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# Particle size determinations of six sand and alluvium samples from Dounreay, Caithness, Scotland

Physical Hazards Programme

Internal Report IR/07/016

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/07/016

# Particle size determinations of six sand and alluvium samples from Dounreay, Caithness, Scotland

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*Key words*

Laboratory testing, particle size distribution, Dounreay, Scotland.

*Front cover*

Cover picture details, delete if no cover picture.

*Bibliographical reference*

ENTWISLE, D C AND NELDER, V.. 2007. Particle size determinations on six samples from Dounreay, Caithness, Scotland. *British Geological Survey Internal Report*, IR/07/016. 21pp.



Keyworth, Nottingham British Geological Survey 2007

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# Summary

This report describes particle size analysis of six soil samples from Dounreay, Caithness, Scotland, provided by Clive Auton in October 2006. It is part of the work under a United Kingdom Atomic Energy Authority (UKAEA) contract to characterise the Quaternary deposits from the Dounreay site and also includes bulk mineralogy, clay mineralogy, particle size distribution, cation exchange capacity (CEC), total organic carbon (TOC) and total inorganic carbon (TIC) data presented elsewhere. These materials were collected using a window sampler during June and July 2006 at the Dounreay site. This data was required by UKAEA to provide background mineralogical, geochemical and physical properties information to enable the evaluation and modelling of the transport radionuclide contamination in the geosphere. This report presents the results of the BGS analyses. The report consists of factual data only.

# 1 Particle size analysis

## 1.1 ANALYTICAL METHOD

Particle size analysis was undertaken using a combination of sieving and X-ray Sedigraph. The coarse grain size distribution (gravel and sand) was obtained by sieving using the methods described in BS1377:Part 2:1990, Tests 9.2 and 9.3: 'Determination of particle-size distribution by wet-sieving and dry sieving Method' (Anon, 1990). The particle size distribution of the fines (silt and sand, <0.063 mm) was determined using an X-ray Sedigraph method, with the material dispersed and suspended in a 0.2% concentration sodium hexametaphosphate solution. Calculations were carried out using the method described in Head (19

## 1.2 RESULTS

Sample details are in Table 1,and the results are summarised in Table 2 and Figure 1. The laboratory data are tabulated and individual particle distribution graphs are in Appendix 1.

The results show that the different deposit types have different particle size distributions. The shell sand samples (PY1977 and 1982) are very similar, well-sorted, medium and coarse sands with 60% coarse sand, over 30% medium sand and less than 5% fine sand or smaller and less than 1% gravel. The quartz feldspar sand samples (PY1986 and 1987) are moderately well-sorted, gravelly, medium coarse sand with less than 7% fines. They comprise about 15% gravel, about 70% medium and coarse sand, about 10% fine sand and less than 7% fines. Sample PY1984 also contained one cobble, which weighed more than the rest of the sample. The alluvium samples (PY1999 and 2005) are poorly sorted and more variable than the other two deposits. Sample PY1999, the deeper and coarser of the two, is a gravelly, silty sand, whereas PY2005 is a slightly gravelly, sandy silt.

# 2 References

ANON. 1990. Method of test for soils for civil engineering purposes. Part 2. Classification tests. *British Standards Institute, BS1377: Part 2*.

Head, K H. 1992. Manual of Soil Laboratory Testing, Volume 1: Soil Classification and Compaction Tests, Second edition. Halstead Press.

**Table 1. Sample details.**

| Core | Sample No. | Easting | Northing | Depth top (m) | Depth base (m) | Description |
|---|---|---|---|---|---|---|
| WS02 | PY1977 | 298386.9 | 966914.0 | 1.35 | 1.40 | Shell sand (Beach deposit) |
| WS07c | PY1982 | 298388.0 | 966980.6 | 4.20 | 4.30 | Shell sand (Beach deposit) |
| WS10 | PY1986 | 298363.4 | 966888.8 | 1.30 | 1.35 | Quartz feldspar sand |
| WS10 | PY1987 | 298363.4 | 966888.8 | 2.20 | 2.25 | Quartz feldspar sand |
| WS15 | PY1999 | 298383.5 | 966911.3 | 2.75 | 2.80 | Gravelly, silty sand (Alluvium?) |
| WS19 | PY2005 | 298399.0 | 966923.0 | 1.75 | 1.80 | Slightly gravelly, sandy silt (Alluvium?) |

**Table 2. Particle size summary results.**

| **Core** | **Sample No.** | **Particle size class (%)** | | | |
|---|---|---|---|---|---|
| | | **Clay** | **Silt** | **Sand** | **Gravel** |
| WS02 | PY1977 | 1.9 | | 97.5 | 0.6 |
| WS07c | PY1982 | 0.7 | | 98.4 | 0.9 |
| WS10 | PY1986 | 6.8 | | 80.9 | 12.3 |
| WS10 | PY1987 | 2.8 | | 80.8 | 16.4 |
| WS15 | PY1999 | 3.9 | 15.7 | 66.9 | 13.5 |
| WS19 | PY2005 | 12.5 | 44.9 | 40.8 | 1.8 |

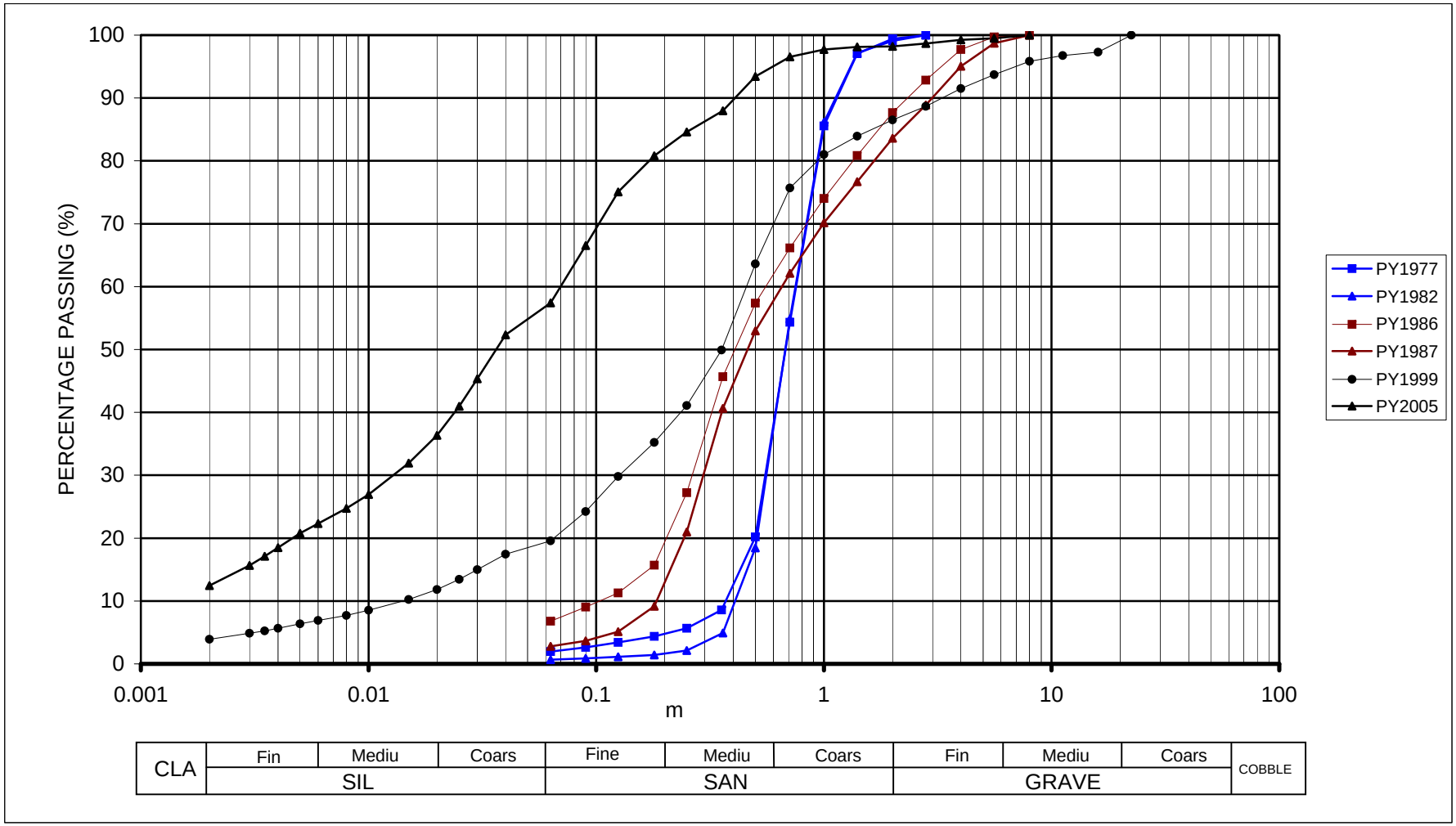



**Figure 1. Summary particle size distribution graph**

# Appendix 1 Particle size test data and individual distribution graphs

Dounreay, borehole WS02, depth 1.35-1.40 m, sample number PY1977.

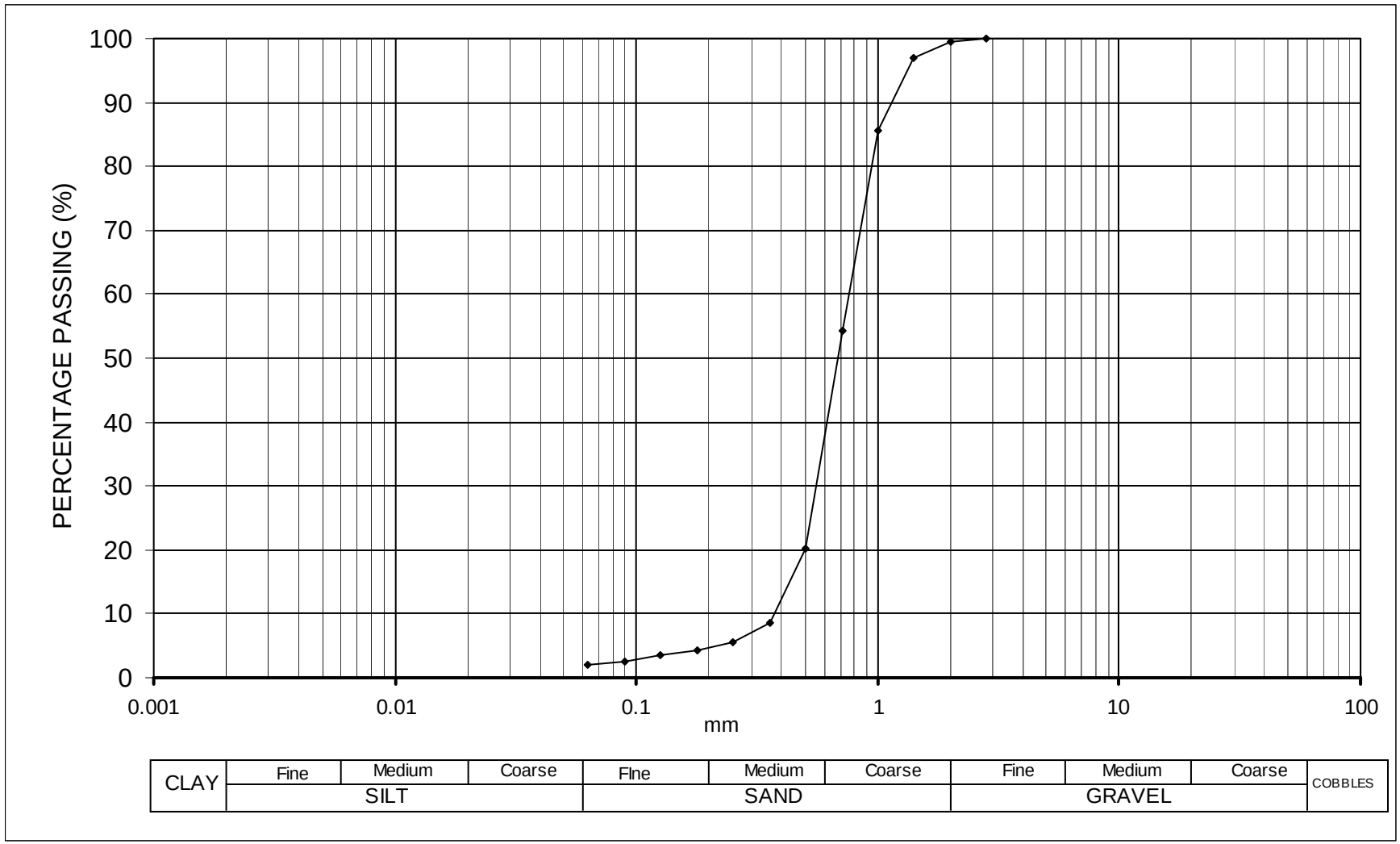
**Course**

**Total Sample Weight** 180.63**g**

**Retained Sample Weight** 177.13**g** **Passing 63µm Sieve** 3.50**g**

| Sieve Size (mm) | Sieve Size (ø) | Retained Weight (g) | Total (g) Retained | % Retained | % Passing |
|---|---|---|---|---|---|
| 2.8 | -1.5 | 0.00 | 0.00 | 0.0 | 100.0 |
| 2.00 | -1.0 | 1.05 | 1.05 | 0.6 | 99.4 |
| 1.40 | -0.5 | 4.29 | 5.34 | 3.0 | 97.0 |
| 1.00 | 0.0 | 20.72 | 26.06 | 14.4 | 85.6 |
| 0.710 | 0.5 | 56.43 | 82.49 | 45.7 | 54.3 |
| 0.500 | 1.0 | 61.68 | 144.17 | 79.8 | 20.2 |
| 0.355 | 1.5 | 20.97 | 165.14 | 91.4 | 8.6 |
| 0.250 | 2.0 | 5.25 | 170.39 | 94.3 | 5.7 |
| 0.180 | 2.5 | 2.36 | 172.75 | 95.6 | 4.4 |
| 0.125 | 3.0 | 1.72 | 174.47 | 96.6 | 3.4 |
| 0.090 | 3.5 | 1.40 | 175.87 | 97.4 | 2.6 |
| 0.063 | 4.0 | 1.26 | 177.13 | 98.1 | 1.9 |

Dounreay, borehole WS02, depth 1.35-1.40 m, sample number PY1977.



Dounreay, borehole WS07c, depth 4.20 - 4.30 m, sample number PY1982.

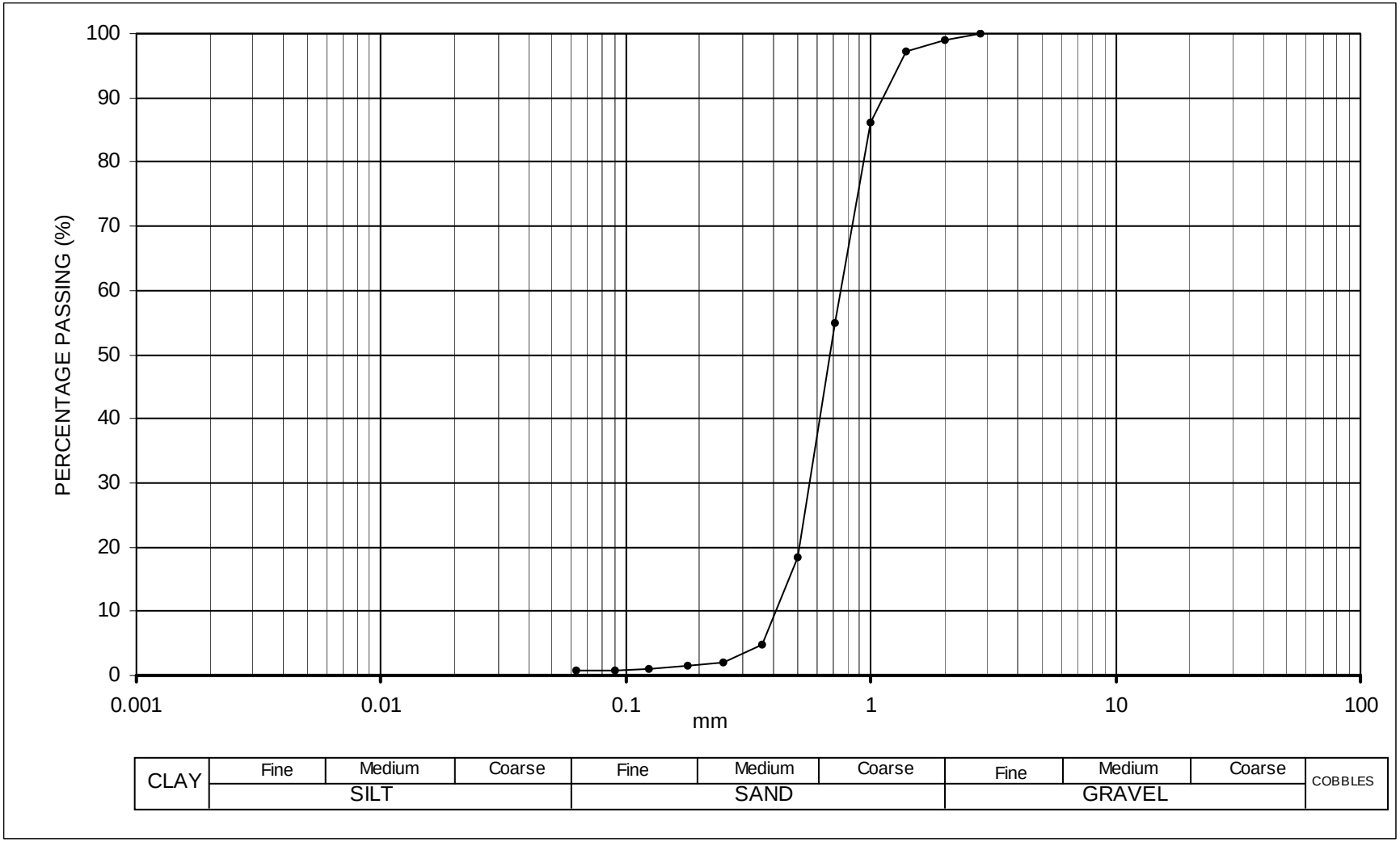
**Course**

**Total Sample Weight** 236.83**g**

**Retained Sample Weight** 235.26**g** **Passing 63µm Sieve** 1.57**g**

| Sieve Size (mm) | Sieve Size (ø) | Retained Weight (g) | Total (g) Retained | % Retained | % Passing |
|---|---|---|---|---|---|
| 2.8 | -1.5 | 0.00 | 0.00 | 0.0 | 100.0 |
| 2.000 | -1.0 | 2.14 | 2.14 | 0.9 | 99.1 |
| 1.400 | -0.5 | 4.53 | 6.67 | 2.8 | 97.2 |
| 1.000 | 0.0 | 26.14 | 32.81 | 13.9 | 86.1 |
| 0.710 | 0.5 | 74.09 | 106.90 | 45.1 | 54.9 |
| 0.500 | 1.0 | 86.30 | 193.20 | 81.6 | 18.4 |
| 0.360 | 1.5 | 32.02 | 225.22 | 95.1 | 4.9 |
| 0.250 | 2.0 | 6.63 | 231.85 | 97.9 | 2.1 |
| 0.180 | 2.5 | 1.59 | 233.44 | 98.6 | 1.4 |
| 0.125 | 3.0 | 0.75 | 234.19 | 98.9 | 1.1 |
| 0.090 | 3.5 | 0.56 | 234.75 | 99.1 | 0.9 |
| 0.063 | 4.0 | 0.51 | 235.26 | 99.3 | 0.7 |

Dounreay, borehole WS07c, depth 4.20 - 4.30 m, sample number PY1982.



Dounreay, borehole WS10, depth 1.30 – 1.35 m, sample number PY1986.

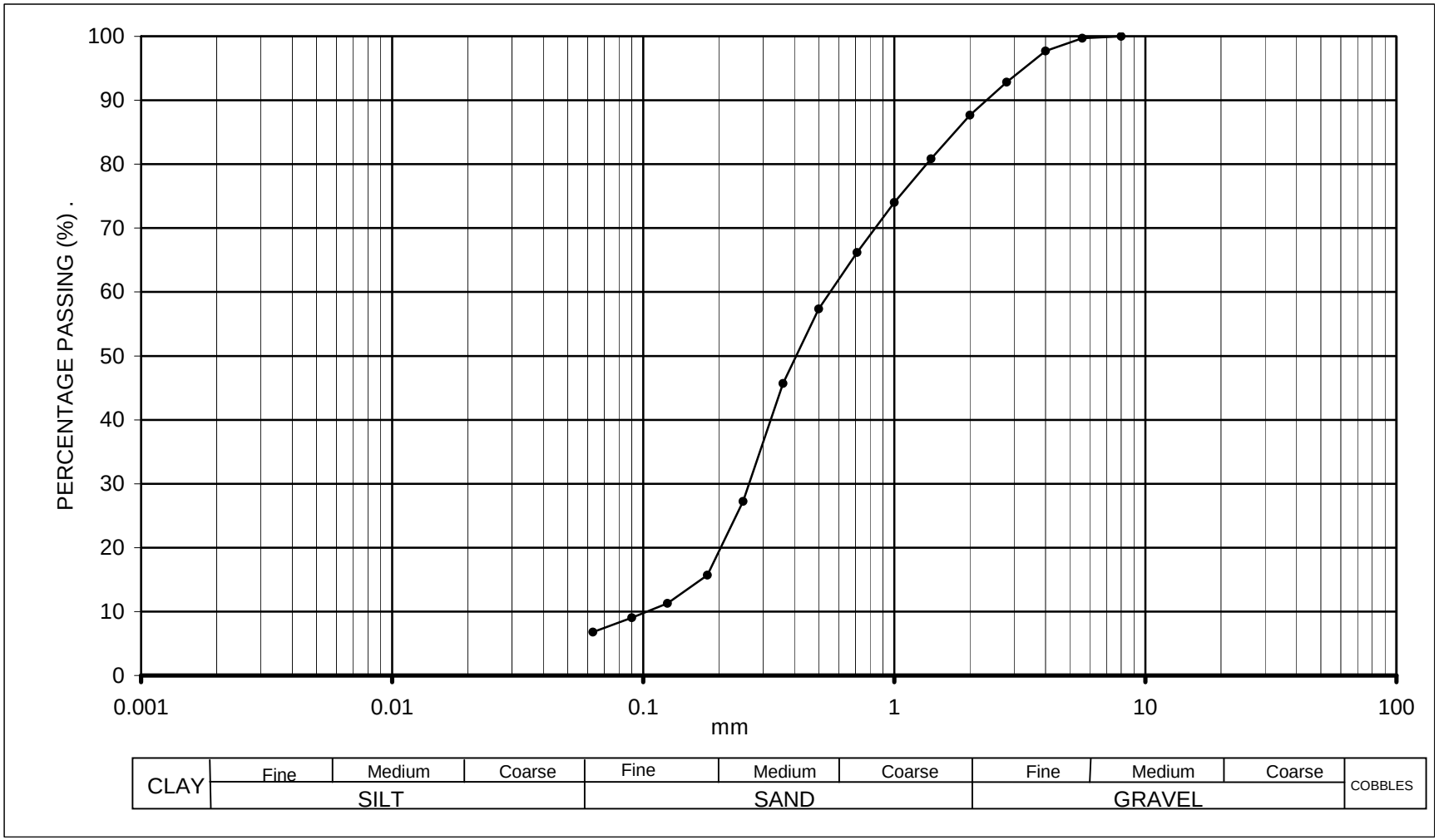
**Course** **286.92g cobble**

**Total Sample Weight** 195.51**g**

**Retained Sample Weight** 168.24**g** **Passing 63µm Sieve** 27.27**g**

| Sieve Size (mm) | Sieve Size (ø) | Retained Weight (g) | Total (g) Retained | % Retained | % Passing |
|---|---|---|---|---|---|
| 8 | -3.0 | 0.00 | 0.00 | 0.0 | 100.0 |
| 5.6 | -2.5 | 0.59 | 0.59 | 0.3 | 99.7 |
| 4 | -2.0 | 3.85 | 4.44 | 2.3 | 97.7 |
| 2.8 | -1.5 | 9.54 | 13.98 | 7.2 | 92.8 |
| 2.000 | -1.0 | 10.14 | 24.12 | 12.3 | 87.7 |
| 1.400 | -0.5 | 13.32 | 37.44 | 19.1 | 80.9 |
| 1.000 | 0.0 | 13.36 | 50.80 | 26.0 | 74.0 |
| 0.710 | 0.5 | 15.36 | 66.16 | 33.8 | 66.2 |
| 0.500 | 1.0 | 17.22 | 83.38 | 42.6 | 57.4 |
| 0.360 | 1.5 | 22.81 | 106.19 | 54.3 | 45.7 |
| 0.250 | 2.0 | 36.05 | 142.24 | 72.8 | 27.2 |
| 0.180 | 2.5 | 22.61 | 164.85 | 84.3 | 15.7 |
| 0.125 | 3.0 | 8.63 | 173.48 | 88.7 | 11.3 |
| 0.090 | 3.5 | 4.37 | 177.85 | 91.0 | 9.0 |
| 0.063 | 4.0 | 4.37 | 182.22 | 93.2 | 6.8 |

Dounreay, borehole WS10, depth 1.30 – 1.35 m, sample number PY1986.



Dounreay, borehole WS10, depth 2.20 – 2.25 m, sample number PY1987.

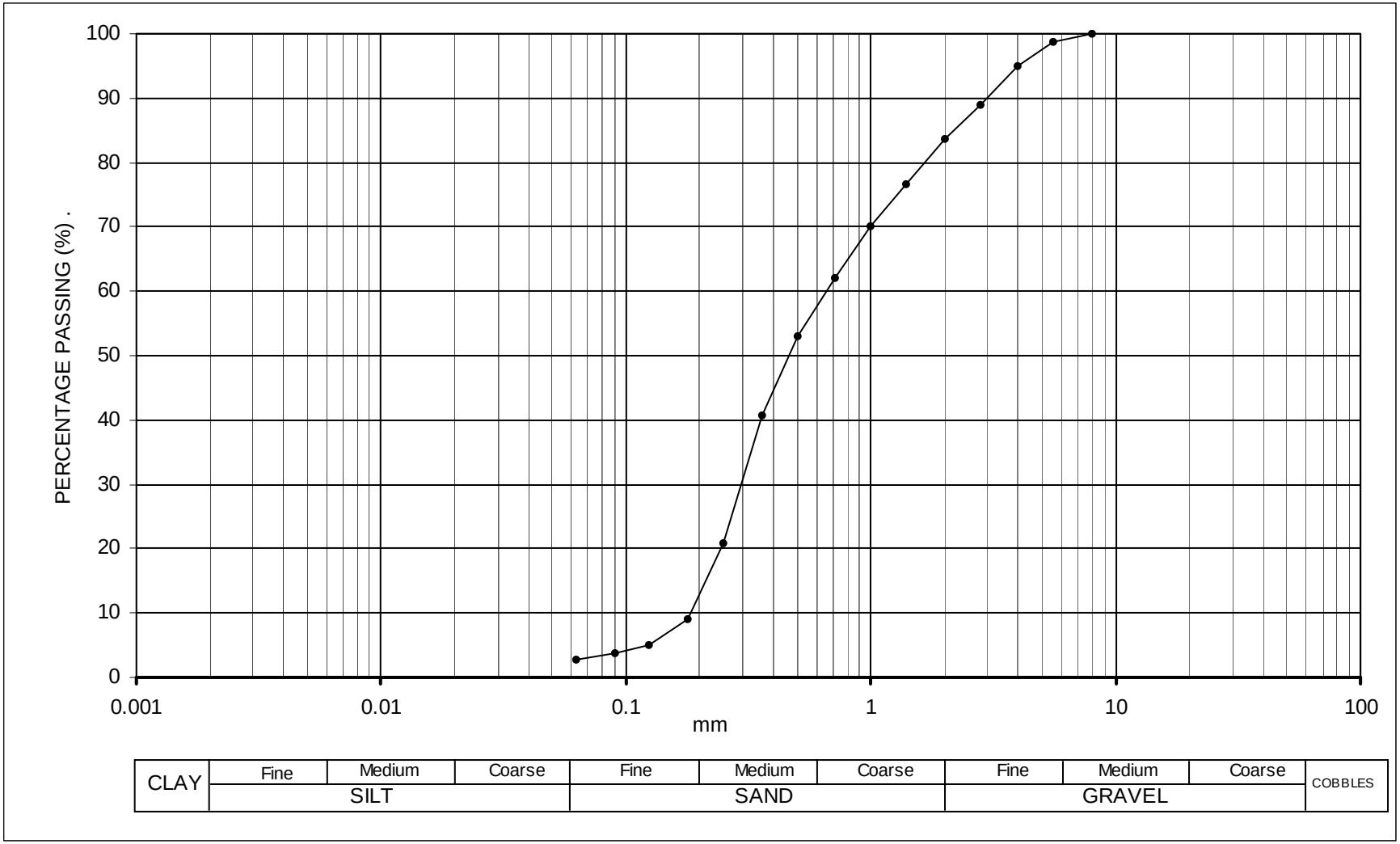
**Course**

**Total Sample Weight** 128.99**g**

**Retained Sample Weight** 111.06**g** **Passing 63µm Sieve** 17.93**g**

| Sieve Size (mm) | Sieve Size (ø) | Retained Weight (g) | Total (g) Retained | % Retained | % Passing |
|---|---|---|---|---|---|
| 8.0 | -3.0 | 0.00 | 0.00 | 0.0 | 100.0 |
| 5.6 | -2.5 | 1.69 | 1.69 | 1.3 | 98.7 |
| 4.0 | -2.0 | 4.68 | 6.37 | 4.9 | 95.1 |
| 2.8 | -1.5 | 7.95 | 14.32 | 11.1 | 88.9 |
| 2.00 | -2.0 | 6.83 | 21.15 | 16.4 | 83.6 |
| 1.40 | -0.5 | 8.91 | 30.06 | 23.3 | 76.7 |
| 1.00 | 0.0 | 8.46 | 38.52 | 29.9 | 70.1 |
| 0.710 | 0.5 | 10.34 | 48.86 | 37.9 | 62.1 |
| 0.500 | 1.0 | 11.82 | 60.68 | 47.0 | 53.0 |
| 0.360 | 1.5 | 15.91 | 76.59 | 59.4 | 40.6 |
| 0.250 | 2.0 | 25.34 | 101.93 | 79.0 | 21.0 |
| 0.180 | 2.5 | 15.27 | 117.20 | 90.9 | 9.1 |
| 0.125 | 3.0 | 5.21 | 122.41 | 94.9 | 5.1 |
| 0.090 | 3.5 | 1.83 | 124.24 | 96.3 | 3.7 |
| 0.063 | 4.0 | 1.14 | 125.38 | 97.2 | 2.8 |

Dounreay, borehole WS10, depth 2.20 – 2.25 m, sample number PY1987.



Dounreay, borehole WS15, depth 2.75 – 2.80 m, sample number PY1999.

**Course** **Fine**

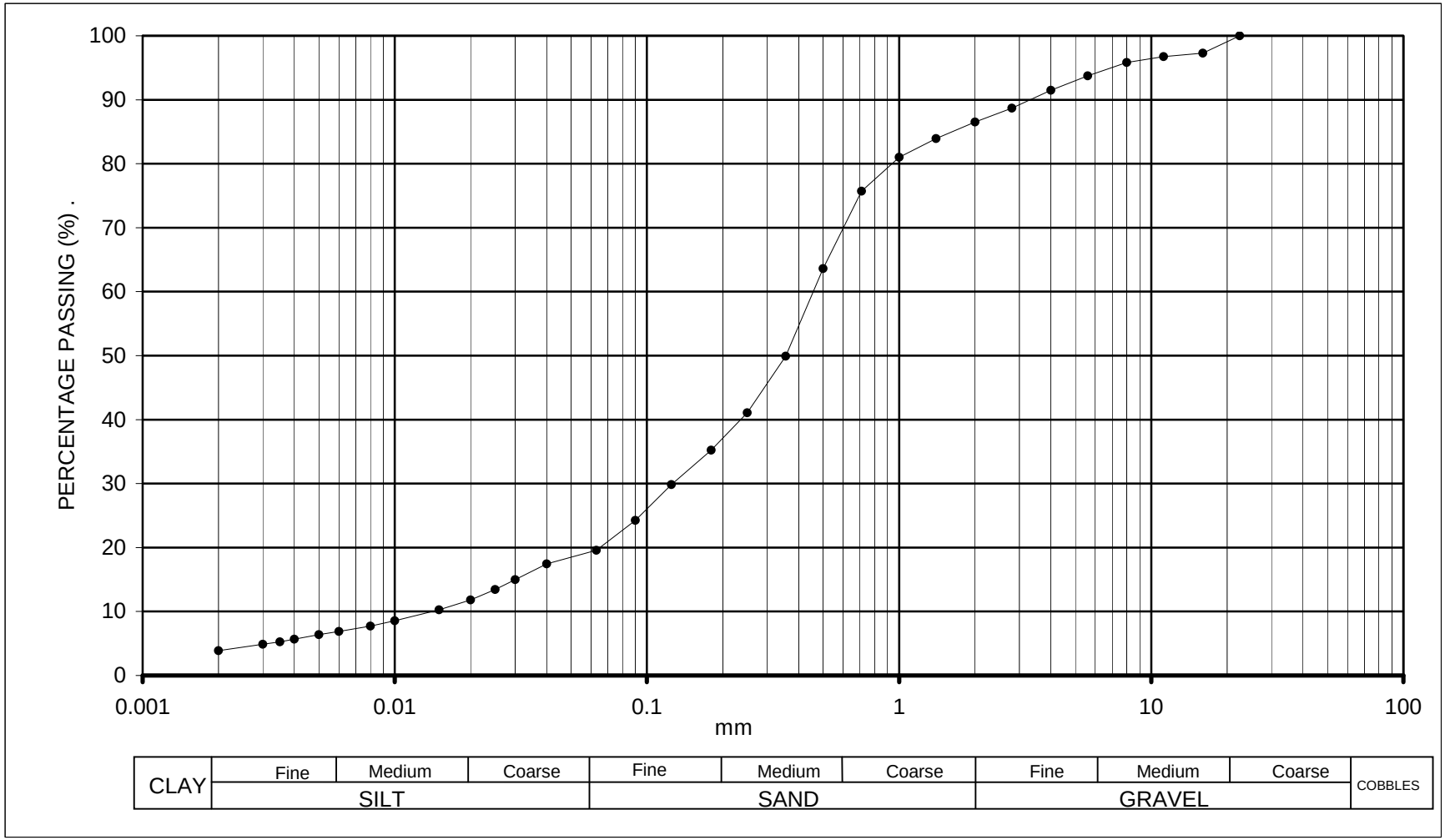
**Total Sample Weight** 284.83**g**

**Retained Sample Weight** 196.85**g** **Passing 63µm Sieve** 87.98**g**

| Sieve Size (mm) | Sieve Size (ø) | Retained Weight (g) | Total (g) Retained | % Retained | % Passing |
|---|---|---|---|---|---|
| 22.4 | -4.5 | 0.00 | 0.00 | 0.0 | 100.0 |
| 16.0 | -4.0 | 7.67 | 7.67 | 2.7 | 97.3 |
| 11.2 | -3.5 | 1.57 | 9.24 | 3.2 | 96.8 |
| 8.0 | -3.0 | 2.64 | 11.88 | 4.2 | 95.8 |
| 5.6 | -2.5 | 5.98 | 17.86 | 6.3 | 93.7 |
| 4.0 | -2.0 | 6.34 | 24.20 | 8.5 | 91.5 |
| 2.8 | -1.5 | 8.02 | 32.22 | 11.3 | 88.7 |
| 2.00 | -1.0 | 6.16 | 38.38 | 13.5 | 86.5 |
| 1.40 | -0.5 | 7.40 | 45.78 | 16.1 | 83.9 |
| 1.00 | 0.0 | 8.31 | 54.09 | 19.0 | 81.0 |
| 0.710 | 0.5 | 15.15 | 69.24 | 24.3 | 75.7 |
| 0.500 | 1.0 | 34.39 | 103.63 | 36.4 | 63.6 |
| 0.355 | 1.5 | 38.99 | 142.62 | 50.1 | 49.9 |
| 0.250 | 2.0 | 25.18 | 167.80 | 58.9 | 41.1 |
| 0.180 | 2.5 | 16.75 | 184.55 | 64.8 | 35.2 |
| 0.125 | 3.0 | 15.33 | 199.88 | 70.2 | 29.8 |
| 0.090 | 3.5 | 15.90 | 215.78 | 75.8 | 24.2 |
| 0.063 | 4.0 | 13.29 | 229.07 | 80.4 | 19.6 |

| Sieve Size (µm) | % Passing | Actual % |
|---|---|---|
| 0.040 | 89.1 | 17.4 |
| 0.030 | 76.6 | 15.0 |
| 0.025 | 68.7 | 13.4 |
| 0.020 | 60.4 | 11.8 |
| 0.015 | 52.4 | 10.3 |
| 0.010 | 43.6 | 8.5 |
| 0.0080 | 39.4 | 7.7 |
| 0.0060 | 35.2 | 6.9 |
| 0.0050 | 32.6 | 6.4 |
| 0.0040 | 28.9 | 5.7 |
| 0.0035 | 26.9 | 5.3 |
| 0.0030 | 24.9 | 4.9 |
| 0.0020 | 19.9 | 3.9 |

Dounreay, borehole WS15, depth 2.75 – 2.80 m, sample number PY1999.



Dounreay, borehole WS19, depth 1.75 – 1.80 m, sample number PY2005.

**Course** **Fine**

**Total Sample Weight** 221.88**g**

**Retained Sample Weight** 91.53**g** **Passing 63µm Sieve** 130.35**g**

| Sieve Size (mm) | Sieve Size (ø) | Retained Weight (g) | Total (g) Retained | % Retained | % Passing |
|---|---|---|---|---|---|
| 8.0 | -3.0 | 0.00 | 0.00 | 0.0 | 100.0 |
| 5.6 | -2.5 | 1.15 | 1.15 | 0.5 | 99.5 |
| 4.0 | -2.0 | 0.52 | 1.67 | 0.8 | 99.2 |
| 2.8 | -1.5 | 1.32 | 2.99 | 1.3 | 98.7 |
| 2.000 | -1.0 | 1.00 | 3.99 | 1.8 | 98.2 |
| 1.400 | -0.5 | 0.20 | 4.19 | 1.9 | 98.1 |
| 1.000 | 0.0 | 0.85 | 5.04 | 2.3 | 97.7 |
| 0.710 | 0.5 | 2.59 | 7.63 | 3.4 | 96.6 |
| 0.500 | 1.0 | 6.97 | 14.60 | 6.6 | 93.4 |
| 0.360 | 1.5 | 12.12 | 26.72 | 12.0 | 88.0 |
| 0.250 | 2.0 | 7.45 | 34.17 | 15.4 | 84.6 |
| 0.180 | 2.5 | 8.46 | 42.63 | 19.2 | 80.8 |
| 0.125 | 3.0 | 12.67 | 55.30 | 24.9 | 75.1 |
| 0.090 | 3.5 | 18.95 | 74.25 | 33.5 | 66.5 |
| 0.063 | 4.0 | 20.27 | 94.52 | 42.6 | 57.4 |

| Sieve Size (µm) | % Passing | Actual % |
|---|---|---|
| 0.040 | 91.2 | 52.3 |
| 0.030 | 79.0 | 45.3 |
| 0.025 | 71.4 | 41.0 |
| 0.020 | 63.3 | 36.3 |
| 0.015 | 55.6 | 31.9 |
| 0.010 | 46.9 | 26.9 |
| 0.0080 | 43.1 | 24.7 |
| 0.0060 | 38.9 | 22.3 |
| 0.0050 | 36.2 | 20.8 |
| 0.0040 | 32.2 | 18.5 |
| 0.0035 | 29.8 | 17.1 |
| 0.0030 | 27.3 | 15.7 |
| 0.0020 | 21.7 | 12.5 |

Dounreay, borehole WS19, depth 1.75 – 1.80 m, sample number PY2005.