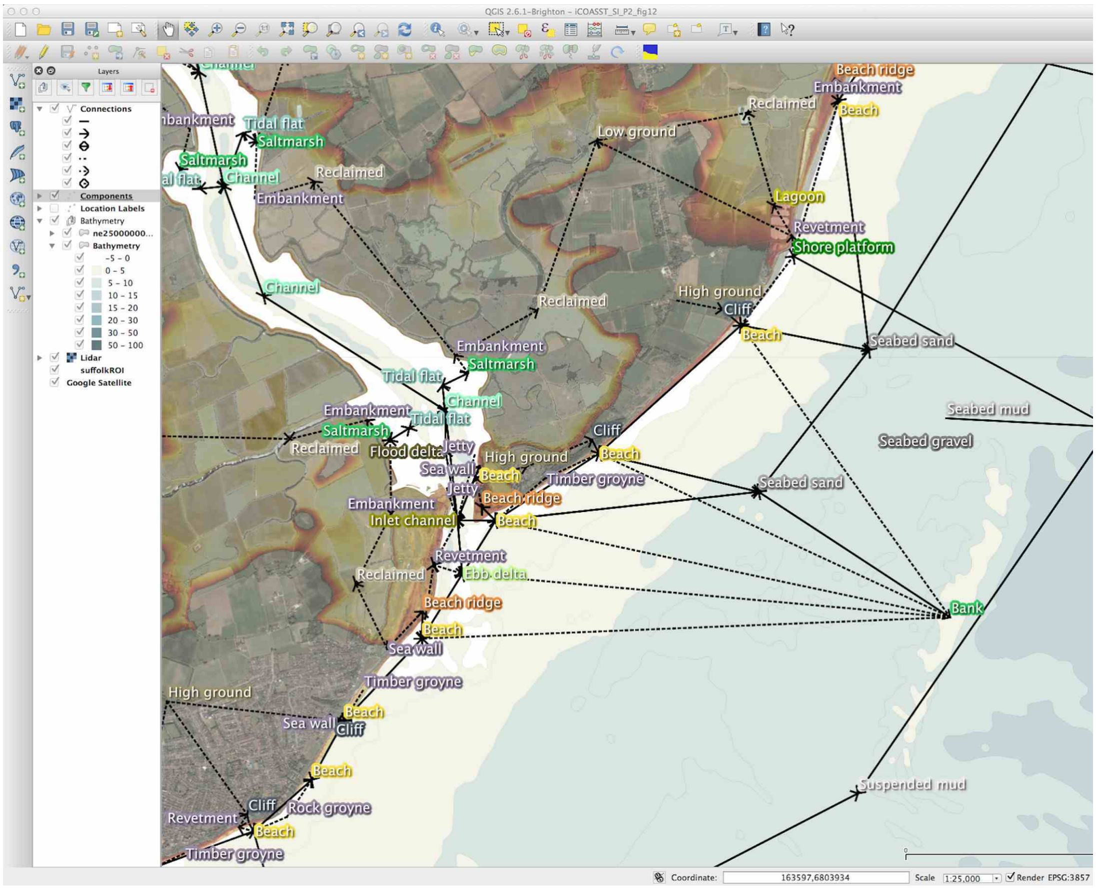
Coastal and **E**stuarine **S**ystem **Mapper**

QGIS plugin for Coastal and Estuarine System Mapping

CESMapper User Manual: release 1.5.xx



UCL Coastal and Estuarine Research Unit

CESMapper User Manual

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CESMapper software repository:

https://github.com/UCL-CERU/CESMapper

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http://www.icoasst.net

http://www.channelcoast.org/iCOASST

The CESM approach is described more fully in:

French, J.R., Burningham, H., Thornhill, G., Whitehouse, R., Nicholls, R.J. 2016. Conceptualizing and mapping coupled estuary, coast and inner shelf sediment systems. *Geomorphology* 256: 17-35. http://dx.doi.org/10.1016/j.geomorph.2015.10.006 [open access]

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1 CESMapper installation

1.1 System requirements

CESMapper is written in Python as a plugin for the open-source Geographical Information System software, QGIS. Provided that a compatible version of QGIS is installed, then CESMapper should function correctly. QGIS may be freely downloaded (either as binary executable application files or source code) from www.qgis.org. Both QGIS and CESMapper may be run on Linux, Mac OS-X, and Windows operating systems.

This manual describes CESMapper release 1.5.xx, which requires that QGIS version 2.8.0 (Wien) or later is installed on the computer. This release has been tested up to QGIS version 2.14.3 (Essen).

As with any GIS, the performance of both QGIS and the CESMapper plugin will be improved on computers equipped with faster processor(s) and larger amounts of memory (RAM).

1.2 Manual installation via GitHub repository

Assuming that a fully functional and compatible version of QGIS is already installed, CESMapper can be downloaded from the public GitHub repository at:

https://github.com/UCL-CERU/CESMapper

This repository contains stable release versions (suitable for most users) as well as the current development and testing versions of CESMapper (suitable only for advanced users or developers).

Installation step 1: download the current release from the repository, unzip the archive file, and copy the CESMapper directory and its contents into the .qgis2/Python/plugins directory on your computer.

On Linux systems the plugins directory is typically found at

/home/{username}/.qgis2/python/plugins (where {username} is the user account name)

On Mac OS-X systems, this directory can usually be found at

/Users/{username}/.qgis2/python/plugins

On Windows systems the plugins directory is typically found at

C:\Users\{username}\.qgis\python\plugins

CESMapper releases also contain a Docs directory (User Manual, possibly supplemented by other documentation), an Ontologies directory (see sections 2.2.3 and 3.3), and a Styles directory (QGIS style files; see section 3.9). These should all be copied to a convenient location on your computer.

Installation step 2: Start QGIS and open the Plugins … Manage and Install Plugins menu from the upper menu bar (Fig. 1.1). Locate the CESMapper plugin on the list of plugins, and check the 'install' box. Close the menu and you should see the CESMapper icon displayed on the main QGIS toolbar (Fig. 1.2).

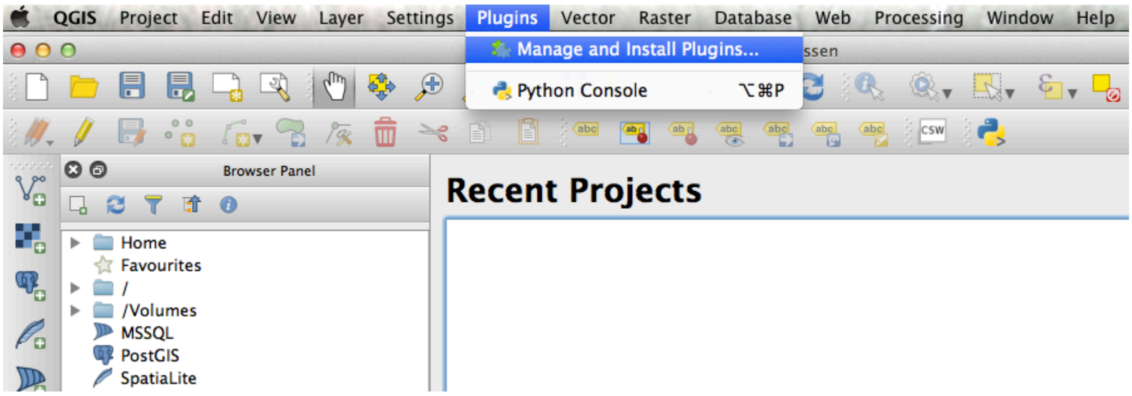

Figure 1.1 Plugin … Manage and Install Plugins on the QGIS upper menu bar.

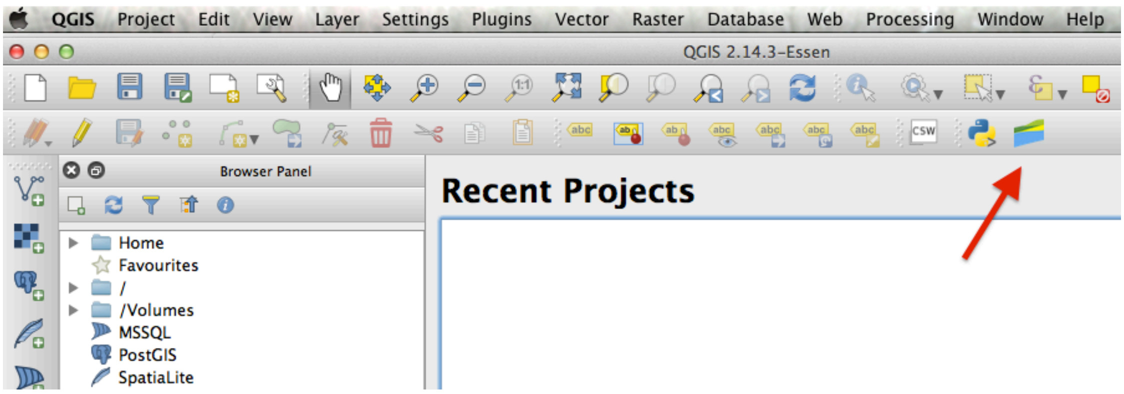

Figure 1.2 CESMapper icon (arrowed) on the QGIS toolbox indicates sucessful installation of plugin.

1.3 Installation via QGIS plugin repository

CESMapper is also being made available via the QGIS repository. This is accessible via the Plugins …. Manage and Install Plugins menu from the upper menu bar (Fig. 1.1). Locate the CESMapper plugin on the list of plugins, and check the 'install' box.

Close the menu and you should see the CESMapper icon displayed on the main QGIS toolbar (Fig. 1.2).

1.4 Software license

CESMapper is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or any later version.

CESMapper is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License (Appendix 1) for more details.

You should have received a copy of the GNU General Public License along with CESMapper. If not, see <http://www.gnu.org/licenses/>.

2 CESM overview and key concepts

2.1 Background

Risks to human populations, assets and activities are anticipated to increase with sea-level rise and climate change. Our ability to mitigate these risks is dependent on our understanding of how coastal landforms evolve their morphology in response to factors such as sea-level rise, the constraints imposed by widespread engineering structures and interventions in the sediment pathways that connect and sustain landforms. From a risk management perspective, landforms function as important mediators of the *pathways* that transfer erosion and flood risk from external *sources* (wave, tide and storm surge etc.) to human *receptors* in vulnerable areas (Sayers et al., 2002; Batten et al., 2015).

Since the pioneering work of Inman and Frautschy (1966) on the coast of southern California, the concept of the littoral cell has provided a framework for analyses of coastal change and for shoreline management. At regional to national scales, hierarchies of cells provide a geomorphological basis for shoreline management that has many advantages over the use of arbitrary administrative boundaries (Komar, 1996). In England and Wales, for example, national mapping of major cells and sub-cells (Motyka and Brampton, 1993) provided the basis for a first generation of Shoreline Management Plans (SMPs) (Cooper et al., 2002). In Western Australia, Eliot et al. (2011) have devised a three-tier hierarchy of cells to inform marine and coastal planning.

The littoral cell concept also has its limitations, however. The criteria used to delimit cells and the stability of their boundaries under variable wave climate or sediment supply are not always clear-cut. Also, littoral cells primarily reflect short-range transfers of non-cohesive ‘beach-grade’ material (i.e. sands and gravels). They are thus not well suited to handling broader scale linkages between estuarine, coastal and offshore systems, especially where longer-range suspended sediment (mud or fine sand) fluxes are important (Cooper and Pontee, 2006). Finally, the littoral cell framework has also tended to perpetuate the separate treatment of open coast and estuary in shoreline management planning (French et al., 2016b).

A behavioural systems approach to the segmentation of the open coast was devised in the FutureCoast project (Burgess et al., 2004). This embedded littoral cells within a spatial hierarchy of geomorphological units (effectively individual landforms), shoreline behaviour units (sub-systems, such as embayments and estuaries) and regional coastal behaviour systems. This approach was applied to the entire coast of England and Wales, where it has provided the basis for a second generation of SMPs.

Another advance has been the concept of the ‘coastal tract’, developed by Cowell et al. (2003a,b). This is based on the idea of a sediment-sharing system that encompasses not only the upper shoreface of the open coast but also estuarine (backbarrier) environments and the lower shoreface. The tract sits at the top of a hierarchy (or ‘cascade’) of sediment-sharing systems that evolve their morphology over progressively shorter timescales. The tract is defined at a scale at which low-order progressive change (which presents some of the most challenging erosion and flood risk management problems) can be disaggregated from higher-order variability. It also acknowledges the interactions between estuary, open coast and the inner shelf. Although the time scales of the tract hierarchy are explicit, the associated spatial scales are largely implied through the definition of morphological complexes, units and elements.

The need for an integrative systems-based perspective has become more pressing as the strategic application and evaluation of management and engineering options has evolved to address the broader time and space scales at which progressive shifts in shoreline position (Nicholls et al., 2013), and possibly overall coastal configuration, may be expected in the face of climate change and sea-level rise (French and Burningham, 2013). Of particular importance is the integration of open coast and estuary into a common conceptual framework. At the same time, there is also need for frameworks that are transparent, and which bridge the gap between the experience and perspectives of scientists, engineers and stakeholders in areas of environmental management that have often proved politically contentious. Communication is vital given the extent to which science has become almost wholly founded on models. In climate science, public understanding and confidence has often been impaired by poor communication of the nature and purpose of complex simulation models (Hall et al. 2014).

Qualitative modelling has a clear role as a means of arriving at shared understanding of the system being studied and the nature of the problems that need to be addressed (e.g. Sano et al. 2014). Coastal and Estuarine System Mapping (CESM; French et al., 2016a) has been developed within the Integrating Coastal Sediment Systems (iCOASST) project which was funded by the UK Natural Environment Research Council (NERC) between 2012 and 2016 (Nicholls et al., 2015). Within iCOASST, CESM was used for identifying the most important processes (and associated management issues) to be included in more quantitative modelling studies (van Maanen et al., 2016) and also as means of aligning stakeholder and scientific knowledge and fostering a 'participatory modelling' approach (Voinov and Bousquet, 2010; French et al., 2016c).

CESM renders the complexity of coastal and estuarine geomorphological systems as a simple ontology of components and interactions, and depicts these in a visual form that provides an effective catalyst for discussion and debate between scientist, stakeholder agencies and organizations, and local citizens. The CESMapper software is intended to facilitate application of this approach within the freely available open-source GIS, QGIS.

2.2 Key concepts

2.2.1 Idealized spatial ontology for coastal and estuarine landforms and human interventions

The starting point for CESM is an idealized spatial ontology that provides a basis for mapping the configuration of coupled assemblages of landforms on the open coast, estuaries and inner shelf. The term ontology refers to a formal specification of a conceptualization (see Gruber, 1993), but CESM adopts a fairly loose interpretation that encompasses a hierarchical classification of components and a set of permitted interactions between them. Put simply, the ontology is a classification and a set of rules.

As outlined in Figure 2.1, the CESM spatial ontology reflects some aspects of the coastal tract concept (Cowell et al., 2003a) in that it depicts a hierarchy of morphologically active sediment sharing landform systems. These are located within the geological context of a coastal shelf that can be considered time-invariant at the decadal to centennial timescales that are most relevant for shoreline management (French et al., 2016a). In contrast to the largely timescale-based hierarchy of the coastal tract, however, CESM emphasizes the spatial nesting of landform components within aggregate landform complexes (cf Burgess et al., 2004; Eliot et al., 2011). It also explicitly represents varied human interventions and the way in which these constrain landform adjustment (see, for example, Hapke et al., 2013).

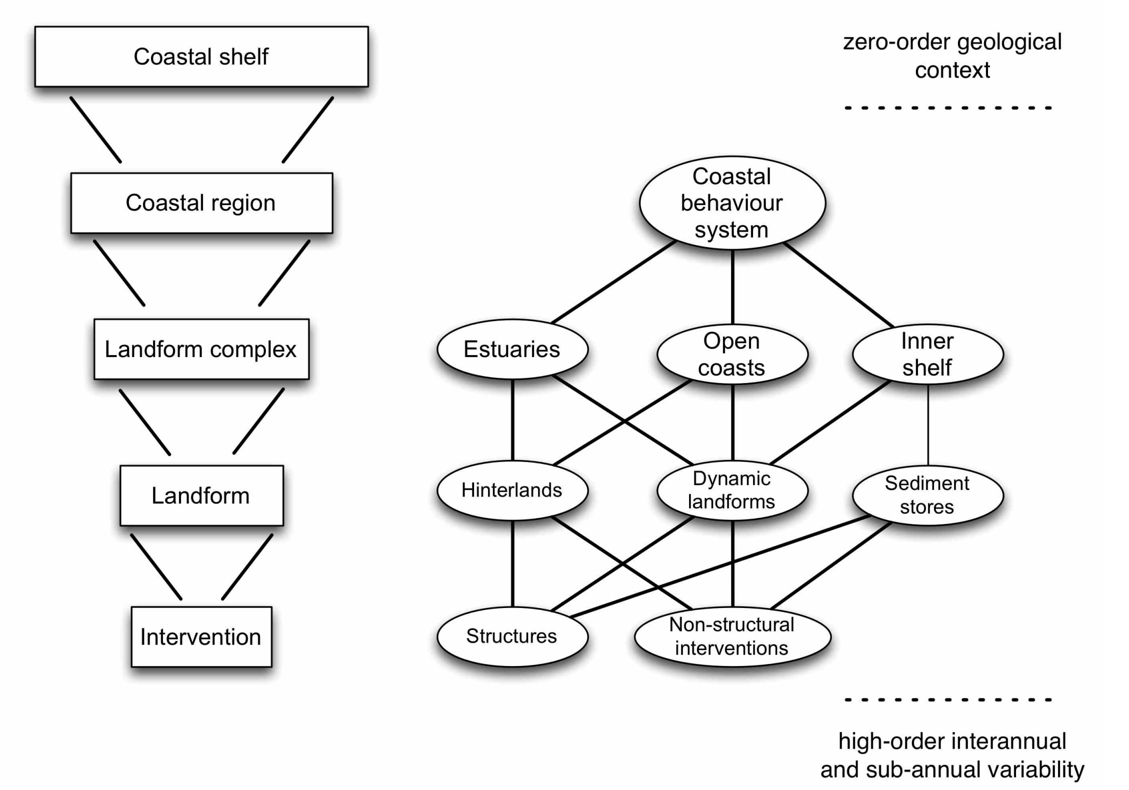

Figure 2.1: Spatial ontology of coupled estuary–coast–inner shelf geomorphic systems, showing nesting of landforms and landform complexes within broader-scale coastal regions. At decadal to centennial scales, the coastal behaviour system integrates the interaction of estuarine, open coastal and inner shelf morphodynamics, within a coastal shelf context that evolves only at much longer timescales. Interannual and sub-annual dynamics are generally not resolved at timescales of decades and longer.

Landform complexes

Estuarine, coastal and inner shelf landform complexes can be classified with reference to existing schemes and the range of landforms encountered in a given regional or shelf context. Figure 2.2a shows a simple estuary classification based on ABPmer (2008). The term ‘inlet’ is here used to define systems in which fluvial influence is negligible and sediments are purely marine in origin; this includes inlets that may be only intermittently active. Such a scheme has quite broad applicability within temperate zones (such as northwest Europe). Its relative simplicity is advantageous from a helps to reduce the ‘operator variance’ that inevitably arises where classificatory judgements have to be made.

Open coasts can similarly be classified (Fig. 2.2b) with headlands and bays for coasts that exhibit more obvious geological control. Cuspate forelands and spits may be large enough to be afforded the status of a landform complex. Barrier islands are also included as a landform complex in their own right and distinguished from other forms of non-detached coastal barrier.

The inner shelf is less replete with discrete landform types, although the drowned palaeo-landscapes of the last glacial are attracting increasing attention. Many shallow shelf seas are characterized by distinctive bank systems of varying morphology and origin. These may exert a significant influence on contemporary shoreline behaviour, either through their role in modifying wave climate (e.g. Chini et al., 2010) or via their participation in coastal sediment pathways. Figure 2.2c presents a simple classification based on work in the North Sea by Dyer and Huntley (1999).

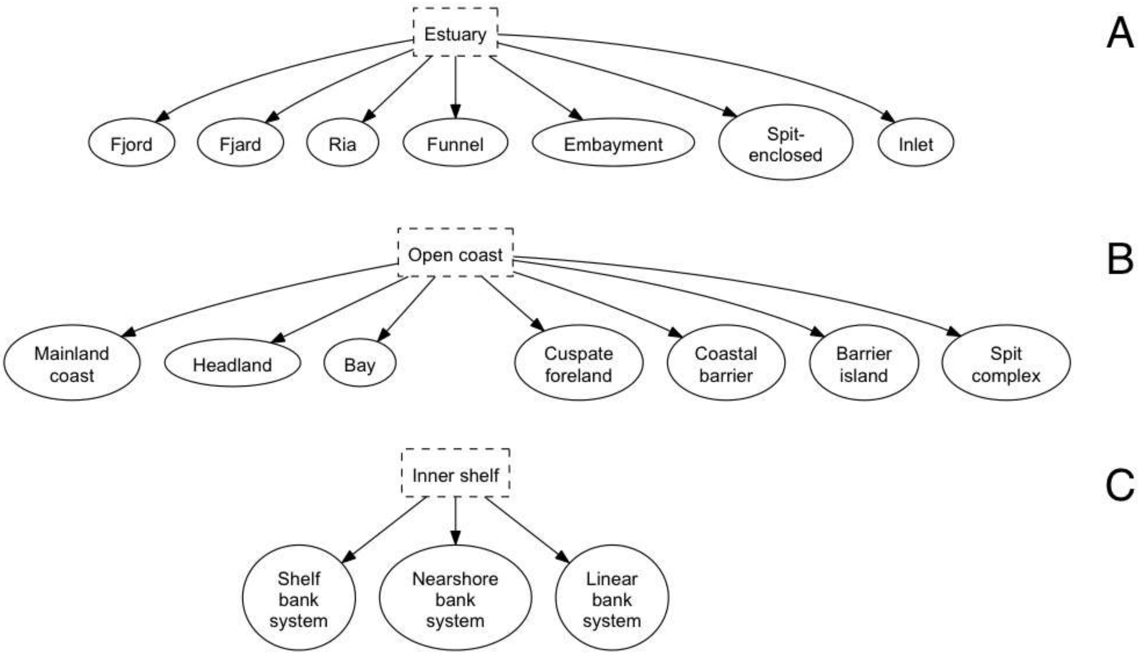

Figure 2.2: Illustrative classification of estuary, coast and inner shelf landform complexes suitable for application within a temperate (e.g. northwest European) context. The basic approach can easily be modified to suit other environments.

Landforms

The estuarine, open coastal, and inner shelf complexes outlined above represent aggregations of landforms. Table 2.1 summarises a basic set of landforms applicable to temperate settings, which includes ‘textbook’ features such as cliff, beach, tombolo, spit etc. Some landform types may occur within more than one type of landform complex (e.g. tidal flat, which can occur in both open coast and estuarine settings). Other landform types such as spits and ebb tidal deltas, occur at the interface between estuary and open coast and, as such, could be considered to be part of either complex. Spits are a special case in that larger examples can be mapped as a complex (with component dune, beach, beach ridge etc.) whilst minor features can be considered as discrete landforms within another complex. This clearly involves an element of subjective judgement.

The set of morphologically active landforms is supplemented by a smaller set of hinterland types that are considered to exert a static boundary condition control. High ground is defined subjectively as terrain that rises well above current and projected future tide and surge elevations and which would be expected to exhibit a predominantly erosional response to sea-level rise. Low ground is identified as being more susceptible to inundation, and this may constitute a more significant hazard (though erosion also leads to increased flood risk so the two hazards are not independent). Reclaimed areas are those that have been historically converted from the intertidal and subtidal zones and are protected from tidal action by defences.

Sediment systems include distinct stores of sediment that can be locally important in mediating landform behaviour. Much of the shelf is veneered by patches of sediment, some of which are essentially inactive under current sea level, wave climate and tide regime, and some of which participate in sediment pathways that interact with coastal or estuarine environments.

Table 2.1: A basic set of landform components common to open coastal, estuarine and inner-shelf complexes. These comprise morphologically active landforms, as well as hinterlands and sediment stores.

Landform		Hinterland	Sediment store
Cliff	Inlet channel	High ground	Seabed gravel
Shore platform	Ebb delta	Low ground	Seabed sand
Beach	Flood delta	Reclaimed	Seabed mud
Beach ridge	Bank		Suspended mud
Tombolo	Channel		
Dune	Tidal flat		
Spit	Saltmarsh		
Rock outcrop	Brackish marsh		
Lagoon	River		

Human interventions
Present-day coastal behaviour is strongly conditioned by, and indeed partly a consequence of, human interventions of various forms over a period of decades to centuries. The effects of coastal protection works are evident locally (Basco, 2006), regionally (Brown et al., 2011) and even nationally at the scale of the USA (Hapke et

al., 2013). The most obvious interventions have been structural, with the goal of erosion control, reclamation or flood risk reduction. Local experiences and requirements, and has given rise to a diverse terminology for interventions that perform the same basic function. Table 2.2 presents a highly generic classification of some basic types of intervention according to the function performed. Most have the effect of arresting shoreline movement, for example by limiting erosion or channel migration. Non-structural interventions in coastal and estuarine sediment systems are also pervasive, not only through dredging and aggregate extraction but also through the adoption of ‘softer’ approaches to coastal management.

Table 1.2: Minimal classification of generic structural and non-structural interventions in estuary, coast and inner shelf sediment systems, with their indicative purpose.

Structural	(indicative purpose)	Non-structural	(indicative purpose)
Seawall	Erosion protection	Dredging	Navigation; mining
Revetment	Erosion protection	Dredge disposal	Spoil disposal
Bulkhead	Erosion protection	Sediment recharge	Restoration of sediment deficit (beach, intertidal)
Embankment	Flood protection	Sediment bypassing	Continuity of sediment pathway; navigation
Barrage	Flood protection	Sediment recycling	Resilience (beach profiling);
Breakwater	Wave energy reduction		
Detached breakwater(s)	Wave energy reduction		
Groyne(s)	Sediment retention		
Training wall	Channel stabilisation / navigation		
Jetty	Varied		
Outfall	Drainage / dispersal		
Quay	Navigation/trade		
Dock	Navigation/trade		
Weir	Regulation of river gradient and/or tidal limit		

Interactions

From a functional perspective, system components influence each other through complex web of interactions. Interactions include any cause-effect relation between components; for example, a jetty exerts an effect on an inlet channel, stabilising its location and influencing its cross-sectional characteristics. A sub-set of the interaction network involves transfers of mass and these sediment pathways, taken together, define the sediment budget (Bowen and Inman, 1966; Rosati, 2005).

Some of the linkages may be simple unidirectional ones, for example where sequential beach units define a littoral drift system. Other interactions are clearly bidirectional, such as the interplay between a seawall and a beach (Basco, 2006). Others may represent more complex causality: a cliff may source sediment to a fronting beach (mass transfer) and the beach may influence the cliff (via an influence through which beach morphology feeds back into the cliff recession rate; Walkden and Hall, 2011). Table 2.3 illustrates some of these interaction types, and the distinction between pure influences and sedimen transfer pathways.

Table 2.3: Illustrative paired examples of system interaction rules for landforms and interventions.

From	To	Interaction	Logic (literature source)
Cliff	Beach	Sediment pathway (sand, gravel)	Cliff sources beach-grade sediment (mud typically lost offshore)
Beach	Cliff	Influence	Presence and morphology of beach feeds back into cliff recession rate (e.g. Walkden and Hall, 2011)
……	……	……	……
Seawall	Beach	Influence	Presence of seawall may cause lowering of beach (e.g. Basco, 2006)
Beach	Seawall	Influence	Beach protects toe of seawall and reduces wave energy on face
……	……	……	……
Jetty	Inlet channel	Influence	Jetty exerts stabilising influence on channel position and constrains width adjustment
Inlet channel	Jetty	none	No direct causal relation in this direction

2.2.2 Mapping the connectivity of coupled coast and estuary systems

CESMapper builds on earlier proof-of-concept work (French and Burningham, 2009; Whitehouse et al., 2009) to define a workflow for mapping the connectivity of coupled coast and estuary systems using the ontology described in the preceding section. This workflow is summarised in Figure 2.3 and involves three main stages:

1. **Specification** of the problem or application
2. **Mapping**, in which the system is conceptualized as a spatial network of interactions
3. **Augmentation**, in which data or meta-data are appended to the system map.

The current release of CESMapper is mainly concerned with the Mapping stage, although future versions will likely support the creation of spatial databases that build on the system map.

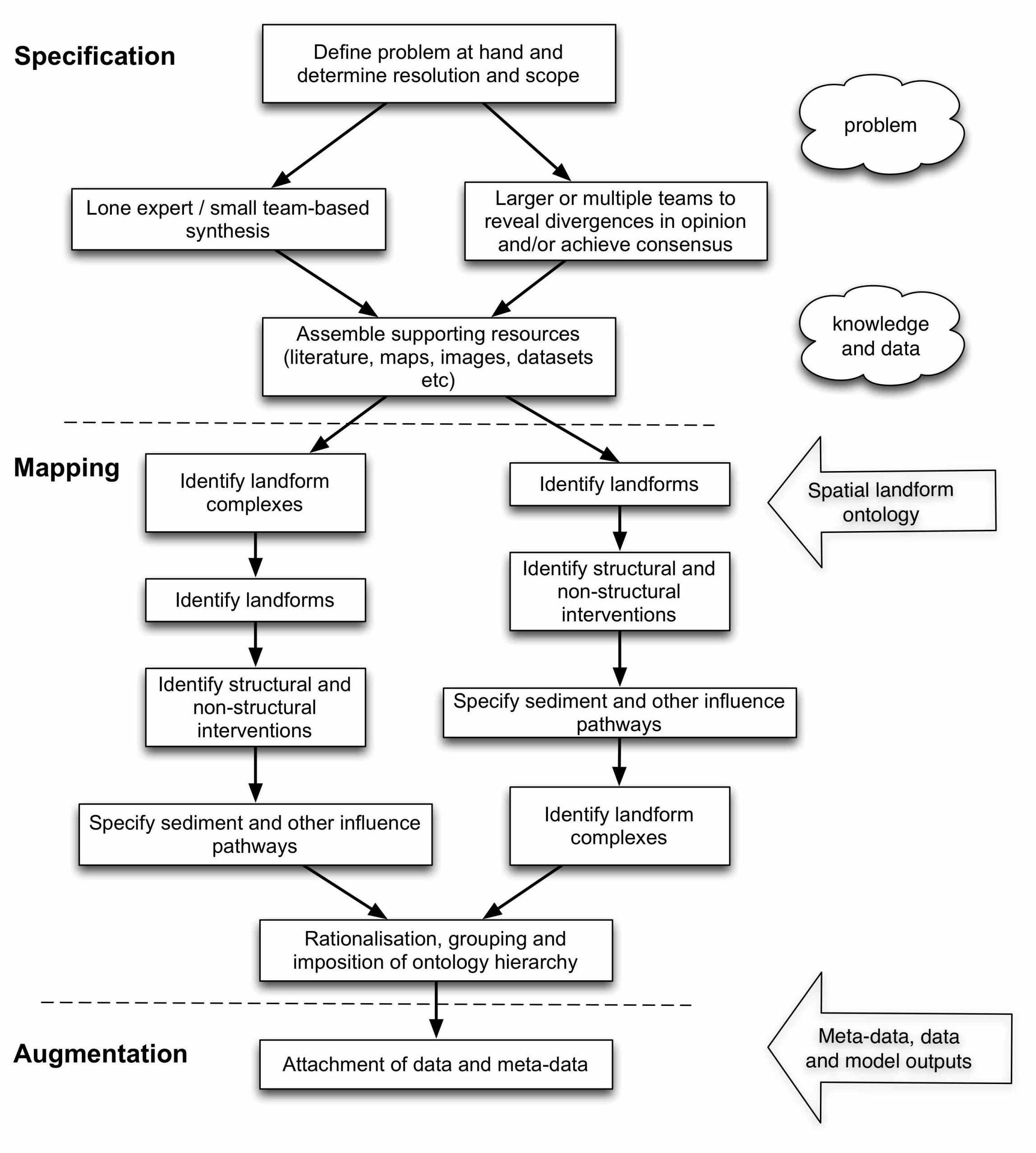

Figure 2.3 – Workflow for Coastal and Estuarine System Mapping. CESMapper is mainly concerned with the Mapping stage.

Key stages of the workflow include:

1. Specification of the problem. This starts with a judgement of the appropriate time-averaging period over which to characterise the system, an appropriate spatial resolution, and the geographical scope. The scope might vary from regional mapping to guide preparation of a shoreline management plan, to a more detailed local map as context for an engineering scheme.

For well-documented and/or understood systems, a lone ‘expert’ or small team of ‘experts’ may be able to achieve a relatively uncontentious synthesis of existing knowledge. Where the system is less well understood, CESM provides a starting point for the progression of a conceptual model and a larger team might be required to achieve a consensus. In either case, participatory involvement of stakeholders may be beneficial.

Once the problem is defined, background knowledge (published papers, reports etc.) and datasets (aerial images, geological maps, bathymetry etc.) are drawn together to inform the mapping process.

2. System mapping. Mapping is undertaken using the hierarchical set of landforms and interventions defined in the ontology. Customization of the ontology will usually be required to suit particular geographical contexts and applications and a feature of CESMapper (see section 2.2.3) is that this can be done via external library files without any modification of the software.

Landforms and interventions are first mapped in detail and then organised into broader-scale complexes. Mapping of the open coast proceeds by identifying distinct hinterland – backshore – nearshore sequences and any local constraints due to structures or known non-structural interventions (e.g. beach nourishment or sediment bypassing programmes). This is similar to the approach taken by Hanson et al. (2010), who presented a scheme for mapping barrier and non-barrier coasts based on sequential transitions in cross-shore profile type, as defined by a set of prescribed landform elements. Within an estuary, distinct subtidal – intertidal – hinterland transitions are similarly mapped with reference to the dominant axis of the estuary.

Interaction pathways are then added, with the directionality of the sediment pathways indicated, and distinction made between these and ‘influence only’ interactions (e.g. those involving the various structures) that are not part of the sediment system. Sediment pathways will often have a preferred direction, but may also be bi-directional where movements are uncertain or oscillatory.

An illustrative conceptualisation of open coast – estuary interaction over an oblique Google earth view is shown in Fig. 2.4.

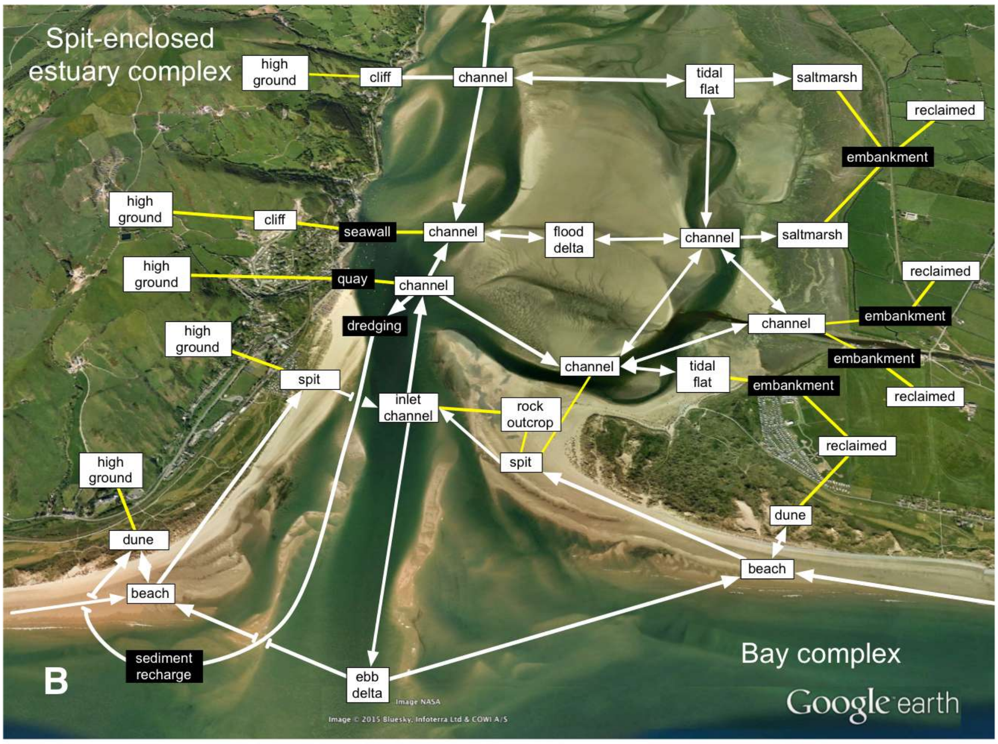

Figure 2.4 Illustrative conceptualisation of open coast – estuary interactions at Aberdovey (Wales, UK). Base image courtesy of Google Earth. Note that this mapping is purely illustrative and not intended to be interpreted as a detailed case study.

3. Augmentation. System maps can be annotated to include metadata (e.g. references and links to relevant research and datasets) as well as data (e.g. quantitatiive sediment flux estimates). CESMapper exports the system map as standard GIS shapefiles and the attributes of these can be modified within QGIS. Future releases of CESMapper will provide a more direct means of appending data.

2.2.3 CESMapper software

The CESM approach has its origins in proof-of-concept work undertaken as part of an Environment Agency-funded project on large-scale coastal geomorphological behaviour (French and Burningham, 2009; Whitehouse et al., 2009). Mapping was initially undertaken using concept mapping software (CmapTools; Cañas et al., 2005). CESMapper provides similar functionality within the geospatial framework provided by a Geographical Information System (GIS).

QGIS (http://www.qgis.org) was selected as a preferred geospatial platform on account of its maturity as an open source GIS, support for multiple operating systems and growing user base. QGIS is written in C++ and allows integration of software plugins coded in either C++ or Python. CESMapper is implemented as a Python plugin that enables system components to be mapped interactively over one or more QGIS data layers.

CESMapper allows the user to add landforms, interventions and interactions on top of a GIS base layer that defines the projection and co-ordinate system. Possible base layers include digital mapping, Web Map Server-based layers (including Google Maps or Bing maps), or digital photography. The base layer can be supplemented by 'helper layers' that provide useful information to guide the identification of landform types and identify human interventions. Airborne LiDAR raster layers are especially useful, as are digital bathymetric charts and geological maps, and vector layers containing information on flood and coastal defence infrastructure.

A key feature of the CESMapper architecture is that the landform ontology is completely separate from the software itself and resides in a user-editable external library file. The ontology is defined using a simple XML-like semantic markup language, which permits the inclusion of optional presentational markup to impose various label and line style settings (these can be overridden within the software). The available components (landforms, interventions) are read from the ontology and used to guide on-the-fly creation of Graphical User Interface (GUI) palettes, which provide the user with a pre-determined set of system elements and impose constraints on how these can be combined. CESMapper then allows the linkages between the various components and specify the type and directionality of the connection (influence, sediment transfer) to be defined. CESM is provided with an ontology devised during the iCOASST project (contained in the file iCOASST-CESMOv1.7.txt) that is intended mainly for application in the UK. Applications outside the UK may require this file to be customized by the user (see section 3.3 and Appendix B).

The selection of a combination of landforms to be included as part of a specific landform complex can be accomplished using the software tool which will automatically provide a check that the grouping is permissible within the defined ontology; this maintains a base level of consistency between different users when producing coastal and estuary system maps. The resulting map (a point layer of components and a line layer of connections) is saved in ESRI shape file format, which can be read by a wide variety of other applications and thus provides a common platform for distribution of system maps to stakeholders.

2.3 Applications of CESM and CESMapper

Within the iCOASST project (Nicholls et al., 2015; Van Maanen et al., 2015), coastal and estuarine system maps were well received by a diverse group of stakeholders that included, inter alia, management agencies and regional authorities, non-governmental organisations, representatives of industry and agriculture, and local inhabitants. Discussions typically centred on matters of detail, such as the omission of local geological controls on shoreline position, as well as broader scale divergences in opinion – notably concerning the consistency of the direction of littoral drift. As a result we revaluated and reformulated our quantitative understanding on the Suffolk coasts. Hence, these discussions have been valuable in capturing stakeholder knowledge and feeding this into both data-driven analyses and modelling studies. The capturing of local knowledge and its incorporation into the formulation of a problem and an approach to it, are key elements of good modelling practice that have all too often be neglected in coastal analysis.

Importantly, CESM is transparent and accessible to a wide range of users. This is partly a consequence of its implementation in open-source software. This counters one of the major shortcomings of a 'top down' approach to shoreline management planning that has historically been heavily reliant on proprietary closed-source model codes and GIS software that is available to the larger consultancies but not to local communities and smaller consultants. As French et al (2016b) note, the open source paradigm of computer science is a good exemplar here, in that it demonstrates the benefits of a genuine community effort, both in terms of transparency and accessibility and also in terms of legacy. CESM has the potential to create conceptual models that are living community efforts, stimulating a greater sense of shared endeavour between modellers and stakeholders than has thus far been possible. These conceptual models and linked databases are free to evolve beyond individual project timelines through the continuing involvement of a community of researchers and stakeholders. Hence, the system maps constitute information products that are not finalised at a project end date but, instead, remain free to evolve as knowledge accumulates and agendas change over time.

3. Using CESMapper within QGIS

3.1 Software workflow

CESMapper implements the various stages of the CESM process set out in French et al (2016a) in a simple workflow. This is summarised in Fig. 3.1.

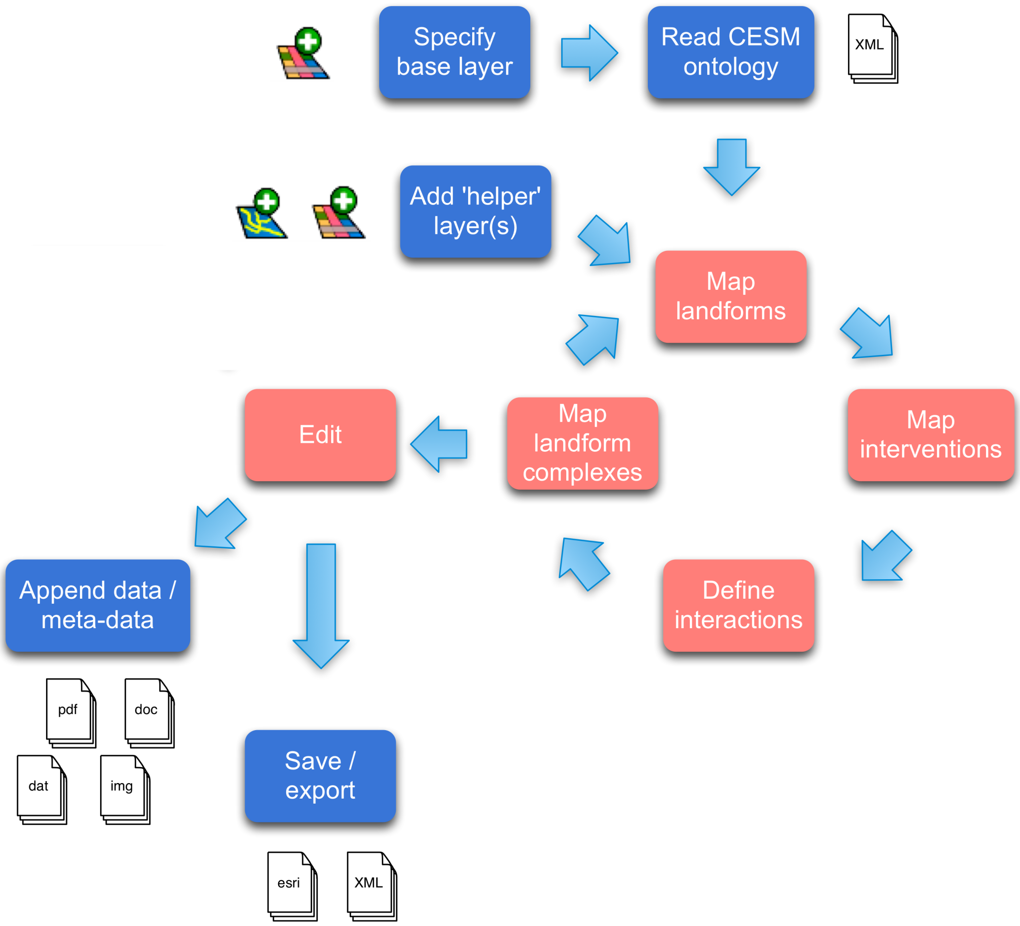

Figure 3.1 Workflow of CESMapper. At least one GIS base layer is required on which to interactively locate landforms, interventions and interactions. Helper layers (bathymetry, geology, flood defence lines etc.) can be used to inform the interpretation of the coastal and estuarine systems.

3.2 Loading a GIS base layer

CESMapper requires that at least one base layer is loaded within QGIS. If no suitable layer is present the user is prompted to load one (Fig 3.2). The base layer is important as it sets the base coordinate system and all subsequent maps will be referred to this.

It can be any raster or vector layer but is typically a chart or georeferenced aerial image. Google or Bing Maps coverages are available via the QGIS OpenLayers Plugin and are particularly useful as a basis for coastal mapping over extended areas.

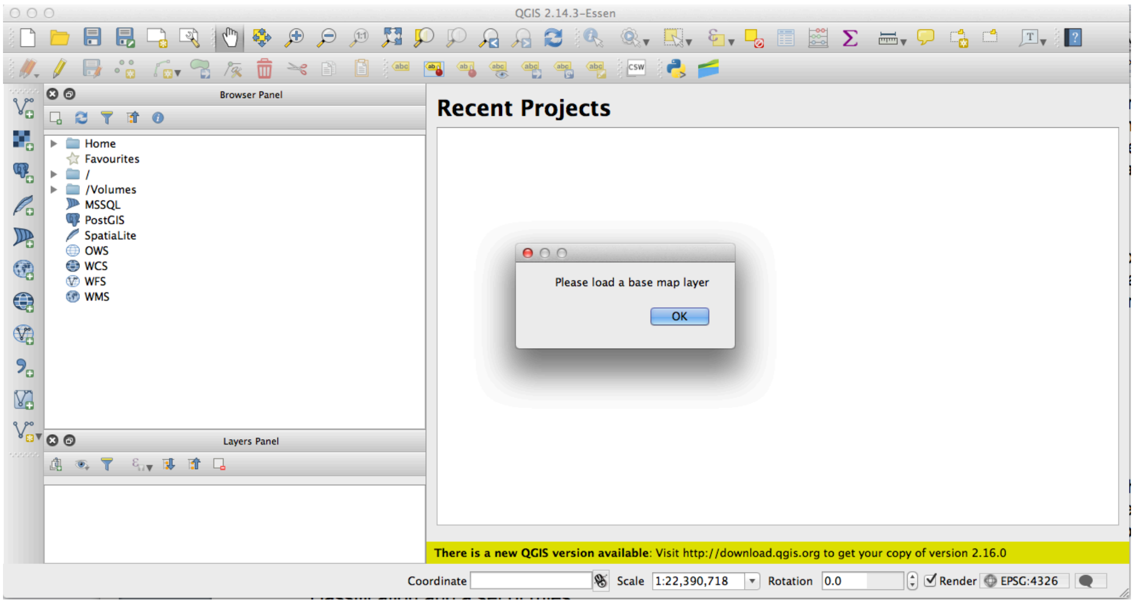

Figure 3.2 On startup, CESMapper will request that a suitable base layer is loaded into QGIS before mapping can be initiated.

3.3 Loading a CESM ontology

A key feature of CESMapper is the separation of the overarching landform ontology from the software itself. The ontology, which specifies the hierarchical set of available system components and the permitted interactions between them, resides in an external library file. This follows a simple XML-based syntax (see Appendix B). CESMapper parses the library file to generate the various interactive map creation menus. Any changes to the ontology will be reflected in the components available within the CESMapper. Because the ontology can easily be modified using a standard text editor, the user can customise the set of system components available within CESMapper.

CESMapper will automatically request that a landform ontology library be loaded (Fig 3.3). An example ontology developed for application in England and Wales as part of the iCOASST project is included with the plugin distribution. This file, “iCOASSTLibraryFilev1.7.txt”, should be copied to a suitable location on your computer.

Select and load the ontology. On completion, the main CESMapper menu will appear (Fig 3.4). This may be dragged to anywhere on your screen, and subsequent windows will open below it.

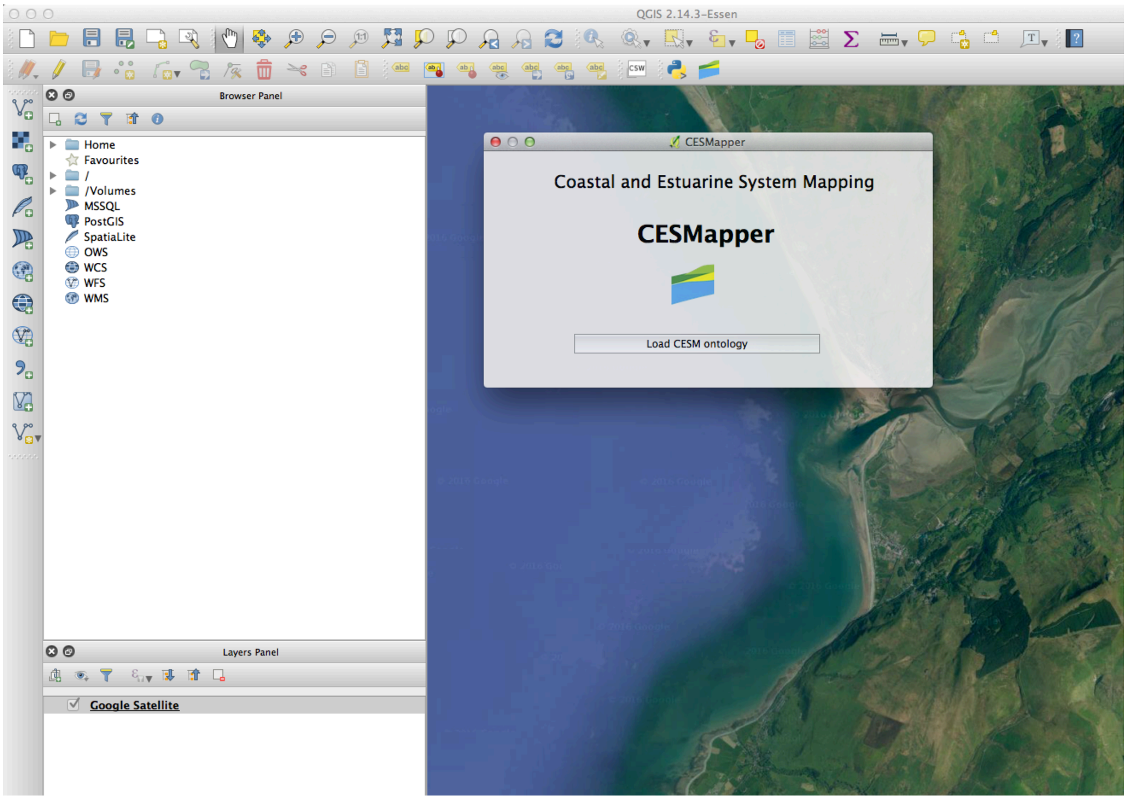

Figure 3.3 Once a base layer is loaded, CESMapper prompts the user to load a CESM ontology library.

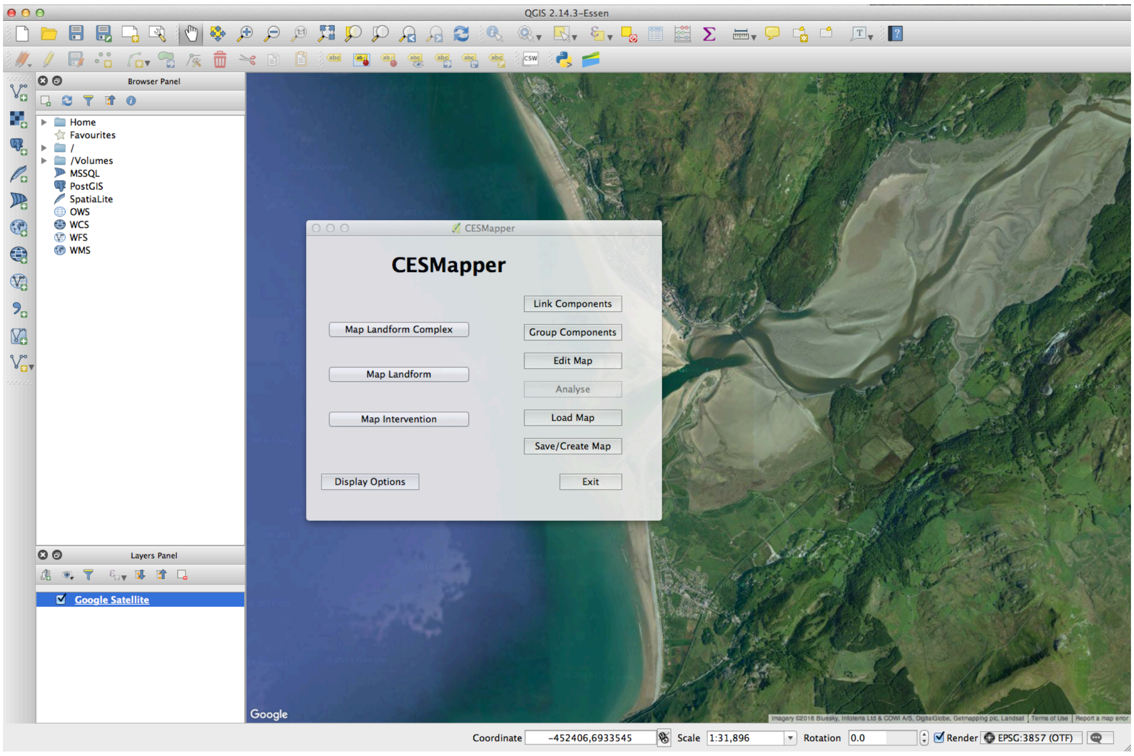

Figure 3.4 Screenshot of the main CESMapper window and tool options.

3.4 Create and save system maps

Within QGIS, the coastal and estuarine maps are created as two shape files. These follow a standard ESRI-shapefile format. One shapefile holds the set of discrete system components (landforms, sediment stores, human interventions), and the other stores the connections between them (influences, sediment pathways). Before mapping can commence, this pair of GIS shapefiles must either be created or a pre-existing map (i.e. previously saved CESM shapefiles) must be loaded.

CESMapper uses a set naming convention for these paired files. This naming convention must be observed to enable the tool to recognise and load the correct paired shape files. Assuming that *{Project}* is the project (or system map) name, the file set should be:

Component layer	Connection layer
{Project}.cpg	*{Project}*Con.cpg
{Project}.dbf	*{Project}*Con.dbf
{Project}.prj	*{Project}*Con.prj
{Project}.qpj	*{Project}*Con.qpj
{Project}.shp	*{Project}*Con.shp
{Project}.shx	*{Project}*Con.shx

To create a new map, click the “Save/Create Map” button (Fig 3.4) and in the dialogue that opens (Fig 3.5) specify a CESM map name and save to the desired location. This will create the paired shape files for both the system components and their interactions and load them as layers into QGIS. A further QGIS dialogue will appear requesting that the user specifies the Coordinate Reference System (CRS) to be used for the CESM components and connections layers.

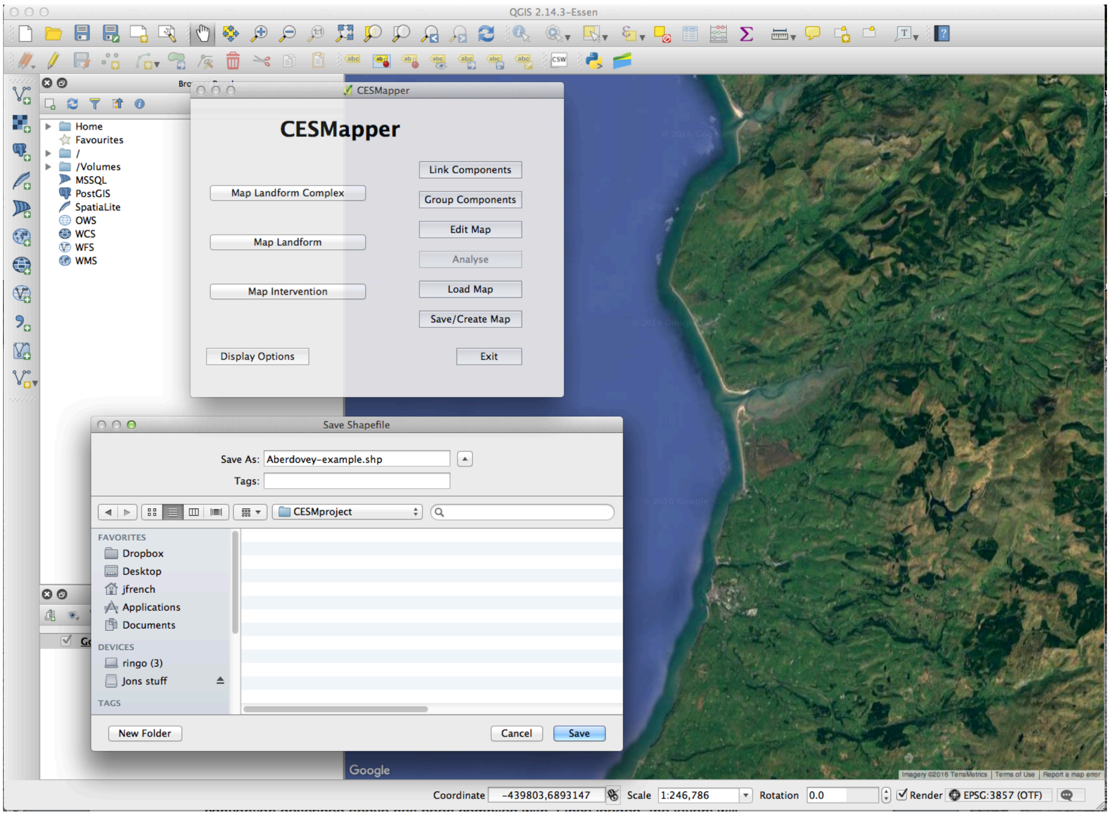

Figure 3.5 Dialogue for creation of new CESM map.

If you have previously created CESM shapefiles and wish to view or continue working on these using CESMapper, click the “Load Map” button (Fig 3.4), navigate to the main project file, *Project*.shp (where *Project* is the title of the project) and select it. The tool will automatically load the corresponding connections file, provided the naming convention described above has been complied with. Once loaded, the layers will appear in QGIS.

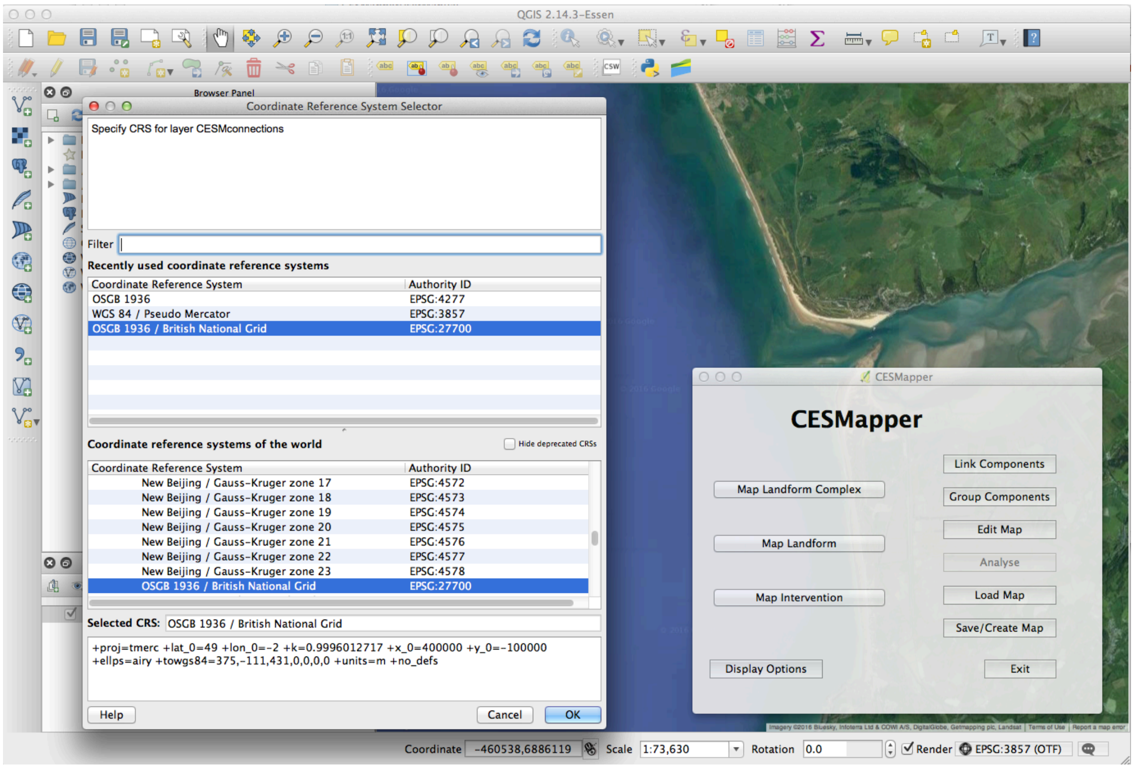

Figure 3.6 Dialogue for specification of Coordinate Reference System.

3.5 Mapping of landforms and human interventions

On the left hand side of the main CESMapper menu (Fig 3.4) are a set of buttons that allow mapping (interactive placement over the base layer) of landform complexes, individual landforms, and human interventions on the base layer. The number and naming of these hierarchical levels is defined by the external CESM ontology and so will vary if this has been customized by the user.

When one of the 'Map …' buttons is clicked, a new menu pane opens with the list of landform complexes, landforms or interventions as appropriate (Fig 3.7). Again, the exact set of components listed will depend on the CESM ontology that is loaded. Choose the component you wish to place via its radio button, then click on the base map to place it. Select and place other components as required (see example in Fig 3.8).

When you have completed mapping for this set of components, click the "Finished Mapping" button. This will save the changes to the layer, close the mapping menu, and return control to the CESMapper main menu. To ensure the changes are saved to the CESM project (i.e. the two component and connections shape files) you must click the "Save/Create Map" button. This saves the updated files.

The above process may be repeated as many times as desired. This allows a large or complex map to be built up in stages.

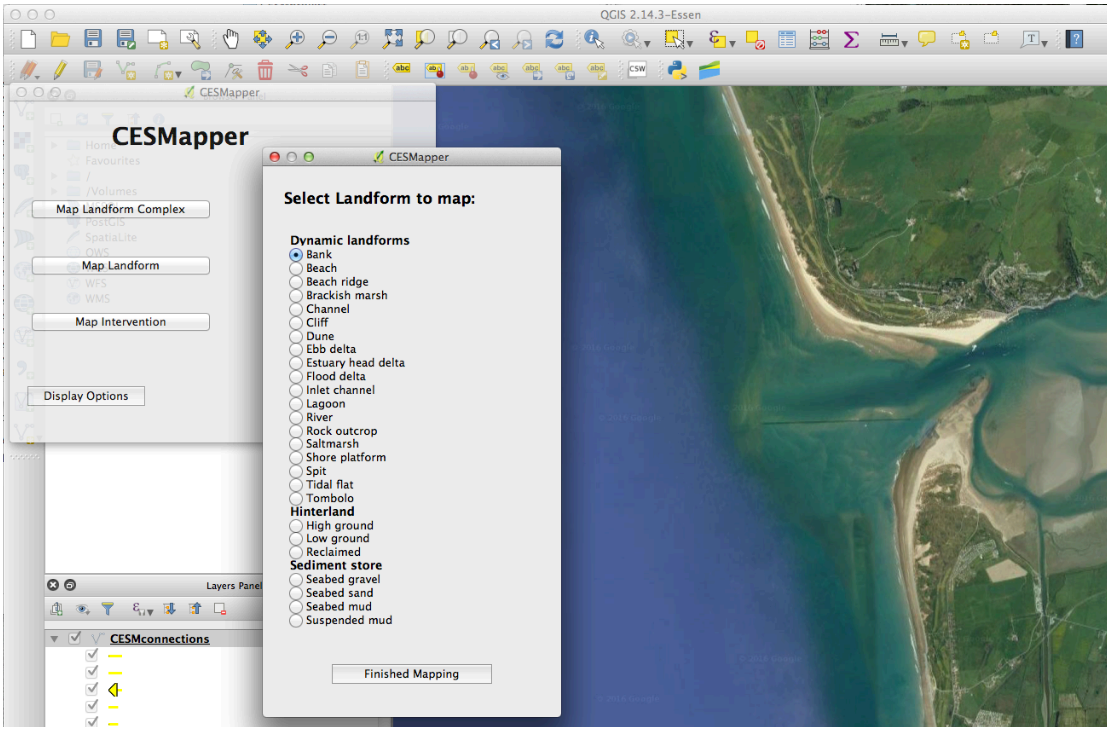

Figure 3.7 Typical menu for interactive mapping of landform components. Exact set of components available will vary according to the contents of the external CESM ontology that is loaded into CESMapper.

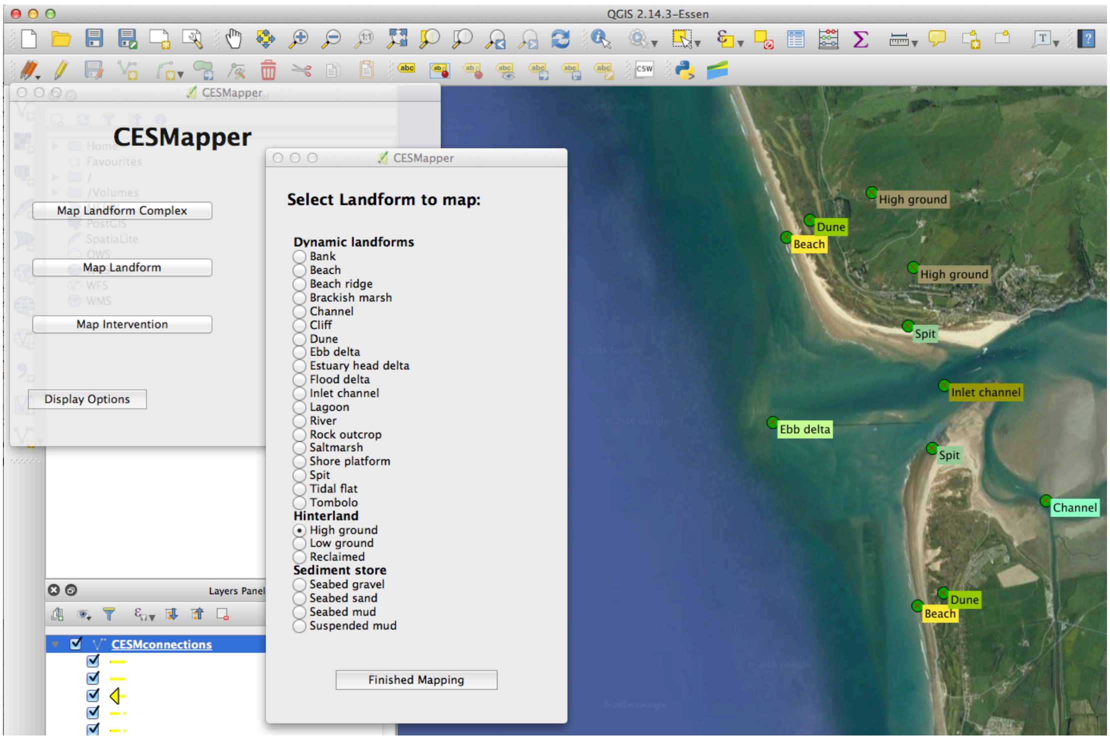

Figure 3.8 Illustration of landform mapping in progress.

3.6 Connecting system components

Once the system components have been mapped, the linking tool can be activated from the “Link Components” button. This opens a menu (Fig 3.9) that allows the user to select the type of connection (mass transfer, influence, or mixed), as well as the direction of the interaction. The direction is established by the order in which components are selected. The user can select two components (and only two components) to connect together. Any mistake at this stage can be corrected by using the “Clear Selection” button to reset the connection process. After the two components have been selected, click “Connection Completed” to add and display the connection on the system map. The type and directionality can be changed for each connection.

When you are satisfied with the connections (see example in Fig 3.10), close the component connection menu. It is advisable to save the system maps frequently whilst performing the connections (use the “Save/Create Map” button on the main CSEMapper menu, which should remain visible). This ensures that any changes are written to the shape files and avoids the loss of this information in the event of any problem with the computer or software.

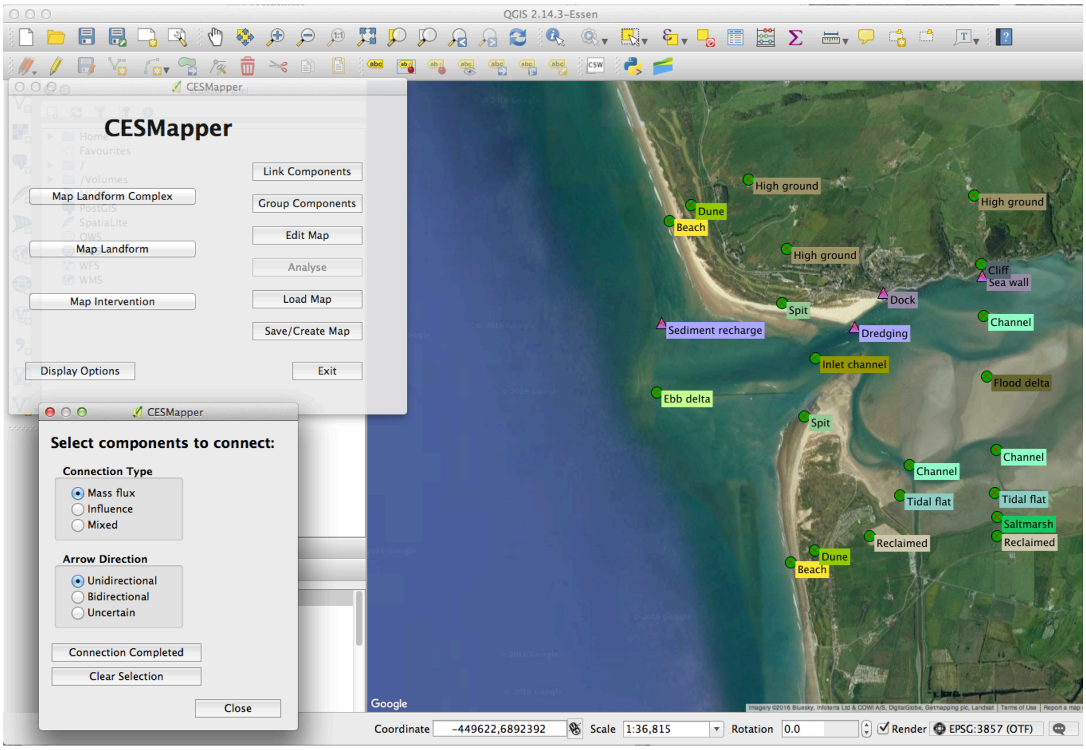

Figure 3.9 Screenshot of the component connection menu.

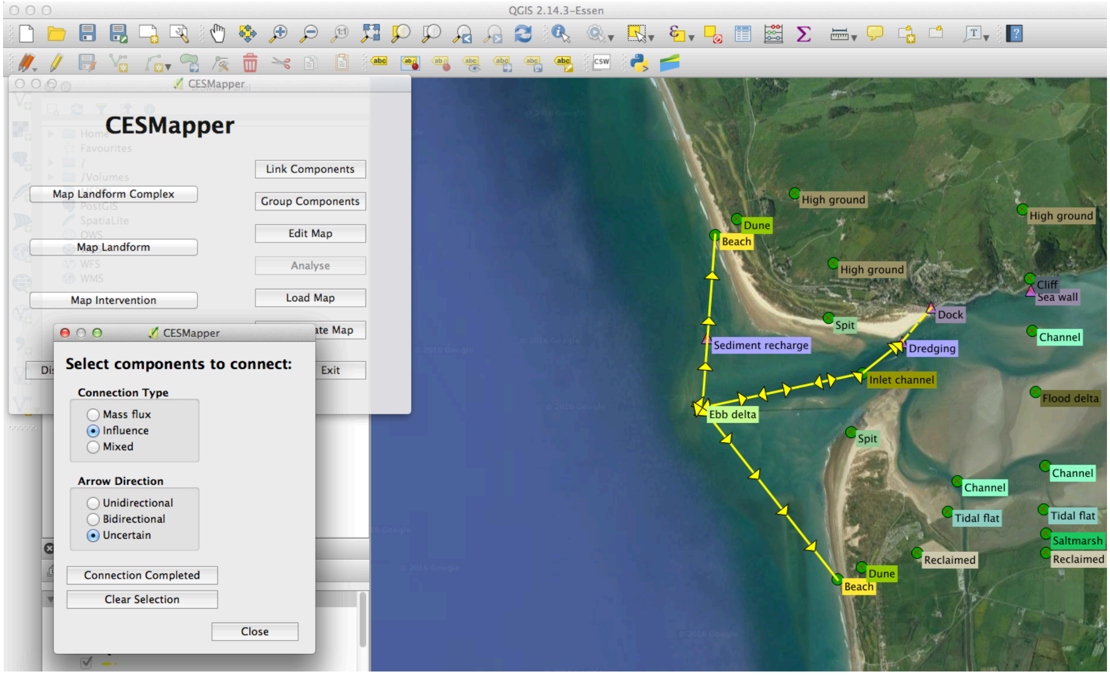

Figure 3.10 Illustration of the component connection stage in progress.

3.7 Grouping of landforms into complexes

This functionality will be completed soon in a new CESMapper release.

3.8 Map editing

If you wish to move or remove a component, it is best to use the built-in editing tool within CESMapper to ensure that the attribute tables are updated, and the links between the two component and connections layers are synchronised correctly. The “Edit Map” button opens an editing menu, which allows the user to select “Move Component” or “Remove Component” (Fig 3.11).

Select the desired action you require, then click on the component. To move a component, click and hold down the mouse button while dragging the component; any connections to that component should be redrawn to maintain the connection. If you select “remove component”, the component will disappear, along with any connections previously made to it. It is necessary to click move or remove for each such edit to ensure the edits are correctly carried out. When editing is completed, click “Done editing”, and close the menu to return control to the main CESMapper menu.

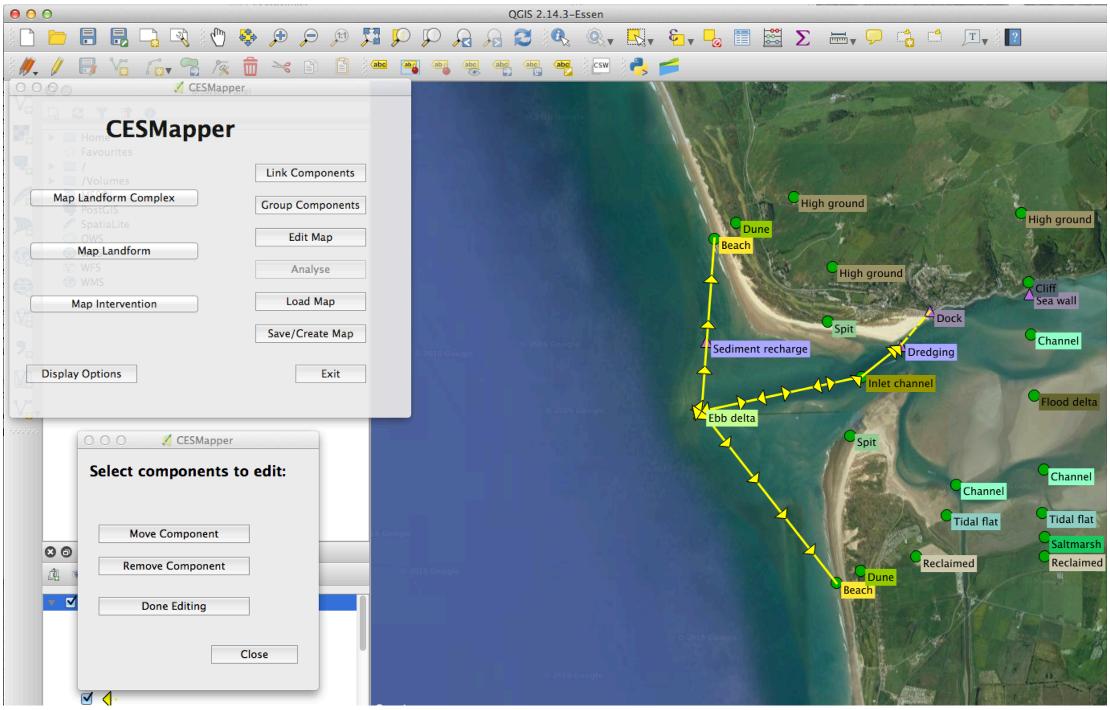

Figure 3.11 Illustration of the component editing menu.

3.9 How to load additional supporting layers into QGIS

It is often useful to load additional layers into QGIS in order to aid the interpretation of the coastal and estuarine environments being mapped. Raster layers (such as georeferenced aerial photographs, scanned bathymetry charts, or airborne lidar mosaics) can be loaded using the 'Add Raster Layer' button on the QGIS toolbar (Fig 3.12). Vector datasets can be added using the 'Add Vector Layer' button.

The CESMapper tool is distributed with style files that identify key attributes of the components and connections shapefiles to display the features clearly. Landform complexes, landforms and interventions in the components shapefile are displayed using large symbols and labelled using tags the colour of which are defined in the Colour field (column) of the layer attribute table. These are previously defined within the ontology library file. Line styles for the connections layer use arrows to denote direction of mass flux/influence, and style to determine the nature of the connection. These style files are designed to aid the mapping process, where large symbols are readily selectable for connecting, editing and grouping. For display and review purposes, where clear labels and connections are important, an alternative set of style files (provided separately) can be used to prioritise the component labels over the symbols and improve the differentiation between connection types.

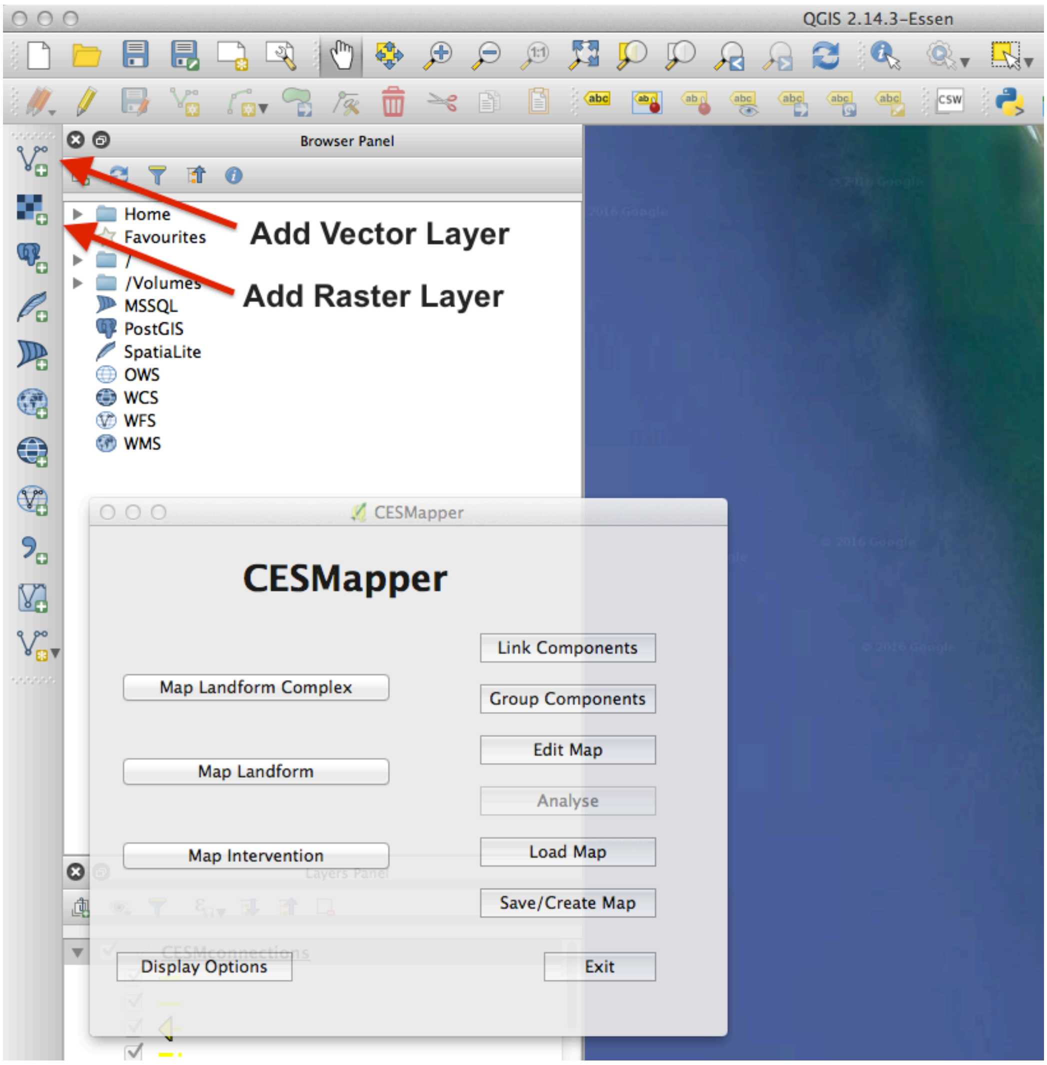

Figure 3.12 Adding additional vector or raster layers within QGIS.

3.10 Manual addition of supplementary information to attribute tables

Slots are provided in the attribute tables for the components and connections. These can be edited within QGIS to include additional information, such as quantitative values for sediment fluxes, or links to meta-data or other sources of information.

4. Frequently Asked Questions

Q: Performance seems slow with a large map – is there anything that can be done to improve the responsiveness within QGIS?
A: Performance can be slow if a large number of QGIS plugins are installed. Try uninstalling any that are not needed.

Q: I can't group landforms into a landform complex
A: This functionality will be completed very soon in a new CESMapper release.

Q: CESMapper is missing some important landform types?
A: The set of landforms and human interventions can be changed to suit a particular regional context by editing the external ontology file. This can be done using any text editor. The format of ontology file is described in Appendix B.

Q: CESMapper asks me to load an ontology – where can I find this?
A: CESMapper releases come with an Ontologies directory. This contains at least one example ontology and should be copied to a convenient location on your computer.

Q: I have found a bug in CESMapper. How do I report it?
A: CESMapper is still at an early release stage. Any can be reported directly to the maintainers (j.french@ucl.ac.uk and h.burningham@ucl.ac.uk). We'll do our best to fix these in a timely fashion.

Q: Where can I get the latest update from?
A: The latest version of CESMapper can be downloaded from the public GitHub repository at: https://github.com/UCL-CERU/CESMapper

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Appendix A

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Appendix B

CESM ontology file format

Coastal System Ontology Markup (CSOML) Version 1.4

This document describes a minimal semantic markup language (with optional presentational markup elements) for the specification of coastal system ontologies. The following tags and associated fields are permitted in a CSOML Library Definition file, with those highlighted in **bold** being mandatory (though these may have empty or null entries):

<library> </library>

Define the beginning and end of any Library Definition file: <library> must always be the first tag and </library> must always be the last.

<CSOMLversion> *version* **</CSOMLversion >**

Specify the CSOML version, which is used to check compatibility with the CSM software. Value of *version* must be numeric (integer or real).

<metadata> *Author="name", Date="13/01/2013"* **</metadata>**

Optionally specify additional information, such as author, date, etc. Syntax for metadata is *itemname1="content1",itemname2 = "content2" …* etc.

<libraryname> *libname* **</libraryname>**

Specify the name of the library, *lname* (text string).

<libraryversion> *libversion* </libraryversion>

Optionally, specify the library version. Value of *libversion* must be numeric (integer or real).

<numorders> *m* **</ numorders >**

Specify the number of orders, *m* (integer), in the system hierarchy. Order 0 is a root order that is not actually used by the CSM software, but which is used in graphical representations of the ontology. Order 0 will always be a root order with no sub-orders (see below); the lowest orders will always be landform complexes < landforms < engineering interventions. The minimum value for *m* is therefore 4.

<order0> </order0>
<order1> </order1>
…..
<order*m*> </order*m*>

Define the orders where *n*=0 is lowest order of the hierarchy and *m* the highest. Coastal system ontologies consider order 0 to represent the largest spatial and temporal scales of behavior, with higher orders (up to order *m*) representing smaller scales.

The following tags must reside inside paired **<order*n*>** and **</order*n*>** tags
<ordername> </ordername>

Specify the name of the order. This is used to populate GUI menus in the CSM software.

<property> ***numcomps=n, numsuborders=m****, shape=0, colour=#FFFFFF*

</property>

Specify the properties, including optional presentational markup, for the current order. The following are currently permitted:

numcomps = n Define the number of components in this order (integer *n*).

In the case of an order that contains two or more sub-orders, then n will be the number of sub-orders. If there are no sub-orders, *n* will be the number of types.

numsuborders=m Defines the number of 'sub-orders' (defined below). Optional, if the components are to be separated into groups within a specific order.

shape {0 (default),1}

Defines the mapped shape of the component: 0=rectangle, 1 = circle

colour {=*#FFFFFF* }

Define the mapped colour of the component as a Hex code

<suborder>…. </suborder>

Optionally, specify a sub-order (e.g. Estuary,Open Coast and Inner shelf, for a Landform complex order). Not all orders will necessarily have sub-orders and Order 0 is never allowed sub-orders. If present, there must be at least two sub-orders. Each sub-order must contain all the components that would be otherwise associated with an order.

<subproperty>*subordername='subname', numcomps=k, shape=0, colour==#FFFFFF* </subproperty>

This defines the properties pertaining to the 'suborder', similar to those for the order.

<component> name="compname", *colour=#FFFFFF,* **children="child1,** child2, child3……..childn**" </component>**

Specify each component of current order, with the name "compname", and list the permitted children for that component in children="…." (a quote-terminated and comma-separated list). The colour for the component can be specified as a Hex code, but may be omitted, in which case the order or suborder colour is used. (N.B. if the colour keyword is used, it must appear between the '**name=**' keyword and the '**children=**' keyword.

There is a special case of children="all" where all the components at the next level down are permitted, or children="none" where there are no permitted children.

Notes:

1. A **<component>** ….. **</component>** entry must be followed by a **</ordern>** tag to close the definitions for that order.

2. As noted above, the library definition file must always be terminated by a **</library>** tag.

3. The CSM software performs a check to ensure that the version of CSMOL is

supported: it should always read CSMOL files at or below, but not necessarily above, its current version.

4. Blank lines are permitted and are ignored. Whitespace is ignored.