so evident.

Example of photo-identification in Portugal (source : CORINE Land Cover)



TOPIC GROUP 6. DEMOGRAPHY

Topic 6.1. Demography

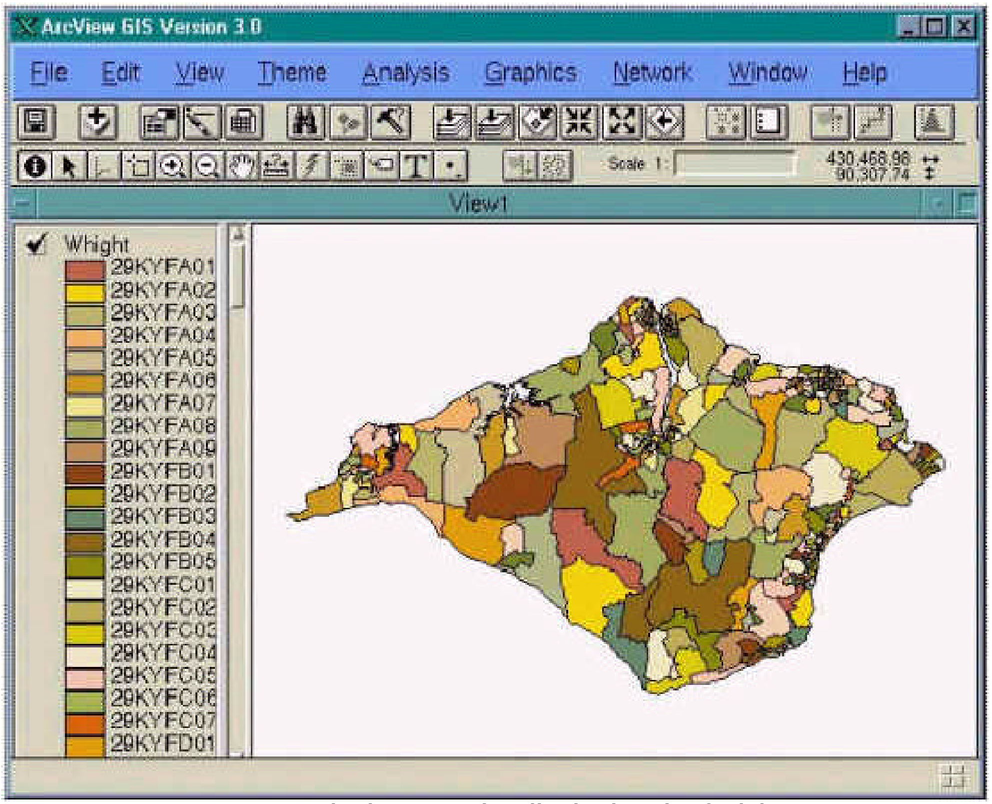
Abstract: Demographic data and their trend analysis provide valuable information to assess the attractive power of coastal areas on citizens. They also provides key information for assessing population at risk opf coastal erosion and coastal flooding and therefore identifying areas where coastal invetsments become a priority.

Spatial extent: In the framework of coastal GIS, demographic data should be made available for municipalities located at less than 10 km from the coastline.

Format:: Demographic data should be made accessible as attribute of census units. Census untis represent areas at the submunicipal level typically regrouping 2000 inhabitants (the size may vary from one country to another). Key demographic data include:

- the total population
- the population by age
- the population by professional categories

Below is an example of census units (enumeration districts) for one of the pilot site of EUROSION.



Census units (*Enumeration districts*) – Isle of Wight

Data acquisition and/or production method: see *availability and costs*.

Spatial accuracy: The geometrical accuracy of census unit boundaries varies from one country to another.

Availability and costs: Best sources for demographic data are national census. In general, census are conducted every 10 years and provides statistics at the level of municipality or ínfra-municipal. Note that most of European countries have demographic data at an infra-municipal level (in general, parcels of approximately 2000 inhabitants or less). These datasets are generally subject to access fees which may vary from one country to another. In France, access to infra-municipal census data (IRIS 2000 database) in GIS format costs 12 Euros per set of 100 inframunicipal units (2000 inhabitants). Below is the list of national statistics office in Europe.

Country	*Statistics office*	*Website*
Belgium	National Institute of Statistics Belgium	http://statbel.fgov.be/home_fr.htm
Denmark	Statistics Denmark	http://www.dst.dk/HomeUK.aspx
Estonia	Statistics Office of Estonia	http://www.stat.ee/
Finland	Statistics Finland	http://www.stat.fi/
France	National Institute for Statistics and Economic Studies (INSEE)	http://www.insee.fr/
Germany	Statistisches Bundesamt Deutschland	http://www.statistik-bund.de/
Greece	National Statistical Service of Greece	http://www.statistics.gr/
Ireland	Central Statistics Office in Ireland	http://www.cso.ie/
Italy	National Institut of Statistics of Italy	http://www.istat.it/
Latvia	Central Statistical Bureau of Latvia	http://www.ksh.hu/
Lithuania	Lithuanian Department of Statistics	http://www.std.lt/
Netherlands	Statistics Netherlands	http://www.cbs.nl/
Poland	Central Statistical Office of Poland	http://www.stat.gov.pl/english/index.htm
Portugal	Instituto Nacional de Estatistica	http://www.ine.pt/
Scotland	General Register Office for Scotland	http://www.open.gov.uk/gros/groshome.htm
Slovenia	Statistical Office of the Republic of Slovenia	http://www.sigov.si/zrs/
Spain	Instituto Nacional de Estadistica	http://www.ine.es/
Sweden	Statistics Sweden	http://www.scb.se/
United Kingdom	National Statistics	http://www.statistics.gov.uk/

Suitability for use: Demographic data and their trend analysis provide valuable information to assess the attractive power of coastal areas on citizens, and define potential pressure on the coast regarding pollution, the need for tourism and seasonal fluctuations pose an indicator for the economical value. This is also essential for the use of cost-benefit analysis for multi-purpose constructions or planning in the coastal zone (see also the guidelines for cost-benefit analysis)

TOPIC GROUP 7. HERITAGE

Topic 7.1. Areas of high ecological value

Abstract: Europe hosts an outstanding amount of natural areas with high ecological values, and which are regularly challenged by human activities. Yet, these areas fulfill a wide range of regulation functions from which human beings - and nature in general – benefit. These regulation functions include for example siting for recreational activities, natural protection against storm surges, preservation of inland freshwater, provision of breeding and nesting facilities for animal species, etc. A number of these areas benefit from a protection status but not all of them.

Spatial extent: In the framework of the coastal GIS, information on natural habitats should be ideally gathered for areas lying from 2 kilometres offshore to 10km inland.

Format: Information on areas of high ecological value should include at least:

- the geographical boundary of the area of high ecological value
- the name of the area as an attribute of the area object.
- its designation status (see data acquisition and production method) as an attribute of the area object. Note that not all areas of high ecological value benefit from a conservation or protection statute.
- the natural habitats it hosts as relation tables between the area object and the table of natural habitats (see data acquisition and production method for the natural habitat classification table).

Data acquisition and/or protection method: Depending on the designation statute, two complementary methods have to implemented:

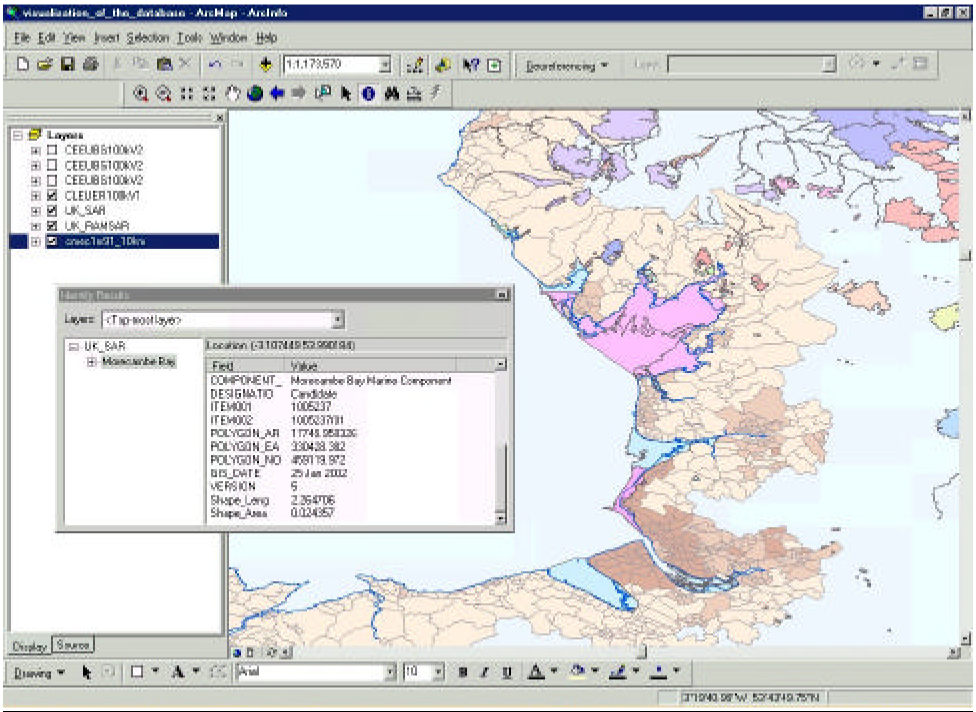
(i) the area is designated

Information on the designated areas can be found at the level of public authorities in charge of nature conservation. There are a number of designation levels which refer to international conventions, european directives or agreements, or specific national regulations. The table below lists the different types of designations encountered in Europe.

Level of designation	Type of designation
Areas of international importance	UNESCO Biosphere Reserves (UNESCO) Wetlands of international importance (Ramsar convention) World Heritage Sites (UNESCO) Specially protected areas of Meditteranean importance (Barcelona Convention)
Areas of European importance	*proposed* Special areas of conservation (under the Habitat Directive) Special areas of conservation (under the Habitat Directive) Special protection areas for birds (under the Bird directive) Biogenetic reserve conservation (Council of Europe)
Areas of national and regional importance	*Commonly found designation statutes, only:* Natural heritage sites National and regional parks Nature reserves Wildfowl reserves Sites of special scientific interest Areas of Outstanding Natural Beauty (AONB) National scenic areas Environmentally sensitive areas

(ii) the area is not designated

Information on areas which are not designated areas are harder to find. In these cases, it is recommended to collect expert judgements.



Example of designated areas in Wales - UK

For both cases, the documentation of natural habitats hosted by each individual area must be conform to the EUNIS standardized habitat classification (see annex). The EUNIS Habitat classification has been developed to facilitate a harmonised description and collection of data across Europe through the use of criteria for habitat identification. It is a comprehensive pan-European system, covering all types of habitats from natural to artificial, from terrestrial to freshwater and marine habitats types.
It is built to link to and correspond with other major habitat systems in Europe:

- It cross-references to all EU Habitat Directive habitat types used for EU Member States and can be used as a basis for EU Habitat Directive extension for Accession Countries
- It builds on the CORINE and Palaearctic Habitat classifications. It will continue to include the Palaearctic Habitat classification's most detailed units as they are further developed over Europe for the Bern Convention EMERALD network (Resolution No.4)
- It contains and will continue to include relevant marine habitat types as they are developed in collaboration with the OSPARCOM marine work
- It cross-references to the Corine Land Cover classification, to some regional and national classifications, and to other systems such as the European Vegetation Survey.

EUNIS is an hierarchical classification based upon ten major (level 1) habitat classes which are then sub-divided into more specific habitats (levels 2 and 3). Further lower level units (ie, below level 3) are drawn from the habitat units and codes of other classifications, name the Palaearctic, BioMar, Mediterranean and Baltic marine habitat classifications. EUNIS can therefore be applied at different levels of complexity and is relatively easy for the non-expert to use. Details on the application of EUNIS in critical loads work and specifically its application to empirical nitrogen critical loads can be found in Hall et al (2003, in press).

Availability and costs: Not available.

Suitability for use: Ecological heritage is a sometimes forgotten aspect in the whole management of the coast. This must be embedded in the societal cost benefit analysis of the coastal zone and forms a basis to deal with legislation on environmental protected areas.

Topic 7.2. Cultural heritage

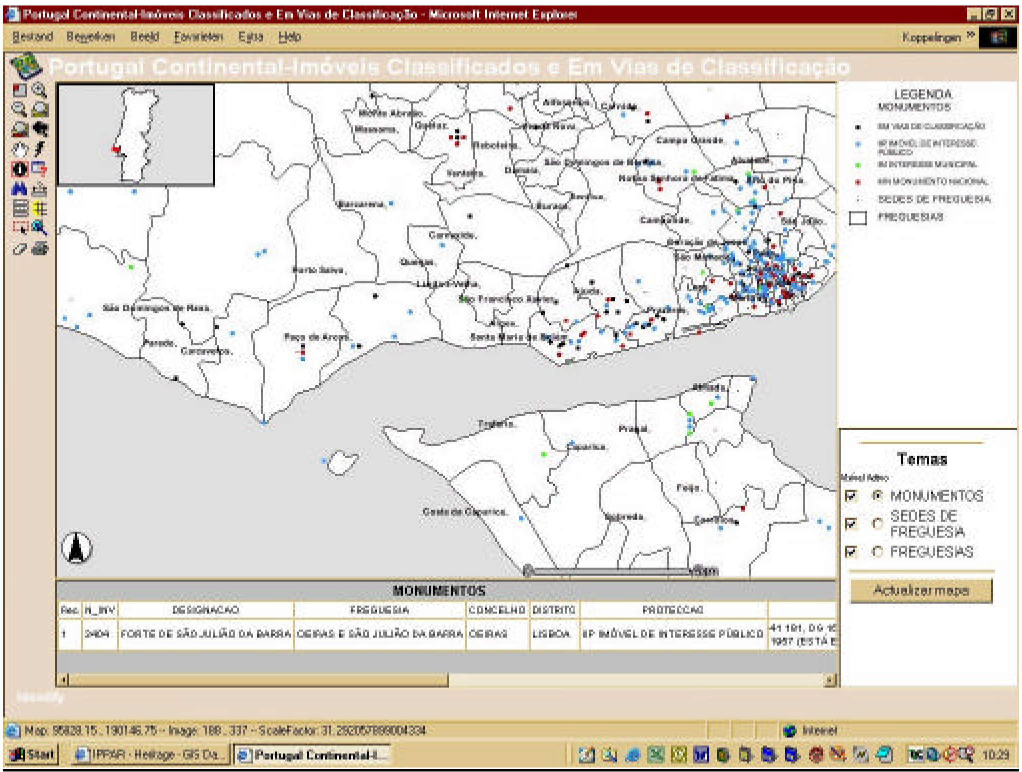
Abstract: Europe's historic structures, archaeological fields and natural sites are major contributors to the quality of life enjoyed by the citizens and visitors of the state. These places are of substantial economic value, contribute to urban revitalization, serve as sources of recreation, and provide important tangible links to Europe's heritage. In Europe, there are about 1,5 millions registered sites which benefit from a specific protection and conservation statutes, a significant part of which is located in coastal areas.

Spatial extent: In the framework of the coastal GIS, information should be gathered for registered cultural heritage sites located within 10km from the coastline.

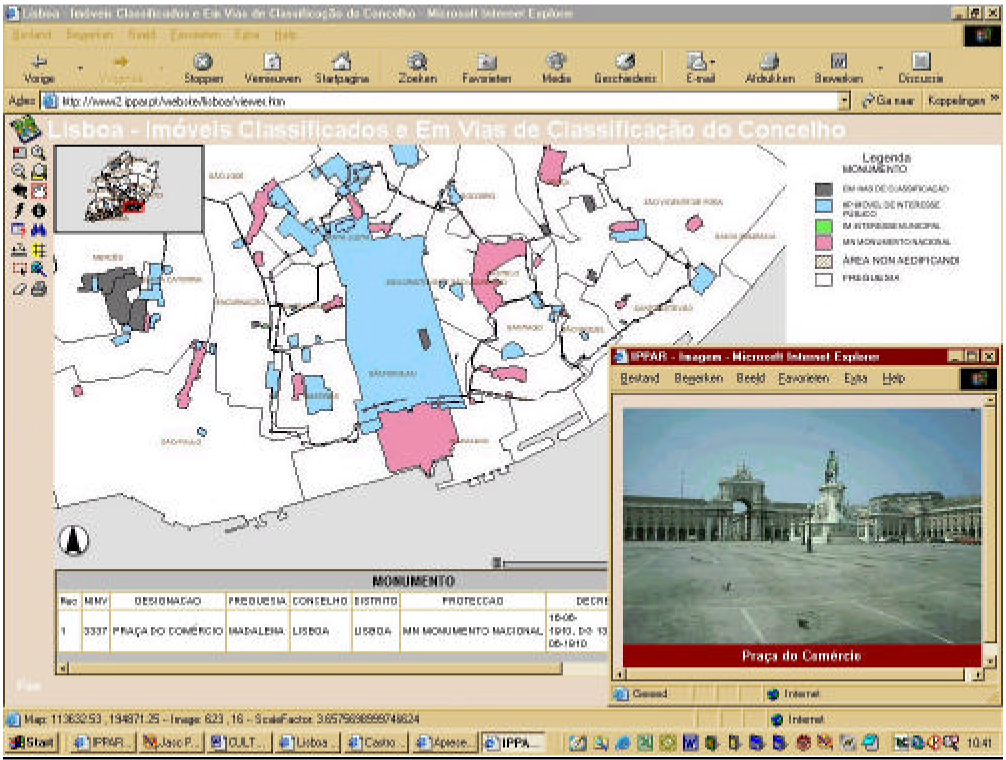
Format: Information on cultural heritage sites should be made available as attributes of vector objects. Each object – point or polygon – depicts the location or the boundaries of cultural heritage sites (e.g. a point for a church, a polygons for a historic park). There is no standard classification of cultural heritage sites in Europe. In practice however, the following types of sites are commonly encountered in Europe :

- Designated buildings
- Ancient monuments
- Archaeologic sites
- Historic gardens of parks
- Historic battlefields
- Remarkable sites

Beside boundaries and locations, information on cultural heritage sites shall include the area, the type of site (ancient monument, archaeological site, etc.), the registration year, an abstract, the state of designation progress, and possibly a picture of the site. Below is an example of cultural heritage database for the region of Lisbon in Portugal. This database has been developed by the National Institute for Cultural Heritage of Portugal (IPPAR).



Example of cultural heritage database (source: IPPAR – Portugal)



Example of cultural heritage database in the city of Lisbon(source: IPPAR – Portugal)

Data acquisition and/or production method: Data acquisition is mostly done through questionnaires and statistical scoring systems in order to quantify qualitative values towards decision makers

Availability and costs: Availability of data in cultural heritage varies from one country to another. A great deal of information on existing inventories and databases on cultural heritage has been established by the European Heritage Network (http://www.european-heritage.net) under the lead of the Council of Europe.

Suitability for use: Coastal ecosystems contribute to the maintenance of human knowledge by providing scientific and educational information. They are also a part of the cultural heritage and provide information about the cultural history of a landscape and a country or can even give spiritual enrichment towards people.

TOPIC GROUP 8. ECONOMIC ASSETS

Topic 8.1. Land market value

Abstract: Land market value is defined as the most probable price in cash, or terms equivalent to cash, which lands or interest in lands should bring in a competitive and open market under all conditions requisite to a fair sale, where the buyer and seller each acts prudently and knowledgeably, and the price is not affected by undue influence. Such a value can be said to comprise two main components: land (or location) and improvement (buildings, etc.).

Spatial extent:: In the framework of a coastal GIS, land value data should be available for inter-tidal and terrestrial areas up to 10 km inland. In low-lying areas, it is recommended to extend the spatial coverage of land value up to the contour line corresponding to an elevation of 2 meters.

Format:: Landvaluescape is best represented by so-called "isovals". Just like contour lines ("landscape"), isovals are vector polylines which join points expected to have the same value per unit area "v".

Data acquisition and/or production method: Land value mapping depends on the availability of land value data, which may vary from one country to another. When such data exist, the following procedure is recommended:
a sample of land value data is collected. A land value data is determined by three elements: the location of the land parcel (more precisely the coordinates of one point of the land parcel), the size, the real estate value as recorded by the cadastre. The sample density should be ideally 10 points per square kilometre, but this depends on the average size of parcels (in urban areas, the sample should be more dense).
Land value data are converted into a scattered set of points characterised by their location and value per unit (parcel value divided by the parcel size).
Once in this format, the data can be converted into data surface using one of a number of interpolation techniques including spline, inverse distance weighting and kriging. These functions are not standards but they may be found in a number of commercial GIS like ArcInfo (module Spatial Analyst)

Spatial accuracy: The accuracy depends on the sample density.

Currency: Land value may vary quite considerably over time, as a result for example of new investments in the neighbourhood. It is therefore recommended to update this layer every 5 years or before.

Availability and costs: Not all national land registration systems in Europe enable a quick and easy access to land value data. When it is not possible, a survey can be conducted among local real estate agencies or association of clerks to retrieve a sample of land value data. The survey may range from a week to a month depending on the sample density and accuracy required.

Suitability for use: Landvaluescape is a key input for a number of analysis, namely assessment of economical capital at risk, and cost-benefits analysis

Topic 8.2. Economic registered activities

Abstract: Such as demography, economic activities provide valuable information to assess the attractive power of coastal areas on citizens and provides as well key input for capital at risk assessment in terms of jobs, turnover, value, production. If the information on economical activities exist in digital format in almost all European countries with a rather good level of details (for tax and statistical purposes), the greatest challenge is to access the data which are stamped "confidential", and when eventually they are made accessible, another challenge is to link these activities with their geographical locations.

Spatial extent: In the framework of a coastal GIS, information on economic activities should be made available for areas located within 10km from the coastline. In case of low lying areas, it is however recommended to boraden the spatial extent up to the 2-meter-contour line.
Format: Information on economical activities should be ideally be made available as attributes of vector points. Each point represent the location a a company duly registered at the level of public authorities (in general chambers of commerce, ministries of finances, or bureau of statistics). Economic information to be gathered should include at least:

- the name of the company
- the address
- the economic activity code (according to the NACE code – see *data acquisition and/or production method*)
- the initial capital
- number of jobs
- the turnover
- the value of assets

Data acquisition and production method: Integration of information of economic activities into a coastal GIS requires two steps:

(i) collection of data on economic activities

Information of economic activities are available at the level of chambers of commerce, ministries of finances, or bureau of statistics (see *availability and costs*).

(ii) geocoding of economic activities

In general, information obtained from national registration companies are not geocoded which means they cannot be automatically displayed on a map, since they contained no geographical coordinate. Instead, each company has an address (street name, number, postal code) duly registered which may be linked to geographical coordinates. This operation is theoretically simple but time-consuming since specialised GIS companies report more than 50 millions of street address in Europe. A cost-effective solution therefore consist in acquiring GIS database of street locations for Europe. The world leading products in the provision of GIS based street locations are TeleAtlas Multinet (www.teleatlas.com) and Navtech Navstreets (www.navtech.com). Information is provided by Teleatlas in a variety of formats including shapefile (ArcInfo), Oracle spatial, or tabfile (Mapinfo). It must be noted however that street-based geocoding of registered companies may be delayed by mismatching errors between the "street address " as registered by registration authorities and the "street address" as recorded within existing databases.

Spatial accuracy: The geometrical accuracy of registered companies' location depends on the data source used for geocoding operations (eg. TeleAtlas, Navstreet). Both Navstreets and Multinet products have an accuracy ranging from 10 metres (in urban areas) to 30 metres (interurban areas).

Availability and costs: Information on economic activities and companies is found at the level of chambers of commerce, trade registries or statistics offices, depending on the countries. A number of national registration authorities have formed a network called the the European Business Register (www.erb.org) to make it possible for everybody to obtain comparable, official company information from the countries connected to the network- at a reasonable price. Below is a list of national services in charge of the provision of data on economical activities.

Country	***Data sources***	***Website***	***EBR member (Y/N?)***
Belgium	EURO DB	www.eurodb.be	Yes
Cyprus	No information		
Denmark	The Danish Commerce and Companies Agency (DCCA)	www.eogs.dk	Yes
Estonia	Centre of Registers	www.just.ee	Yes
Finland	Patentti- ja rekisterihallitus (National Board of Patents and Registration)	www.prh.fi	Yes
France	Le Tribunal de Commerce : The Commercial Court	www.infogreffe.fr	Yes
Germany	Creditreform (derived from the Handelsregister / Trade	www.creditreform.de	Yes

	register)		
Greece	Athens chamber of commerce	www.acci.gr	Yes
Ireland	Companies Registration Office	www.cro.ie	Yes
Italy	Infocamere (centralises data from Italian chambers of commerce)	www.infocamere.it	Yes
Latvia	The register of enterprises	www.ur.gov.lv	Yes
Lithuania	Statistics Lithuania	www.std.lt	Yes
Malta	Registry of Companies Malta Financial Services Centre	registry.mfsc.com.mt	Yes
Netherlands	Central Bureau van Statistiek	www.cbs.nl	No
Northen Ireland	Registry of Companies, Credit Unions and Industrial & Provident Societies	w w w.companiesregistry-ni.gov.uk	Yes
Poland	No information		
Portugal	Instituto Nacional de Estatistica	http://www.ine.pt/	No
Slovenia	Statistical Office of the Republic of Slovenia		Yes
Spain	Registro mercantil central	http://www.rmc.es/	Yes
Sweden	PRV Bolag	www.prv.se	Yes
UK (except Northen Ireland)	Companies house	www.companies-house.gov.uk	Yes

As for street locations, GIS database are extremely expensive. A typical licence for one country (e.g. France) is 80,000 Euros for TeleAtlas Mutinet and 40,000 Euros for Navtech Navstreets. The costs for acquiring a coverage of only a region or a city has to be negotiated on a case-by-case basis. The availability of other sources of street location data varies from one country to another. Below is an extract of TeleAtlas database for 4 pilot areas reviewed during EUROSION.

Sitges (Catalunya, Spain)

Mersea Island (Essex, UK)


Ventnor (Isle of Wight, UK)


Lacanau (Aquitaine, France)