Chapter 6 Gravel and 'shingle' beaches — GCR site reports

Introduction

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The gravel structures and beaches of the British coast are among its best-known and longest-studied geomorphological features. In England, deposits of well-rounded beach gravel are known as 'shingle', and this less geomorphologically precise word is retained for the English and Welsh sites described in the present chapter, where the usage is more common in the literature.

'Shingle' is characterized by grain sizes between 4 and 64 mm (–2 to –6 phi). Many shingle structures are formed predominantly of clasts within this size range, but even the most distinctively sorted such as Dungeness and Chesil Beach contain clasts of many different sizes. Some beaches are characterized by clasts whose long axis exceeds –6 phi and are described as 'cobbles'. The eastern part of Chesil Beach, and the majority of the materials at Budleigh Salterton and Westward Ho! exceed shingle size. Many shingle beaches are, in reality, of mixed clast sizes, with varying quantities of both finer- and coarser-grained materials.

Although most shingle beaches in England and Wales are formed of flint or chert, many include clasts comprising relatively weak materials such as sandstone or chalk or other harder materials; a wide range of clasts formed from harder materials are characteristic of western and northern beaches and in Scotland.

Scolt Head Island, Chesil Beach and Dungeness are three of the most scientifically well-known coastal shingle structures of international renown, but there are many other geomorphologically important types of shingle and gravel features in Britain including small cliff-foot beaches, bay-bars, small recurved spits and beach plains. Some coastal gravel/shingle structures in Britain are at least 5500 years old. Others are relatively young, such as recently formed cliff-foot beaches.

About 1040 km of the British coast is formed by gravel structures (excluding any cliff-foot beaches). But gravel structures also form the base of many sand spit and dune features. If the sand structures with a gravel *base* are added, then the British coast is fringed by about 2900 km of gravel-dominated beaches.

The extent to which gravel beaches are well-sorted affects permeability and the extent to which they behave as reflective or dissipative structures.

Gravel/shingle features have been classified according to their plan-form (e.g. Pethick, 1984; see (Figure 6.1)), and their profile (e.g. Wright and Short, 1983). Pethick (1984), following many earlier writers, summarized the plan-form of beaches at different scales, ranging from the small rhythmic features such as *cusps* that occur on many beaches, to the very large detached beaches such as spits. Wright and Short (1983), in contrast, focused on the relationship between beach profiles and wave conditions, with a specific emphasis on the differences between a dissipative domain in which beaches display a flat shoaling slope and wide surf zone, with multiple parallel nearshore bars and a reflective domain, characterized by steep beaches (> 6°), with no nearshore bars. Between these extremes there are several intermediate domains that are dominated by longshore bar-troughs, rhythmic bars, transverse (welded) bars or low-tide terraces.

The GCR sites descibed in the present chapter (Figure 6.2) and (Table 6.1) contain many short-timescale features, but as major landforms owe their origins to processes acting over considerable periods of time. They include cliff-foot fringing beaches, pocket beaches, bay-bars, cheniers, spits (some with complex recurves), barrier beaches and cuspate forelands.

The simplest gravel and shingle structures are cliff-foot fringing beaches. They fall broadly into two groups:

1. beaches at the foot of cliffs that are the present-day source of most clasts in the beach.

2. cliff-foot beaches where the gravel/shingle is derived from longshore transport. In southern Britain, many shingle beaches are formed from flint that was eroded from the chalk under periglacial conditions and, in northern Britain, under glacial conditioni from a range of lithologies, and then transported landwards by the postglacial transgressing seas.

Gravel and shingle beach ridges

The process of migration of a ridge across the sea floor during a marine transgression has often been used to explain the establishment of large linear features such as Slapton bar, Chesil Beach, and Blakeney Point. They may be parts of barrier beaches that have assumed their present form because they have been built up against the coast. As they transgress the pre-existing landscape, these fringing beaches can become compartmentalized by headlands into smaller embayment beaches, as for example between Osmington and Kimmeridge and in Spey Bay. Chesil Beach is undergoing a similar change between West Bay and Abbotsbury. Slapton bar is attached to headlands at both ends and is in continuity with a cliff-foot fringing beach, whereas Chesil Beach fringes cliffs for much of its western half and then stands separately as a tombolo joining the Isle of Portland to the mainland. In contrast, Blakeney Point is only attached at its eastern end where it continues the line of fringing beach below Sheringham cliffs. It then becomes aligned towards the dominant waves from the north-east. However at its distal end it lies in deeper water, and waves from the north and north-west have been instrumental in developing a series of modern and relict recurves. Gradual elongation of a barrier partially blocking an embayment or the extension of a spit may give rise to a bay-bar.

Larger shingle structures are characteristically built up of series of beach ridges, several hundred in the case of Dungeness, which preserve earlier episodes of beach-construction. Beaches that are initially oriented alongshore as drift-aligned features show a tendency to swash-align-ment through time (Davies, 1972). This process involves erosion updrift and the truncation of former ridges, often at a significant angle to the present-day ridge orientation. As spits extend into deeper water, they develop recurves under the influence of different wave directions. Recurves are often grouped, as for example at Scolt Head Island and Blakeney Point, and may be related to pulses of greater sediment flux. Such pulses have been identified at Spey Bay by Gemmell *et al*. (2001a,b) along the main gravel structures but the extent to which these might contribute to recurring at the western end of Spey Bay is less clear.

On some coasts, large cuspate forms develop.

(Table 6.1) Main features and sediment sources of gravel/shingle beach and ness GCR sites, including coastal geomorphology GCR sites described in other chapters of the present volume that contain shingle beach/ness structures in the assemblage.

Site*	Main features	Other geomorphological features	Present day natural sources of sediment	Tidal range (m)
Marsden Bay	Beach phases	Cliff, stack	Local cliff erosion — small	4.2
Furry Cliff to Peveril Point (Dorset Coast)	Shingle pocket beaches	Cliffs/platforms Mass movements	Cliff erosion — small, restricted	1.7 (E)–2.0 (W)
Nash Point	Cobble and shingle pocket beaches	Platforms, caves	Local cliff/platform erosion — small	6.0
Kingsdown to Dover	Cliff-foot beach	Cliffs and platforms	Cliff erosion — small	5.9
Seven Sisters, (Beachy Head to Seaford Head)	Cliff-foot fringing beaches	Cliffs and platforms	Cliff/platform erosion — small	6.0
South-west Isle of Wight	Cliff-foot beach and feeder cliffs	Cliffs	Chalk and sandstones — small	3.3 (E)–2.2 (W)
Lyme Regis to Golden Cap	Shingle beach sediment supply and budget	Feeder cliffs	Significant inputs of flint/chert	3.5
Ynyslas	Sand and shingle spit	Dunes	Reworking till — restricted	4.0

Westward Ho!	Cobble beach and spit	Dunes	Reworking of emerged beach — restricted	7.9
Loe Bar	Shingle bay-bar	Cliffs, ria	Local cliff erosion — small	4.7
Slapton Sands and Hallsands	Shingle bay-bar Beach destruction	Emerged beach, relict cliff and platform	Minimal	4.4
Budleigh Salterton	Shingle beach and spit Major former feeder to south coast beaches	Soft cliffs	Cliff erosion — maintains budget	4.0
Chesil Beach	Barrier beach Tombolo		Minimal — local	2.0
Porlock	Retreating shingle barrier with both swash-aligned and drift-aligned longshore sections	Recent breached tidal inlet allowing active back-barrier saltmarsh development	Minor source of gravel from updrift coastal slides. Main solifluction source of sediment now exhausted until future sea-level rise creates new supply	9.3
Hurst Castle Spit	Shingle spit and recurves	Saltmarsh	Possible from offshore	2.2
St Osyth Marsh	Cheniers	Saltmarsh	Localized reworking of gravels and chenier root	3.8
Dengie Marsh	Cheniers	Saltmarsh	Localized reworking of gravels and chenier root	3.8
Blakeney Point (North Norfolk Coast)	Major shingle spit	North Norfolk coast assemblage	Cliff erosion — restricted Longshore transport — large	6.4 (W)–4.7 (E)
Scolt Head Island (North Norfolk Coast)	Barrier beach and spits	North Norfolk coast assemblage	Longshore transport — large	6.5
Pagham Harbour	Double spit development		Local cliffs — restricted Kelp rafting	3.4
Ayres of Swinister	Complex of bay bars and spits		Local tills — small	1.5
Rye Bay	Spit developments Shingle beach plain		Reworking proximal end	5.8
Benacre Ness	Shingle ness	Rapidly retreating cliffs	Longshore — minimal Cliff erosion — maintains input	2.1
Whiteness Head	Spit		Longshore transport — large	3.5
Spey Bay	Spits, bay bars, emerged gravel ridges		Longshore — now partially restricted fluvial input	3.5
West Coast of Jura	Over 11 000 year sequence of emerged gravel ridges	Emerged shore platforms	Local, between headlands	2.5
Orfordness and Shingle Street	Major shingle ness and spit		Longshore — restricted by groyne fields	1.9 (N)–3.4 (S)

	Major cuspate foreland		
Dungeness ridges	Relict barrier beach Over 5000 year sequence of beach	Re-distribution within site	6.2
		* Sites described in the present chapter are in bold typeface	

Often known in Britain as 'nesses', these cuspate forelands may result from the convergence of opposing movements of sediment alongshore, as at Buddon Ness (Barry Links GCR site), Angus, or may be a horizontal wave-form that migrates alongshore progressively transferring sediment from the windward face to the opposite side. Some nesses are fringing features, for example Benacre Ness, which lies at the foot of cliffs cut in Quaternary tills and gravels. In contrast, the longshore-parallel spit at Orfordness has developed a distinct cuspate feature or ness at a point where there is a change in shore alignment combined with the effects of wave refraction by offshore banks. Most nesses are strongly associated with substantial offshore banks, although Dungeness is unusual amongst such features in lacking an associated offshore bank. These banks affect wave refraction, but it is not possible to state unequivocally whether the shoals develop as a result of offshore transport of sediment from the foreland as it aligns itself at an angle to the shore, or if their presence is a contributory factor in the development of the foreland. The forms of gravel and shingle beaches are predominantly the result of wave action, with the small-scale features responding to each individual wave. Over longer timescales, however, gravel beaches are strongly controlled by the dominance of particular wave directions and the effects on longshore transport of clasts.

Where isostatic uplift has been substantial, emerged gravel ridges occur where supply is, or has been, plentiful, such as on the west coast of Jura, in the Inner Hebrides (see GCR site report).

On many British upland coasts, gravel and shingle structures form the base upon which sand spits and dune fields have accreted, but with a few exceptions such as at Culbin, Moray (Comber, 1993) and at Central Sanday (Rennie and Hansom, 2001) (see GCR site reports in chapters 11 and 8) many of these buried gravel structures have not been interpreted. Gravel extraction from these locations may put the sand structures at risk of accelerated erosion, as happened at Spurn Point prior to the 1849 breach (IECS, 1992).

Past management also influences the ability of gravel structures to adjust to sea-level change and storminess, Porlock being a good example of a free-standing gravel structure undergoing post-management adjustment.

The conservation value of gravel and shingle beaches

In spite of reductions in sediment supply, many gravel/shingle beaches remain scientifically important, and worthy of conservation-protection measures so that they can continue to evolve and provide information about the development of coastal gravel systems, coastal form development and the effects of coastal management. It is important that such sites are managed wisely so that the systems can be allowed to develop as naturally as possible. The sites are of high conservation value because

1. internationally, they are among the most well-known coastal features of Britain, especially Chesil Beach, Dungeness and Culbin,
2. they have a distinct flora and support several endemic species of invertebrates,
3. they continue to act as sources of sediment for adjacent beaches,
4. they preserve several millennia of recent coastal deposition and changes in their form reflect variations in wave and wind climates.

In the present chapter the GCR sites (Figure 6.2) and (Table 6.1) follow a sequence from shoreline or fringing beaches to the more complex forms of detached beaches.

Gravel and shingle structures as biological SSSIs and Special Areas of Conservation (SACs)

In Chapter 1, it was emphasized that the SSSI site series is constructed both from areas nationally important for wildlife, and GCR sites. An SSSI may be established solely for its geology/geomorphology, or its wildlife/habitat, or it may comprise a 'mosaic' of biological and GCR sites that may be adjacent, partly overlap, or be coincident. There are a number of coastal SSSIs that are crucially important to the natural heritage of Britain for their wildlife value, but which implicitly contain interesting geomorphological features — such as gravel/shingle structures — that are not included independently in the GCR because of the 'minimum number' criterion of the GCR rationale (see Chapter 1). These sites are not described in the present geomorphologically focused volume.

In addition to being protected through the SSSI system for their national importance, certain types of gravel/shingle habitat are eligible for selection as Special Areas of Conservation (SACS; see Chapter 1) under the 'Habitats Directive'. The principal Annex I SAC coastal gravel/shingle habitat present in the UK is 'Perennial vegetation of stony banks', but on gravel/shingle beaches commonly fringing this habitat, the more transient 'Annual vegetation of drift lines' also occurs.

Coastal gravel/shingle SAC site selection rationale

The Habitats Directive Annex I habitat type most relevant to the present chapter is 'Perennial vegetation of stony banks'. Ecological variation in this habitat type depends on stability, the amount of fine material accumulating between clasts, climatic conditions, width of the foreshore, and past management of the site. The ridges and lows formed in gravel/shingle structures also influence the vegetation patterns, resulting in characteristic zonations of vegetated and bare gravel/shingle. The presence of the yellow horned-poppy *Glaucium flavum* and the rare sea-kale *Crambe maritima* and sea pea *Lathyrus japonicus,* all species that can tolerate periodic movement, is significant. In more stable areas above this zone, where sea spray is blown over the gravel/shingle, plant communities with a high frequency of salt-tolerant species such as thrift *Armeria maritima* and sea campion *Silene uniflora* occur. These may exist in a matrix with abundant lichens.

On the largest and most stable structures the sequence of vegetation includes scrub, notably broom *Cytisus scoparius* and blackthorn *Prunus spinosa.* Heath vegetation with heather *Callum vulgaris* and/or crowberry *Empetrum nigrum* occurs on stable structures, particularly in the north. This sequence of plant communities is also influenced by natural cycles of degeneration and regeneration of the shrub vegetation that occurs on some of the oldest ridges.

(Table 6.2) Candidate and possible Special Areas of Conservation in Great Britain supporting Habitats Directive Annex I habitat 'Perennial vegetation of stony banks' and/or Annual vegetation of drift lines' as qualifying European features. Non-significant occurrences of these habitats on SACS selected for other features are not included. (Source: JNCC International Designations Database, July 2002.)

SAC name	Local authority	Gravel/ shingle habitat extent (ha)
Bae Cemlyn/ Cemlyn Bay	Ynys Mon/ Isle of Anglesey	1.3
Chesil Beach and the Fleet	Dorset	96.2
Culbin Bar	Highland; Moray	122.5
Dee Estuary/ Aber Dyfrdwy*	Cheshire; Fflint/ Flintshire; Wirral	1
Dungeness	East Sussex; Kent	2266.1
Isle of Portland to Studland Cliffs	Dorset	1.4
Lower River Spey–Spey Bay	Moray	65.2
Minsmere to Walberswick Heaths and Marshes	Suffolk	8.8
Morecambe Bay	Cumbria; Lancashire	57.5
North Norfolk Coast	Norfolk	98.4
North Uist Machair	Western Isles / Na h-Eileanan an Iar	3
Orfordness-Shingle Street	Suffolk	553.3
Sidmouth to West Bay	Devon; Dorset	4.4

Solent Maritime	City of Portsmouth; City of Southampton; Hampshire; Isle of Wight; West Sussex	226.5
Solway Firth	Cumbria; Dumfries and Galloway	8
South Uist Machair	Western Isles / Na h-Eileanan an Iar	†

***** Possible SAC not yet submitted to EC

† Feature is minor component of SAC

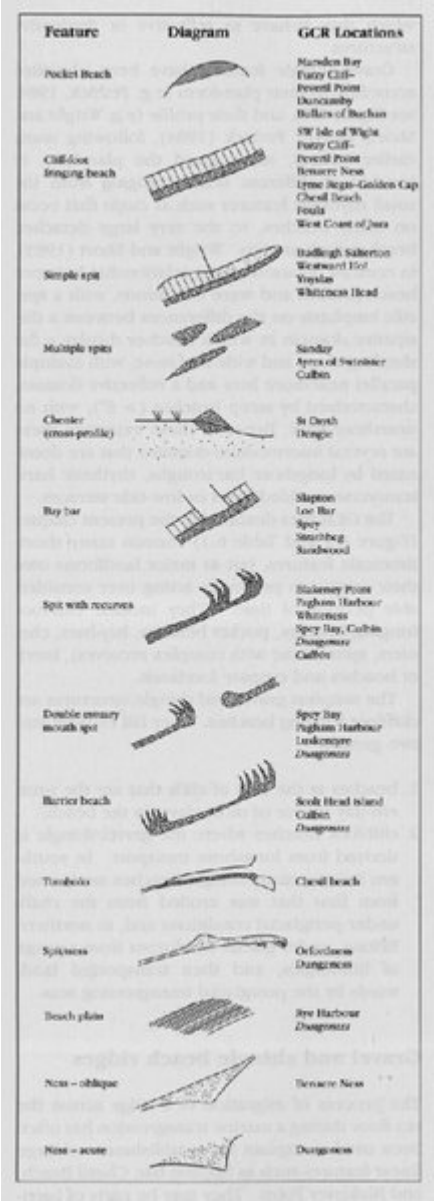
Bold type indicates a coastal geomorphology GCR interest within the site

Vegetated stony banks are scarce. There are only a few large sites in Europe, and the UK hosts a significant part of the European resource of this habitat. Although there are only some 4000 ha of stable or semi-stable vegetated gravel/shingle around the whole of the coast of the UK, the habitat is widely distributed and also exhibits a wide range of variation. The selection of sites reflects the UK's special responsibility for conservation of this habitat type and aims to cover the geographical range and variation of the habitat type. All the largest examples with good conservation of structure and function have been selected, together with additional smaller sites to complete the coverage of range. Site selection has also favoured gravel/shingle structures that support vegetation sequences ranging from pioneer communities to heath and scrub. The selected sites represent a substantial proportion of the European resource.

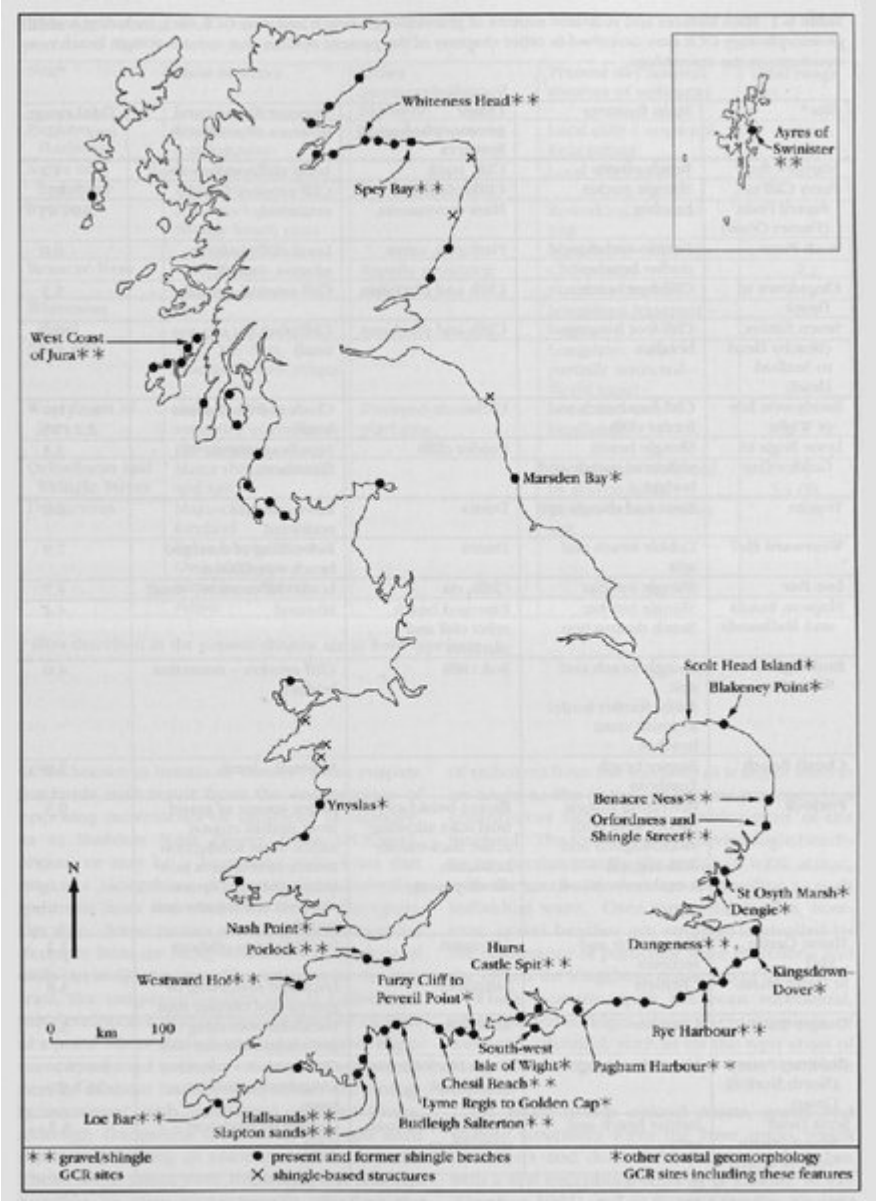
The vegetation that colonizes drift lines of gravel/shingle at or above mean high-water spring tides is dominated by annual plants. The types of deposits involved are generally at the lower end of the clast-size range (2–200 mm diameter), with varying amounts of sand interspersed in the gravel/shingle matrix. These deposits occur as fringing beaches that are subject to periodic displacement or overtopping by high tides and storms. The distinctive vegetation, which may form only sparse cover, is therefore ephemeral and composed of annual or short-lived perennial species. At most sites where it occurs, the habitat is naturally species-poor, and there is a limited range of ecological variation. Many gravel/shingle beaches are too dynamic to sustain drift-line vegetation. Many of the fringing beaches supporting drift-line vegetation are small, and annual vegetation may exist in one location in one year but not another.

Therefore, although widespread around the UK, sites where this Annex I type is persistent are rare, and even the largest sites probably support less than 10 ha of this habitat. Sites have been selected to reflect the more constant occurrences of drift-line vegetation, normally found in association with larger, more stable areas of grav-el/shingle structures. The selected sites represent the majority of the more persistent examples of this habitat type in the UK. They all exhibit good conservation of structure and function (i.e. they are relatively unmodified and are less prone to human disturbance) and represent the range of variation in substrate type and physical structure.

(Table 6.2) lists coastal shingle SACs, and indicates which of these sites are also (at least in part) important as part of the GCR and are described in the present chapter.



(Figure 6.1) Forms and typology of gravel and shingle structures and the GCR sites that represent them. The schematic diagrams show the plan form of the structure concerned. Italic type indicates presence of relict features at a site. In some cases gravel forms the core of the feature, and is now covered in sand.



(Figure 6.2) Coastal shingle and gravel structures around Britain, showing the location of the sites selected for the GCR specifically for gravel/shingle coast features, and some of the other larger gravel structures.

Site*	Main features	Other geomorphological features	Present day natural sources of sediment	Tidal range (m)
Marsden Bay	Beach phases	Cliff, stack	Local cliff erosion– small	4.2
Furzy Cliff to Peveril Point (Dorset Coast)	Shingle pocket beaches	Cliffs/platforms Mass movements	Cliff erosion – small, restricted	1.7 (E)– 2.0 (W)
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West Coast of Jura	Over 11 000 year sequence of emerged gravel ridges	Emerged shore platforms	Local, between headlands	2.5
Orfordness and Shingle Street	Major shingle ness and spit		Longshore – restricted by groyne fields	1.9 (N)– 3.4 (S)
Dungeness	Major cuspate foreland Relict barrier beach Over 9000 year sequence of beach ridges		Re-distribution within site	6.2

* Sites described in the present chapter are in **bold** typeface

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Vegetated stony banks are scarce. There are only a few large sites in Europe, and the UK hosts a significant part of the European resource of this habitat. Although there are only some 4000 ha of stable or semi-stable vegetated gravel/shingle around the whole of the coast of the UK, the habitat is widely distributed and also exhibits a wide range of variation. The selection of sites reflects the UK's special responsibility for conservation of this habitat type and aims to cover the geographical range and variation of the habitat type. All the largest examples with good conservation of structure and function have been selected, together with additional smaller sites to complete the coverage of range. Site selection has also favoured gravel/shingle structures that support vegetation sequences ranging from pioneer communities to heath and scrub. The selected sites represent a substantial proportion of the European resource.

The vegetation that colonizes drift lines of gravel/shingle at or above mean high-water spring tides is dominated by annual plants. The types of deposits involved are generally at the lower end of the clast-size range (2–200 mm diameter), with varying amounts of sand interspersed in the gravel/shingle matrix. These deposits occur as fringing beaches that are subject to periodic displacement or overtopping by high tides and storms. The distinctive vegetation, which may form only sparse cover, is therefore ephemeral and composed of annual or short-lived perennial species. At most sites where it occurs, the habitat is naturally species-poor, and there is a limited range of ecological variation. Many gravel/shingle beaches are too dynamic to sustain drift-line vegetation. Many of the fringing beaches supporting drift-line vegetation are small, and annual vegetation may exist in one location in one year but not another.

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