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Northern Sea Wall to Castle Coote

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Summary

A shingle sediment budget for Northern Sea Wall to Castle Coote was generated to gain an understanding of sediment movements through the frontage. The frontage is characterised by persistent longshore transport in a westerly direction, however localised drift reversals are noted throughout the units.

- Northern Sea Wall shows a net drift in an easterly direction, the only unit to do so on this frontage. It loses 800m^3/yr, however regular recycling and replenishment mask the underlying trend. 1,250m^3/yr is transported around the final rock groyne into Minnis Bay. Transport rates are typically higher than in other units, at around 5,500m^3/yr, due to the more open nature of the beaches as well as the presence of more permeable control structures.

- Bishopstone exports a small volume of sediment, 600m^3/yr, feeding the downdrift beaches of Herne Bay.

- Herne Bay shows relative stability, losing 800m^3/yr. Despite this, 1000m^3/yr is effectively lost to the system as it is deposited at the toe of Neptune's arm breakwater. This has been highlighted as an area to include in future monitoring surveys to gain a greater indication of the gain at this location. No material is transported out of the unit, with Hampton Pier preventing shingle moving into Swalecliffe.

- Swalecliffe shows low transport rates of less than 500m^3/yr. A small localised drift reversal is noted in the middle of the unit, which has been consistently accreting over the last 10 years. 300m^3/yr is transported out of Swalecliffe into Tankerton.

- Long Rock is a dynamic spit development within Tankerton unit. The northern section is eroding, with 2,200m^3/yr being passed into the southern section which is accreting at the equivalent rate. The high foreshore and the discharge of the Swale Brook cause 500m^3/yr to be deposited just off the beach toe.

- Tankerton shows suppressed sediment transport rates due to the large groynes on the frontage. It is losing a small amount of volume (327m^3/yr) which is deposited in Whitstable Harbour. Large losses were calculated after the schemes in 1998 and 2004 which have been accounted for in the budget.

- Whitstable seems to be responding well to the scheme in 2006 with small losses shown after placement. Again, the heavy presence of controlling structures mean that sediment transport rates are rarely above 700m^3/yr. 440m^3/yr is passed into Seasalter.

- Seasalter is the only unit to show a natural import of sediment gaining 1,200m^3/yr annually. This gain is focussed in the west of the unit at Castle Coote spit. An onshore migrating bar is shown in the middle of the unit, which is suggested will have some controlling influence on longshore drift in the future.

These trends are analysed over various temporal and spatial scales in the following report.

1.0 Introduction

This report details the regional shingle sediment budget for Northern Sea Wall to Castle Coote Spit. A sediment budget is essential in defining longshore sediment transport rates, sediment pathways and areas of erosion and accretion, within defined boundaries, over a given period in time (Kana, 1995). The budget provides transparent and quantitative evidence of beach losses, gains and sediment pathways, in combination with both natural and artificial movements of beach grade material. The outcomes of this report will feed into Beach Management Plans (BMP). The report primarily focuses on the shingle sediment movement, as this has the most importance to beach management operations.

The data used for this report has been sourced from the Strategic Regional Coastal Monitoring Programme (SRCMP). The topographic beach data has been extensively collected since 2003 using ground based GPS measurements, Lidar and bathymetric surveys. This data is analysed and reported over small management units, with very little regional analysis undertaken. Therefore, this report will take the local analysis to the regional scale to gain a greater insight into beach behaviour over interconnected sediment sub-cells.

The sediment budget is analysed over a range of spatial scales. Each spatial scale has been assigned a level relating to how much detail is provided, as shown below:

Level 1 – Very-fine analysis polygons
Level 2 – Fine analysis polygons
Level 3 – Coarse Sediment Budget
Level 4 – Regional Sediment Budget

The method for the production of the shingle sediment budget is discussed in detail in Appendix A. The transparent and repeatable methods will allow future budgets to be conducted and analysed using the same techniques developed here. The limitations and solutions in the methodology have been highlighted at the relevant stages and justifications made wherever possible.

2.0 Study Area

Throughout the entire sediment budget analysis, the frontage has been split into 7 sections (or cells) which broadly coincide with SRCMP survey units (Table 3.1). This also serves to maintain the boundaries between different beach management organisations which allows for easy accounting of the anthropogenic management on the individual frontages. As the dominant drift direction is from east to west, survey units are always considered with the most easterly unit first.

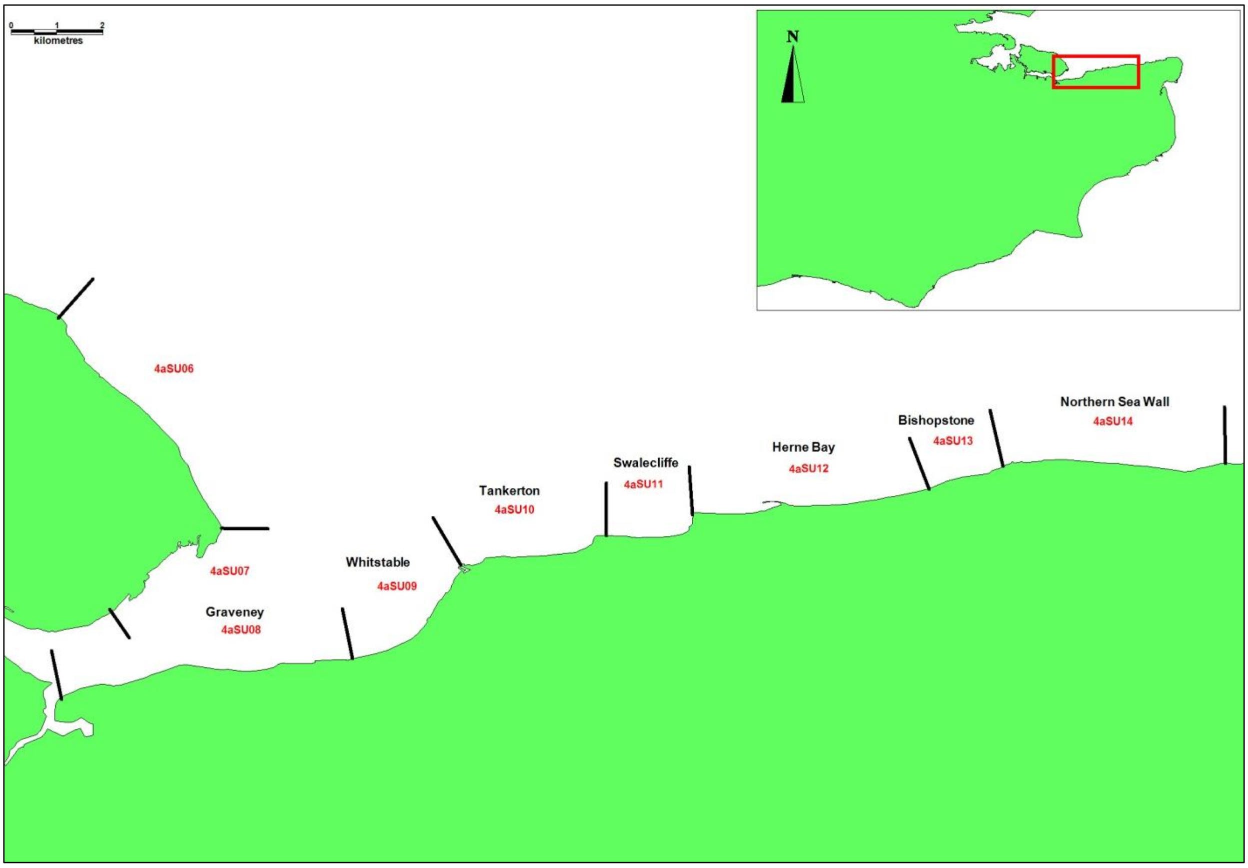

Figure 2-1 Location of study area

2.1 Northern Sea Wall

Northern Sea Wall is the most easterly extent of the study site and predominantly consists of a shingle beach with a sandy foreshore, fronting low lying marshland. Up until the end of the 17th century it was the mouth of the Wantsum Channel, which linked the north and east coasts of Kent. There are outcrops of Thanet Sands and Cretaceous Chalk on the foreshore, whilst the central area is comprised of alluvium.

The coastline is defended by the Northern Sea Wall, a concrete structure built after the 1953 flood event when the original clay embankment was breached in three places. Fourteen rock groynes were added in 1995 to help maintain the shingle beach, and 110,000m^3 of shingle was added to the beach in 1996. It is also thought that the stone apron which protects Reculver Towers (at the western end of this survey unit) from erosion acts as a barrier to westward transport, except in times of prolonged easterly winds. According to the Shoreline Management Plan[1] (SMP), sediment transport patterns can be complex, possibly as a result of the presence of Margate Sands. There is also seepage of shingle through the eastern-most rock groyne into Minnis Bay (estimated to be 2,000m^3/yr). There is a regular programme of recycling &

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[1] **Isle of Grain to South Foreland Shoreline Management Plan (Halcrow, 2010)**

reproofing along this frontage, principally to maintain the shingle ridges that defend two saline lagoons.

2.2 Bishopstone

The Bishopstone coastline is unique along the north Kent coast in that it is characterised by mostly unprotected sandstone cliffs with a small shingle beach. The foreshore is also higher than surrounding areas, due to Tertiary sandstones bringing more resistant strata to the surface. There are no groynes along this section of coastline, although there is a short stretch of sea wall and rock revetment at the eastern end of the section, around Reculver Towers. The alongshore transport rates are believed to be low. Landslides provide some input, although this is mainly fines due to the low percentage of coarse material in the cliffs.

2.3 Herne Bay

This 5.25km mixed shingle beach is backed by the low lying residential and commercial town of Herne Bay. This coastline is managed by Canterbury City Council who implements the Hold the Line policy in order to protect residential and business infrastructure. The town is currently defended by a concrete sea wall fronted by a mixed shingle beach, held in place by a timber groyne field. A rock breakwater is situated approximately central within the unit, which along with the pier forms a harbour. There is also a short section of rock revetment at Beltinge.

Regular recycling schemes have been carried out in the harbour beach, recycling material from in front of the bandstand to its original location east of the pier within the harbour arm. Approximately 5,000m^3 is transported between these locations annually.

2.4 Swalecliffe

The Swalecliffe frontage runs from Long Rock to Hampton Pier and comprises 2km of low lying coastal land with residential properties set back from it. This stretch of coastline is set seaward of Tankerton, but inland of Herne Bay, creating a ‘stepped’ pattern in plan view. It is backed by a seawall and has a dense groyne field. The natural sediment flow in this area is from east to west, although the presence of Hampton Pier at the eastern end of this survey unit hinders material entering the frontage. Actual transport rates are low due to the presence of groynes. Offshore, the main feature is an extensive shingle bank near Long Rock that is exposed at low tide. There has been no significant movement of shingle at Swalecliffe in recent years.

2.5 Tankerton

Tankerton Bay extends from Whitstable Harbour to Long Rock and comprises low-lying land and floodplains to the west, with coastal slopes to the east. Over time, Tankerton’s frontage has undergone many changes with multiple sea defence schemes having been implemented. The sea wall was built in the 1950’s since when groynes have been constructed along the frontage. Between 1998 and 2004 the frontage between The Street and Long Rock had additional timber groynes added at 40m intervals. This, along with 180,000m^3 of shingle replenishment over three stages has maintained the standard of defences.

One of the main features along this stretch of coastline is ‘The Street’, a linear shingle bank that runs perpendicular to the coastline at the western end of this survey unit. It is estimated to be around 2km long, with at least 1km visible during low tide. Swalecliffe Brook is located at the boundary between Tankerton and Swalecliffe. The area surrounding the brook mouth is an accreting area known as Long Rock.

Long Rock itself is a sediment sink with material transported into the area from Swalecliffe and to a lesser extent from Tankerton. On average 3,000m^3/yr of shingle is recycled annually from the mouth of Swalecliffe brook where it enters the sea on the western flank of Long Rock. This material is distributed mostly east to Swalecliffe although a small amount is moved west onto the Tankerton frontage. The presence of a shingle bank in Swalecliffe Bay is likely to have some impact of wave patterns and sediment transport, but this is still to be quantified.

2.6 Whitstable

The 3.25km mixed shingle beach is backed by the low lying residential and commercial town of Whitstable. The shingle beaches that dominate Whitstable are primarily relict, as since the construction of the harbour very little material moves around the mouth from the east. In recent decades the beaches have been enlarged artificially through beach recharge to enable sufficient protection to the low lying town behind.

The western end of this survey unit is characterised by graded clay coastal slopes 3-15m high. Minor slope failures and landslides characteristic of this type of hillside have been largely alleviated by the provision of the seawall and drainage to the slopes. Properties have been built up to the seawall, and the main north Kent railway line also runs along the side of the slopes. The hinterland towards Whitstable harbour lower and the hinterland is vastly low lying, with c.110ha within the flood plain. This comprises the town centre, the main commercial area of the town, the harbour area and high density residential development.

The presence of a large and closely spaced groyne field effectively locks the shingle beach in place. The potential alongshore transport rate decreases westward, partly because the shoreline orientation is closer to the natural equilibrium position and partly because the foreshore levels rise to the west, resulting in reduced wave energy (Halcrow, 2010). The actual shingle transport rates, however, increase from east to west as a result of the varying size and condition of the controlling groyne fields. In the east the groynes are large and well maintained and allow no alongshore transport. At Seasalter the groynes are smaller, allowing some material to bypass west.

Seawalls have protected Whitstable since the early 1950s, positioned at a level of +5.8m OD. However, many lengths are founded at a high level on shingle (as high as +3.0m OD at the golf course). Improvements to the seawall were completed as part of the 1989 defence scheme. Additionally in 1992 at West Beach further sheet piling was added to the seawall toe. As part of the replenishment scheme in 2006, several improvements to the seawall were undertaken and the groyne field was significantly upgraded. The final stretch of open beach, fronting the railway wall near the golf course, was finally groyned in winter 2011 in response to beach cut-back and cliffing.

2.7 Graveney

As with beaches at Whitstable, the mixed sand and shingle beaches that dominate the area are relict beaches that have been enlarged artificially through recharge. There is little contemporary feed of coarse material into the area, although most of that which currently exists on the beaches does remain within the boundaries of this process unit.

The potential longshore transport rates along this section of coast decrease westward. This is partly because the shoreline orientation is closer to an equilibrium position, and partly because the foreshore levels rise to the west, resulting in reduced wave energy. However, actual shingle transport rates increase from east to west as a result of the varying size and condition of the groyne fields, from adequate to poor, with unconstrained movement of shingle occurring in some areas (Halcrow, 2010).

Alongshore transport of coarse material terminates at Castle Coote spit. At this location, approximately 1 km east from Faversham Creek, the beach separates from the sea wall and extends westwards forming a mixed shingle / sand / shell spit. The growth of the spit in recent years is probably attributable to increased alongshore transport resulting from progressive decay of the beach control structures to the west of the frontage.

The majority of 4aSU08 is presently defended by a concrete seawall built in 1954. The seawall sits on a clay bund with a blockwork apron on the seaward side. At The Sportsman public house, a third of the way along the frontage there is no seawall, and a defence is provided by a setback clay bund, protected by a shingle barrier beach ridge. At the eastern end, the defence line moves inland side of Faversham Road and consists of a grassed clay bund.

In recent years only minor maintenance has been carried out to the defences. However, the seawall is noticeably settling at a couple of locations, and many of the joints are in need of renewal. At a number of points, the blockwork is starting to be broken out and could cause the apron to be undermined.

3.0 Methodology

3.1 Source data

In order to undertake the sediment budget a review of all topographic data was conducted (Table 3.1). This review was focussed on the topographic survey data from both ground based GPS and aerial Lidar sources, over the 2011-2003 period, the longest available timescale since regular monitoring began. Where both Lidar and GPS measurements were available, GPS was preferentially chosen due to the tailored nature of the surveys. This data was used in the formulation of the sediment budget explained below. For more information, refer to Appendix A.

Table 3-1 Available DTM's and Difference Models for Frontages

Frontage	Management Organisation	SRCMP Survey Units (Phase II)	Available DTM's	Data Type	Difference models
Northern Sea Wall	Environment Agency	4aSU14	2003-2012	Ground Based GPS	All years
Bishopstone	Canterbury City Council	4aSU13	2003, 2006, 2007, 2012	Ground Based GPS	2003-2006, 2006-2007, 2007-2012
Herne Bay	Canterbury City Council	4aSU14	2003-2012	Ground Based GPS	All years
Swalecliffe	Canterbury City Council	4aSU11	2003-2012	Ground Based GPS	All years
Tankerton	Canterbury City Council	4aSU10	2003-2012	Ground Based GPS	All years
Whitstable	Canterbury City Council	4aSU09	2003-2012	Ground Based GPS	All years
Graveney	Environment Agency	4aSU08	2003-2012	Ground Based GPS	All years

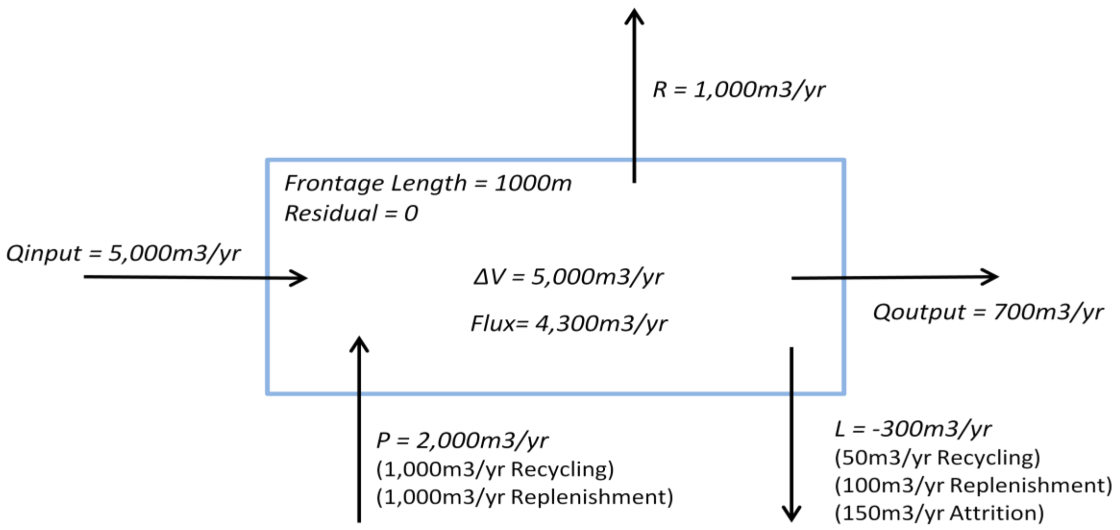
3.2 Generation of the Sediment Budget (Level 3 and 4)

A sediment budget presents a quantitative model of the magnitude of volumetric change, sediment transport rates and losses and gains within a self-contained coastal cell, in a defined period of time (Rosati and Kraus, 1999). At its most basic, using the principles of conservation of mass (volume), it is an attempt to balance all inputs into a cell with all outputs leaving a cell as shown in Equation 1 below (Adapted from Rosati and Kraus, 1999):

$$\sum Qinput - \sum Qoutput - \Delta V + P - R + L = Residual \qquad (1)$$

Where:
Q_{input} - Volume input from the updrift cell
Q_{output} - Volume output into the downdrift cell
ΔV - Volumetric change within the cell
P - The material placed into the cell e.g. beach replenishment
R - The material removed from the cell e.g. beach recycling
L - The losses to attrition and material lost during placement.

The Residual is the volume of the cell remaining or the degree to which the cell is balanced. In a balanced sub-cell the residual should near 0 or be no larger than the combined error in the data collection.



$$Residual = \Sigma Qinput - \Sigma Qoutput - \Delta V + P - R + L$$
$$Residual = 5000 - 700 - 5000 + 2000 - 1000 + -200$$
$$Residual = 0$$

Figure 3-1 Sample balanced sediment cell

Volumetric change in each SRCMP polygon was calculated through analysis of the difference models shown in Table 3.1. Different methods for calculating ΔV were explored in depth provided in Appendix A. All replenishment and recycling logs were collated and P and R were calculated for each polygon.

Losses expected on this frontage can be broadly split into three categories, attrition losses, replenishment losses and recycling losses. Offshore losses are not considered significant due to the predominance of coarse grained sediments and the topography and geomorphology of the beaches. The losses applied to each cell are shown in the table below, with justification for the figures applied provided in Appendix A.

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Table 3-2 Losses to a sediment cell

Source of Loss	Loss	Reference
Attrition	0.15m^3/m/year	Dornbusch *et al*. 2003
Losses during replenishment	10%	Clarke and Brooks 2008
Losses during recycling	5%	Clarke and Brooks 2008

While the SRCMP polygons (Level 2) are useful in providing detailed losses and gains over a management unit, they are too fine when considering the regional view of the sediment budget. Polygons exhibiting similar coastal behaviour were grouped together to create a coarser system of sub-cells, or the Level 3 analysis sub-cells. This set of sub-cells now contained values for $\Delta V, P, R$ and L. Using these figures, the average annual flux can be calculated through:

$$Flux = \Delta V - P + R - L \qquad (2)$$

The flux can be thought of as the volume of sediment added (when flux is negative) or removed (when flux is positive) of the sediment system. This is an important parameter for working out what volume of sediment is actually being exported out of the cell after all losses, extractions and placements have been excluded.

With the residual nearing 0 in a closed sub-cell, Equation 1 can be solved for Q_{input} and Q_{output}. Starting at the most western extent of Eastbourne where the sediment input from Beachy Head into the frontage is known to be minimal or $Q_{input} = 0$:

$$Qoutput = -(\Delta V - P + R - L) + Qinput \tag{3}$$

The Q_{output} of the updrift cell then feeds the downdrift cell as the Q_{input} and the next cell can be balanced. Examples of this can be found in Appendix A.iii. An overview budget was also developed helping to place the changes within the context of management frontages (Level 4). This can provide feedback on those frontages that are significantly gaining or losing material. Sovereign Harbour was split into the Eastbourne and Pevensey Bay cells as they were considered to be part of the respective frontages. Equation 1 can be applied over the whole sediment budget with the residual determining whether or not the cell can be thought of as a self contained sediment unit.

Finally, when using the Q_{output} figures to assess sediment transport rates it needs to be recognised that an *a priori* assumption of net transport direction has been made. In most areas along the study a distinct net transport direction prevails each year but is obviously composed of transport in either direction. For a large scale sediment budget covering several years, annual net transport is the crucial factor though locally and on operation time scales, actual rates are invariably different in both magnitude and direction.

3.3 Historic beach calculation

Historic beach DGMs were generated through an assumed relationship between the MHW, beach crest and beach toe elevation. MHW marks were mapped from historical images from the 1890's, 1910's and 1930's. For a more in depth methodology on the creation of historic DGMs from historical maps refer to Appendix C. The elevations used to generate the DGMs are shown below.

Table 3-3 Data used to generate Historic DTMs

		Height (mAOD)					Distance from MHW (m)	
Cell	Section	**Back of Beach****	**Crest ****	**MHW***	**Beach Toe ****	**MLW***	**Beach Crest (L1)**	**Beach Toe (L2)**
Northern Sea Wall	West of Towers	3.4	3.4	2.13	0.6	-1.67	4.74	12.46
	Reculver Towers	1	1		-1.6		-4.22	30.38
	Towers - Coldharbour Outfall	5.4	5.4		-1		20.15	8.14
	Central Lagoon	6.5	6.5		-1		24.26	8.14
	East	5.5	5.5		-1		20.53	8.14
Bishopstone	All	3.4	3.4	2.13	0.6	-1.67	4.74	12.46
Herne Bay	Hampton	4.7	4.7	2.13	-1	-1.67	9.59	25.49
	Harbour	3.7	3.7		-1.7		13.81	13.85
	Beltinge	3.5	3.5		-0.9		13.06	7.33
Swalecliffe	All	3.6	3.6	2.13	-0.4	-1.67	5.49	20.61
Tankerton	The Paddock	4.3	4.3	2.21	-0.1	-1.74	7.8	18.81
	Tankerton Slopes	4.7	4.7		-1.6		17.54	13.03
	Long Rock	3.7	3.7		0.5		13.81	13.93
Whitstable	Preston Parade	4.4	4.4	2.21	08	-1.74	8.17	11.48
	Golf Course				1.6			4.97
	Lower Island Wall				0.9			10.67
	Town Centre				-0.2			1.63
Graveney	All	4.5	4.5	2.21	1.2	-1.74	8.55	8.23

*** Note: found from Admiralty tide curves; ** Found through analysis of SANDS profiles**

4.0 Results

The results have been split into their various temporal and spatial scales. Note: Level 2 (SRCMP polygons) are not analysed, as this level was a processing level used to gain volumetric change values to feed into the Level 3 analysis. Level 2 was considered to be too fine to conduct a sediment budget analysis over a regional scale. As this is a feeder report for the individual Beach Management Plans, full analysis of trends will be discussed at length in that report.

4.1 Level 1 - Volumetric Change per 50m Length

The year on year volumetric change been analysed in the following pages to gain an insight on the variability around the mean volumetric change (ΔV) used in the sediment budget analysis in Section 4.2 and 4.3. The methodology for the production of the contour plots is explained in depth in Appendix A.

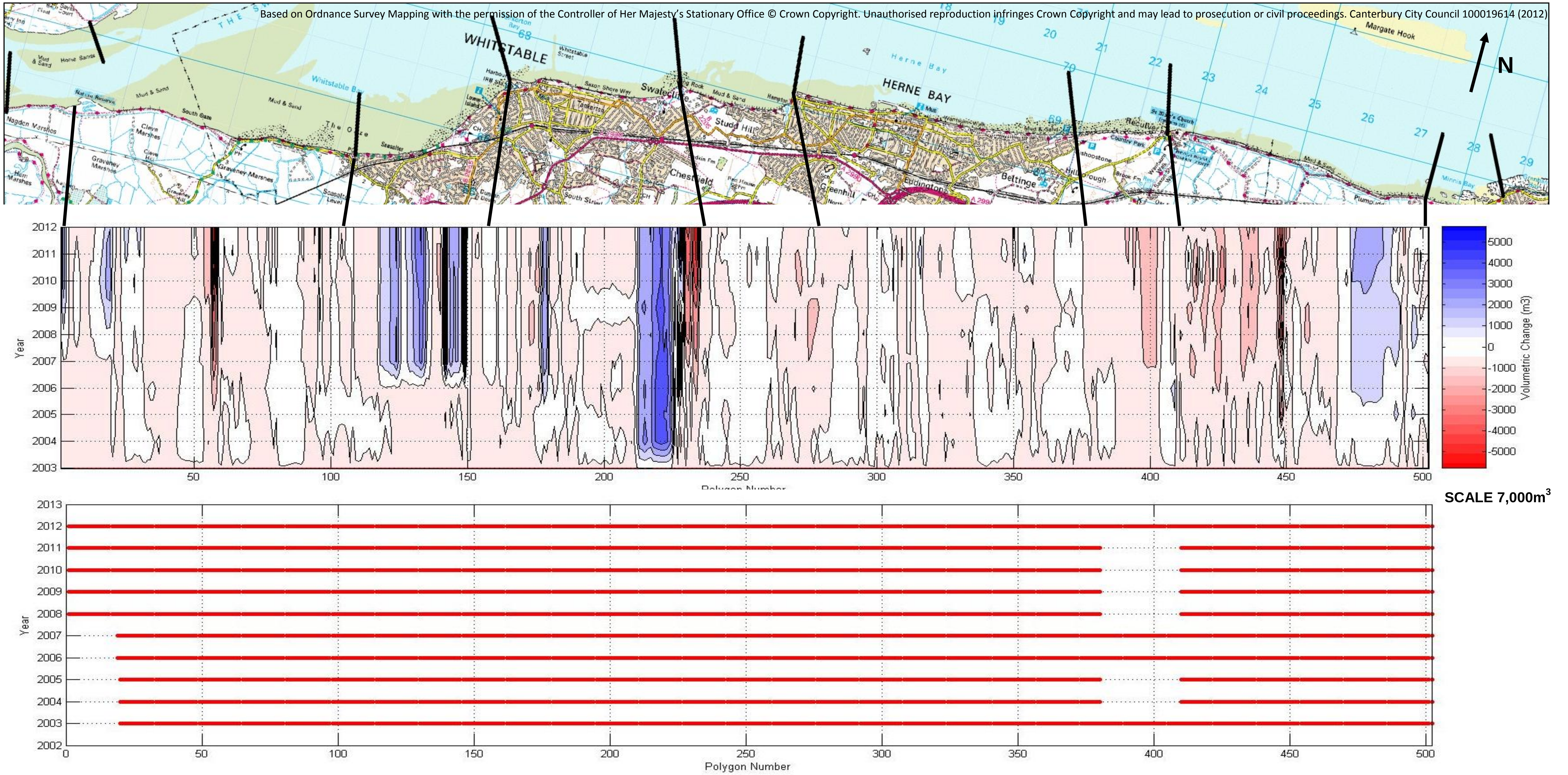

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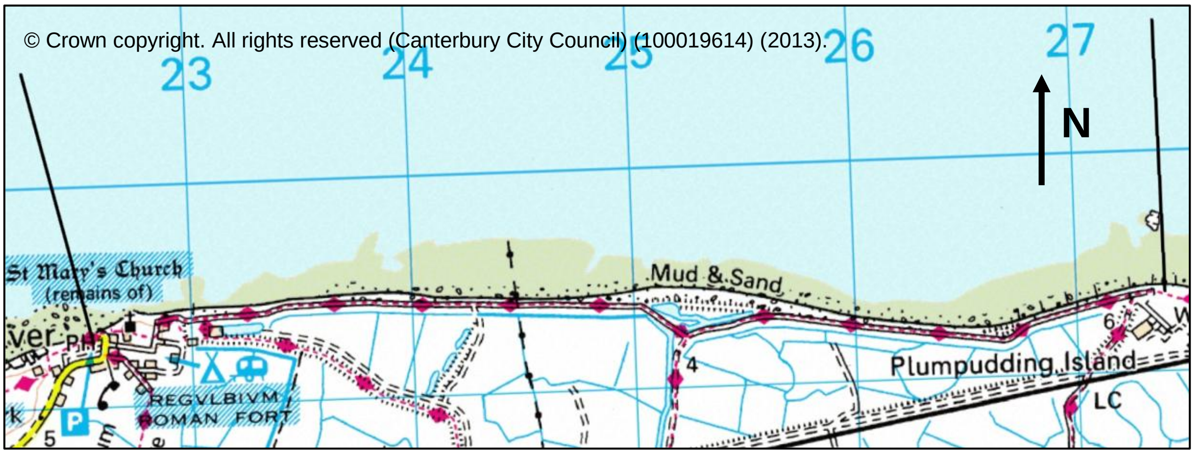
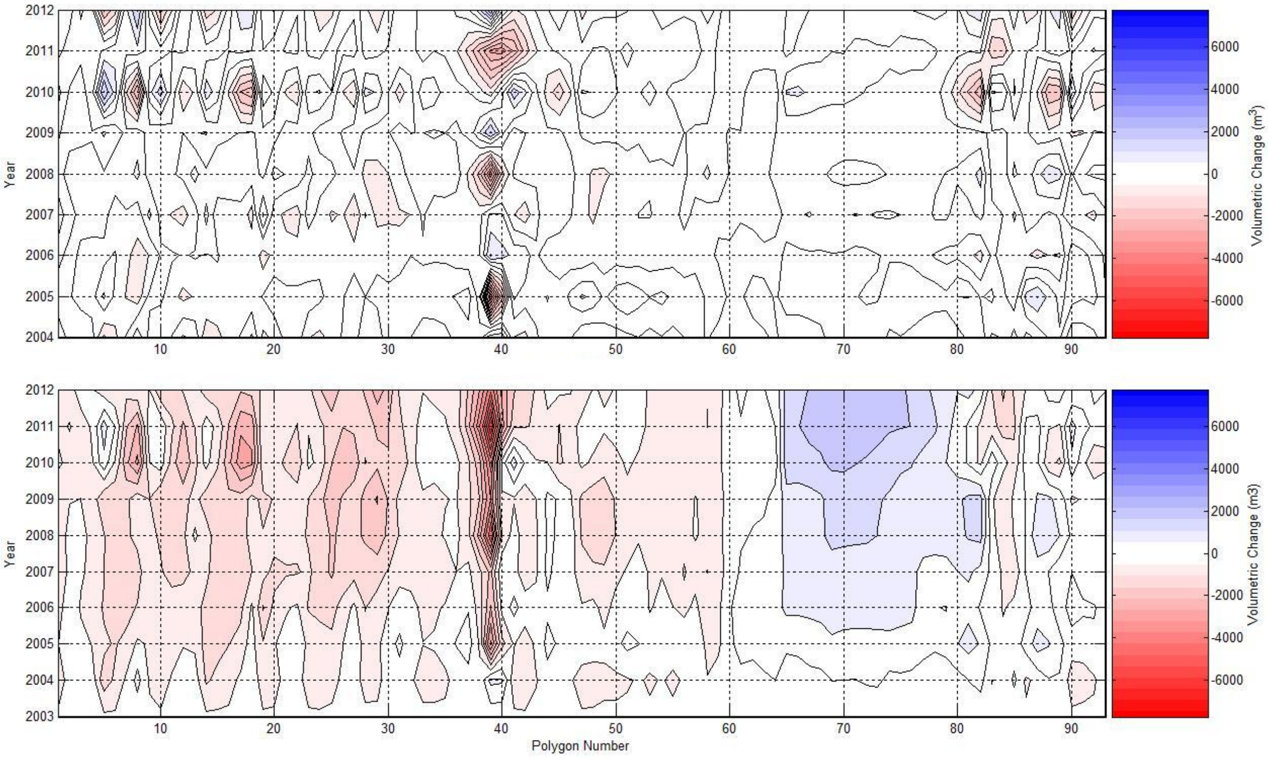
Figure 4-1 Cumulative contour plot of beach volumetric change since 2003 over the entire sediment budget

The contour plots show the volumetric change for each 50m stretch of coast over the whole budget. The X axis refers to the distance along shore from Castle Coote, and the Y axis refers to time. The Z axis is the volumetric change recorded for each 50m wide polygon over each monitoring period, calculated through analysis of the difference models. The data used to generate the plots are shown in the second plot, with a red dot representing a data point on the contour plot. Gaps in the data exist at Bishopstone and Castle Coote spit due to problems with access. Where there is missing data, change is interpolated from known points. On the whole, the frontage is characterised by large, relatively stable sections were there is little change through time (e.g. Seasalter, Swalecliffe, and Herne Bay). There is a section of gradually increasing beach volumes along the Northern Sea Wall frontage and a more rapid change noted in Tankerton in 2004 and Whitstable in 2006 due to the implementation of capital replenishment schemes. The frontages are explored in more depth in the following pages.

4.1.1 Northern Sea Wall



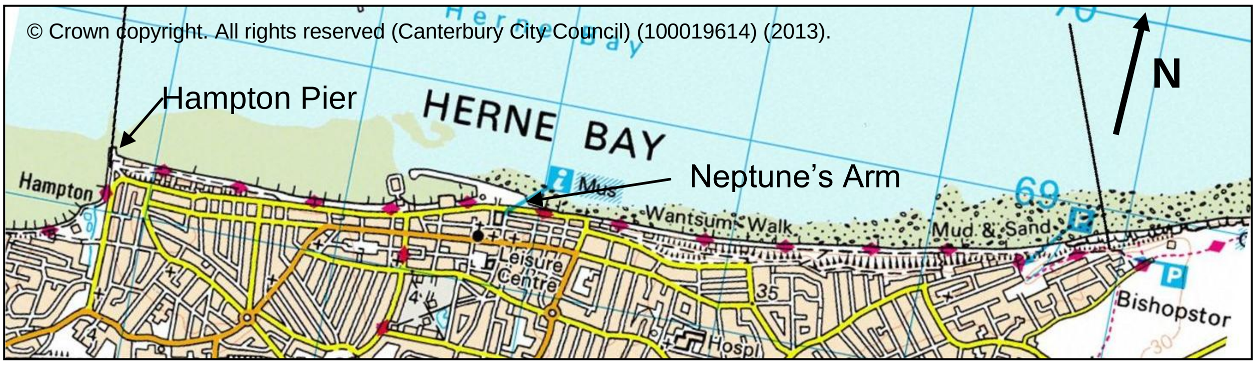


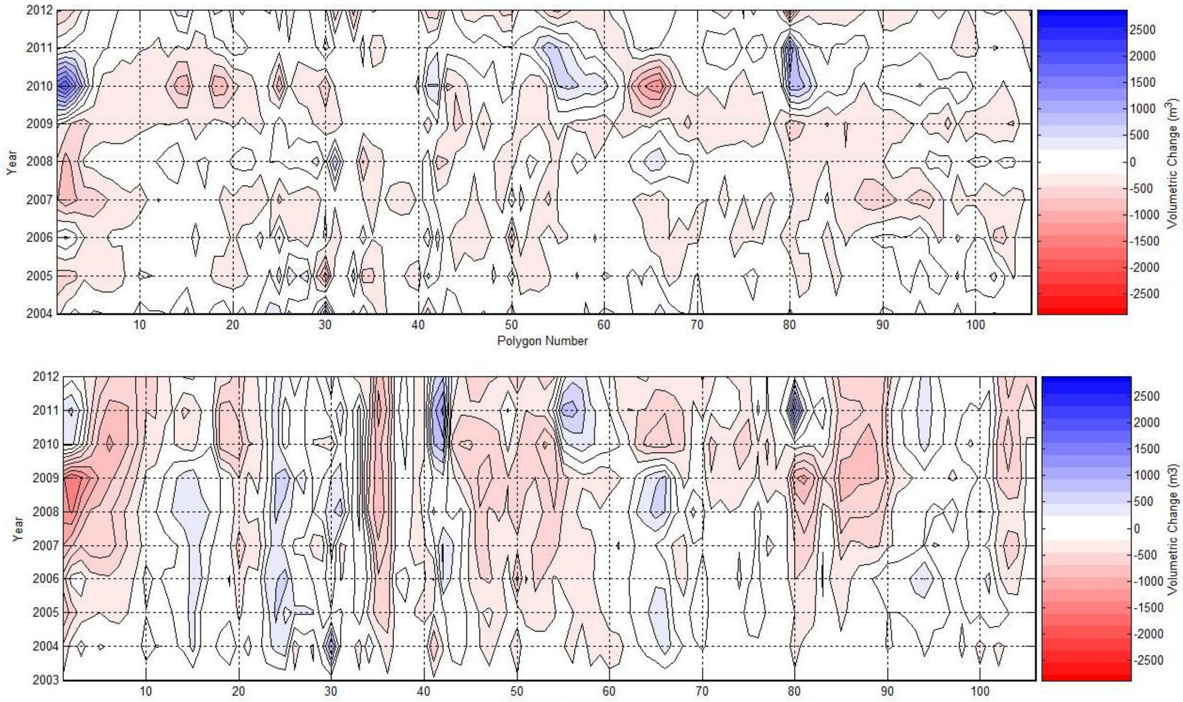
SCALE 7,000m^3

Figure 4-2 Year on year (top) and Cumulative (bottom) contour plots for beach volumetric change at the Northern Sea Wall since 2003

Northern sea wall is a typically erosive frontage, shown by the dominance of losses in Polygons 0 to 60 in the cumulative contour plot. These losses are not shown in the year on year plot highlighting small but persistent year on year losses are contributing to significantly lower beach volumes compared to 2003. The regular recycling works can clearly be seen in the year on year plot, with pockets of accretion and erosion as material is removed and deposited. This is particularly evident at Polygon 38-40 where material is removed on an annual basis and deposited in the west of the unit. A large build up between Polygons 65-80 shows how the beach has been growing naturally at the section backed by the lagoons from the material eroded in the previous section. Again, these changes are not particularly evident in the year on year plot showing that it is a gradual but continued increase in material.

4.1.2 Herne Bay



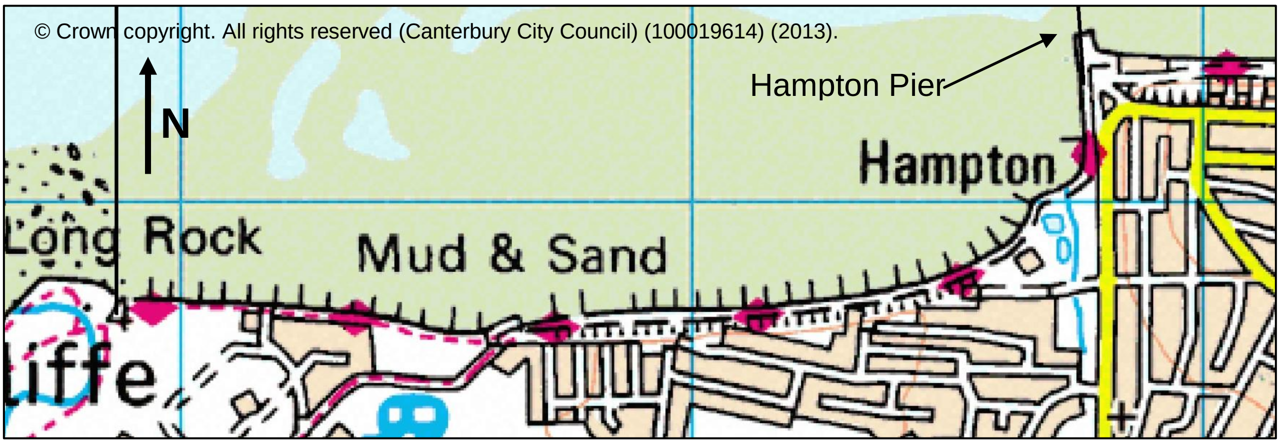


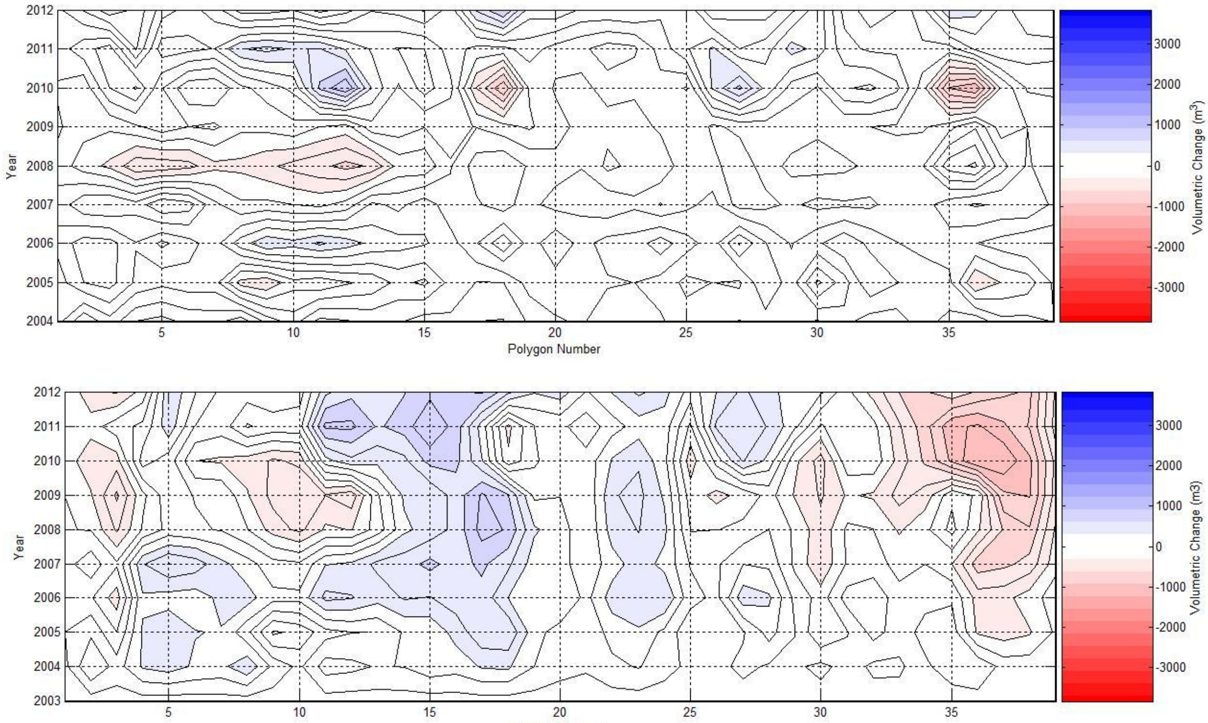
SCALE 3,000m^3

Figure 4-3 Year on year (top) and Cumulative (bottom) contour plots for beach volumetric change in Herne Bay since 2003

The Z-scale has been reduced to 3000m^3-3000m^3 to reflect the low level of change shown on this frontage. The entire frontage is characterised by alternating trends of erosion and accretion reflecting the bidirectional and heavily managed nature of the beaches. There has been a significant build up in the lee of Neptune's arm over the last 20 years which is not registered in the contour plots due to the area not being surveyed. Material moving into the final groyne bay to the east of Neptune's arm is deposited on the high foreshore in the direction of dominant drift. The entire frontage shows a trend of relative stability.

4.1.3 Swalecliffe



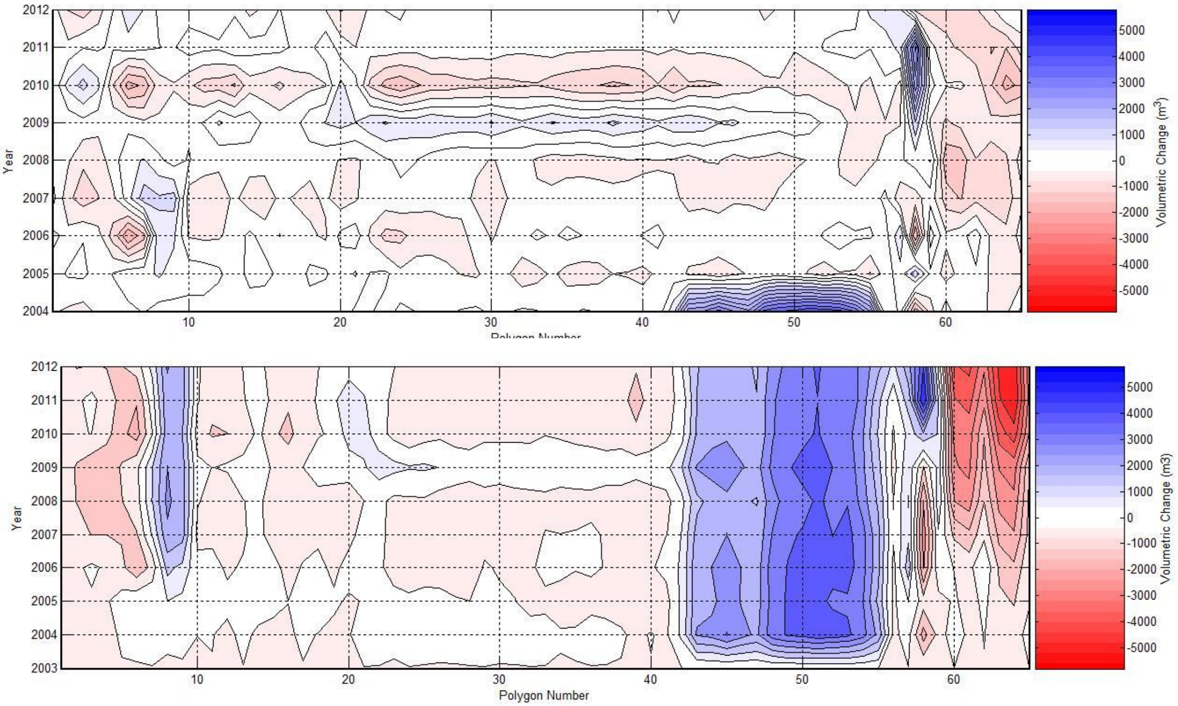


SCALE 4,000m^3

Figure 4-4 Year on year (top) and Cumulative (bottom) contour plots for beach volumetric change in Swalecliffe since 2003

The unit shows alternating bands of erosion and accretion through both space and time. The east of this unit is characterised by erosion as the feed from Hampton has been reduced by Hampton Pier (top right of the map). Between Polygons 10-30 there is a large and continual build up of material. The west of the unit returns to an erosive trend as material is passed onto Long Rock.

4.1.4 Tankerton

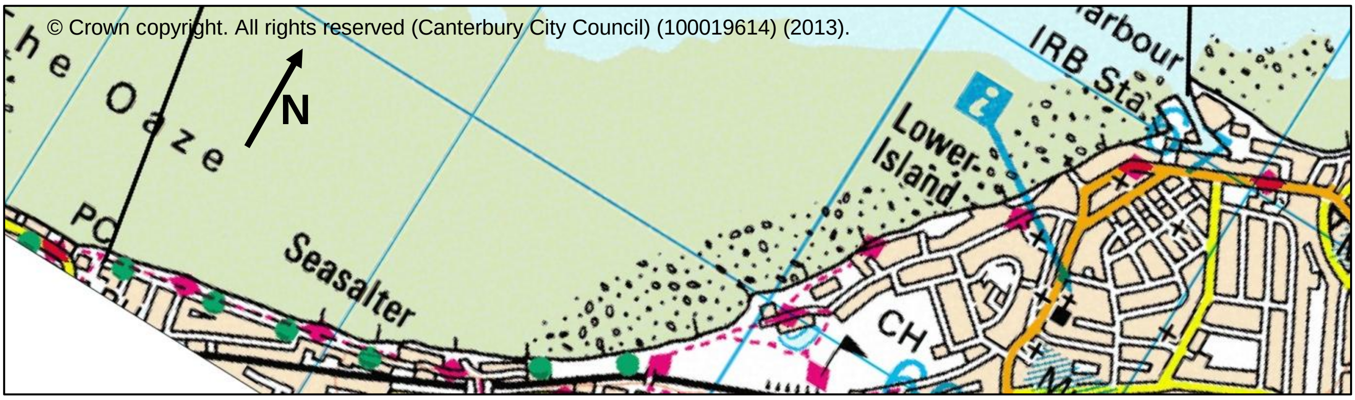


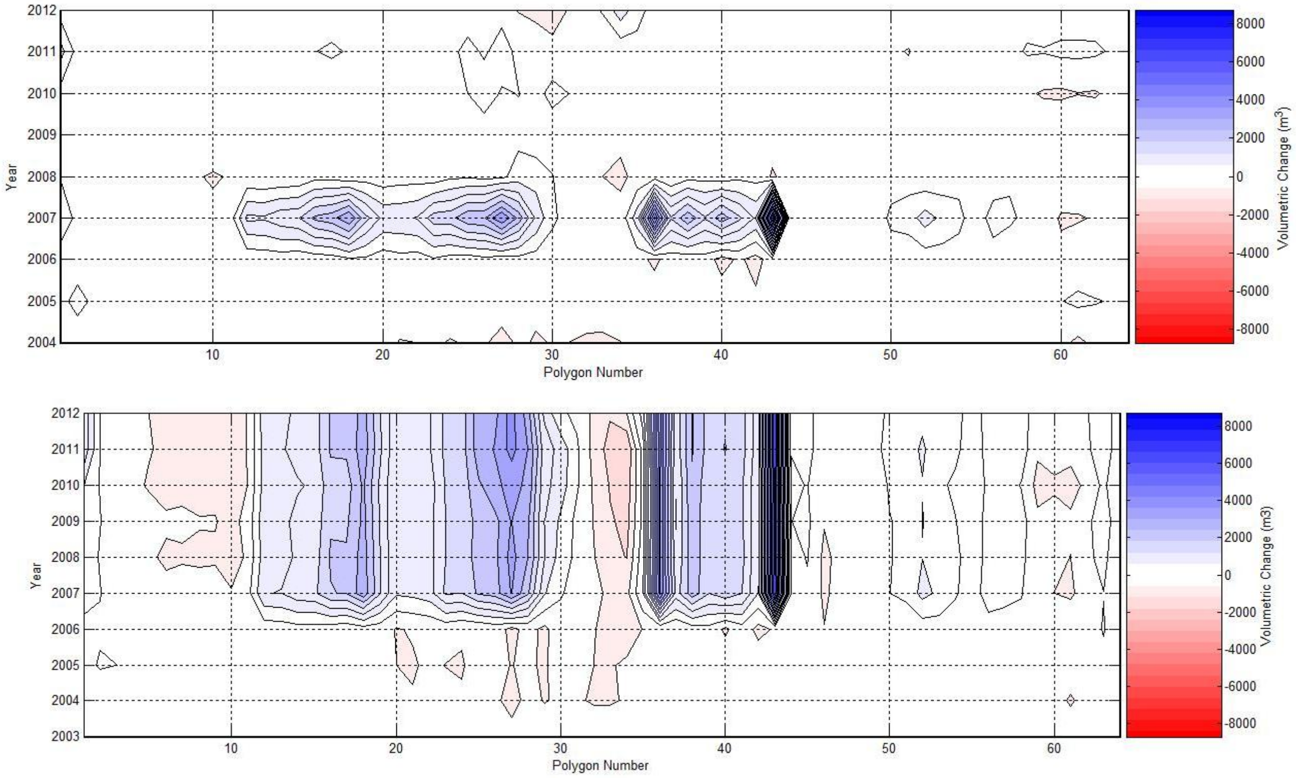
SCALE 6,000m^3

Figure 4-5 Year on year (top) and Cumulative (bottom) contour plots for beach volumetric change in Tankerton since 2003

The eastern stretch of Long Rock (Polygons 60-65) is characterised by persistent significant losses. This eroded material is being deposited on the spit at the mouth of the Swale Brook (Polygons 58-60). Due to regular recycling works on the spit, there was little volume increase to 2009, after which a significant accretion was recorded. This volume has been maintained through to 2012. Phase 3 of the Tankerton Scheme can be seen by significantly higher beach levels after 2004 in the cumulative contour plot. The year on year plot highlights that there were losses after the scheme in response to the significantly higher beach levels. The middle of the unit shows relative stability, tending towards erosion. A particularly accretive year is shown in 2009 possibly a result of strong north easterly waves bringing material from Long Rock. The west of the unit shows accretion in Polygons 7-10 and then losses from 1 to 7 as a result in the change in orientation of the coastline. The year on year plot highlights a potential problem with the 2009 data as there is an equal erosion in 2010 to the accretion in 2009. This may suggest that the data was artificially higher in 2009 than in reality.

4.1.5 Whitstable



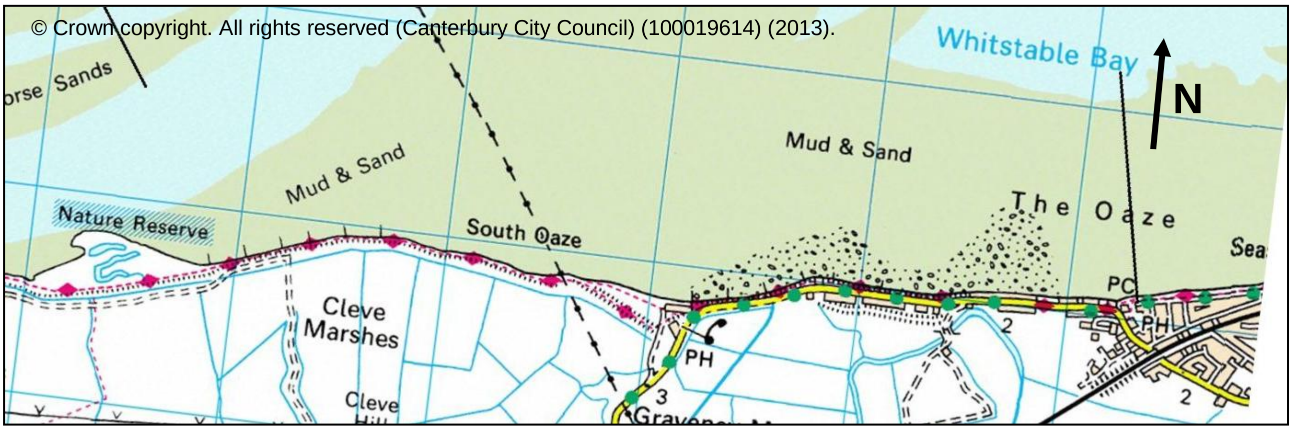


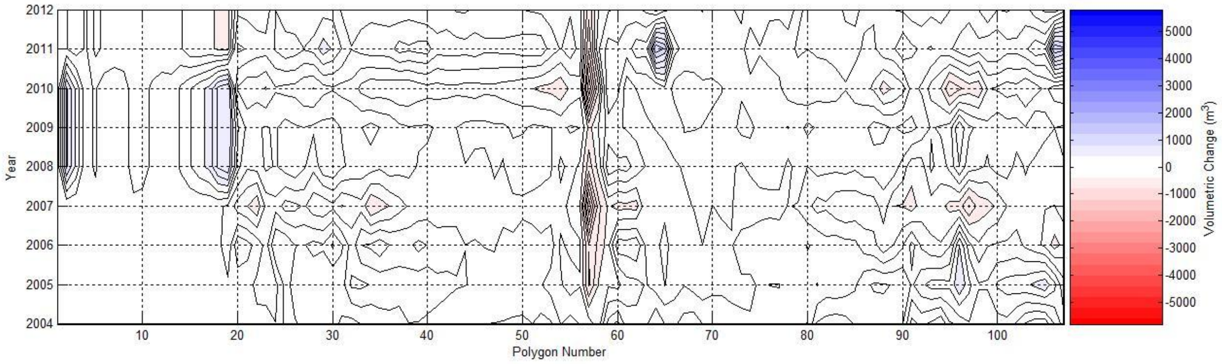
SCALE 8,000m^3

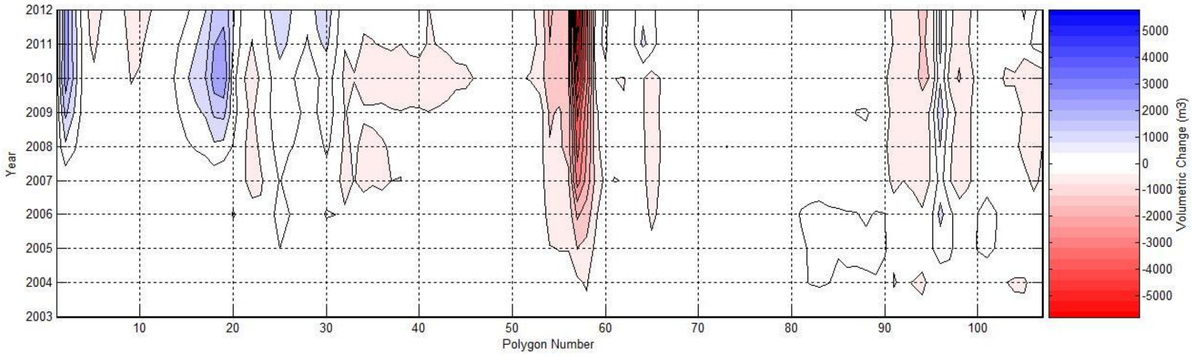
Figure 4-6 Year on year (top) and Cumulative (bottom) contour plots for beach volumetric change in Whitstable since 2003

Whitstable is shown to be a very stable frontage with very little change noted in either of the plots. However, this is due to the Z-scale being increased to +/- 8000 to accommodate for the large volumetric increase due to a capital scheme completed in 2006. Therefore actual changes may be masked as they are small in relation to the large change from the scheme. Nevertheless the scheme (and the entire frontage) seems to be performing relatively well, with little loss of beach with time.

4.1.6 Graveney







SCALE 6,000m^3

Figure 4-7 Year on year (top) and Cumulative (bottom) contour plots for beach volumetric change in Graveney since 2003

Seasalter is characterised by relatively low level change across the frontage. Within, this however, there are areas that are eroding and accreting. Polygons 90-100, in front of the houses, show yearly losses contributing to a large loss in volume in relation to the 2003 baseline. However losses at the beach fronting the Sportsman in Polygon 55-60 are much more significant for this frontage. This stretch of beach changes from a groyned frontage to an open beach and so could explain the large cutback. The west of the unit shows gains as material is deposited on the spit at Castle Coote.

Figure 4.8 summarises the findings from the Spatio-temporal plots by providing a cumulative annual loss or gain from each frontage over the reporting period. This can provide a direct comparison between each frontage, to identify their behaviour in relation to the adjacent frontages. The majority of frontages show relative stability, being +/10,000m^3 from the baseline. The schemes in Tankerton and Whitstable show a significant volumetric increase of +45,000m^3 and + 60,000m^3. During 2004-2005 Northern Sea Wall gainied 10,400m^3, given the frontages location this seems unlikely as there is no real source of this material. This is therefore thought to be explained through a combination of missed recycling logs from material from Minnis Bay, and survey error.

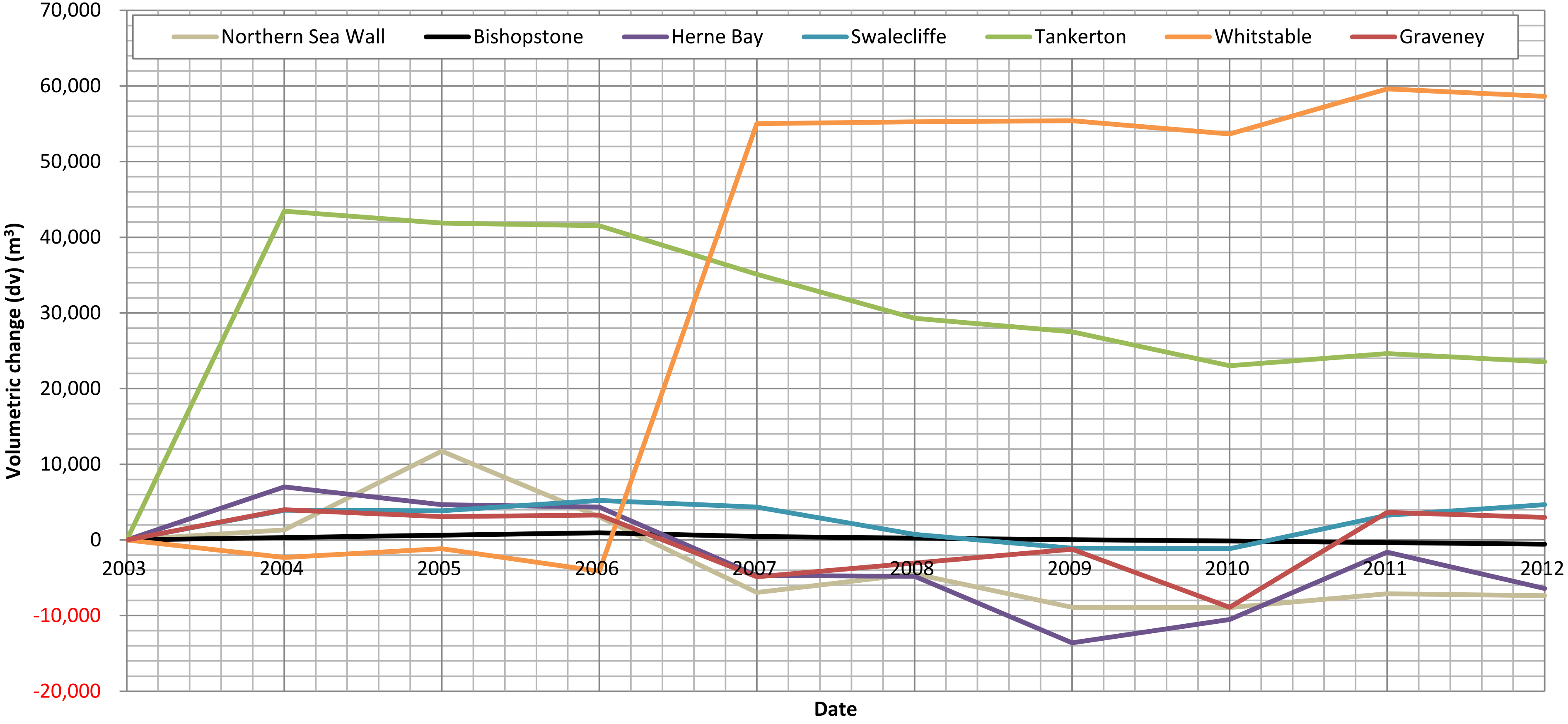


Figure 4-8 Cumulative volumetric change (dv) on all frontages since 2003

4.2 Level 3 - Coarse Sediment Budget

The level 3 sediment budget breaks down the management units into sub-cells according to similar coastal processes. The data is provided in visual and tabular format in the proceeding pages.

Attrition losses calculated at 0.15m^3/m/yr often produced losses larger than the volumetric change alone. This attrition loss was designed and produced on the south coast, where wave intensity and exposure are much higher. Wave heights on the North Kent coast rarely exceed 1.5m at the beach toe and the high foreshore means that for much of the tidal cycle, the beaches are not exposed to direct wave action. Consequently attrition losses are much lower on these frontages. The attrition losses were reduced to 0.015m^3/yr to bring them in line with the magnitude of change experienced on this stretch of coastline. Northern sea wall is a section of open coast with a lower foreshore and subject to increased wave activity, consequently, the attrition rate was increased to 0.075m^3/yr. Given that there is no accurate method for calculation of attritional losses, these values represent a best estimate. In reality, these volumes are so small that they have very little impact on the sediment budget. However, they do acknowledge that some small volume is lost offshore during wave action.

The Northern Sea Wall frontage is thought to not add material into Bishopstone, due to the presence of large controlling structures as well as a change in orientation of the coastline. Therefore it was isolated as being part of its own budget and its own cell. The section is bidirectional, but tends towards a dominant easterly drift direction, so was balanced from Reculver towers towards Minnis Bay (Note: negative drift volume imply a west to east as opposed to east to west – the dominant drift for the North Kent coast). Material is thought to be able to move past the eastern boundary into Minnis Bay under a strong north westerly wave climate. This is backed up by records of recycling and from consultation with local authorities. Therefore, this cell cannot be completely closed. The residual for this frontage was 1,259m^3/yr which is most likely transported past the final groyne into Minnis Bay via the high foreshore. The transport rates are typically higher than the rest of the frontage due to the more open nature of the beaches.

Neptune's Arm in Herne Bay is a 600m curved rock breakwater. It prevents material being transported into the downdrift beach at Hampton. Over the last 10 years, the levels at the toe of the structure have been increasing. However, no survey records exist for this small section of beach and so actual volumetric increase is not known. A residual volume of 1,038m^3/yr is left at the beach just east of the pier, which is transported onto the foreshore at the breakwater. While 1,083m^3 is transported into this area, not all is deposited here; some is deposited out on the foreshore where local consultation has shown that shingle has been accreting. This area has been highlighted as an area to include in the current monitoring programme, to attempt to quantify future gains on this small beach.

The beach within Neptune's arm shows no transport rate out of the cell which shows the method is working well, as very little can move round the large rock groyne (under Herne Bay Pier). The final cell in Herne Bay has a residual of -10m^3/yr which is very small considering the accuracy of the survey equipment and the assumptions in the methodology.

A small local drift reversal is noted in the central section of Swalecliffe, where beach levels have showed continued accretion. Long Rock is a dynamic spit development in the eastern section of Tankerton. It is known to be formed due to a convergence of drift from the east and west due to diffraction of the waves around the headland. A residual of 521m^3/yr is shown at the mouth of the Swale Brook. This is not transported over the mouth, but deposited on the high foreshore. A further drift reversal is shown just west of Long Rock, providing the convergence for the accretion at the spit.

Figure 4-9 Western sections of Tankerton

Tankerton behaves as a series of smaller sub-cells, with limited transport between sections (Figure 4.9). No material is thought to be able to move past the large groynes at Section 2 and Section 3 behaves almost as its own cell. Using the principle of conservation of mass alone, 876m^3/yr was calculated leaving Section 1. In order to limit the material moving into Section 2, transport rates had to be reduced through a Distance Weighted Residual (DWR), calculated as:

$$Distance\ Weighted\ Residual\ (DWR) = \ Length\ of\ cell. \left(\frac{residual\ for\ section}{length\ of\ section}\right)$$

The DWR represents an additional ‘unaccounted’ loss to the system, which needs accounting for in order to calculate more representative transport rates. This loss of volume is likely to be due to larger than expected losses from the Tankerton scheme in 2004 where ~50,000m^3 was deposited. The material came in too fine and was consequently mobilised offshore (not alongshore), the DWR attempts to quantify this loss of volume due to the problems in placed material. The residual is divided equally across the frontage so that errors are not compounded through the unit.

This forced the transport rate past the groynes to 0 and reduced the alongshore transport rates to those to be expected on this type of frontage. After distance weighting the residual in the central section (justified through larger than expected losses in the replenishment scheme) the section balanced well with the expected beach behaviour and magnitude of change shown. At Whitstable Harbour 326m^3/yr leaves Tankerton and is deposited in the harbour mouth. Dredging records show that ~400m^3/yr of shingle is extracted from the harbour annually, showing the system is performing well.

The first two cells in Whitstable showed fluxes of ~50m^3/yr. Considering the accuracy of the survey equipment this was determined to be a non-significant change in relation to its area. From site investigations it is known that these two cells have lost little if any material over the past 10 years, In addition, the sheltering effect of Whitstable Harbour from north easterly waves, means that transport in a westerly direction is unlikely. Therefore the transport rate has been artificially reduced to no net movement into and out of these cells. This is the same justification for 0 transport out of the first cell at Bishopstone as the flux is deemed non-significant in relation to its area.

The reasons for the formation of Seasalter bank are not well known. Analysis of historic images as well as survey data from the monitoring programme, show a landward movement of the bank through time (Figure 4.10). This suggests there is a seaward source of material feeding the growth of the bank. Over the last 10 years, very little, if any, material transported through longshore drift is thought to have been deposited on the bank. However, in 2012, the bank joined the beach toe and now has the potential to accrete material in the future from updrift sources.

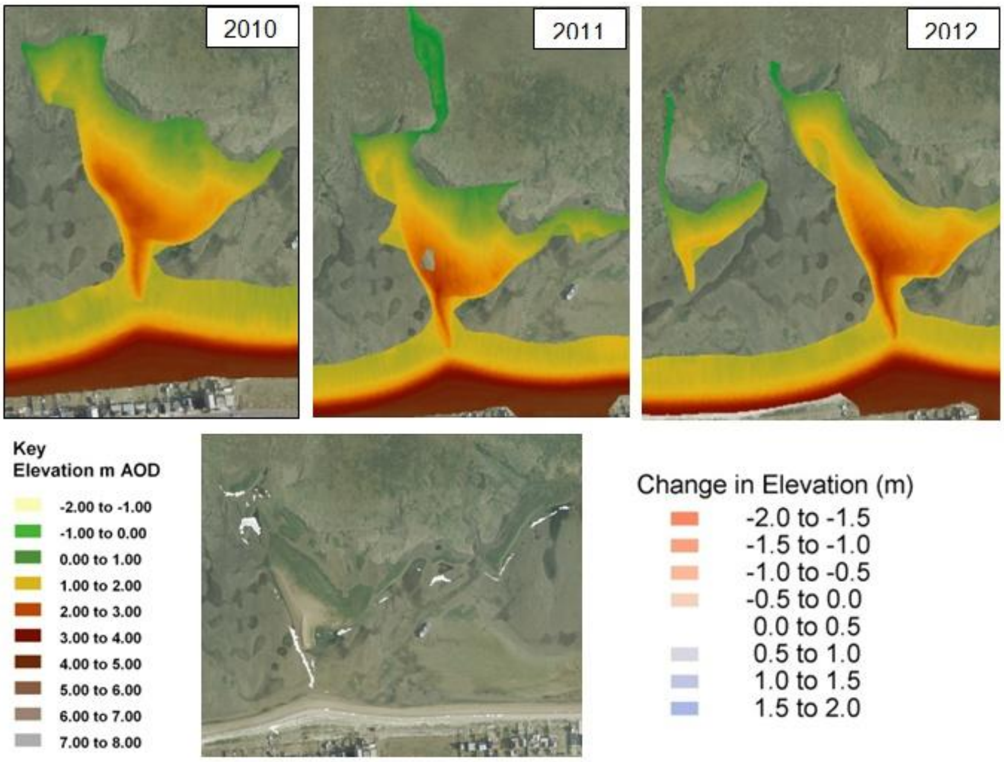


Figure 4-10 - Evolution of Seasalter bank

]

Table 4-1 Level 3 - Coarse Sediment Budget (All values in m^3/year)

Cell	Sub-cell	Average annual change (ΔV)	Recharge (P1)	Recycling		Losses			Average annual flux (ΔV-P+R-L)	Distance* Weighted Residual (L4)	Qinput/output** from offshore sources	Qoutput***
				Deposition (P2)	Extraction (R1)	Attrition (L1)	Recharge (L2)	Recycling (L3)				
Minnis Bay												-1,259
Northern Sea Wall	1	-32	0	355	-767	-39	0	-18	437			-1,696
	2	3,721	0	741	-413	-89	0	-37	3,519			-5,215
	3	-3,144	0	0	-3,472	-136	0	0	464			-5,679
	4	-1,259	1,140	3,557	0	-69	-114	-178	-5,595			-84
	5	-100	0	0	0	-17	0	0	-84			0

Cell	Sub-cell	Average annual change (ΔV)	Recharge (P1)	Recycling		Losses			Average annual flux (ΔV-P+R-L)	Distance* Weighted Residual (L4)	Qinput/output** from offshore sources	Qoutput***
				Deposition (P2)	Extraction (R1)	Attrition (L1)	Recharge (L2)	Recycling (L3)				
Bishopstone	1	9	0	0	0	-3	0	0	12			0
	2	-582	0	0	0	-13	0	0	-570			570
	3	-29	0	0	0	-3	0	0	-26			596
Herne Bay	1	106	0	0	0	-10	0	0	116			480
	2	-330	0	0	0	-8	0	0	-322			801
	3	-151	0	0	0	-19	0	0	-132			933
	4	-128	0	0	-12	-11	0	0	-105		-1,038	0
	5	-135	0	2,822	-2,810	-6	0	-141	0			0
	6	-164	0	3,021	-3,021	-22	0	-151	10			-10
Swalecliffe	1	-109	0	0	0	-3	0	0	-106			106
	2	-201	0	0	0	-5	0	0	-196			302
	3	247	0	0	0	-5	0	0	251			50
	4	205	0	0	0	-5	0	0	210			-159
	5	457	0	185	0	-6	0	-9	287			-446
	6	-83	0	704	0	-7	0	-35	-746			300
Tankerton	1	-2,120	0	0	0	-5	0	0	-2,116			2,415
	2	668		0	-1,224	-2	0	0	1,894		-521	0
	3	362	0	0	0	-5	0	0	367			-366
	4	2,398	2,882	336	0	-4	-288	-17	-510	-111		33
	5	1,600	2,174	0	0	-7	-217	0	-350	-181		202
	6	-506	0	0	0	-14	0	0	-491	-398		296
	7	102	0	0	0	-7	0	0	109	-187		-0
	8	245	0	611		-9	0	-31	-327			326

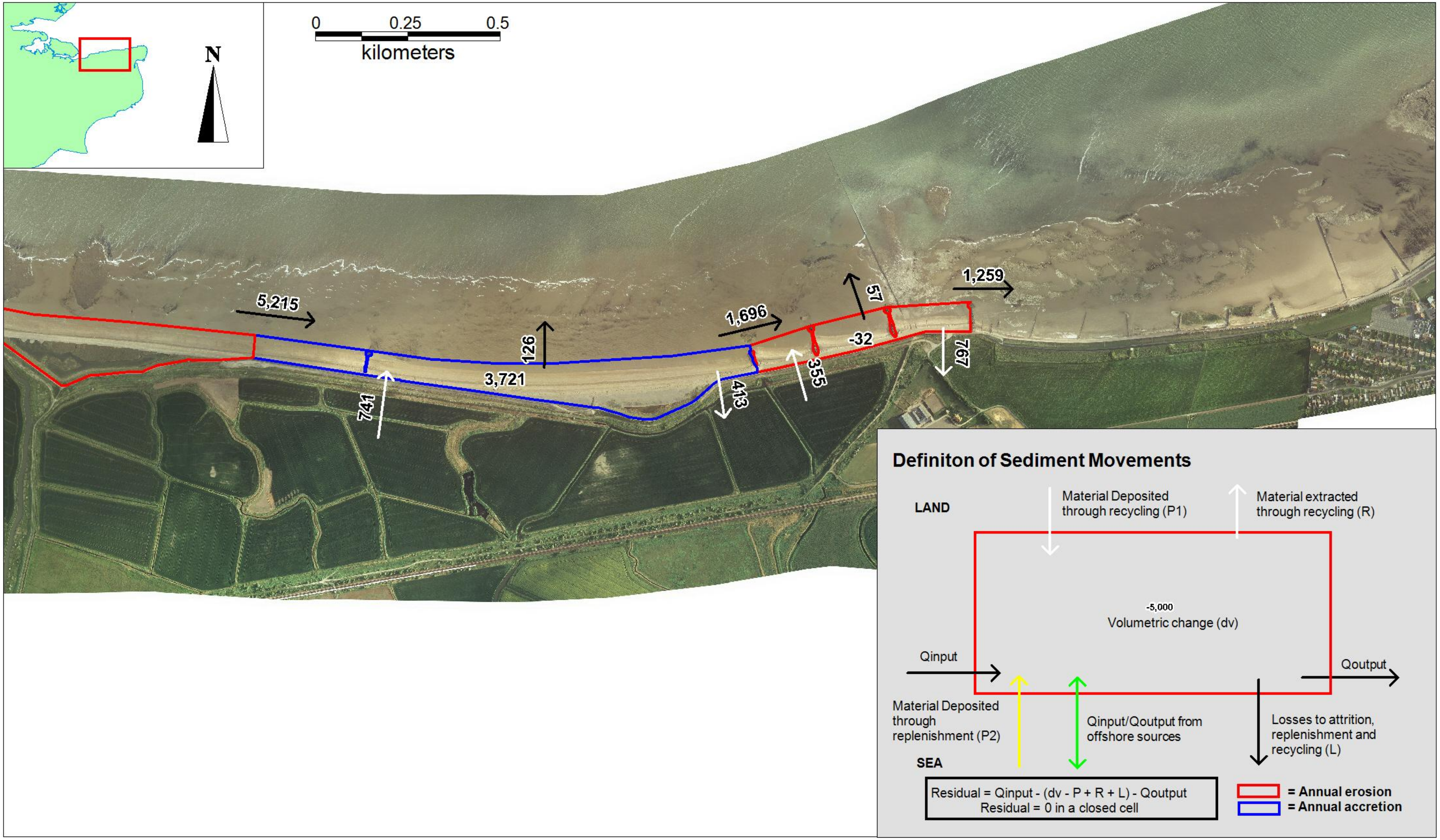
Cell	**Sub-cell**	**Average annual change (ΔV)**	**Recharge (P1)**	**Recycling**		**Losses**			**Average annual flux (ΔV-P+R-L)**	**Distance* Weighted Residual (L4)**	**Qinput/output** from offshore sources**	**Qoutput*** **
				Deposition (P2)	**Extraction (R1)**	**Attrition (L1)**	**Recharge (L2)**	**Recycling (L3)**				
Whitstable	1	52	0	0	0	-4	0	0	57			0
	2	271	244	0	0	-4	-24	0	56			0
	3	300	574	0	0	-7	-57	0	-209			209
	4	2,347	2,626	200	0	-7	-263	-10	-199			409
	5	76	380	78	-44	-4	-38	-4	-291			700
	6	1,369	1,325	0	-233	-3	-132	0	413			286
	7	2,455	2,701	0	0	-11	-270	0	34			252
	8	-198	0	0	0	-7	0	0	-191			443
Seasalter	1	233	353	0	0	-12	-35	0	-73			516
	BANK	161	0	0	0	0	0	0	161		161	516
	2	126	0	0	0	-11	0	0	136			380
	3	268	0	0	0	-10	0	0	278			102
	4	-1,170	322	0	0	-9	-32	0	-1,450			1,552
	5	1	0	0	0	-16	0	0	17			1,535
	6	1,620	0	0	0	-23	0	0	1,643		74	-108

* Distance Weighted Residual represents a further unaccounted loss, created through dividing the residual across the frontage to bring transport rates and behaviour in line with expected trends. See above for more details

** Positive values for this cell indicate a volume transported into the cell (Qinput), Negative values for this cell indicate a volume transported out of the cell (Qoutput) to offshore/foreshore.

*** Positive Qoutput values represent east to west drift, Negative Qoutput values represent west to east drift

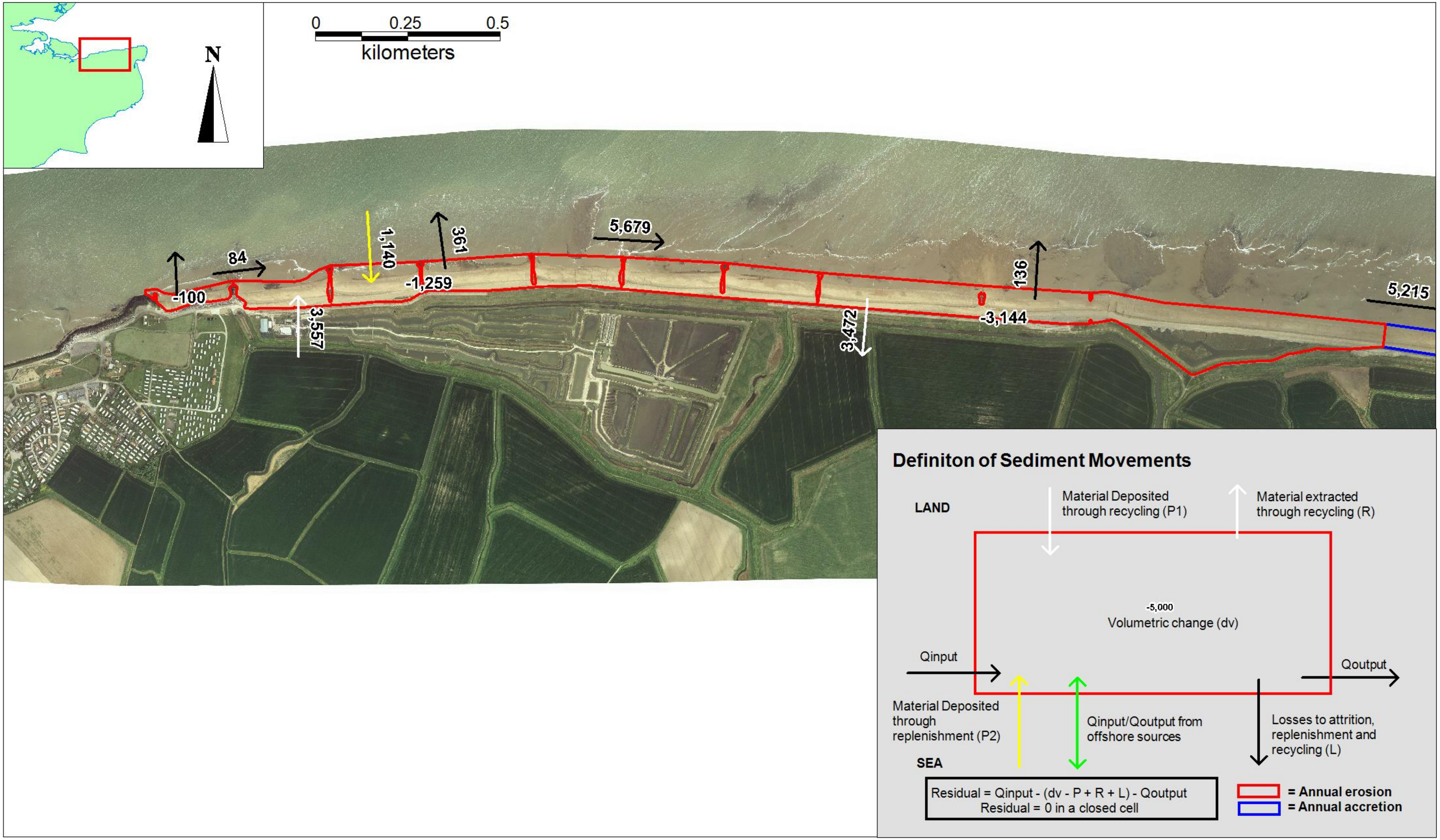
Note: For sub-cell location diagrams please refer to Section 6.0



Northern Sea Wall to Castle Coote Sediment Budget

Northern Sea Wall

Plate 2 (1 of 10)



Northern Sea Wall to Castle Coote Sediment Budget

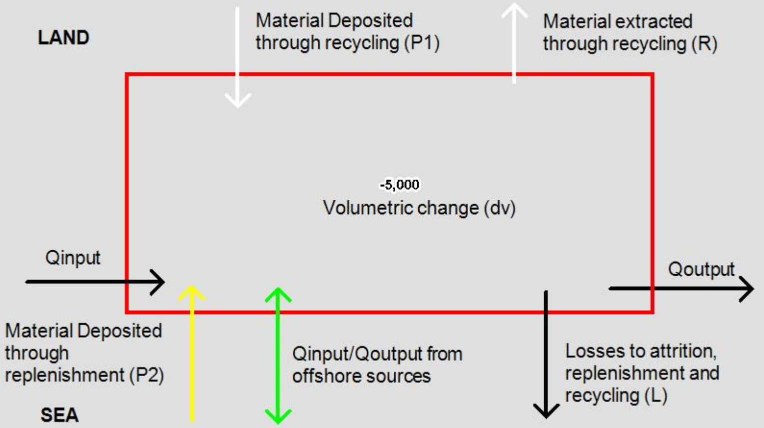
Reculver

Plate 2 (2 of 10)

South East Regional Coastal Monitoring Programme **Level 3 - Sediment Budget**

Residual = 12m^3/yr

Definiton of Sediment Movements



Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell

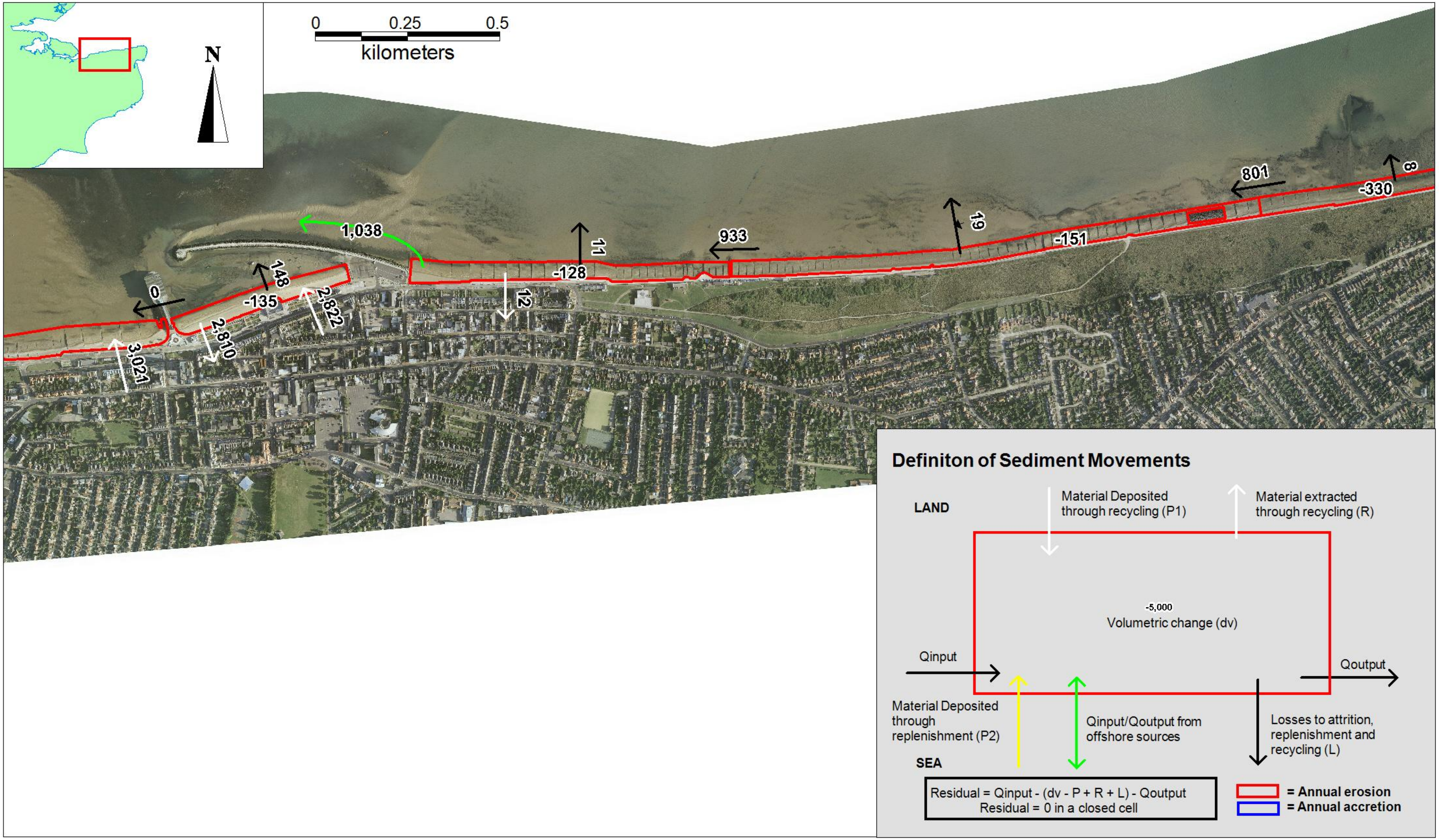
🟥 **= Annual erosion**
🟦 **= Annual accretion**

Northern Sea Wall to Castle Coote Sediment Budget

Beltinge

Plate 2 (3 of 10)

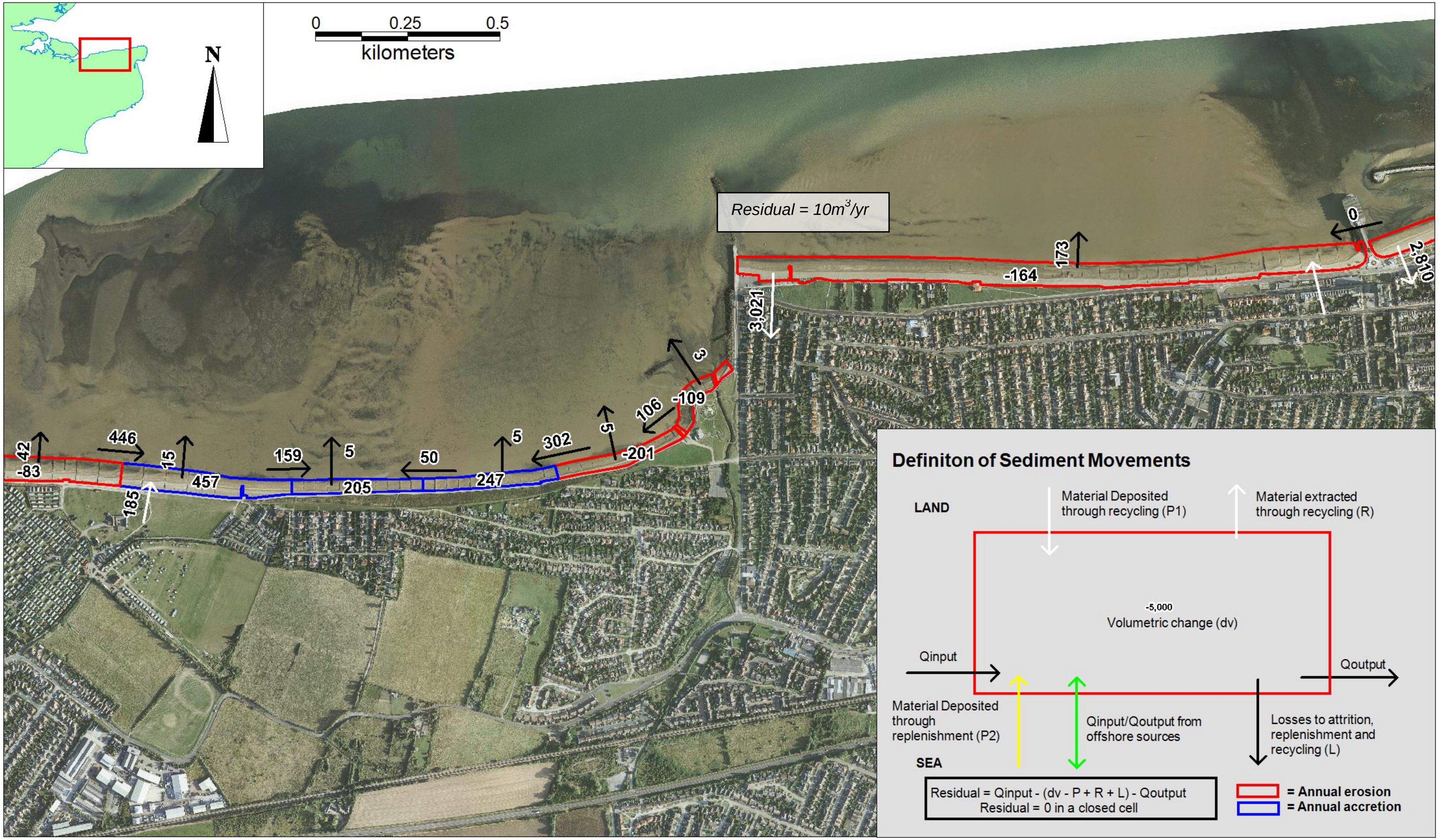
South East Regional Coastal Monitoring Programme **Level 3 - Sediment Budget**



Northern Sea Wall to Castle Coote Sediment Budget

Herne Bay

Plate 2 (4 of 10)



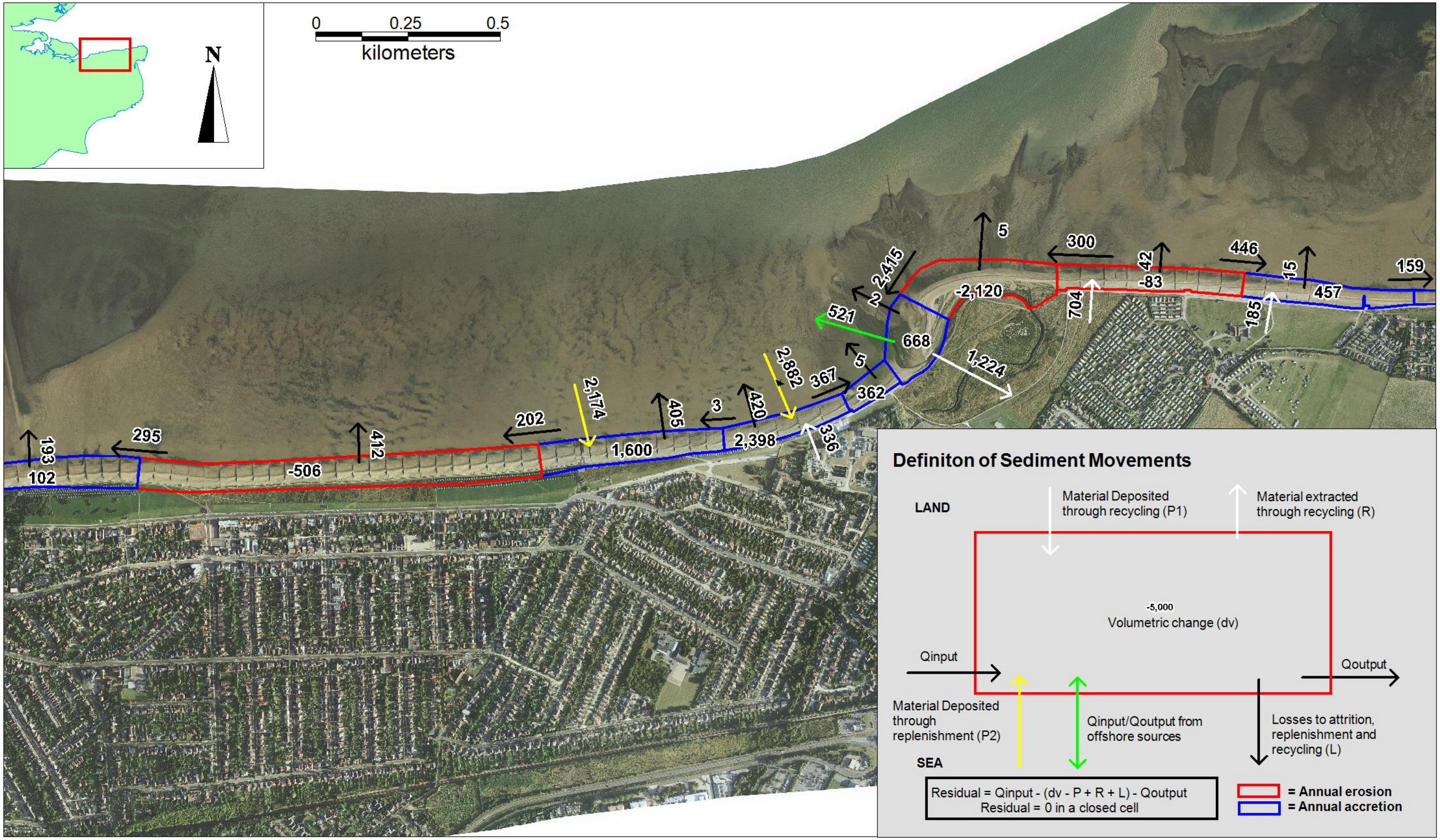
Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell

Northern Sea Wall to Castle Coote Sediment Budget

Hampton

Plate 2 (5 of 10)

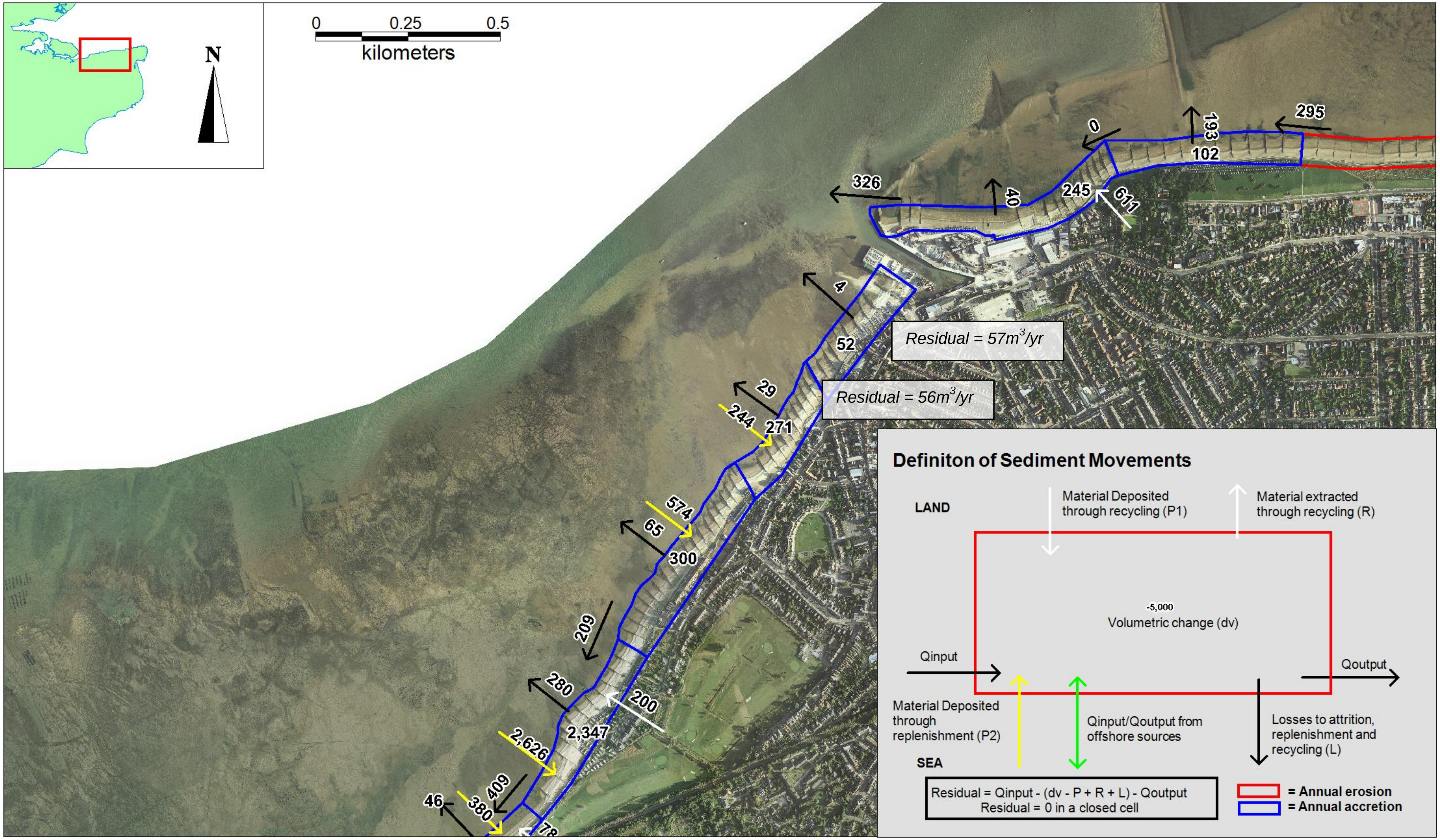
South East Regional Coastal Monitoring Programme **Level 3 - Sediment Budget**



Northern Sea Wall to Castle Coote Sediment Budget

Tankerton

Plate 2 (6 of 10)



Definiton of Sediment Movements

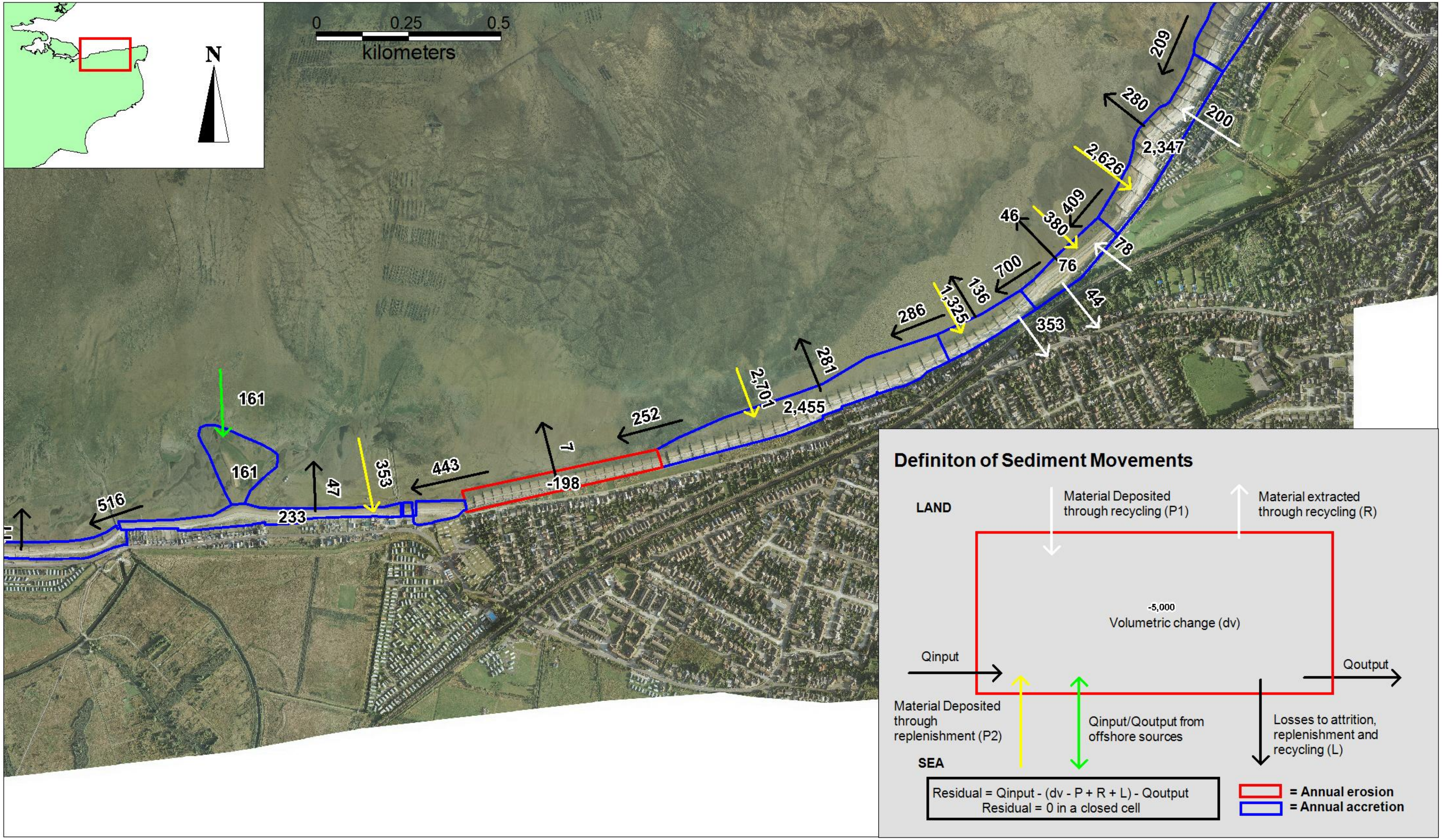
Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell

🟥 = **Annual erosion**
🟦 = **Annual accretion**

Northern Sea Wall to Castle Coote Sediment Budget

Whitstable Harbour

Plate 2 (7 of 10)



Definiton of Sediment Movements

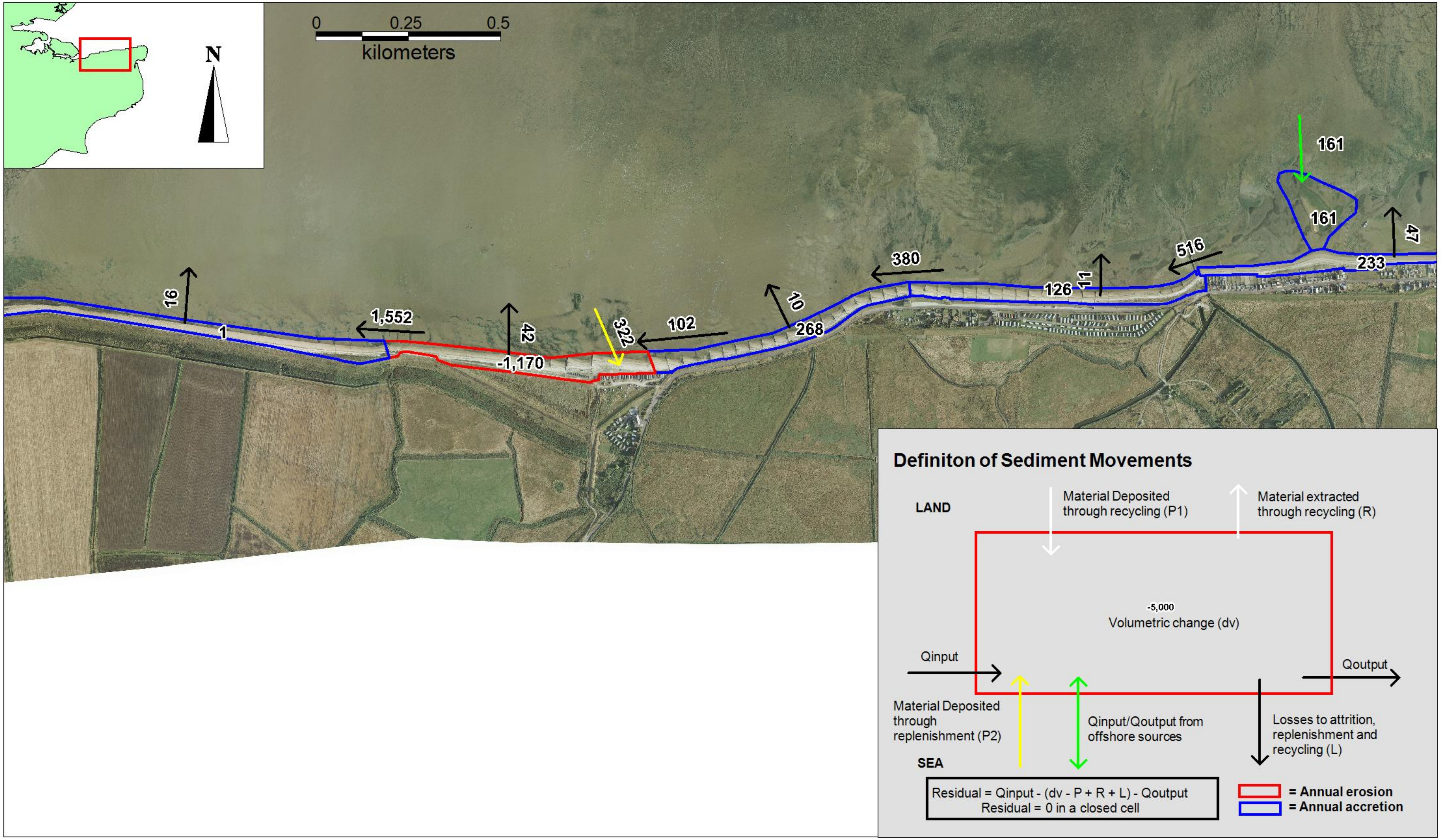
Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell

🟥 = Annual erosion
🟦 = Annual accretion

Northern Sea Wall to Castle Coote Sediment Budget

Whitstable

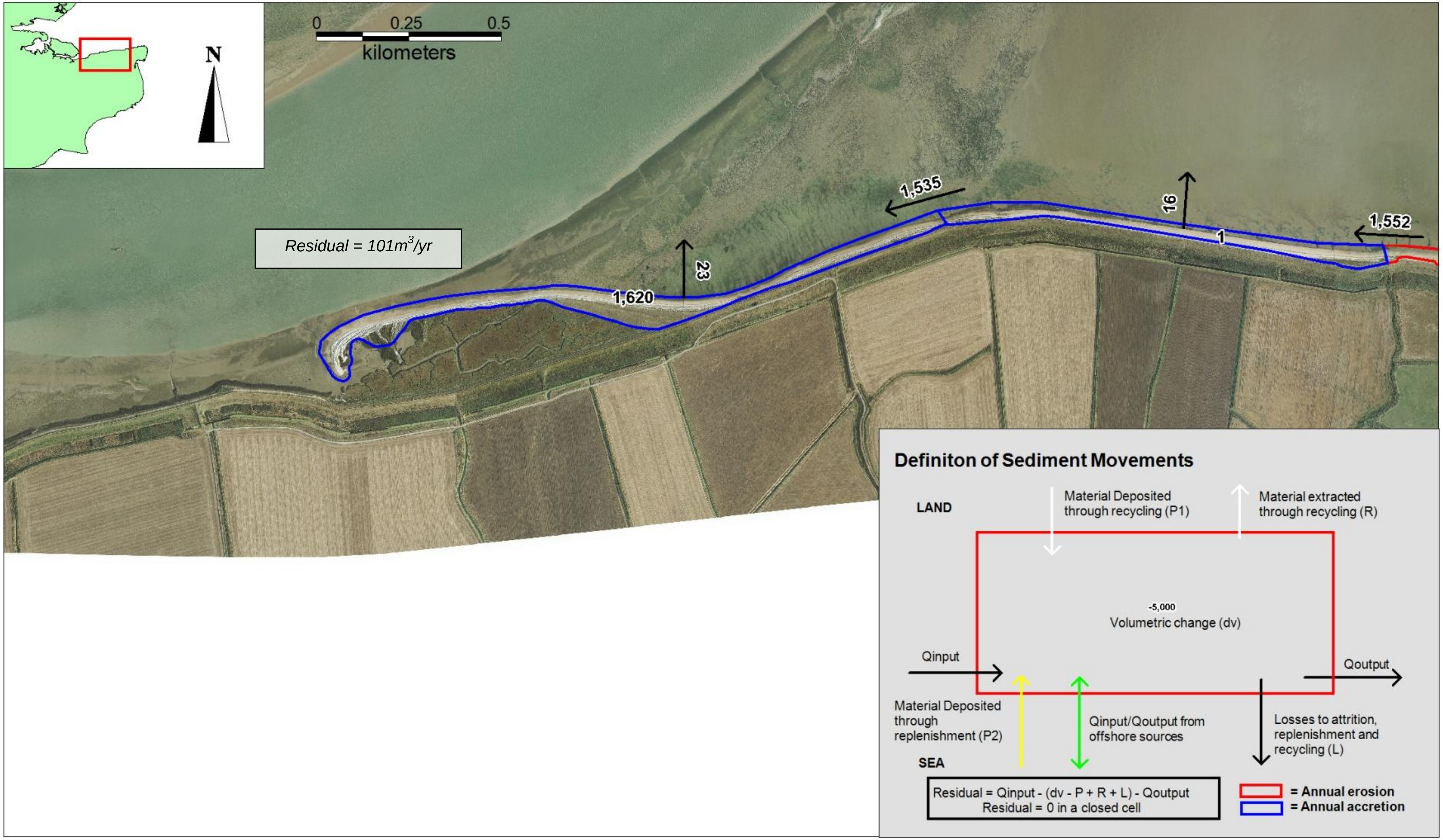
Plate 2 (8 of 10)



Northern Sea Wall to Castle Coote Sediment Budget

Seasalter

Plate 2 (9 of 10)



Definiton of Sediment Movements

Residual = Qinput - (dv - P + R + L) - Qoutput
Residual = 0 in a closed cell

🟥 = Annual erosion
🟦 = Annual accretion

Northern Sea Wall to Castle Coote Sediment Budget

Castle Coote

4.3 Level 4 - Regional Sediment Budget

The level 4 sediment budget has been analysed and displayed in both tabular and visual formats on the following pages to summarise the Level 3 coarse sediment budget.

All frontages (except Graveney) export a small amount material. However these volumes are small and transport rates are typically no larger than 1,000m^3/yr due to the heavily managed coastline and reduced wave intensity. Northern sea wall is the only frontage that has a net drift in an easterly direction, with all other frontages showing westerly dominance. However, localised drift reversal are noted within cells, and all frontages are thought to have the ability to show drift in either directions on an annual basis.

Table 4-2 Level 4 - Regional Sediment Budget (All values in m^3/year)

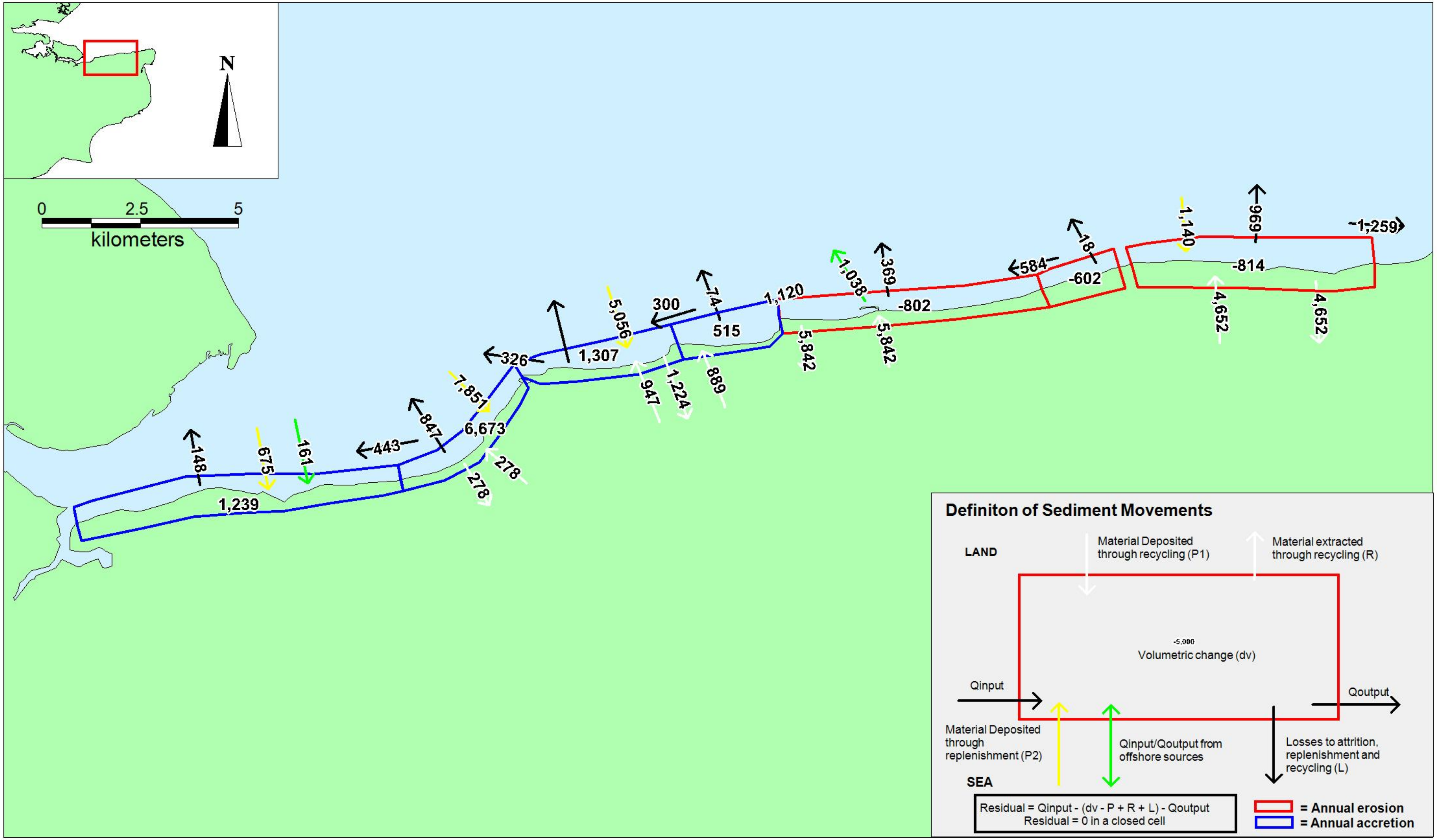
		Average Annual Change (m3/yr)							Total (m^3/yr)
		Northern Sea Wall	Bishopstone	Herne Bay	Swalecliffe	Tankerton	Whitstable	Graveney	NSW to Graveney
AVERAGE ANNUAL CHANGE (ΔV)		-814	-602	-802	515	2,749	6,673	1,239	8,958
RECHARGE (P1)		1,140	0	0	0	5,056	7,851	675	14,723
RECYCLING	DEPOSITION (P2)	4,652	0	5,842	889	947	278	0	12,609
	EXTRACTION (R1)	-4,652	0	-5,842	0	-1,224	-278	0	-11,996
LOSSES	ATTRITION (L1)	-350	-18	-77	-30	-52	-48	-81	-656
	RECHARGE (L2)	-114	0	0	0	-506	-785	-68	-1,472
	RECYCLING (L3)	-233	0	-292	-44	-47	-14	0	-630
AVERAGE ANNUAL FLUX (ΔV-P+R-L)		-1,259	-584	-432	-300	-1,424	-331	712	-3,619
DISTANCE WEIGHT RESIDUAL (L4)*		0	0	0	0	-877	0	0	877
QINPUT/OUTPUT FROM FORESHORE**		0	0	-1,038	0	-521	0	161	-1,398
QINPUT***		0	0	584	0	300	0	443	
QOUTPUT***		-1,259	584	-22	300	326	443	-108	

* Distance Weighted Residual represents a further unaccounted loss, created through dividing the residual across the frontage to bring transport rates and behaviour in line with expected trends. See Section 4.1 for more details

** Positive values for this cell indicate a volume transported into the cell (Qinput), Negative values for this cell indicate a volume transported out of the cell (Qoutput) to offshore/foreshore.

*** Positive Qoutput values represent east to west drift, Negative Qoutput values represent west to east drift.

South East Strategic Regional Coastal Monitoring Programme **Level 4 - Regional Sediment Budget**



Northern Sea Wall to Castle Coote Sediment Budget

Plate 1 (1 of 1)

4.4 Level 4 – Beach Volumes

Beach volumes over all timescales were calculated for each frontage to show the actual total volumes of sediment rather than just the volumetric change. The method for the calculation of these volumes is provided in Appendix B. The beach volumes show logical and conceivable beach volumes over the majority of frontages and time scales. This provides confidence in both the methodology for calculating the volumetric change and the methodology for calculating the beach volume.

Table 4-3 Beach Volumes

	BEACH VOLUME (m3)												
	2012	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**1930**	**1910**	**1890**
NORTHERN SEA WALL	816,626	816,868	815,040	815,063	819,466	817,025	827,003	835,694	825,294	823,972	401,938	690,007	1,178,676
BISHOPSTONE	50,032					51,034	51,545			50,591	127,960	162,440	196,857
HERNE BAY	558,522	563,317	554,415	551,348	560,150	560,237	569,295	569,620	571,957	564,946	739,920	754,673	751,661
SWALECLIFFE	179,826	178,430	174,029	174,099	175,912	179,511	180,397	179,012	179,107	175,172	439,362	798,111	904,304
TANKERTON	573,816	574,907	573,269	577,771	579,556	585,369	591,796	592,150	593,723	550,263	356,316	476,514	405,806
WHITSTABLE	354,022	355,004	349,050	350,817	350,669	350,434	291,259	294,236	293,074	295,406	152,900	152,574	182,046
GRAVENEY	323,173	323,844	311,307	318,982	317,168	315,331	323,511	323,304	324,182	320,207	565,774	694,057	559,113

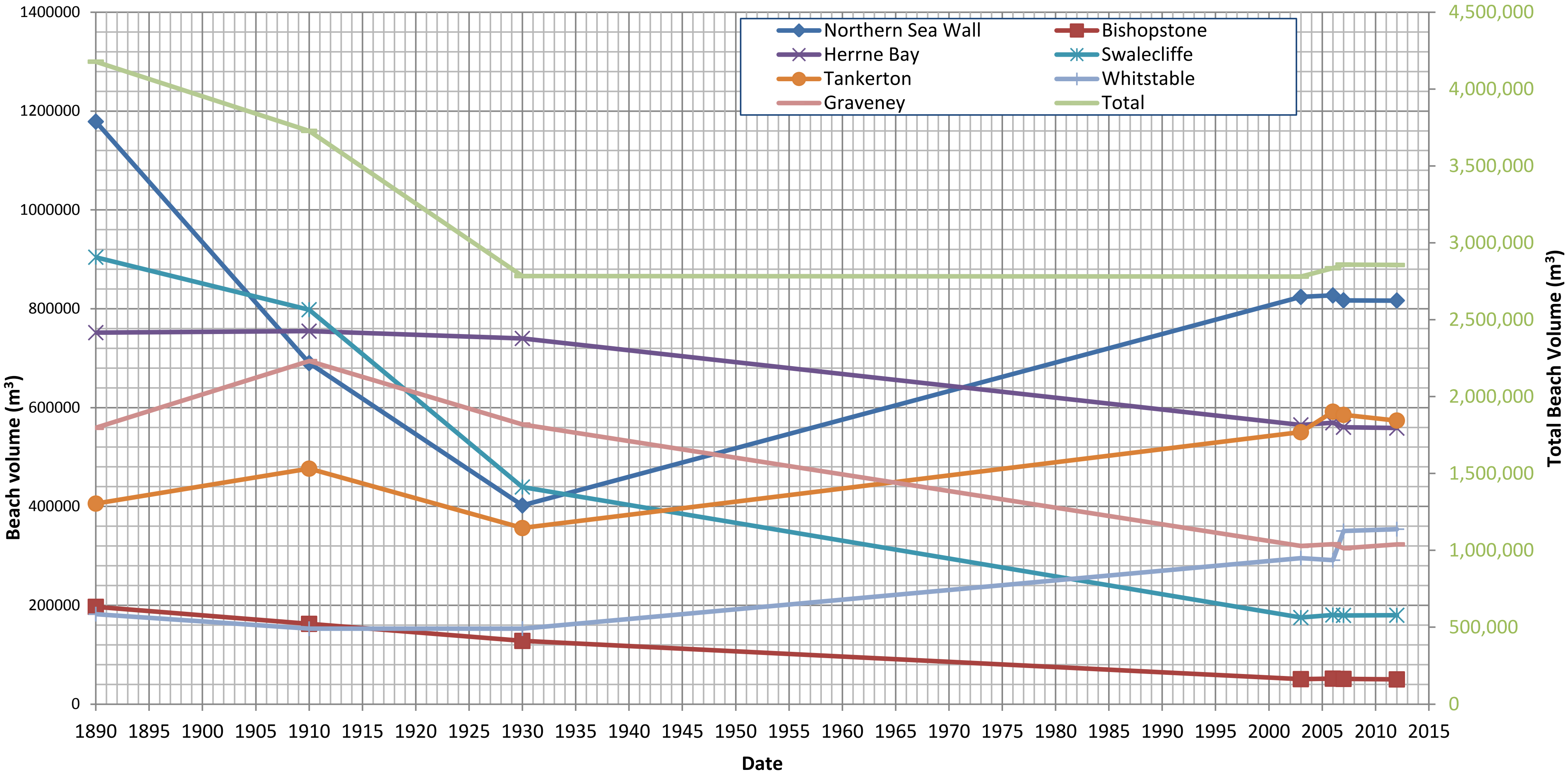


Figure 4-11 Comparison of beach volumes since 1870

Figure 4.11 has been provided to show the relative changes in total beach volume over a longer period of time. This helps to put the more recent volumetric changes explored through the contour plots and sediment budgets into perspective. Taking Swalecliffe as an example, it shows that the recent gain of material is fairly insignificant in relation to the long term trend over the past 100 years.The large loss in volume between 1890 and 1930 could be a result of the beaches of the North Kent being used as a source of aggregate for the cement industry in the late 19th century.

4.5 Historic Volumetric Change (Level 4)

The historic beach volumetric change has also been provided to help place the most recent changes and sediment budget interpretations into the context of a longer time scale. Stive *et al*. (2002) identified that the spatial and temporal scale of an analysis are interlinked. When looking over very small timescales, a very fine spatial analysis is possible. As the analysis of historic beach change is over multiple decades, it is unfeasible to view beach volumetric changes on a small spatial scale (Stive *et al*., 2002). Therefore, analysis of historic beach volumetric change has been undertaken at Level 4 as the most appropriate spatial scale to the temporal period of the analysis.

Table 4-4 Historic beach volumetric change since 1890

		Volumetric Change (m3)							**Total Change (m^3)**
		Northern Sea Wall	**Bishopstone**	**Herne Bay**	**Swalecliffe**	**Tankerton**	**Whitstable**	**Graveney**	
1910-1890	Change	-488,669	-34,417	3,012	-106,193	70,708	-29,472	134,944	-450,087
	Annual Change	-24,433	-1,721	151	-5,310	3,535	-1,474	6,747	-22,504
1930-1910	Change	-288,069	-34,480	-14,753	-358,749	-120,198	326	-128,283	-944,206
	Annual Change	-14,403	-1,724	-738	-17,937	-6,010	16	-6,414	-47,210
2003-1930	Change	422,034	-77,369	-174,974	-264,190	218,689	142,506	-245,567	21,129
	Annual Change	5,147	-944	-2,134	-3,222	2,667	1,738	-2,995	258

The annual rate is provided to place volumetric changes into perspective. This assumes a linear rate of change between the known beach volumes which is a significant and erroneous assumption. Consequently, no analysis of annual rates of change is undertaken in the following pages. The analysis of beach volumetric changes since 1890 seeks to justify the figures provided in Table 4.4, rather than explain why those changes occur which was deemed to be outside the scope of this report.

4.5.1 Northern Sea Wall

Northern Sea Wall gained ~420,000m^3 over the 90 years from 2003-1930, although this followed a ~775,000m^3 loss between 1890 & 1930. Despite uncertainty about volume changes for most of that period, much of this increase can be attributed to the 1995-1996 capital scheme that saw the rock groyne field constructed and replenishment of 110,000m^3. In general, the beach has advanced seaward along the majority of its length. The exception to this is at the central lagoon, just east of Coldharbour Outfall where what was a slight beach headland has moved back in line with the modern-day seawall (Figure 4-12). Between 1890 & 2003 the crest and beach face retreated by up to 70m. The shingle ridge that separates the lagoon from the sea is susceptible to erosion, which would suggest this is a continuing long-term problem.

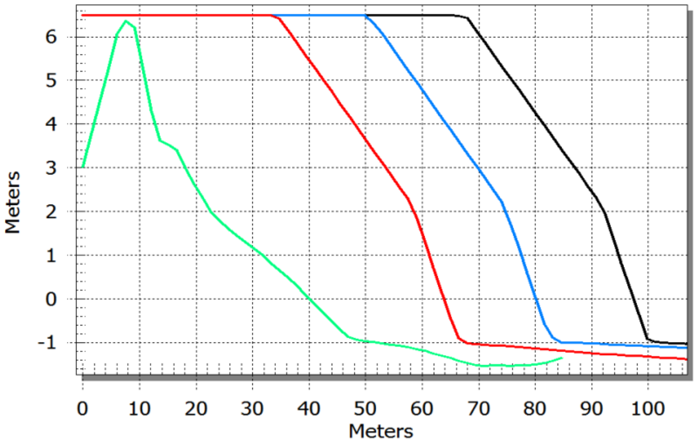


Figure 4-12 Cross section through DTM's in Northern Sea Wall in 2003 (green), 1930 (red), 1910 (blue) & 1890 (black)

4.5.2 Bishopstone

Since 1890, Bishopstone has lost ~150,000m³. The most significant retreat of the cliffline, and hence the beach, occurred to small headland to the east of the Coastguard Lookout, as shown in Figure 4-13. This is also evident, although not as clearly, when comparing the photographs in Figure 4-14, where the cliffline in the distance seems to be flatter in plan-form in 2008 than 1930.

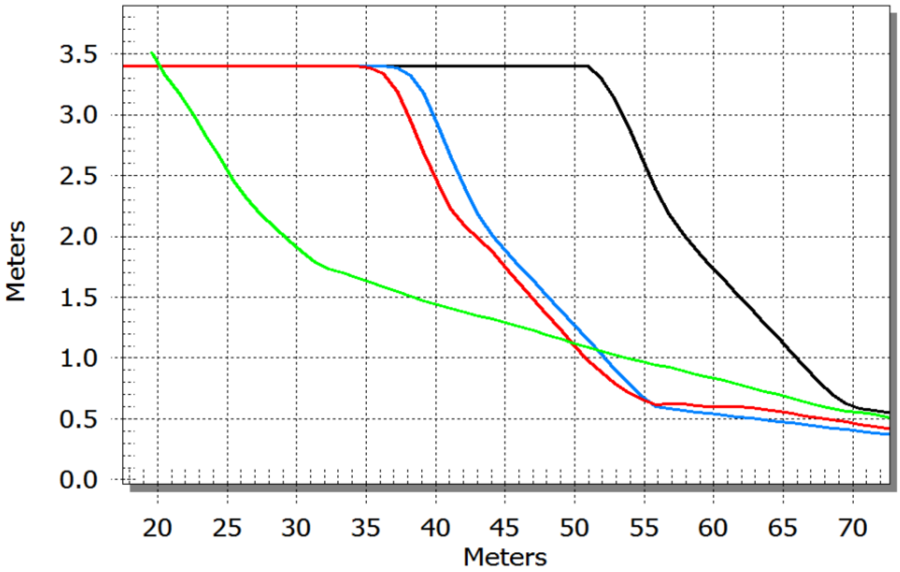


Figure 4-13 Cross section through DTM's in 2003 (green), 1930 (red), 1910 (blue) and 1890 (black) at Bishopstone

Figure 4-14 Bishopstone in c.1930 (left) and 2008 (right).

4.5.3 Herne Bay

Herne Bay also lost material, ~190,000m^3 between 1890 and 2003. This material was mostly lost between Hampton and the Pier, and between what is now Neptune Arm car park and Beltinge cliffs. However, the area around the Pier has experienced accretion, as a result of the construction of the Neptune Arm and enlarging the beach in front of the bandstand. This is illustrated in Figure 4-15, which shows that between 1910 & 1930 the beach was eroding back to the seawall. However, with the recharge as part of the Neptune Arm scheme, the beach is now seaward of the 1910 levels. Accretion has also occurred at the mouth of Bishopstone Glen.

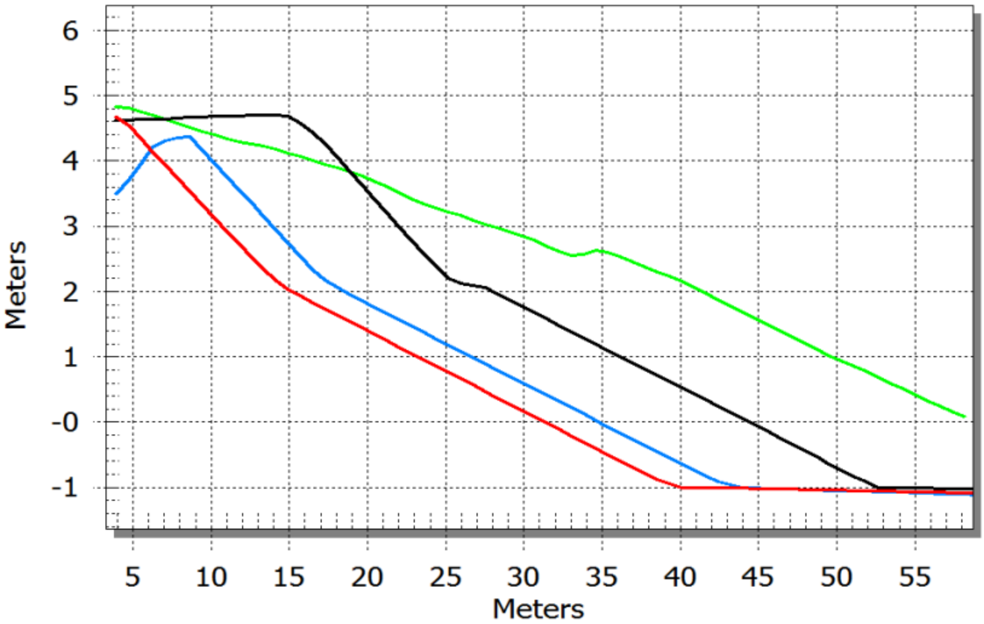


Figure 4-15 Cross sections through Herne Bay DTM's in 2003 (green); 1930 (red); 1910 (blue); and 1890 (black)

Figure 4-16 Herne Bay in 1890 (top left), 1922 (bottom left) and 2008 (right) showing the area around the Bandstand before and after the construction of Neptune Arm.

4.5.4 Swalecliffe

Swalecliffe experienced the greatest net loss of beach material between 1890 and 2003 (~730,000m^3) over the 130 year period. The entire beach has moved onshore over the past 102 years, particularly at the eastern end. This is illustrated in Figure 4-17, showing that since 1890 the crest has retreated ~180m. This is likely caused by the erosion of soft cliffs at Studd Hill (Figure 4-18), which are now largely gone. The frontage has now been stabilised by a concrete seawall and timber groyne field. The only area of accretion is the offshore bank, which is not included in the volume calculations due to its offshore position.

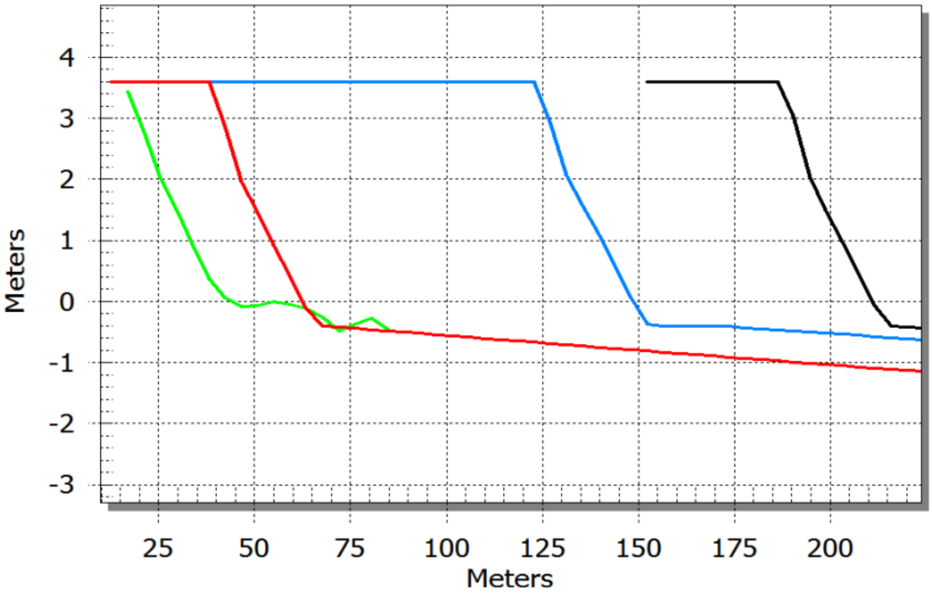


Figure 4-17 Cross sections through Swalecliffe DTM's in 2003 (green); 1930 (red); 1910 (blue); 1890 (black)

Figure 4-18 Swalecliffe prior to the construction of a seawall (probably pre-1900) and in 2010

4.5.5 Tankerton

Since 1890, the Tankerton frontage has alternated between erosion and accretion. Between 1890 & 1910 it gained ~70,000m^3, but between 1910 & 1930 the frontage lost ~120,000m^3. This was followed by an increase in beach volume of ~200,000m^3 by 2003. By the present day the coastline is fixed in place by a concrete seawall and timber groyne field, apart from the spit at Long Rock (Figure 4-20). This is still relatively mobile, with erosion on the northern edge, and accretion at the western end of the spit. Figure 4-19 illustrates a profile through the northern side of the spit, showing how it has consistently retreated since 1890, a total of ~50m although the crest has increased in height by ~0.75m,

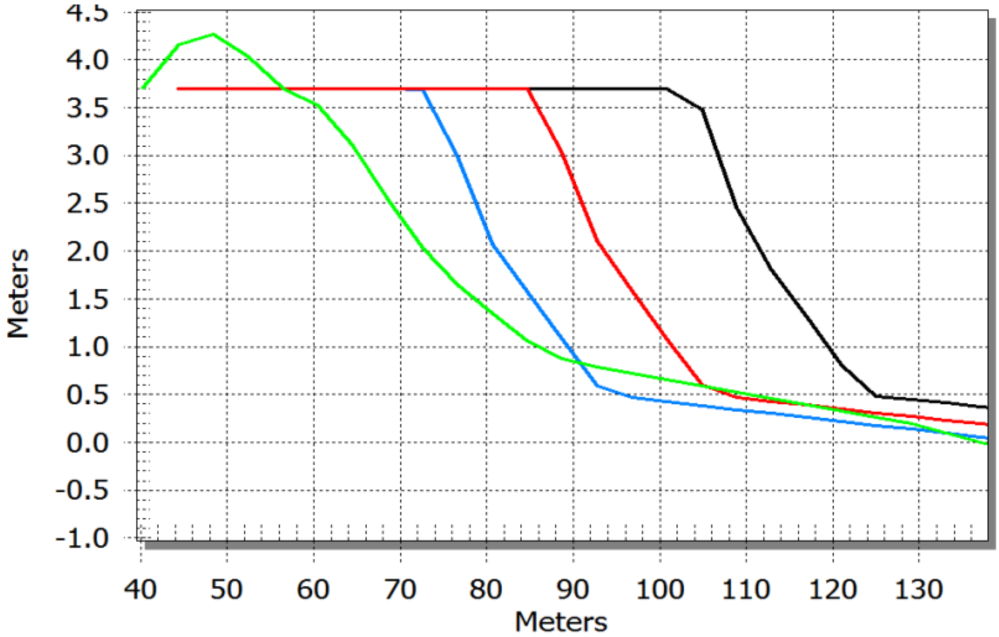


Figure 4-19 Cross sections through Tankerton DTM's in 2003 (green); 1930 (red); 1910 (blue) and 1890 (black)

Figure 4-20 Tankerton in 1890 (top left), and 2011 (right), and Long Rock (bottom left)

4.5.6 Whitstable

Like Tankerton, Whitstable is unusual for this sediment budget in that it has experienced a net accretion between 1890 & 2003. However, between 1890 & 1910 the frontage lost ~30,000m^3, although the frontage stabilised between 1910 & 1930 (it only gained 300m^3). However, from 1930-2003 the frontage gained ~140,000m^3, probably the result of the 100,000m^3 recharge that occurred as part of the 1989 capital scheme. Since 2003 the beach has continued to increase (net) in size with a 60,000m^3 recharge as part of the 2006 capital scheme. However, there are some areas that historically have continually eroded over time, such as at Preston Parade, illustrated in Figure 4-21. Like Studd Hill in Swalecliffe, this is an area of soft cliffs, which until stabilised have experienced erosion, in this case causing the crest to retreat 60m since 1890.

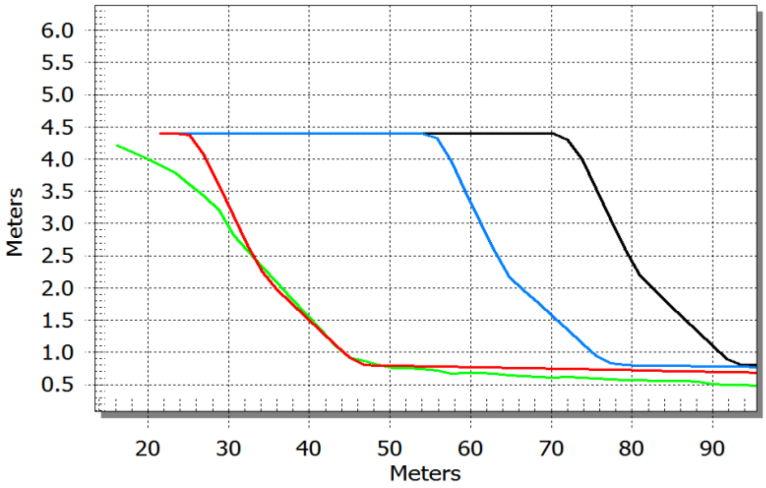


Figure 4-21 Cross section through Whitstable DTMs in 2003 (green); 1930 (red); 1910 (blue); and 1890 (black)

Figure 4-22 Whitstable in 1930 (left) and 2008 (right)

4.5.7 Graveney

Graveney has shown variable beach change since 1890. Between 1890 & 1910, the frontage gained ~135,000m^3, but from 1910 – 2012 has lost ~370,00m^3. In general, erosion and accretion occur along the whole frontage, with only the eastern end showing consistent change (accretive) since 1890. Castle Coote spit (Figure 4-24, at the western end of the frontage) also experienced accretion between 1890 & 2003, suggesting that the spit is extending westwards. A typical profile is shown in Figure 4-23, showing accretion from 1890 -1910, and erosion since then to 2003.

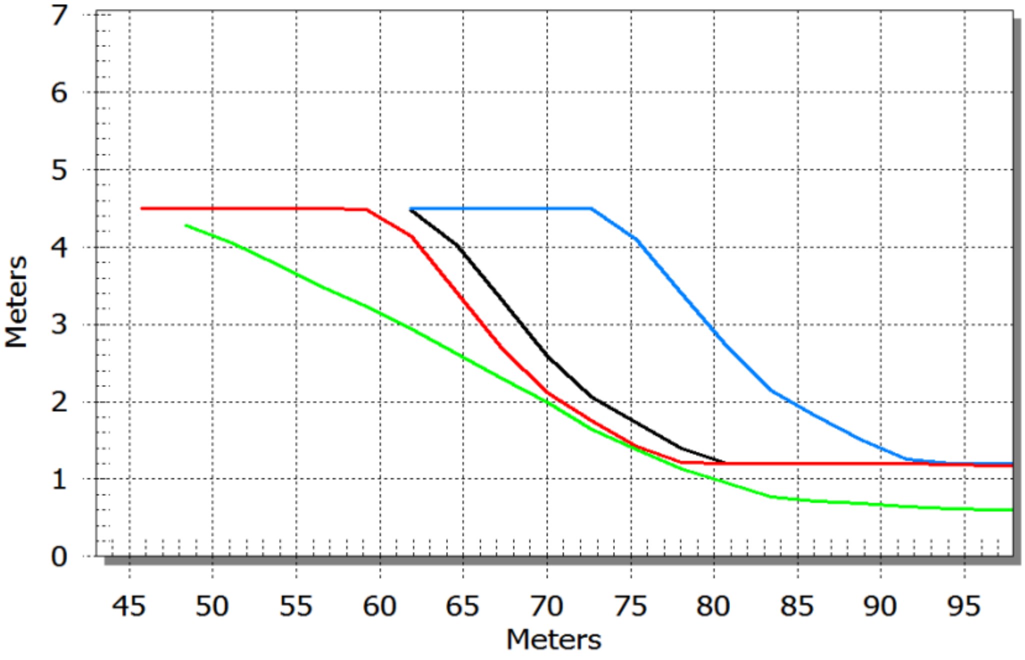


Figure 4-23 Cross section through Graveney DTMs in 2003 (green); 1930 (red); 1910 (blue) and 1890 (black)

Figure 4-24 Graveney in 1930 (top left) and 2011 (top right), and Castle Coote spit in 2008 (bottom)

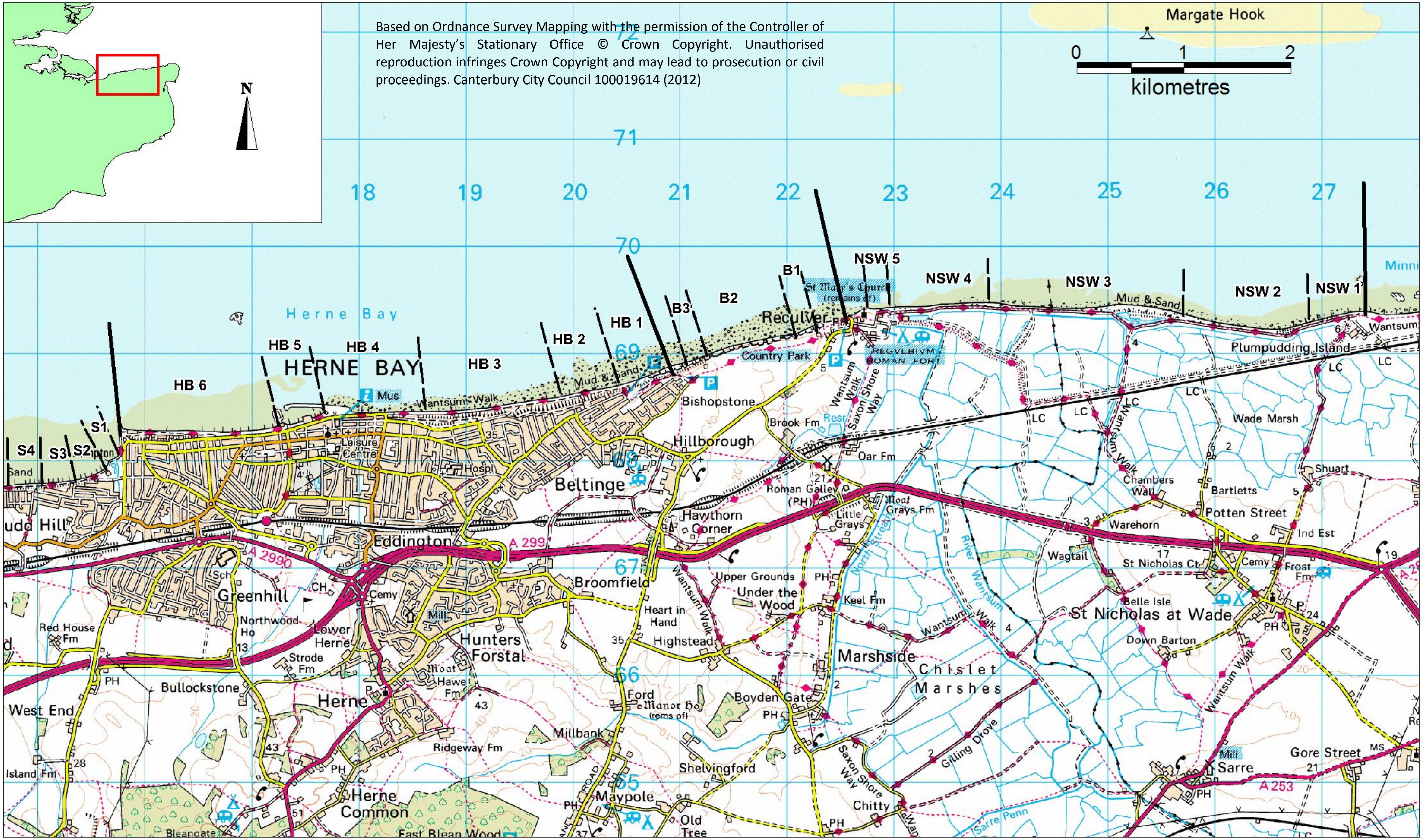
5.0 Available data

The data that can be provided with regards to the above analysis is shown in the table below. The data will be provided in CD format when the report has been finalised.

Table 5-1 Available GIS data

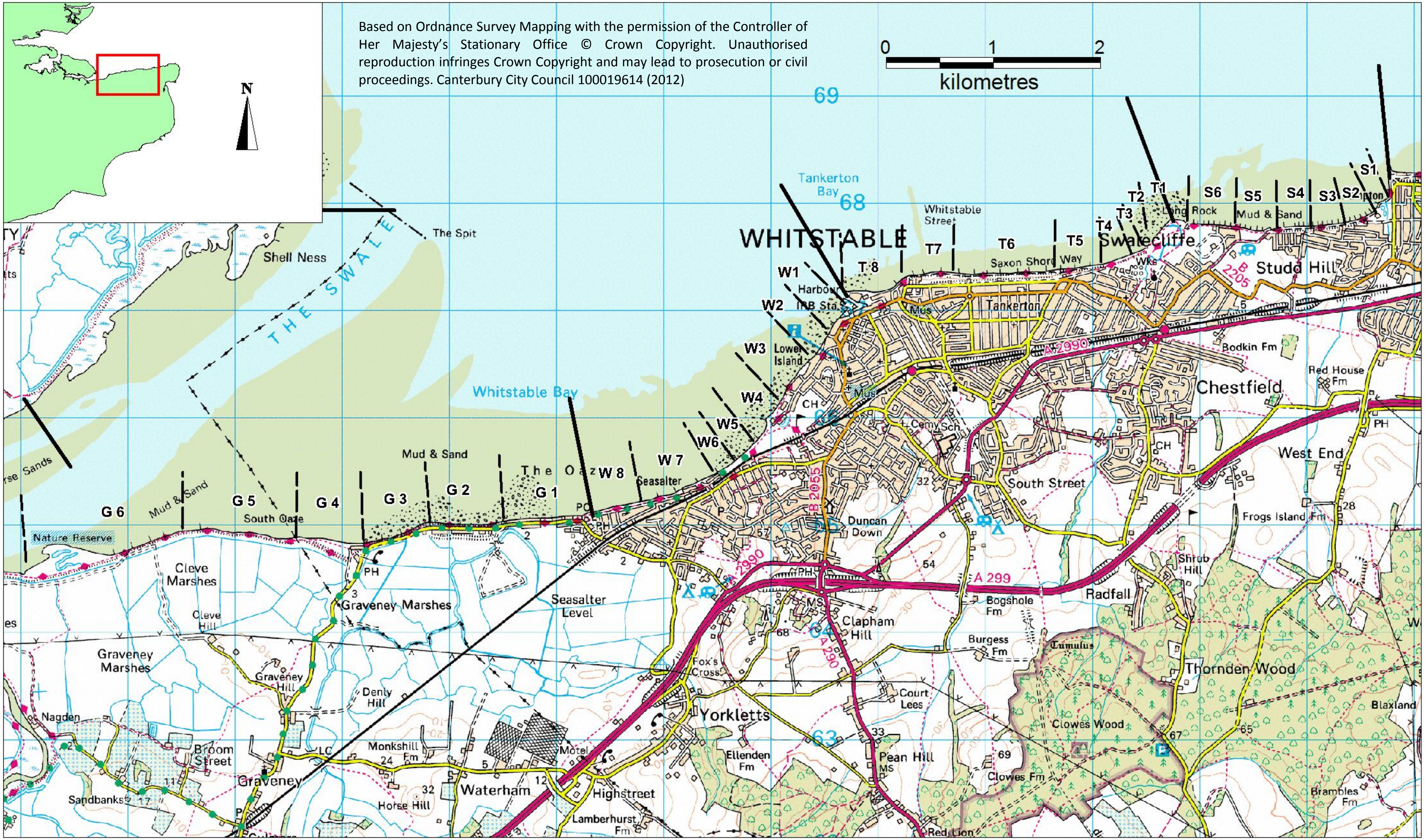
Data	**Type**	**Description**
GIS (1)		**AVAILABLE FROM CANTERBURY CITY COUNCIL**
	DTMs	2012 -2003 DTMs for all frontages
	Difference Models	For all frontages
	Analysis Polygons	Level 1 - 50m length
		Level 2 - SRCMP Polygons
		Level 3 - Coarse Polygons
		Level 4 - Regional Polygons
	Historic	Historic feature lines for all frontages
		Historic DTMs for all frontages in 1890, 1910 and 1930
		Historic difference models, 1910-1890, 1930-1910, 2011-1930
	Sediment Budget	Polygons as above
		Level 3 sediment movements
		Level 4 sediment movements
GIS (2)		**AVAILABLE FROM THE ENVIRONMENT AGENCY**
	Lidar	All available Lidar data sets
SPREADSHEETS		**AVAILABLE FROM CANTERBURY CITY COUNCIL**
	Level 1	All Level 1 data in .txt format
	Level 2-4	All levels data in .xlsx format
PLATES		**AVAILABLE FROM CANTERBURY CITY COUNCIL**
	1 and 2	All plates in .jpg format
REPORT		**AVAILABLE FROM CANTERBURY CITY COUNCIL**

6.0 Sub-cell Location Diagrams



Northern Sea Wall to Castle Coote Sediment Budget

Plate 3 (1 of 2)



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Northern Sea Wall to Castle Coote Sediment Budget

Plate 3 (2 of 2)

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