Staithes Coastal Strategy

Appendix K

Technical Report #2 – Geology, Geomorphology and Coastal Processes Overview

Overview

The geology, geomorphology and coastal processes in the Study Area have previously been assessed in detail in the following documents:

- Huntcliffe to Flamborough Head Shoreline Management Plan (1997)
- Cowbar Coast Protection & Cliff Stabilisation Strategic Study (1999)
- Staithes Harbour Phase 3 Improvements (1999)
- River Tyne to Flamborough Head Shoreline Management Plan 2 (2007)
- Cell 1 Sediment Transport Study Phases 1 & 2 (2013 & 2014)

Work for the previous Strategic Study in 1999 included:

- Site Investigation
- Joint Probability Assessment
- Environmental Considerations
- Coastal Inspections

Work for the previous Staithes Harbour Phase 3 Improvements in 1999 included:

- Physical Model Testing

These previous reports have been reviewed and key information on geology, geomorphology and coastal processes has been synthesised in this note. Information has been brought up to date through a review of the findings from the following monitoring programmes:

- Scarborough Borough Council Coastal Monitoring Programme (2001 - 2006)
- Cell 1 Regional Coastal Monitoring Programme (2008 – 2019)
- Cowbar Nab Monitoring (2011 – 2018)

Geology and Geomorphology

The majority of the rocks within the study area are of Jurassic Age and are sedimentary in nature. It is the Lower Jurassic rocks of the Staithes Sandstone Formation (interbedded sandstones, siltstones and shales) and the Redcar Mudstone Formation (interbedded shales and mudstones) which predominantly outcrop on the cliffs. The older Redcar Mudstone Formation (of the Lower Lias) are also exposed on the rock platform. The cliffs are mantled with a deposit of Glacial Till of Devonian Age (Table 1).

Table 1 - Geological sequence at Cowbar

Geology	Composition	Thickness
Glacial Till	Silty sandy clay with some gravel	5 – 26 m thick
Staithes Sandstone Formation	Interbedded sandstones, siltstones and shales	22 – 40 m thick
Redcar Mudstone Formation	Interbedded shales and mudstones	230 – 275 m thick (base not seen)

The geological beds dip gently to the east, with joints trending approximately normal and parallel to the bedding throughout the cliff face at 20 – 60 cm spacings. Two normal faults, at Sandy Wyke and Dove Hole, can be observed either side of the Red Nabs headland (Figure 1). The rock fabric near these faults has weakened and provided an opening for waves to induce a higher rate of erosion triggering the development of sea caves.

A series of small headlands and embayments have developed, reflecting the variable response to marine erosion by the bedrock and discontinuities within the cliff units. A series of scallop-like slope failures have developed in the cliff top as a result of receding rock cliff line and groundwater conditions in the Till.

The Till deposits are over-consolidated silty sandy clays with some gravel and are relatively uniform in composition across the study area.

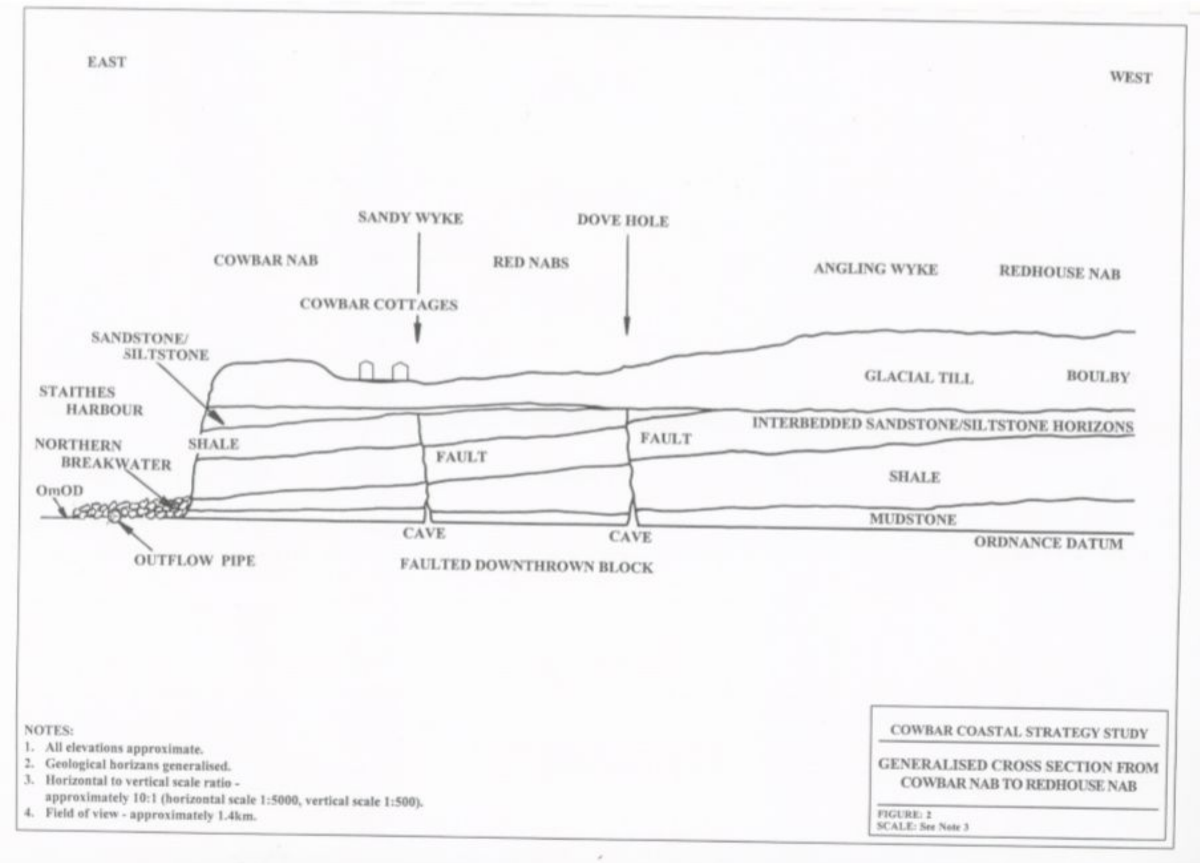

Figure 1 – Generalised Cross Section from Cowbar Nab to Redhouse Nab
(from High Point Rendel, 1999)

Bathymetry and Sediments

The bathymetry of the sea bed is shown in Figure 2 from an Admiralty Chart. The 10mCD contour is generally within approximately 1km of the cliff line, indicating a relatively steeply shelving sea bed. The only notably feature in the sea bed is the indentation in plan form and sea bed depth at Staithes Harbour.

The inter-tidal foreshore largely comprises rock platform that is bare of surficial sediment, other than occasional patches of sand, gravel, cobbles or boulders, with the exception of Staithes Harbour which has a small sand beach within the harbour arms.

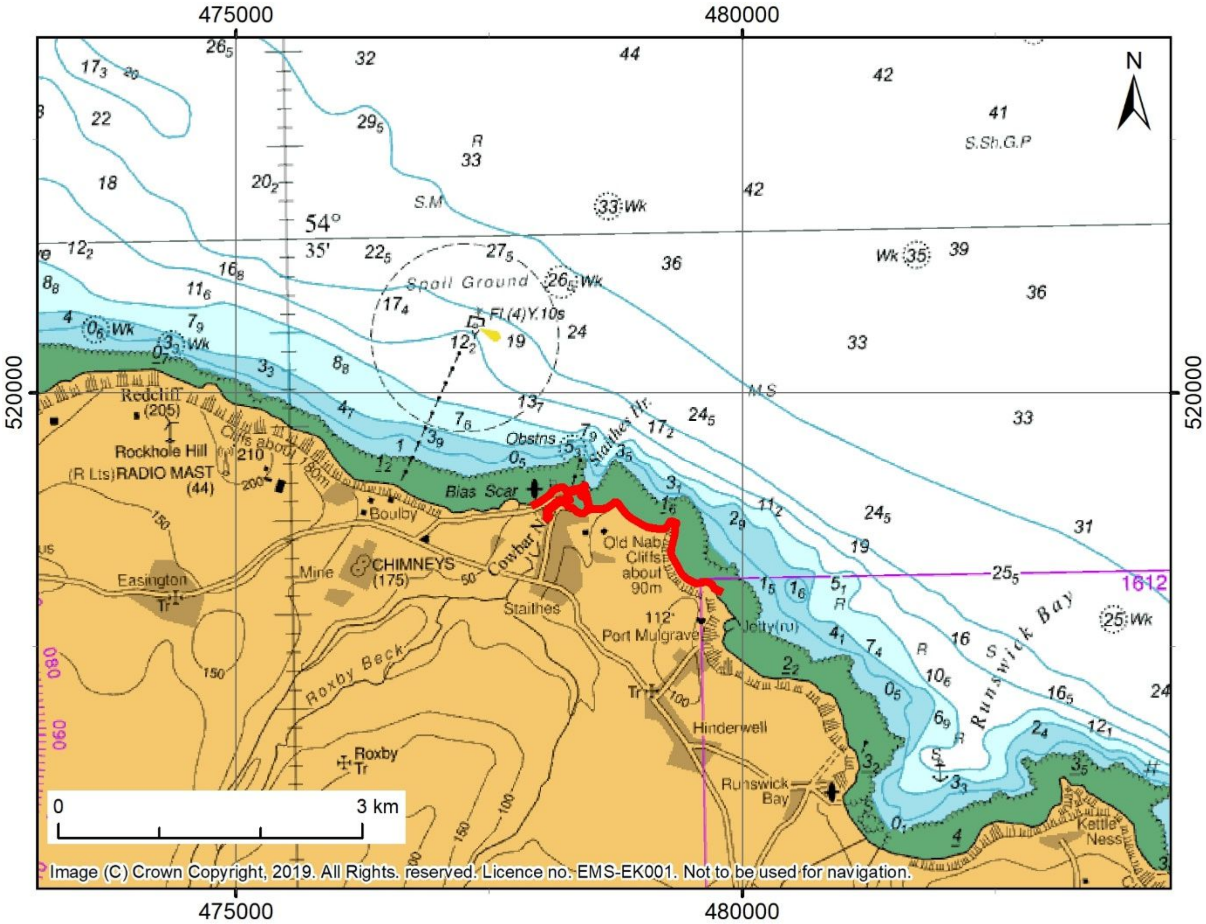

Figure 2 – Sea bed bathymetry

Tidal Levels

Astronomical tidal levels that are representative of the study area are shown in Table 2.

Table 2 – Astronomical tidal levels at Staithes

Parameter	Water level (m OD) *
Highest Astronomical Tide	+3.0
Mean High Water Springs	+2.4
Mean High Water Neaps	+1.3
Mean Sea Level	+0.13
Mean Low Water Neaps	-1.0
Mean Low Water Springs	-2.2
Lowest Astronomical Tide	-3.1

* Chart Datum is 3.0m below ODN

The astronomical tidal levels can be affected by positive surge conditions to create extreme water levels as shown in Table 3 for various return period events.

Table 3 – Extreme levels at Staithes

Return period event	Water level (m OD)
1 in 1 year	+3.30
1 in 10 years	+3.61
1 in 50 years	+3.85
1 in 100 years	+3.99
1 in 200 years	+4.10
1 in 1000 years	+4.31

Waves

The most significant waves at Staithes are from the north and north east sectors, which can regularly exceed 3m in height in the offshore zone. Due to wave transformation processes across the sea bed and inter-tidal rock platform, inshore waves in excess of 2.5m can be expected from the north and northeast, on average, once every 50 years.

Sea level rise

It is important to consider how projections of climate change may affect the impacts on coastal processes over the lifetime of the Coastal Strategy from 2020 to 2120.

Changes in sea level are the result of a combination of isostatic factors (a gradual and long term rebound of depressed land mass under ice during the last ice age) and eustatic changes (an increase in water volume due to both thermal expansion and melting of ice caps associated with rises in global temperatures).

The Cowbar Coast Protection & Cliff Stabilisation Strategic Study (1999) used sea level rise projections of 6mm/year (for its 50 year horizon). However, when considering future projections, the latest scientific projections are available from UKCP18 (Met Office, 2018). This programme uses three Representative Concentration Pathways (RCPs) to determine likely changes in sea level (Table 4).

Table 4 - Sea level rise projections between 2020 and 2045 (25 years), 2070 (50 years) and 2120 (100 years) for three RCPs with 5th, 50th and 95th percentile confidence (Met Office, 2018)

Representative Concentration Pathway (RCP)	Year	UKCP18 projected increase in sea level (m relative to 2020 values)		
		5th percentile	50th percentile	95th percentile
RCP 2.6	2045	0.067	0.102	0.149
RCP 4.5		0.076	0.112	0.162
RCP 8.5		0.093	0.137	0.195
RCP 2.6	2070	0.123	0.199	0.313
RCP 4.5		0.158	0.243	0.371
RCP 8.5		0.219	0.331	0.488
RCP 2.6	2120	0.230	0.376	0.658
RCP 4.5		0.315	0.429	0.808
RCP 8.5		0.526	0.786	1.216

Based on the above, the sea level rise values used in the Cowbar Coast Protection & Cliff Stabilisation Strategic Study (1999) may be deemed conservative over its 50-year time horizon, irrespective of which RCP is now considered over the short term (25 years to 2045).

The River Tyne to Flamborough Head Shoreline Management Plan 2 (2007) projected future cliff erosion to 2025, 2055 and 2105 (from a base date of 2005). This was based upon past erosion rates multiplied by a factor of 2.5 to allow for sea level rise over the 100-year time horizon the SMP2. When considering the most pessimistic of the UKCP18 outputs, namely RCP8.5, factor of past sea level rise rates (from the 1995 baseline to 2020) to future projected sea level rise rates (from 2020 to 2120) is a value of 2.34 at the 50-percentile projections. This indicates that the scale factor used by the SMP2 still remains appropriate in light of the UKCP18 outputs, even under the most pessimistic RCP outputs. In actual fact, due to the non-linear nature of the projections, the scale factors (based upon the 50-percentile projections) would be better as follows:

- 2020 to 2045 – scale factor of 1.63
- 2020 to 2070 – scale factor of 1.97
- 2020 to 2120 – scale factor of 2.34

The Staithes Coastal Strategy will need to consider how the latest UKCP18 output affects erosion rates and coastal management decisions to the medium- and longer-term horizons of 2070 (50 years) and 2120 (100 years), respectively.

Sediment Transport

Longshore sediment transport is likely to be to the east, although the actual sediment transport volumes are low considering the nature of the foreshore (shore platform with little mobile sediment). Skinningrove jetty and Hummersea Scar further to the west are effective barriers to longshore transport into the study area. There is the potential for sediment transport reversal across Penny Steel (immediately east of Staithes) because of the protection afforded by Cowbar Nab (Royal Haskoning, 2005).

Monitoring of cliff recession at Cowbar has been ongoing in collaboration between Redcar & Cleveland Council and Durham University since 2004. The work has involved combined digital photogrammetry and digital terrestrial laser scanning (Lim et al., 2005; Rosser, 2018) and revealed generally low rates of cliff recession and sediment yield to the coastal system, but recognises that larger scale rates and yields could be derived from less frequent but higher magnitude events such as larger-scale rock falls.

The cliffs are eroding at low long-term rates (100 years) (Agar, 1960; High-Point Rendel, 2002), and the yield of beach-building sediment is low. However, short-term retreat rates appear to be more variable, i.e. long periods of no retreat separated by short periods of relatively large losses.

Staithes Harbour is sheltered by closely spaced north and south breakwaters (built in the 1920s) and the village is protected by a sea wall with two small groynes. Anecdotal evidence from the fishermen suggests that the harbour is accreting silt since the construction of the breakwaters.