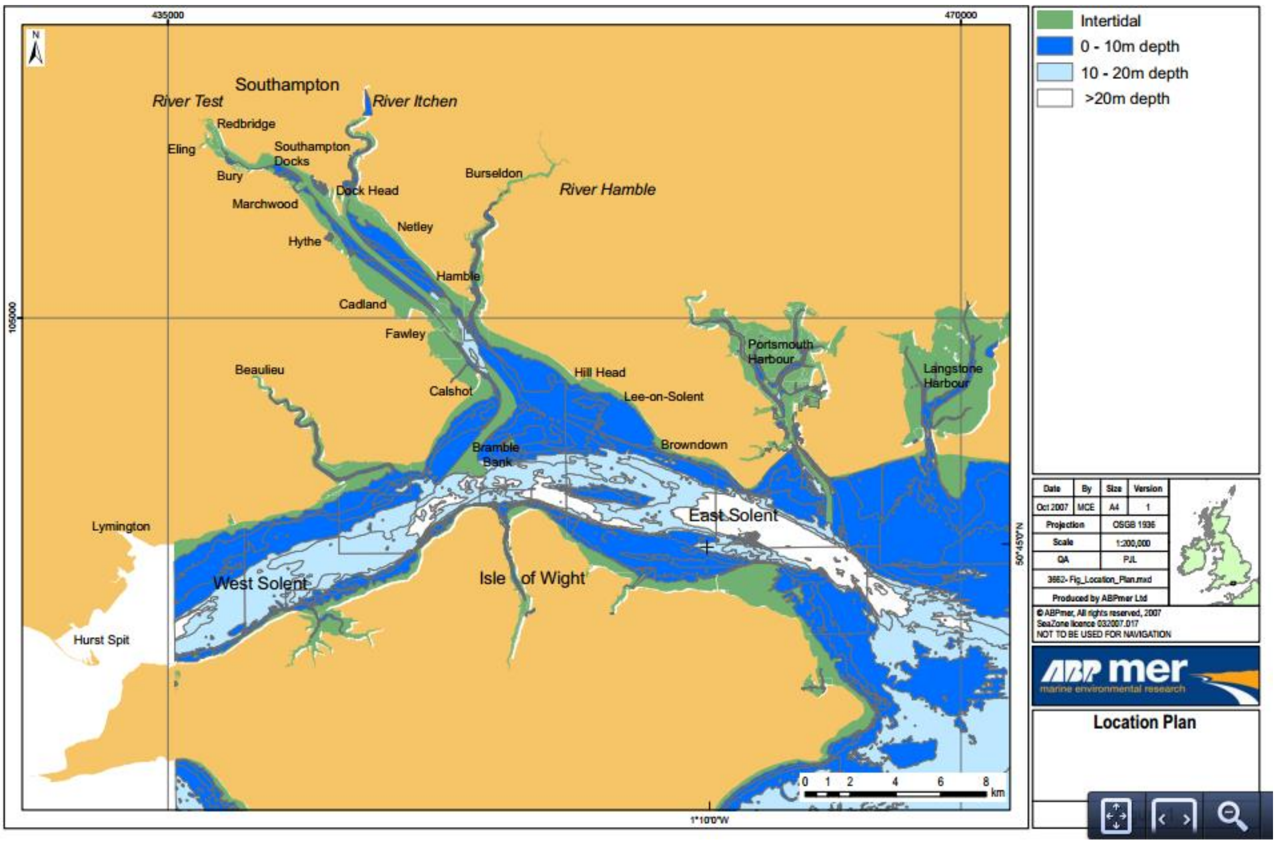
Some background notes on Southampton Water

Introduction

Southampton Water situated in central southern England houses one of the UK's premier ports. The villages, towns, and the city of Southampton, on the edge of Southampton Water, prosper due to their maritime influence, in particular the growth of the port industry. Southampton Water is situation north of the Solent – an approximately 5km band of water running between the mainland and the Isle of Wight to the south. There have been many studies of the Water, and one of the first attempts to draw information together about the Solent and Southampton Water was the *Survey of Southampton and its Region*, published in 1964 by Southampton University Press (Monkhouse, 1964). A more focussed review of the Solent as an estuarine system resulted from the ad hoc workshops that led to the series of papers compiled into NERC Report No 22 (NERC, 1980). More recently the Solent Science conference held in 1998 has provided a comprehensive up date, covering coastal processes, water quality and the local biodiversity (Collins & Ansell, 2000). Also worthy of special mention is the reflections on a lifetime's involvement in conservation around the Solent by Colin Tubbs (Tubbs, 1999). Finally, the recent continuing development of the port, has led to an extensive range of studies specifically focussed on Southampton Water (ABP, 2000). There is therefore a substantial body of research relating to the Solent and Southampton Water.

This note draws together some of the existing knowledge and findings of recent studies to present an overview of the dominant processes and the resultant morphological development. The focus is on Southampton Water, with some consideration of the three tributaries, the Test, Itchen and Hamble, Figure 1.

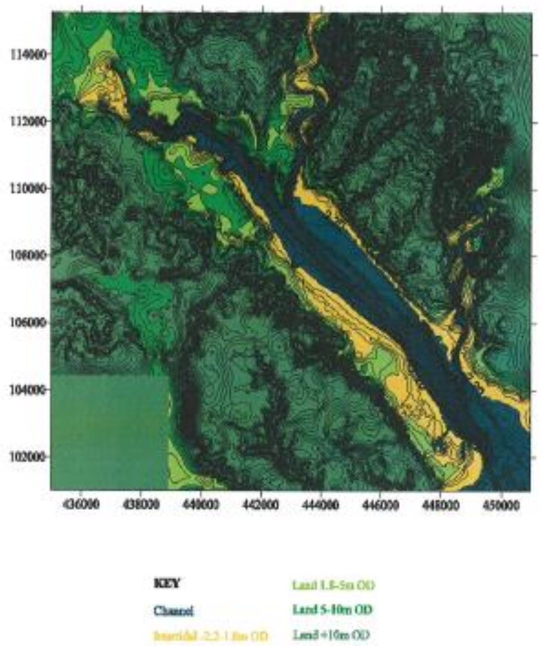
Figure 1 – Location map of Southampton Water (courtesy of ABPmer).



Estuary Characterisation

Southampton Water is a meso-tidal spit enclosed estuary, draining a catchment of about 1,500 square kilometres. From the mouth the tidal limit is about 17km in the north and the tidal range is around 4m on springs with a relatively small river flow (see Table 1 for more details). For much of its length, it has an artificially deepened channel. The present day morphology of the estuary highlights the constrained nature of the system (Figure 2). Between Calshot and Dock Head, the estuary is flanked by land, which rises rapidly from the high water mark to over +10 m ODN. The hinterland does not therefore represent a floodplain for the estuary and there is only limited scope for lateral roll back (landward movement) of the intertidal, in response to sea level rise. Upstream of Dock Head a flood plain exists in the valley bottom, with a significant area between +5 m ODN and mean high water springs (MHWS @ +1.8 m ODN).

Figure 2 – Topography of surrounding area
Source: ABP 2000



The River Test is heavily constrained by the existing developments (Port of Southampton and Marchwood) and the bridges at Redbridge. An extensive dendritic marsh system is to be found north of this area. The lower reaches of the River Itchen are also heavily constrained by a mix of waterside developments. Upstream of the Woodmill Lane Bridge, the river is more natural in form, but is still confined by housing/small industry in the west and a recreation park in the east. Only north of the M27 motorway is the river free of constraints. In much the same way, the River Hamble meanders through open countryside north of the motorway. South of it, the river has only limited hard protection to its banks, but is extensively developed with numerous marinas and moorings. Some dredging takes place within the river and in the marinas.

Table 1 - Estuary characteristics for Southampton Water

Property	**Values for Southampton Water**
Lengths	To tidal limit on R Test, 16.7 km; Itchen, 23.4 km; Hamble, 32.9 km
Areas	Cross Sectional Area @ mouth = 16500 m^2 to MTL Plan area @ HW = 3.0 x 10^7 m^2; @ LW = 1.9 x 10^7 m^2 Intertidal area = 1.1 x 10^7 m^2 Saltmarsh area = 1.9 x 10^6 m^2 (all between Calshot and Redbridge)
Volumes	Total volume @ HW = 2.2 x 10^8 m^3 Total volume @ LW = 1.1 x 10^8 m^3 Tidal prism = 1.09 x10^8 m^3 (springs); 0.54 x 10^8 m^3 (neaps)
Widths and depths	Width @ mouth = 1960 m; hydraulic depth @ mouth = 7.2 m Average width = 1480 m; average hydraulic depth = 6.2 m
Tidal levels and range	MHWS = 1.76; MHWN = 0.96; MLWN = -0.94; MLWS = -2.24 (all levels metres Ordnance Datum Newlyn at Southampton)
Freshwater flows	Average winter flow: Test=17.6m^3s^{-1}; Itchen=11.9m^3s^{-1}; Hamble=1.3 m^3s^{-1}

Geology and geomorphology

Southampton Water (along with the Solent, Portsmouth, Langstone and Chichester Harbours) lies at the centre of a large structural depression known as the Hampshire Basin. Throughout the Cretaceous Period the Solent lay beneath an extensive sea in which a large thickness of chalk accumulated. At the end of the Cretaceous Period, approximately 65 M BP (million years before present) there was a period of uplift followed by a period of down-warping which produced a smaller, shallower sea over southeast England and the eastern Channel. During the early Tertiary, sedimentation led to the infilling of this sea and the transition from marine to brackish or freshwater environments in more coastal areas. After this, there was a long phase of folding, uplift and erosion during the Neogene Period (Miocene and Pliocene Epochs, 23 to 2 M BP).

The most recent geological Epoch, the Pleistocene (2M to 10,000 BP), was characterised by alternating glacial (cold) and interglacial (warm) conditions, which were associated with low and high sea levels respectively. During periods of low sea level the valleys of the local rivers were cut below the present sea level and extensive sheets of plateau and valley gravels were deposited. The most recent warm stage began 10,000 BP and is known as the Holocene during which the Flandrian sea level rise or transgression occurred (approximately 6,400 BP). This transgression flooded the previous valleys to form the modern estuary (NERC, 1980). During this period, erosion occurred on exposed parts of coast, whilst accretion of tidal mudflats and saltmarshes occurred in areas sheltered from the prevailing south-westerly winds.

Within the Solent, sedimentation has kept pace with sea level rise and the proportion of shallow intertidal area has increased (Hodson & West, 1972). The development of Calshot Spit at the western mouth will have had a particular influence on Southampton Water. Whilst there is evidence that the spit has been in place since around 7,000 BP, the spit has not been static and has experienced several episodes of extension and breaching. Changes in the morphology of the spit, due to varying combinations of changes in sediment supply, rate of sea level rise and storm incidence will have altered the degree of protection afforded Southampton Water.

Prior to inundation by the sea after the last ice age, the Solent was a river system (Figure 3). Marine conditions are likely to have reached the outer part of Southampton Water in the early Holocene, following the rapid sea level rise around 7,000 BP. The form of the estuary and in particular its extent in relation to the tributary rivers has largely been controlled by changes in sea level. During periods of rapid rise the estuary will have widened and extended further landwards. Equally, when sea level has stood still, or fallen, freshwater wetlands have encroached on the estuary, causing substantial narrowing and shortening.

The bed of the main channel of Southampton Water downstream of Fawley is composed of Pleistocene gravels covered by thin Holocene silts and clays. Upstream of Fawley the channel cuts through the Pleistocene gravel into the laminated silts, clays and fine-coarse sands of the Bracklesham beds. Present day freshwater discharges to the system from the component rivers, the Test, Eling, Itchen and Hamble, derive primarily from chalk aquifers.

The present day morphology of the estuary highlights the anthropogenic effect of progressive development and reclamation since about 1783. Furthermore, as already noted, the constrained nature of the estuary can be seen from the topographic setting (Figure 2). In Southampton Water the intertidal zone from Highest Astronomical Tide (HAT) to Mean Low Water Spring (MLWS) covers approximately 1350 ha. Saltmarsh fringes the estuary and covers approximately 190 ha. Saltmarsh most notably occurs along the western side of Southampton Water. The eastern shore in the outer estuary is bordered by mudflats which are backed by a series of low cliffs. These cliffs are composed of fluvial terrace gravels, sands, silts and clays of the Bracklesham Beds.

Historical development in Southampton Water

The development of Southampton Water and the tributary rivers has taken place over many centuries. This development overlays much of the original geomorphological character of the estuary and has a significant influence on present day processes. An account of developments and reclamation works is given in the paper by Coughlon (1979). Using this in conjunction with City archives, port records and newspaper clippings and various books about the port, a reasonably complete account of developments can be established (although some dates remain uncertain). This is presented in terms of reclamation and channel deepening in Tables 2 and 3 (further details can be found in ABP, 2000).

Table 2 – Reclamation history

Date	Development
1890-1910	Development of Eastern Docks out over the mudflats at the confluence of the Rivers Test and Itchen.
1920s	Reclamation of some 8 ha for Marchwood Power Station and the Military Port.
1927-34	Reclamation of the Western Docks between Royal Pier (outside the De Vere) and Millbrook Point.
1920s-60s	Dredged Material has been used to reclaim approximately 80 ha of land around the Fawley Esso Oil Refinery, the majority of which took place in the early 1960s.
1930s-70	Maintenance dredge spoil used to reclaim Dibden (north of Marchwood) in four stages: Phase 1 – 1930-55; 36 ha Phase 2 – 1956-60; 40 ha Phase 3 – 1960-62; 36 ha Phase 4 – 1962-70; 64 ha
1950-51	Fawley Power Station reclamation using material from dredging of Calshot approaches to reclaim some 46 ha.
1967-68	Western Dock extension scheme, Phase 1 for 201 Berth reclaimed 6 ha.
1970-72	Phase 2 of Western Dock extension scheme created Berths 202-205 by reclaiming 32 ha.
1972-75	Phase 3 for Berth 206 involved reclaiming 45 ha.
1995-96	Berth 207 construction was completed

Table 3 – Channel deepening

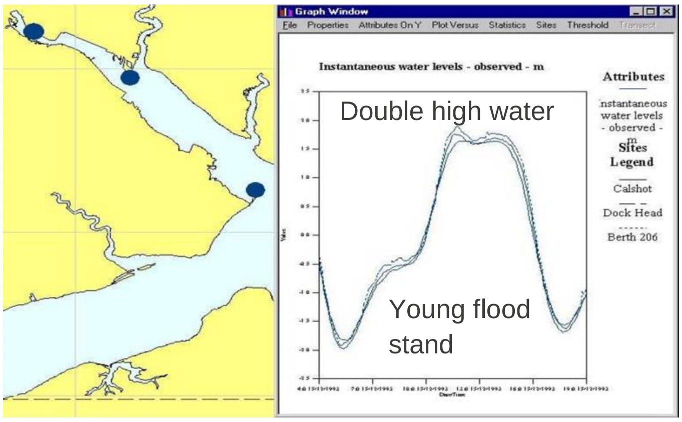
Date	Development
1882	Southampton Harbour Board was empowered by Act of Parliament to deepen approach channels, Netley Shoal and Test Bar. Channel dredged to 7.4 m below CD in 1889 from Fawley to the docks.
1893	Dredged channel depth increased to 8.6 m below CD.
1907	Dredged channel depth increased to 9.3 m below CD to accommodate new liners. Length of dredged channel extended.
1922-27	Continuous operations to widen and deepen stretches of the channel between Fawley and the Docks and from Calshot out towards Brambles Bank (a sandbar in the centre of the Solent).
1931	Project to widen channel to 305 m and deepen reach below Calshot to 11.1 m below CD. From Calshot to the Docks channel was dredged to 10.2 m below CD.
1951	The largest single dredging contract at the time was awarded to The Dredging and Construction Company Ltd, to remove 2,900,000 m^3 of material by: (i) straightening the western channel; (ii) restoring a portion of the Calshot channel to 11.1 m below CD; (iii) cutting off a portion of the bend around Calshot Spit; (iv) restoring a depth of 10.2 m below CD throughout the main channel from Calshot to the Docks, including the middle and lower swinging grounds, and widening the channel to 610 m.
1960s	Deepening in the area of the Thorn Channel (running SW to NE parallel to Calshot Spit) to 12.6 m below CD.
1973-78	Deepening in vicinity of the Container Port.
1996-97	Approach channel between Fawley and the container terminal deepened from 10.2 m below CD to 12.6 m below CD

Note: Chart Datum (CD) is –2.74 m below ODN

Estuary processes

Tides

Figure 3 – Water levels for spring tide at Dock Head
Source: ABP, 2000



The tidal characteristics of the English Channel are the controlling factor for tides in the Solent. Low water at Penzance, Cornwall, south-west England occurs at approximately the same time as high water in the eastern reaches. This indicates that there is a degree of resonance within the channel; the natural period of the channel being approximately 10 hours (Webber, in NERC,1980).

The structure of the tides in the Channel, and the resonance in particular, produces rapid increases in the tidal range close to the Isle of Wight. This is very apparent from the Nab Tower (in the east) to Christchurch Bay (in the west) (where the range doubles in a distance of approximately 80 km) and also within the Western Solent where major changes occur over about 16 kilometres. To the west of the Solent (inland of Weymouth) is an amphidrome for the main tidal constituent. Close to the amphidromic point, this semi-diurnal harmonic constituent is relatively weak. However, the configuration of Christchurch Bay produces strong shallow water effects, which interact with the phase of the main tidal harmonic to generate the double high water. Further east, along Spithead in the eastern Solent, the phase relationship alters slightly, resulting in an extended rather than a double high water.

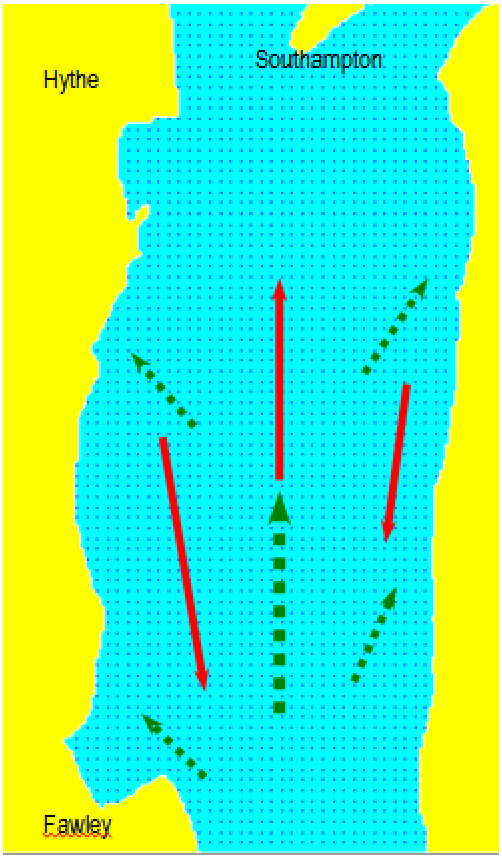
In Southampton Water the tidal characteristics are unique (Figure 3), and are described by a "young flood stand" and a double high water where there is little change in water level (lasting for up to 3 hours). The stand on the flood is most pronounced on spring tides and can last for about 2 hours. The tidal profiles are also asymmetric with the ebb phase of the tide taking about 5 hours compared to over 7 hours for the flood. The spring and neap tidal ranges experienced in Southampton Water are detailed in Table 1.

The flood tide within Southampton Water can last for up to 7.5 hours on a spring tide. High water then lasts for about 2 hours, followed by the ebb, which can be as short as 2.5 hours. The differences reflect the strong asymmetry in tidal movement in and out of the estuary, with differences in flood and ebb duration resulting in stronger currents on the ebb tide than on the flood. Peak velocities at Calshot on a spring tide have speeds of 1.0 ms^{-1} on the ebb compared to 0.7 ms^{-1} for the flood (ABP, 2000).

Within Southampton Water the tidal excursion is strongly ebb dominant but reduces in magnitude towards the head of the estuary. In contrast, the slack duration, which is the difference between the periods of still water before the ebb and before the flood shows a flood dominance until close to the head. Because of the ebb dominance in terms of tidal excursion and currents, it is likely that there is a net movement of coarse material of bed load out of the estuary.

Counteracting this export of material is a landward migration of finer sediments. The higher slack duration before the ebb than on the flood is likely to promote the settling out of fine sediment from suspension, particularly within the inner estuary. Furthermore, a hydrodynamic mechanism which can transport sediment along the intertidal zone has been identified from modelling results. This mechanism has been termed ‘flow reversal’ and occurs during the young stand and, to a lesser extent, during the double high water (ABP, 2000; Velegrakis, 2000). Over this period, momentum caries the water from the initial part of the flood upstream, such that water levels become higher upstream than at the mouth. Enhanced frictional effects over the intertidal area mean that motion is slowed more quickly in these areas and ultimately give rise to a seaward-directed flow. These return flows occur on the Hythe Marshes intertidal area, the shore between the rivers Itchen and Hamble and on the Dibden foreshore. When the flood tide resumes, the recirculation ceases and flow directions in the intertidal zone are up on to the upper intertidal areas.

Figure 4 – Tidal circulation with a reverse flow set up during the young stand and the double high water. Red arrows indicate recirculation at time of the young stand. Green arrows show direction as flood resumes.
Source: ABP, 2000



This is shown in Figure 4, where the red (solid) arrows show the recirculation that takes place at the time of the young stand, causing sediment to settle in the null zones between opposing flow directions. The green (dashed) arrows show the flow directions as the flood resumes, moving any sediment available shoreward, over the intertidal areas. In the area between the opposing flows is an area of slack water where sediment can settle out. As the flood resumes, this material is picked up and moved on to the intertidal flats and saltmarsh (if water levels are high enough). The slack at high water also means that this sediment has time to settle out, with little opportunity for re-erosion, on the following ebb, because of the fall in water level.

Winds and waves

The wave climate is relatively mild because of the orientation of the estuary and sheltering by the Isle of Wight, which limits exposure to prevailing south-westerlies, and the limited distances (fetches) over which waves can be generated. A wind rose which describes the wind climate is shown on Figure 5.

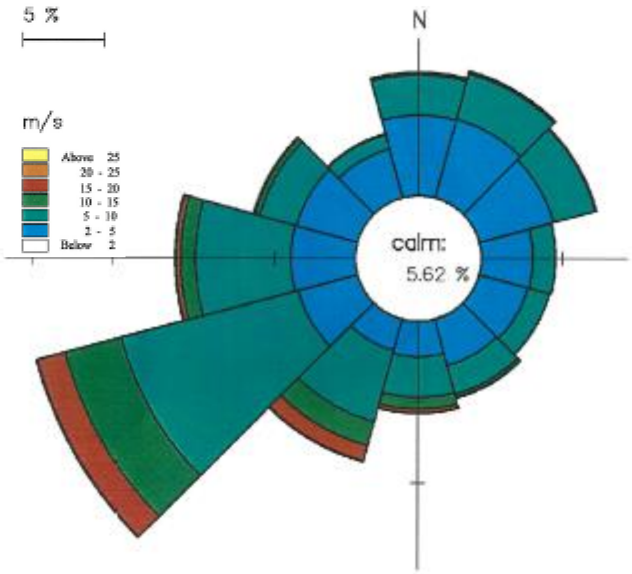


Figure 5 – Wind rose recoding speed (recorded at Lee-on–the-Solent)
Source: ABP, 2000

Over a period of years wave heights were monitored at Lee-on-the-Solent and it was calculated that the maximum significant wave height during the peak autumn and winter months was of the order of 1.2 m (NERC, 1980). In Southampton Water no direct wave measurements have been made. Estimates based on numerical predictions suggest a 1 in 1 year significant wave height of 1.2 m and 1 in 10 year value of around 1.5m. Within Southampton Water wave energy will be greater on the Netley (eastern) shore because it faces the prevailing wind direction, whereas the Hythe to Calshot (western) shore is usually sheltered because it is in the lee and the prevailing winds blow away from it.

Within Southampton Water vessel wakes also provide a significant source of wave energy at the shoreline. A detailed study of ship wash was undertaken on the Hythe foreshore in 2001 (ABP, 2000). This allowed the total energy arriving at the Netley and Hythe shore due to wind waves and vessels to be compared, Table 4.

The difference between the two shores reflects the relative shelter from wind-waves afforded to the Hythe shore. As a result ship waves make about an 8% contribution to the overall wave energy on the Netley shore but about a 41% contribution on the Hythe shore. However, the total energy on the Hythe shore remains about four times less than the energy incident on the Netley shore.

Table 4 – Comparison of energy from wind and ship waves.

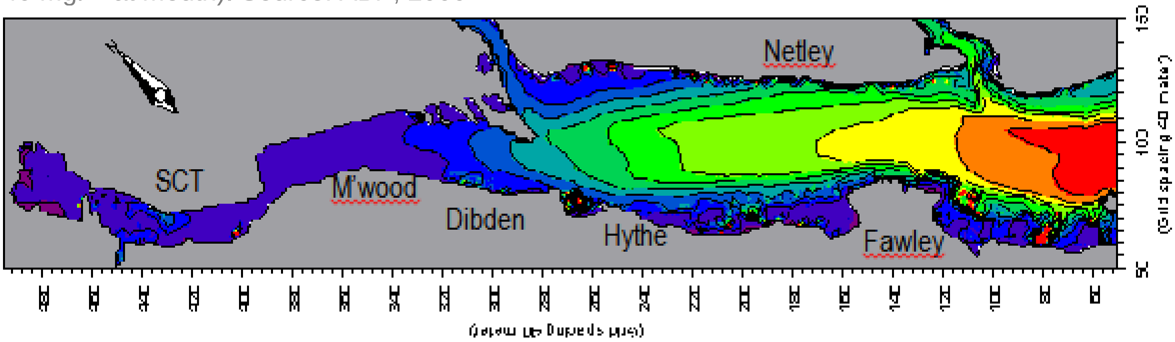
Location	Incident Energy			Ratio
	Wind	Vessel	Total	(W:V)
Mid channel	3.9E+09	3.1E+09	7.0E+09	100 : 82
Netley	4.4E+09	4.0E+08	4.8E+09	100 : 9
Hythe	7.7E+08	5.4E+08	1.3E+09	100 : 70

These studies also noted the significant inter-annual variability in the wave climate. Two wind data sets were used, these covered the periods, 1984-91 and 1988-97. This revealed an increase in wave energy on the Hythe shore of 17% between the two intervals, which was attributed to the increasing prevalence of easterlies in the more recent interval.

Sediment Budget

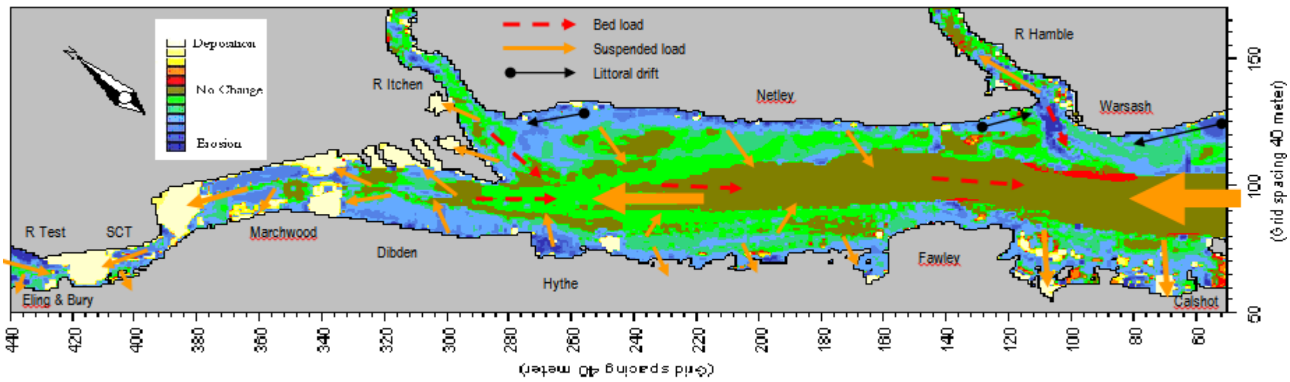
The levels of suspended sediment in the water column exhibit a density gradient along the length of Southampton Water, Figure 6. A clear sub-division can be seen, above and below Dock Head, which is also evident in the plot of peak bed shear stresses. We have, in effect, the Solent as a large reservoir of suspended sediment and the heads of the rivers supplying very little suspended sediment. The process of advection-diffusion draws sediment into the estuary and gives rise to the observed gradient. This gradient exists from Calshot to Fawley, flattens between Fawley and Hythe (note the reduced number of contours over this reach in the plot below) and then steepens again between Hythe and Marchwood. Suspended sediment concentrations fall off rapidly within Southampton Water, from an average level of around 40 mgl^{-1} at the mouth, concentrations fall to around 10-20 mgl^{-1} at Dock Head and as low as 5-10 mgl^{-1} in the vicinity of the container terminal. Fluctuations in fluvial inputs can thus make a significant difference to suspended sediment concentrations towards the head of each river.

Figure 6 – Suspended sediment concentrations in Southampton Water (contour intervals of 4 mgl^{-1} with ~40 mgl^{-1} at mouth). Source: ABP, 2000



Erosion rates within the estuary have been identified from a combination of historical sources and modelling approaches (ABP, 2000). Some of the model results are summarised in Figure 7 and the patterns of erosions and accretion are consistent with the historically recorded trends. Erosion is occuring along the outer estuary intertidal zone and inner estuary along the Dibden shore and deposition in the inner estuary docks and berths. In the outer estuary the analysis correctly shows deposition in the embayments at Hythe. The River Hamble shows a small net erosional tendency particularly in the lower reaches.

Figure 7 – Erosion, deposition and principle transport pathways. Source: ABP, 2000



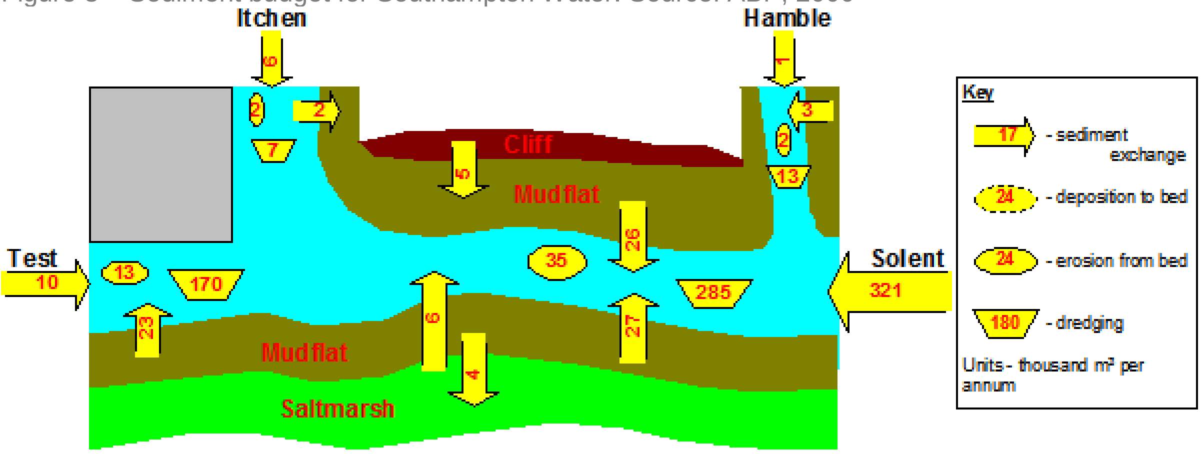
Within the Western Docks the deposition patterns are consistent with the locations which normally require to be dredged, e.g. the berths and docks around Dock Head, the container berths and Upper Swinging Ground, including the embayment associated with the Marchwood Military Port. Deposition is also shown to occur in the marina at Ocean Village (near to the city centre and Dock Head). However, deposition on the margins of the channel, downstream of Dock Head is not predicted but does occur and occasionally builds up sufficiently to require dredging in order to maintain the channel depth.

In the intertidal areas the rate of erosion is estimated at an average of about 6-7 mm per year in the outer estuary. Within the River Hamble the current average erosional rate is estimated at 0.4 mm per year. Within the River Itchen there is no discernible erosional trend.

The sediment budget for an estuary expresses the balance of sediment imports and exports. This is difficult to quantify because the net quantities are small in comparison to the gross exchanges that are taking place. Measuring fluxes, such as through the mouth of the estuary, is also very difficult and can only serve to establish the relative magnitude of the exchange.   For Southampton Water, a number of different approaches have been applied to estimate the sediment budget (ABP, 2000).

Contributions from the rivers, cliffs and saltmarshes are identified and these are combined with changes to the estuary bed. The latter are considered based on historical data (for which there is incomplete coverage) and using the model estimates. The balance of these various sources and sinks is assumed to be provided by the import of sediment for the Solent, Figure 8. Overall the rivers, saltmarsh and cliff contribute 6% of the dredged volume, the subtidal provides 7% through net erosion and the intertidal inputs 12%. The balance of the dredged volume, some 75%, must therefore be made up by marine import from the wider Solent system.

Figure 8 – Sediment budget for Southampton Water. Source: ABP, 2000



It is interesting to note that the resilience of the estuary and especially the intertidal areas is very dependent on the suspended sediments delivered to the mouth of the estuary. Much of the analysis presented above was based on a characteristic value of around 40 mgl^{-1}. This was derived from measured data and is a typical value, representative of tidal and seasonal variations. However, the mechanisms outlined for moving sediment into the estuary and maintaining a supply to the intertidal areas suggests that the system might be highly sensitive to the concentration at the mouth. A model was used to examine the sensitivity of the response for three cases, with the baseline (40 mgl^{-1}) zero and double the suspended sediment concentration (SSC) applied at the model boundary. The plots in Figure 9 show the volume changes over a year, where positive is accretion and negative is erosion.

The results indicate the interplay of three mechanisms. First the runs with no marine source highlight the relative importance of bed erosion as a source of sediment. Secondly, as the supply is increased the amount of suspended sediment moving in and out on a tide is altered. And thirdly, the concentration gradient along the estuary alters the amount of material that can settle out during times of slack water. This in turn influences how much of the material moving in and out on the tide is retained in the system.

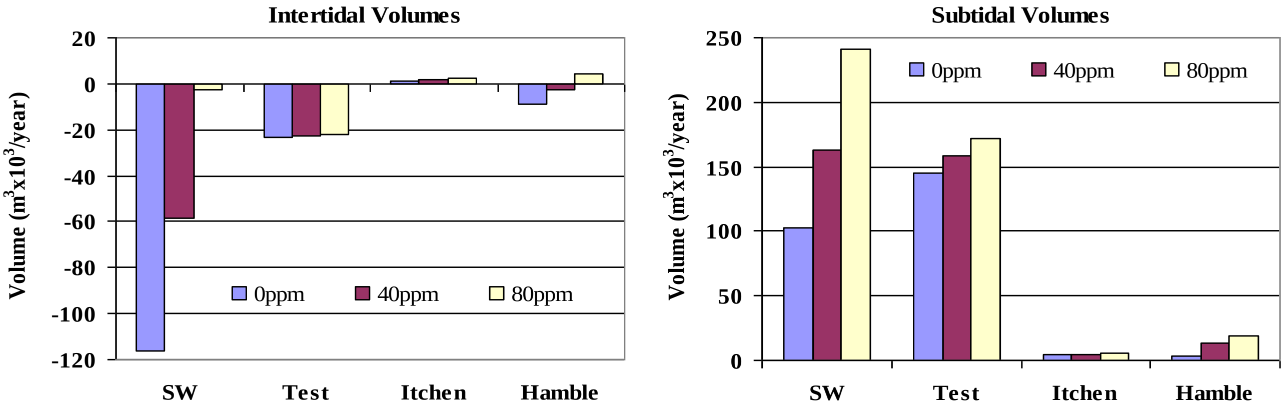
This is illustrated by considering the effect of the 1996/97 deepening of the main channel[1]. This causes an increase in the erosion of the bed (intertidal and subtidal) regardless of the marine sediment supply. As the marine supply is increased, so sediment concentrations at high water increase but are little changed at low water, suggesting that more sediment is being drawn in to the estuary and settling out. To some extent, this offsets the increase in bed erosion, at least in the subtidal. However, intertidal erosion increases, even though there are higher suspended loads over the intertidal at times of high water. The first two mechanisms therefore appear to be the main controls for the channel deepening.

Finally it is worth noting that the marine suspended sediment concentration has little influence on the intertidal and only a small influence on the subtidal in the Rivers Test and Itchen (Figure 9). However this is not the case in Southampton Water and the River Hamble, where the marine SSC significantly influences the

[1] The channel deepening increased the subtidal volume for the estuary as a whole by some 4% but had little effect on the tidal prism.

amount of erosion and siltation. Overall, the sensitivity results indicate that the marine supply has a significant influence on the patterns of erosion and deposition.

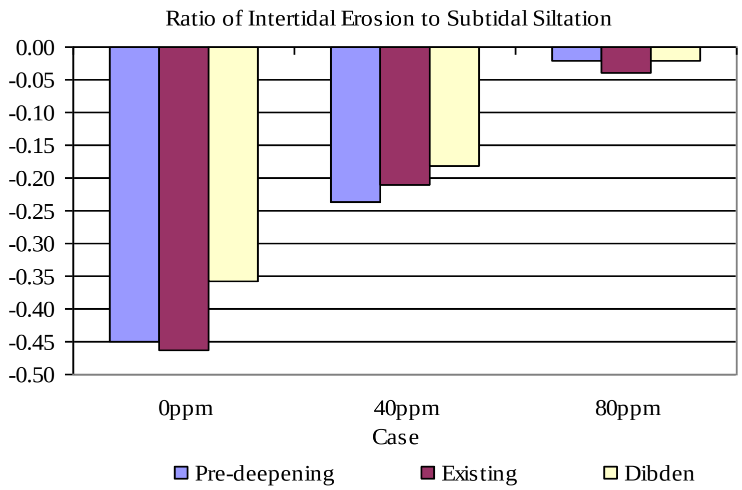
Figure 9 – Sensitivity to changes in sediment supply from the Solent. Plots show the rate of change intertidal and subtidal volumes. Source: ABP, 2000



Summing these results for the estuary as a whole, one can evaluate the relative balance of intertidal erosion and subtidal deposition, Figure 10. This illustrates how the concentration at the mouth influences the demand for sediment exerted by the main channel. With a high concentration, the demand can be largely met by sediment imported from the wider Solent. In contrast if the concentration is very low, the demand is met by increasing the rate of erosion of the intertidal. Historically, the annual erosion has been about 12% of the quantity that is dredged (which is taken to approximately equal the rate of deposition each year). The figure also illustrates how deepening the channel (pre-deepening to existing cases) and reclaiming the intertidal with some local channel deepening (existing to Dibden cases). It is also notable that a change in suspended sediment concentration at the mouth has a much greater influence than the scenarios investigated.

Figure 10 – Sensitivity to changes in sediment supply from the Solent. Plot of the balance between intertidal erosion and subtidal siltation (~=to the quantity of dredging required). For the estuary as a whole, Plotted as the ratio of erosion to siltation and negative to reflect loss of intertidal. Historical ratio was ~12%. Source: ABP, 2000

Historic value
- suggests typical ssc value is between 40-60 ppm



Summary of changes over time

The way in which the different parts of the estuary have changed over time, as well as the system as a whole, are summarised briefly in the following table.

Time Scale **Feature**	**Short-Term Change** **(Tides and Storms)**	**Decadal Change** **(10-100 Years)**	**Holocene Change** **(8000 BP-Present)**
Solent	The circulation in the Solent is complicated by the openings at Hurst Spit (to the west) and Selsey Bill (to the east), and moves around Bramble Bank. The tide throughout the system exhibits a marked surface distortion, which increases up estuary. The orientation of the system means that fetch lengths and hence waves are limited for the prevailing winds. Sedimentation concentrations are relatively low, although cliffs and intertidal areas are eroding.	The river basin as a whole will respond to the current trend of sea level rise. This will entail some form of landward transgression but the understanding of just how this scale of system will adjust remains limited. Erosion of cliffs and beaches around the margins is however likely to continue.	The estuary is part of the larger Solent River system formed during cold periods of the Pleistocene. Five phases of relative sea level change have been identified, leading to periods of shoreline advance and retreat.
Mouth	Circulation in the Solent leads to complex interactions at the mouth of Southampton Water. The mouth itself is naturally deep and Calshot Spit limits the width and offers significant protection to Southampton Water.	The spit has a substantial lobe into the Solent, which indicates a sediment sink and means that the spit is unlikely to breach in the foreseeable future.	Although Calshot Spit is thought to have existed for much of the Holocene, there have been periods of extension and breaching.
Southampton Water	Although an ebb dominant system, fine sediments are imported because of the tidal asymmetry and gradient in sediment concentration. The young stand produces flow reversals over the intertidal areas, which enhance movement of sediment up on to the upper intertidal. Prevailing south-westerlies mean that the area is relatively sheltered with slightly more energy reaching the Netley (eastern) shore than the Hythe (western) shore.	Over the long-term (200 years) the system appears to have been remarkably stable. Erosion on the intertidal has been more marked in recent years and contributes, along with the marine input, to the siltation in the inner sub-tidal. Saltmarshes in the estuary expanded rapidly in the late 19th century and have been eroding since the 1940s. The rate of loss appears to be reducing.	Siltation has kept pace with sea level changes, with extent and character of intertidal changing to reflect exposure (e.g. extent of protection afforded by Calshot) and the prevailing climate.

Time Scale Feature	**Short-Term Change (Tides and Storms)**	**Decadal Change (10-100 Years)**	**Holocene Change (8000 BP-Present)**
Rivers: Test Itchen Hamble	Relatively low flows at about 1% of the tidal prism and importing only a small amount of sediment. This may increase during periods of high flow, or the density effects may be causing a greater proportion of the marine supply to be deposited.	Climate changes (particularly rainfall) and developments within the catchment will alter the run-off characteristics. Flow and sediment inputs are however likely to remain small. Increased freshwater flow may increase the importance of stratification and density currents.	Probably freshwater marsh systems during the early Holocene, and have oscillated between marine and freshwater conditions over the last 6,000 years 6-5,000 BP-> marine 5-4,000 BP -> freshwater 4-3,000 BP -> marine 3-1,500 BP-> freshwater 1,500 - present -> marine

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Also see www.estuary-guide.net for a more complete case study of Southampton Water

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