



# Silica Sand Study, 2016

## Final Report

*(updated and revised edition of the report originally published as the 'Soft Sand & Silica Sand Study', 2015)*

November 2016

Cuesta Consulting Limited



**Bibliographic Reference:**

Thompson, A. and Poole, J. S. (2016): **South Downs National Park Silica Sand Study, 2016**. Report to the South Downs National Park Authority and West Sussex County Council.  
Cuesta Consulting Limited, East Lambrook. (75pp + separate Appendix)

---

# CONTENTS

---

<b>Executive Summary .....</b>	<b>1</b>
<b>1. Introduction and Terms of Reference .....</b>	<b>4</b>
Introduction.....	4
Background.....	4
Aim.....	4
National Policy.....	5
Previous Work .....	6
<b>2. Geological and Technical Assessment of the Folkestone Formation Sands. ....</b>	<b>8</b>
Introduction.....	8
The Geology of the Folkestone Formation Sands .....	8
Existing and Promoted new Sites in the Study Area, within the Folkestone Formation.....	12
Site Visits and Sampling.....	13
Physical and Chemical Testing of Sands within the Study Area .....	15
Summary of Physical and Chemical Test Results.....	33
<b>3. Markets and End Use Specifications.....</b>	<b>36</b>
Markets.....	36
End Use Specification Requirements.....	38
Summary.....	51
<b>4. Processing Methods .....</b>	<b>53</b>
<b>5. Comparison of the Folkestone Formation Sands with Market Specifications.....</b>	<b>56</b>
Introduction.....	56
Comparisons by End Use .....	56
<b>6. Consideration of Alternatives .....</b>	<b>60</b>
Introduction.....	60
Alternative Geological Resources and Reserves .....	60
Technical Comparison of Alternative Resources.....	65
Recycled Glass .....	68
Transportation Distances .....	70
Glass Industry Views.....	71
Summary and Implications for the SDNPA.....	72
<b>7. Assessment of the Significance of Sand Resources within the Study Area. ....</b>	<b>74</b>
<b>References.....</b>	<b>75</b>
<b>APPENDIX A: Laboratory Testing Results for Individual Sites .....</b>	<b>(see separate pdf document)</b>

## Executive Summary

This report presents the findings of an investigation carried out by Cuesta Consulting Limited on behalf of the South Downs National Park Authority and West Sussex County Council, as part of the evidence base for their emerging Joint Minerals Local Plan (JMLP). This revised edition of the original 'Soft Sand & Silica Sand Report' (which was dated 10<sup>th</sup> June 2015) incorporates additional evidence obtained through consultation on the emerging Plan, and through subsequent further enquiries, and therefore supersedes the original publication.

The study has focused on the sands of the Folkestone Formation, along that part of the outcrop which extends, to the north and east of the main Chalk ridge of the South Downs, from East Hampshire, through the National Park and adjoining parts of West Sussex and into the western part of East Sussex. The Folkestone Formation has traditionally been regarded as a source of 'soft sand' used for construction purposes, but has recently been recognised as a potential source of specialist 'silica sand'. This is defined as sand which has a silica content of more than 95%. It is a mineral of national importance and has a wide range of uses from golf courses to industrial applications. It is used in a wide range of specialist products and industrial processes including (where the purity is high enough) glass manufacturing. Because of its use in specific non-aggregate applications, and because it occurs within only a limited number of locations within the UK silica sand is treated differently from general construction aggregate sands in terms of mineral planning.

The National Planning Policy Framework (NPPF) requires Minerals Planning Authorities (MPAs) to plan for a steady and adequate supply of industrial minerals by co-operating with other MPAs; encouraging the safeguarding of industrial mineral resources; and by providing a stock of permitted reserves to support the level of investment required in production and processing.

Whilst recognising that minerals can only be worked where they are found, the NPPF (Paragraph 144) also requires that MPAs should, when determining planning applications seek to avoid "as far as practical" the need for mineral development to take place within areas covered by major designations such as National Parks. In circumstances where such development is being considered, the NPPF (Paragraph 116) sets out the 'exceptional circumstances' and 'public interest' tests which need to be applied. In order to develop appropriate policies for the JMLP, there is therefore a need to investigate potential silica sand resources within West Sussex including that part of the County within the South Downs National Park (SDNP), and to draw comparisons with silica sand resources elsewhere, particularly those which are not subject to national landscape designations.

The study has involved field investigation, sampling and testing of sands from a number of sites within the Folkestone Formation (both within and adjacent to the South Downs National Park), comparison with existing test data, where available, and with the specification requirements for a wide range of specialist silica sand end-uses. The findings indicate that most if not all of the Folkestone Formation sands within the study area are likely to be capable of being defined as 'silica sands' in the broadest sense. Taken together, they are likely to be capable of being used in virtually all specialist end uses, the only exceptions being hydraulic fracturing (because the sands generally do not have sufficiently high roundness and); golf bunkers (because the sands are not sufficiently angular); and water filtration (because the sands are generally too fine-grained).

This is not to say that all sites would be capable of serving the full range of other end uses. The suitability for different markets will vary from one site to another, and sands which meet the most exacting requirements in terms of chemical purity and consistency (as required for clear glass and sodium silicate manufacturing) are likely to be relatively scarce. Such sands have been identified at one location within the National Park through more detailed drilling and testing by a commercial operator. Deposits of comparable quality might also exist in other parts of the study area, although far more investigation and testing would need to be done to prove this. Such work is beyond the scope of this strategic study.

Given that most, if not all, of the Folkestone Formation sands within the study area seem likely to be capable of being classified as silica sands, in the broadest sense, it is appropriate that they should be considered as strategic resources. As such, they should be safeguarded from needless sterilisation by other forms of development.

Where it is demonstrated, through detailed investigation and testing, that sites are suitable for supplying the highest quality sand for glass manufacture and sodium silicate production, the associated resources would be considered to be of national importance. This is because alternative resources of comparable quality are very limited within the UK (by comparison with other bulk minerals, such as aggregates) and are becoming increasingly scarce, particularly within England.

The study has confirmed that there are alternatives to the Folkestone Formation resources elsewhere in the country, particularly with regard to the relatively low purity specialist applications relating to agricultural, horticultural, sports and leisure end-uses. These alternative resources are still quite limited in extent (compared with resources of more general construction aggregate) but many of them fall outside nationally designated landscapes and (subject to planning consent) are capable of supplying the geographical areas which could potentially be served from the South Downs. In some (but not all) of these applications, the alternatives also include the option of utilising recycled glass.

In the case of high purity and high consistency sands needed for glass and sodium silicate production alternative resources exist elsewhere in the UK. Within England, the alternative resources are quite limited and, of the four individual sites which currently supply sand for glass manufacturing (in Lincolnshire, Cheshire East, Norfolk and Surrey) none is currently thought to have more than 10 years of permitted reserves. Furthermore, the operator in each of these areas (Sibelco) advises that only one of those sites (in Surrey) is capable of supplying sand which is suitable for sodium silicate production. Additional silica sand resources have been identified in each of these counties, mostly outside nationally designated landscapes. Norfolk and Surrey have included Areas of Search for silica sand in their adopted plans to encourage potential new applications and the emerging Cheshire East plan includes Preferred Areas, identified as extensions around existing sites.

Additional silica sand resources which are suitable for clear glass manufacturing, and which are already used for this purpose, are also available at three sites in Scotland. Two of those sites already supply much of their output to glass producers in the north of England, over distances which are comparable to those from West Sussex, and have considerably higher levels of permitted reserves. In order to make up for the progressive depletion and current shortfall of reserves in England, there may be scope for one or more of these sites to increase their output and/or to divert some (or more) of their output to customers in England, should the need arise.

Taking account of the foregoing observations, it is clear that there is considerable uncertainty, at present, regarding the long-term security of supply of silica sand to support glass manufacturing within the UK. Equally, however, whilst this might have long-term implications for the need for resources within the South Downs area, there is no clear evidence that is likely to be the case for the period of the emerging Joint Minerals Local Plan. It is also pertinent to note that, at present, there is no indication from the UK glass industry of an impending critical shortage. These uncertainties have to be balanced against the very clear need for protection of the South Downs National Park, as set out in national legislation and policy. The situation will need to be monitored, however, and there will be a need to consider the role which the South Downs area may need to play in maintaining a long-term, strategic, continuity of supply of these materials in future years.

Whatever the short-term outcome in terms of SDNPA policy, it is clear that continued and close cooperation between the various MPAs in the United Kingdom will therefore be needed in order to monitor the availability of permitted reserves and to develop a suitably balanced, long-term national strategy for silica sand production within the UK.

# 1. Introduction and Terms of Reference

## ***Introduction***

- 1.1 In March 2015, Cuesta Consulting Limited was appointed by the South Downs National Park Authority, acting in conjunction with West Sussex County Council, to undertake a study of Soft Sand and Silica Sand as part of the evidence base for their emerging Joint Minerals Local Plan (JMLP). This revised edition of Cuesta's original report incorporates additional evidence obtained through consultation on the emerging Plan, and through subsequent further enquiries. **It therefore supersedes the original 'Soft Sand & Silica Sand Report' (dated June 2015) and the title has been changed to reflect the fact that the new report is focussed primarily on silica sand.**

## ***Background***

- 1.2 Silica sand is defined (in the British Geological Survey (BGS) minerals planning factsheet, 2009) as sand which normally has a silica content of more than 95%. In the UK, most silica sand deposits are also 'soft' sands – so-called because of their relatively fine and predominantly more rounded grains which give them a softer feel, compared with more angular 'sharp' sands. Such sands are commonly used as construction aggregates, but those which are also silica sands (which constitute only a proportion of all soft sand resources) are capable of being used in more specialist applications.
- 1.3 Silica sand is recognised in the National Planning Policy Framework (NPPF) as an industrial mineral, to which particular national planning policies apply (as explained in more detail below). The associated online Planning Practice Guidance notes that, because industrial minerals (in general) provide essential raw materials for a wide range of downstream manufacturing industries, their economic importance extends well beyond the sites from which they are extracted<sup>1</sup>.
- 1.4 In the case of silica sand, those industries range from iron foundries to the production of ceramics, resins, plastics, paints, polymer compounds, sealants and adhesives, as well as glass manufacturing and sodium silicate production. The sands are also used in a wide range of other specialist applications, from water filtration and hydraulic fracturing ('fracking') to equestrian, sports and horticultural end-uses. Each application has different specification requirements and any given deposit is likely to be suitable for only some of the foregoing range of potential end-uses. Clear glass-making and sodium silicate production require the highest levels of purity and consistency and deposits in the UK which are capable of supplying these industries are particularly scarce.

## ***Aim***

- 1.5 The aim of the study was *"to provide up to date evidence to enable the authorities to develop strategy options for both soft sand and silica sand in the JMLP area"*. The study has focused on the sands of the Folkestone Formation, along that part of the outcrop which extends, to the north and east of the main Chalk ridge of the South Downs, from

---

<sup>1</sup> Paragraph: 086 Reference ID: 27-086-20140306

East Hampshire, through the National Park and adjoining parts of West Sussex and into the western part of East Sussex. The Folkestone Formation has traditionally been regarded as a source of soft sand used for construction purposes, but has recently been recognised as a potential source of specialist silica sand.

### **National Policy**

- 1.6 As noted above, silica sand is recognised as an important industrial mineral. It occurs within only a limited number of locations within the UK and is used in a range of specialist (non-aggregate) applications. For both of these reasons it is therefore treated differently from more general construction aggregate materials in terms of mineral planning.
- 1.7 Paragraph 146 of the NPPF states that minerals planning authorities should plan for a steady and adequate supply of industrial minerals by:
- Co-operating with neighbouring and more distant authorities to co-ordinate the planning of industrial minerals to ensure adequate provision is made to support their likely use in industrial and manufacturing processes;
  - Encouraging safeguarding or stockpiling so that important minerals remain available for use; and
  - Providing a stock of permitted reserves to support the level of actual and proposed investment required for new or existing plant and the maintenance and improvement of existing plant and equipment.
- 1.8 For silica sand, the stock of permitted reserves required by the NPPF is “*at least 10 years for individual sites*” (quarries) or “*at least 15 years where significant new capital is required*” (as may be the case, for example, where investment in specialist processing facilities is needed in order to ensure that higher specifications and consistency standards are met, and/or where completely new sources of specialist sand are being developed).
- 1.9 Known or potential silica sand resources occur within certain parts of the Folkestone Formation within West Sussex, East Sussex and Hampshire, including areas within and directly adjacent to the South Downs National Park. Policies in the NPPF relating to mineral extraction in National Parks (and other nationally-designated landscapes) are therefore also relevant. Para 144 (2nd Bullet) of the NPPF requires Mineral Planning Authorities to “*as far as practical, provide for the maintenance of landbanks of non-energy minerals from outside National Parks, the Broads, Areas of Outstanding Natural Beauty and World Heritage sites, Scheduled Monuments and Conservation Areas*”.
- 1.10 In circumstances where major development (which includes minerals extraction) is being considered within any of these designated areas, paragraph 116 of the NPPF sets out the ‘exceptional circumstances’ and ‘public interest’ tests which would need to be applied. These require an assessment of:
- The need for the development, including in terms of any national considerations, and the impact of permitting it, or refusing it, upon the local economy;
  - The cost of and scope for, developing elsewhere outside the designated area, or meeting the need for it in some other way; and

- Any detrimental effect on the environment, the landscape and recreational opportunities, and the extent to which that could be moderated.
- 1.11 These tests would be applicable to any future applications to develop new extraction sites within the National Park or to extend existing quarries into that area. They are therefore also applicable to the allocation of new extraction sites within Minerals Local Plans.
- 1.12 This is clearly an issue for the SDNPA and WSCC, as well as Hampshire and East Sussex since (as noted above) the outcrop of known and potential silica sand resources occurs in all of these areas, both within and immediately adjacent to the National Park. Four existing quarries within West Sussex (West Heath, Minsted, Coates Pit and Heath End) and one in neighbouring East Sussex (Stanton Farm) fall within the National Park, whilst three others in West Sussex (Sandgate Park, Rock Common and Hampers Lane) and two in Hampshire (Kingsley and Frith End) lie directly adjacent to the Park boundary. Of these, only the sites in Hampshire have hitherto been worked (in part) as silica sand resources.
- 1.13 NPPF para. 116 should be applied when site-specific proposals are brought forward by industry, and also to policy development<sup>2</sup>. There is therefore a need to consider the issue of potential alternatives in a more proactive way at the plan making stage and in advance of applications. This is an important part of the evidence base for the emerging Joint West Sussex and South Downs National Park Minerals Local Plan (JMLP). More specifically, it is needed to inform the intended joint strategy for the working, processing and importation of non-aggregate and aggregate minerals and the setting of a framework for the identification of sites for both resource types. The present study, however, focuses primarily on silica sand, and does not examine the issue of alternatives or sites allocations for soft sand.
- 1.14 As such, the need to investigate potential silica sand resources within and adjacent to the National Park, and the need to draw comparisons with similar resources elsewhere, are the main 'drivers' for this study. The need is heightened by the fact that the resources within the SDNP have not traditionally been worked for specialist silica sand uses but instead as soft sand for use in the construction industry, and little has been known, hitherto, regarding their potential suitability for use as specialist silica sand.

### ***Previous Work***

- 1.15 A Soft Sand Study for the South Downs National Park and adjoining areas, extending from Hampshire to East Sussex, was completed in August 2012, by Capita Symonds Ltd. That work provided a detailed examination of the relevant planning policies, site allocations, emerging proposals for new sites and landbanks for soft sand throughout the area, as well as a brief review of the geological characteristics of the sand and the various applications for which it is currently used. The study identified a number of sites (all but three of those mentioned in para. 1.12 above) which were known (or at least claimed by operators) to be capable of supplying silica sand for specialist end uses. The study also

---

<sup>2</sup> see Legal Opinion obtained by SDNPA: <http://southdowns.gov.uk/wp-content/uploads/2015/01/Legal-Opinion-of-Major-Development-June-2011.pdf>

briefly considered the potential for other sites in Surrey and Kent to act as alternative sources of supply of soft sand.

- 1.16 More detailed information regarding silica sand quality and end uses in Surrey and Kent was provided by GWP consultants in their 2010 report to Kent and Surrey County Councils, and similar information was also given in GWP's 2009 report for Surrey County Council on the assessment of an individual preferred area for silica sand, at Pendell Farm. Both of these reports provided information about the specifications for industrial and other end-uses of silica sand, as well as information about the geology of existing quarries and the production and markets for sand in that area.
- 1.17 Broadly similar information for silica sand sites and resources within Bedfordshire was provided in two earlier studies by Cuesta Consulting Ltd. The Bedfordshire Aggregates Landbank Study, published in 2006, covered all sources of soft sand, silica sand and sharp sand & gravel in the county, and addressed the difficult issue of maintaining separate landbanks (silica sand and soft sand) from the same geological resource. The follow-up Bedfordshire Silica Sand Study, published in 2008, examined these specialist sands and their markets in much greater detail. Together, these studies provided first-hand information on silica sand production, including technical properties, processing methods, end-use, specifications and marketing approaches.
- 1.18 Within the Study Area, additional information was produced in 2014 following exploratory drilling at a prospective new site (promoted by the landowner – Barlavington Estates) at Horncroft, to the south of Petworth. A report, produced by OTB Engineering for the landowner, included a comparison of some of the test results from that site with the nearby dormant minerals permission at Coates Pit. Additional, and more detailed but confidential testing information for the Horncroft site was provided to Cuesta by a commercial operator (Sibelco), as part of the original study, and the full laboratory testing results from that investigation have been made available to inform this updated report. Whilst the Sibelco data itself is strictly confidential, summary information derived from it has been used in this study with the company's consent.

## 2. Geological and Technical Assessment of the Folkestone Formation Sands.

### *Introduction*

- 2.1 The Folkestone Formation forms the uppermost part of the Cretaceous 'Lower Greensand Group' which crops out around the outer perimeter of The Weald (Fig 2.1). Traditionally, the formation has been worked as a source of 'soft' construction sand, although its potential for use as a 'silica sand' in higher value specialist and industrial applications is now becoming recognised, following deliberations at the Hampshire Minerals & Waste Local Plan Examination in 2012/13. Before looking in more detail at the geology and technical properties of the deposits, it is therefore worth considering the differences between soft sand and silica sand.
- 2.2 '**Soft sand**' is generally fine-grained sand in which the individual grains are well-rounded, imparting a relatively soft texture and free-flowing nature to the sand. Such sands are commonly deposited in marine environments, where constant movement by the sea results in the rounding, polishing and sorting of the grains. They therefore occur within strata, such as the Cretaceous Greensands, which originated in such environments. The characteristics of such sands lend themselves especially to products which are required to 'flow' or be easily 'workable' by hand when they are being used - particularly mortars, but also plaster, in the case of very fine grained sand. These are collectively known as 'building sands'. Soft sand may also be used in asphalt products where it is used to stiffen the bitumen binder, and in concrete products - although sharp sand (a coarser-grained and more angular sand, usually laid down by rivers) is more commonly used for that purpose. Soft sands generally comprise a high proportion of silica (quartz), but also impurities such as iron oxide, which impart colour to the sand (mostly in shades of yellow, orange, brown and red).
- 2.3 Similar sands but with fewer impurities and thus with a silica content of more than 95%, are classed as '**silica sands**'. These are generally lighter in colour and, whilst they can still be used for construction purposes - and often are (for example in Bedfordshire, as reported by Cuesta Consulting Ltd., 2006) - they can also be used for more specialist end-uses. These range from high value industrial applications such as glass manufacture and sodium silicate production (where the chemical purity is high enough) to foundry sand, other industrial processes, sports pitches, golf courses, equestrian sands, play sand, and various horticultural and rootzone products. Other applications, for coarser-grained silica sands, include water filtration and, for very fine-grained sands, in resins, tile and brick facings and industrial filler applications. Sands which have exceptionally well-rounded, spherical grains may also be suitable for use in hydraulic fracturing ('fracking'). **It is important to understand that the term 'silica sand' is used, throughout this report, to cover all of these potential end-uses, but that the deposits found at individual locations may be suitable only for some of them.**

### *The Geology of the Folkestone Formation Sands*

- 2.4 While resources exist elsewhere in the UK, the Folkestone Formation contains the only significant sources (and potential sources) of silica sand within the whole of South East

England. It comprises a sequence of predominantly medium-grained, well-sorted, cross-bedded sands and weakly-cemented sandstones, up to 80m in thickness. The outcrop extends around much of the perimeter of the Weald (Fig 2.1), to the south and east of the North Downs through Kent, Surrey and Hampshire, and to the north of the South Downs through West Sussex and the western-most part of East Sussex. Figure 2.2 provides a more detailed map of the outcrop within the study area, which focuses on the South Downs National Park and adjoining parts of West Sussex, East Sussex and Hampshire.

- 2.5 Within at least parts of the study area, the Folkestone Formation is known to be divisible into three parts. A thin, ferruginous, pebbly quartz sand occurs at the base, overlain by rose-pink to white sands ('silver sands'), with a thick unit of ferruginous, and locally pebbly sands at the top (Allen, 1982). Not all of these units are always seen in any single location, however, and this study has shown that the central unit of relatively fine-grained sands commonly displays considerable lateral and vertical variations in colour and grain size - even within individual sand pits or other exposures.
- 2.6 Despite these variations, the British Geological Survey (Mitchell, 2015, pers. comm.) has confirmed that there are no mappable sub-divisions of the Folkestone Formation (i.e. the different units cannot be satisfactorily correlated between the various exposures as continuous or consistent sub-divisions). Nevertheless, it is the central unit of fine-to-medium-grained sands which is generally the main focus of mineral extraction in this area, and it is these deposits on which the present study is focused. These sands were deposited by tidal currents within a marine environment and thus exhibit classic features of large-scale cross-bedding with periodic thin 'drapes' of mud, which represent temporary still-water periods between tidal cycles (Allen, 1982). Examples of these features are seen in several of the site photographs within Appendix A. In between the individual mud drapes, the sands tend to be relatively 'clean' (i.e. with minimal proportions of 'fines' i.e. silt and clay), and this is confirmed by the particle size analyses carried out for this and other studies (see below).
- 2.7 Colour variations, ranging from white to pale yellow, orange-brown and rose-pink, appear to reflect slight variations in the content of impurities (primarily iron oxide) within sands which otherwise are predominantly composed of quartz grains. The fact that quartz (Silicon dioxide - SiO<sub>2</sub>) is the predominant mineral is clearly evidenced by chemical analyses carried out for this and previous studies (see below). It is not surprising, therefore, that some of the material has already been identified as 'silica sand' and, thus, as being potentially suitable for a range of end-uses where a high silica content is an important factor.

**Figure 2.1: The Folkestone Formation Outcrop and Quarries within SE England**

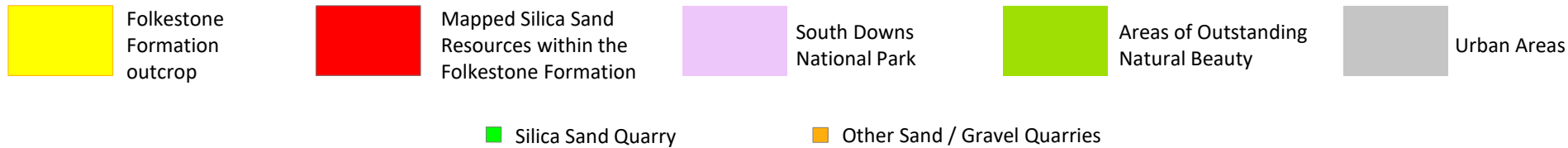
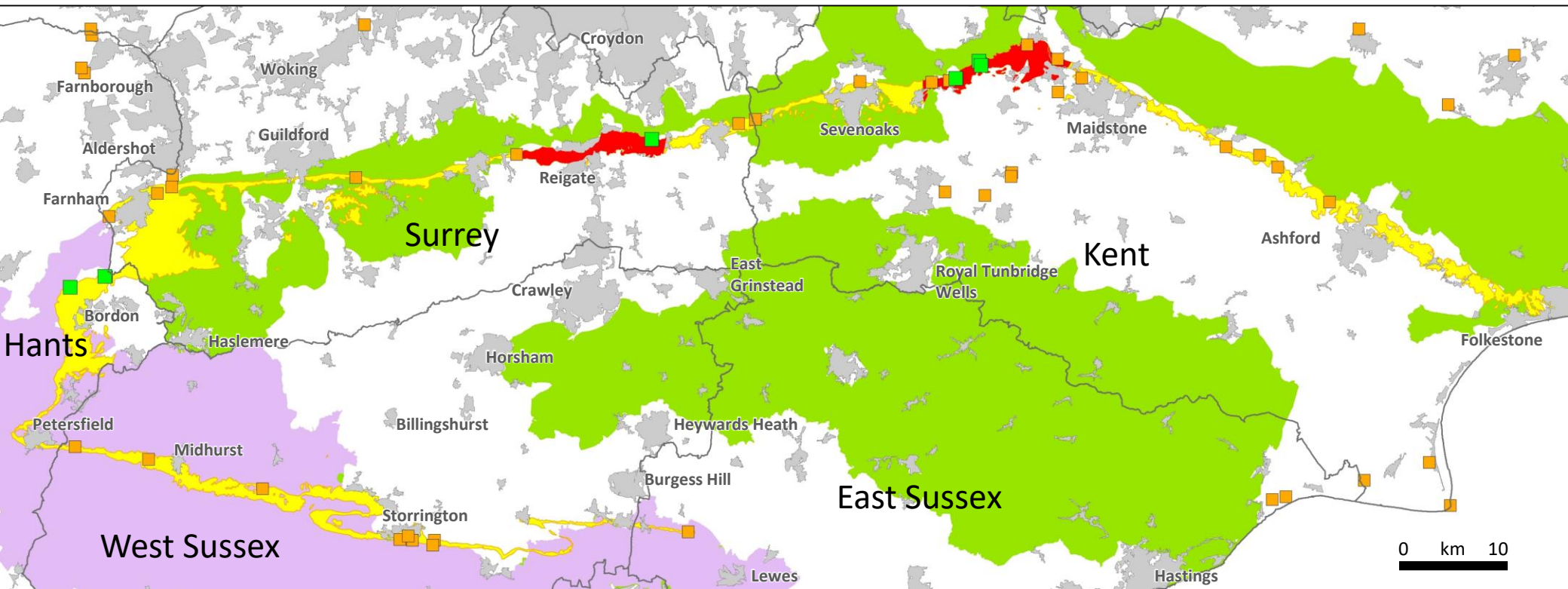
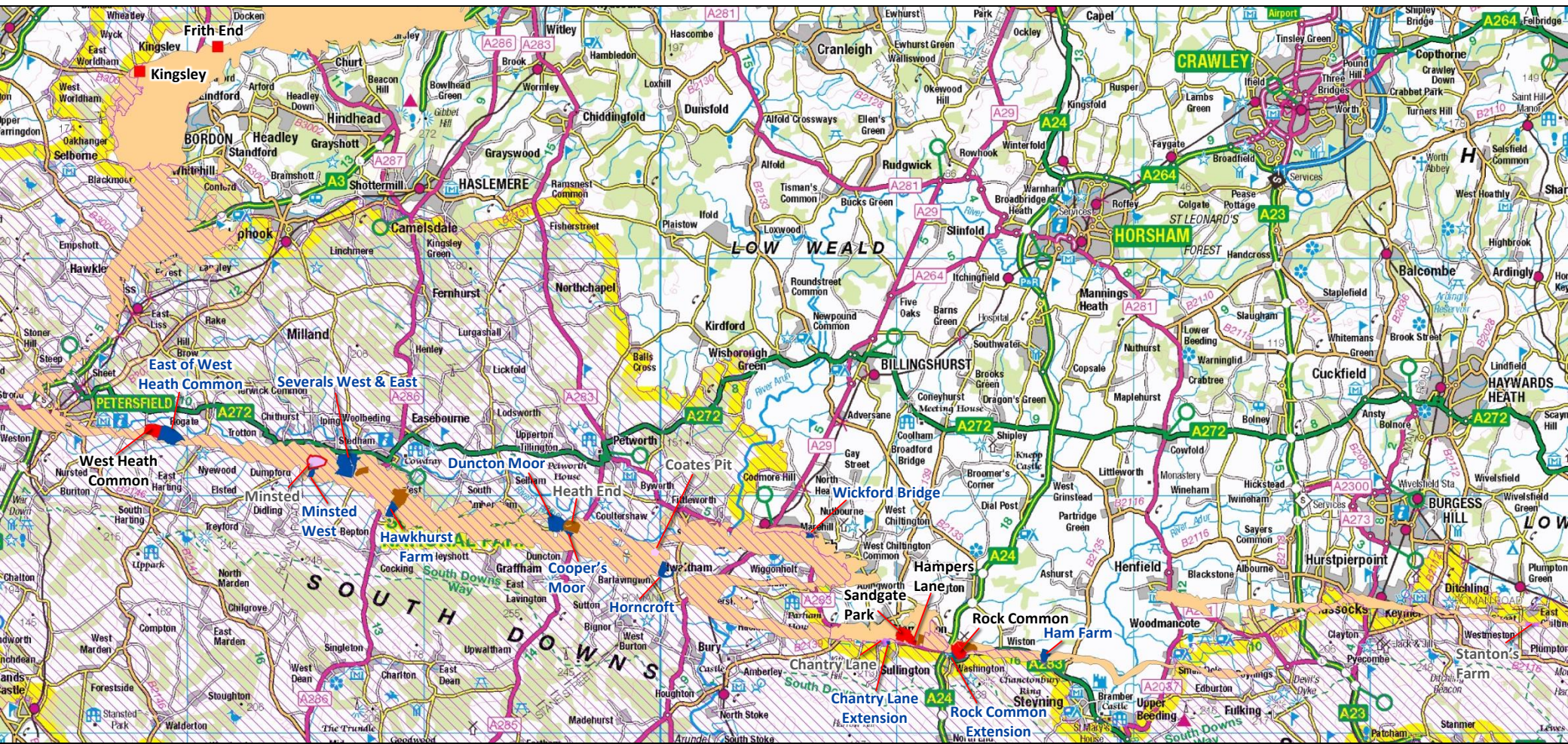









Figure 2.2: The Folkestone Formation Outcrop and Sites within the Study Area



- |  |   |  |   |  |
|--|---|--|---|--|
|  Folkestone Formation outcrop |  South Downs National Park |  Active quarry  |  Inactive quarry |  Suspended quarry |
|  |   |  Dormant quarry |  Closed quarry   |  Proposed site    |

Resource mapping reproduced from the British Geological Survey Map data at the original scale of 1: 50 000. Licence 2015/029B British Geological Survey. ©NERC. All rights reserved.

### ***Existing and Promoted new Sites in the Study Area, within the Folkestone Formation***

- 2.8 The study area<sup>3</sup>, as depicted in Figure 2.2, includes a number of existing mineral permissions which produce (or are capable of producing) ‘soft’ and/or ‘silica’ sand, together with a larger number of sites that were assessed for allocation in the West Sussex Joint Minerals Local Plan. The latter were promoted by various operators and land-owners and assessment of these sites, described in the Mineral Sites Selection Report, has led to the proposed allocation of a single site for soft sand extraction known as Ham Farm. The process of site assessment included consideration of the need for the mineral and (in the case of those which fall within the National Park) of whether or not each of the sites met the NPPF ‘exceptional circumstances’ and ‘public interest’ tests for working within Nationally-designated landscapes (see para. 1.10 above). The Mineral Sites Selection Report is available on the WSCC Website ([here](#)).
- 2.9 The existing and promoted sites within West Sussex and East Sussex are listed in Tables 2.1 and 2.2, below, respectively. In each case, the sites are listed in geographical sequence, from west to east. Their locations are shown on Figure 2.2, above. Also shown on Figure 2.2 (but not listed in the tables) are two active Folkestone Formation quarries within Hampshire, including the Kingsley site which already has an established market for supplying certain grades of specialist silica sands, and which was visited and sampled as part of this study.

**Table 2.1: Existing Mineral Permissions\*, \*\*  
within the Folkestone Formation, in West and East Sussex**

Site Name	MPA	Status	Operator
West Heath Common Quarry	SDNPA	Active	CEMEX UK
Minsted	SDNPA	Suspended*	Dudman Group Ltd
Heath End	SDNPA	Closed**	Dudman Group Ltd
Coates Pit	SDNPA	Dormant	n/a
Chantry Lane Sand Pit	WSCC	Inactive	Dudman Group Ltd
Sandgate Park Quarry	WSCC	Active	CEMEX UK
Hampers Lane Sand Pit,	WSCC	Active	Britaniacrest Recycling Ltd
Rock Common Sand Pit	WSCC	Active	Dudman Group Ltd
Stanton Farm Quarry	ESCC	Inactive	Dudman Group Ltd

\*Planning permission for mineral extraction at Minsted Sandpit is currently suspended, pending the submission of information relating to a Review of Minerals Permission (ROMP) application.

\*\* Site was closed at the time of the original study, but planning permission was subsequently granted at appeal on the 8th September 2016 allowing operations to continue – recommencement of operations is therefore anticipated.

<sup>3</sup> Note that, although the study area included those parts of the Folkestone Formation in Hampshire and East Sussex, that was primarily to provide an overall context for the work, the main focus of which has been on the outcrop within West Sussex.

**Table 2.2: Sites Promoted\* for Future Extraction within the Folkestone Formation, within West Sussex**

Site Name	MPA	Status	Potential Operator	MSS Ref.
East of West Heath Common	SDNPA	proposed	CEMEX UK	M/CH/7B
Minsted West	SDNPA	proposed	Dudman Group Ltd	M/CH/8A
Severals West	SDNPA	proposed	Unknown	M/CH/8D
Severals East	SDNPA	proposed	Unknown	M/CH/8C
Hawkhurst Farm	SDNPA	proposed	Unknown	M/CH/9A
Duncton Common	SDNPA	proposed	Dudman Group Ltd	M/CH/10A
Coopers Moor	SDNPA	proposed	Dudman Group Ltd	M/CH/10C
Horncroft	SDNPA	proposed	Confidential	M/CH/11
Wickford Bridge	SDNPA	proposed	Unknown	M/HO/7
Chantry Lane Extension	SDNPA	proposed	Dudman Group Ltd	M/HO/2
Rock Common Extension	WSCC	proposed	Dudman Group Ltd	M/HO/3A
Ham Farm	WSCC	proposed	Dudman Group Ltd	M/HO/4A

\*The sites listed above are those which underwent detailed technical assessment as part of the process of identifying suitable sites for allocation in the JMLP. Of these, only two (Horncroft and Minsted West) were specifically promoted for the extraction of silica sand, the others being intended for soft sand production. Only Ham Farm was assessed by WSCC as being suitable for allocation (as a soft sand site). For more information check the WSCC [website](#).

### ***Site Visits and Sampling***

- 2.10 Most of the sites listed above were visited during the course of this study, with the exception of those where the operator would not allow access. Sand samples were obtained wherever suitable exposures could be accessed, in order to enable independent laboratory testing to be carried out, as described in the next section.
- 2.11 Table 2.3, below lists the sites visited and the samples obtained. The sites included active quarries at Sandgate Park and West Heath Common in West Sussex and Kingsley in Hampshire. The latter was deliberately included as a reference for comparison since, as noted above, this site already has an established market for specialist sands. Also included were Coates Pit which has a currently dormant permission, close to the promoted Horncroft site, and a disused pit at Midhurst Common, directly adjacent to the promoted site of 'Severals East'. The latter no longer has planning permission for minerals extraction but simply provided an opportunity for sampling. None of the other promoted sites contained exposures that could be sampled, although a surface soil sample was obtained from an area of disturbed ground at the Wickford Bridge site.

**Table 2.3: Details of Samples Obtained During this Study**

Sample Number	Site Name	Sample Details	Date of Sampling
SASS1	Sandgate Park Quarry	In-situ sample from current working face	05/03/2015
SASS2	Sandgate Park Quarry	In-situ sample from face at side of haul road	05/03/2015
SASS3	Sandgate Park Quarry	Disturbed sample from blended and washed sand stockpile	05/03/2015
SASS4	West Heath Common Quarry	In-situ sample of "White Sand" from northern end of original quarry	05/03/2015
SASS4a	West Heath Common Quarry	In-situ sample of mixed black, brown and pink sands from eastern side of current workings	05/03/2015
SASS5	West Heath Common Quarry	Disturbed 'as dug' sample of yellowish sand from current workings (excavated below water)	05/03/2015
SASS6	West Heath Common Quarry	Disturbed 'as dug' sample of pink sand from eastern side of current workings (excavated dry)	05/03/2015
SASS7	Midhurst Common Quarry	In-situ sample of yellowish sand from above thin clay drape	05/03/2015
SASS8	Midhurst Common Quarry	In-situ sample of yellowish-orange sand from below thin clay drape	05/03/2015
SASS9	Coates Pit	In-situ sample from lower part of quarry face in NE corner	05/03/2015
SASS10	Coates Pit	In-situ sample from higher part of quarry face in S side of quarry	05/03/2015
SASS11	(Not used)		
SASS12	Wickford Bridge	Disturbed surface sample of sandy soil from SE part of site	06/03/2015
SASS 13	(Not used)		
SASS14	Kingsley Quarry	Disturbed and washed sample of yellowish sand from current workings (excavated below water and washed)	06/03/2015
SASS15	Kingsley Quarry	In-situ sample of yellowish sand from southern edge of current workings (above water level)	06/03/2015

- 2.12 In addition, the promoted site at Horncroft has recently been subject to exploratory drilling by a commercial operator. Samples from that investigation were shown to Cuesta, for visual comparison with our own samples from elsewhere, and corresponding test data was supplied to us in confidence - although permission was given for us to summarise some of the data for the benefit of this study. An additional, non-confidential report which compares the Horncroft sand with that obtained from nearby Coates Pit was also provided by the mineral Agent for those sites.
- 2.13 More generally, a range of typical recent test data was provided to Cuesta by the operators of Kingsley Quarry (Tarmac) and of West Heath and Sandgate Park Quarries (Cemex UK) and for sites in Bedfordshire<sup>4</sup> by Aggregate Industries.

<sup>4</sup> Similar sites, in a geologically comparable deposit, which have been used to supply both soft and silica sand (Cuesta Consulting Ltd., 2006)

2.14 Together, the sites for which sampling was able to be carried out, and/or existing test data was able to be obtained, provide a good geographical spread across most of the Folkestone Formation outcrop within the study area, as indicated on Figure 2.2. It is important to recognise that the samples and results obtained were not directly comparable with some of the testing carried out by commercial operators. In particular, most of our analyses were carried out on unwashed 'as-dug' samples, in order to identify the natural characteristics of the deposits, whereas a specialist silica sand operator would normally wash the samples before testing, in order to remove the fine-grained material which may be expected to have a higher concentration of impurities. With the exception of samples obtained from washed stockpiles (SASS3 and SASS14), our test results thus represent a rather pessimistic view of the likely sand quality at each of the sites. Notwithstanding this important caveat, and although data was not able to be obtained for some of the sites, an overall assessment of the quality of sand which may be found within much of the Study Area was able to be made. These findings are presented below (and in Appendix A for individual sites) and are summarised at the end of this Chapter.

### ***Physical and Chemical Testing of Sands within the Study Area***

2.15 The key physical properties which need to be examined in order to assess the potential suitability of sand for specialist end-uses comprise:

- Particle Size Distribution (PSD) using wet sieve analysis;
- Observation of colour (as an initial indicator of the purity of the sand); and
- Sand grain shape (Sphericity and Roundness) using standard charts.

2.16 In addition, the chemical composition of the material, which is critically important for some applications - particularly glass and sodium silicate manufacture, needs to be examined, for example through:

- X-ray Fluorescence chemical analysis - particularly focusing on silica content and the percentage of impurities, especially iron oxides.

2.17 The relevance of each of these tests varies from one end-use to another, as described in more detail within the next Chapter. It was decided, however, that all four properties should be assessed, as far as possible, for each of the sites.

2.18 Testing was therefore commissioned, as described below, for each of the samples obtained from the site visits.

#### Particle Size Distribution

2.19 The particle size distribution or 'grading' of each sample was assessed by means of wet-sieving, in accordance with British Standard 1377-2: 1990, clause 9.2. This enables the proportions of sediment within each of several different particle size classes to be expressed as cumulative percentages passing through each of a sequence of diminishing sieve sizes. Each sample is initially washed and oven-dried to fully separate any adhering silt and clay particles from the sand fraction. The sample is then passed through a nested series of British Standard sieve sizes and the mass retained on each sieve is recorded. This

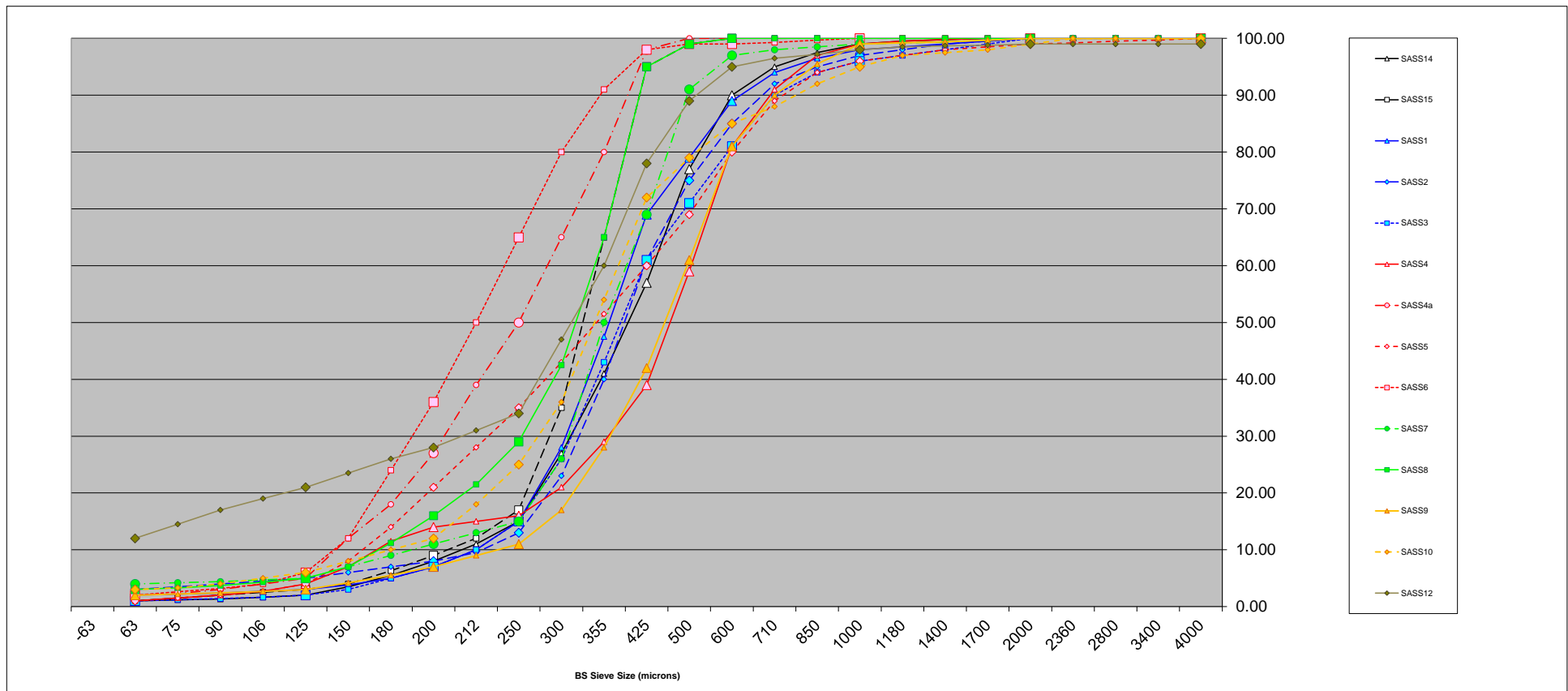
is done in two parts for sands and gravels. First, the finer sands, silts and clays (between 2mm and 63 microns) are wet sieved – washing gently assists in moving this finer fraction through the smaller sieve sizes. The remaining coarser gravel fraction (if present) is then dry sieved. The results are then plotted on a graph showing the ‘percentage passing’ each sieve size.

- 2.20 Sub-division of the fines fraction (everything less than 63 microns) can be achieved by means of sedimentation (recording the settling of fines out of the solution over a period of time) using either the pipette method (which is generally preferred) or the hydrometer method (clauses 9.4 and 9.5 of BS 1377-2), where this is necessary - though that is not usually a requirement for testing aggregates and was not carried out on the samples from this study.
- 2.21 Different sequences of mesh sizes can be used for different purposes. Testing carried out by aggregate companies generally utilises sieves which enable comparisons to be made with the British and European Standard grading requirements for various aggregate products, ranging from fine-grained plastering sands to coarse aggregate. Companies producing silica sands, on the other hand, generally utilise a number of different and/or additional mesh sizes within the fine to coarse sand particle size range, because of the ‘tighter’ grading requirements or definitions for individual products (i.e. where a high proportion of the product needs to fall within a very limited range of particle size classes) and to conform to internationally used guidance such as that within the Foundryman’s Handbook. In some applications, such as ‘frac sands’, currently only US Standard Sieve sizes are used in the standard specifications. Therefore, a very wide range of sieve sizes has traditionally been used within the sand industry to determine the PSD, dependant on intended end use.
- 2.22 For the purposes of this study, where PSD results from various sources needed to be compared with each other and with specified ‘grading envelopes’, all results were compiled into a standard spreadsheet format which included the full range of BS sieve sizes. By expressing the data in the form of cumulative percentage passing each sieve size, it was then possible to extrapolate values for intermediate sieve sizes which had not been utilised for any given sample, so that all of the cumulative grading curves could be compared. The results, which clearly distinguish between observed and interpolated values, are presented in the form of both tables and cumulative graphs in Figures 2.3 to 2.7, below.
- 2.23 Figure 2.3 shows the PSD results for all of the samples obtained by Cuesta for this study. The table lists the data by individual site, in sample number order, except for the two samples from Kingsley in Hampshire, which are presented on the left hand side of the table and used as a source of comparison with a site that is already being used to supply material into certain (relatively low-grade) specialist silica sand markets. The graphs below the table then show the resulting grading curves for each site with line colours used to distinguish between the sites. The original PSD results sheets for each sample, which show the same data presented on semi-logarithmic graphs, are provided in the combined data sheets for each site at Appendix A.

Figure 2.3: Particle Size Analysis for Cuesta's South Downs sand samples, March 2015

BS Sieve Size (microns)	Hampshire (for reference)		West Sussex - Sandgate Park Quarry			West Sussex - West Heath Common Quarry				West Sussex - Midhurst Common disused pit		West Sussex - Coates Quarry		W. Sussex - Wickford Br.
	Kingley Quarry, dredged and washed	Kingley Quarry, in-situ sample	Current working face	Lower face by haul road	Washed sand stockpile	White sand in-situ sample from northern face	Dark coloured sand from eastern side of quarry	Yellow sand 'as dug' from lake	Pink sand 'as dug' from eastern side of quarry	in-situ sample of higher layer at lake edge	in-situ sample of lower layer at lake edge	in-situ sample from lower unit in NE of quarry	in-situ sample from higher unit in S of quarry	Surface soil sample
	SASS14	SASS15	SASS1	SASS2	SASS3	SASS4	SASS4a	SASS5	SASS6	SASS7	SASS8	SASS9	SASS10	SASS12
	Cumulative % Passing													
4000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.00
3400	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.70	100.00	100.00	100.00	100.00	100.00	99.00
2800	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.50	100.00	100.00	100.00	100.00	100.00	99.00
2360	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.20	100.00	100.00	100.00	100.00	100.00	99.00
2000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.00	100.00	100.00	100.00	100.00	99.00	99.00
1700	100.00	100.00	99.50	99.50	99.00	100.00	100.00	98.50	100.00	99.70	100.00	99.70	98.00	98.80
1400	99.80	100.00	99.00	99.00	98.00	99.80	100.00	98.00	100.00	99.40	100.00	99.40	97.50	98.70
1180	99.50	100.00	98.50	98.00	97.00	99.50	100.00	97.00	100.00	99.20	100.00	99.20	97.00	98.50
1000	99.00	100.00	98.00	97.00	96.00	99.00	100.00	96.00	100.00	99.00	100.00	99.00	95.00	98.00
850	97.50	100.00	96.50	95.00	94.00	97.00	100.00	94.00	99.70	98.50	100.00	95.50	92.00	97.20
710	95.00	100.00	94.00	92.00	90.00	91.00	100.00	89.00	99.30	98.00	100.00	90.00	88.00	96.50
600	90.00	100.00	89.00	85.00	81.00	81.00	100.00	80.00	99.00	97.00	100.00	81.00	85.00	95.00
500	77.00	99.00	79.00	75.00	71.00	59.00	100.00	69.00	99.00	91.00	99.00	61.00	79.00	89.00
425	57.00	95.00	69.00	61.00	61.00	39.00	98.00	60.00	98.00	89.00	95.00	42.00	72.00	78.00
355	41.00	65.00	47.50	40.00	43.00	29.00	80.00	51.50	91.00	50.00	65.00	28.00	54.00	60.00
300	27.00	35.00	28.00	23.00	26.00	21.00	65.00	43.00	80.00	26.00	42.50	17.00	36.00	47.00
250	15.00	17.00	15.00	13.00	15.00	16.00	50.00	35.00	65.00	15.00	29.00	11.00	25.00	34.00
212	11.00	12.00	10.00	9.50	10.00	15.00	39.00	28.00	50.00	13.00	21.50	9.00	18.00	31.00
200	8.00	9.00	7.00	8.00	7.00	14.00	27.00	21.00	36.00	11.00	16.00	7.00	12.00	28.00
180	5.50	6.30	5.00	7.00	5.00	11.50	18.00	14.00	24.00	9.00	11.20	5.50	10.00	26.00
150	3.50	4.00	3.80	6.00	3.00	7.00	12.00	8.00	12.00	7.00	7.00	4.20	8.00	23.50
125	2.00	3.00	3.00	5.00	2.00	4.00	5.00	4.00	6.00	5.00	5.00	3.00	6.00	21.00
106	1.65	2.50	2.70	4.50	1.65	2.70	4.00	2.70	4.00	4.70	4.30	2.70	5.00	19.00
90	1.32	2.00	2.40	4.00	1.40	2.00	3.00	2.00	3.20	4.37	3.70	2.40	4.00	17.00
75	1.20	1.50	2.20	3.50	1.20	1.50	2.30	1.50	2.60	4.20	3.30	2.20	3.30	14.50
63	1.00	1.00	2.00	3.00	1.00	1.00	2.00	1.00	2.00	4.00	3.00	2.00	3.00	12.00
-63														

IMPORTANT NOTE: highlighted figures (only) are measured values; all other figures are extrapolated values to enable comparisons to be made with other analyses



- 2.24 Figure 2.3 reveals that all of the samples are composed predominantly of fine- to medium-grained sand, with only a minor proportion of coarse sand and very little silt/clay (<63 micron) - usually being less than 2 or 3%. In most cases, the steepest part of the grading curve (indicating the predominant grain sizes) lies within the 300 to 600 micron range. The significance of these characteristics, in relation to specification requirements for silica sands, is examined in Chapter 5 of this report.
- 2.25 Whilst most of the grading curves are fairly consistent, Figure 2.3 does also indicate certain differences between the sites, with some of the samples from West Heath Common, and to a lesser extent those from Midhurst Common, being much finer-grained than those from elsewhere. However, there is also considerable variation within the West Heath Common site itself, as discussed in more detail in relation to Figure 2.4, below.
- 2.26 The most striking anomaly within Figure 2.3 is the sample from Wickford Bridge (SASS12) which, whilst falling within the usual range at the coarser end of the grading curve, has a markedly increased 'tail' of fine and very fine sand than other samples and a much higher proportion of silt and clay. This is simply because the only opportunity for sampling at that site was from a disturbed area of surface soil which naturally contains higher quantities of fines and organic material than would be expected from the underlying, undisturbed sands. The sample was included simply as a provisional indicator for a site which, otherwise, has no testing data available.
- 2.27 Figures 2.4 to 2.7, arranged in geographical order from west to east across the study area, and Figure 2.8 (for Kingsley in Hampshire) present a range of PSD data for each of the individual sites. In each case the tables and graphs combine the results from our own testing with existing test data supplied by the operating companies concerned. The latter are shown as 'envelopes' (i.e. the typical coarser and finer limits of a range of recent test data) rather than as data for individual tests. This is partly for reasons of data confidentiality, but also to show how the results obtained from our own samples compare with the range of grading that can be obtained from each site. In each case, the tables and graphs also include an average grading curve for the Tarmac site at Kingsley. Again, this is to allow comparisons with a site that is already supplying some grades of specialist sand, and to provide a single common reference curve for all of the graphs.
- 2.28 Figure 2.4 illustrates the relatively wide diversity of gradings available within the West Heath Common site where the relatively coarse-grained white sands (sample SASS4), though not currently being worked, tend to be quarried separately and used (as silica sand) for certain specialist end-uses. It is noticeable that these tend to approximate the grading curve for Kingsley far more closely than some of the other, finer-grained sands that are currently being worked at West Heath and used for more general-purpose building sand.

Figure 2.4: Particle Size Analysis Comparisons for West Heath Common Quarry

		Hampshire (for reference)	West Sussex - West Heath Common Quarry							
		Lafarge Tarmac data - Kingsley No. 1 sand 0/2mm - 2014 average	White sand in-situ sample from northern face	Yellow sand 'as dug' from lake	Pink sand 'as dug' from eastern side of quarry	Dark coloured sand from eastern side of quarry	average of CEMEX samples	fine envelope of CEMEX samples	coarse envelope of CEMEX samples	
		<b>Kingsley - LT Average</b>	<b>West Heath white (SASS4)</b>	<b>West Heath yellow (SASS5)</b>	<b>West Heath pink (SASS6)</b>	<b>West Heath dark (SASS4a)</b>	<b>CEMEX West Heath Ave</b>	<b>CEMEX West Heath Fine</b>	<b>CEMEX West Heath Coarse</b>	
		Cumulative % Passing								
gravel	BS Sieve Size (microns)	4000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
		3400	100.00	100.00	99.70	100.00	100.00	100.00	100.00	100.00
		2800	100.00	100.00	99.50	100.00	100.00	100.00	100.00	100.00
		2360	100.00	100.00	99.20	100.00	100.00	100.00	100.00	100.00
		2000	100.00	100.00	99.00	100.00	100.00	100.00	100.00	100.00
lv coarse sand		1700	99.80	100.00	98.50	100.00	100.00	99.90	100.00	99.90
		1400	99.50	99.80	98.00	100.00	100.00	99.90	100.00	99.70
		1180	99.00	99.50	97.00	100.00	100.00	99.80	100.00	99.50
		1000	98.60	99.00	96.00	100.00	100.00	99.30	100.00	99.00
		850	97.50	97.00	94.00	99.70	100.00	98.50	99.50	98.00
lv coarse sand		710	95.00	91.00	89.00	99.30	100.00	97.50	99.00	96.50
		600	90.00	81.00	80.00	99.00	100.00	96.10	98.00	94.50
		500	79.50	59.00	69.00	99.00	100.00	94.10	97.00	90.00
		425	60.00	39.00	60.00	98.00	98.00	84.00	94.00	75.00
		355	44.00	29.00	51.50	91.00	80.00	73.00	90.00	60.00
medium sand		300	28.50	21.00	43.00	80.00	65.00	63.00	85.00	43.00
		250	18.60	16.00	35.00	65.00	50.00	53.20	79.00	27.00
		212	16.00	15.00	28.00	50.00	39.00	41.50	64.00	21.00
		200	13.50	14.00	21.00	36.00	30.00	30.00	45.00	15.00
		180	9.00	11.50	14.00	24.00	18.00	19.00	26.00	9.00
fine sand		150	5.00	7.00	8.00	12.00	12.00	10.00	11.00	5.00
		125	2.90	4.00	4.00	6.00	5.00	5.10	6.00	3.00
		106	2.50	2.70	2.70	4.00	4.00	4.00	4.70	2.50
		90	2.00	2.00	2.00	3.20	3.00	3.00	3.70	1.90
		75	1.00	1.50	1.50	2.60	2.30	2.30	3.10	1.20
silt / v. fine sand		63	0.60	1.00	1.00	2.00	2.00	1.54	2.70	0.90
		-63								

**IMPORTANT NOTE: highlighted figures (only) are measured values; all other figures are extrapolated values to enable comparisons to be made with other analyses**

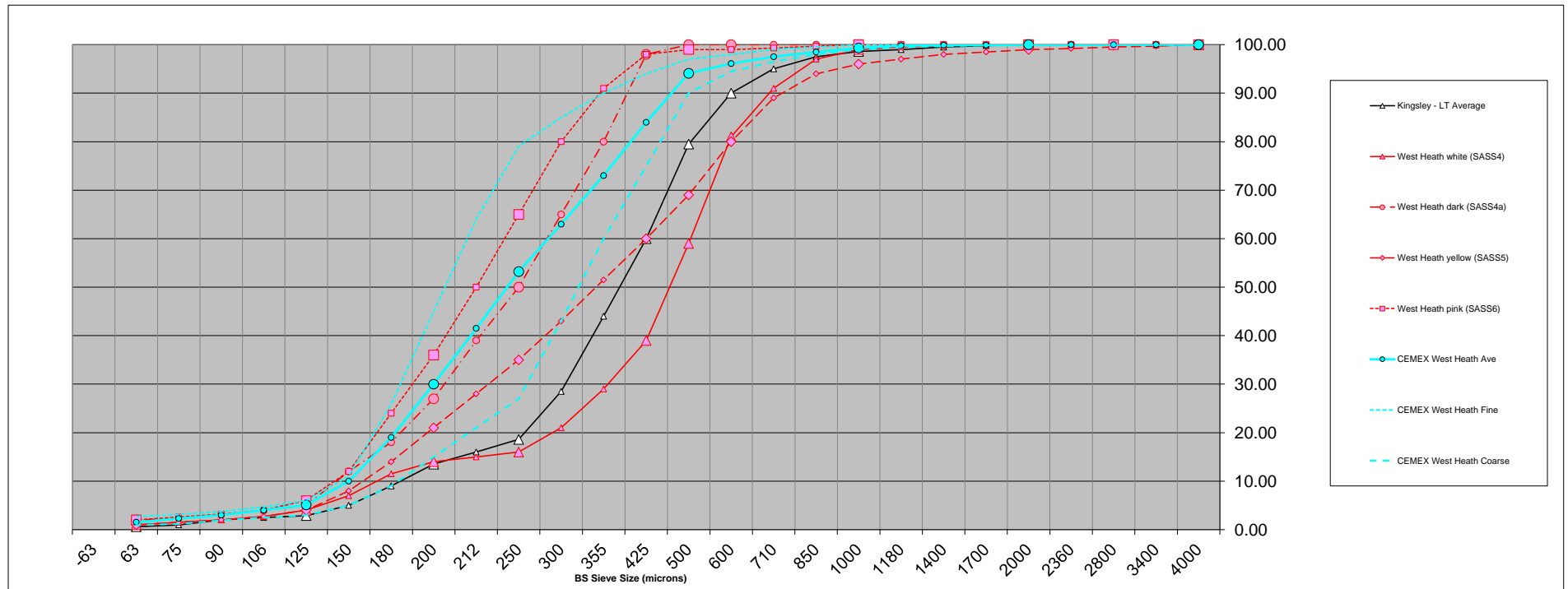


Figure 2.5: Particle Size Analysis Comparisons for Midhurst Common

BS Sieve Size (Microns)	Hampshire (for reference)	West Sussex - Midhurst Common disused quarry	
	Lafarge Tarmac data - Kingsley No. 1 sand 0/2mm - 2014 average	in-situ sample of higher layer at lake edge	in-situ sample of lower layer at lake edge
	<b>Kingsley - LT Average</b>	<b>SASS7</b>	<b>SASS8</b>
	cumulative % passing		
4000	100.00	100.00	100.00
3400	100.00	100.00	100.00
2800	100.00	100.00	100.00
2360	100.00	100.00	100.00
2000	100.00	100.00	100.00
1700	99.80	99.70	100.00
1400	99.50	99.40	100.00
1180	99.00	99.20	100.00
1000	98.60	99.00	100.00
850	97.50	98.50	100.00
710	95.00	98.00	100.00
600	90.00	97.00	100.00
500	79.50	91.00	99.00
425	60.00	69.00	95.00
355	44.00	50.00	65.00
300	28.50	26.00	42.50
250	18.60	15.00	29.00
212	16.00	13.00	21.50
200	13.50	11.00	16.00
180	9.00	9.00	11.20
150	5.00	7.00	7.00
125	2.90	5.00	5.00
106	2.50	4.70	4.30
90	2.00	4.37	3.70
75	1.00	4.20	3.30
63	0.60	4.00	3.00
-63			

**IMPORTANT NOTE: highlighted figures (only) are measured values; all other figures are extrapolated values to enable comparisons to be made with other analyses**

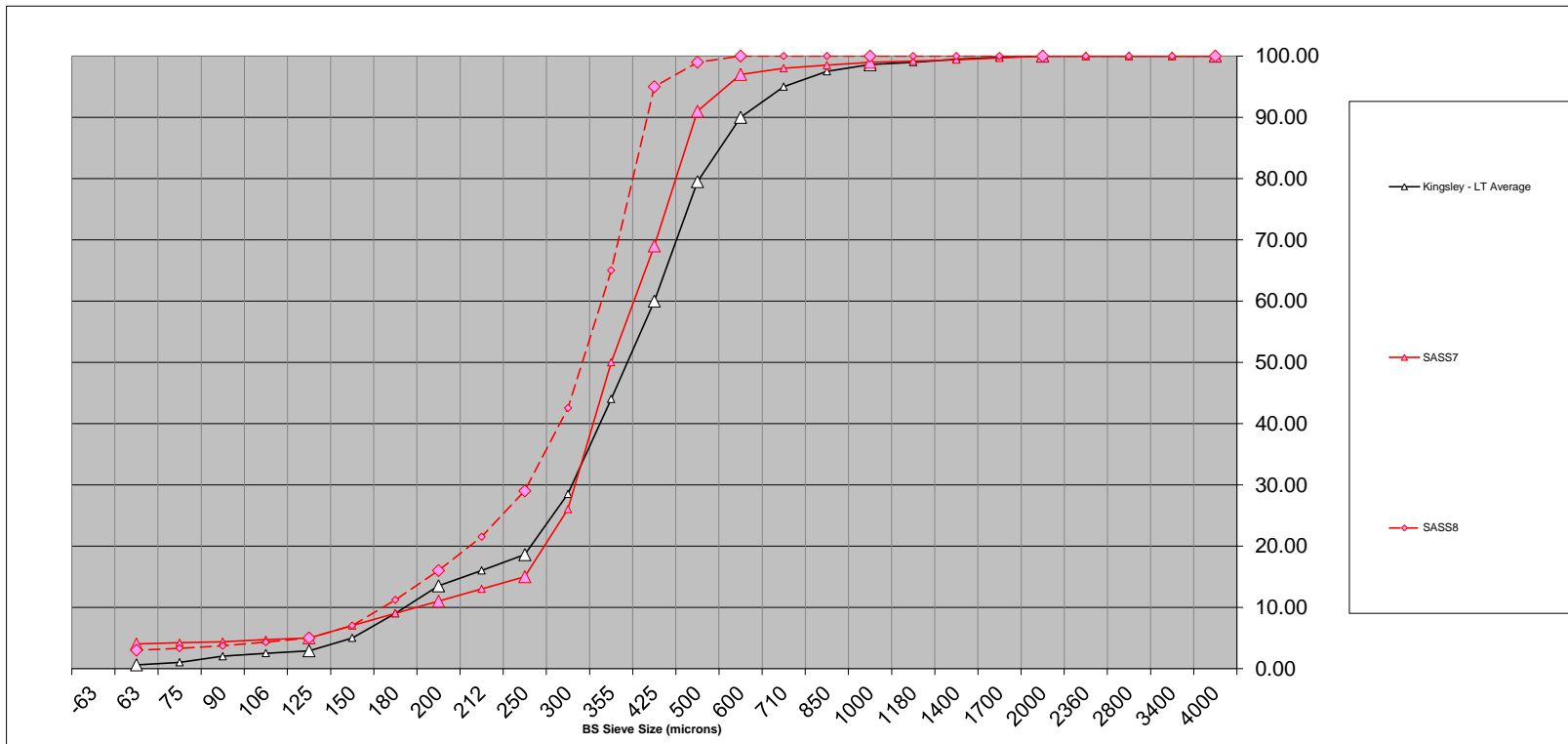


Figure 2.6: Particle Size Analysis Comparisons for Coates Quarry and Horncroft Site

BS Sieve Size (microns)	Hampshire (for reference)	West Sussex - Coates Quarry				West Sussex - Horncroft Site		
	Lafarge Tarmac data - Kingsley No. 1 sand 0/2mm - 2014 average	in-situ sample from lower unit in NE of quarry	in-situ sample from higher unit in S of quarry	OTB Report Coates Pit sample A	OTB Report Coates Pit sample B	OTB report Horncroft composite sample of lower unit	Confidential commercial data for the relatively fine-grained middle part of the sequence	Confidential commercial data for the relatively coarse-grained lower part of the sequence
	Kingsley - LT Average	Coates lower (SASS9)	Coates upper (SASS10)	OTB Report (Coates A)	OTB Report (Coates B)	OTB Report - Horncroft Composite	Horncroft Middle	Horncroft Lower
	cumulative % passing							
4000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
3400	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2800	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2360	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2000	100.00	100.00	99.00	100.00	100.00	100.00	100.00	100.00
1700	99.80	99.70	98.00	100.00	100.00	100.00	100.00	99.90
1400	99.50	99.40	97.50	100.00	100.00	100.00	99.90	99.60
1180	99.00	99.20	97.00	100.00	99.00	100.00	99.80	99.30
1000	98.60	99.00	95.00	100.00	98.80	99.80	99.30	98.70
850	97.50	95.50	92.00	99.90	98.50	99.00	98.60	96.50
710	95.00	90.00	88.00	99.80	98.00	98.00	97.40	92.60
600	90.00	81.00	85.00	98.00	94.00	96.00	95.00	83.50
500	79.50	61.00	79.00	87.00	83.50	93.00	92.50	72.10
425	60.00	42.00	72.00	76.00	72.00	88.00	89.00	57.00
355	44.00	28.00	54.00	65.00	60.00	80.00	81.10	42.30
300	28.50	17.00	36.00	53.00	48.00	69.00	66.00	29.00
250	18.60	11.00	25.00	41.50	37.50	55.00	54.10	21.60
212	16.00	9.00	18.00	29.50	28.00	42.00	45.00	17.00
200	13.50	7.00	12.00	19.00	20.00	30.00	35.00	14.20
180	9.00	5.50	10.00	9.00	11.00	22.00	25.30	11.10
150	5.00	4.20	8.00	4.00	6.00	18.00	15.90	7.10
125	2.90	3.00	6.00	3.50	4.50	16.00	10.10	5.00
106	2.50	2.70	5.00	3.00	3.50	14.00	7.00	3.50
90	2.00	2.40	4.00	2.80	3.00	12.00	4.30	2.30
75	1.00	2.20	3.30	2.30	2.50	10.00	2.50	1.30
63	0.60	2.00	3.00	2.00	2.00	8.00	0.80	0.40
-63								

**IMPORTANT NOTE: highlighted figures (only) are measured values; all other figures are extrapolated values to enable comparisons to be made with other analyses**

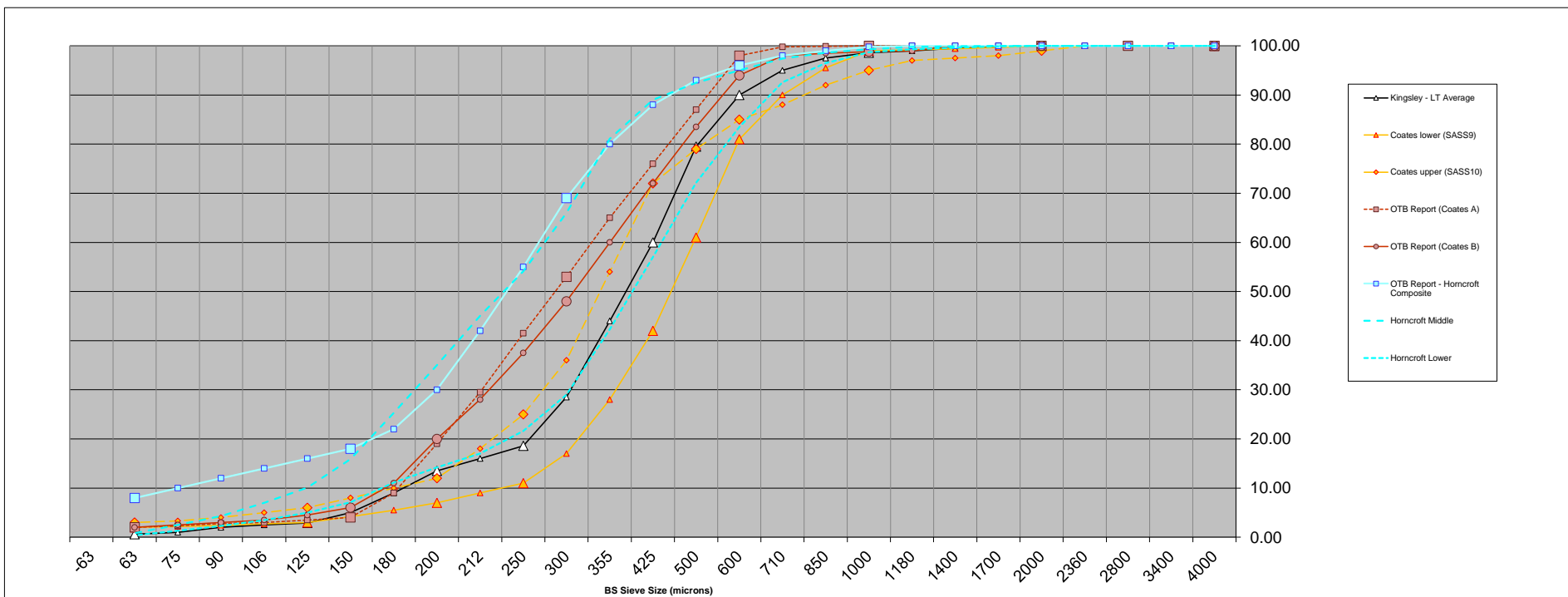


Figure 2.7: Particle Size Analysis Comparisons for Sandgate Park Quarry

		Hampshire (for reference)	West Sussex - Sandgate Park Quarry					
		Lafarge Tarmac data - Kingsley No. 1 sand 0/2mm - 2014 average	Upper sands within current working face	Lower sands exposed by haul road	Washed sand stockpile	Average of CEMEX samples for Fine Washed Soft Sand from Sandgate	fine envelope of CEMEX samples for Fine Washed Soft Sand	coarse envelope of CEMEX samples for Fine Washed Soft Sand
		Kingsley - LT Average	Sandgate Upper Face (SASS1)	Sandgate Lower Face (SASS2)	Sandgate Washed (SASS3)	CEMEX Sandgate Ave	CEMEX Sandgate Fine	CEMEX Sandgate Coarse
		Cumulative % Passing						
BS Sieve Size (Microns)								
	gravel							
	coarse sand							
	medium sand							
	fine sand							
	silt / v. fine sand							
	clay							
4000		100.00	100.00	100.00	100.00	100.00	100.00	100.00
3400		100.00	100.00	100.00	100.00	100.00	100.00	100.00
2800		100.00	100.00	100.00	100.00	100.00	100.00	100.00
2360		100.00	100.00	100.00	100.00	100.00	100.00	100.00
2000		100.00	100.00	100.00	100.00	100.00	100.00	100.00
1700		99.80	99.50	99.50	99.00	99.50	99.50	99.00
1400		99.50	99.00	99.00	98.00	99.00	99.00	98.00
1180		99.00	98.50	98.00	97.00	98.00	98.00	97.00
1000		98.60	98.00	97.00	96.00	96.30	97.00	96.00
850		97.50	96.50	95.00	94.00	92.00	95.00	90.00
710		95.00	94.00	92.00	90.00	85.00	90.00	84.00
600		90.00	89.00	85.00	81.00	77.70	84.00	75.00
500		79.50	79.00	75.00	71.00	70.90	76.00	67.00
425		60.00	69.00	61.00	61.00	59.80	60.00	53.00
355		44.00	47.50	40.00	43.00	40.00	45.00	40.00
300		28.50	28.00	23.00	26.00	25.30	30.00	23.00
250		18.60	15.00	13.00	15.00	17.60	21.00	13.00
212		16.00	10.00	9.50	10.00	14.60	19.00	11.00
200		13.50	7.00	8.00	7.00	11.80	17.00	9.00
180		9.00	5.00	7.00	5.00	8.50	12.00	7.00
150		5.00	3.80	6.00	3.00	5.50	9.00	4.50
125		2.90	3.00	5.00	2.00	3.60	6.00	3.00
106		2.50	2.70	4.50	1.65	3.30	5.50	2.50
90		2.00	2.40	4.00	1.40	2.90	5.00	2.00
75		1.00	2.20	3.50	1.20	2.50	4.70	1.50
63		0.60	2.00	3.00	1.00	1.73	4.30	1.20
-63								

**IMPORTANT NOTE: highlighted figures (only) are measured values; all other figures are extrapolated values to enable comparisons to be made with other analyses**

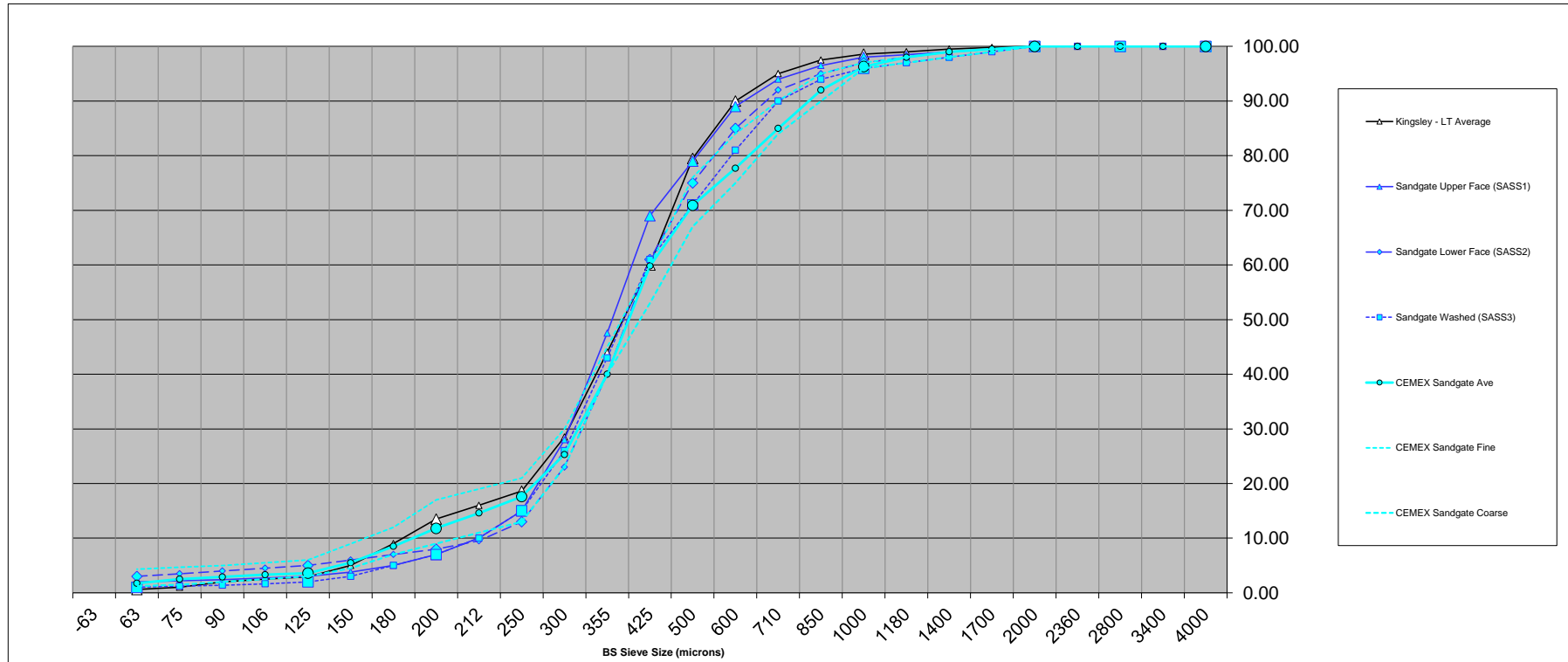
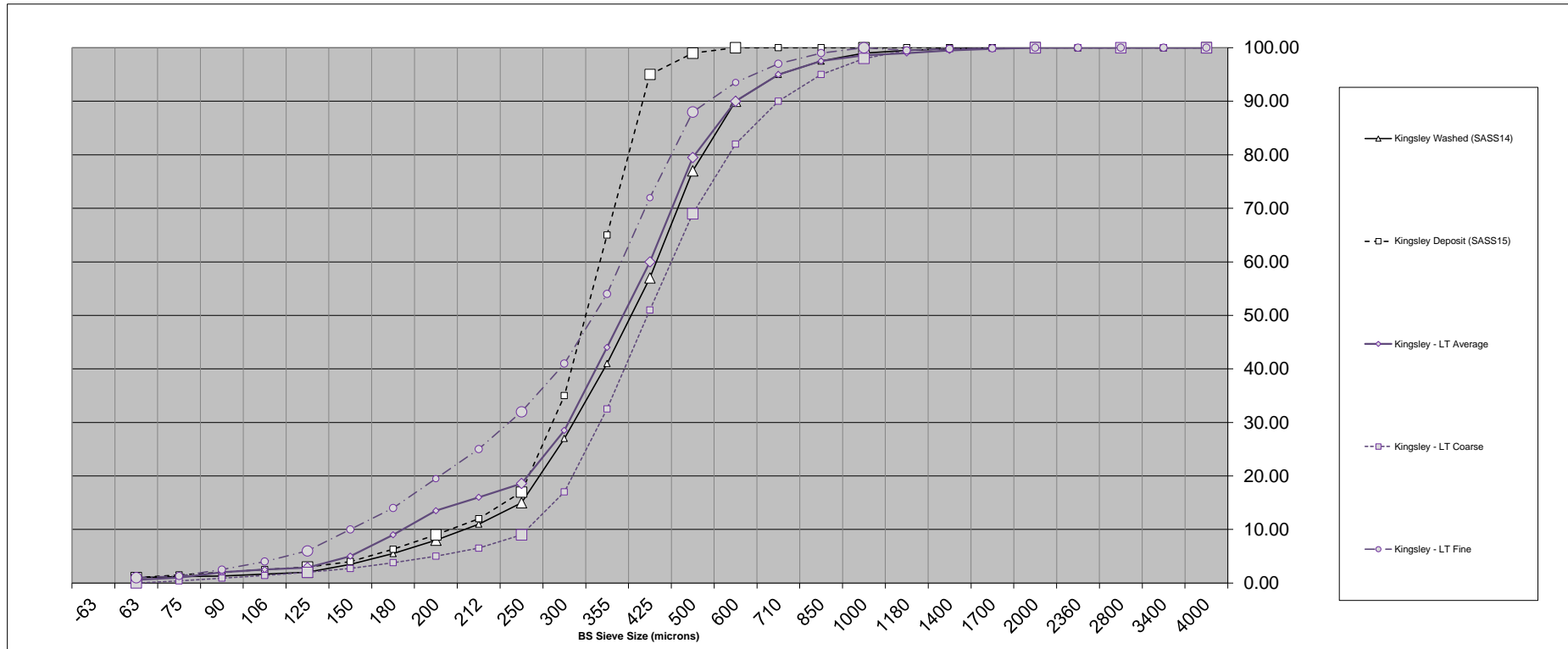


Figure 2.8: Particle Size Analysis Comparisons for Kingsley Quarry

Hampshire - Kingsley Quarry (for reference)					
BS Sieve Size (Microns)	Kingsley Quarry, dredged and washed	Kingsley Quarry, in-situ sample	Lafarge Tarmac data - Kingsley No. 1 sand 0/2mm - 2014 average	Lafarge Tarmac data - Kingsley No. 1 sand 0/2mm - 2014 coarse envelope	Lafarge Tarmac data - Kingsley No. 1 sand 0/2mm - 2014 fine envelope
	Kingsley Washed (SASS14)	Kingsley Deposit (SASS15)	Kingsley - LT Average	Kingsley - LT Coarse	Kingsley - LT Fine
Cumulative % Passing					
4000	100.00	100.00	100.00	100.00	100.00
3400	100.00	100.00	100.00	100.00	100.00
2800	100.00	100.00	100.00	100.00	100.00
2360	100.00	100.00	100.00	100.00	100.00
2000	100.00	100.00	100.00	100.00	100.00
1700	100.00	100.00	99.80	99.90	99.90
1400	99.80	100.00	99.50	99.80	99.80
1180	99.50	100.00	99.00	99.50	99.50
1000	99.00	100.00	98.60	98.00	100.00
850	97.50	100.00	97.50	95.00	99.00
710	95.00	100.00	95.00	90.00	97.00
600	90.00	100.00	90.00	82.00	93.50
500	77.00	99.00	79.50	69.00	88.00
425	57.00	95.00	60.00	51.00	72.00
355	41.00	65.00	44.00	32.50	54.00
300	27.00	35.00	28.50	17.00	41.00
250	15.00	17.00	18.60	9.00	32.00
212	11.00	12.00	16.00	6.50	25.00
200	8.00	9.00	13.50	5.00	19.50
180	5.50	6.30	9.00	3.80	14.00
150	3.50	4.00	5.00	2.70	10.00
125	2.00	3.00	2.90	2.00	6.00
106	1.65	2.50	2.50	1.40	4.00
90	1.32	2.00	2.00	0.90	2.50
75	1.20	1.50	1.00	0.40	1.30
63	1.00	1.00	0.60	0.00	1.00
-63					

**IMPORTANT NOTE:** highlighted figures (only) are measured values; all other figures are extrapolated values to enable comparisons to be made with other analyses



- 2.29 Figure 2.5 presents data for the two samples obtained from the disused quarry at Midhurst Common. Although little remains of the sand at this site (which was formerly quarried for use in the manufacture of distinctive, white-coloured lime bricks), it provides the closest in-situ exposure of sand to the adjoining proposed sites of Severals East and Severals West. Both samples have grading characteristics which are remarkably similar to the average grading at Kingsley, particularly so in the case of sample SASS7, obtained from the higher part of the sequence. The lower layer (SASS8) is finer-grained but this should not be taken as being indicative of a more general trend. In detail, there is likely to be more variability within the sequence.
- 2.30 Figure 2.6 combines the data from our samples at Coates Pit (SASS9 and SASS10) with results from the same site contained within the OTB report, and with data for the nearby promoted site at Horncroft. The latter includes OTB's analysis for a 'composite sample' from several boreholes, together with gradings relating to the coarser and finer parts of the sequence found within the boreholes. These were selected by Cuesta from a much larger dataset provided in confidence by Sibelco (the operator with an interest in this site) and are meant to be indicative of the range of gradings obtained, rather than being an absolute grading envelope. The diagram shows that most of the results, for both sites, fall within the indicative range for Horncroft and that they are generally somewhat finer-grained than the average grading for Kingsley. The exception is SASS9, the lower and relatively coarse-grained sand within Coates Pit, which is slightly coarser than the Kingsley average.
- 2.31 Figure 2.7 presents data for Sandgate Park Quarry, located just outside the National Park, towards the eastern end of the outcrop. In marked contrast to West Heath Common (Fig. 2.4), the results here fall within a far more limited range, which very closely approximates to the 'average' grading for Kingsley. This includes both our testing of in-situ and processed samples and the typical range of recent grading data for processed 'fine washed sand' provided by the quarry operator.
- 2.32 Figure 2.8 presents similar data for Kingsley Quarry in Hampshire - a site which already supplies around 75% of its output as specialist silica sand, primarily for use in various sports and horticultural applications (but not for higher end-uses such as glass-making or sodium silicate production). Figure 2.8 includes results from our own analyses and typical recent data supplied by the operator Tarmac). It is included in this sequence primarily to enable comparisons to be made with the various West Sussex sites in terms of grading variability. The range of gradings at Kingsley appears to be significantly less variable than those at West Heath Common, but comparable to the findings for Sandgate Park.
- 2.33 More detailed comparisons of grading data with a range of end use requirements are given in Chapter 5, below.

### Colour

- 2.34 To a certain extent, the colour of a sand indicates the likely proportion of iron, clay minerals or other impurities within it. A completely pure silica sand, made up only of clear or translucent quartz grains with no impurities would appear completely white, whereas a sand with significant amounts of iron oxide within it would generally appear orange, brown or red. In between, most silica sands contain relatively small amounts of impurities

and are therefore generally found in much lighter shades of these colours. Pale coloured sands are therefore generally likely to be purer than others and this can be a useful indicator in field assessments. For some end-uses, colour can have a more intrinsic and direct influence on the suitability of the sand. It is important, for example, in many sports, equestrian and play sand end uses where staining and/or aesthetic appearance could be an issue.

- 2.35 For each of the samples obtained in this study, colour was identified visually, both in terms of simple colour descriptions and, more scientifically by using Munsell colour charts. In both cases the findings were recorded by the testing laboratory on the PSD certificates.
- 2.36 The Munsell colour classification system was designed specifically for defining the colour of soil samples on the basis of three independent parameters: **hue** (the closest 'pure' colour), **value** (tone or lightness); and '**chroma**' (or degree of colour purity).
- **Hue** is described by numbers and letters denoting the principal colours observed. For example, vermillion red is notated as 10R and pure yellow is 10Y. In between there are seven incremental steps: 2.5YR, 5YR, 7.5YR, 10YR, 2.5Y, 5Y and 7.5Y, each of which has decreasing amounts of red and increasing amounts of yellow. The mid-point of this particular series (10YR) corresponds to a shade of orange.
  - **Value** in the Munsell colour system represents the closest shade of grey to the soil being considered, expressed on a simple linear scale from 0 (black) to 10 (white). In practice, the numbers used are between 1 and 9.
  - **Chroma** is the degree of 'colour purity' or 'colour strength' of the sample, expressed in terms of the distance away from grey towards the pure colour on a simple linear scale ranging from 0 (grey) to values of 10 to 18, depending on the hue.
- 2.37 Putting all three descriptors together, a typical Munsell colour number for a sand would be **10YR 5/8**, which would describe material that is orange in colour (10YR), mid-way between dark and light (5), and with a fairly strong purity of colour (/8). Actual numbers are found by comparing samples with printed colour charts.
- 2.38 Table 2.4, below, shows both the Munsell numbers and simple visual descriptions made by the laboratory technician for each of the samples obtained in this study.

**Table 2.4: Munsell Colour Numbers and Visual Descriptions for Samples obtained by Cuesta**

Site Name	Sample No.	Closest available Munsell Soil Colour Number	Simple colour description by laboratory technician
Sandgate Park Quarry	SASS1	2.5YR 5/8	'Red'
Sandgate Park Quarry	SASS2	10YR 6/6	'Brownish yellow'
Sandgate Park Quarry	SASS3	2.5YR 6/6	'Light red'
West Heath Common Quarry	SASS4	10YR 6/6	'Yellow'
West Heath Common Quarry	SASS4a	10YR 2.5/1	'Reddish black'
West Heath Common Quarry	SASS5	10YR 7/6	'Yellow'
West Heath Common Quarry	SASS6	10R 4/4	'Pale red'
Midhurst Common Quarry	SASS7	10YR 6/4	'Light yellowish-brown'
Midhurst Common Quarry	SASS8	10YR 6/2	'Light brownish'
Coates Pit	SASS9	7.5YR 6/8	'Reddish yellow'
Coates Pit	SASS10	10YR 7/8	'Yellow'
Wickford Bridge	SASS12	10YR 3/4	'Dark yellowish brown'
Kingsley Quarry	SASS14	10YR 6/6	'Brownish yellow'
Kingsley Quarry	SASS15	2.5Y 6/6	'Olive yellow'

- 2.39 Most of the samples are of a similar hue, with 10YR being the most common, although some are redder (e.g. 2.5YR) and one is more yellow (2.5Y). Most of the samples are also fairly pale (values of 6 or 7 being the most common), and most have a moderately strong purity of colour (chromas of 6 to 8). Those within these ranges are all likely to have relatively low levels of iron and other impurities and should therefore potentially offer good prospects for silica sand production.
- 2.40 The only exceptions to this are those which are redder in hue, darker in tone and/or with very low chroma values - all of which would signify higher levels of chemical impurity. Such exceptions are seen in the case of SASS4a (a rather 'atypical' sample of dark coloured sand from one part of West Heath Common Quarry); SASS8 (a sample of iron-stained sand from Midhurst Common); and SASS12 which, as previously noted, was an anomalous surface soil sample with much higher than usual fractions of clay, silt and organic material.

### Chemical Analysis

- 2.41 As previously noted, the foregoing colour descriptions are purely indicative of the purity or otherwise of the sands and, whilst they offer a useful preliminary field assessment method, they would never be relied upon to determine whether or not silica sand could be produced from a given location. The only reliable way of assessing the proportions of silica, iron and other constituents within the sands is through chemical and/or mineralogical analysis. Chemical analysis by means of X-Ray Fluorescence (XRF) is the industry standard method for the assessment of potential silica sands and was used in this study.
- 2.42 Portions of each of the samples obtained from the site visits were sent to the specialist laboratories of PANalytical, in Nottingham. Whilst a representative sand sample was used, no initial wet sieving or washing was completed in order to remove the finer silt and clay content. Pre-washing often would be carried out by commercial companies,

particularly for sands being used in glass-making, since the fines component may sometimes contain higher proportions of impurities than the rest of the sand. As noted earlier, this needs to be born in mind when looking at the test results although, with just one exception, all of the samples had very low fines contents. The main implication is that the chemical analyses obtained for our samples may show slightly higher levels of impurities than those likely to be obtained by a commercial operator.

- 2.43 In order to carry out the XRF analysis, each sand sample is initially dried and ground to produce a sample powder with grain sizes less than 63 microns. This powder is mixed with a lithium borate flux and melted at 1,200°C before being cast into a glass bead. This then gives a homogeneous sample with a very flat analysing surface to be presented to the XRF spectrometer which exposes the sample to a beam of primary X-Rays. The atoms within the sample absorb energy from the X-rays, become temporarily excited and then emit secondary X-rays. Each chemical element emits X-rays at a unique energy. By measuring the intensity and characteristic energy of the emitted X-rays, quantitative analysis regarding the composition of the material being tested can be determined. The analysis used was a Major Oxides determination. The accuracy on total analysis is 100% +/-1%.
- 2.44 The results of the chemical analyses of both Cuesta's samples and those obtained from other sources are presented in Table 2.5, below. Data for individual sites are repeated in the combined data sheets for each sampling location, in Appendix A (available as a separate pdf document).
- 2.45 The results of the XRF analysis on the samples from this study show that all but one these sands may be classified as 'silica sands' with some of them being of high purity. The total silica content of these samples generally ranges from 96.76% to 98.69% with the only exception (not unexpectedly) being that of the soil sample obtained at Wickford Bridge which has a total silica content of only 93.4%. With that exception, the results are comparable to the two samples taken from Kingsley Quarry which show total silica contents of 97.69% and 98.92%, respectively, and to the results of a separate analysis for Kingsley as supplied by the operator (97.72%). These comparisons are useful since, as noted earlier, Kingsley already has an established market for supplying specialist silica sand, albeit not for the highest specification end uses. These percentages are slightly lower than those given in the OTB report for both Coates Pit and the Horncroft site (99.34% and 98.90%, respectively for 'raw' samples (without washing), and up to 99.67% after washing). Additional (confidential) chemical testing data for the Horncroft site, supplied to Cuesta by Sibelco (who have an interest in the resource), demonstrated that, after full water-based processing (i.e. washing, attrition scrubbing and high intensity magnetic separation), the percentage silica content at that site could be increased to 99.74% (as an average of 305 samples). See paragraph 2.51, below, for further details of those tests.
- 2.46 It is important to remember that, whilst chemical test results are a vital aspect of defining the potential suitability of a silica sand resource for high grade end-uses, on their own, they do not confirm whether or not a site is economically viable (see also para. 2.64, below).

**Table 2.5: Chemical Analyses of Cuesta Samples from the South Downs Soft And Silica Sand Study, March 2015, with additional data from operators**

Sample #	LIMS ID	SiO <sub>2</sub> %	TiO <sub>2</sub> %	Al <sub>2</sub> O <sub>3</sub> %	Fe <sub>2</sub> O <sub>3</sub> %	Mn <sub>3</sub> O <sub>4</sub> %	MgO %	CaO %	Na <sub>2</sub> O %	K <sub>2</sub> O %	P <sub>2</sub> O <sub>5</sub> %	SO <sub>3</sub> %	Cr <sub>2</sub> O <sub>3</sub> %	SrO %	SnO <sub>2</sub> %	ZrO <sub>2</sub> %	BaO %	NiO %	CuO %	ZnO %	PbO %	V <sub>2</sub> O <sub>5</sub> %	HfO <sub>2</sub> %	F %	Cl %	LOI %	Total %
SASS1	2015016-0001	98.54	0.04	0.43	0.22	<0.01	<0.05	<0.01	<0.05	0.01	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.36	99.6
SASS2	2015016-0002	98.19	0.03	0.47	0.15	<0.01	<0.05	<0.01	<0.05	0.02	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.44	99.3
SASS3	2015016-0003	98.69	0.03	0.10	0.09	<0.01	<0.05	<0.01	<0.05	<0.01	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.23	99.14
SASS4	2015016-0004	98.19	0.05	0.27	0.35	<0.01	<0.05	<0.01	<0.05	<0.01	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.37	99.23
SASS4a	2015016-0005	96.76	0.12	0.60	0.32	<0.01	<0.05	<0.01	<0.05	0.03	<0.01	<0.1	<0.01	<0.01	n/a	0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	1.29	99.14
SASS5	2015016-0006	98.31	0.07	0.33	0.28	<0.01	<0.05	<0.01	<0.05	0.02	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.39	99.4
SASS6	2015016-0007	97.79	0.11	0.66	0.18	<0.01	<0.05	<0.01	<0.05	0.03	<0.01	<0.1	<0.01	<0.01	n/a	0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.58	99.37
SASS7	2015016-0008	97.52	0.07	1.03	0.20	<0.01	<0.05	<0.01	<0.05	0.06	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.63	99.51
SASS8	2015016-0009	98.52	0.10	0.40	0.19	<0.01	<0.05	<0.01	<0.05	0.02	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.36	99.59
SASS9	2015016-0010	97.77	0.04	0.59	0.42	<0.01	<0.05	<0.01	<0.05	0.02	0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.46	99.31
SASS10	2015016-0011	98.30	0.04	0.65	0.34	<0.01	<0.05	<0.01	<0.05	0.02	<0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.34	99.69
SASS12	2015016-0012	93.40	0.18	2.07	0.86	0.01	<0.05	0.03	<0.05	0.17	0.05	<0.1	<0.01	<0.01	n/a	0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	2.38	99.17
SASS14	2015016-0013	98.92	0.05	0.20	0.75	<0.01	<0.05	<0.01	<0.05	0.05	0.02	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.3	100.29
SASS15	2015016-0014	97.69	0.06	0.41	0.43	<0.01	<0.05	<0.01	<0.05	0.12	0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.36	99.08
Kingsley MPLT619	13145-0006	97.72	0.05	0.25	0.72	<0.01	<0.05	0.02	<0.05	0.06	0.01	<0.1	<0.01	<0.01	n/a	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	0.27	99.1
Horncroft (Raw)	(OTB report)	98.90	0.04	0.46	0.32	<0.01	<0.02	0.02	<0.03	0.04	<0.02	<0.05	<0.01	<0.01	<0.01	<0.02	<0.01	n/a	<0.01	<0.01	<0.02	n/a	<0.01	n/a	n/a	n/a	99.78
Horncroft (Washed)	(OTB report)	99.50	0.03	0.16	0.19	<0.01	<0.02	0.01	<0.03	0.02	<0.02	<0.05	<0.01	<0.01	<0.01	<0.02	<0.01	n/a	<0.01	<0.01	<0.02	n/a	<0.01	n/a	n/a	n/a	99.91
Coates Pit (Raw)	(OTB report)	99.34	0.04	0.30	0.12	<0.01	<0.02	0.01	<0.03	0.02	<0.02	<0.05	<0.01	<0.01	<0.01	<0.02	<0.01	n/a	<0.01	<0.01	<0.02	n/a	<0.01	n/a	n/a	n/a	99.83
Coates Pit (Washed)	(OTB report)	99.67	0.04	0.13	0.07	<0.01	<0.02	0.01	<0.03	0.02	<0.02	<0.05	<0.01	<0.01	<0.01	<0.02	<0.01	n/a	<0.01	<0.01	<0.02	n/a	<0.01	n/a	n/a	n/a	99.94

- 2.47 Those samples at the lower end of the range in terms of total silica content were SASS4a (96.76%), SASS6 (97.79%), and SASS7 (97.79%). These samples also had a relatively lower Munsell value and chroma (see Table 2.4 above), i.e. they were darker in tone and had a relatively lower purity of colour. By contrast, the samples that were fairly pale (values of 6 and above) with a moderately strong purity of colour (chromas of 6 and above) generally had values of total silica content above 98%. This suggests that tone (value) and chroma provide reasonable indications of the chemical purity of the sand, although this can be used only for the purposes of preliminary field assessment. It cannot be relied upon as an indication of being able to meet particular chemical specification requirements.
- 2.48 The analyses show that the main 'other' constituents in all of the Cuesta samples were:
- Iron Oxide ( $\text{Fe}_2\text{O}_3$ ) - values generally ranging from 0.09% to 0.43% but rising to 0.75% in one of the Kingsley samples and to 0.86% at Wickford Bridge;
  - Alumina ( $\text{Al}_2\text{O}_3$ ) - values generally from 0.1% to 0.66%, but rising to 1.03% in one of the Midhurst Common samples and to 2.07% at Wickford Bridge;
  - Titania (or Titanium Dioxide -  $\text{TiO}_2$ ) - values generally from 0.03% to 0.1% but slightly higher than this in two of the West Heath samples and rising to 0.18% at Wickford Bridge.
- 2.49 The relatively high iron oxide content in one of Cuesta's Kingsley samples is very similar to that shown for the same site in an analysis supplied by the operator (0.72%). That analysis also gave values for Alumina and Titania at comparable levels to those shown above (0.25% and 0.05%, respectively).
- 2.50 The OTB results for both 'raw' and washed samples from Coates Pit and Horncroft (also shown in Table 2.5) revealed values within the same general ranges for all three oxides.
- 2.51 In order to understand the potential achievements of full processing, at least at the Horncroft site, additional details of the chemical analyses carried out by Sibelco were made available by the operator to Cuesta and to both SDNPA and WSCC. These were provided under the terms of a confidentiality agreement, following a request for additional information. Whilst the data itself remains confidential, it has been subject to detailed scrutiny by Cuesta, and the following key observations have been made:
- Eleven boreholes were drilled within an indicative 20 hectare working area within the Horncroft site during 2014, to depths of between 30 and 36m. These revealed a deposit of sand, ranging from 20m to at least 34m in thickness beneath an overburden of between 1.4m and 9m of clayey and/or gravelly superficial deposits. Bulk disturbed samples were taken at 1m intervals throughout the full investigated depth of the sand deposits (beneath the overburden) and were subjected to particle size analysis and full chemical analysis, by X-Ray Fluorescence. The analysis was carried out after full processing (i.e. washing, attrition scrubbing and high intensity magnetic separation), which Sibelco suggest simulates the standard treatment carried out at their existing processing plant at North Park in Surrey.

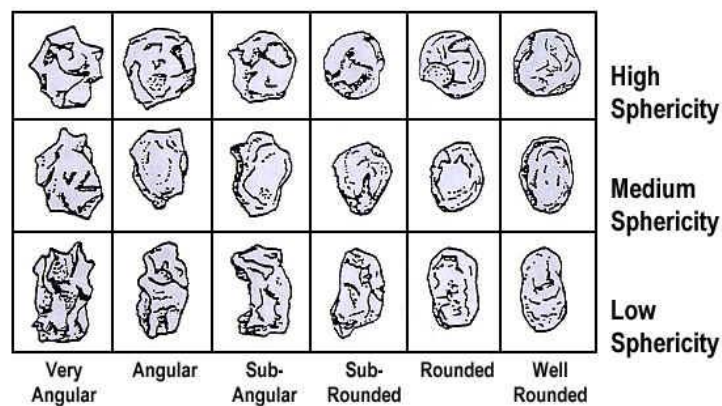
- A total of 305 samples were analysed, after full processing, from an estimated total resource of 2.5 million m<sup>3</sup>. A small proportion (6%) of those near the very top of the deposit in some of the boreholes were found to have relatively high residual levels of iron oxide. In practice, these would be recognisable by their colour, due to iron staining within the sand, and it is likely that they would be separated from the main body of the deposit during excavation. For the remaining 286 fully-processed samples, representing 94% of the total, the average proportions of silica, and of iron, aluminium, titanium and chromium oxides were found to be as follows:
  - **Silica** (SiO<sub>2</sub>): 99.74%
  - **Iron** (Fe<sub>2</sub>O<sub>3</sub>): 0.035%
  - **Alumina** (Al<sub>2</sub>O<sub>3</sub>): 0.06%
  - **Titanium** (TiO<sub>2</sub>): 0.014%
  - **Chromium** (Cr<sub>2</sub>O<sub>3</sub>): 0.0003%
- In detail, these averages inevitably encompass some degree of variation from one sample to another, with some layers of even higher purity sand and, on the other hand, others with higher levels of residual iron oxide (though with very few samples exceeding 0.05%). In practice, however, those variations would be eliminated by blending during extraction and processing and the average composition will determine the suitability of the sand as feedstock for particular end uses.
- Analysis of the Sibelco data indicates that, for the majority of the deposit, as represented by 94% of the samples (excluding a minor proportion of near-surface material) the average composition meets the specification requirements for all types of glass manufacturing, including clear container glass and flat glass (see Chapter 5 below).
- The analysis further shows that all of the deposit (as represented by all 305 samples) would meet the requirements for sodium silicate production.
- Given the large number of samples, and their distribution across most (though not all) parts of the site, these findings provide a good indication of the quality and consistency of sand that is capable of being produced from this site.

2.52 Analysis of the Sibelco data relating to the Horncroft site should not be taken to imply that similar quality and consistency can necessarily be achieved in other parts of the Folkestone Formation, elsewhere in the study area. Although comparable analysis of fully processed samples is not available for other sites, the 'raw' results (as presented in Table 2.5 above) indicate considerable variation from one location to another.

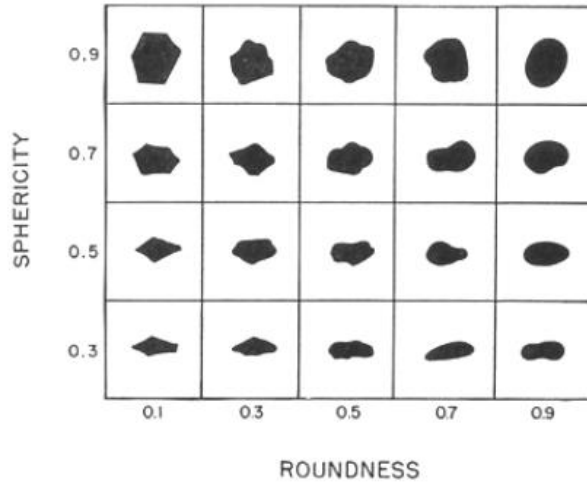
2.53 The percentage of organic matter in the Cuesta samples, as identified from Loss on Ignition as part of the chemical analysis, ranges from 0.23% to 0.63% with the exception of SASS12, the soil sample from Wickford Bridge which (not surprisingly) showed a value of 2.38% and also SASS4a which showed a value of 1.29%. Both SASS4a and SASS12 were rather darker in tone with both a low Munsell value and low chroma (see Table 2.4 above) which correlates well with the higher organic content found in these samples.

Grain Shape Analysis

- 2.54 Analysis of grain shape provides useful additional information to confirm the suitability or (otherwise) of the sand for certain end-uses where shape is important.
- 2.55 The shape of sedimentary particles, including sand grains, is governed by material composition, age, and the distance and mechanism by which it is transported. The method for describing sedimentary particle shape has remained consistent over many decades. Particle shape is generally considered to be comprised of two independent geometric concepts: **Sphericity** and **Roundness**. Sphericity was initially defined by Wadell (1932) and is a measure of the degree to which the shape of a particle approaches that of a sphere. Roundness measures the smoothness (or irregularity) of the grain surface and was also initially defined by Wadell (1932) as the ratio of the curvature of the corners and edges of the particles to that of the overall particle. Both these measurements required time-consuming mathematical calculations. In order to shorten the time required to estimate roundness, Krumbein (1941) created a chart showing pre-classified particle shapes.
- 2.56 Today, geologists still qualitatively and quantitatively describe the shape (both sphericity and roundness) of sedimentary particles using standard charts, such as that developed by Krumbein & Sloss (1951). These charts may be based purely on descriptions (see Figure 2.9, below) – a method favoured by most of producers and end-users of silica sand. However, a numerical index may also be used, based on the theoretical maximum value of sphericity being 1.0 (see Figure 2.10) – this method is favoured in describing frac sands where a high degree of both roundness and sphericity is needed (as explained in Chapter 3). True sphericity is extremely rare amongst natural sediments, where grains generally tend to reach a maximum of 0.7.

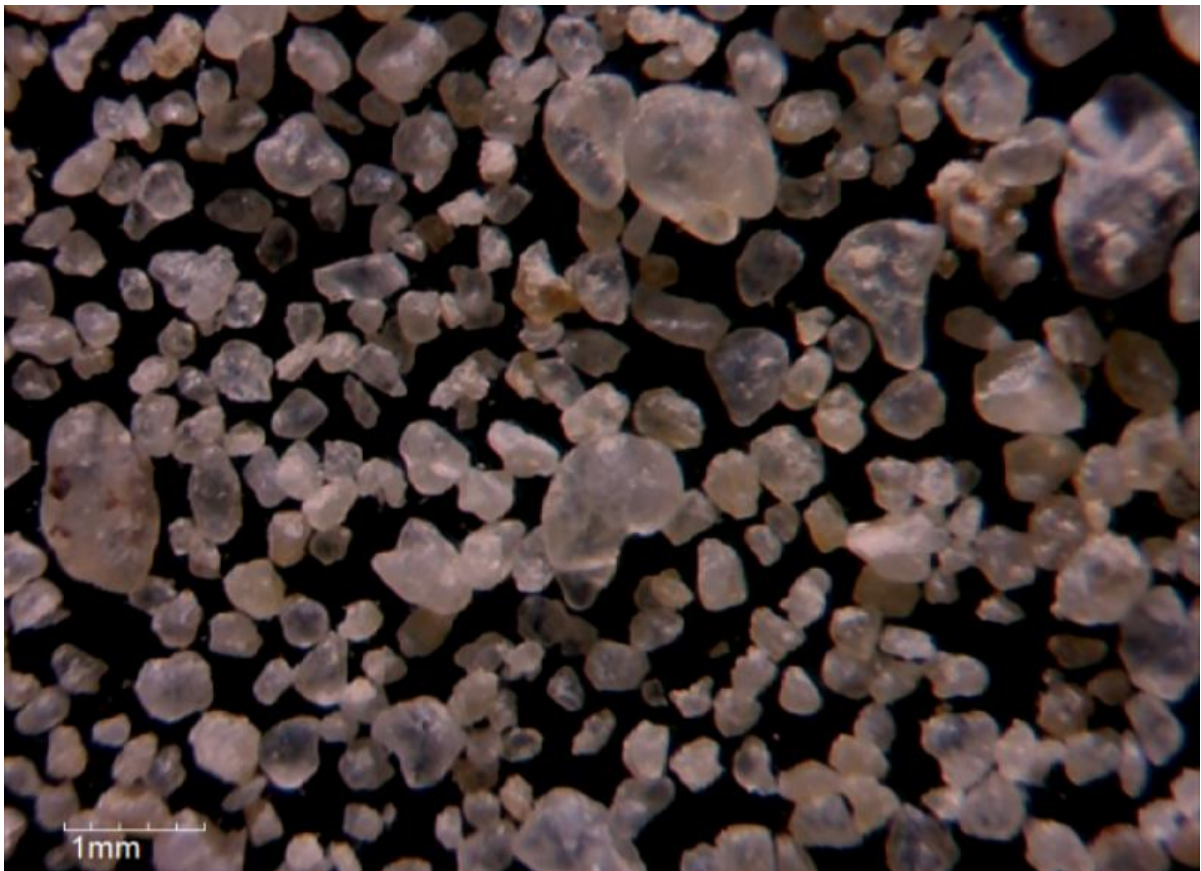


**Figure 2.9: Sand Sphericity and Roundness Chart**



**Figure 2.10: Sphericity and Roundness Index**

2.57 The shape of the sand grains from each sample was assessed with the use of a stereo-zoom microscope and camera. A stereo-zoom microscope gives a good depth of field which assists in identifying the 3-dimensional shape of the sand grains and the camera enables scaled photomicrographs to be obtained, such as the example shown in Figure 2.11, below. Similar photographs for all samples are provided in Appendix A (available as a separate pdf document).



**Figure 2.11: Example Photomicrograph of Silica Sand from Coates Pit (x10 magnification)**

- 2.58 A representative portion of the sand was placed in a petri-dish, dried, crushed gently with a rubber-headed pestle to break up the particles and observed at magnifications of 10- to 30- times the actual size. It was found that greater clarity for the photomicrographs could be gained if a portion of the sand from the petri dish was placed on sticky tape. This enabled more of the grains to be contained within the limited depth of field available, with fewer of them being out of focus. Each sample was described according to the colour as viewed down the microscope, the range of grain size, the typical grain size and the degree of sphericity and roundness observed using the descriptions shown in Figure 2.7 above.
- 2.59 To enable a comparative assessment, Southern Testing Laboratories also recorded particle shape independently using a more traditional compound microscope but otherwise using the same method of preparation. Due to the inevitably subjective nature of shape assessment, the resulting descriptions are not identical, but are generally close (for example varying between sub-angular and sub-rounded for the same sample). The descriptions obtained using the stereo-zoom microscope are considered to be the more reliable, however, and these are presented for all samples in Table 2.6, below. The descriptions for each individual sample are also given, along with representative photomicrographs, PSD results and colour descriptions, in the combined data sheets for each site in Appendix A (available as a separate pdf document).
- 2.60 In all of the samples, the majority of sand grains were of medium sphericity with some of the samples showing some of the grains to be of high sphericity. The sand grains tended to be mostly sub-angular to sub-rounded, with the exception of those from Sandgate Park Quarry (SASS1 to 3) and from Coates Pit (SASS9 and 10) where, on average, the grains tended to be more rounded.

### ***Summary of Physical and Chemical Test Results***

- 2.61 The foregoing test results indicate that most of the sites investigated in this study are likely to be capable of yielding silica sand that is comparable to, and in some cases better than, that seen at Kingsley in Hampshire, which is already being utilised for specialist end-uses.
- 2.62 Some of the samples yielded test results which are very close, in terms of grading, colour and chemistry, to the findings of the OTB report on Coates Pit and Horncroft, which claimed those deposits to be of 'National importance' in terms of their chemical purity and consistency, and suitable (after processing) for clear glass and sodium silicate manufacturing as well as for a range of other specialist applications. Additional, comprehensive (but confidential) test data, as supplied by Sibelco, has confirmed the sands at Horncroft to be of that quality.
- 2.63 Although the samples obtained and tested in this study were limited in number, they appear to be consistent with existing test results, where these are available. Moreover, by virtue of their geographical spread across the whole of the Folkestone Formation outcrop within the SDNP and adjoining parts of West Sussex and Hampshire, they provide a reasonable indication of the physical and chemical properties capable of being exhibited by the Formation within that area.

**Table 2.6: Grain Shape Analysis and Related Observations for Samples obtained by Cuesta**

Site Name	Sample No.	Roundness	Sphericity	Colour under Microscope	Other Observations
Sandgate Park Quarry	<b>SASS1</b>	Sub-Rounded to Rounded	Medium Sphericity	Golden yellow and translucent white, coated in red 'silt'	A range of grain sizes observed a few at around 1mm but the majority smaller. Larger grains have red stained 'pock marks' or indentations. Grains coated in very fine grained red 'silt' like material. Groups of grains 'stick together' before use of pestle. Some grains of low sphericity, some of high sphericity but generally medium sphericity. More occasional sub-angular grains.
Sandgate Park Quarry	<b>SASS2</b>	Sub-Rounded to Rounded	Medium Sphericity	Golden yellow and translucent white	A range of grain sizes observed a few at around 1mm but the majority smaller. Very occasional larger grains have iron stained 'pock marks' or indentations. Groups of grains 'stick together' before use of pestle. Some grains of low sphericity, some of high sphericity but generally medium sphericity. More occasional sub-angular grains.
Sandgate Park Quarry	<b>SASS3</b>	Sub-Rounded to Rounded	Medium Sphericity	Clear (like fine glass) translucent white with some golden yellow grains with red staining	A range of grain sizes observed a few at around 1mm but the majority smaller. Some grains of low sphericity, some of high sphericity but generally medium sphericity. More occasional sub-angular grains. About half the grains clear like glass.
West Heath Common Quarry	<b>SASS4</b>	Sub-Angular to Rounded	Medium to High Sphericity	Clear (like fine glass) translucent white with very occasional golden yellow grains with red staining	A range of grain sizes observed a few at around 1mm but the majority smaller. The majority of the grains are clear like fine glass. Grains vary in shape some are almost well rounded are others sub-angular.
West Heath Common Quarry	<b>SASS4a</b>	Sub-Angular to Sub-Rounded	Medium to High Sphericity	Clear (like fine glass) translucent white and light grey sand grains coated in grey 'silt'	No coarse sand grain sizes observed. Grains all very similar in size. Groups of grains 'stick together' before use of pestle. Despite the colour of the sand being almost black, the sand grains themselves are clear to light grey in colour but coated in darker grey fine grained 'silt' like material.
West Heath Common Quarry	<b>SASS5</b>	Sub-Angular to Sub-Rounded	Medium to High Sphericity	Golden yellow and translucent white with some clear (like fine glass) grains and some orange grains	A range of grain sizes observed with occasional larger than 1mm size grain. Very occasional black 'silt' like material coating the grains.
West Heath Common Quarry	<b>SASS6</b>	Sub-Angular to Sub-Rounded	Medium to High Sphericity	Clear (like fine glass) translucent white and light grey	No coarse sand grain sizes observed. Grains all very similar in size. Some parts of the sand form hard compact lumps that break up with the pestle. Occasional orange stained grains. Occasional fine 'silt' like coating on the grains. Occasional Angular grains.
Midhurst Common Quarry	<b>SASS7</b>	Sub-Angular to Sub-Rounded	Medium to High Sphericity	Clear (like fine glass) translucent white and some light orange	No coarse sand grain sizes observed. Grains all very similar in size. Occasional light grey or orange 'silt' like material coating some grains
Midhurst Common Quarry	<b>SASS8</b>	Sub-Angular to Sub-Rounded	Medium to High Sphericity	Clear (like fine glass) translucent white and light grey	No coarse sand grain sizes observed. Grains all very similar in size. Occasional light grey 'silt' like material coating some grains
Coates Pit	<b>SASS9</b>	Sub Rounded	Medium to High Sphericity	Golden yellow and translucent white	No coarse sand grain sizes observed. Dark orange staining on some grains. Occasional light orange 'silt' like material coating some grains
Coates Pit	<b>SASS10</b>	Sub Rounded	Medium to High Sphericity	Golden yellow and translucent white	A range of sand grain sizes observed some more than 1mm but the majority smaller. Dark orange staining on some grains. Occasional light orange 'silt' like material coating some grains
Wickford Bridge	<b>SASS12</b>	Sub-Angular to Sub-Rounded	Medium to High Sphericity	Yellow and white grains heavily coated in light brown 'silt'	No coarse sand grain sizes observed. Grains heavily coated in fine grained light brown 'silt' material. Small roots present.
Kingsley Quarry	<b>SASS14</b>	Sub-Angular to Sub-Rounded	High Sphericity	Yellow orange and clear (like fine glass) translucent white	No coarse sand grain sizes observed. Occasional brown grain present. Grains very 'clean'.
Kingsley Quarry	<b>SASS15</b>	Sub-Angular to Sub-Rounded	Medium to High Sphericity	Yellow orange and clear (like fine glass) translucent white	No coarse sand grain sizes observed. Occasional brown grain present. Some dark orange staining on some grains.

- 2.64 Clearly, much more investigation and testing would need to be done to prove that individual sites are capable of producing sands which meet particular specifications, and that they are capable of being worked in an economically viable way, but both of those things are beyond the scope of this strategic study. What has been shown is that there is potential, throughout the area, subject to the economic viability of individual proposals which may come forward, for producing silica sand for specialist (non-aggregate) end-uses of one kind or another. In some cases, the potential may be limited to the production of agricultural, horticultural, equestrian and sports sands, but qualities suitable for end-uses such as clear glass manufacture and sodium silicate production (which require higher chemical purity and consistency) have been shown to be capable of being obtained, after processing, in at least one location (subject to the consideration of economic viability).
- 2.65 In order to consider this potential in further detail, consideration must first be given to the particular requirements and specifications for each of the various specialist end-uses.

### 3. Markets and End Use Specifications

- 3.1 This Chapter provides up to date information about the main markets for silica sand in the UK, both at a national scale and within the south east, together with a review of available information regarding the physical and chemical quality requirements within each market sector, where this is known.

#### **Markets**

- 3.2 In the UK, existing and potential markets for silica sand range from industrial glass production and foundry casting / moulding sand (traditionally the primary markets for such materials) to emerging and potentially highly significant markets such as hydraulic fracturing ('frac' sands). In between, there has been a steadily expanding range of markets for which specialist (silica) sand is the preferred or only suitable material. These range from water filtration and industrial product manufacturing (paints and plastics, polymer compounds, rubber, sealants, resins, adhesives and ceramic products) to various sports and leisure uses (golf courses, sports pitches, rootzone products, top-dressing materials, bunker sand, equestrian sand, jumping pit sand and play pit sand) and to a number of horticultural and agricultural applications.
- 3.3 Except at a very broad scale (such as that reported in the Office of National Statistics Business Monitor PA1007: *Mineral Extraction in Great Britain*, and in the *United Kingdom Minerals Yearbook* published by the BGS - which uses the same information), very little quantitative data is available on either levels of demand from (or sales to) any of these specialist markets. ONS data on silica sand production in Great Britain from 1970 to 2013, (but with broad subdivisions by market sector only since 1999<sup>5</sup>) is shown in Table 3.1, below.
- 3.4 Drawing largely on this data, and on a 2007 survey by the Silica and Moulding Sand Association, the BGS factsheet on silica sand (2009 version) notes that, historically, foundry casting was an important market for silica sand but that, with the progressive decline in UK heavy manufacturing industries, there has been a steady reduction in demand within that sector. From the data shown in Table 3.1, that trend seems to have continued through to the present day. Glass manufacturing became the largest consumer of silica sand in the UK in the mid-1980s<sup>6</sup>. Demand within that sector appears to have peaked in about 2006, however, and has since declined slightly. Over the same period there has been a substantial increase in the 'other' markets for silica sand which, together, now exceed the total sales to glass manufacturing, and have done since at least 2006. Since 2003, sales to agricultural, horticultural and leisure uses have been recorded separately from 'other industrial sands' and, by 2013, this sector had become comparable in scale, in terms of tonnage, to the current market for glass sand (although still a long way short of the 2006 peak for glass sand, which needs to be borne in mind as the economy recovers from the recent prolonged recession).

<sup>5</sup> PA1007 data is available online from 1999 onwards. Earlier data - for Great Britain as a whole - is given in the former Minerals Planning Guidance Note 15, and is included in Table 3.1. More detailed subdivisions of that data is given only in printed editions of the PA1007 reports, which are commercially available but have not been accessed for the purposes of this study.

<sup>6</sup> See Figure 2 of the BGS mineral planning factsheet on silica sand

**Table 3.1: Silica Sand Production in Great Britain, 1970 to 2013** (Source: Business Monitor PA1007)

Year	Total Silica Sand Production in Great Britain (mt)	Foundry Sand (mt)	Glass Sand (mt)	Other Industrial Sand (mt)	Agriculture, Horticulture and Leisure (mt)
1970	5.782				
1971	5.645				
1972	5.478				
1973	6.775				
1974	5.990				
1975	6.139				
1976	5.901				
1977	6.283				
1978	6.224				
1979	5.829				
1980	5.708				
1981	4.451				
1982	4.123				
1983	4.026				
1984	4.328				
1985	4.178				
1986	4.108				
1987	4.029				
1988	4.340				
1989	4.380				
1990	4.132				
1991	4.201				
1992	3.615				
1993	3.587				
1994	4.038				
1995	?				
1996	?				
1997	4.704				
1998	4.662				
1999	4.092	1.043	1.593	1.456	
2000	4.095	0.987	1.755	1.353	
2001	3.848	0.880	1.853	1.115	
2002	3.833	Confidential	1.940	1.331	
2003	4.073	Confidential	1.896	1.645	
2004	5.011	Confidential	2.663	Confidential (>0.886)	0.838
2005	4.146	Confidential	2.120	0.954	Confidential (> 0.553)
2006	5.174	Confidential	2.206	1.306	Confidential (> 1.086)
2007	4.909	0.527	1.930	1.178	1.274
2008	4.777	0.443	1.932	1.186	1.216
2009	3.755	Confidential	Confidential	1.096	0.988
2010	4.070	0.353	1.582	0.913	1.222
2011	3.969	0.382	1.528	0.956	1.104
2012	3.888	0.340	1.489	0.782	1.277
2013	3.961	Confidential	Confidential	0.837	1.448

Detailed breakdown not readily available before 1999 (see footnotes on previous page)

Foundry sand dominant

Glass sand dominant

'Other' sands growing

- 3.5 This progressive shift in market demand, from heavy manufacturing prior to the mid-1980s to the far more diverse markets seen today has had very important implications for the types of sand required. This is brought into sharp focus by comparing the current situation with that prevailing when the former Minerals Planning Guidance note 15 was published, in 1996. That document reported a growing market requirement for higher quality processed sands which was tending to focus attention, at that time, on fewer sites with high quality raw materials and more sophisticated processing plant. It noted that, because of this, the suitability of some of the permitted reserves for industrial applications may be neither economically nor practically viable in the future. The more recent diversification of the market has significantly changed this outlook. Whilst there is still a requirement for high quality sands and sophisticated processing (as discussed in more detail below), there is also now a much broader range of applications and a correspondingly wide range of requirements for different types of sand.
- 3.6 Potentially, the market could change again in the near future, with the emerging requirement for 'frac' sands. If hydraulic fracturing of onshore deposits becomes an established method of 'unconventional' oil and gas production in the UK, this will introduce an additional, high specification sector to the market for silica sand, and potentially could greatly increase the overall level of demand. Whether or not this would have any impact on the study area, however, will depend not only on the fate of this industry but also on the suitability of the resources for this particular end use. This is considered later in this report.
- 3.7 Monitoring the availability of sands to meet the increasingly diverse range of requirements is a further complication. Separate landbanks are required (by the NPPF) to be maintained for silica sand and for other forms of sand & gravel. This is carried out in all MPAs where silica sand is produced, but is often a difficult exercise, particularly where silica sand and construction sand are produced from the same deposits (as is the case in several areas including Bedfordshire, Hampshire, Surrey, Kent, Cheshire and Essex, as well as the South Downs and West Sussex). In such cases, unless it is possible to subdivide the resource outcrops into distinctly separate geological units (which does not seem to be the case in the South Downs area), the available permitted reserves can only be apportioned between the separate landbanks on the basis of recent sales information, as supplied by the operators. Whilst this is done, where necessary, in other MPAs, in practice it is difficult. This is because the split between different markets supplied from individual quarries may vary over time depending on the success or otherwise of individual operators in marketing their products for specific end-uses.

### ***End Use Specification Requirements***

- 3.8 Previous research in Bedfordshire (Cuesta Consulting Ltd., 2006 and 2008) and in Surrey/Kent (GWP, 2009 & 2010) found that there were limited published specifications or industry-wide standards for most of the specialist end-uses noted above (with the exception of frac sands) and instead, individual product specifications are developed. For some end-uses, particularly for glass sand and foundry sand, manufacturers and customers develop their own specifications and associated products. Partnerships are established between particular suppliers and customers, and parameters and testing methods are agreed to establish a suitable product fit. In other cases, particularly for

sports, leisure and horticultural sand, the operating companies tend to develop their own 'bespoke' products and then aim to encourage brand loyalty among their particular customers through demonstrable quality and skilful marketing.

- 3.9 This section of the report initially outlines the relative importance of the different physical properties and the chemical composition of the sand for different end-use applications. Each of the main end-use types are then reviewed in turn, noting details of either generic or more specific requirements (or at least end-user preferences), where these are known.

#### Properties of Silica Sand and their Relevance in End Use Applications

- 3.10 Several properties of silica sand are commonly evaluated to determine end-use suitability. As described in Chapter 2, the most common properties assessed are: Particle Size Distribution or PSD (the range of sand grain sizes present), colour, sand grain shape (sphericity and roundness) and chemical composition (particularly the total silica content and percentage presence of impurities). However, the relative significance of these properties and the values or specifications required varies according to end-use. In some applications, particularly for 'frac-sands', additional physical properties, such as the strength of the sand grains, are also important.
- 3.11 The range of sand grain sizes present is important in all end-use applications. Most applications require 'tightly graded' or 'well sorted' sand – one that contains a limited range of sand grain sizes. Some applications, such as water filtration sand, some 'frac-sands' and horticultural sands require material that is relatively coarse. Other applications tend to require a medium-grained or fine-grained sand. In all of these applications there are limits to the quantity of 'fines' (the clay and silt content, less than 63 microns) and the gravel-sized content (greater than 2mm), both of which need to be controlled by screening before any further processing takes place (or as part of that process where screening is all that is needed).
- 3.12 Colour is used intuitively by operators as an indicator of end-use suitability. A white sand is generally regarded as being 'clean' – having low or negligible silt, clay and organic matter content – and is more likely to have a higher silica content and lower iron oxide content. So, for example, a layer or lens of white sand in a building sand quarry may be extracted and marketed separately - say as cattle bedding material - without any additional processing. The intrinsic higher grade physical properties are understood simply by the colour of the sand.
- 3.13 Whilst a more detailed analysis of chemical composition is required in industrial applications (see para. 3.15 below), it would appear that colour is used more widely in sports, leisure and horticultural applications to indicate end-use suitability. For example, a play-sand, golf bunker sand and equestrian sand should be 'off-white' in colour and non-staining.
- 3.14 Sand grain shape has little or no importance in glass making, where the grains are melted at high temperatures, or in applications using 'silica flour', where the grains are crushed down to a powder. However, it is of importance in all other end-use applications. The shape of sand grain required varies widely depending on the end-use. So, for example, a filter sand should generally be more rounded and of higher sphericity to improve

permeability, and for 'frac sands' these properties are essential to enable the particles to be emplaced within minute fractures; whereas a golf bunker sand should generally be more angular to improve compaction.

- 3.15 The chemical composition of the sand is most important in true industrial manufacturing applications, since the chemistry of a material can have a significant impact on the final product in a process involving heat and/or pressure. Therefore, end-use chemistry specifications are most important in glass-manufacture, in the use of foundry sand, in the production of sodium silicate, in the manufacture of fillers, and in the production of ceramic glazes and clay-based white ceramics.
- 3.16 The more detailed specifications (or at least widely-agreed preferences) for each end use application are discussed in more detail in the following sections.

### Industrial Manufacturing Applications

#### **Glass**

- 3.17 The most common type of glass is soda-lime-silica glass, found in such everyday objects as glass bottles and jars (glass containers), and mirrors and windows (flat glass). Glass containers may be made from clear glass (known in the glass manufacturing industry as 'flint glass') or from coloured glass. Glass fibre for insulation and reinforcement, glass bulbs and fluorescent tubes are also produced in the UK.
- 3.18 Soda-lime-silica glass contains between 70% and 74% silica (from silica sand or recycled glass 'cullet') and other constituents including limestone, dolomite, feldspar and salt. Silica sand therefore forms a large percentage of the raw materials entering the batch and must itself be of very high silica content (at least 97% - see below). Moreover, the **consistency of the chemical composition** is of paramount importance and **uniformity** of feedstock must therefore be maintained. Glass making is a continuous process, with furnaces being run continually for many years at a time, and it is imperative for them to be provided with an equally continuous supply of consistent, high quality sand. Variations in the chemistry of the sand could lead to variations in melting characteristics and thus in the quality of the finished glass.
- 3.19 The former standard used in glass manufacture was: *BS2975:1988 Methods for sampling and analysis of glass-making sands*. This included specifications for the various types of glass described above. The revised *BS2975-1:2004 Sampling and analysis of glass-making sands, Methods for sampling and physical testing of glass-making sands* and *BS2975-2:2008 Sampling and analysis of glass-making sands, Methods for chemical analysis* omit these specifications. There is now greater flexibility and product specifications are developed instead by individual glass-manufacturers. However, the former standard specifications are still used as guidance between suppliers and manufacturers.
- 3.20 The quality of the sand demanded by glass manufacturers depends on the type of glass made. For clear container glass, the sand must have very high silica content (99% or more) and be essentially almost free of coating, staining or detrital heavy minerals. For coloured glass, a silica content of 97% may be tolerated.

- 3.21 Very small amounts of certain impurities, particularly iron oxide, in the sand will lead to tinted or opaque glass. This is critical for clear container glass but for flat glass and coloured container glass, slightly higher proportions of iron content are allowed. The BGS factsheet gives the following broad chemical specification: '*Glass sand for colourless glass containers generally has an iron content of <0.035% Fe<sub>2</sub>O<sub>3</sub>, for flat glass in the range 0.06% to 0.1% Fe<sub>2</sub>O<sub>3</sub>, and for coloured containers 0.2%-0.3% Fe<sub>2</sub>O<sub>3</sub>*'. This is consistent with the specifications given in the former B2975:1988. Titanium Dioxide (TiO<sub>2</sub>) should generally be below 0.03% in clear glass and Chromium (Cr<sub>2</sub>O<sub>3</sub>) below 0.002%, as these compounds may also impart colour to the glass. Higher levels of both are tolerated in coloured glass.
- 3.22 Alumina (Al<sub>2</sub>O<sub>3</sub>) can be considered an impurity in glass sand as it increases the viscosity of the glass, making it difficult to work and, as with iron oxide, can lead to decreasing glass transparency. However, alumina can also be added to some glass batches as it gives greater chemical durability, a lower coefficient of expansion and greater resistance to devitrification (crystallization of glass). For flint glass, Al<sub>2</sub>O<sub>3</sub> can be around 0.5%, and for some types of coloured glass, up to about 4% may be tolerated.
- 3.23 Sands must also have a very low content of grains which do not melt easily (highly refractory minerals), such as chromium, kyanite and andalusite, otherwise unmelted grains in the glass will form unsightly 'stones' and points of weakness. The levels of aluminium, magnesium, calcium and the alkalis (sodium and potassium) affect the melting properties and therefore need to be kept at consistent levels.
- 3.24 The range of sand particle sizes present in the silica sand is also important in glass manufacture. Excessive fines in the sand are undesirable because they tend to carry impurities, cause dusting and lead to blisters in the glass. Coarse grains are also undesirable as they can survive in the melt and cause scum in the batch or 'stones' in the finished product. Coarse sand is also more difficult to fuse and tends to increase the cost and time taken to finish a batch. A **narrow size distribution** is preferred, usually in the range 125 to 300 microns with typically no more than 0.2% greater than 500 microns and no more than 1% less than 125 microns. There should be no fraction greater than 710 microns or less than 63 microns.

#### **Foundry Casting.**

- 3.25 Silica has a higher melting point than the pouring temperature of iron, steel, copper and aluminium. This enables castings, which form the basis of the heavy engineering and manufacturing industries, to be produced by pouring molten metal into moulds made out of silica sand. In the past naturally-bonding sands were used containing enough clay to give the mould strength without adding an additional bonding agent. However, as noted in the BGS factsheet, the requirements for foundry sand are now of higher quality, due to the greater precision required for the aerospace, military and automotive parts now being produced. It is therefore currently far more common for clay-free washed sands with a high silica content to be used. A binding agent such as bentonite clay or a chemical, such as resin, is added to the sand as a bonding agent. These synthetically bonded sands can be controlled to offer moulding properties that are dependably uniform with a superior surface finish and greater dimensional accuracy.

- 3.26 First published in 1946 by the American Foundrymen's Society, *The Foseco Ferrous Foundryman's Handbook: 2000* (now in its *Eleventh Edition*, edited by John R. Brown) would appear to still be the common comprehensive reference guide used by the Foundry Industry. Suitable specifications for various castings are described.
- 3.27 A foundry mould must be able to withstand the high temperature of molten metal, be strong enough to withstand the pressure of the molten metal without yielding, yet be permeable enough to allow the steam on contact and the gases in the metal to dissipate through the sand. The PSD, particle shape and chemistry of the sand are all important in satisfying these requirements, although some compromise must be made in order to best meet them all.
- 3.28 The **chemical composition of the foundry sand is most important as an indication of its refractoriness** – its ability to withstand strength at high temperatures. The chemical composition of the sand also can affect the acid demand value which has an important effect on the catalyst requirements of cold-setting acid catalysed binders. The Foundryman's Handbook gives a guide on the appropriate limits for the chemical composition of silica sand for foundry use as follows:
- SiO<sub>2</sub>      95-96% min    the higher the silica, the more refractory the sand
  - LOI        0.5%            limits on organic content
  - Fe<sub>2</sub>O<sub>3</sub>     0.3% max      Reduces refractoriness
  - CaO        0.2 max        Raises the acid demand value
  - K<sub>2</sub>O, Na<sub>2</sub>O 0.5% max      Reduces refractoriness
  - Acid demand value to pH<sub>4</sub> - 6ml max as a high acid demand adversely affects acid catalysed binders.
- 3.29 Whilst in the past values such as the average grain size and AFS (American Foundry Society) Grain Fineness Number (GFN) were used, the latest edition of the handbook states that the choice of sand should now more typically be based on PSD. The **smaller or finer the grains, the smoother the metalwork produced**. However, if the sand grains are too small, the venting of gases and steam becomes poor. Therefore, the selection of a moulding sand is a **balance using the finest grain size possible that still allows safe venting of the moulds**. Foundry sands usually fall into the range 150–400 microns, with 220–250 microns being the most commonly used. No more than 2% should be less than 200 microns and no more than 0.5% less than 63 microns.
- 3.30 The best permeability of moulding sands is achieved where the grains are both rounded and uniform. Angular-grained sand tends to pack and if the grains are not uniform, small grains may pack between larger ones. However, despite the fact that the highest permeability can be obtained by using a uniform-sized sand, in practice a range of 5 or 6 sieve sizes of sand is used to prevent all the grains from reaching a critical temperature and change in volume at the same time (for silica this is 573°C), which would cause 'scabbing' in the product. High sphericity of grains is also ideal in foundry sand as the

surface area of grains decreases with increasing sphericity minimising the amount of binder needed. The Foundryman's Handbook states that '***the best foundry sands have grains which are rounded with medium to high sphericity giving good permeability and high strength at low binder additions. More angular and lower sphericity sands require higher binder additions, have lower packing density and poorer flowability***'. In practice, a range of grain shapes may be used depending on the end result required.

### **Sodium Silicate Manufacture**

- 3.31 Sodium silicates form a range of soluble compounds, produced from soda ash and silica sand and marketed as glassy clear or powdered solids or as a liquid. They are used in the production of soaps, detergents, adhesives, zeolites, glaze and enamels and within passive fire protection. Silica gel is a highly pure, porous solid made by acidifying sodium silicates and is used for its desiccant and absorption properties in the preservation of food, in the cosmetic industry and in cat litter.
- 3.32 No particular commonly used end-use specifications were identified. However, a typical product data sheet for a sand that is used in the manufacture of sodium silicates was provided by a commercial operator. This indicates that high purity silica sands with a silica content greater than 99% may be required. As the final product is white, limits on iron oxides ( $\text{Fe}_2\text{O}_3$ ) are important and were given at 0.05% with an alumina ( $\text{Al}_2\text{O}_3$  content) of less than 0.1%. Limits were also given for other metals and alkalis. Of particular note is the alumina content which, if too high, forms insoluble aluminium silicates causing operational problems with the filtration systems used in sodium silicate production<sup>7</sup>. The PSD was given as: no portion > 1mm, at least 90% between 125um and 500um with a maximum of 7% less than 125um. The grain shape used was of medium sphericity and sub-angular grains.

### **Paints and Plastics, Polymer Compounds, Rubber, Sealants, Resins and Adhesives.**

- 3.33 Crystalline silica, when ground into very fine flour is used as a reinforcing filler in a wide range of manufactured products. It is used to improve the appearance and durability of architectural and industrial paint and coatings. High purity silica contributes critical performance properties such as brightness and reflectance, colour consistency, and oil absorption. In architectural paints, silica fillers improve tint retention, durability, and resistance to dirt, mildew, cracking and weathering. Low oil absorption allows increased pigment loading for improved finish colour. In heavy-duty offshore or marine paints and self-cleaning exterior wall coatings, the durability of silica imparts excellent abrasion and corrosion resistance. Silica flour is also used in plastics for encapsulating electronic components and as a filler in a wide range of specialist epoxy resins, sealants adhesives and flooring compounds.
- 3.34 No particular commonly used end-use specifications were identified although information from a range of product sheets marketed by Garside Sands would indicate that there is some flexibility in chemical composition, with total silica content of around 96-97% acceptable and relatively high levels of iron oxides ( $\text{Fe}_2\text{O}_3$ ) at around 2%.

<sup>7</sup> This places an important limitation on the suitability of many silica sand resources being used for this purpose. In England, such sand is currently understood to be supplied from only one quarry (North Park in Surrey, within the Folkestone Formation).

**Ceramics.**

- 3.35 Ground silica is an essential component of the glaze (converted by heat to Cristobalite) and body formulations of all types of ceramic products, including tableware, sanitary ware, ornaments and floor and wall tiles. In the ceramic body, silica is the skeletal structure upon which clays and flux components attach. The silica is used to modify thermal expansion, to regulate drying and shrinkage, and to improve both structural integrity and appearance.
- 3.36 No particular commonly-used end-use specifications have been identified, although the GWP report states in section 4.6 that, for this end-use, sand should typically have a silica content above 97.5%, less than 0.55% alumina ( $Al_2O_3$ ) and less than 0.2% iron oxide ( $Fe_2O_3$ ).

**Hydraulic Fracturing Sands**

- 3.37 Hydraulic fracturing (commonly referred to as 'fracking') is the process of pumping a fluid into wells at high pressure to fracture the host rock to stimulate oil or gas flow in low permeability host rocks. These fractures allow the oil and gas to escape from the host rock into the well to be pumped to the surface. One of the components of the fluid is typically water, the other is a proppant which remains packed tightly in the fractures to keep (or 'prop') them open. The proppant also acts as a permeable medium within the fractures that allows the oil and gas to flow out of the host rock.
- 3.38 Approximately 70% of the proppants used in hydraulic fracturing are naturally occurring silica sand ('frac sand'). Other less cost-effective types of proppants include resin-coated silica sand, and ceramic proppants such as calcined alumina and calcined bauxite. Whilst frac sands for use in low permeability strata are not yet exploited as an end-use in the UK, if onshore hydraulic fracturing becomes established in the UK in future, then this could potentially become a very important new market for suitable types of silica sand.
- 3.39 There are two standards that are widely used in determining the suitability of silica sand as a frac sand. These are: American Petroleum Institute (API) Recommended Practice (RP) 19C: 2006 Measurement of Proppants used in Hydraulic Fracturing and Gravel-Packing Operations (replaced RP56:1995) and BS EN ISO 13503-2:2006 and A1:2009. Petroleum and Natural Gas Industries. Completion Fluids and Materials. Measurement of Properties of Proppants used in Hydraulic Fracturing and Gravel-Packing Operations.
- 3.40 **Frac sand must also be capable of withstanding the high pressures found at depths** of several thousand metres below the surface. A very high grade silica content of greater than 99% is required as other deleterious materials may crush under the high pressures reducing permeability. In addition, a laboratory test should show that the sand produces no more than 10% fines at 4000 - 6000 psi (28 - 42 MPa).
- 3.41 If the proppant sand contains carbonate, it could have a tendency to 'cement' inside the fracture which will reduce permeability. Acid solubility can be an indication of carbonate content and other impurities and this test is used for frac sands. Less than 2% weight loss in acid solution is appropriate for frac sand falling between UK sieve mesh sizes 30 (600 microns) and 50 (300 microns).

- 3.42 The PSD impacts the permeability and strength of the frac sand and **a narrow size distribution is preferred to retain a high permeability**. If a wide range of grain sizes were used, the smaller grains would fall between the larger grains when tightly packed together as a proppant. Proppant sizes are generally defined and marketed as falling between two standard US sieve mesh sizes: 90% of the sand should fall between these sieve sizes. As a general rule coarser sands are used for oil production and finer sands for gas production. The most commonly used size designation is 20/40 (850/425 microns). Others include 12/20 (1700/850 microns) and 40/70 (425/212 microns). Most frac sand is between 850 and 212 microns.
- 3.43 In addition, there are limits on the silt (2 microns to 63 microns) and clay content (<2 microns). Finer clays and silts could be carried back into the host rock blocking off paths for the oil or natural gas and slowing harvest rates. The presence of clays on the surface of frac sand could also create additional friction slowing harvest rates by reducing conductivity. A turbidity test (the degree to which transparency of the fluid is lost) is used to measure the amount of fines – the maximum turbidity should be 250 FTU (Formazin Turbidity Unit).
- 3.44 Frac sands must be as **spherical and round** as possible to flow into fractured shale and then **provide good porosity, permeability and compressive strength** once in place. Angular grains and fragments tend to pack together at high pressures, which will decrease porosity and permeability. Average sphericity and roundness values of more than 0.6 are required for frac sands.

#### Water Filtration

- 3.45 Silica sand is widely used by the water industry in the filtration of solids from drinking water, in the treatment of wastewater and in the production of water from wells. It is also used for water filtration in the food & drink industry, for effluent treatment in other manufacturing industries and in swimming pools. Silica sand (and silica gravel) is used in many types of filter including rapid gravity filters, slow sand filters and continuous sand filters.
- 3.46 For sand used as a filter in drinking water, the following standard applies: *BS EN 12904:2005 Products used for treatment of water intended for human consumption. Silica sand and silica gravel*. Limits on chemical composition are given.
- 3.47 Important characteristics of the sands that are used for these purposes include:
- high silica content (an intrinsic property: silica is chemically inert, so will not degrade, dissolve or react when it comes into contact with acids, contaminants, volatile organics or solvents) – a figure of more than 96% is given on many sand filter product sheets and a Type 1 sand used as a filter in drinking water must have a silica content greater than 96%;
  - uniform sub-angular to rounded grain shapes (another intrinsic property of the sand grains: some degree of angularity allows for better retention of solids, whereas greater roundness improves porosity and rate of through-flow);

- closely-graded size distributions - by comparison with most other specialist grades of silica sand, the particle sizes required for water filtration grades are relatively coarse, usually in excess of 500 microns and are supplied in several very narrow, overlapping grading categories (e.g. 1180 to 600 microns; 1700 to 850 microns; 2.00 to 1.00mm and so on, continuing up into gravel size fractions). There is a limit on the oversize and undersize portion of 10%;
- cleanliness, i.e. containing minimal impurities and minimal silt/clay content (the first is an intrinsic characteristic of the sand, whereas the second can be improved by washing and screening).

### Sports & Leisure Applications

- 3.48 An increasingly important market for silica sand, which is now becoming dominant, in terms of quantity supplied, is in various sports and leisure applications, particularly in golf courses, natural (turf) sports pitches, synthetic sports pitches, equestrian surfaces, athletics (jumping pits) and children's play sand. For the most part, these end-uses cannot be supplied from the more common sources of construction sand, because of the requirements for grain roundness, strength, colour and other properties. However, sand with a silica content of less than 95% (and therefore not strictly 'silica sand' as defined by the BGS) has proved suitable for use in some of these applications – notably in the case of sand for use on sports pitches, supplied from Triassic sandstones in Nottinghamshire (Rees, 2016). The requirements in each case and the reasons for those requirements vary slightly between different applications, as described below.
- 3.49 Guidance produced by the Sports Turf Research Institute (STRI) is widely used in sports turf construction and maintenance in both golf courses and sports pitches. The most recent guidance is: *Stephen W. Baker (2006) Rootzones, Sands and Top Dressing Materials for Sports Turf* which refers to the *United States Golf Association (USGA): 2004 Revision Recommendations for a Method of Putting Green Construction* where relevant.
- 3.50 In turf applications, total **lime content** is the most influential chemical component. A greater lime content within a sand strongly influences the alkalinity of the turf, raising the pH which in turn increases the competitiveness of weeds and meadow-grass. For most applications on sports turf areas, the lime content of any sand, root-zone or top dressing should be below 0.5%. On winter games pitches with fairly acid soil, top dressing sands with a lime content up to 2% might be acceptable. pH should be reasonably neutral, between 4.5 and 9.3.
- 3.51 Sand selection is a balance between the needs of good drainage and aeration, reasonable moisture retention and stability. The range of sand grains present is important in consideration of all these requirements. Therefore, **PSD is probably the most important property of the sand for sports and leisure applications**. With the exception of bunker sand, a **narrow grain size distribution** within the medium and smaller coarse-grained sand sizes is required. A number of PSD grading envelopes are given in the STRI guide for different end-uses, with upper and lower limits being defined for what is 'acceptable' and what is recommended (the latter comprising more restrictive (narrower) grading envelopes). The acceptable limits (only) are shown in Figure 3.1, below. It is reasonable to assume that, for any sand which falls within these limits in its natural state, it should

be possible to comply with the more stringent recommended limits by means of simple processing (dry screening or, if necessary, wet screening to remove any excess fine material).

- 3.52 For most turf construction and maintenance purposes, it is considered by the STRI that the effect of grain shape is relatively small compared to PSD. Nevertheless, recommendations for particle shape are given for different applications. Particle shape has been shown to influence the stability of the sand and angular grains are generally avoided (except in bunker sand). Rounded to sub-angular grains are considered to be the most suitable shape, promoting good drainage without excessive compaction.
- 3.53 Total silica content is not generally specified for any sports and leisure applications, although non-staining white sands (implying high-purity silica sand) are required in some applications. However, high silica content does make the sand resistant to further weathering and helps it retain its original particle size and shape, thereby ensuring that the required drainage and air-filled porosity characteristics of the materials are maintained. In addition, sand deposits conforming to the relatively narrow grain size specifications required are typically found within sands composed predominantly of silica, thereby limiting the washing and screening required.

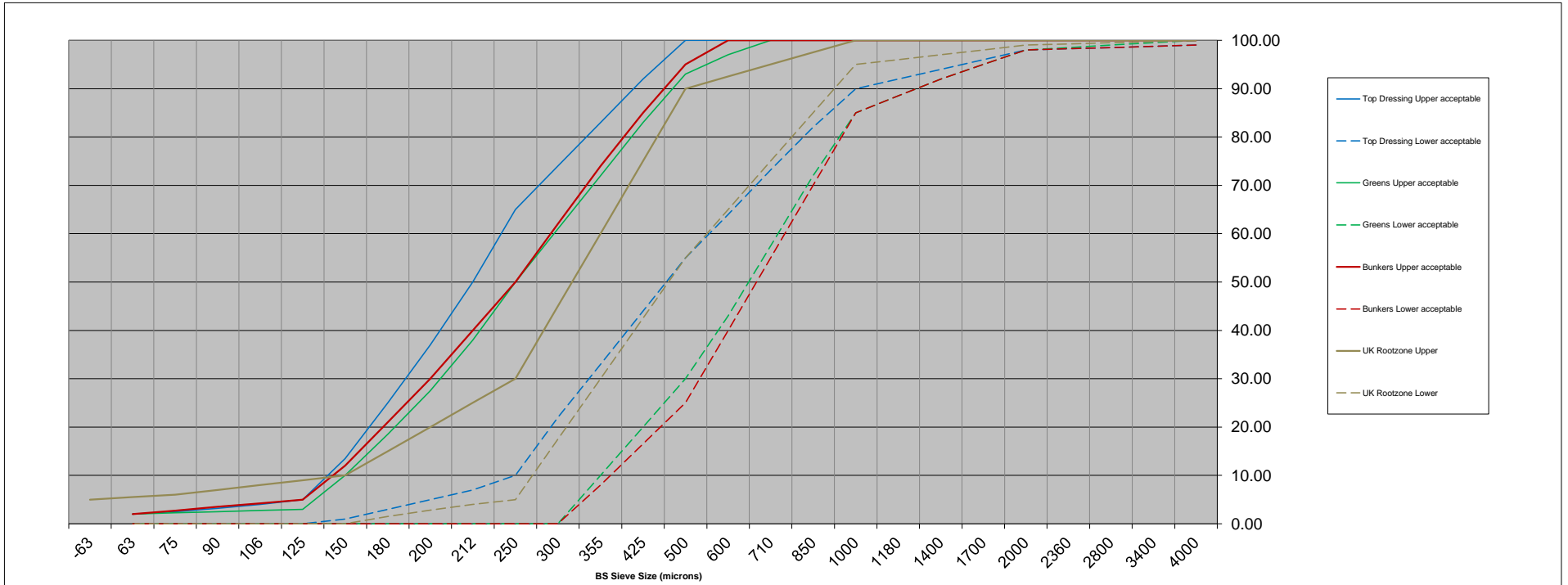
#### **Golf Courses**

- 3.54 Golf courses require large quantities of sand, both in construction and in annual maintenance. An 18-hole course will require at least 3,500 tonnes of an 80% sand (or sometimes 100% sand) rootzone mixture for the construction of the greens and tees, up to 1,000 tonnes of bunker sand and would typically use at least 100 tonnes p.a. of an 80% sand mixture for top dressing.
- 3.55 The status and reputation of a golf course is judged to a large extent on the quality and appearance of its greens and bunkers. Materials and treatments which can enhance these qualities are therefore extremely important and have become increasingly sophisticated over the last 30 years. Whereas green-keepers would have made do, in the past, with locally available sands and soils, the commercial production and marketing of specialist sands and top-dressing mixtures has raised the standards significantly and virtually all golf clubs now source top dressings and bunker sands from specialist suppliers.
- 3.56 Rootzone sand should be free of gravel (to avoid damage to mower blades and bed knives) and, to conform to a USGA mix should contain 60 percent or more between 250 microns and 1mm, the medium range with no more than 10 percent coarser than 1.00mm. The sand may also contain up to 20 percent of particles in the fine (125 to 250 micron) range with an additional 5 percent or less in the very fine (75 to 125 micron) range. The use of excessively fine sand, or material that includes more than ten percent of very fine sand, silt and clay, results in rootzones that are slow to drain and poorly aerated. Particles with a sub-angular or sub-rounded shape are preferred, since highly angular sands tend to pack tightly and may injure turf roots, while highly rounded sands may be loose and unstable during turf establishment. Colour is generally of little importance for a rootzone sand, since it is mixed with dark organic material and is quickly covered by the turf.

Figure 3.1: Upper acceptable and Lower acceptable grading envelopes for silica sand, as recommended by the Sports Turf Research Institute (STRI)

BS Sieve Size (Microns)	Top Dressing Lower acceptable	Top Dressing Upper acceptable	Greens Lower acceptable	Greens Upper acceptable	Bunkers Lower acceptable	Bunkers Upper acceptable	UK Rootzone Lower	UK Rootzone Upper
	cumulative % passing							
4000	99.00	100.00	100.00	100.00	99.00	100.00	100.00	100.00
3400	98.75	100.00	99.50	100.00	98.75	100.00	99.75	100.00
2800	98.50	100.00	99.00	100.00	98.50	100.00	99.50	100.00
2360	98.25	100.00	98.50	100.00	98.25	100.00	99.25	100.00
2000	98.00	100.00	98.00	100.00	98.00	100.00	99.00	100.00
1700	96.00	100.00	95.00	100.00	95.00	100.00	98.00	100.00
1400	94.00	100.00	92.00	100.00	92.00	100.00	97.00	100.00
1180	92.00	100.00	88.50	100.00	88.50	100.00	96.00	100.00
1000	90.00	100.00	85.00	100.00	85.00	100.00	95.00	100.00
850	82.00	100.00	72.00	100.00	70.00	100.00	85.00	97.50
710	73.20	100.00	57.50	100.00	55.00	100.00	75.00	95.00
600	64.00	100.00	43.00	97.00	40.00	100.00	65.00	92.50
500	55.00	100.00	30.00	93.00	25.00	95.00	55.00	90.00
425	44.00	92.00	20.00	83.00	18.50	85.00	42.50	75.00
355	33.00	83.00	10.00	72.00	8.00	74.00	30.00	60.00
300	22.00	74.00	0.00	61.00	0.00	62.00	17.50	45.00
250	10.00	65.00	0.00	50.00	0.00	50.00	5.00	30.00
212	7.00	50.00	0.00	38.00	0.00	40.00	4.00	25.00
200	5.00	37.00	0.00	27.50	0.00	30.00	2.80	20.00
180	3.00	25.00	0.00	18.50	0.00	21.00	1.50	15.00
150	1.00	13.50	0.00	10.00	0.00	12.00	0.00	10.00
125	0.00	5.00	0.00	3.00	0.00	5.00	0.00	9.00
106	0.00	4.00	0.00	2.75	0.00	4.25	0.00	8.00
90	0.00	3.20	0.00	2.50	0.00	3.50	0.00	7.00
75	0.00	2.50	0.00	2.25	0.00	2.70	0.00	6.00
63	0.00	2.00	0.00	2.00	0.00	2.00	0.00	5.50
-63								5.00

**IMPORTANT NOTE: highlighted figures (only) are specified values; all other figures are extrapolated values to enable comparisons to be made with other grading curves**



- 3.57 Alternatively, the STRI has more recently produced more specific guidelines restricted to the temperate, maritime conditions found in the UK (see grading envelope within Figure 3.1, above).
- 3.58 Top dressing sands help to keep established turf in good condition by promoting a good balance of water retention and drainage. They should have a particle size distribution that is similar to (and therefore compatible with) that of the original rootzone material and previous top dressings, in order to maintain the existing characteristics and playing quality. Coarser-grained sand laid over finer-grained material, for example, may result in a green surface that is deficient in nutrients and has a low water retention, whereas fine over coarse may result in a surface which retains water with very little air-filled porosity.
- 3.59 Bunker sand needs to be cleaner than root-zone sands. Higher proportions of silt and clay may cause the sand to crust over frequently, requiring repeated maintenance to keep it in playable condition. Other than this, the particle size distribution should be similar to that used in the greens themselves (since the sand is often blasted out of the bunkers and onto the greens). The preferred particle shape for bunker sand is angular, since this helps the sand to resist movement under impact from a golf ball, thus resulting in fewer buried balls. Sports Turf Research Institute (STRI) guidance suggests a limit of 'no more than 60% of the particles in the rounded and well-rounded shape categories'.
- 3.60 The colour of bunker sand is important, since it is exposed to view and adds aesthetic appeal. Light-coloured sands are generally preferred, usually white, light brown, yellowish brown or light grey. While some clubs use a pure white sand to provide dramatic contrast in colours, tans or light browns are more natural, easier to maintain and are easier to play from because they reflect and glare less. Except where white or very light coloured sand is demanded, there is actually no necessity to use silica sand for bunkers. In fact, provided that it is suitably graded, as detailed above, a sharp sand (e.g. from a river terrace deposit) may provide a better source of material than a soft sand, which will generally be much less angular.

#### **Natural (turf) sports pitches**

- 3.61 The demand for top quality winter sports pitches (football, rugby and hockey) at all levels from Premier League down to school pitches has increased significantly in recent years placing a premium on high quality turf surfaces in which good drainage, increased carrying capacity and high standards of maintenance are required. In a typical top class football pitch such as the new Wembley Stadium the 200mm lower rootzone will comprise 100% sand with the 100mm upper rootzone 80% sand plus 20% soil. Such constructions will require 3-4,000 tonnes of sand depending on the size of the pitch.
- 3.62 With regard to the selection of suitable sand for these pitches, most of the basic principles outlined above for the construction and maintenance of greens on golf courses are equally relevant. Sub-rounded to sub-angular silica sands are again preferred for the same basic reasons, both in root-zone construction and in top dressing. However, as noted above, sand with a silica content of less than 95% can sometimes be used for these purposes, provided that it has these characteristics. Consistency of colour and texture are important for aesthetic reasons, although the actual colour is generally not significant.

**Synthetic sports pitches**

- 3.63 Synthetic (e.g. AstroTurf) sports pitches represent an important and growing market for silica sand, which is used both in the supporting layers, beneath the synthetic material, and as an infilling within the 'carpet' itself, to support the individual fibres of the material. The sand has to be resilient and stable, so that it achieves and maintains good drainage characteristics without excessive compaction, as well as achieving the desired levels of energy dispersement and ball bounce. The characteristics of silica sand that make it a preferred material for golf courses and natural turf pitches are therefore once again important (see above). Subrounded to sub-angular particle shape is especially important, since more angular grains would damage the fibres of the carpet and would also lead to more compaction and poorer drainage, whilst excessively rounded grains would not allow a firm enough surface to be developed.

**Equestrian Applications**

- 3.64 Silica sand is used in a growing number of equestrian applications, from riding arenas to training gallops. Different surfaces require different types of construction and different materials, but the fundamental principles are, once again, to achieve the right balance between good drainage, water retention, surface resilience and the need to minimise maintenance. Silica sand is again preferred because of its ability to achieve these requirements, particularly when 'single sized' (or at least, closely graded) sands are used: these tend to drain extremely quickly, passing water straight through to drainage layers beneath, yet will maintain a certain degree of moisture (dependent on grain size).
- 3.65 The combination of fast drainage and moisture retention creates a riding surface that mimics that of a beach foreshore. The surface stays firm enough to prevent the hoof sinking in, yet yielding enough to avoid jarring the hoof on impact with the ground. The requirement is for a material that will not furrow, but will compact sufficiently to give a surface upon which horses and ponies will gain the necessary exercise, yet will not be placed under any undue strain.
- 3.66 As well as having size and shape characteristics that will achieve these requirements, the individual sand grains need to be hard and durable, so that the overall characteristics of the surface do not degrade over time. In many cases the sands are also required to be non-staining (i.e. virtually free of impurities such as iron and of silt/clay particles).
- 3.67 Untreated sand needs to be watered to keep fines down. However, the sand can be mixed with wood chips, fibres or rubber to reduce the need to water. Fines (particles less than 63 microns) should be negligible.

**Jumping pits and play sand**

- 3.68 Long jump, high jump and triple jump landing pits demand high purity, non-staining durable silica sands that will provide and maintain a soft landing surface with good drainage (i.e. rounded to sub-rounded grains).
- 3.69 Sands which are supplied for play pits are also required to be soft (i.e. with rounded to sub-rounded grains) and to be non-staining and usually white or pale in colour.

- 3.70 Play Sand should conform to BS EN 71-1:2014 *Safety of toys. Mechanical and physical properties for Play Sand* and, if used beneath play equipment, it must also comply with: BS EN 1177:2008 *Impact attenuating playground surfacing, Determination of critical fall height*. Play Sand must be laid to depth of 300mm. There is no equivalent standard for jump sand.
- 3.71 Play Sand and Jump Sand are generally double-washed to remove greater quantities of fines and impurities. H65 (from North Park) marketed by Bourne Amenity has a PSD of 30.6% between 250 and 500 microns, 63.9% between 250 and 125 microns and 5.1% between 125 and 50 microns.

### Horticultural and Farming Applications

#### **Horticulture**

- 3.72 Silica sand is used in horticulture, market gardening and forestry as a soil conditioner and as component of specialist compost and lawn dressing mixtures. As with the top dressing mixtures described above, the clean, inert, durable and neutral pH characteristics of the silica grains are important in these applications.
- 3.73 There are very limited specifications for horticultural end-uses. A wider range of sand sizes can be used, including the coarser fraction. Horticultural sands are usually marketed according to the ratio of sand to organic soil material. An 80:20 mix for example would comprise 80% sand and 20% soil. Particularly brands are also promoted, such as a 'Kingsley mix' by Tarmac which uses indigenous topsoil blended with the silica sand from Kingsley Quarry in Hampshire, just outside the SDNP.

#### **Agriculture**

- 3.74 In farming, silica sand is used as a carrier for fertiliser and animal feed additives where, in addition to the characteristics listed above, sub-rounded to rounded particle shapes help to ensure free-flowing characteristics and to minimise compaction of the products.
- 3.75 Off-white high purity silica sand is preferred as a bedding material for cattle due to its 'cleanliness' and lack of impurities. This restricts the growth of bacteria and other micro-organisms.

### Other Specialist Applications

- 3.76 Other, specialist uses for silica sand (excluding the construction market) range from traction sand used in the rail industry (which need to be strong, durable and free-flowing), to aquariums (which need washed, graded lime-free sands of any kind, but 'silver sands' are commonly used), and the construction of Japanese ornamental 'Zen' gardens (which use washed medium to coarse quartz sand).

### **Summary**

- 3.77 There are a wide range of specialist and industrial end-uses for silica sand but the relative importance of the different markets has varied significantly over time. The need for

foundry sand has progressively declined since the 1970s, whilst the demand for sports, leisure and horticultural sands has steadily increased, particularly within the last decade. These latter applications (taken as a group) are now beginning to dominate the market, in terms of overall tonnage supplied, overtaking the demand from the glass industry which, itself, has declined in recent years, though it still remains important. In future, the requirement for 'frac sands' may change the markets again, potentially adding greatly to the overall level of demand if the unconventional oil and gas industry becomes established in the UK (though this report suggests that the sand resources in West Sussex would not be suitable for this purpose).

- 3.78 Each of the growing number of end-uses has its own particular requirements in terms of grading (particle size distribution), grain shape, silica content and maximum levels of impurities. Very high purity silica sands (typically greater than 98% or even 99%) are required in glass making and sodium silicate production, where both the level of impurities and consistency of chemical composition are crucial. Other industrial and specialist applications can utilise lower purity sands, but still require material with a silica content of around 96% or more. Whilst many of the required properties can be modified to some extent by processing - as discussed in the next Chapter - there are limits to what can be achieved, both practically and economically, and it is therefore of major importance to utilise sands which have intrinsic qualities which are as close as possible to those which are needed.
- 3.79 A key message from this review is that, whilst some significant beneficiation can be achieved by processing, high quality specialist sands cannot be created from deposits which are inherently unsuitable. For example, while some parts of the Folkestone Formation may contain material which is suitable for processing as glass sand, this will not be the case in all areas.

## 4. Processing Methods

- 4.1 Specialist sands almost always require various degrees of processing in order to meet the requirements for specific end uses. Only in a limited number of cases can 'as dug' material be used without any kind of processing, and this is only for very localised, low specification requirements - such as cattle bedding - in locations where the natural characteristics of the sand are already suitable.
- 4.2 The simplest form of processing, which may be sometimes be suitable for certain agricultural, horticultural and equestrian applications, involves dry screening (to produce separate size fractions) and/or blending on-site. This includes mixing with natural soils, peat, compost or other soil-forming materials to produce bespoke top-dressing and rootzone mixtures. Depending on the scale and complexity of operations this may require a large surface area for processing and storage, adjacent to the area of extraction, as well as investment in fixed or mobile grading equipment. Where blending is required, this may include a requirement for separate conveyor feeds which can be adjusted to varying speeds to provide suitable mixes for different specifications, and it requires segregated storage hoppers for each of the different mixes.
- 4.3 More commonly in these applications, and for all other types of specialist and industrial sands, there is a requirement for more complex processing. At a basic level this includes washing (to remove any excess fines and to facilitate the separation/classification of sand grain sizes) and, in some cases, drying and controlled dry storage. Washing applies equally to both silica sand and many types of construction sand, depending on the nature of the deposit, whereas drying (after washing) tends to be required only where the sand is to be supplied either in tankers or in sealed bags, or where it is utilised directly on site in the production of asphalt. Sealed bags may be used for building sands and play sands - e.g. when supplied to retail outlets - as well as for specialist sand supplied directly to customers, whereas tankers tend to be used only for the bulk supply of industrial sands (e.g. glass-making, foundry sands and other manufacturing processes where a high degree of quality control is essential).
- 4.4 Where drying, storage and either bagging and/or tanker loading is required, there is a need for even greater space to be available on site. In some cases, (for example where there are a number of sand pits within a single company's ownership), the processing plant, storage and loading facilities may be concentrated on just one of that company's sites.
- 4.5 Washing will frequently achieve the added benefit of reducing the level of impurities within a sand to at least some degree - particularly where these are associated with fine coatings of silt and clay-sized materials. However, for the highest specification industrial end-uses, including glass-making and sodium silicate production, additional processing may be needed to enable the impurities to be reduced further. Such processes may include a combination of **hydrosizing** and/or **froth flotation** (to remove heavy minerals), **attrition scrubbing** (to remove coatings), and **high intensity magnetic separation** (specifically to remove iron). All three of these processes avoid the need for chemical treatments, such as hot acid leaching, which has been used until recently elsewhere in the UK, and thus avoid the associated risks of environmental impact, but they do require

the use of water (which is largely recirculated), the investment in expensive processing equipment, and the separation and disposal of silt, usually in a series of silt lagoons or by means of a mechanical filter press. All of this requires additional space to be available, either within the quarry or at a remote processing plant. It also requires very considerable (multi-million pound) investment which, in turn, usually necessitates a significant security of permitted reserves. The NPPF (para 146) implies that this should be sufficient for at least 15 years' supply.

- 4.6 Further details of the processing technologies used within the silica sand industry are given in Chapter 6 of the GWP report on Silica Sand end uses in Kent and Surrey, and so are not repeated here.
- 4.7 Notwithstanding the wide range of options available, the degree of processing carried out for any given sand depends on the ratio of extraction, processing and delivery costs to the price which consumers are willing to pay. Products that are able to command a high price, because of a combination of proven demand and scarcity of supply, can justify additional processing, storage and transportation costs, where these are needed.
- 4.8 But there are limits to what can be achieved by processing, and it is important to recognise this. A particular grading requirement, for example, cannot be achieved if the grain sizes needed are not present within the deposit itself (or are present only in small quantities). Coarse-grained filtration sand cannot therefore be derived from a fine-grained deposit. Consideration also has to be given as to what can be done with the remaining coarser and/or finer particles that are not required for that particular end use. Quite often, these can be utilised in other applications, but that is not always the case, and this will clearly influence whether or not the processing is cost-effective.
- 4.9 Equally, high levels of impurities or deleterious materials may not be able to be sufficiently reduced without resorting to more expensive and potentially unacceptable methods of treatment. Techniques such as hydrosizing, chemical treatment and high intensity magnetic separation can help to improve the chemical composition of the end product. Consideration must then also be given to the use or disposal of the material which is separated as well as the higher processing costs involved and the potential additional costs of monitoring and avoiding or mitigating associated environmental impacts (particularly in the case of chemical treatment, though this is now rarely used in the UK). In some cases, processing requirements and costs may mean that a particular site is not economically viable. Transporting sand to a separate established processing plant may reduce costs although additional transport costs would then need to be taken into account.
- 4.10 Most significantly of all, perhaps, the roundness and/or sphericity of individual sand grains cannot be improved upon at all (other than by the relentless continuation of natural geomorphological processes, over millennia). This has particular implications for the identification of frac sand resources which, as discussed in the previous chapter, have more exacting requirements in terms of both roundness and sphericity.
- 4.11 Processing is therefore primarily an economic and commercial issue which affects the 'deliverability' of any proposed site. Planners are required to assess deliverability when preparing Minerals Local Plans as this is related to soundness and (more fundamentally)

it is also an issue for landowners and operators. Before promoting a site for potential extraction (and certainly before committing to a planning application), a commercial operator will need to consider these issues very carefully, having full regard to the characteristics of the deposit, and to the processing, storage, environmental mitigation and transportation costs involved. It is reasonable to assume therefore that proposals for specialist sand extraction which are backed by commercial operators, are more likely to be deliverable than those which are not.

- 4.12 Fortunately, many of the natural characteristics of the Folkestone Formation lend themselves to the more general requirements for silica sand production, so that only limited processing is likely to be required for many applications. All of the samples tested in this study have grading characteristics which need only minimal processing to meet the physical requirements for a wide range of applications. Moreover, the paler-coloured sands, in particular, seem likely to have a very high silica content and very low levels of impurities, giving them potential suitability (after more intensive processing) for higher-grade end-uses such as glass-making. However, whether a deposit is actually viable to be worked depends on more than just the quality of the sand within it. A more detailed comparison of the deposits with typical specification requirements is given in the following chapter.

## 5. Comparison of the Folkestone Formation Sands with Market Specifications

### *Introduction*

- 5.1 Chapter 2 of this report has identified the key characteristics of the Folkestone Formation sands within the study area, in terms of grading (Particle Size Distribution), colour, chemical composition and particle shape. Chapter 3 has then identified the key requirements and specifications, where they exist, for the wide range of specialist and industrial end-uses in which silica sands are currently utilised in the UK and elsewhere.
- 5.2 This chapter seeks to bring both of these together in order to identify the extent to which the Folkestone Formation sands are likely to be capable of being used in specialist applications.
- 5.3 **An important caveat needs to be added at this point to reflect the fact that, with the exception of one site, where more comprehensive testing has been carried out by a commercial operator, testing of the sands within the study area has so far been very limited and that no guarantee can be either given or implied regarding the actual suitability of any of the deposits within this area to any given end-uses. The general findings and comparisons can only be used at a strategic level, as an indicator of what might be possible, so as to inform the policy approach within the emerging Joint Minerals Local Plan.**

### *Comparisons by End Use*

- 5.4 Table 5.1, below, summarises the extent to which the samples of Folkestone Formation sands that were tested in this study are capable of meeting the key specification requirements for the range of specialist end-uses that have been identified, either in their natural state ('as dug') or with processing. As explained in Chapter 4, the nature and extent of processing required would vary from one application to another, requiring very substantial investment in the case of the highest specifications, but little or no processing other than grading in other cases.
- 5.5 The table reveals that, for the most part, the sands within the study area are likely to be capable of being used in virtually all specialist end uses, with the exception of **hydraulic fracturing** (because the sands generally do not have sufficiently high roundness and sphericity - although some sites may have potential, subject to further testing); **golf bunkers** (because the sands are not sufficiently angular); and **water filtration** (because the sands are generally too fine-grained).
- 5.6 This is not to say that all sites would be capable of serving the full range of other end uses; the suitability of sands for different markets will vary from one site to another, and those which meet the most exacting requirements in terms of chemical purity and consistency (as required for clear glass and sodium silicate manufacturing) are likely to be relatively scarce. Much more investigation and testing would need to be done to prove that individual sites are capable of producing sands which meet particular specifications, but that is beyond the scope of this strategic study.

Table 5.1: Comparison of Folkestone Formation Sands with End Use Specifications

End Use	Key requirements	Natural Suitability of the Folkestone Formation within the Study Area	Potential to Achieve Suitability with Processing
Colourless glass	SiO <sub>2</sub> >99%	Yes, in some areas	Moderate to High
	Fe <sub>2</sub> O <sub>3</sub> <0.035%	No*	Moderate to High
	Al <sub>2</sub> O <sub>3</sub> <0.5%	Yes, or Close	High
	TiO <sub>2</sub> <0.03%	Close	High
	Cr <sub>2</sub> O <sub>3</sub> <0.002%	Possibly	Probably High
	Chemical consistency: High	Not known	Moderate to High
	< 0.2% coarser than 500 microns	Generally no	Very High
<1% finer than 125 microns	Generally no	Very High	
Flat glass	SiO <sub>2</sub> >99%	Close in some areas	Moderate to High
	Fe <sub>2</sub> O <sub>3</sub> <0.1%	Generally no*	High
	Al <sub>2</sub> O <sub>3</sub> <0.5%	Yes, or Close	High
	TiO <sub>2</sub> <0.03%	Close	High
	Cr <sub>2</sub> O <sub>3</sub> <0.002%	Possibly	Probably High
	Chemical consistency: High	Not known	Moderate to High
	< 0.2% coarser than 500 microns	Generally no	Very High
<1% finer than 125 microns	Generally no	Very High	
Coloured Glass	SiO <sub>2</sub> >97%	Generally yes	Very High
	Fe <sub>2</sub> O <sub>3</sub> <0.3%	Generally yes, or close*	Very High
	Al <sub>2</sub> O <sub>3</sub> <0.5%	Yes, or Close	High
	TiO <sub>2</sub> <0.03%	Close	High
	Cr <sub>2</sub> O <sub>3</sub> <0.002%	Possibly	Probably High
	Chemical consistency: High	Not known	Moderate to High
	< 0.2% coarser than 500 microns	Generally no	Very High
<1% finer than 125 microns	Generally no	Very High	
Sodium Silicate	SiO <sub>2</sub> >99%	Close in some areas	Moderate to High
	Fe <sub>2</sub> O <sub>3</sub> <0.05%	No*	High
	Al <sub>2</sub> O <sub>3</sub> <0.1%	No	Moderate to High
	0% coarser than 1.0mm	Yes or close	Very High
	>90% between 125 and 500 microns	Yes in some areas	Very High
	<7% finer than 125 microns	Yes	Very High
Foundry Sand	SiO <sub>2</sub> >95%	Yes	Very High
	Fe <sub>2</sub> O <sub>3</sub> <0.3%	Generally yes, or close	Very High
	CaO <0.2%	Yes	Very High
	K <sub>2</sub> O + Na <sub>2</sub> O <0.5%	Yes	Very High
	Loss on Ignition <0.5%	Yes or close	Very High
	Acid demand to pH4 <6ml	Not known	Not known
	< 2% finer than 200 microns	No	High
	<0.5% finer than 63 microns	No	Very High
	Sub-rounded to rounded grains	Generally OK	Moderate to High
Medium to high sphericity grains	Generally OK	Moderate to High	

Paints, Plastics, Polymer Compounds, Rubber, Sealants, Resins and Adhesives	SiO <sub>2</sub> >96%	Yes	Very High
	Fe <sub>2</sub> O <sub>3</sub> <2%	Yes	Very High
Ceramics	SiO <sub>2</sub> >97.5%	Yes or close	Very High
	Fe <sub>2</sub> O <sub>3</sub> <0.2%	Close	Very High
	Al <sub>2</sub> O <sub>3</sub> <0.55%	Yes, or close	High
Frac Sands	SiO <sub>2</sub> >99%	Close in some areas	Moderate to High
	< 10% fines produced at 4,000 - 6,000 psi (28 - 42 MPa)	Not known	Not known
	<2% weight loss in acid solution	Not known	Not known
	90% < 850 microns (most common)	Yes	Very High
	90% >212 microns (most common)	Generally no	Very High
	< 250 FT turbidity	Not known	Not known
	High Sphericity > 0.6	Generally no	Low
High Roundness > 0.6	Generally no	Low	
Water Filtration	SiO <sub>2</sub> >96%	Yes	Very High
	sub-angular to rounded grain shapes	Yes	Very High
	100% coarser than 0.5mm	No	Low
	Minimal impurities	Close	High
Top Dressing	Lime content <0.5%	Probably yes	Very High
	STRI grading envelope	Yes	Very High
	Rounded to sub-angular grains	Yes	Very High
Sports Greens & Pitches	Lime content <0.5% (or <1.0% acceptable on winter games pitches)	Probably yes	Very High
	STRI grading envelope	Yes, or close	Very High
	Rounded to sub-angular grains	Yes	Very High
Golf bunkers	Lime content <0.5%	Probably yes	Very High
	STRI grading envelope	Yes, or close	Very High
	Angular grains	No	Low
UK Rootzone	Lime content <0.5%	Probably yes	Very High
	STRI grading envelope	Yes, or close	Very High
	Rounded to sub-angular grains	Yes	Very High
Equestrian	Non - staining	Often yes	Moderate to High
	Narrow grading envelope	Yes or close	Very High
	Rounded to sub-angular grains	Yes	Very High
Jumping Pits	Non - staining	Often yes	Moderate to High
	Narrow grading envelope	Yes or close	Very High
	Rounded to sub-rounded grains	Yes	Very High
Play Sand	Non - staining	Often yes	Moderate to High
	BS EN 71-1:2014 + BS EN 1177:2008	Not known	Probably High
	Narrow grading envelope	Yes or close	Very High
	Rounded to sub-rounded grains	Yes	Very High
Horticulture	Lime content Low	Probably yes	Very High
	pH Neutral	Probably yes	Very High
	Rounded to sub-angular grains	Yes	Very High

<b>Agriculture - fertiliser</b>	Rounded to sub-rounded grains	Yes	Very High
<b>Cattle Bedding</b>	Off-white & non-staining	Often yes	Moderate to High
<b>*see text at para. 5.7 et seq., below regarding suitability for glass and sodium silicate manufacture.</b>			

- 5.7 The fact that Cuesta's samples generally have a higher iron content, before processing, than is required for colourless glass, flat glass and sodium silicate manufacturing largely reflects the fact that the samples were analysed without pre-washing (in order to provide a true indication of the 'raw' material and of the level of processing likely to be required). Analyses of washed samples would generally be expected to show lower levels of iron and other impurities, and this is confirmed for the Horncroft site by confidential data provided by Sibelco (as summarised in paragraph 2.51, above). That information also demonstrates that, even for deposits (such as Horncroft) which already have a very high silica content additional, water-based processing (including attrition scrubbing and high intensity magnetic separation) may be needed to achieve the highest specifications required for clear glass manufacturing.
- 5.8 In light of the Horncroft data, the potential for sands within the study area to achieve glass specifications, after processing, is shown in Table 5.1 as being 'moderate' to 'high' (or even 'very high', in the case of coloured glass). It must be emphasised, however, that not all parts of the Folkestone Formation will be able to achieve this potential; it is only those parts of the deposit which already have a very high natural silica content (i.e. before washing) that are likely to be capable of doing so. Much further investigation and testing would need to be carried out before any clear indication could be given as to the likelihood of any particular site being able to meet the highest specification requirements.
- 5.9 As previously noted, chemical consistency of feedstock is also important for glass production, because of the continuous nature of the manufacturing process. This does not mean to say, however, that all parts of a particular deposit need to be identical. Inevitably there will be variations from one seam to another within a particular site, usually reflected in colour variations of the sand. Provided that localised areas with particularly high levels of impurity (e.g. heavily iron-stained sands) can be extracted separately, consistency can be achieved for the remainder of the deposit by the blending which naturally takes place through extraction, stockpiling and processing of the sand. Data provided by the promoter of the Horncroft site suggests (as noted in para. 2.51) that after separating a small proportion (6%) of the samples at the top of the deposit, the average chemical composition for the remaining 94% of the deposit meets the requirements for clear glass manufacturing, after processing.

## 6. Consideration of Alternatives

### *Introduction*

- 6.1 An important aspect of this study has been to consider the extent to which alternative sources, capable of meeting the same silica sand end uses, exist outside the South Downs National Park, and the extent to which these are capable of serving the same geographical market areas. This is a vital element of being able to consider sites within the SDNP against the 'Exceptional Circumstances' tests in paragraph 116 of the NPPF (as discussed in para. 1.10, above). Consideration is given firstly to the availability and distribution of resources and reserves, and to the technical comparisons between different sources, including recycled glass. This is followed by observations relating to transport distances and the UK glass industry's views regarding future supply sources.

### *Alternative Geological Resources and Reserves*

- 6.2 General information on alternative geological sources is provided in the BGS mineral planning factsheet on Silica Sand (September 2009 version); the additional BGS geology and mineral factsheet on silica sand in Scotland (2007); the comprehensive UK site listing given in Appendix 1 of the GWP report on Kent and Surrey (March 2010); and the Cuesta report on silica sand in Bedfordshire (February 2008). The following account is updated from these various sources by utilising information from existing and emerging minerals local plans, planning application details and other public domain information.

### Resources within England

- 6.3 Silica sand sources within England are to be found in a relatively limited range of geological resources and geographical areas. Those which are currently producing sands for one or more specialist end-uses are listed (in alphabetical order of county) in Table 6.1, below. The estimated stock of permitted reserves for each quarry or producing area, as shown in Table 6.1, is based on the latest available public domain information, usually with some extrapolation to allow for ongoing production in recent years<sup>8</sup>. Silica sand was also previously worked at Blubberhouses in North Yorkshire, where approximately 4mt of permitted reserves still remain, but that site is currently dormant. Additional sites were also previously worked in Durham, Central Bedfordshire, Staffordshire and Kent, but are now either closed or no longer produce silica sand. This has reduced the number of sites currently supplying sand for glass manufacturing in England to four, of which it is understood that only one (North Park in Surrey) – also supplies sand for sodium silicate production. All of these are operated by a single company (Sibelco). Two of these and five other sites still supply foundry sand, although in some cases the scale of production is small. To varying degrees, all of the sites supply sand for other industrial, agricultural, horticultural and leisure uses. Overall, the number of sites currently supplying silica sand of one type or another is seen, from Table 6.1, to be small. The same appears to be true in terms of the estimated stocks of permitted reserves: very few areas (and none of the areas of glass sand production) appear to currently have sites with permitted reserves in

<sup>8</sup> Table 6.1 has been updated from the one given in the original (superseded) version of this report to incorporate information provided to the SDNPA by other MPAs in September 2015, through the 'Duty to Cooperate' process.

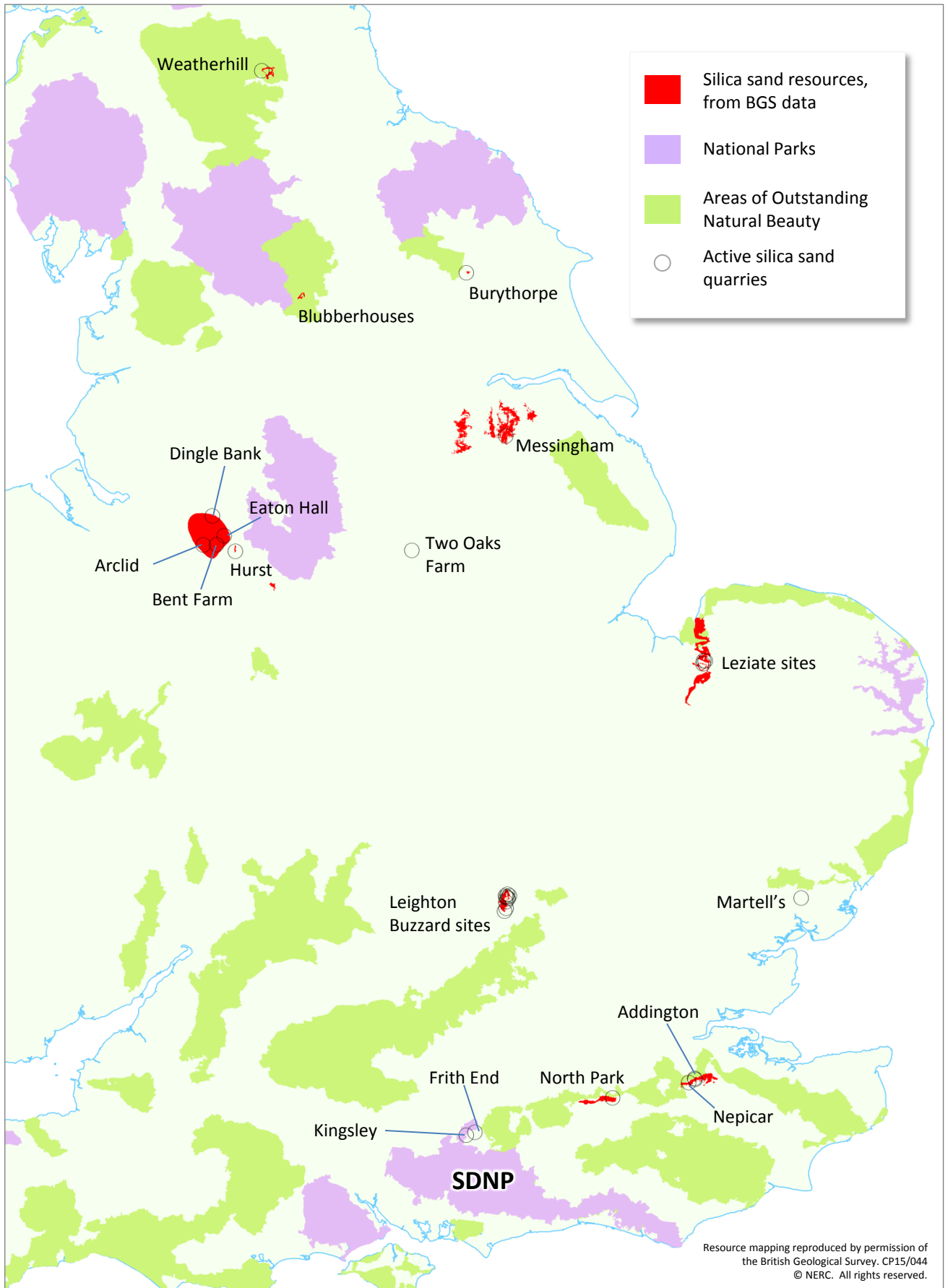
excess of 10 years (for Minerals Local Plans para. 146 of the NPPF expects a minimum of 10 years (or 15 years where significant new capital investment is required).

**Table 6.1: Sources of Silica Sand Production in England, as at September 2016**

MPA, Formation	Active Quarries	Foundry Sand	Glass Sand	Other Industrial Sand	Agriculture, Horticulture and Leisure	Stock of permitted reserves (Sept 2016)
<b>Bedfordshire</b> (Woburn Sand Formation)	Leighton Buzzard (multiple sites)	✗	✗	✓	✓	(tbc, following the closure of some sites)
<b>Cheshire East</b> (Chelford Sand)	Dingle Bank	✗	✓	✓	✓	~4 years
<b>Cheshire East</b> (Gawsworth Sand)		✗	✗	✓	✓	
<b>Cheshire East</b> (Congleton Sand)	Eaton Hall	✓	✗	✓	✓	>10 years at two of these sites
	Bent Farm	✓	✗	✓	✓	
	Arclid	✓	✗	✓	✓	
<b>Dorset</b> (Poole Formation)	Warmwell	✗	✗	✓	✗	~2 years
	Henbury	✗	✗	✗	✓	~10 years
<b>Essex</b> (Kesgrave Sands)	Martell's	✗	✗	✓	✓	~13 years
<b>Hampshire</b> (Folkestone Formation)	Kingsley	✗	✗	✗	✓	~6 years
	Frith End	✗	✗	✗	✓	~3 years
<b>Kent</b> (Folkestone Fm)	Addington	✓	✗	✓	✓	>10 years
<b>North Lincolnshire</b> (Quaternary Sand)	Messingham	✓	✓	✓	✓	<10 years
<b>Norfolk</b> (Leziate Beds)	Leziate sites	✗	✓	✓	✓	~4 years
<b>Norfolk</b> (Mintlyn Beds)		✗	✗	✓	✓	
<b>North Yorkshire</b> (Osgodby Fm)	Burythorpe	✓	✗	✗	✓	>10 years
<b>Nottinghamshire</b> (Nottingham Castle Formation)	Two Oaks Farm (<95% silica)	✗	✗	✓	✓	~38 years
<b>Staffordshire</b> (Rough Rock Sandstone)	Hurst	✗	✗	✗	✓	Not known
<b>Surrey</b> (Folkestone Fm)	North Park	✓	✓	✓	✓	~8 years

6.4 Although Messingham in North Lincolnshire is thought to have reserves of close to 10 years, that site only produces sand for coloured glass containers (and lower-grade applications). The other three glass sand sites (in Cheshire East, Norfolk and Surrey) are each thought to currently have stocks of less than 10 years.

- 6.5 Additional silica sand resources are known to occur in each of these areas, mostly outside nationally designated landscapes. Norfolk and Surrey County Councils have noted, in their recent 'Duty to Cooperate' responses to the SDNPA, that they are currently relying at least partly on further development within Areas of Search to address their respective shortfalls of permitted reserves. In Norfolk, this has resulted from the fact that previously adopted Specific Site allocations were found to be unsuitable because of uncertain impacts on a European designated wildlife site. Cheshire East is relying on further development within Preferred Areas, identified as extensions around existing sites.
- 6.6 More detailed information regarding the remaining availability of resource outcrops in most of these areas is given in a series of BGS reports on Resource Information in Support of National, Regional and Local Planning, for each of the relevant counties, and in the 1:100,000 scale maps which accompany them. The report for West Sussex was produced by Hopson, et al., in 1997. Figure 6.1, below, presents the same BGS resource information at a smaller scale, together with the locations of currently active production sites, as listed in Table 6.1, and the areas covered by National landscape designations.
- 6.7 **It is important to note that the resource outcrops in Figure 6.1 are generally far more restricted than those shown on the BGS Minerals Planning Factsheet (2009 edition).** This is because the latter included the whole of each geological formation within which there was at least one site known to be capable of supplying silica sand; whereas the newer information, shown here, is more refined, identifying only the most relevant parts of each formation (as indicated on the more detailed BGS resource maps). This provides a more realistic indication of potential resource availability with regard to the more 'traditional' uses of silica sand (i.e. glass manufacturing, foundry sand and other industrial sands), but perhaps less so for the rapidly expanding markets for specialist sands in the lower-specification sports, leisure and horticultural sectors. For some of those markets, the available resources would be slightly more extensive, in some areas.
- 6.8 As demonstrated in this study, sands of the Folkestone Formation within West Sussex, although not identified as silica sand resources on the BGS maps, appear to be suitable for a wide range of specialist end uses including, in some cases at least, for glass and sodium silicate manufacturing. It is possible that other areas, within the wider outcrops shown on the BGS factsheet, but beyond the areas identified in Figure 6.1, might also be capable of supplying at least some of the more general silica sand end-uses, particularly where higher levels of impurity are acceptable.
- 6.9 This applies, for example, to the Triassic sandstones of the Nottingham Castle Formation, as currently worked by Mansfield Sand at Two Oaks Farm in Nottinghamshire (and formerly at Ratcher Hill). These deposits have a silica content of around 92.4% to 93.3% (Rees & Ryan, 2016) and are therefore not shown on the BGS resources map.



**Figure 6.1: Resources and Sites of Silica Sand Production in England, outside the SDNP, April 2015, with National Landscape Designations.**

- 6.10 It can be seen from Figure 6.1 that the majority of resource outcrops and silica sand quarries in England fall outside the National Parks and Areas of Outstanding Natural Beauty (AONBs). The exceptions are the dormant Blubberhouses Quarry, which falls within the Nidderdale AONB; some of the resources to the north of the Leziate sites, which overlap with the Norfolk Coast AONB; part of the northern edge of the resources in Kent which, along with Addington East Quarry, fall within the Kent Downs AONB; and part of the northern edge of the resources in Surrey, which extend slightly into the Surrey Hills AONB.

#### Resources within Scotland

- 6.11 Information relating to silica sand resources within Scotland is given in the BGS minerals planning factsheet produced for the Scottish Executive in 2007. Whilst the basic geological information provided by the factsheet still remains valid, the ownership of the various sites and the markets which they supply has changed over the past decade. Updated information for the purposes of this study has therefore been obtained, as far as possible, from the current operators and the local planning authorities involved.
- 6.12 Of the eight sources indicated on the BGS factsheet, four have supplied silica sand of sufficient quality for glass-making, either now or in the past, and two of those (Lochaline Mine on the Morvern peninsula and Burrowine Moor near Alloa in Fife) currently supply sand to glass manufacturers in England. A third site, at Devilla Forest adjacent to Burrowine Moor, is owned by an international glass-making company (O-I Manufacturing) and the majority of its silica sand output is currently devoted to that company's container glass plant in Alloa. The fourth site - Levenseat - was formerly owned by WBB minerals (now Sibelco) but is now operated by Aggregate Industries and its output is currently used primarily for sports and horticultural applications, mostly within Scotland. It is not known whether either Devilla Forest or Levenseat might be capable of supplying glass sand to England in future, should the need arise.
- 6.13 The deposit at **Lochaline Mine** is an exceptionally high quality (low iron) sand which is used for the highest specification optical glass as well as higher volume clear glass applications. It is also a key ingredient in the manufacture of silicon carbide abrasives, borosilicate glass for laboratory and scientific use and chemical and domestic ovenware. The mine is currently operated by Lochaline Quartz Sand (LQS), a joint venture between Minerali Industriali of Italy and NSG (Pilkington Glass). Its output capacity is in excess of 100,000 tpa (tonnes per annum) and approximately 80% of this is shipped directly to Runcorn in north-west England, from where it is transported by road to NSG's float glass plant in Ormskirk, Lancashire and to other customers in northern England<sup>9</sup>. The site has a planning permission which is subject to renewal at five yearly intervals and has access to additional proven resources sufficient for at least 10 further years of supply.
- 6.14 **Burrowine Moor** is also a high purity silica sand operation and has far more extensive permitted reserves. It has planning permission, granted in 2009, to allow working over a period of 60 years at a maximum output rate of 450,000 tpa (equating to a total of some 27mt). Its current output is understood to be about 250,000 tpa<sup>10</sup>, which implies a

<sup>9</sup> Personal Communications, Massimo Rizza, sales manager of Minerali Industriali Srl – Italy, 28<sup>th</sup> & 29<sup>th</sup> July 2016

<sup>10</sup> GWP Consultants, 2010: A Study of Silica Sand Quality and End Uses in Surrey & Kent, page 14.

theoretical 'spare' capacity of about 200,000 tpa. However, only about 30% of the output from this site is said to be suitable for the manufacturing of clear container glass<sup>11</sup>. This equates to about 75,000 tpa at present, the vast majority of which is exported to glass manufacturing companies in Yorkshire and Lancashire. The site has good access to the M8 and M9 motorways and is located no further away from the major glass factories in northern England by road than would be the case for sites in West Sussex. In addition, it has access to the deep water port at Grangemouth, which enables it to export by sea to those factories via the port of Goole.

- 6.15 Thus, although there are additional sources of high grade silica sand in Scotland, one of these is primarily dedicated to glass production in Scotland and the other two are already part of the existing supply pattern for the major glass manufacturing companies in northern England. Whilst those sites have substantial reserves and resources, it is not clear whether or not they would be capable of increasing and/or diverting some of their production in future years to accommodate any shortfall in production from sources in England.

### ***Technical Comparison of Alternative Resources***

- 6.16 It has proved difficult to obtain technical information on the 'raw' (unprocessed) sands at most of the existing supply sources, although some grading and chemical analysis data has been provided by two of the main producers and grading data for processed materials from a number of producers is freely available on various websites. In addition, grading data for several sites in Bedfordshire has previously been given to Cuesta for use in an earlier study (Cuesta Consulting Ltd., 2006). At the operators' request, all of the data obtained is used without revealing specific locations or sources, but is considered to be reasonably representative of the materials concerned.

### Particle Size Distribution

- 6.17 Figure 6.2, below, compares the grading curves for a range of examples of both natural silica sand deposits, and processed sands, with the gradings obtained for our samples within the Study area. The black curve, for general reference, is the grading for our sample of washed sand from Kingsley in Hampshire, and the two red curves are the coarser and finer extremes of the samples we obtained - both of which are from West Heath Common quarry. These are compared with:
- Green curves, representing the full range of natural deposits found around Leighton Buzzard in Bedfordshire, comprising a very fine grained sand, a more typical sand, and a very coarse grained sand (used primarily for water filtration);
  - Blue curves, representing three typical examples of fully processed silica sand for use in glassmaking; and

---

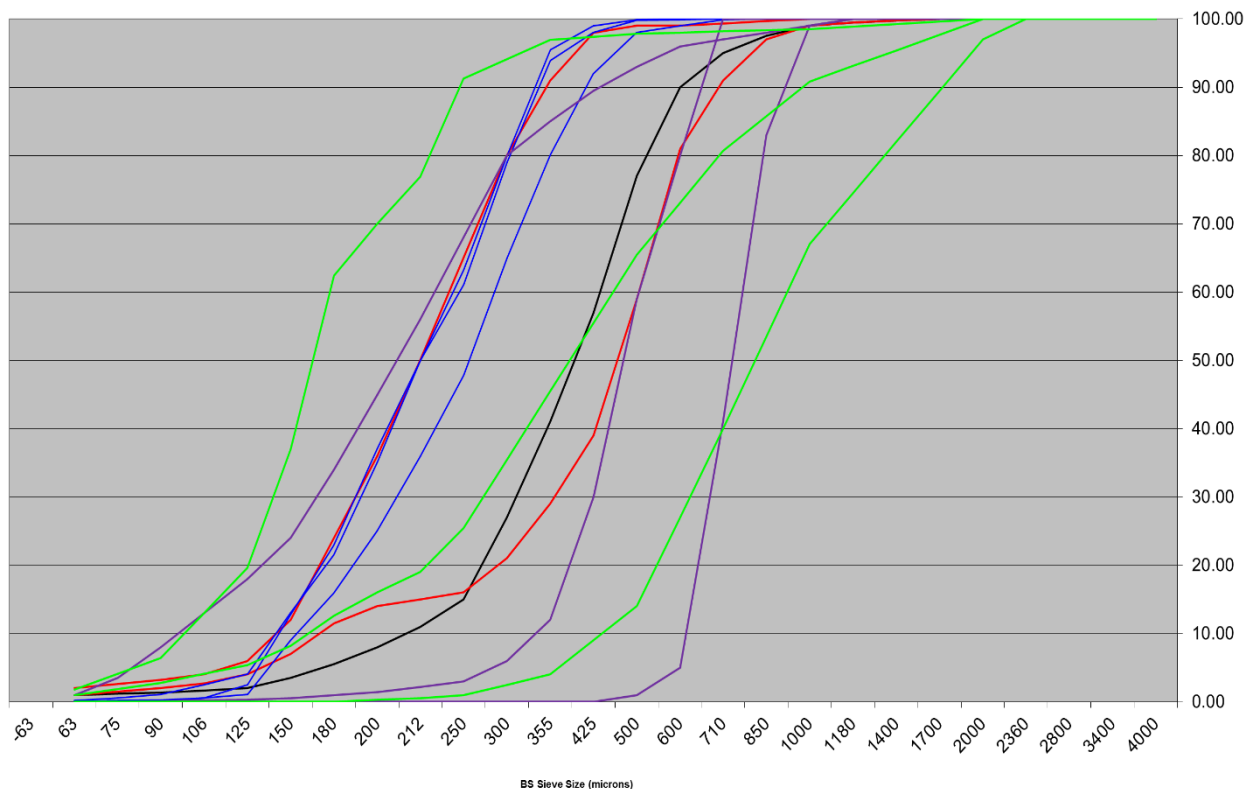
<sup>11</sup> Personal Communication: Martin McGroarty, Lead Professional (Minerals), Fife Council, 3<sup>rd</sup> August 2016

- Purple curves, representing a selection of fully processed silica sand for other end uses, including relatively fine-grained sand for sports and leisure applications and coarser, very tightly graded sand for water filtration.

6.18 The diagram shows, firstly, that the range of samples from this study (the red and black lines), fall well within the much broader spectrum of gradings for the deposits in Bedfordshire (the green lines), but that the coarsest of the Bedfordshire sands are not matched by anything found (so far) in this area. This is why, in contrast to Bedfordshire, the deposits in West Sussex and Hampshire do not appear to be suitable for the production of water filtration sands (one specific example of which is shown by the right-hand purple curve).

6.19 Secondly, the diagram reveals that the finer end of the spectrum of sands in the study area (the red line on the left) matches very closely indeed with the three examples of processed sand for use in glass making (shown in blue). With processing, it is likely that most if not all of the West Sussex silica sands could achieve similar gradings. This would leave a residue of slightly coarser sand, but that would almost certainly be capable, in theory, of being used in other applications, as indicated, for example by the central purple line, which is identified by the operator as being suitable for use in synthetic sports pitches and in adhesives, grouts, paints and brick facings. Whether the sands can be worked economically, however, is not clear from this analysis alone. That would be dependent on a more detailed examination of the deposits, including determination of the relative proportions of material which would be suitable for different end uses, after processing.

**Figure 6.2: Comparison of Silica sand grading curves for various deposits and products in England**  
(see foregoing text for explanation)



### Chemical Analysis

- 6.20 Comparisons can also be made in terms of chemical analysis, but only with examples of processed sands which have benefited to varying degrees by the removal of excess impurities. Unfortunately, no analyses were able to be obtained for the unprocessed deposits at any sites (other than those in this study).
- 6.21 Table 6.2, below, thus compares three typical analyses from unprocessed sands obtained in this study with those for processed silica sands produced elsewhere in the UK. The latter include three examples of sand processed for high specification manufacturing of float glass, clear container glass and sodium silicate, together with three other lower specification uses: sports pitch sand, fine washed silica sand (suitable for equestrian uses) and a water filtration sand. The table focuses on the most important chemical constituents (as discussed in Chapter 2), together with Loss on Ignition (LOI), which provides an indication of organic content. It is important to emphasise that, with the exception of SASS3 and SASS14, the samples from our study were tested without pre-washing, and that the levels of impurities which they contain are therefore likely to be higher than would be achieved by full commercial processing. The two sets of results are therefore not directly comparable, although the unwashed samples serve to illustrate the need for processing, which varies from one end-use to another.

**Table 6.2: Comparison of chemical analyses of silica sands**

	Study Sites (unprocessed)			Typical Products from other Sites (after processing)					
	Kingsley	West Heath White	Coates Pit	Float Glass	Clear Container Glass	Sodium Silicate sand	Sports Pitch sand	Fine washed s. sand	Filter Sand
SiO <sub>2</sub>	98.92%	98.19%	98.30%	98.53%	99.53%	99.7%	97.31%	94.6%	98.29%
Fe <sub>2</sub> O <sub>3</sub>	0.75%	0.35%	0.34%	0.055%	0.033%	0.045%	1.71%	1.20%	1.29%
Al <sub>2</sub> O <sub>3</sub>	0.20%	0.27%	0.65%	0.76%	0.08%	0.01%	0.31%	1.52%	0.31%
TiO <sub>2</sub>	0.05%	0.05%	0.04%	0.033%	?	0.025%	0.04%	0.33%	0.02%
Cr <sub>2</sub> O <sub>3</sub>	<0.01%	<0.01%	<0.01%	0.0003%	0.0004%	0.0007%	0.0004%	?	0.0002
L.O.I.	0.30%	0.37	0.34	0.19%	0.13%	0.10%	0.26%	0.93%	0.19%

- 6.22 Not surprisingly, the comparisons reveal that products supplied for glass and sodium silicate manufacture generally have the lowest levels of impurities, with the exception of a relatively high Alumina content in the float glass sample (though that still falls within the required limits for that process). It also reveals, however, that (even without washing or other processing) the silica contents of our samples from the SDNP are very close to those of the sands used for clear glass manufacture, and generally better than those used in other applications.
- 6.23 Although the data presented above is necessarily limited, and notwithstanding the fact that the samples from this study were generally of unprocessed materials, the comparisons of both gradings and chemical analyses reveal that the Folkestone Formation sands found within the study area appear to be broadly comparable with a range of silica sands produced elsewhere in England. Conversely, this also means that there are resources elsewhere in the country which (to varying degrees in each case, and

subject to a more detailed examination of availability and constraints in those areas) appear to represent genuine alternatives to the resources within the National Park.

- 6.24 The more comprehensive testing carried out at the Horncroft site by Sibelco, as reviewed in para. 2.51, suggest that the sand at this site (at least) exhibits qualities which are likely to be comparable to the highest purity glass sands produced in other parts of the country. Subject to further investigation, it may well be that other sites within or close to the National Park could meet similarly high specifications, subject to processing.

### ***Recycled Glass***

- 6.25 An alternative to silica sand in many, though not all, of its specialist applications, is recycled glass. Glass can be re-melted and formed into new glass containers (bottles and jars) an infinite number of times without any degradation of its physical properties. This applies primarily for the production of coloured glass containers - for clear glass there are limitations on the proportion of recycled material that can be used, and high purity silica sand may need to be added in order to limit the overall level of impurities. Recycled glass is therefore used as at least part of the primary feedstock for the glass manufacturing industry. In the UK, that industry cannot consume all of the recycled glass that we produce, however, mainly because of the dominance of clear glass container manufacture in the UK and the amount of wine we import in green bottles. The resulting surplus of green glass may either be exported, in particular to wine producing countries, or used locally in an increasingly wide range of secondary end uses.
- 6.26 Stimulated by research and processing trials funded by the Waste and Resources Action Programme (WRAP), these applications include several for which silica sand would otherwise be the preferred material, as discussed below. To further encourage the use of recycled glass in applications other than glass-making, and to establish quality requirements (colour, contamination limits and particle size requirements), the British Standards Institute (BSI) in conjunction with WRAP has published Publicly Available Specification (PAS) 102 to provide a "*Specification for Processed Glass for Selected Secondary End Markets*". The markets covered by the Specification comprise:
- Glass in water filtration media (currently relating to non-potable applications including tertiary sewage treatment, industrial process water treatment, landfill leachate and swimming pool filtration. It excludes potable water filtration, specifications which are still under development);
  - Glass in sports turf and related applications (including top dressing, root zone material and golf bunker sand. Other uses such as greyhound tracks and synthetic sports turf are cited as additional potential applications);
  - Glass in ceramic sanitary ware production;
  - Glass as a fluxing agent in brick manufacture;
  - Glass as an abrasive.
- 6.27 Of these, the first two are the most obvious and well developed examples of glass being used as a direct replacement for silica sand, and further details of these are given below.

The use of glass in ceramics, brick manufacture and abrasives appears not to be as a direct replacement for silica sand.

#### Recycled Glass in Water Filtration Media

- 6.28 Processed sand, manufactured from crushed and screened recycled glass, can be used as an effective alternative to silica sand in water filtration systems for the treatment of waste water, industry effluent and swimming pools. It may also be suitable for the treatment of drinking water, subject to approvals. For non-potable applications, at least, processed sand is capable of meeting existing (and ever-tightening) legislative standards; in many instances outperforming traditional sand filters. One of its main advantages is in relation to the clogging or "biofouling" of filters, which is a common problem in both drinking water and waste water treatment, leading to poor filter performance and reduced water quality. Sand filters in swimming pools can also clog easily, often necessitating the increased use of chlorine and other chemicals as a secondary control mechanism. Research has shown that bacteria and other deposits do not adhere to glass sand like they do with silica sand, and can therefore be more easily removed from the filters during the backwashing maintenance process. This property can increase the life of the filtration system. Commercial trials using recycled glass filter media, in place of sand, have demonstrated a 30% improvement in filter performance - realising significant benefits in environmental health and water quality. To date, the cost of using recycled glass in this way has been high – up to four times the cost of good quality sand, but the price may well fall considerably as the scale of production increases.

#### Recycled Glass in Sports Turf and Related Applications

- 6.29 As noted earlier in this report, the sports turf industry is a major consumer of silica sand, and uses it in a wide range of applications. Here again, processed sand manufactured from recycled glass can provide an acceptable alternative which reduces the need for quarrying.
- 6.30 Recent research for WRAP by the UK Sports Turf Research Institute (STRI) has shown that suitably processed glass sand passes the necessary 'fitness for use' criteria for use in golf course construction and maintenance – and can offer a number of benefits. In bunkers, for example, it can outperform conventional sand by providing firmer underfoot conditions, less plugging of the ball on impact and ability to rest at a slightly steeper angle, due to its greater angularity (which in turn allows the design of steeper bunker faces). Although perceived problems with colour and safety have been raised as potential issues, these are being quickly addressed and overcome by continuing research.
- 6.31 The STRI research has also shown that processed glass sand is perfectly acceptable as a substitute for silica sand in rootzone construction and top dressing applications, where it can be used either on its own or blended with natural sand. It is claimed by the STRI to provide increased capillary porosity and improved infiltration rates. It can also reduce the visual impact of worm castings – they tend to disintegrate more readily – and has proved to be excellent for divot repairs, where its natural green colouration provides good camouflage for the repair.

- 6.32 Recycled glass has also proved to be an acceptable substitute for silica sand in at least some equestrian applications, including horse gallops and horse rings. Such areas must be well-drained and must absorb impact well but should not be so soft as to stress the horse's feet and legs. The greater angularity of finely-crushed recycled glass provides more open spaces between the granules. This provides better drainage and prevents "clumping" when wet.

### ***Transportation Distances***

- 6.33 As silica sand tends to be moved in relatively small quantities, this lends itself to transportation by road. The feasibility of supply to particular markets is therefore generally likely to be affected by road transport costs and market prices. Significant exceptions to this are one silica sand processing plant in Norfolk, which is rail-linked, and the two sites in Scotland (Lochaline and Burrowine Moor) which are able to export by sea.
- 6.34 Price information is inevitably confidential but consideration can be given to the relative value of minerals that are used for different purposes, based on the relative scarcity of the mineral and the nature of the markets. Intuitively, commodity value is likely to be considerably higher for silica sand - and especially for high purity glass sand - than is the case for most bulk construction aggregates, but the differences between the various silica sand markets are more difficult to judge. In many cases, the different markets are supplied from the same geological resource, and it is the nature of the markets themselves (e.g. whether sand is supplied in bulk to major customers or in smaller quantities to individual sports clubs etc.) which account for differences in 'value'.

### **General (lower-grade) Silica Sand Markets**

- 6.35 Specialist sand and mixtures for use in sports, leisure and horticultural applications are known to be supplied from the existing operations at Kingsley in Hampshire to customers as far away as the Midlands and Wales. More commonly they are supplied to customers within southern England, including London and the Home Counties, with distances of up to 40 miles being common, and less frequently up to 80 miles. Another operator noted that travel distances for these types of products will vary depending on the location of the source of supply; the location of the end-users; the existence of any competing sources; quality considerations and any constraints on the availability of supply by the producer. This operator noted that travel distances would often be up to around 100 miles one way but also that, due to all or any of the reasons above, it is not uncommon for such sand products to travel up to 200 miles one way. Assuming a notional 100 mile radius for lower-grade silica sand, most of the markets which could potentially be served from sites within the SDNP area would also be accessible to suppliers in Surrey, Kent, Bedfordshire and Essex. At the northernmost limit of that radius, additional sites within Norfolk, Lincolnshire and Cheshire would also be able to compete.

### **Silica Sand Markets for Glass Making and Sodium Silicate Manufacture**

- 6.36 As noted above, currently there are only a limited number of glass sand supply sources within the UK, and currently only three commercial suppliers, two of which are in Scotland. Sands for glass making can and do therefore travel any distance necessary if the glass customer requires a certain specification to be met and if the supplier can

achieve this. One example is sand for sodium silicate manufacture which is transported by road from Surrey to Warrington in Cheshire (approximately 216 miles). From the South Downs area (e.g. Midhurst), the road distance would be slightly further (232 miles).

- 6.37 With the exception of specialised glass crystal producers in Devon and Cumbria, most industrial glass manufacturers are located in Yorkshire (Goole, Eggborough, Leeds, Knottingley, Rotherham & Barnsley); and around Ormskirk and Wigan in Lancashire. Others are located at Broxburne in Hertfordshire and at Harlow in Essex. The factories within Yorkshire and Lancashire are at road distances of 208 to 250 miles from Midhurst. Assuming a nominal radius of up to 250 miles from these various processing areas, any of the known glass sand resources in Cheshire, Lincolnshire, Norfolk and Surrey would represent economically viable alternatives to material obtained from the South Downs, and in most cases would offer reduced transportation distances and costs. In addition, Burrowine Moor in Scotland is only slightly further away from the Yorkshire and Lancashire factories than Midhurst (230 to 270 miles), but has the option, which is utilised for at least part of its output, of supplying by sea, as does Lochaline mine.
- 6.38 Thus, although the alternative sources of high quality glass sand are fewer than those for lower grade industrial sand, they are all able to compete with sand from the South Downs area in terms of transport economics.

### ***Glass Industry Views***

- 6.39 In light of evidence responses from other MPAs to the Draft JMLP, which suggested there was more uncertainty of permitted reserves than had originally been suggested in earlier correspondence, questions were put to all current industrial-scale glass manufacturers within the UK and to their trade organisation – British Glass, regarding their views on the security of supply of silica sand raw materials.
- 6.40 Email enquiries were initially sent, in July 2016, to Pilkington/NSG, Guardian, Saint Gobain, O-I, Beatson Clark, Ardagh Glass, Allied Glass and Stölzle Flaconnage. Each manufacturer was asked whether or not they could foresee any difficulties in maintaining an adequate security of supply from existing sources in future years, or whether there could be a need for additional sources of supply.
- 6.41 None of the companies said that they predicted any difficulty in maintaining an adequate supply of silica sand. In fact, only two replies were received at all, indicating, in one case that they would be very interested should another suitable source be identified as a realistic opportunity and, in the other case, that ensuring the availability of silica sand resources, such as those identified in the South Downs and West Sussex areas, may well be of long term interest to them.
- 6.42 The first respondent noted that they are currently limited to just one quarry that can supply them with enough volume at the correct specification, which, in itself, gives them reason to consider any other suitable sources. They also noted that their glass specification has evolved over the years, and that their raw material specification has needed to adapt with this evolution. Although no further details were forthcoming, implication of this is that glass specifications might change again in future years. Whether

this would rule out certain sources, or enable the company to accommodate different sources of supply is not clear.

- 6.43 The second respondent noted that it had recently switched sources of supply from Cheshire (where suitable supplies were becoming exhausted) to Norfolk (described as “*an operation with insufficient capacity to supply all our needs*”), with additional material being imported from the Lochaline Mine in Scotland (described as being “*an operation not optimised for clear glass sand production*”). They added that their current supply arrangements are probably adequate for the next ten years but in the longer term they need to see the development of silica sand resources to permit the continued large scale manufacturing of value-added glass products in the UK. They noted that, “*whilst some of this could possibly be supplied by extensions to existing glass sand operations, any additional sources could make the long term planning of UK glass production more certain*”.
- 6.44 A third response was obtained from the trade organisation British Glass who were able to say that, so far as they are aware, the UK is almost self-sufficient with regards to supply of silica sand, but did not know how long stocks are expected to last. They also noted, however, that if there were a dire shortage of raw material supplies and the industry was at risk, they were sure it would have been flagged-up by their members.
- 6.45 The overall message to be gleaned from this consultation is that there is (perhaps) beginning to be some modest concern within the glass industry over the long-term security of supply of silica sand, and that the industry would certainly welcome additional supply options, but that there is no impending critical shortage.

### ***Summary and Implications for the SDNPA***

- 6.46 This brief review has confirmed that there are alternatives to the Folkestone Formation resources of the South Downs National Park, particularly with regard to the relatively low purity applications relating to agricultural, horticultural and leisure end-uses. These alternative resources are relatively limited in extent but many of them fall outside nationally designated landscapes and (subject to planning consent) are capable of supplying all of the geographical areas which could potentially be served from the South Downs. In some (but not all) applications, the alternatives include the additional option of utilising recycled glass.
- 6.47 In the case of high purity and high consistency sands needed for glass and sodium silicate production, the alternatives are more limited in extent. Of the four individual sites within England which currently supply sand for glass manufacturing, only one is thought to have at least 10 years’ worth of permitted reserves (and that is used for coloured container glass, not clear glass). The other three sites are currently thought to have lower stocks of permitted reserves. Furthermore, only one of those sites is understood to be capable of supplying sand which is suitable for sodium silicate production.
- 6.48 Additional silica sand resources have been identified in each of these areas, mostly outside nationally designated landscapes. Two of those areas are currently relying on Areas of Search to encourage potential new applications and the third is similarly relying on Preferred Areas.

- 6.49 Additional silica sand resources which are suitable for glass-making, and which are already used for this purpose, are also available at three sites in Scotland. Two of those sites already supply much of their output to glass manufacturers in the north of England, over distances which are comparable to those from West Sussex, and have considerably higher levels of permitted reserves. It may be possible that these sources could either increase their rates of output and/or divert some of their existing output to make up for the depletion of reserves in England though further work would be needed to confirm this.
- 6.50 Taking account of the foregoing observations, it is clear that there is considerable uncertainty, at present, regarding the long-term security of supply of silica sand to support glass manufacturing within the UK. Equally, however, whilst this might have long-term implications for the need for resources within the South Downs area, there is no clear evidence that is likely to be the case for the period of the emerging Joint Minerals Local Plan. It is also pertinent to note that, at present, there is no indication from the UK glass industry of an impending critical shortage. These uncertainties have to be balanced against the very clear need for protection of the South Downs National Park, as set out in national legislation and policy. The situation will need to be monitored, however, and there will be a need to consider the role which the South Downs area may need to play in maintaining a long-term, strategic, continuity of supply of these materials in future years.

## **7. Assessment of the Significance of Sand Resources within the Study Area.**

- 7.1 Given that most, if not all, of the Folkestone Formation sands within the study area seem likely to be capable of being classified as silica sands, in the broadest sense, it is appropriate that they should be considered as strategic resources. As such, they should at least be safeguarded from needless sterilisation by other forms of development.
- 7.2 In the case of specific sites which are able to demonstrate, through detailed investigation and testing, their suitability for supplying the highest quality sand for glass manufacture and sodium silicate production, those particular resources should be recognised as being of National importance. This is because alternative resources of comparable quality are very limited within England, although there are more extensive resources and reserves in Scotland which also supply users in the north of England.
- 7.3 Sands of this quality have been confirmed, to date, at only one location within the National Park (Horncroft, as detailed in paragraph 2.51, above). Notwithstanding the variability of the Folkestone Formation as a whole, it is possible that other sites of National importance might also be identified elsewhere within the Park and/or adjoining areas, subject to future detailed exploration and analysis. This will apply most especially to sites which prove to be capable of supplying high purity sands for glass-making and/or sodium silicate manufacture, but other sites which are capable of supplying a wide range of slightly lower-grade silica sands may also justify being regarded as nationally or at least regionally important. This is not least because of the rapid growth and increasing diversity of new markets for silica sand, and the relatively shorter distances of economically viable transportation for such materials (compared with glass sand), which (currently) effectively limits the number of alternative supply sources.
- 7.4 Alternative resources (and, more especially, the prospects for securing new permitted reserves in those areas) are gradually reducing and so it is quite possible that there will be increasing pressure on the South Downs National Park for the release of new reserves in future years.
- 7.5 Regardless of the final SDNPA policy on silica sand supply, it is clear that continued and close cooperation between the various MPAs will thus be needed in order to monitor the national availability of permitted reserves and to develop a suitably balanced, long-term national strategy for silica sand production within the UK.

## References

- Allen, J.R.L. (1982): Mud drapes in sand-wave deposits: physical model with application to the Folkestone Beds (Early Cretaceous, southeast England). *Philosophical Transactions of the Royal Society*, v. **A306**, pp. 291–345.
- Baker, S.W. (2006): *Rootzones, Sands and Top Dressing Materials for Sports Turf*. Sports Turf Research Institute. 112 pp. (ISBN 187-343-1600)
- British Geological Survey (2009): *Minerals Planning Fact Sheet: Silica Sand* (10pp).
- Brown, J.R. (editor) (2000): *The Foseco Ferrous Foundryman's Handbook*. Eleventh Edition. Butterworth Heinemann (ISBN 0-7506-4284-X).
- Capita Symonds Limited (2012): *South Downs National Park - Soft Sand Study*. Report to the South Downs National Park Authority, in partnership with Hampshire, West Sussex and East Sussex County Councils (43pp + Appendices).
- Cuesta Consulting Limited (2006): *Bedfordshire Aggregates Landbank Study 2005*. Report to Bedfordshire County Council (36pp).
- Cuesta Consulting Limited (2008): *Bedfordshire Silica Sand Study 2006 - 2007*. Report to Bedfordshire County Council (28pp).
- GWP Consultants (2009): *Assessment of Pendell Farm Preferred Area for Silica Sand*. Report to Surrey County Council (11pp + Appendices).
- GWP Consultants (2010): *A Study of Silica Sand Quality and End-Uses in Surrey and Kent*. Report to Kent and Surrey County Councils (63pp + Appendices).
- Hopson, P.M.; Bloodworth, A.J.; Harrison, D.J.; Highley, D.E. & Holloway, S. 1997: *Resource Information for Development Plans: Phase One West Sussex Resources and Constraints*. British Geological Survey Technical Report WF/98/5 (37pp + map)
- Krumbein, W.C. (1941): Measurement and geological significance of shape and roundness of sedimentary particles. *Journal of Sedimentary Petrology*. v.11, pp 64-72.
- Krumbein, W.C. and Sloss, L.L. (1951): *Stratigraphy and Sedimentation* (2nd Edition, published in 1963). W.H. Freeman and Company, San Francisco.
- Mitchel, C.J. (in press, 2015): *UK frac sand resources*. In: Hunger, E., Brown, T.J. and Lucas, G. (Eds): *Proceedings of the 18th Extractive Industry Geology Conference*, EIG Conferences Ltd.
- OTB Engineering UK (2014): *Horncroft Site - Assessment of Sand Properties*. Report to the Mineral Planning Group, on behalf of the Barlavington Estate. (Ref. UK13043-R-02 02). (13pp + Appendices).
- Rees, S. and Ryan, D (2016): *Landsearch for a New Greenfield Site: Two Oaks Silica Sand Quarry Development*. Paper presented at the 19<sup>th</sup> Extractive Industries Geology Conference, University of Birmingham, England. September 2016
- Wadell, H. (1932) Volume, Shape and Roundness of Rock Particles, *Journal of Geology* **40**:443-451.