

Appendix 2:

Extracts from Standing Conference on Problems Associated with the Coastline
(SCOPAC) (2004), "Sediment Transport Study"



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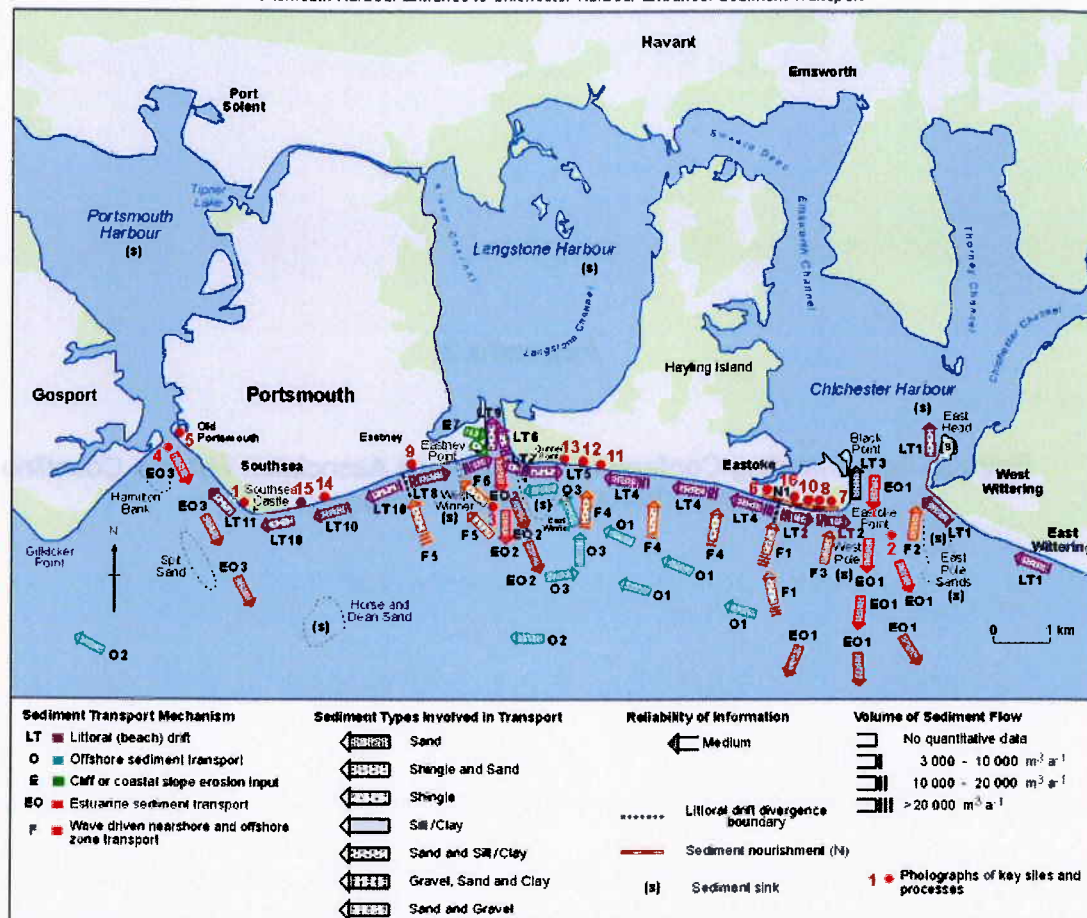


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Appendix 2 – Extracts from the SCOPAC “Sediment Transport Study” 2004

<http://www.scopac.org.uk/sedimenttransport.htm>

Portsmouth Harbour Entrance to Chichester Harbour Entrance: Sediment Transport



4.2 Estuarine Outputs - EO1 EO2 EO3 References Map

The narrow entrances of Portsmouth, Langstone and Chichester harbours confine the tidal flow of large volumes of water into and out of the harbour, thereby setting up strong tidal currents which extend several kilometres offshore. Residual current speeds are in the order of $0.15-0.16\text{m.s}^{-1}$. Analysis of tidal currents at Portsmouth Harbour (Hydraulics Research, 1959; Harlow, 1980), Langstone Harbour (Grontmij, 1973; Portsmouth Polytechnic, 1976; Harlow, 1980) and Chichester Harbour (Webber, 1979; Harlow, 1980; Wallace, 1988; HR Wallingford, 1995) reveal that the ebb current at each entrance is of shorter duration, but significantly greater velocity, than the flood current, resulting in the scour of channels to depths of up to 20m. Thus, net transport of sand and gravel entering the tidal currents is offshore and dispersal and deposition of these materials occurred as tidal currents weakened. Further details of tidal regime and current velocities are given in the separate unit covering the three harbours. Output of sediment by navigation dredging has a strong impact on the quantities moved both in and out of each entrance. This is discussed in detail in the unit on Portsmouth, Langstone and Chichester Harbour.

EO1 Chichester Harbour Entrance (see Introduction to Estuarine Outputs)

Sediment supply to the main tidal channel is possible by either eastward or westward littoral drift at the harbour entrance. (See Section 3 and the unit covering East Head to Pagham

Harbour). Sediment is supplied at rates up to $70,000\text{m}^3\text{a}^{-1}$ from East Head via the Winner gravel bank or directly from the distal end of the spit (Webber, 1979; ABP Research and Consultancy Ltd, 2000). Supply from this source has reduced significantly with the progressive and comprehensive protection of the shoreline of Bracklesham Bay since 1874 (Harlow, 1980) and has probably now virtually ceased following extension and upgrading of the groynes at West Wittering in the mid 1980s. Eastward littoral drift at Eastoke Point supplies sediment to the tidal channel at a minimum rate of $5000\text{m}^3\text{a}^{-1}$ (Harlow, 1980). Beach replenishment at Hayling Island initially enhanced eastward drift to $45\text{--}50,000\text{m}^3\text{a}^{-1}$ (Hydraulics Research, 1988), later reducing to a mean of $11\text{--}15,000\text{m}^3\text{a}^{-1}$ (Whitcombe, 1995; Havant Borough Council, 1999). Although some of this material accumulated at Eastoke Point, significant quantities were lost to the entrance channel and flushed offshore to be deposited in the tidal delta. A rock groyne and rock armouring, designed to retain sediment on the updrift beach, were completed at Eastoke Point in 1991/2. Compared with the other harbours, the entrance channel to Chichester Harbour is deeper and has higher ebb and flood tidal current velocities. Sediments entering the tidal channel are flushed offshore and deposited at varying distances from the entrance depending upon sediment size, wave conditions and water depth. Gravel can be transported a maximum of 1 to 2km offshore and sand a maximum of 3.5km offshore (Webber, 1979). Dynamic change of the plan shape of West Pole Sand since the 1960s is a result of variations in the balance between erosion and deposition (Whitcombe, 1995). Sediment sampling by Harlow (1980) revealed a series of sedimentary zones related to current velocity and suggested that wave action could mobilise surficial sediments. The volume of sediment transported offshore by tidal currents was not calculated, but fresh supply could be estimated from littoral drift inputs at the entrance, as tidal current bedload movement of sediment from within the harbour is negligible. Contemporary supply to the tidal channel consists almost entirely of eastward drift of mostly fine gravel and sand from Eastoke Point. Virtually no fresh material is now introduced into the offshore transport pathway in the tidal channel; sediments transported will be those periodically pushed onshore from the tidal delta by storms from the south. The tidal delta is therefore a finite resource and any outputs -in particular, dredging- are likely to represent a net loss to the local sediment budget. It is significant that the Winner lowered by 0.5-1.0m between at least 1926 and the present time, contributing to an increase in the pivotal movement and erosion of East Head, and thus expansion of the cross-sectional area of harbour mouth (ABP Research and Consultancy, 2000). The main channel has deepened, partly in consequence of increased tidal current scour. Whitcombe (1995) calculated that the outer Chichester bar lost some $90,000\text{m}^3$ of sand, 1989-1995. The Winner has also moved northwards in recent decades (Geosea Consulting, 2000). It is presumed that the progressive increase in the width and depth of the Chichester Harbour entrance reflects its adjustment to a more stable condition, in equilibrium with hydrodynamics and hydraulic regime. It is not clear if this has yet been fully attained (ABP Research and Consultancy, Ltd, 2000).

Further discussion, including details of dredging, is contained in the unit covering East Head to Pagham Harbour. See also the unit concerned with Chichester, Langstone and Portsmouth Harbours.

4.2 Dredging

Dredging across Chichester Bar, on the ebb tidal delta, is carried out routinely to maintain a channel for navigation; some of the material is used for beach renourishment on south-east Hayling Island. Dredging for aggregates, on a small scale on The Winner, was carried out between the early nineteenth century and about 1920. Dredging for navigation access, however, did not become significant until 1973.

A total of $600,00\text{m}^3$ of gravel was thus removed over the period 1974-1982 (Harlow, 1985) and between 1988-1996 dredging was permitted up to an annual limit of 20,000 tonnes ($12,500\text{m}^3\text{a}^{-1}$). Analysis of hydrographic surveys indicated that water depths increased over the dredged area in the 1970s (Webber, 1979). Despite this, it was difficult to attribute this change solely to dredging because the Chichester tidal delta is a large sediment reservoir (25 million m^3) characterised by major natural internal fluctuations and sediment redistribution (ABP Research and Consultancy, 2000). From bathymetric information (Posford Duvivier,

2001) it can be concluded that the Chichester tidal delta has more recently lost material due to reduction of littoral supply from Bracklesham Bay in combination with outputs by dredging. For the period 1974 to 2000 this can be estimated at 1.4 million cubic metres. This quantity is quite significant in comparison to the total estimated volume of the delta, particularly when it is considered that the bulk of output comprises gravel from the inner bar whilst much of the estimated stored volume comprises sand on the outer bar. Continued dredging and onshore feed might therefore be expected to deplete reserves, such that natural onshore feed could reduce in the near future (or may already have done so).

F1 Gravel Feed from the Chichester Tidal Delta

At Chichester Harbour Entrance ([Photo 2](#)), the ebb tidal current is of shorter duration, but significantly greater velocity, than the flood current. Net transport direction of all sediment moving into the channel is therefore offshore, thereby creating a major sediment accumulation extending 3 km to 4 km offshore (Harlow, 1980; Wallace, 1988). Its sediment volume was established at 25 million cubic metres by Webber (1979) and water depths over the delta are relatively shallow, particularly the outer and inner bars (Webber, 1979; Harlow, 1980; Wallace, 1988). Significant sorting and transport of sediments occurs on the delta by combined action of waves and tidal streams. Sedimentological analysis of the delta deposits indicate that net transport of gravel is westward, resulting in accumulation offshore West Pole (Harlow, 1980; Geosea Consulting, 2000; Whitcombe, 1995). By contrast, sand is more widely distributed both eastward and westward forming the outer bar deposits (Webber, 1979; Harlow, 1980). It has been suggested by Hydraulics Research (1980) that sand could be transported onshore from this source to feed a wide frontage on Hayling Island, extending as far west as the East Winner (ABP Research and Consultancy, 2000/2001). Conclusive evidence to support this possibility, and the volume of feed, is uncertain. Further discussion is included in the unit on Portsmouth, Langstone and Chichester Harbours, including the possible impacts of dredging in Chichester Harbour entrance channel on beach morphodynamics.

Analysis of beach volumes on Hayling Island previous to 1985 revealed a transient littoral drift divergence at, or close to, the Beach Club (Harlow, 1980; Whitcombe, 1995). Despite loss of sediment by littoral drift eastward and westward, beach levels in this immediate vicinity did not fall as dramatically as might have been anticipated. Onshore gravel feed between 6 to $13,000\text{m}^3\text{a}^{-1}$, sufficient to offset littoral drift losses, was therefore postulated by Harlow (1980). This figure probably conceals significant annual variations, for drift rates fluctuated markedly over this period. (See Section 3). Although beach levels at the Beach Club have a long history of decline, levels were particularly low over the period 1976 to 1985 and very little new material appeared to be supplied (Harlow, 1980; Hydraulics Research, 1988; Whitcombe, 1995). Thus, it appears that onshore feed declined significantly during this period (Hydraulics Research, 1988). In 1985, a 2.2km frontage between Eastoke and Sandy Point was artificially nourished with $530,000\text{m}^3$ of gravel ([Photo 7](#) and [Photo 8](#)) obtained from a source 15km, offshore Littlehampton. The recharged beach showed very variable patterns of post-project accretion/depletion (Whitcombe, 1995), but with an overall trend for depletion. These changes resulted from the lack of attainment of beach equilibrium and high initial losses due to the low permeability of recharge sediments. Some 55% of material added in 1985 had been lost offshore or downdrift by 1994 (HR Wallingford, 1993a and b; 1995). It is difficult to employ volumetric analysis of the nourished beach to determine the present status of any onshore gravel feed. Initial depletion of the nourished beach in the vicinity of the Beach Club indicated that onshore feed was significantly less than loss by littoral drift, but net drift rates increased after recharge was complete (Hydraulics Research, 1988); Whitcombe, (1995) attempted to calculate a provisional beach budget for the eastern and central sectors of Hayling beach. He calculated that onshore improvement of some $12,000\text{m}^3\text{a}^{-1}$ may substantially compensate for losses caused by longshore transport east and west of the drift divide.

Evidence for onshore gravel feed is indirect and relies largely upon beach volume analysis. Information is thus of medium reliability until confirmed by direct means e.g. tracer experiments. Analysis by Harlow, (1980) was for a representative time period (1842-1976) so

mean rates were accurately calculated. Because the analytical technique was indirect, short-term variations in supply and the exact path of transport were uncertain. Thus, when the hydraulic regime was altered in 1985 it became difficult to calculate the volume and spatial distribution of onshore transport. The post-nourishment beach profile record is now of sufficient length to allow this to be determined, though no reported research has been located.

F2 Sand Feed from the Chichester Tidal Delta to East Head

Sand deposited on the outer bar and East Pole Sands can be transported onshore by wave action to supply East Head (Webber, 1979; Harlow, 1987; ABP Research and Consultancy Ltd, 2000; HR Wallingford, 2000). The counter-clockwise circulation pattern involving material moving out of the estuary mouth along its western side and into it on the eastern margin (**Photo 2**) has been quantitatively demonstrated through sediment grain size trend analysis (Geosea Consulting, 2000; ABP Research and Consultancy, 2001). However, evidence remains indirect and is mostly based upon sampling of particle size variations over the tidal delta. As with the Winner, which is a sand and shingle bank at the harbour entrance, East Pole Sands has exhibited net erosional lowering since the late 1920s (ABP Research and Consultancy Ltd, 2000). Removal of sand by dredging from the East Winner was formerly a small scale activity, but is unlikely to be an explanation of erosional loss. The proximal sector of East Head has also diminished, with thinning and recession the dominant trend since the early 1960s (Searle, 1977; ABP Research and Consultancy Ltd, 2000, 2001). Further details are given in the unit on East Head to Pagham Harbour.

3. LITTORAL TRANSPORT - LT1 LT2 LT3 LT4 LT5 LT6 LT7 LT8 LT9 LT10 LT11 **References Map**

The transport of sediments in the beach, breaker and nearshore zones is considered to be wholly wave induced. Tidal currents in the nearshore zone have insufficient velocities to entrain any significant quantities of material. Rectilinear tidal currents at each of the harbour inlets are much more significant (Section 4.2), but their contribution to littoral transport along the intervening sectors of shoreline is unlikely.

LT1 Westwards Drift towards Chichester Harbour Entrance

This is discussed in the unit on East Head to Pagham Harbour. It is not considered that littoral transport can directly move sediment across the harbour entrance.

LT2 Eastward Drift to Eastoke Point

The 1985 beach replenishment scheme has had significant effect on littoral drift on the southern coast of Hayling Island, so information is assessed for before and after its completion.

Pre-replenishment. Littoral drift was determined by measuring beach volume changes from Ordnance Survey 1:2500 plans covering the period 1842-1972 and thereby calculating the minimum drift rate (Harlow, 1980; 1985). This approach was effective in determining a representative long-term drift rates. Analysis indicated a transient littoral drift divide approximately 100m west of the Beach Club, confirmed by site observations of sediment distribution within groyne compartments (Harlow, 1980; Hydraulics Research, 1980). The precise location of this divide at any one time (or for short periods) is determined by variations in incident waves, with wave refraction under contrasting sets of prevailing wave directions being particularly important (W.S. Atkins, 1998; Whitcombe, 1995), and on net drift rates to east and west. Net potential eastward drift was the lesser volume, and varied between $2,000\text{m}^3\text{a}^{-1}$ and $12,000\text{m}^3\text{a}^{-1}$ over the study period, with a long-term mean of $5000\text{m}^3\text{a}^{-1}$ (Harlow, 1980). Drift increased at Eastoke Point due to changed coastal orientation; Hydraulics Research (1980) suggested a mean rate of $10,000\text{m}^3\text{a}^{-1}$ for this sector.

Post-replenishment. Littoral drift rates increased by several magnitudes after replenishment for the following reasons:

- (i) Large quantities of gravel became available for transport on a beach that was previously severely depleted.
- (ii) Replenishment completely buried some existing groynes (although others were increased in height shortly after completion of the programme. Subsequently, some groynes were extended back to the pre-existing sea wall).
- (iii) The replenishment caused slight changes in beach alignment, especially at the western and eastern extremities.
- (iv) The recharge material was relatively poorly sorted and the initial artificial profile was steeper than the natural equilibrium profile. This promoted enhanced sediment mobility due to the reflective nature of this profile, and its progressive adjustment to an equilibrium form.

The replenished beach has been routinely monitored, initially by an intensive series of monthly beach profiles. These were analysed by Hydraulics Research (1987 and 1988) and littoral drift was calculated by assuming that all beach volume changes were solely the result of longshore transfers. Information from this approach may be misleading where significant onshore/offshore transport operates. Analysis demonstrates that the littoral drift divide remained in approximately the same position as before replenishment, (Whitcombe, 1995) but that eastward drift increased to $53,000\text{m}^3$ between February 1986 and February 1987 (Hydraulics Research 1987 and 1988). Further analysis of beach profiles and short-term deployment of tracing experiments using aluminium pebbles revealed that mean eastward drift over the period 1986-1990 was about $30,000\text{m}^3\text{a}^{-1}$ (Havant Borough Council, 1992b), declining to $11,500\text{m}^3\text{a}^{-1}$ between 1990 and 1991 (Whitcombe, 1995). Littoral drift was therefore initially very rapid on the replenished beach but declined as the beach approached an equilibrium. Wave refraction analysis suggests that net eastward movement is promoted by modified swell waves approaching from the south-west and, south-south west. South south-easterly and east south-easterly waves, which occur for less than 7% of the year, set up a net westward movement (W.S. Atkins, 1998). During these short periods, the littoral drift divide is probably inoperative. Groynes were constructed in between 1987 and 1991, to reduce the rate of eastwards drift and beach erosion (Hydraulics Research, 1988; Whitcombe, 1995). Havant Borough Council (1991) calculated that the prevailing drift was $13,300\text{m}^3\text{a}^{-1}$. W.S. Atkins (1998) proposed the lower rate, of $11,300\text{m}^3\text{a}^{-1}$. Thus, as expected, net eastward drift rates have declined as the beach has progressively attained morphodynamic stability.

Before implementation of the scheme, both Harlow (1980) and Hydraulics Research (1980) assessed previous experience with beach replenishment and anticipated initial losses from the nourished beach would be significantly greater than long-term rates. This was confirmed by H.R Wallingford (1995) and Whitcombe (1995) who reported that slightly more than 45% of the immediate post-replenishment volume was in place in 1994, i.e. an annual loss of $30\text{--}40,000\text{m}^3\text{a}^{-1}$. Data from W.S. Atkins (1998) and Havant Borough Council (1999) indicate a loss of $27,100\text{m}^3\text{a}^{-1}$, 1991-1998, declining from $46,000\text{m}^3\text{a}^{-1}$, 1991-94 to $25,000\text{m}^3\text{a}^{-1}$, 1996-98. This is based on regular beach topographic surveys and post-1992 data on recycling inputs. The proportion of this quantity which is lost directly offshore is not known, though there is circumstantial evidence (eg. from gravel - filled gutters across the sandy foreshore) to indicate that this process operates.

The result of rapid eastward drift since replenishment has been significant accretion at Eastoke Point, particularly of sand and fine gravel. Material has been artificially recycled from this accumulation area and replaced over the replenished beach. In January 1991, a terminal rock reinforced groyne was completed at Eastoke Point, designed to restrict littoral drift into the Chichester Harbour entrance channel, thereby facilitating retention of sediment for recycling. A rock revetment was added to the frontage of Eastoke Point in 1992 to provide further beach stability.

The Eastoke Peninsula Beach Management Strategy Plan (Havant Borough Council, 1999, 2000) proposes: (i) a continuing programme of annual gravel recycling, taking accretion excesses to areas of deficit over the existing beach; and (ii) quinquennial recharge, using material obtained by dredging the approach channel to Chichester Harbour. The initial quantity will be 50,000m³, followed thereafter by inputs of approximately 25,000m³. The major advantage of this approach is that it retains material in the local sediment transport sub-cell. Without recycling, rates of loss would probably slowly but progressively increase, to at least 30,000m³a⁻¹ by 2005 (Havant Borough Council, 1999, 2000).

LT3 Eastoke Point to Black Point (Sandy Point Spit)

Site observations indicate northward drift from Eastoke Point to Black Point (Harlow, 1980). The volume of sediment involved is probably small because wave action in the harbour entrance is relatively weak and net drift (particularly on the upper beach) is interrupted by groynes. Prior to the recharge scheme to the west, depletion at a rate of almost 8000m³a⁻¹ was indicated by beach volume analysis (Hydraulics Research, 1980; Beard, 1984) but littoral drift was probably less rapid, for some of this material was probably diverted to the tidal channel. Studies by Harlow (1980) revealed depletion of the Black Point Spit, at 1000 to 2000m³a⁻¹ between 1932 and 1967, which was preceded by accretion at 1000-5000m³a⁻¹ between 1842 and 1932. Thus it appears that potential littoral drift may be between 1000m³a⁻¹ and 8000m³a⁻¹, although transport may be effectively prevented by coast protection structures when beaches are depleted. It is unlikely that the beach replenishment scheme has had a significant effect on this coastal segment as the major area of accretion is at Eastoke Point; further downdrift transport is more likely to enter Chichester Channel, rather than along this south to north shore (Hydraulics Research, 1988). Sediment supply has been further regulated with the completion of the terminal rock groyne and rock revetment at Eastoke Point (1990-1992). Quinquennial dredging of the approach channel to Chichester Harbour will provide a small quantity of sediment for periodic replenishment, if required (Havant Borough Council, 2000). Alternatively, any surplus will be removed to Eastoke Beach. A mix of coast protection structures between Black Point Spit and the western limit of the Sandy Point Nature Reserve currently maintain beach levels, but they remain vulnerable to extreme wave conditions. Sediment stored here might therefore rapidly increase littoral drift throughput in the event of any breakdown of stability, and increased erosion.

LT4 Westward Drift to Gunner Point

The presence of the East Winner banks, eastward of the Langstone Harbour Channel, is evidence of the long-term operation of westwards drift, particularly when waves from the east-south-east and south-east operate.

Pre-replenishment. Net westward drift from the Beach Club drift divide to Gunner Point was determined by Harlow (1979; 1980) from field observations of sediment distribution in groyne compartments, combined with map and air photo evidence. Detailed assessment of littoral transport was undertaken by volumetric beach analysis using Ordnance Survey plans. Drift rates were calculated for nine separate periods between 1842 and 1976, which revealed significant spatial and temporal variability. Generally, the drift rate increased westward, sustained by progressive eastward beach erosion; most transport was considered to take place during high-energy waves approaching from the south-east or east-south-east. Further west towards Gunner Point, drift declined due to reduced wave energy resulting from shelter from the Isle of Wight. Maximum drift of over 80,000m³a⁻¹ was recorded for the period 1931-1940, but rates fell subsequently due to sediment shortage as supply beaches became depleted. Immediately west of the Beach Club, a mean potential westward drift of 17,000m³a⁻¹ was calculated. This increased to 20,000m³a⁻¹ one kilometre to the west and declined to 19,000m³a⁻¹ at the Beachlands surface water outfall (constructed in 1973 (Webber, 1974b)). Further west, it declined to 13,000 m³ at Beachcot (in part due to the obstructing effect of the outfall) and increased to 15,000m³ at Gunner Point (Harlow, 1980; Hydraulics Research, 1980). These figures were long-term means, the period 1842-1976 and therefore likely to be representative. Other calculations of drift over limited time periods revealed rates of 14,000m³a⁻¹ (1967-1976) and 14,000m³a⁻¹ (1976-1978) at Beachcot. Only the figure for

Beachcot was probably unrepresentative of drift immediately before replenishment because coast protection structures at this site interrupted transport of medium to coarse gravel on the upper beach, so that drift was restricted to fine gravel and sand on the mid/lower beach (Harlow, 1980). A modest increase in drift rate probably occurred west of Beachlands after 1979, with the installation of a piped outfall. However, the protection of the 'Inn on the Beach' in 1976 added a limited impediment to westwards drift (Photo 11), necessitating the subsequent construction of a revetment (Photo 12) and groynes (Photo 13) to modify downdrift beach recession. Gunner Point has a long history of fine gravel and sand accretion extending back about 380 years; Harlow (1980) suggests that, since about 1850, the average accretion rate has been about $5,000 \text{ m}^3 \text{ a}^{-1}$. Mean High Water Mark at Gunner Point has moved 195m seawards since approximately 1880 (Havant Borough Council, 2000). HR Wallingford (1995) suggest progradation of $0.8 \text{ m}^3 \text{ a}^{-1}$ since 1910 ($90,000 \text{ m}^3$, 1976-1992 or $5,000 \text{ m}^3 \text{ a}^{-1}$). A total of between $10\text{-}15,000 \text{ m}^3 \text{ a}^{-1}$ of sediment either passed around Gunner Point, or was transported directly into the Langstone tidal channel, between approximately 1880 and 1980. (Harlow, 1980). The north-trending, sandy gravel ridge that defines the eastern boundary of the Kench may be a remnant spit pre-dating the development of the Gunner Point foreland.

Post-replenishment. Volumetric analysis using measured beach profile data revealed that drift was $37,000 \text{ m}^3 \text{ a}^{-1}$ (February 1986 to February 1987) and between $6,000$ and $13,000 \text{ m}^3 \text{ a}^{-1}$ (1987-97) immediately westward of the Beach Club on the replenished beach (Hydraulics Research, 1987, 1988; HR Wallingford, Whitcombe, 1995). Initially, the replenished segment was not groyned and Harlow (1985) reported significant accretion in the old groyne field and revetment to the west. Whitcombe (1995) and W.S. Atkins (1998) note this frontage subsequently steadily lost material, (see section 5.4). Hydraulics Research (1988) reported that accretion resulting from westward movement of replenished material was not apparent very far west, at that time, suggesting that drift was much less rapid in the groyned coastal segments. A peak drift rate was recorded at the western extremity of the replenished beach immediately following its construction, where the change in alignment (caused by replenishment) was greatest. Volumetric analysis derived from beach profiles for the periods 1986-1990 and 1993-97 indicated that westwards littoral drift declined to between $9,500 \text{ m}^3 \text{ a}^{-1}$ (Whitcombe, 1995) and $4,800 \text{ m}^3 \text{ a}^{-1}$ (W.S. Atkins, 1998). Whitcombe (1995, 1996) identified the transfer of a "wedge" of gravel west of the replenished beach. Since 1990, the beach westwards to the Fun Fair and Norfolk Crescent has shown net accretion (W.S. Atkins, 1998), thus representing a potential source for future re-cycling operations to maintain the Eastoke replenished beach. Havant Borough Council (1999) estimate that net westwards drift along this entire sector, west to the Inn by the Sea, is approximately $20,000 \text{ m}^3 \text{ a}^{-1}$.